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Watershed Overview
Sulphur River Basin Overview

Final Report

Prepared for:

Corps of Engineers

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EXECUTIVE SUMMARY

The demand for water within the Sulphur River Basin is expected to grow significantly through 2060. The region possesses potential for significant economic growth, and water availability (or lack thereof) is a primary consideration in whether or not that potential is achieved. The total municipal demand for surface water within the basin by the year 2060 is projected to be between 39,000 ac-ft./yr. to 64,000 ac-ft./yr. Industrial demand within the Sulphur River Basin currently accounts for approximately 70% of the total water demand in the basin and is could, under aggressive growth assumptions, reach 210,000 ac-ft./yr. by 2060. The most aggressive in-basin demand for surface water in the Sulphur River Basin predicted to be approximately 274,000 ac-ft./yr.

Based on the Sulphur Basin Water Availability Model, the Texas portion of the basin produced an average of 1.5 million ac-ft./yr. during the historical drought-of-record for the basin. Approximately 26 percent of this average drought flow (382,000 ac-ft./yr.) is appropriated by existing water rights. Accordingly, there is a total of approximately 1.1 million ac-ft./yr. of water potentially available to meet in-basin needs of 274,000 ac-ft/yr.

Notwithstanding the general availability of surface water as evaluated on a basinwide scale, water users within the Sulphur River Basin currently experience water resources problems and needs, and those problems and needs are predicted to continue into the future. Sufficient storage and/or treatment and distribution infrastructure is lacking in many instances. Some water user groups have an immediate and critical need to develop additional sources or infrastructure, while others have sufficient capacity for now but develop constraints at a future time.

Additional water supply could be developed from the Sulphur River Basin from a variety of sources. Reallocation of storage from flood control or sediment storage to water conservation storage at Wright Patman Lake could substantially increase the firm yield of the project. For scenarios raising the top of the conservation pool, firm yield continues to increase significantly with the increase in storage at all elevations. With the entire reservoir storage dedicated to water conservation (no sediment storage or flood control storage), the firm yield of the reservoir exceeds 1.2 million acre-feet per year.

Storage in Wright Patman Lake is predicted to decline over time due to ongoing sedimentation from the watershed. Absent a reallocation or other change to Wright Patman Lake operations, the firm yield of the reservoir would be reduced by approximately 12% by the year 2070.

Implementation of specified Best Management practices in the portions of the Sulphur River Basin contributing the greatest sediment loads is predicted to reduce sedimentation at Wright Patman by 28% (223,518 metric tons per year.) The reduced loss of storage has a beneficial effect on the predicted firm yield of Wright Patman Lake, generally in the 1-5% range depending on the scenario.

Alternative storage locations in the Sulphur River Basin also have the potential to generate new water supply for the region. Some alternatives generate substantial annual yields on their own and appear to have merit as stand-alone alternatives while others may be more attractive as a component of a project in combination with another storage feature. Construction of upstream reservoirs would also have a substantial effect on the sediment load to Wright Patman Lake.

As expected, sedimentation would affects the yield of any upstream reservoir over time. The magnitude of this effect varies. Modeling results indicate that sediment loads to upstream reservoirs could be reduced by the large scale application of Best Management Practices. Reductions in load range from 59% for Marvin Nichols IA to 92% for Parkhouse II. These reductions in sediment load are in addition to reductions in sediment loads to Wright Patman Lake ranging from 14% to 70% as compared to the unmodified watershed scenario. The reduction in annual sediment load over time has a generally small but beneficial effect on yield and results in cumulative savings over the 40 year period of analysis.

1.0 INTRODUCTION

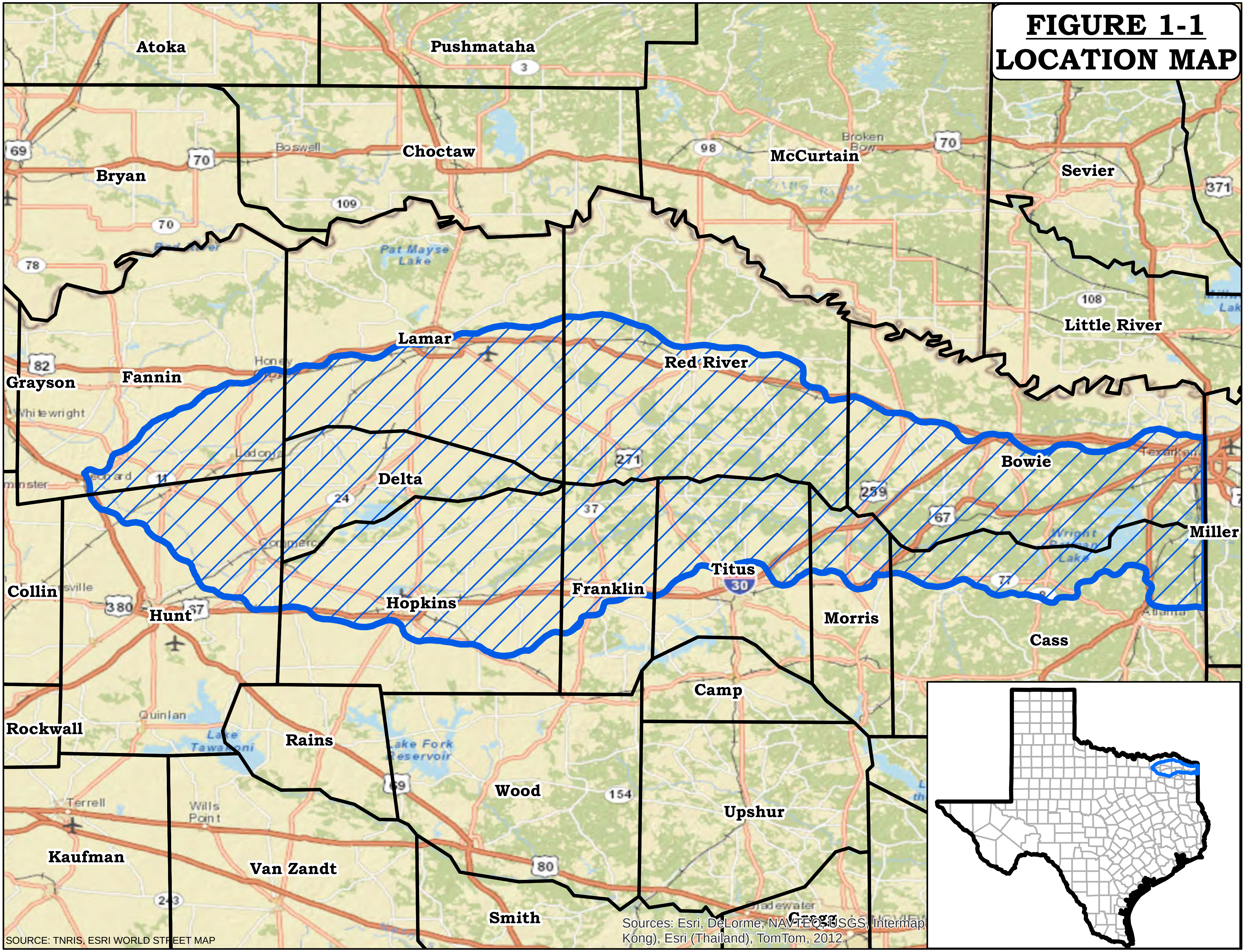
The Sulphur River basin encompasses some 3,558 square miles in Northeast Texas. (Figure 1-1) Included in the basin are all or part of 11 Texas counties (Fannin, Lamar, Red River, Bowie, Hunt, Delta, Hopkins, Franklin, Titus, Morris, and Cass.) From the eastern state line of Texas, the Sulphur River flows into Arkansas and joins with the Red River, a tributary of the Mississippi River. (The portion of the Sulphur River drainage within Arkansas is not addressed in detail within this study.) The South and North Sulphur Rivers originate in southern Fannin County and flow eastward approximately 50 miles to their confluence near the eastern boundary of Delta and Lamar counties. (The Middle Sulphur joins the South Sulphur River approximately 23 miles upstream of its confluence with the North Sulphur.) White Oak Creek, the largest tributary of the Sulphur River, drains approximately 500 square miles and joins the main stem of the Sulphur River further downstream in Cass County.

The Corps of Engineers owns and operates two Federal reservoirs in the Sulphur River Basin, Jim Chapman Lake (formerly known as Cooper Lake) and Wright Patman Lake, known at one time as Texarkana Lake. Together, these two reservoirs account for over 85% of the authorized diversions in the Basin. (FNI,2003). Wright Patman Lake is located on the Sulphur River in Bowie and Cass Counties. Wright Patman was authorized as part of a comprehensive plan to reduce flood damages in the Red River drainage below Denison Dam. Construction was initiated in 1948 and completed in 1956. Jim Chapman Lake is located in the upper part of the basin on the South Sulphur River in Delta and Hopkins Counties. Construction was authorized in 1955 for purposes including flood control, water supply storage and recreation. Construction was initiated in 1959. Legal concerns delayed completion of the reservoir; however deliberate impoundment began in September 1991.

The Sulphur Basin has the largest average watershed yield of any major river basin in Texas (TWDB) and has more unappropriated water than any major river basin in the state with the exception of the Neches Basin (FNI, 2012). See Figure 1-2. Due to the abundance of water in the region, the Sulphur Basin has been the focus of numerous studies for potential development of new water supply projects. The 2012 Region C Water Plan identified a need to develop 584,400 acre-feet per year of water supply yield from the Basin for use within the North Central Texas region.

Historically, the Sulphur River has been subject to channelization practices intended to increase agricultural development.

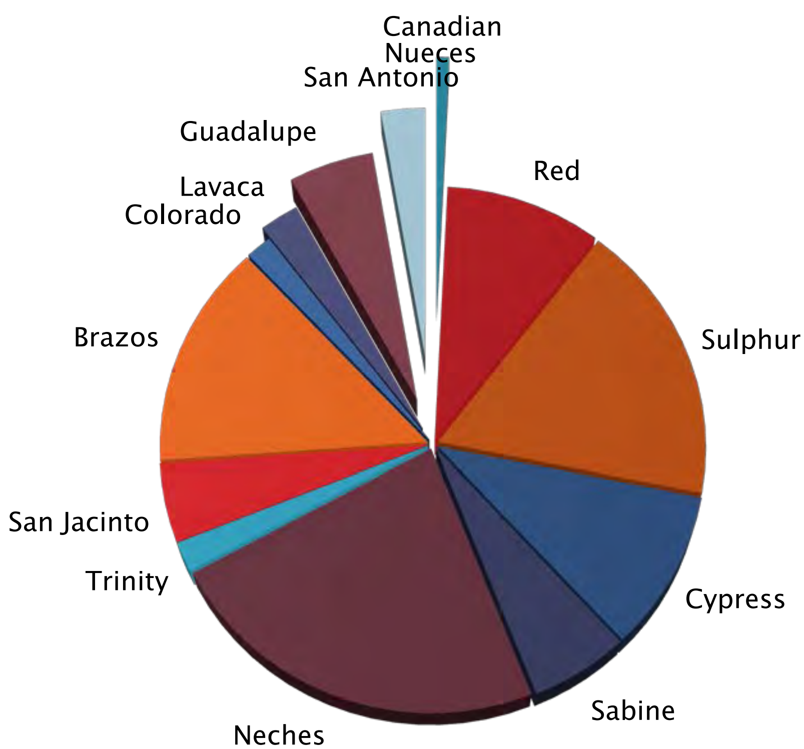
FIGURE 1-1
LOCATION MAP



In addition, the Corps of Engineers channelized portions of the South Sulphur and Sulphur Rivers in the 1950s as part of the congressionally authorized Cooper Lake and Channels project. Channelization removed many meanders and oxbows and led to extensive clearing of much of the land adjacent to the channel, erosion and siltation in the steeper channel. The heavy silt and debris load has contributed to a number of problems throughout the watershed including extensive reservoir sedimentation. Figures 1-3 and 1-4 provide illustration of typical erosion and/or sedimentation problems. In 2010, the Texas Water Development Board conducted a volumetric survey of Wright Patman Lake and concluded that Wright Patman Lake loses between 730 and 1,362 acre-feet of storage capacity within the conservation pool per year due to sedimentation. (TWDB,2012)

Figure 1-2: Proportion of the State's Unappropriated Water by River Basin

Based on Minimum 5-yr Average from Period of Record (acre-ft)



In 2011, under authority of the Planning Assistance to States Program (Section 22, Water Resources Development Act of 1974), the Corps of Engineers and the Sulphur River Basin Authority executed an agreement to study various aspects of water supply development in the Sulphur River Basin. The primary focus of the study was to be estimation of the potential water supply yield that could be developed from a variety of alternative sources. Consideration was to be given to the current and future of effects of sedimentation on the sustainability of those sources as well as the potential to mitigate those effects through sediment management practices. Results of this analysis are presented in subsequent chapters of this report.

Figure 1-3: Sulphur River Watershed Erosion

Figure 1-4: Sediment Deposition along Sulphur River Bridge

2.0 INSTITUTIONAL SETTING

Water resources development in the Sulphur River Basin would occur within the context of currently-held water rights and institutional constraints. This chapter provides background on the development of existing projects, the physical and legal connections between existing projects, and provides insights as to how this background affects development of new sources within the basin. A discussion of current water quality in Wright Patman Lake and in Jim Chapman Lake is also included.

2.1 BACKGROUND/TIMELINE

2.1.1 Early Studies

Federal participation in development of water resources in the Sulphur River Basin has been studied for decades. House Document No. 378 (74th Congress, 2nd Session), dated 3 January 1936, contained the results of a comprehensive survey of the Red River and its tributaries for dam sites suitable for stand-alone flood damage reduction as well as for flood damage reduction in conjunction with power generation and navigation. One of the ten dam sites evaluated was located in the Sulphur River Basin, but none of the projects were economically justified at that time.1

In 1940, the Vicksburg Engineer District developed a comprehensive plan for a system of levees and reservoirs to reduce flood hazards in the Sulphur River Basin. Additionally, a reservoir at the Wright Patman site (originally Texarkana Reservoir) was included as part of the "Seven Reservoir Plan" for the Red River in a report submitted by a special Board of Officers in March 1941 (E.D. 7249 – 310). Neither of these plans was found to be economically justified.

During the spring of 1945, widespread flooding occurred across the Lower Mississippi Basin including the Red River and Sulphur River Basins. Dennison Dam at Lake Texoma, completed the previous year, contained a portion of the floodwaters and prevented in excess of $3,000,000 in damages in 1945 dollars.2) At Shreveport, the Red River crested approximately 30' above normal stage, and flows of up to three times the river's bank-full capacity were observed. Farther downstream, the Bonnett Carre' spillway, which diverts excess Mississippi River flows into the Atchafalaya Basin during flood events, was open for 57 days.3 Damages within the Red River Basin were estimated to exceed $16,000,000 in 1945 dollars. This event established a new flood of record for the Red River and affected more than 1,000 square miles and 1,000,000 residents in the basin.

This flood event triggered significant interest in Federal flood protection. On April 19, 1945, the Committee on Flood Control of the U.S. House of Representatives requested that the Board of Engineers for Rivers and Harbors (BERH) review prior reports on the Red River and Tributaries in light of the 1945 flood experience (emphasis added) with a view to determining what improvements would be advisable to provide protection downstream of Denison Dam. In December of 1945, the Board provided a response in the form of an interim report recommending additional levee construction, bank stabilization, channel work, and new reservoirs on six tributary streams, including Texarkana Reservoir on the Sulphur River in Texas.

2.1.2 Texarkana Reservoir (Wright Patman Lake)

In May 1946, the U.S. House of Representatives recommended authorization of the project described in the December 1945 BERH report. This recommendation is contained in House Document #602-79-2. On July 24, 1946 (Public Law 79-526), Congress authorized the project for flood control of Red River, Texas, Oklahoma, Arkansas, and Louisiana below Denison Dam, including construction of Texarkana Reservoir (now known as Wright Patman Lake.) The first construction contract for Texarkana Reservoir, for clearing within the reservoir footprint, was awarded on August 20, 1948.

On March 5, 1951, the City of Texarkana filed Application #1684 with the Texas Water Commission (TWC) for the right to divert and use 14,572 acre-feet per year from Texarkana Reservoir for municipal purposes. The water right (Permit #1563) was issued on April 18, 1951.

In April of 1952, the Corps approved the Detailed Project Report (DPR) for Texarkana Reservoir. This document provided certain finalized design parameters for the reservoir and designated “flowage easement” as the appropriate real estate interest for lands above elevation 235.0 feet.

On February 16,1954, the United States and the City of Texarkana executed a water supply contract (DA-16-047-ENG-2033) providing for a minimum conservation pool elevation of 220.0 feet in order to provide adequate storage to meet a water supply demand of 13 million gallons per day (MGD). In consideration, the City agreed to pay an annual sum of $7,000 (including capitalized Operation and Maintenance costs.) Deliberate impoundment at the reservoir began on June 27, 1956.

On February 18, 1957, the City of Texarkana filed a request to modify their water right with the Texas Water Commission (Application #2025). This application sought to increase Texarkana’s diversion right by 10,428 acre-feet per year for municipal purposes and 35,000 acre-feet per year for industrial purpose to a total diversion of 60,000 acre-feet per year. This amended water right (Permit #1563A) was issued by the TWC on March 27, 1957. In December of 1958, Texarkana began making water supply withdrawals in accordance with their water right permit and the 1954 contract with the Corps.

2.1.3 Cooper Reservoir (Jim Chapman Lake) Authorization

The report submitted by the BERH in December 1945 in response to the April 1945 study request was identified by the Corps as an interim response to that Committee Request (emphasis added.) In June 1950, the Board submitted a report entitled Red River and Tributaries, Texas, Oklahoma, Arkansas, and Louisiana that constituted a consolidated response to that study resolution and to nine additional resolutions related to the Red River Basin passed by the Congress between 1937 and 1949. Included among the recommendations for authorization contained in this report was construction of Cooper Dam and Reservoir (now known as Jim Chapman Lake) on mile 29 of the South Sulphur River.

As described in the report, the Cooper project was envisioned to provide "5,000 acre-feet of storage for conservation and 130,000 acre-feet for flood control in substitution for 120,000 acre-feet of the flood-control storage in the authorized Texarkana Reservoir."[1] The Cooper Reservoir was intended to "assist in the alleviation of flooding along the 98 miles of South Sulphur and Sulphur Rivers between Cooper Dam site and the upper end of Texarkana Reservoir, through regulation of the flow from 450 square miles of drainage area." Flood control benefits for the area below Texarkana Dam would remain unchanged. Channel improvements and levee construction along the Sulphur River were recommended in conjunction with the reservoir.

Subsequent to its completion, the Division Engineer's report was circulated to local and Federal agencies for comment. In their review and transmittal memo, the Bureau of the Budget notes that in response to comments received the 1950 report was revised "to a considerable extent." (ibid, p. VI) At least two of the issues related specifically to the Cooper Project. Firstly, there was considerable local support for increasing the amount of conservation storage from 5,000 acre-feet to 15,000 acre-feet with a commensurate reduction in the flood control storage from 130,000 acre-feet to 120,000 acre-feet. (p. X) Secondly, the Department of the Interior objected to the recommendation to construct the Cooper project due to inadequate consideration to the conservation of fish and wildlife resources.

In March, 1954 of the Corps completed coordination and revision of the report and it was transmitted from the Chief of Engineers to the Secretary of the Army. In July of that year the report was submitted by the Secretary of the Army to the Speaker of the House. The report was recommended for authorization as House Document 488/83/2 in August, 1954 and construction of the Cooper project was authorized in August, 1955 as part of Public Law 84-218. Construction of the levees and channel improvements upstream of the dam site along the Middle and South Sulphur Rivers was begun in 1958 and substantially completed in 1959. This work consisted of 18.4 miles of realigned river channel, clearing of a "floodway" within the realigned channel and improvement to 7.4 miles of existing agricultural levees. [2]

Between 1955 and 1967, the Cooper project underwent a series of preconstruction expansions and modifications. House Document 1056, 84th Congress, and Senate Document 1027, 84th Congress, authorized an additional 10,000 acre-feet of conservation storage. In 1959, water supply storage was expanded to 75,400 acre-feet pursuant to 43 USC 390(b), Development of Water Supplies for Domestic, Municipal, Industrial, and other Purposes. [3]

By resolution dated February 28, 1964, the Texas Water Commission designated the City of Irving, the North Texas Municipal Water District, and the Sulphur River Municipal Water District as agents of the commission for the purpose of negotiation with the Federal Government for the municipal and industrial water supply storage space in Cooper Reservoir. At some point before 1965, the Texas Water Commission, in response to requests from these entities, requested that the New Orleans District Engineer investigate the feasibility of enlarging Cooper Reservoir to include 273,000 acre-feet of water supply storage.[4] These expansions were made in 1965 under authority of 43USC 390(b) (Bowman, 1979.)

In November 1965, the Sulphur River Municipal Water District (SRMWD), the North Texas Municipal Water District (NTMWD), and the City of Irving submitted applications numbered 2414, 2415, and 2416, respectively, to the Texas Water Commission for the right to impound and divert surface waters from Cooper Reservoir.

During 1966, project planning for Cooper was modified again to accommodate the Texas Water Plan (TWP). The preliminary plan for the Sulphur River Basin included construction of two reservoirs between Cooper Lake and Texarkana Reservoir as well as infrastructure needed to move water upstream through a series of pump stations, pipelines, and canals. In addition to having a major effect on the flood control benefits Cooper would have provided to the floodplain area between its dam site and Texarkana Reservoir, implementation of the TWP would have required structural modifications to the Cooper Reservoir itself. In order to integrate Cooper planning with state water planning, the Texas Water Development Board (TWDB) entered into Contract #DACW29-68-A-0102 with the Federal Government, agreeing to serve as the non-Federal sponsor for the additional costs of the Cooper project associated with implementing the Sulphur River portion of the TWP. Due to uncertainty as to implementation of these features, TWDB eventually determined to withdraw from its sponsorship role. Its contract with the Corps was rescinded on July 28, 1976.

On April 2, 1968, the State issued water rights to SRMWD, NTMWD, and the City of Irving in accordance with Table 2-1 below. The SRMWD water rights were subsequently contracted to the cities of Sulphur Springs, Cooper, Commerce, Texas and the NTMWD.

Table 2-1: Cooper Water Rights

	Permit (Certificate) Number	Permitted Diversion (Municipal) Acre-feet per Year	Permitted Diversion (Industrial) Acre-feet per Year	Total Permitted Diversion Acre-feet per Year
SRMWD	2336 (CA 4797)	23,746	11,560	35,306
NTMWD	2338 (CA 4798)	44,820	9,180	54,000
City of Irving	2337 (CA 4799)	44,820	9,180	54,000

Concurrent with receiving their state water rights (29 March, 1968), the three Cooper partners executed contracts with the Corps of Engineers for water storage space. These contracts apportioned the authorized conservation storage for the first ten years after deliberate impoundment as well as the additional storage available on the tenth anniversary of deliberate impoundment. In addition, the contracts established the payment schedule for each entity for a proportionate share of the storage costs and the annual operation and maintenance costs. The contract included a requirement for a low flow release of a minimum of 5 cubic feet per second (cfs) at all times. Total apportionment of the storage among the partners is described in Table 2-2 below.

Table 2-2: Apportionment of Water Supply Storage in Cooper Lake

	Contract #	Proportionate Share	Storage (Acre-Feet)
SRMWD	DACW-68-A-0101	26.282 %	71,750
NTMWD	DACW-68-A-0100	36.859 %	100,625
City of Irving	DACW-68-A-0099	36.859 %	100,625

2.1.4 Modifications at Texarkana Reservoir in Light of the Cooper Project

As progress was made on the Cooper project throughout the early-to-mid 1960's, the City of Texarkana began to make preparation for the conversion of 120,000 acre-feet of flood control storage to conservation storage as permitted by the Cooper authorization. By an order dated 6 September 1966, the Texas Water Commission (TWC) designated the City of Texarkana, Texas the cooperating local sponsor for purposes of negotiating with the Government for the acquisition of rights to the storage space. The TWDB was designated co-negotiators on behalf of the State.[5]

On September 19, 1967 the City filed application #2552, seeking to amend their existing water right for post-Cooper operations and obtain rights for an additional diversion and use in amounts not to exceed 20,000 acre-feet per year for municipal use and 100,000 acre-feet per year for industrial use. The permit amendment (#1563B) was issued by the TWC on April 18, 1968. (This permit has since been replaced by Certificate of Adjudication #CA 4836.)

The City also sought to amend their water supply storage contract with the Corps. On April 16, 1968 contract number DACW29-68-A-0103 was executed between Texarkana and the United States. This contract modified the storage space available to Texarkana and established a repayment schedule for the increased storage. Under this contract, the bottom of conservation storage in Texarkana Reservoir was established as elevation 220' and the top of the conservation storage was set at varying elevations between 224.89' and 228.64' depending on the month of the year. Development of a variable rule curve rather than a constant top-of-conservation-pool elevation reflected the New Orleans District approach to reservoir operations and was intended to maximize available storage in light of the strong seasonality associated with storm systems and flooding hazards in East Texas. The specific monthly elevations specified in Contract #103 for Texarkana Reservoir are often referred to as the "Ultimate" rule curve.

Additionally, this contract specified that the City may not make withdrawals which would lower the water level below elevation 220' "unless expressly approved in writing by the Contracting Officer." [6] Contract # DACW29-68-A-0103 was to become effective on the date upon which Cooper Reservoir was deemed complete for flood control purposes, or the date of completion of all modifications to Texarkana Reservoir required to effect the conversion of the storage space, whichever is later.

At the time, construction of the reservoir component of the Cooper project was expected to be initiated in the near term and completed within a few years. In order to allow the City of Texarkana to take advantage of their inreased water right during the interim period, a second contract with the Corps was executed in September 1968. Contract # DACW29-69-C-0019 defined an operating rule curve for the top of conservation storage ranging from elevation 220.6 to 227.5,depending on the month, and established a modified payment schedule for the smaller amount of storage. With respect to storage below the minimum elevation, the rule curve is foot-noted as follows:

> "Under certain exceptional conditions, provisions of the quantities of water described in …this Article may require that storage space in Texarkana Reservoir below the normal minimum pool elevation of 220 feet above mean sea level be utilized."[7]

Table 2-3 provides a comparison of key parameters of the permanent and interim contracts.

Table 2-3: Permanent and Interim Contracts - Water Conservation Storage, Texarkana Reservoir

	Interim Contract	Permanent Contract
Effective Storage Available to Texarkana (AF)	76,663	139,320
Construction Cost Allocated to Texarkana ($1968)	$1,437,647	$1,997,604
Total Annual Payment to Corps ($1968)	$55,300	$269,308

On December 15, 1973, President Richard Nixon signed H.R. 945, officially re-naming Texarkana Reservoir as "Wright Patman Dam and Lake" in honor of Congressman Patman, who represented the First Congressional District of Texas for 47 years.

2.1.5 Cooper Litigation

In Fiscal Year 1971, the Corps received funding to initiate construction of the reservoir component of the Cooper Project. However, in the interim since the previous construction of levee and channel components, Public Law 91-190, the National Environmental Policy Act (NEPA), had been passed by the U.S. Congress. NEPA established a process for consideration of the effects of Federal actions on the environment, and litigation was filed by the Texas Committee on Natural Resources (TCONR) to halt construction of the reservoir until such time as the NEPA process had been fulfilled. In May, 1971, the U.S. District Court for the Eastern District of Texas enjoined reservoir construction pending completion of an Environmental Impact Statement (EIS) in compliance with NEPA.

In accordance with the Court's direction, the New Orleans District began to prepare an EIS. The Draft EIS was filed by the Corps with the Council on Environmental Quality (CEQ) on 10 June 1976. Public comment substantially reflected the need for dependable surface water and downstream flood control as perceived by local area residents and environmental concerns, particularly associated with the downstream channelization components.[8] The Final EIS, filed on 24 June 1977, recommended construction of the "Reservoir and Levees Plan" including the reservoir plus 27 miles of additional levees and 6.6 miles of channel improvement downstream of the dam site.

The original Cooper EIS also peripherally addressed the conversion of flood control storage at Wright Patman to water supply. Section 1.06 of the Cooper EIS states the following:

> "a. The Cooper Lake project is related to the Wright Patman Lake project in that the construction of the 131,400 acre-foot flood control pool at Cooper will permit the conversion of 120,000 acre-feet of existing flood control space in Wright Patman lake into water supply space. The flood control pool at Cooper Lake provides upstream substitute flood control storage for the space that will be converted at Wright Patman Lake, and thus, will not impair the present level of flood protection below Wright Patman Lake. The conversion is only possible if and after Cooper Lake is completed.
>
> b. The completion of Cooper Lake merely makes possible the reallocation of storage space at Wright Patman Lake. This reallocation is not mandated by the authorizing legislation for the Cooper project; it is, however, permitted by that legislation. The decision to implement this feature will be a future determination, and in accordance with the policies prescribed by the National Environmental Policy Act of 1969, and environmental statement for this action will be prepared prior to implementation." (p. I-15, I-16)

In December 1978, the Court issued a Memorandum Opinion detailing five inadequacies of the 1977 FEIS and permanently extending the construction injunction pending their resolution in a revised EIS. The inadequacies of the 1977 FEIS as determined by the Court included:

1. Absence of state agency comments, and failure to address those comments that were made;
2. Failure to set out, concurrently with implementation of the project, adequate mitigation measures for losses of fish and wildlife;
3. Failure to discuss the alternative of a water supply project without provision for flood control;
4. Inadequate explanation of nonstructural flood control measures;
5. Bias in presentation of cost-benefit ratios and failure to analyze those presented.

In 1979, responsibility for the Cooper project, along with operation of Wright Patman Lake and Lake O' the Pines was transferred from the Corps' New Orleans District to the Fort Worth District as part of a boundary realignment.

On October 31, 1980, the Fort Worth District provided notice of availability of a Draft Supplemental EIS for the Cooper Reservoir in the Federal Register. The Supplemental EIS focused specifically on the inadequacies of the 1977 FEIS as identified in the Memorandum Opinion. The recommended plan identified in this document differed from that of the 1977 FEIS in that the downstream levees and channels were omitted ("Reservoir Only Plan".) The recommended plan was estimated to result in the loss or degradation of about 25,400 acres of terrestrial wildlife habitat including 2,100 acres of wetlands and 21 miles of riverine habitat. The plan to mitigate these losses required the acquisition and management of approximately 25,500 acres of mitigation lands.

The Final Supplemental EIS was filed by the Corps on March 27, 1981. Concurrently (March 1981), the Fort Worth District prepared a Draft Report on the Acquisition of Mitigation Lands which evaluated two general configurations for the terrestrial mitigation lands as well as other alternatives to compensate for identified wildlife losses. This report recommended conversion of approximately 25,500 acres of bottomland hardwood habitat in the flood pool of Wright Patman Lake from flowage easement to fee title; acquisition of a 751-acre tract between the Cooper Dam and Highway 19/154; and management of 7,000 acres of project lands at Cooper Lake for wildlife purposes.

At the time the mitigation plan for Cooper was formulated, the Corps lacked authority to implement it, as neither the Wright Patman authorization nor the Cooper authorization had originally envisioned the need to mitigate terrestrial resources. Accordingly, the Mitigation Report followed the standard internal Corps process for requesting a new or modified project authority from Congress. The Division Engineer's notice of the report's availability and intent to seek authorization was issued on June 15, 1981 and the final report incorporating Headquarters and Division comments was completed in September. In October 1981, the Board of Engineers endorsed the report recommendations to the Chief of Engineers for approval, and in May 1982, the Mitigation Report was submitted to the Congress for authorization.

The formulation of the Recommended Plan in the Supplemental EIS had included significant amounts of coordination with local and state agencies including the Texas Parks and Wildlife Department (TPWD). By letter dated January 6, 1982, Mr. Charles Travis, the TPWD Executive Director, indicated that the

Texas Parks and Wildlife Commission had approved TPWD's acceptance of Operations and Maintenance responsibilities for the wildlife mitigations lands, both at Cooper and in the White Oak Creek Mitigation Area.

Meanwhile, the Courts were reviewing the Final Supplemental EIS for compliance with the Memorandum Opinion. In March 1983, the District Court issued a decision citing deficiencies in the Supplemental EIS and issuing a second permanent injunction of construction. The Government decided to appeal the District Court's Decision. The Corps was joined in the appeal by the three water supply sponsors (SRMWD, NTMWD, and the City of Irving). On July 16, 1984, the U.S. Court of Appeals, Fifth Circuit, overturned the District Court's 1983 decision and lifted the construction injunction.

The mitigation plan was authorized by Congress in Public Law 99-662, the Water Resources Development Act of 1986, Title VI:

> "The project for the mitigation of fish and wildlife resource losses, *Cooper Lake and Channels, Texas*: Report of the Chief of Engineers, dated May 21, 1982, at a total cost of $14,800,000, with an estimated first Federal cost of $8,160,000 and an estimated first non-Federal cost of $6,640,000."

Later that year, implementation of the mitigation plan and Cooper reservoir construction were initiated by the Corps. *Design Memorandum No. 10*, *Cooper Lake Master Plan* was completed in early 1988 and approved in April of that year. This document assumed TPWD maintenance of all mitigation lands in accordance with the agency's 1982 commitment. *Design Memorandum No. 22, Real Estate –Acquisition of Wildlife Mitigation Lands*, which described the acquisition in detail, was approved in October 1988. The Master Plan was supplemented in 1990 with a detailed plan of development for the White Oak Creek Mitigation Area.

Deliberate impoundment at Cooper began on 28 September 1991. In 1998, the Cooper project was officially renamed Cooper Dam and Jim Chapman Lake in honor of the local Congressman and longtime project supporter.

2.2 SCENARIOS FOR FUTURE WATER RESOURCES DEVELOPMENT

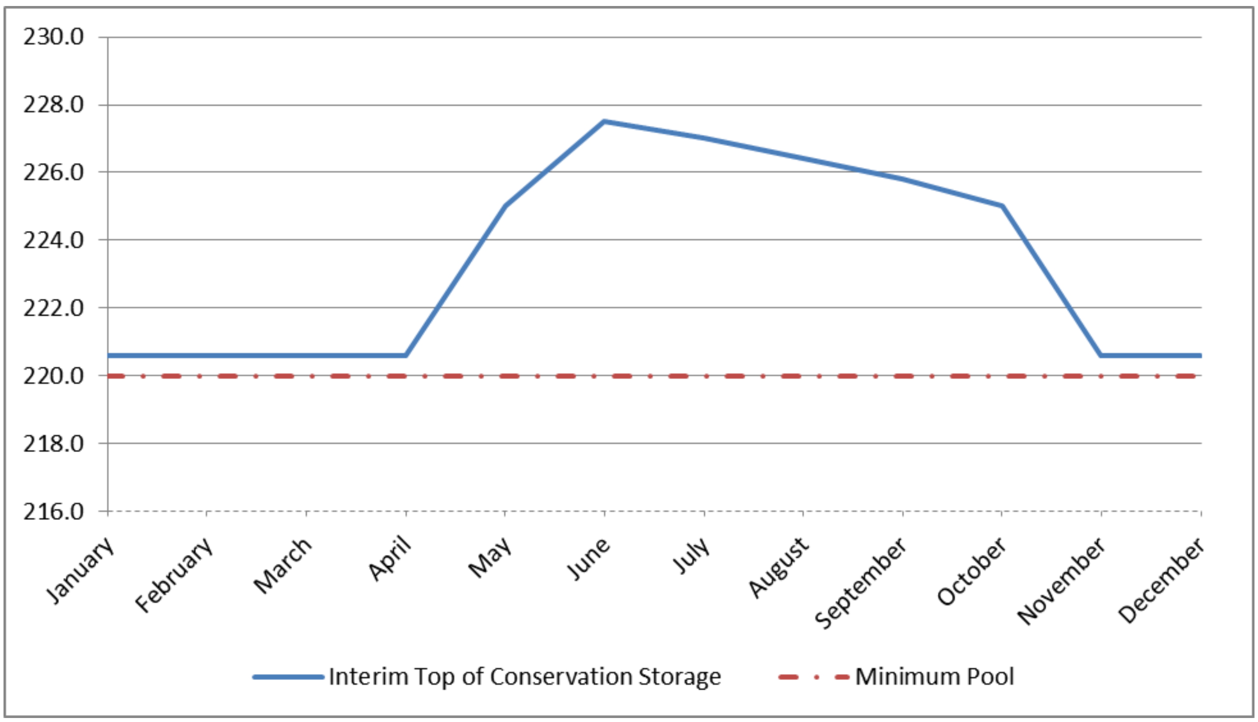
Discussion of a number of potential future water resources scenarios associated with operation of Wright Patman Lake and/or Jim Chapman Lake is enlightened by the background and history provided in the previous narrative. Problems and opportunities are discussed in more detail below.

2.2.1 Current Wright Patman Lake Conditions

A. Current Operations

The Corps of Engineers currently operates Wright Patman Lake consistent with the rule curve specified in the interim contract, shown in Figure 2-1 below. In addition to specifying the lake elevation which constitutes water supply storage, this contract specifies a maximum allowable average daily rate of withdrawal for various months. On an annual basis, the average daily rate of withdrawal may not exceed 13 million gallons per day (MGD) or 14,562 acre-feet per year. The water supply contract specifies that the Corps will reserve the right to release at least 6.5 MGD (10 cfs) through the Wright Patman Dam for the maintenance of minimum flows in the Sulphur River downstream of the dam site.

Figure 2-1: Wright Patman Interim Rule Curve



The operating rule curve provides the Corps some degree of flexibility, particularly in moving from one zone of the rule curve to another. The Corps typically utilizes this flexibility to cooperate with the City of Texarkana in maintaining lake levels to minimize problems with ongoing siltation around their intake structure. Additionally, during very dry conditions and at the request of the City, the Corps has occasionally sought and received a waiver to deviate from the rule curve in order to hold water high enough for water to reach the intake structure.

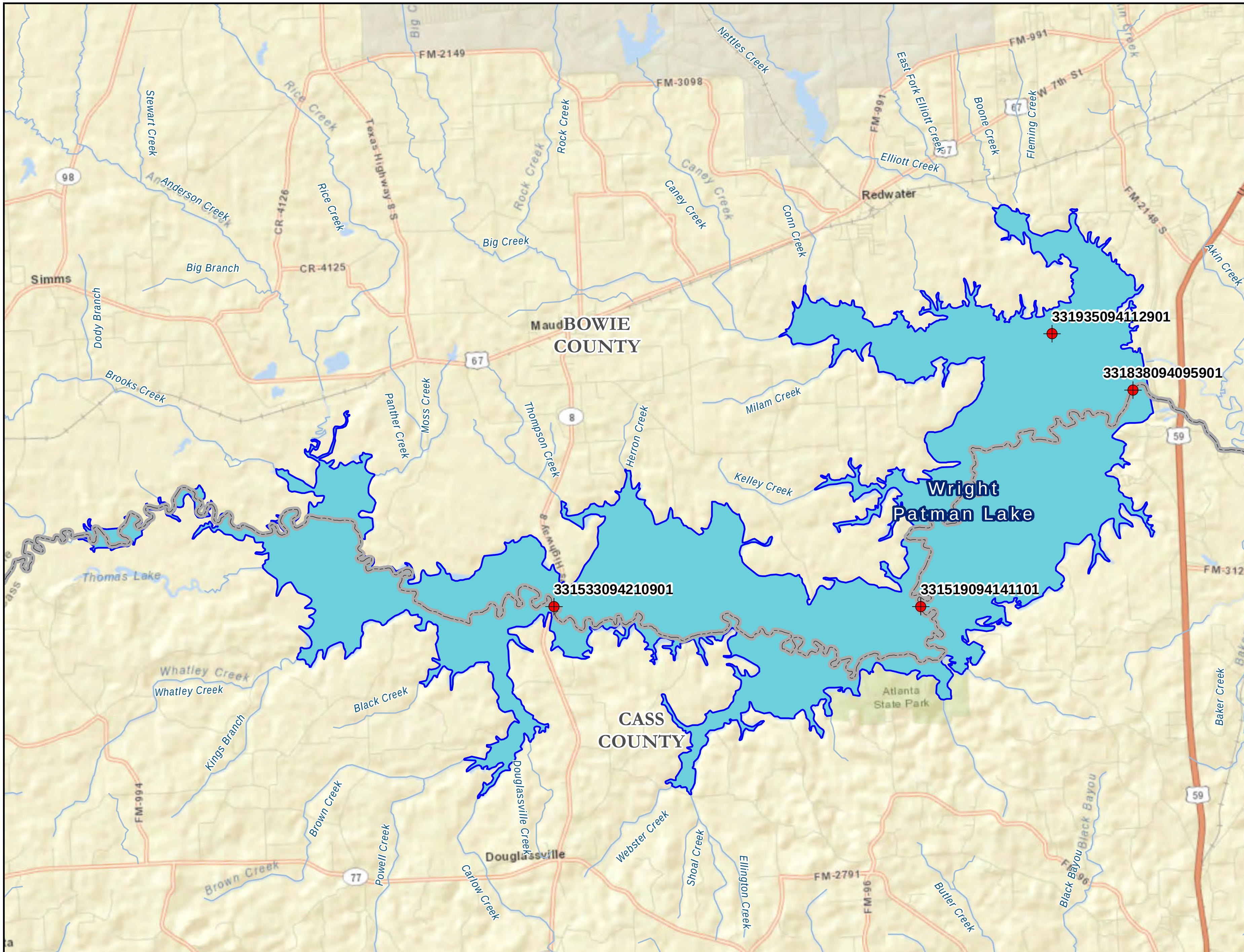
Although International Paper Company (IP) does not hold a water right from Wright Patman Lake, they hold a long-term contract with the City of Texarkana for a substantial portion of Texarkana's water right. International Paper uses water under this contract for both process water at the plant, and, when needed, to augment flows in the Sulphur River and meet the conditions of their effluent discharge permit from TCEQ. The Corps also typically cooperates with IP (through the City of Texarkana) to the extent practical in making releases from the flood pool in a manner that facilitates IP's management of their effluent holding system. The Corps has some degree of flexibility in the timing of releases and can make minor adjustments to optimize storage and release of treated IP effluent.

B. Current Water Quality

Water quality data have been collected from Wright Patman Lake periodically since the 1970's by the U.S. Geological Survey (USGS), the Texas Commission on Environmental Quality (TCEQ) and, most recently, by Texarkana College under the State of Texas' Clean Rivers Program (CRP). As of 2011, the lake (TCEQ water quality segment 0302) is listed as an impaired water body on the State of Texas 303(d) list for low dissolved oxygen (DO), although recent test results show improvement. The lake is also listed on the 303(d) list for high pH. Chlorophyll-a, orthophosphorus, pH and total phosphorus are constituents of concern listed in the Texas Water Quality Inventory 305(b) Report. All other water quality constituents sampled as part of the Clean Rivers Program are within the allowable ranges.[9]

Upstream of Wright Patman Lake, White Oak Creek (segment 0303B) is included on the 303(d) list as impaired for high levels of bacteria and low levels of DO (SRBA, 2012). DO, nitrate, orthophosphorus and total phosphorus are identified as constituents of concern in the 305(b) report.

Data collected at four USGS water quality sampling sites on Wright Patman Lake were analyzed by FNI for indicators of improving or degrading water quality between 1978 and 2007. Sampling locations are shown in Figure 2-2. The low number of water quality data points (159 points at site 331533094210901 to 222 points at site 331838094095901) collected over the 29 year period of record was inadequate to provide a statistically significant and meaningful analysis of long-term water quality trends. Additionally, water quality samples were not always taken at the same time on a year-to-year basis, making it difficult to compare data from one year to another. A water quality study utilizing continuous sampling techniques at a consistent time step would be necessary for a valid analysis of variations in lake water quality over time.



Project Location

USGS Sample Sites | County Borders | Wright Patman Existing Lake

NORTH

0 | 4,000 | 8,000 | 12,000
Feet

FREESE AND NICHOLS
4055 International Plaza Suite 200
Fort Worth, Texas 76109-4895
817-735-7300

U.S. Army Corps of Engineers, Fort Worth District
Sulphur River Watershed

Wright Patman Lake USGS Water Quality Sample Site Locations

FILE NAME: Wright Patman .mxd
DATUM & COORDINATE SYSTEM: NAD83 State Plane (ft) N. Central Texas
SCALE: 150,000
DRAFTER: JJC
DATE: September, 2013
F&N JOB NO.: MHP11453

2-2
FIGURE

Stakeholders have suggested that erosion and sedimentation in the Sulphur River watershed may be negatively affecting water quality in the lower portions of the watershed and in Wright Patman Lake. The nutrient phosphorus (which contributes to eutrophication) attaches to clay particles in soil or sediment and can be transported downstream through erosional processes. Erosion and sedimentation in the Sulphur River watershed may be contributing high nutrient loads to Wright Patman Lake. To date, no studies have been undertaken to investigate the link between upstream overland and channel erosion to downstream impaired water quality in the Sulphur River watershed. A multi-year water quality and sediment study would be required to adequately quantify the relationship between upstream erosion and potential water quality degradation in Wright Patman Lake.

2.2.2 Interim vs. Permanent Operations at Wright Patman (Conversion)

A. Conversion Description

Conversion of 120,000 acre-feet of flood control storage in Wright Patman Lake to water supply storage upon completion of Jim Chapman Lake (Cooper) was envisioned in the original planning and authorization documents for Cooper. House Document 488/83/2 describes this feature, and the 1977 Environmental Impact Statement for Cooper explicitly states that the conversion is permitted by the enabling legislation. (p. I-16) The City of Texarkana has negotiated and signed a contract with the Corps of Engineers for the additional storage that would result from the conversion (DACW29-68-A-103), and has received a water right from the State of Texas (#1563B) to divert additional water for municipal (20,000 acre-feet per year) and industrial purposes (100,000 acre-feet per year) based on the additional storage.

In summary, the conversion was authorized by Congress in 1955 and both the storage contract (Federal) and the water right (State) have been in place since 1968. However, Contract #DACW29-68-A-103 establishes two conditions for the “effective date for water withdrawal” on which the City would have the right to begin withdrawal of water from Wright Patman pursuant to the contract. The “effective date for withdrawal” is determined as the later of:

1. The date of deliberate impoundment (the date upon which Cooper Reservoir becomes operative for storage of water for the purpose of flood control), or
2. The date of completion of all modifications to Texarkana Reservoir which are required to effect the conversion.[10]

Deliberate impoundment began at Cooper in September 1991. Description and enumeration of the "modifications" to Wright Patman Lake necessary to effect the conversion would typically be developed in a detailed study of the conversion that has not yet conducted. Because the storage conversion at Wright Patman has not yet been effected, the Sulphur River Basin currently has 120,000 acre-feet more storage dedicated to flood risk reduction than project justification included. In April 2004, the City of Texarkana entered into a dialog with the Fort Worth District regarding actions necessary to fulfill the second condition of their permanent water supply contract.

B. Conversion Issues

As previously discussed, the original Cooper EIS noted that the decision to implement the conversion would be addressed under NEPA prior to implementation. Accordingly, the Corps determined that a NEPA document would be needed in advance of contract "activation." Development of the NEPA document would typically encompass compliance with other environmental statutes, including the Clean Water Act (Section 404/401) and the National Historic Preservation Act.

Any modification to the top of the conservation pool has the potential to effect cultural resources located in the perimeter around the lake due to erosion and wave action. The Corps has initiated work on an abbreviated cultural resources survey of the lands immediately above the current conservation pool in a proactive attempt to assess the scope of this concern.

Typically, a modification to the operating rule curve would also be expected to impact recreation facilities, particularly those at the lowest elevations. The Corps would be expected to require a detailed study of the recreation facilities to be affected as well as development of a plan to relocate or replace them.

The results of these and related analyses would be assembled into a decision document supporting the Corps' determination that the conditions of the contract have been met and that that the storage contract is effective. It is expected that the cost of developing the technical analyses and decision document would be 100% non-Federal and be borne by the City of Texarkana.

In addition to these considerations, there is the potential issue of dam safety. In 2005, the Corps began an initiative to prioritize Corps-maintained and operated dams nationwide based on the risk presented. The Screening Portfolio Risk Analysis performed considered both project performance and the anticipated consequences of failure. Wright Patman Dam was screened in 2007, and as a result of this screening, was placed in Dam Safety Action (DSAC) Category III, High Priority. Projects in this classification have issues where the dam is significantly inadequate OR the combination of life, economic, or environmental consequences with probability of failure is moderate to high.

Current Corps policy, as defined in EC 1165-2-210, "Water Supply Storage and Risk Reduction Measures for Dam Safety," is that a reallocation that would require raising the conservation pool is not permitted while a project is classified DSAC I, II, or III. Whether an already-authorized conversion for which a storage contract has been signed would be considered a reallocation under this current policy is unclear.

2.2.3 Potential Wright Patman Reallocation

A. General Reallocation Requirements

If the conversion of flood control storage in Wright Patman to water supply storage discussed above were to occur, Wright Patman would still have more than 2,000,000 acre-feet of storage dedicated to flood risk reduction.[11] In concept, reallocation of some, or all, of this remaining storage to water supply purposes is possible, provided a number of conditions are met.

Reallocation is defined by the Corps as "the reassignment of the use of existing storage space in a reservoir project to a higher and better use."[12] The Corps provides water supply storage in multi-purpose reservoirs primarily under authority of the Water Supply Act of 1958. This legislation, while affirming that water supply is primarily a non-Federal responsibility, directs the Federal government to cooperate and support local efforts and authorizes Corps involvement in storage for Municipal and Industrial water supply. This legislation also provides authority for the Corps to consider reallocation existing storage to water supply. However, the Corps may not act unilaterally. Section 301(d) states:

> "Modifications of a reservoir project heretofore ...planned or constructed to include storage as provided in subsection (b), which would seriously affect the purposed for which the project was authorized…or which would involve major structural or operational changes, will be made only upon the approval of Congress as now provided by law."

When a reallocation is contemplated, a Reallocation Report must be prepared. The length and cost of the reallocation report depends on the scale of change envisioned and the complexity of the issues. In general, a Reallocation Report addresses the following topics:

1. The amount of storage to be reallocated, the need for the additional water, and the specific new users of the water.

2. Impacts on other project purposes and users.
3. Environmental effects.
4. The price to be charged for the storage.
5. Appropriate compensation, if any, to existing users or beneficiaries.

Reallocations of up to 15 percent of the total storage capacity allocated to all authorized project purposes, or 50,000 acre-feet (whichever is less) may fall within the discretion of the Chief of Engineers. Larger reallocations require Congressional approval (see above.) Additional guidance regarding Corps' policies regarding reallocation is contained in Engineer Regulation 1105-2-100, the Planning Guidance Notebook, and in Institute for Water Resources Report 96-PS-4, Water Supply Handbook.

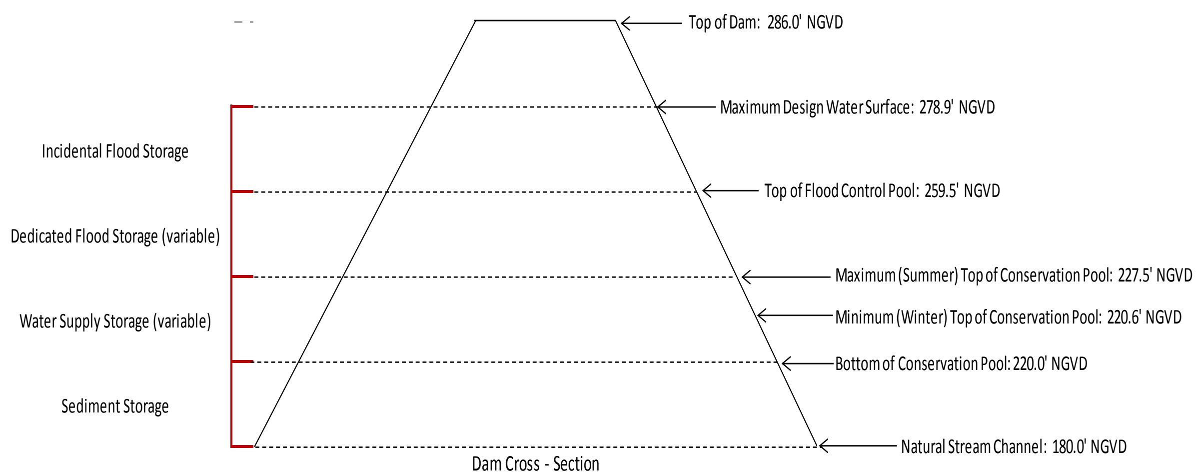
Typically a reallocation report would include a NEPA document as well as documentation of compliance with other applicable environmental statutes. Because the decision to implement a reallocation (or to recommend a reallocation to Congress) is a Corps action, a separate permit under Section 404 of the Clean Water Act is not required. (The Corps does not issue itself permits.) The reallocation proposal would, however, be subject to the same guidelines under Section 404(b)(1) as used by the Corps to administer the 404 permitting process, and compliance with those guidelines must be documented. As with any action subject to the Clean Water Act, compliance with Section 401, as administered by the State of Texas, would be required.

Approval of a reallocation report does not, in and of itself, constitute approval to reallocate storage. An updated storage contract is required; approval is conveyed by the final signature on the updated water supply agreement. In any case, the process for approval of storage reallocation in a Corps reservoir is a Federal process completely separate from the State process for obtaining any needed water right to divert and utilize State surface waters.

B. Reallocation Options

The top of Wright Patman Dam is at elevation 286.0' NGVD (National Geodetic Vertical Datum.) In order to protect the integrity of the structure, the spillway crest was constructed at elevation 259.5'; above that elevation, water would begin to flow through the "uncontrolled" spillway. (The "uncontrolled" spillway is a 200-foot section of the dam set lower than the balance of the structure to prevent overtopping of the main structure in the event of an extreme flood event.) In terms of normal operations, elevation 259.5 NGVD is considered the top of the flood control pool. At this elevation, Wright Patman Lake would have a cumulative storage capacity of 2,659,000 acre-feet. On an average basis, the cumulative storage at the top of the conservation pool (after conversion of the 120,000 acre-feet discussed previously) would be 177,626 acre-feet, of which 68,000 acre-feet is below elevation 220.0 and comprises the sediment, or "dead" storage zone of the reservoir.[13] The dedicated flood control storage represents the difference between the top of the conservation pool and the top of the flood control pool, approximately 2,481,300 acre-feet. See Figure 2-3 for illustration.

Figure 2-3: Wright Patman Lake Schematic
(Interim Rule Curve – not to scale)



Theoretically, reallocation of almost any portion of the flood storage is possible. In a practical sense, reallocations are typically limited by either the need to maintain a large amount of flood control storage in order to protect downstream lives and properties, or the constraint on the increase in dependable yield that can be obtained as a result of limited water rights availability, or both. Within the State of Texas, however, the Sulphur River Basin is fairly unique with respect to the availability of significant amounts of unappropriated surface water. As a result, larger-than-typical reallocations may have particular merit in this specific set of circumstances. To establish "bookends" for the range of possible options, yield and impact studies will initially be made for alternative top-of-conservation-pool elevations in 5-foot increments from the top of the conservation pool under the Permanent Rule Curve (220.6- 227.5' NGVD) through 259.5'NGVD. These analyses will inform a more robust dialog regarding the range of practical choices, if any.

C. Reallocation Issues

A reallocation study for Wright Patman has not been comprehensively scoped. Several issues, however, can be quickly identified as important to any potential Reallocation Report. For example, a thorough evaluation of the value of the downstream flood risk reduction that would be foregone under reallocation scenarios would be an essential component of the evaluation.

The effects of a higher conservation pool would also be thoroughly evaluated. At the top of the flood control pool, Wright Patman would have an area of 119,700 acres. Not all this land is owned in fee title by the Federal Government. Of the lands owned in fee by the Government, some portion may be leased for grazing or other purposes. Timber harvests are also conducted periodically on Government lands. Between elevation 227.5 and elevation 259.5, most land remains in private ownership with the Government simply holding a flood easement limiting the right of the landowner to construct damageable structures in this zone. Financial costs and socio-economic impacts associated with purchase and permanent--rather than periodic--inundation of property within various portions of the flood control pool would require careful analysis.

Likewise, the environmental effects of a higher conservation pool would require evaluation. The Wright Patman Lake perimeter lands are known to have high potential for cultural resources, which can be affected by changed water surface elevations. These effects would be evaluated in the NEPA process, along with those associated with the inundation of terrestrial resources and the relocation/replacement of recreation facilities and any other significant issues identified during the scoping process.

D. White Oak Creek Mitigation Area

The White Oak Creek Mitigation Area (WOCMA) presents a special set of circumstances with respect to a potential reallocation at Wright Patman Lake. As discussed in the previous section of this report, conversion of approximately 25,500 acres of flood easements in the upper reaches of the original Wright Patman flood pool to fee title and the management of those lands for wildlife habitat constituted the plan to mitigate the fish and wildlife impacts associated with Cooper Reservoir. This plan was described conceptually in the Supplemental EIS for Cooper developed to address inadequacies in the original EIS as defined in the District Court's 1978 Memorandum Opinion. The specific location of the mitigation lands was defined in the 1982 Mitigation Report which formed the basis of the Congressional authorization in 1986. Mitigation lands are currently leased to Texas Parks and Wildlife Department, which discharges the Corps' mitigation responsibilities on a reimbursable basis. Under contract #DACW63-92-C-0025, the

Federal Government reimburses 76% of TPWD's management expenses. Revenues generated through hunting permits and other fees are retained by TPWD to further offset management expenses. Annual management activities are defined in a 5-year plan developed by TPWD and approved by the Corps.

In general, the mitigation lands at White Oak Creek Mitigation Area are located between elevation 230 and 280 NGVD. Seventy-three per cent of the mitigation lands are at elevations below 259.5' NGVD (FNI, 2003). Depending on the specific reallocation option and operational regime, the mitigation performance of those lands could be adversely affected. In the context of NEPA, those impacts would be required to be evaluated and disclosed as part of the informed decision-making process. Consultation with resource agencies, including the Texas Parks and Wildlife Department, would be required. To the degree that the Congressionally-authorized purpose--whether wildlife mitigation or flood risk reduction--would be significantly affected by any reallocation proposal, Congressional approval would be required.

E. Dam Safety

Funds were received by the Fort Worth District in Fiscal Year 2012 to conduct a seepage study which would provide more detailed information than was utilized in the 2007 screening and classification of Wright Patman Dam. The results of this seepage study will be used in conjunction with the next Periodic Inspection of the dam, currently scheduled for 2014, to assess continued classification of Wright Patman Dam as DSAC III.

A deeper understanding of the 2007 survey results and the reason(s) for Wright Patman Dam's classification is needed in order to evaluate the practicality of any needed repair or remediation and the process implications for a potential reallocation. Assessment of this relationship is beyond the Scope of Work for this effort but is being conducted under separate contract and will be completed during calendar year 2014.

2.2.4 Current Jim Chapman Lake Conditions

A. Current Operations

The top of Cooper Dam is at elevation 464.5' NGVD, with a spillway crest at elevation 446.2' NGVD. At elevations greater than 446.2', water would flow over the spillway in an uncontrolled fashion. Under this condition, the reservoir provides incidental (or surcharge) storage; however, the primary reason for the unregulated discharge is protection of the dam's integrity. At elevations within the flood pool, the objective of reservoir management is to minimize downstream damages by storing as much floodwater as practical. Unlike Wright Patman Lake, Jim Chapman Lake is not operated utilizing a rule curve. Instead, the conservation pool is simply defined as the area between elevations 415.5 and 440 NGVD. Operational criteria for Lake Jim Chapman are defined in the June 1999 Corps of Engineers' publication Jim Chapman Lake Cooper Dam Water Control Manual. These criteria are summarized in Table 2-4 below.

Table 2-4: Current Jim Chapman Lake Release Criteria [14]

Reservoir Elevation	Minimum Release	Maximum Release
Above 447.5'	Calculated from Spillway Rating Curve	Calculated from Spillway Rating Curve
446.2-447.5'	Calculated from Spillway Rating Curve plus amount that will not exceed downstream control	6,000 cfs
441.0-446.2	3,000 cfs	3,000 cfs subject to downstream control
440.4-441.0	1,000 cfs plus inflow	3,000 cfs subject to downstream control
440.0-440.4	50 cfs plus inflow, or amount needed to bring reservoir to 440.0 feet	3,000 cfs subject to downstream control
Below 440.0	5 cfs or amount needed to meet downstream water rights, whichever is greater	None, subject to downstream control

The manual provides for flexibility in releases in order control recession rates (the rate at which lake levels drop when releases and evaporation exceed inflow) during the summer for mosquito control. Operational modifications for the purposes of mosquito control have not been typically been made in the more recent decades.

As indicated in our Water Availability Modeling for Jim Chapman submitted as Deliverable #2 of this task order, the stand-alone yield of Jim Chapman Lake is 117,000acre-feet per year[15] —29,000 acre-feet per year less than the permitted diversion of 146,520 acre-feet per year authorized by the reservoir's Texas water right. Under severe drought conditions, Jim Chapman Lake cannot provide sufficient water to meet all permitted water rights. An accounting plan developed by R.J. Brandes is used to track water use from Lake Chapman and determine how much water is available to each user. [16]

The accounting plan divides the conservation storage in the reservoir among the five authorized water users (UTRWD, Irving, NTMWD, Sulphur Springs and Cooper). These divisions are called storage accounts. The maximum volume in each account is based on the percentage of total conservation storage available to each user. If the reservoir is full, the storage accounts are full. As storage in the reservoir begins to drop, diversions are subtracted from each user's account. Inflows, evaporative losses and the 5 cfs constant release are divided among the accounts based on that account's percentage of the total water in conservation storage. As long as a user has storage in their account, they can use water from the reservoir up to their authorized diversion (less an allotment for future evaporative losses). Once a user's account has been depleted, that user cannot use any more water from the reservoir unless inflows partially or entirely fill their account. Other users may continue to use their accounts until either their account is depleted or inflows partially or entirely fill their account.

The main diversion station at Jim Chapman Lake is comprised of two identical pumping units, each rated at 55 mgd (combined capacity of 110 mgd). Additional smaller pumps have been added by Irving and Sulphur Springs. Water from Jim Chapman Lake is delivered to Metroplex customers (NTMWD and the City of Irving) via an 84" pipeline to Indian Creek, a tributary of Lavon Lake. The hydraulic head between the diversion location and the pipeline outfall is 419 feet. [17]

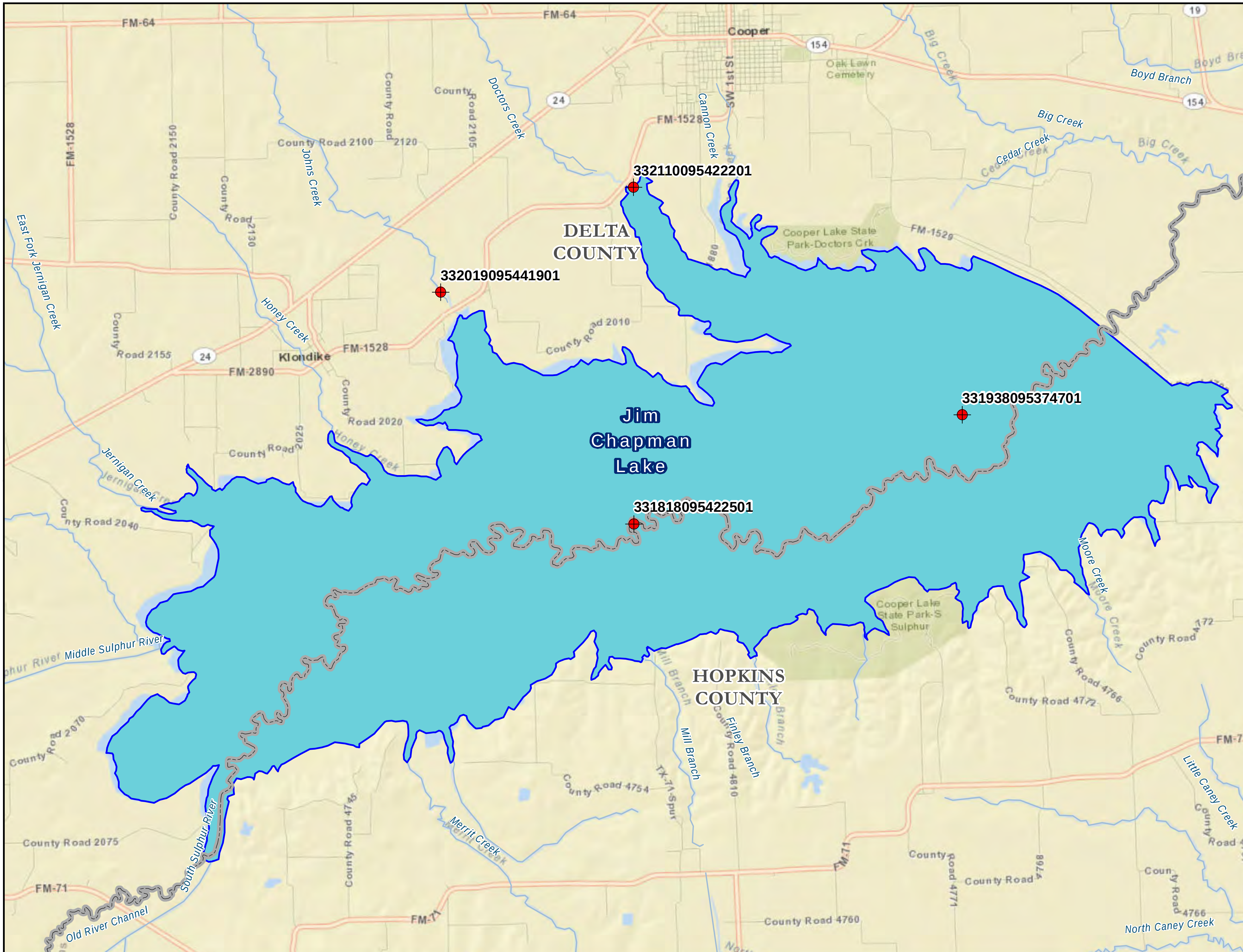
B. Current Water Quality

Water quality data have been collected from Jim Chapman Lake periodically since the 1990's by the U.S. Geological Survey (USGS), the Texas Commission on Environmental Quality (TCEQ) and, most recently, by Texarkana College under the State of Texas' Clean Rivers Program. As of 2011, the lake (TCEQ water quality segment 0307) is listed as an impaired water body on the State of Texas 303(d) list for high pH. Nitrate is the only constituent of concern identified in the 305(b) report. All other water quality constituents sampled in Jim Chapman Lake as part of the Clean Rivers Program are within the allowable ranges (SRBA, 2012). Upstream of Jim Chapman Lake, portions of the Upper South Sulphur River are included on the 303(d) list as impaired for high pH (SRBA, 2012).

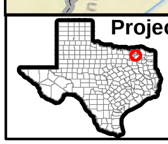
Data collected at four USGS water quality sampling sites on Jim Chapman Lake were analyzed by FNI for indicators of improving or degrading water quality between 1991 and 2001. The 10 year period of record provided some insight into water quality trends at that time. Water quality samples were not always taken at the same time on a year-to year basis, making it difficult to compare data from one year to another. The four USGS sites included in the analysis were 331818095422501, 331938095374701, 332019095441901, and 332110095422201 (Figure 2-4). Water temperature, DO, and pH were the constituents chosen for the analysis because those were the most widely available data over the entire period of record. The constituents were analyzed in groups on the basis of the depths at which the data were collected. The water quality data were, in general, measured at three depths: one foot below the surface, the approximate midpoint of the vertical water column, and near the bottom. The site nearest the dam (331938095374701) was deep enough to allow for sampling at four equally spaced depths.

Figures 2-5 through 2-16 show trends in water temperature, DO, and pH over the 10-year monitoring period. Water temperature at all depths at sites 331818095422501 and 331938095374701 increased over the monitoring period. Sites 332019095441901 and 332110095422201 showed an increasing trend in water temperature at the upper two sampling depths and a decreasing trend at the bottom depths. In general, DO levels increased throughout the monitoring period at all sites, at all depths. The deepest sampling location (331938095374701) experienced a decrease in DO levels at the deepest sampling depth. All sites also showed a general increase in pH. Slightly decreasing trends occurred at the deepest sampling depths at sites 331938095374701 and 332110095422201.

All water quality constituents showed a significant spread/distribution in values over the period of record. The samples appeared to have been collected on an approximately quarterly basis. A water quality study utilizing continuous sampling techniques at a consistent time step would be necessary for a valid analysis of variations in lake water quality over a longer period of time and/or assessment of any relationship between lake water quality and sedimentation.



Project Location



USGS Sample Sites | County Borders | Jim Chapman Existing Lake

NORTH

0 2,500 5,000 7,500

Feet

FREESE AND NICHOLS

4055 International Plaza Suite 200
Fort Worth, Texas 76109-4895
817-735-7300

U.S. Army Corps of Engineers, Fort Worth District
Sulphur River Watershed

Jim Chapman Lake USGS Water Quality Sample Site Locations

FILE NAME: Jim Champan .mxd

DATUM & COORDINATE SYSTEM: NAD83 State Plane (ft) N. Central Texas

SCALE: 80,000

DRAFTER: JJC

DATE: September, 2013

F&N JOB NO.: MHP11453

2-4

FIGURE

Figure 2- 5 Water temperature trends at USGS site 331818095422501

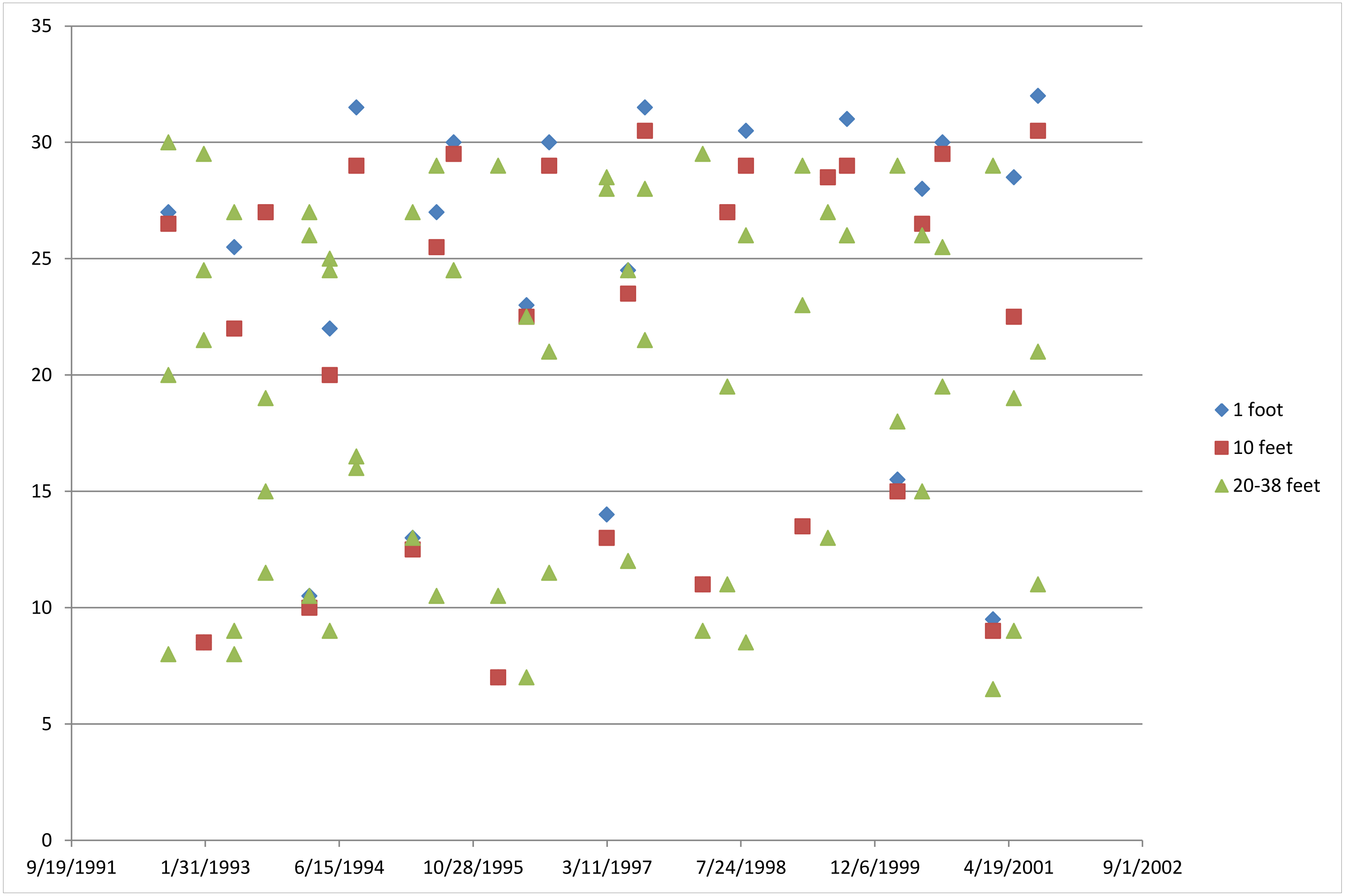


Figure 2-6 DO trends at USGS site 331818095422501

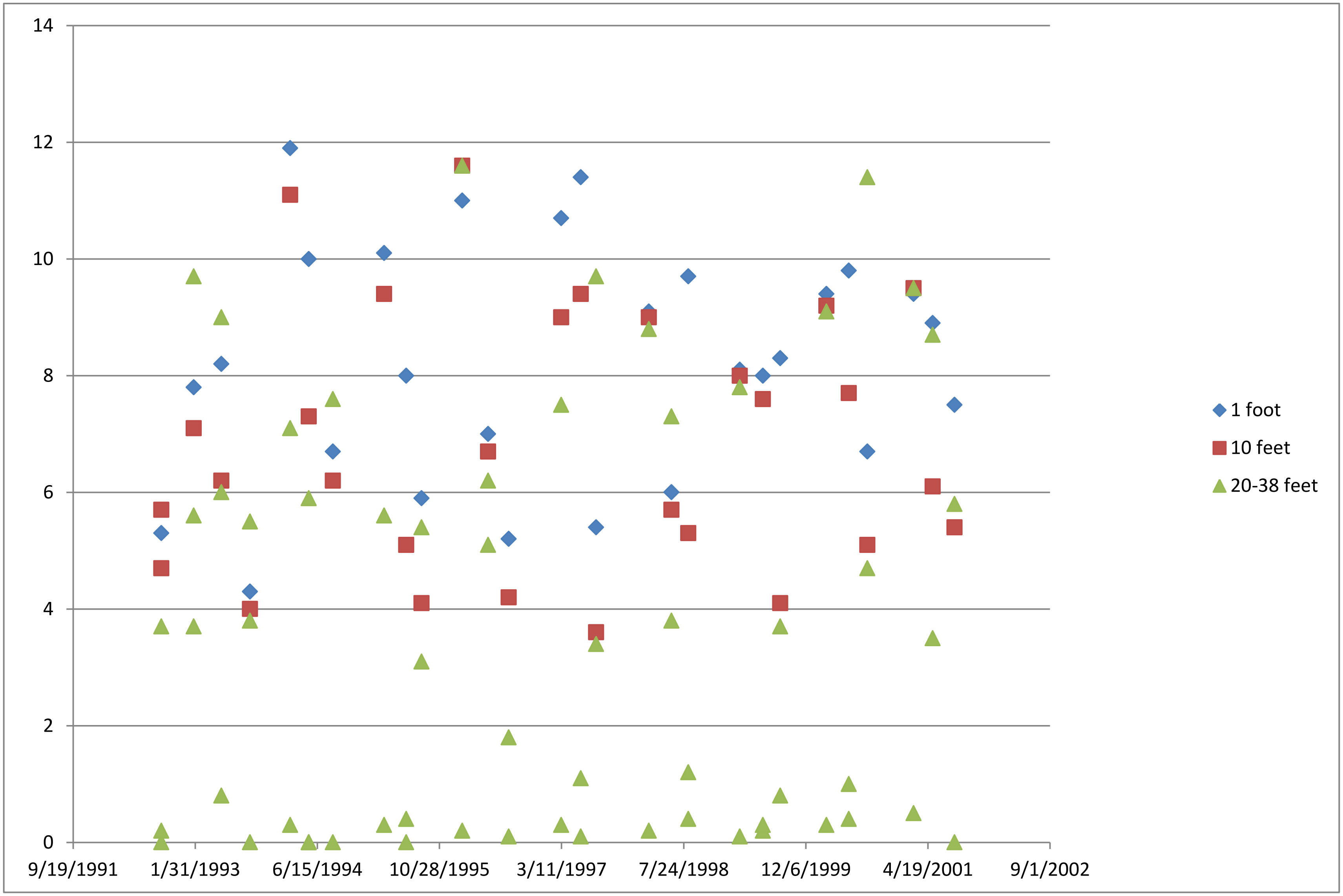


Figure 2-7 pH trends at USGS site 331818095422501

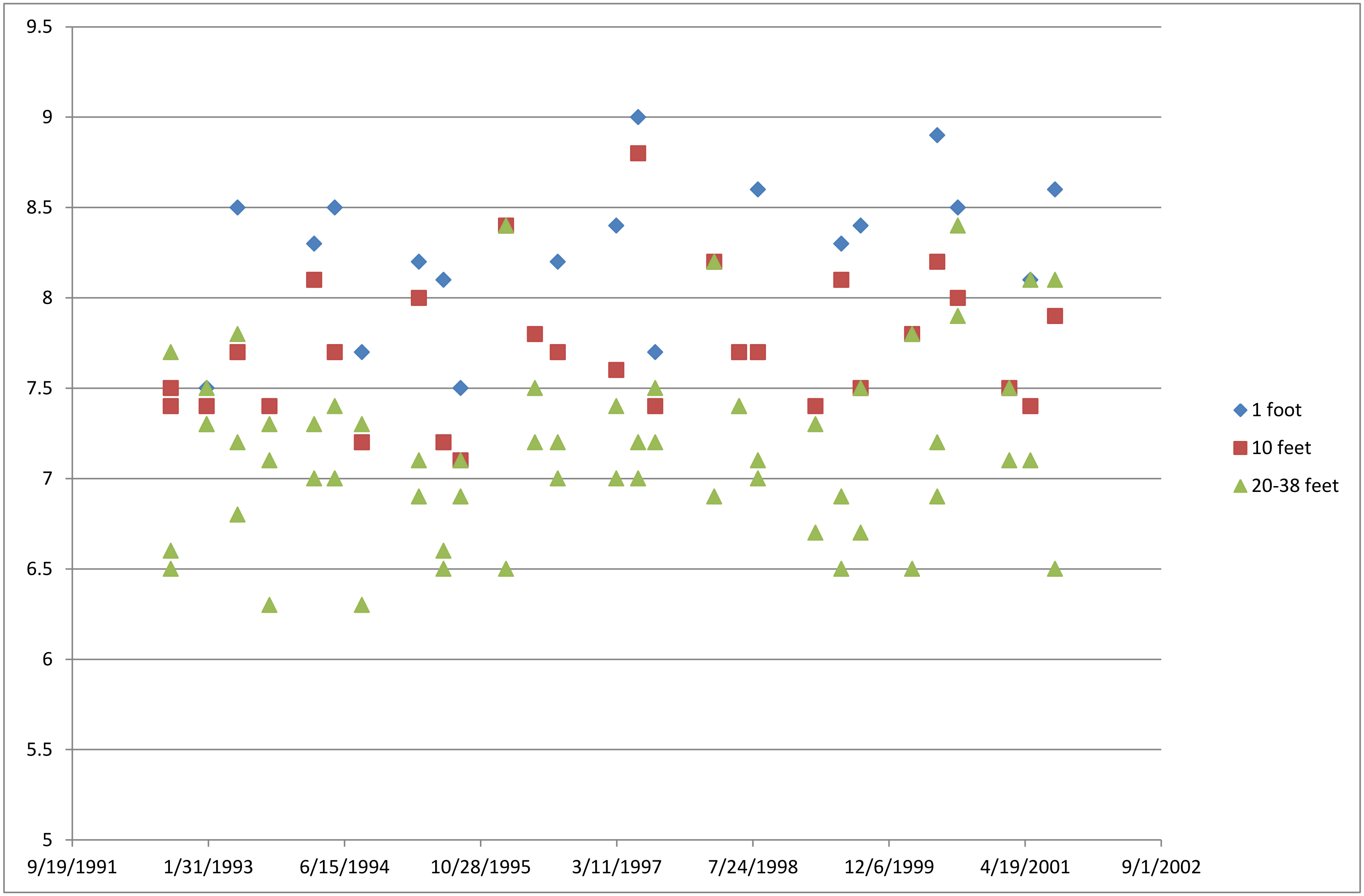


Figure2- 8 Water temperature trends at USGS site 331938095374701

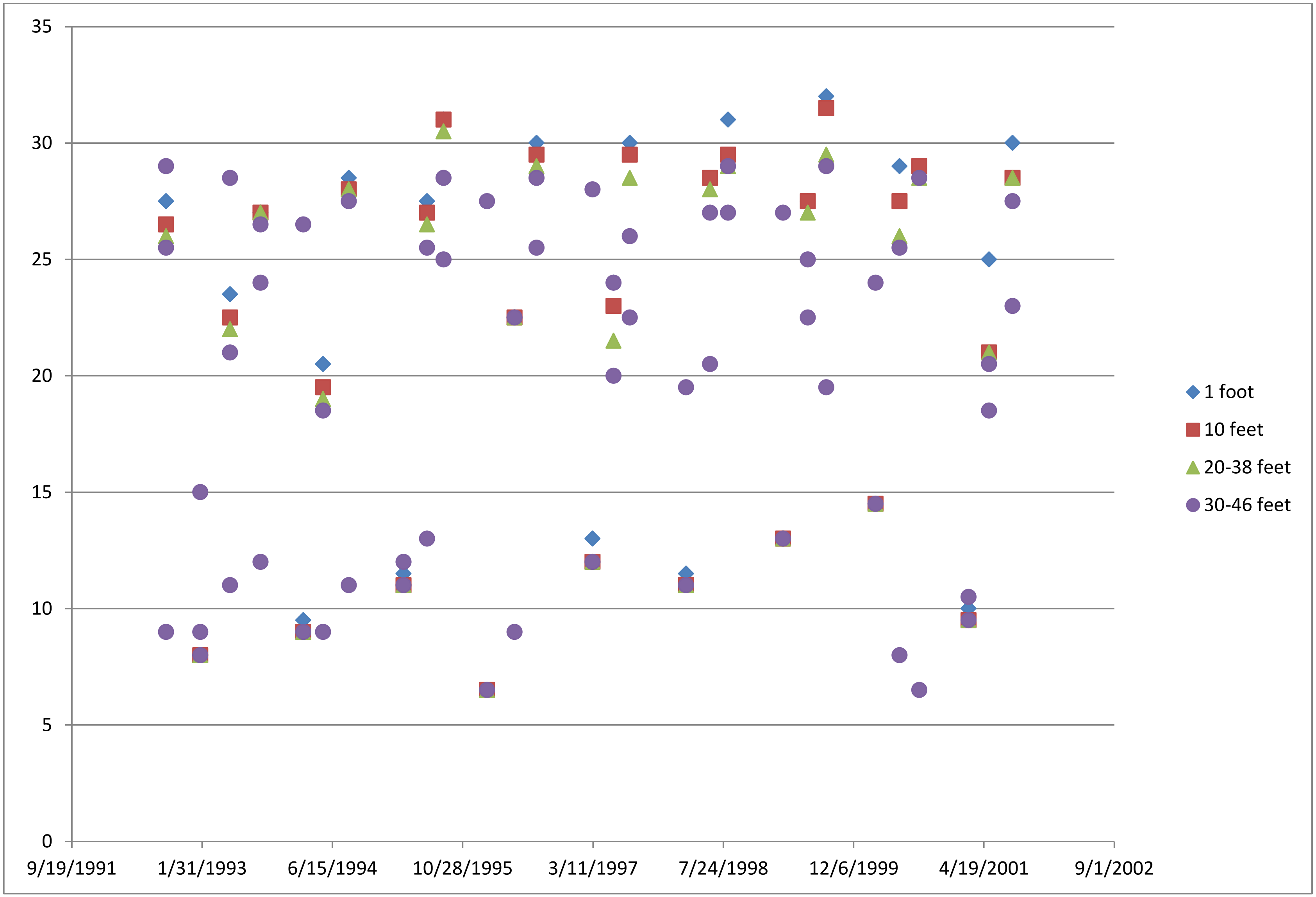


Figure 2-9 DO trends at USGS site 331938095374701

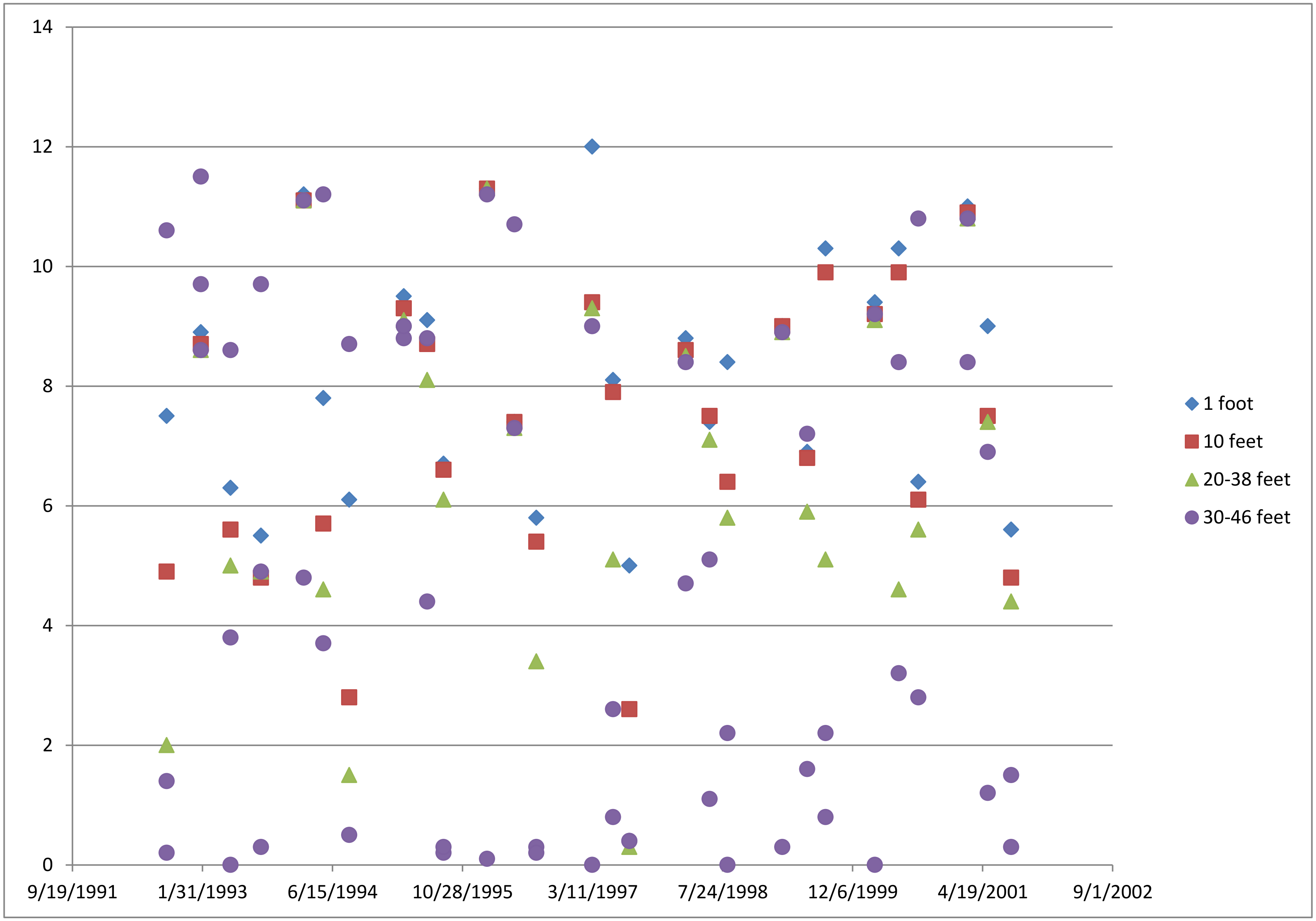


Figure 2-10 pH trends at USGS site 331938095374701

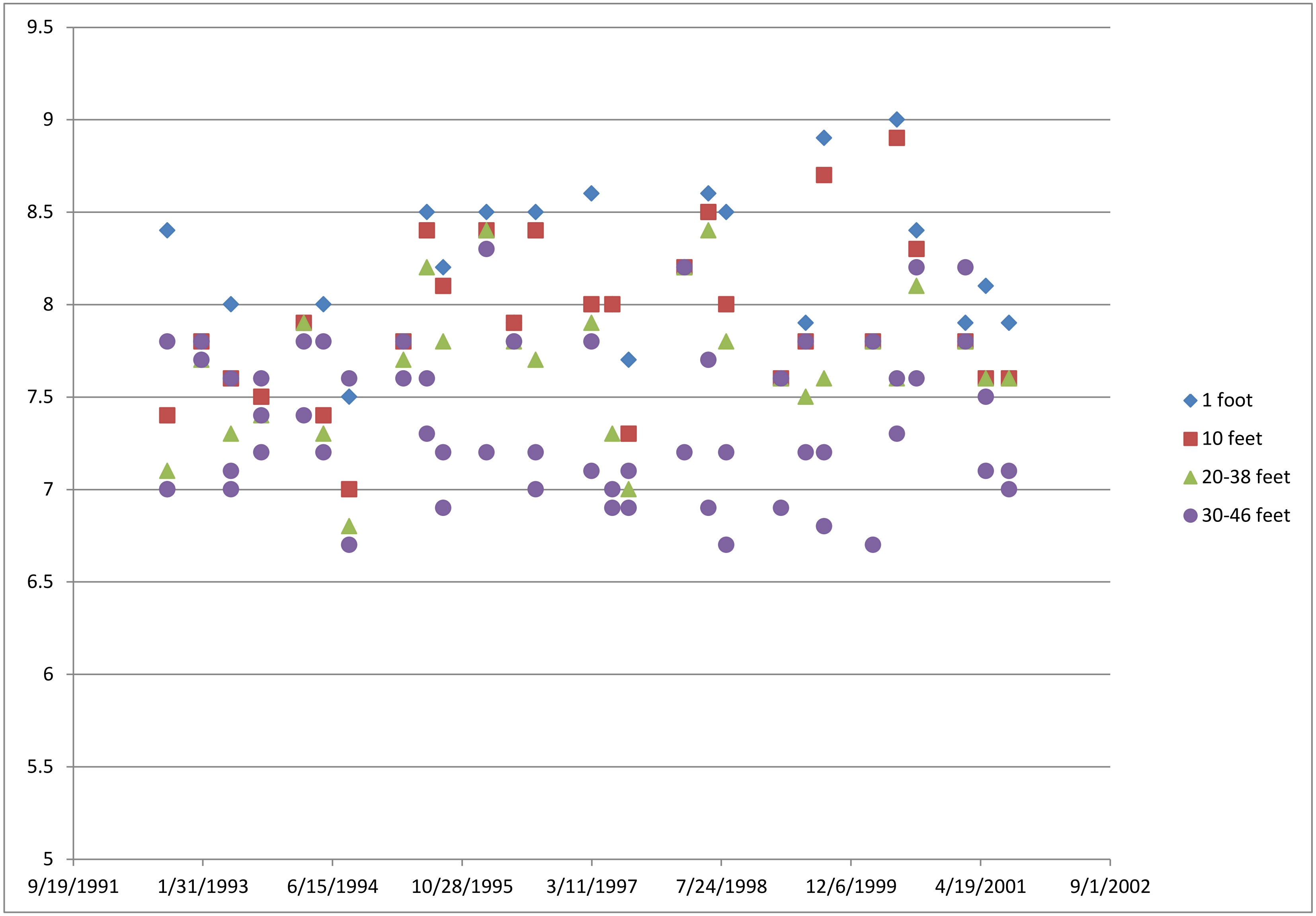


Figure 2-11 Water temperature trends at USGS site 332019095441901

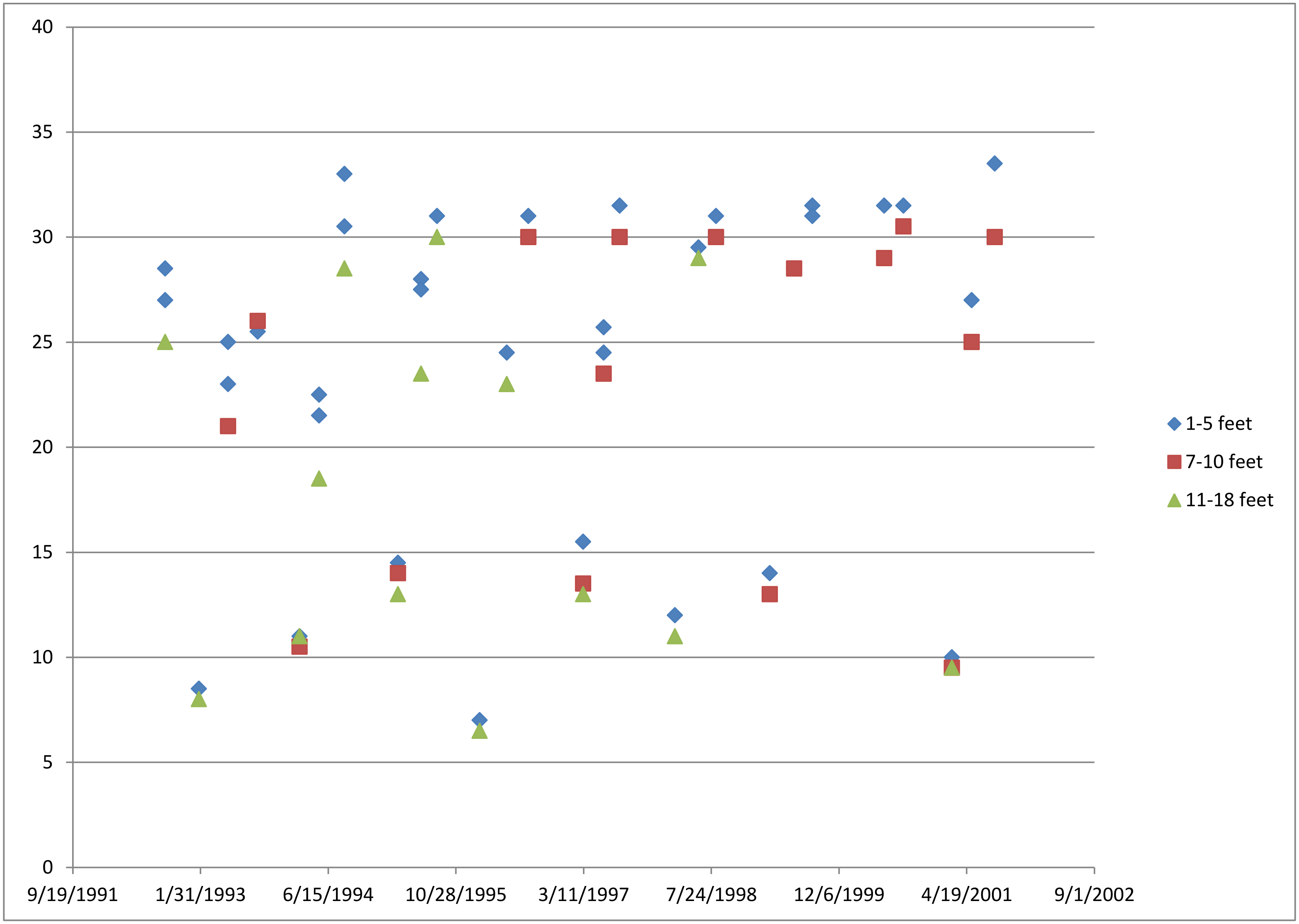


Figure 2-12 DO trends at USGS site 332019095441901

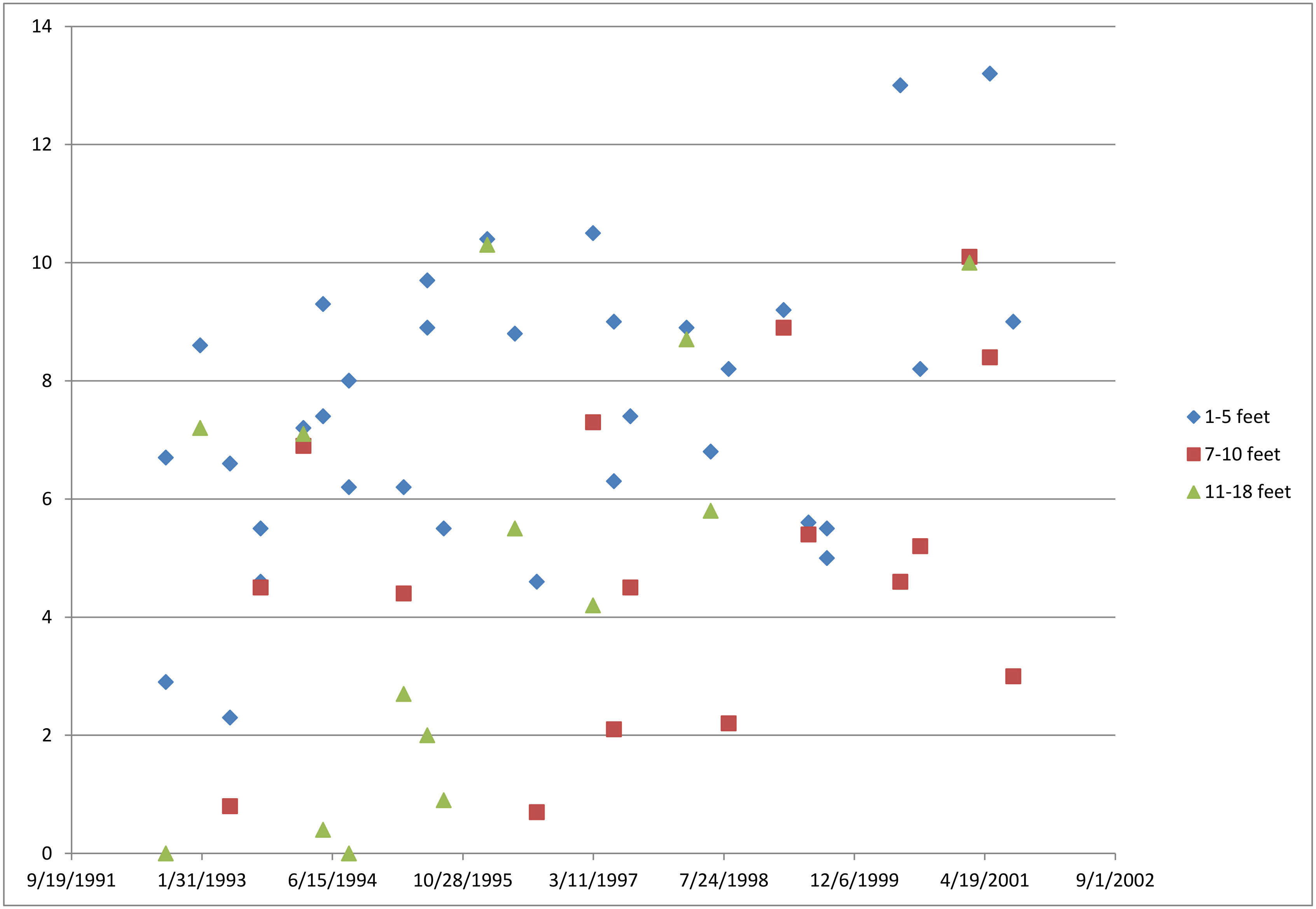


Figure 2-13 pH trends at USGS site 332019095441901

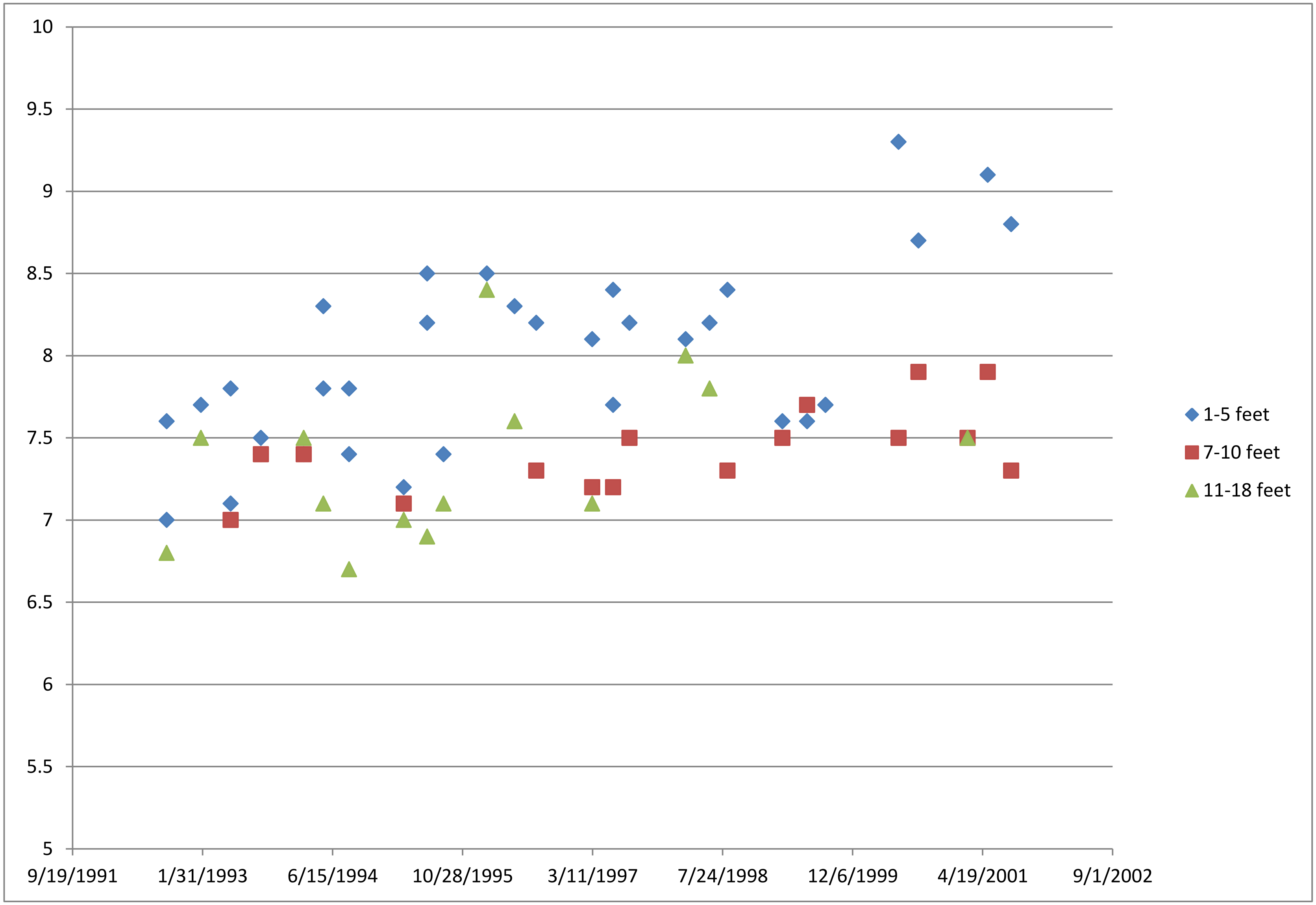


Figure 2-14 Water temperature trends at USGS site 332110095422201

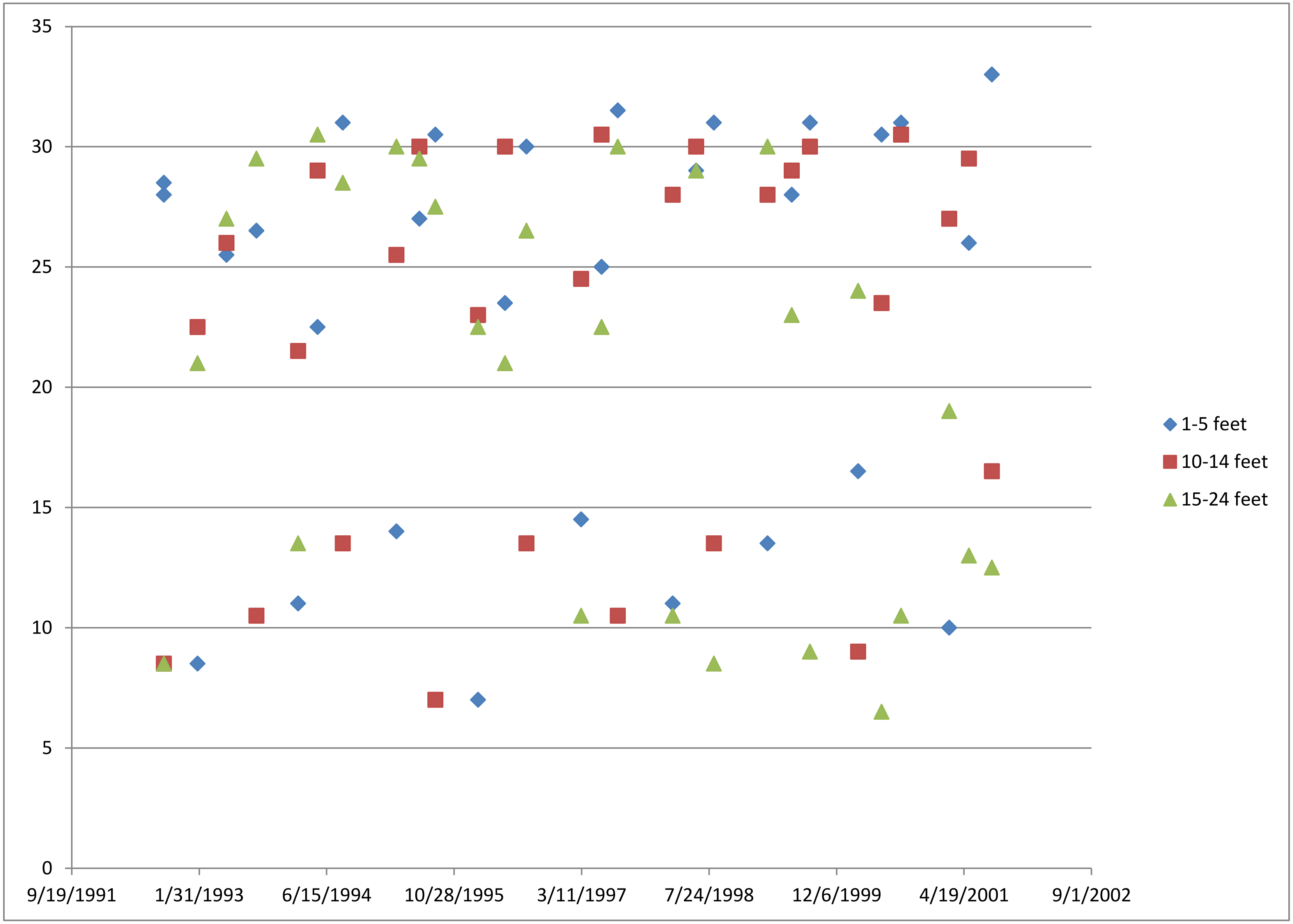


Figure 2- 15 DO trends at USGS site 332110095422201

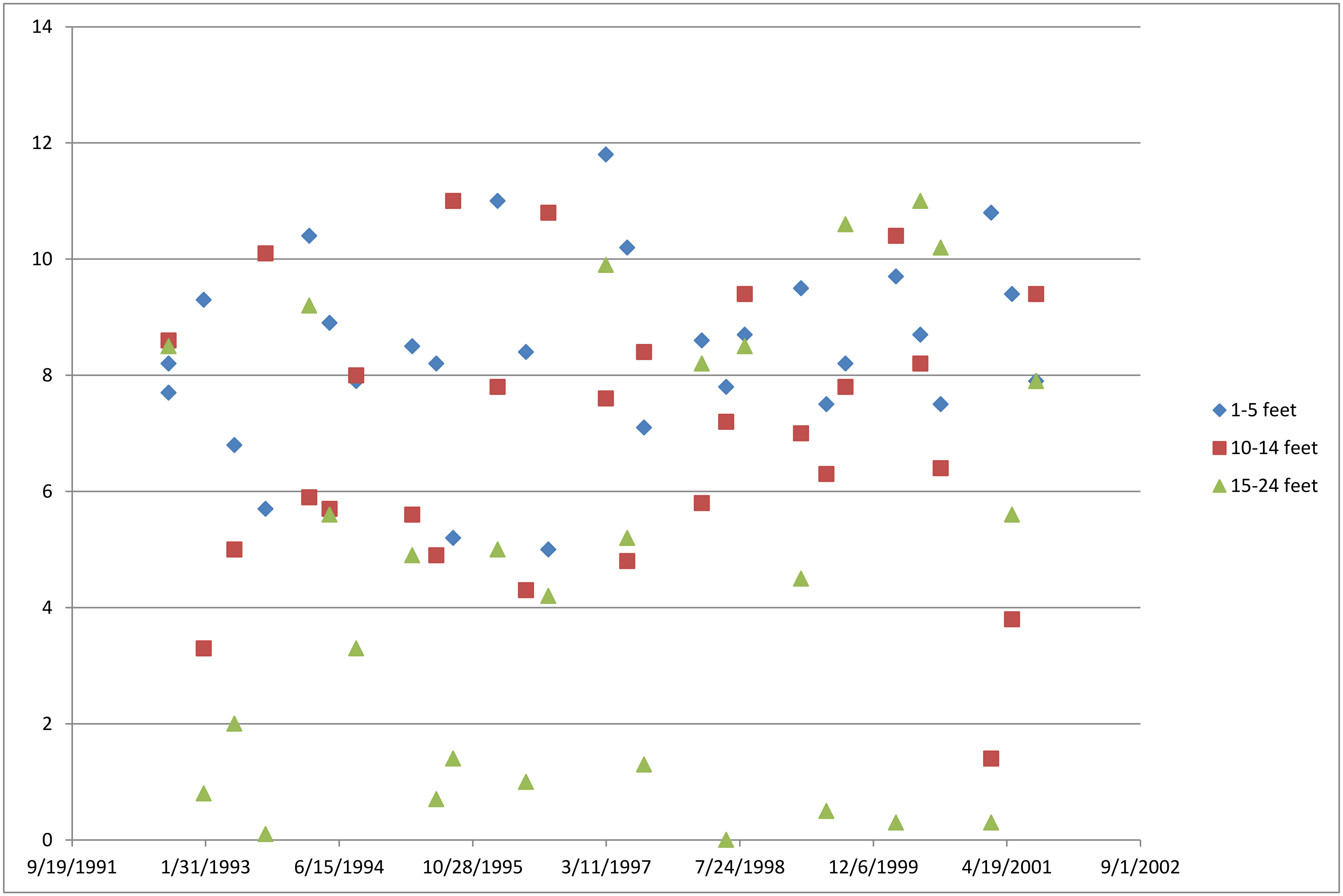
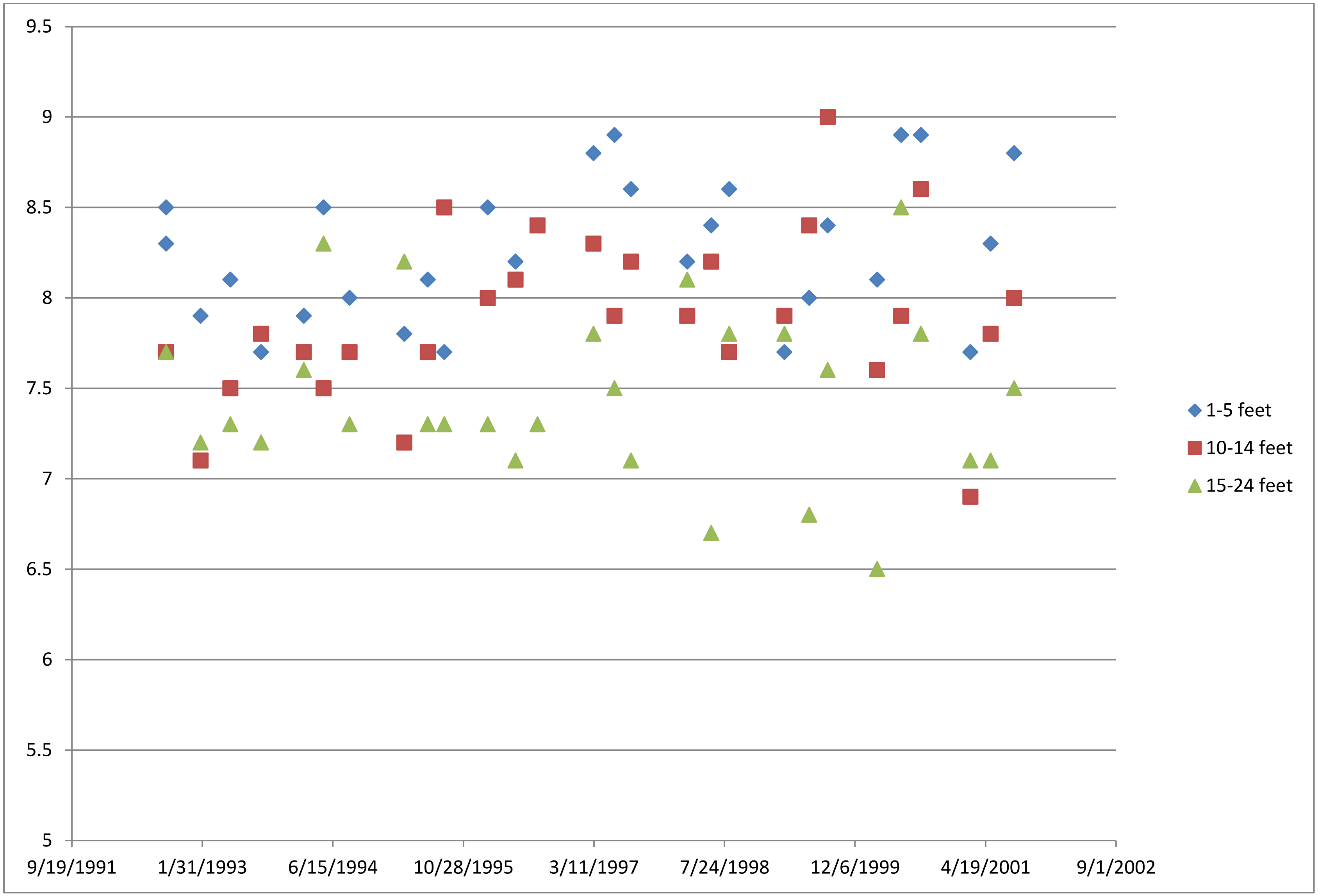


Figure 2-16 pH trends at USGS site 332110095422201



2.2.5 Potential Jim Chapman Lake Reallocations

A. Reallocation Options

The flood storage pool at Jim Chapman Lake is between elevations 440 and 446.2' NGVD and has a storage volume of 130,361 acre-feet. In contrast to Wright Patman Lake, which has a flood storage volume of almost 2.5 million acre-feet, reallocation options likely to be practical for Chapman Lake are more limited. To establish "bookends" for the range of promising options, yield and impact studies will initially be made for a very small reallocation of 50,000 acre-feet (within the Chief of Engineer's discretionary authority) and for full reallocation of the flood pool. Depending on the results of these analyses and other related work, more finely-tuned scenarios may be developed.

B. Reallocation Issues

As previously noted, any reallocation recommendation requires careful consideration of the proposal's effect on authorized project purposes and existing users/stakeholders. At a minimum, those considerations would include the nature of the flood risk reduction that would be foregone under a reallocation, the effects of an increased elevation for the conservation pool on recreation facilities and terrestrial resources in the current flood pool, and the effects on any property owners or leaseholders.

In the case of Jim Chapman Lake, the majority of the perimeter lands are leased to the Texas Parks and Wildlife Department and managed by them for mitigation of project-induced impacts to wildlife resources. Management expenses incurred by TPWD in discharging the Corps' mitigation responsibilities are reimbursed 76% by the Corps under provision of contract #DACW63-92-C-0094. As at WOCMA, revenues generated by fee-based activities on the wildlife lands are retained by TPWD to further offset management expenses. Any proposal that affects this arrangement would require thorough coordination with TPWD and other resource agencies as well as appropriate compensatory mitigation elsewhere.

Jim Chapman Lake has been assigned by the Corps to Dam Safety Action Classification IV. Current Corps policy regarding reallocations at DSAC IV Dams states:

> "Recommendations for reallocations that would require raising the conservation pool will be considered by Headquarters USACE on a case-by-case basis. Reallocation reports that recommend pool raises must include a review of the Potential Failure Mode Analysis (PFMA) for the dam and an analysis of the effect of a higher pool elevation on the probably failure due to seismic or hydrologic conditions." [18]

2.3 Endnotes

[1] U.S. Army Corps of Engineers; Red River and Tributaries, Texas, Oklahoma, Arkansas, and Louisiana; 1950, p.28

[2] U.S. Army Corps of Engineers, Fort Worth District; Supplemental Draft Environmental Impact Statement, Cooper Lake and Channels, Texas; 1980; p. 17

[3] Bowman, Stephen K. ; "Corps Texas Cooper Lake and Channels Project Halted" ; HeinOnline; 1979

[4] Forrest and Cotton, Inc.; Report on Hydrology and Water Needs, Cooper Reservoir, South Sulphur River, Texas; for the North Texas Municipal Water District; 1965; p. 12

[5] Texas Water Commission; "Notice of Final Determination of all Claims of Water Rights in the Sulphur River Basin"; June 10, 1985

[6] Contract # DACW29-68-A-103; 1968, p. 4

[7] Contract # DACW29-69-C-0019; 1968, p. 2

[8] U.S. Army Corps of Engineers, Fort Worth District; Supplemental Draft Environmental Impact Statement, Cooper Lake and Channels, Texas; 1980; p. B-3

[9] Sulphur River Basin Authority; *Clean Rivers Program Highlights Report*; in cooperation with Texas Commission on Environmental Quality; 2012

[10] Contract #DACW29-68-A-0103, p. 2

[11] U.S. Army Corps of Engineers, Fort Worth District; Wright Patman Pertinent Data Sheet; website

[12] U.S. Army Corps of Engineers, Institute for Water Resources; Water Supply Handbook; IWR Report 96-PS-4, 1998; p. 4-1

[13] Contract #DACW29-69-C-0019, Exhibit B

[14] Freese and Nichols, Inc.; Systems Operation Assessment of Lake Wright Patman and Lake Jim Chapman; for the U.S. Army Corps of Engineers, Fort Worth District; 2003; Main Report, p. 3-5

[15] Freese and Nichols, Inc.; Sulphur River Watershed Overview - Water Demand/Availability Interim Report; for the U.S. Army Corps of Engineers, Fort Worth; 2012; p. 45

[16] Brandes, R.J.; Technical Memo: *Accounting System for Jim Chapman Lake;* September, 2006

[17] Freese and Nichols, Inc.; Report on Water Transfer Pumping Policy; for North Texas Municipal Water District; 2000; p. 2-2

[18] U.S. Army Corps of Engineers; Water Supply Storage and Risk Reduction Measures for Dam Safety; EC 1165-2-210; p.3

3.0 WATER DEMAND AND AVAILABILITY IN THE SULPHUR RIVER BASIN

3.1 Introduction

This chapter provides comprehensive catalog and summary of current and projected surface water use in the Sulphur River Basin as well as the current and projected status of surface water availability within the Basin. This analysis serves as the foundation for subsequent analyses related to potential water resources development in the Sulphur River Basin.

3.1.1 Relationship to State Water Planning

The State of Texas conducts a stakeholder-driven water planning process in which each of sixteen regions of the state prepare an assessment of water resources needs, and projects to meet those needs, over a 50 year planning horizon. Their regional plans are "rolled up" by the Texas Water Development Board (TWDB) into a comprehensive Texas Water Plan. In order to be eligible for State funding, projects must be included in the approved version of the Plan. With the exception of Fannin County, the Sulphur River basin is included in the North East Texas Regional Water Plan (herein referred to as the Region D Plan), along with the Cypress Bayou Basin, a portion of the Sabine and Neches Basins, and a portion of the Red River Basin (Figure 3-1). (Fannin County is included in the Region C Water Planning Group.) A portion of the permitted yield from the Sulphur Basin is currently held by water users in Region C, which includes the Dallas/Ft. Worth Metroplex, and exported from the basin. The current (2011) Region D Plan does not include development of any additional newly-permitted supplies while the 2011 Region C Water Plan (herein referred to as the Region C Plan) calls for development of two new reservoirs in the Sulphur basin (Lake Ralph Hall and Marvin Nichols Reservoir), for a total of 618,350 ac-ft./yr. of newly permitted supplies. In December 2011, the Texas Water Development Board issued the final 2011 Texas Water Plan, which included development of the two Sulphur basin reservoirs identified in the Region C plan. Subsequently, in response to litigation filed by Ward Timber, *et.al.*, the Eleventh Court of Appeals held that the Texas Water Development Board failed to resolve interregional conflicts between the 2011 Region C Plan and the 2011 Region D plan and inappropriately approved the Region C plan. Resolution is pending, as of the date of this report.

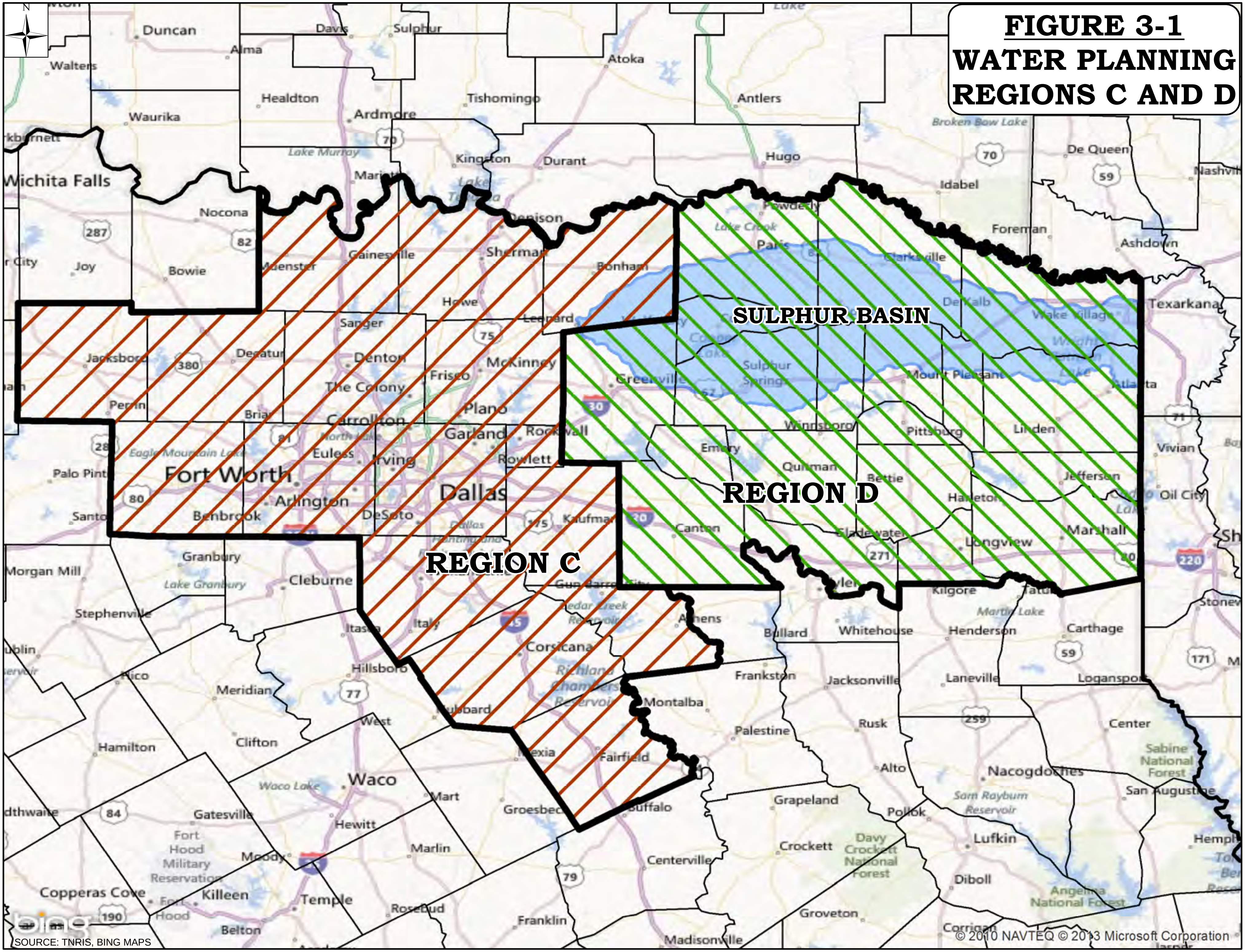


FIGURE 3-1
WATER PLANNING REGIONS C AND D

This planning effort is intended to complement, and not replace, the State planning process. This effort differs from the state process in several ways. For example, a range of municipal water demand has been developed in this study, rather than selecting a single "most-likely" scenario. Likewise, alternative scenarios for future in-basin industrial demands for water have been developed. This scenario-based approach is expected to inform, but not supersede, the next round of Texas regional planning efforts. In addition, recommendations on future water needs from the 2011 Region D Plan have been reviewed, and incorporated into our planning effort where possible. And finally, close coordination is being maintained between this effort and the initial stages of both the Region C and Region D 2016 plans, and data shared where available and appropriate.

3.1.2 Basin Overview

A. Sulphur River Basin Geography

The Sulphur River basin encompasses some 3,558 square miles in Northeast Texas. Included in the basin are all or part of 11 Texas counties (Fannin, Lamar, Red River, Bowie, Hunt, Delta, Hopkins, Franklin, Titus, Morris, and Cass.) From the eastern state line of Texas, the Sulphur River flows into Arkansas and joins with the Red River, a tributary of the Mississippi River. (The portion of the Sulphur River drainage within Arkansas is not addressed in detail within this study.) The South and North Sulphur Rivers originate in southern Fannin County and flow eastward approximately 50 miles to their confluence near the eastern boundary of Delta and Lamar counties. (The Middle Sulphur joins the South Sulphur River approximately 23 miles upstream of its confluence with the North Sulphur.) White Oak Creek, the largest tributary of the Sulphur River, drains approximately 500 square miles and joins the main stem of the Sulphur River further downstream in Cass County.

B. Sulphur River Basin Socio Economic Characteristics

According to the 2000 Census, the population within the eleven-county area was 378,306. In 2010, the population in the eleven counties was 401,991. Growth rates across the region varied significantly, with two counties having rates of growth higher than anticipated by the Region D planning process (Hunt and Titus) and some counties showing a population decline, as shown in Table 3-1. In general, the fastest rate of population growth occurred along the Interstate Highway 30 (IH-30) corridor. Overall, the region grew slower than the statewide average for the same time period. The major population center in the basin includes the combined MSA of Texarkana, Texas and Texarkana, Arkansas. Sulphur Springs, Paris, and Mount Pleasant serve as regional hubs.

Table 3-1: Growth Comparisons for Census and Regional Water Planning Data

County	Census Data			Regional Water Planning Data	
	2000 Population	2010 Population	% Growth	2010 Population	% Growth
Bowie	89,306	92,565	3.6%	96,953	8.6%
Cass	30,438	30,464	0.1%	30,990	1.8%
Delta	5,327	5,231	-1.8%	5,728	7.5%
Fannin	31,242	33,915	8.6%	38,129	22.0%
Franklin	9,458	10,605	12.1%	11,533	21.9%
Hopkins	31,960	35,161	10.0%	35,934	12.4%
Hunt	76,596	86,129	12.4%	82,948	8.3%
Lamar	48,499	49,793	2.7%	52,525	8.3%
Morris	13,048	12,934	-0.9%	13,039	-0.1%
Red River	14,314	12,860	-10.2%	14,251	-0.4%
Titus	28,118	32,334	15.0%	31,158	10.8%
Total	**378,306**	**401,991**	**6.3%**	**413,188**	**9.2%**

Major land use categories within the eleven-county area include agriculture and timber management. According to the National Land Cover Database (NLCD) Land Classifications, approximately 24% of the basin is forested areas and 33% is pasture. A number of lignite mines are located in the basin, including several owned by Luminant Mining Co LLC. Luminant uses the mined resources at a power plant in the region and holds a water right for water sources used at the power plant.

The largest employer in the Sulphur River Basin is the Red River Army Depot in Bowie County, employing more than 4,500 civilian and military personnel (Red River Today, 2012). The Texas A&M University System has recently established a new campus in Texarkana, employing nearly 200 faculty and staff and having a current student population of over 1,600 (Find the Best, 2010). Significant industrial activities in the basin include the large International Paper plant in Cass County and a significant cluster of food processing industries including Ocean Spray, Sara Lee Bakery Group, and Pilgrim's Pride. Cooper Tire, which specializes in the manufacturing of passenger tires and is located in the Arkansas portion of Texarkana, employees approximately 1,700 local employees (Economic Development, 2009). The Bureau of Labor and Statistics reports that in May 2010 the Eastern Texas Nonmetropolitan Area employed nearly 29,000 people in production occupations (manufacturing) which accounts for approximately 10.5 percent of the employment in the area. The Eastern Texas Nonmetropolitan Area is comprised of 28 counties and includes all the counties in the Sulphur River Basin except Bowie, Fannin, Delta, and Hunt.

A number of factors have the potential to significantly expand the economic future of the Sulphur River Basin. In general, the area possesses the desirable characteristics of proximity to the existing Dallas/Fort Worth Metroplex, abundant land, an available workforce, and a lack of air quality restrictions. Interstate 30 provides convenient access, linking Texarkana, Mount Pleasant, and Sulphur Springs to the Metroplex and to Little Rock, Arkansas. The construction of Interstate 49 from Lafayette, Louisiana to Texarkana is nearing completion and similar interstate access will be further enhanced by the addition of Interstate Highway 69 (IH-69). Interstate 69 will begin at the southern portion of Texas and run from Houston into Cass and Bowie counties until it merges with IH-30 near Texarkana. The portion of the highway near Texarkana is still in the conceptual planning stages. In addition, the former Lone Star Army Ammunition Plant has been converted from military use to the TexAmericas Center, and has in excess of 15,000 acres of industrial property available for future development.

C. Current Water Use in the Sulphur River Basin

Current water use in the Sulphur River Basin is concentrated in the municipal and industrial categories. Timber management, agriculture, and mining, while important land uses in the region, are not as significant with respect to water use. Table 3-2 shows the percent use by category for the Sulphur River Basin from the 2011 Region D Plan.

Table 3-2: Percent Water Use by Category for the Sulphur River Basin

Use Category	2000	2010	2020	2030	2040	2050	2060
Municipal	20.5%	19.5%	19.5%	19.5%	19.7%	20.1%	20.4%
Manufacturing	70.1%	72.3%	72.8%	73.1%	73.2%	73.2%	73.2%
Mining	1.0%	0.9%	0.9%	0.8%	0.8%	0.8%	0.8%
Steam Electric	0.5%	0.4%	0.3%	0.3%	0.4%	0.4%	0.5%
Livestock	5.9%	5.3%	4.9%	4.7%	4.4%	4.2%	3.9%
Irrigation	2.0%	1.7%	1.6%	1.5%	1.4%	1.4%	1.3%

Groundwater provides the municipal water supply for many of the smaller entities within the basin. In many cases, groundwater availability, as estimated through the regional planning process, will be sufficiently abundant for those users through 2060. In other cases, groundwater resources, limited by either quantity or quality considerations, may not be dependable. In those cases, municipalities would be expected to switch to a surface water source at some point during the next 50 years. Section 3.2 presents a more detailed analysis of those entities projected to move from groundwater to surface water sources before 2060.

Surface water is abundant in the basin and provides the majority of the municipal and industrial supply. Wright Patman Lake and Jim Chapman Lake are the largest surface water impoundments in the basin. Both are multi-purpose reservoirs, constructed and managed by the U.S. Army Corps of Engineers (USACE). Jim Chapman Lake, located at river mile 23.2 on the South Sulphur River, was constructed by USACE, with deliberate impoundment in 1991. Jim Chapman Lake has both a conservation pool and a flood storage pool; the conservation pool includes 310,312 acre-feet of storage up to elevation 440. The flood storage pool includes 130,361 acre-feet between 440 and 446.2, below the uncontrolled spillway. The storage in the conservation pool of Jim Chapman Lake is used by the City of Irving, the North Texas Municipal Water District, and the Sulphur River Municipal Water District under contract with the Corps.

Wright Patman Lake likewise has both a conservation pool and a flood storage pool; the conservation pool includes that storage in the lake below a rule curve that varies between elevations 220.6 and 227.5, depending on the time of year. The average storage in the conservation pool is 158,000 acre-feet including the sediment pool below. The flood storage pool includes storage above the variable top of conservation pool, and has the capacity to store 2,496,000 acre-feet of flood waters below the uncontrolled spillway. The conservation storage in Wright Patman Lake is held by the City of Texarkana, Texas under contract with the Corps of Engineers.

In addition to these two large reservoirs, there are a number of smaller reservoirs in the Sulphur River Basin that supply municipal and industrial water. These include the reservoirs listed in Table 3-3. Additional smaller reservoirs, not listed in Table 3-3, are used for irrigation and recreational purposes. Figure 3-2 provides an overview of the most significant surface water impoundments in the Sulphur River basin.

Table 3-3: Smaller Reservoirs in the Sulphur River Basin

Reservoir Name	Water Right Holder	Use Type	Reservoir Authorized Storage (ac-ft.)
Langford Creek Lake	Red River County WCID 1	Municipal/Industrial/Irrigation	1,225
Lake Sulphur Springs	City of Sulphur Springs	Municipal/Industrial/Recreation	17,838
Rivercrest	Luminant Generation Co	Industrial	7,100
Wolfe City Reservoir	City of Wolfe City	Municipal	855
City Lake	City of Cooper	Municipal	164
Lake Coleman	City of Sulphur Springs	Municipal/Recreation	408
Turkey Creek Lake	City of Wolfe City	Municipal	855
	City of Pecan Gap	Municipal	152
Big Creek	City of Cooper	Municipal/Recreation	4,890
B-15, B-18 and D-03	Luminant Mining Co LLC	Mining	1,002
Denton Creek	City of Mount Vernon	Municipal	434
M-1, J-2, L-1, L-2, L-4	Luminant Mining Co LLC	Mining, Domestic and Livestock	513.11
Rice Creek and Holly Creek	City of New Boston	Municipal/Recreation	259 and 8
Reservoir 1 and 2	Red River Redevelopment Authority	Municipal	4,074

Some municipal entities within he Sulphur Basin use surface water that comes from reservoirs located outside the basin. Bonham Lake, Crook Lake, Lake Pat Mayse (Red River Basin), Lake Bob Sandlin and Lake Cypress Springs (Cypress Bayou Basin), and Lake Tawakoni (Sabine Basin) are of the Texas out-of-basin reservoirs that serve Sulphur Basin municipalities. In addition, through the Texarkana Water Utilities which provides integrated water and sewer services to the combined cities of Texarkana, Texas and Texarkana, Arkansas, up to 15 MGD of out-of-basin water from Millwood Lake in Arkansas may be provided to Texas Sulphur Basin users. Figure 3-3 provides a schematic showing the surface water sources and transfers among significant municipal water users in the basin.

FIGURE 3-2
SIGNIFICANT SURFACE WATER IMPOUNDMENTS

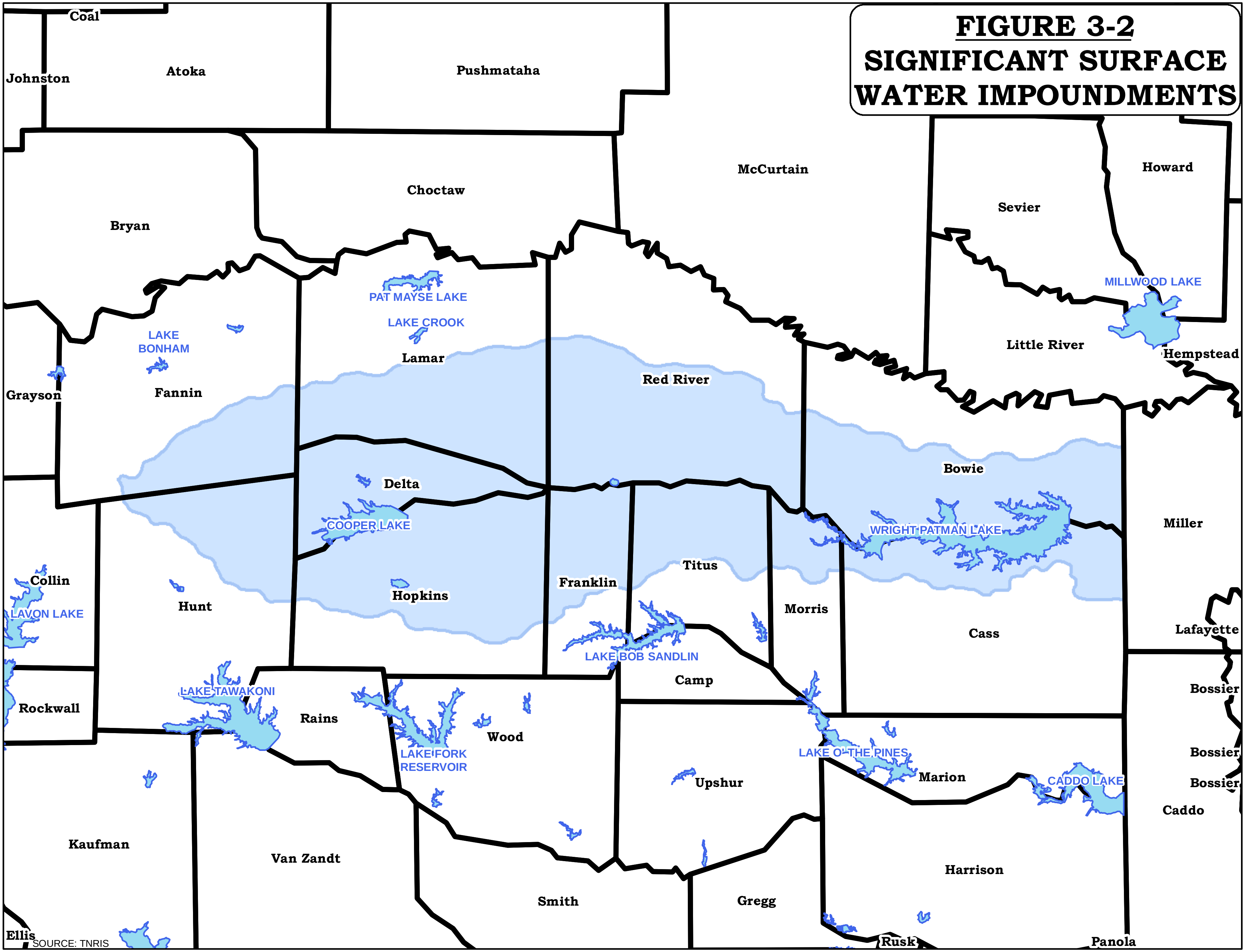
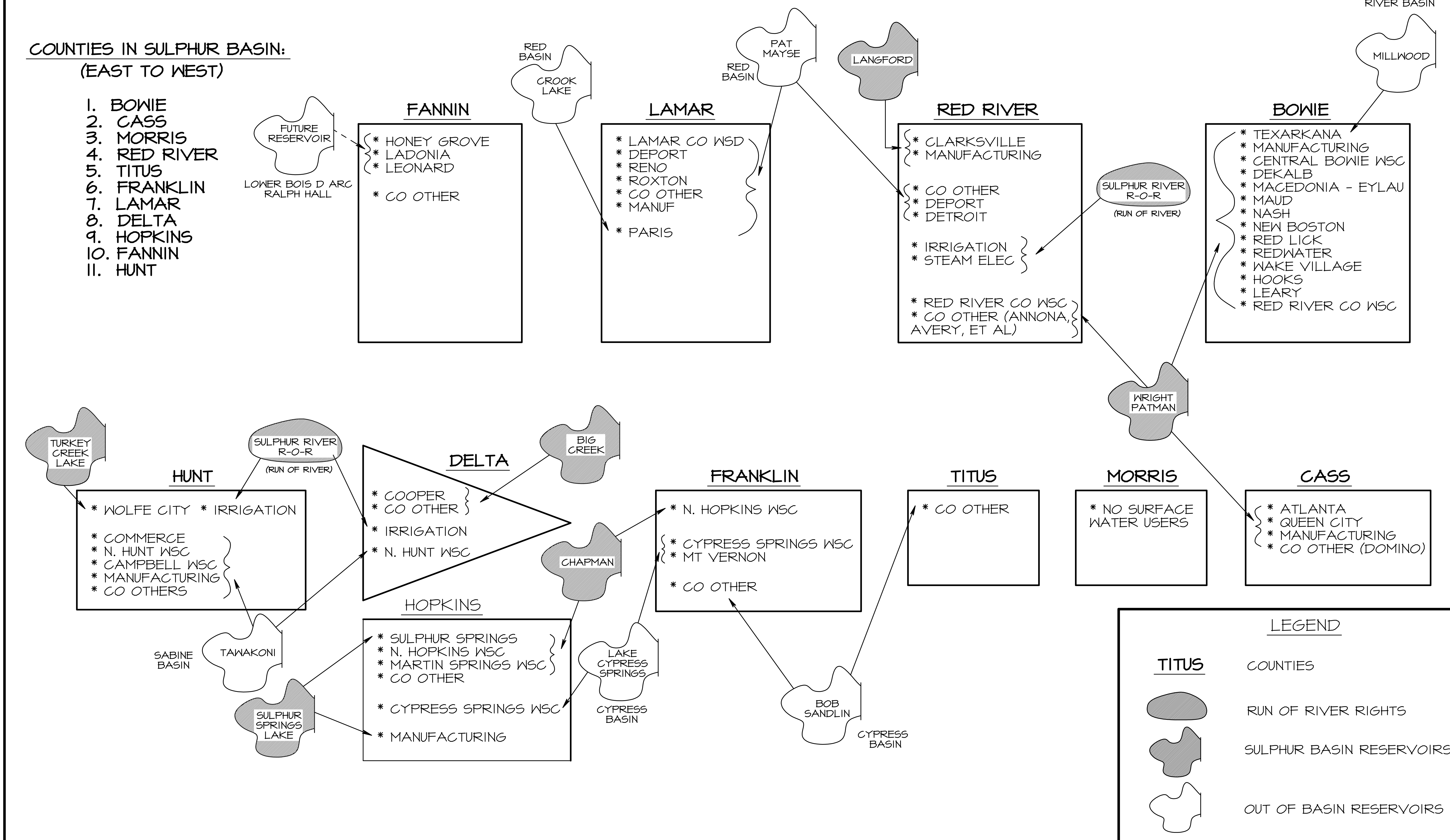


FIGURE 3-3
SCHEMATIC OF SURFACE WATER SOURCES AND TRANSFERS



3.2 WATER DEMAND

3.2.1 Demand for Water within the Sulphur Basin

To adequately plan for the future needs of the Sulphur River Basin, a reasonable assessment of future water demands needed to be made. As noted in the basin overview, over 90% of the basin's water use is either municipal or industrial. This analysis focuses on those two categories of use, but also includes the smaller use associated with other non-municipal categories. For the purpose of this study, only the demands on Sulphur Basin surface water supplies are included in the analysis.

A. Populations included in the Demand Analysis

In order to estimate population-driven municipal demand, an evaluation was made of municipal Water User Groups (WUGs) within the basin currently using Sulphur Basin surface water supplies and municipal WUGs that may be reasonably expected to use Sulphur Basin surface water supplies in the future. Below is a description of which WUGs were included. A list of those WUGs is included in Appendix A.

- All municipal WUGs in Bowie, Cass, Red River, Hopkins and Delta Counties were included with two exceptions. The first exception is the City of Hughes Springs in southern Cass County (outside of the Sulphur Basin) which currently uses water from Lake O' the Pines and will not be likely to need Sulphur Basin surface water in the future. The other exception is the rural population of Cass County located in the Cypress River Basin, which currently uses a combination of groundwater and water from Lake O' the Pines. Any future conversion from groundwater to surface for rural Cass County would likely be from Lake O' the Pines, not Sulphur Basin water.
- Only select municipal WUGs in Hunt, Franklin, Morris, Titus, and Fannin Counties were included. Those included were selected because they currently use Sulphur Basin surface water, or because they currently use either groundwater or out-of-basin surface supply and may convert to Sulphur Basin Surface supply in the future.
- All of Lamar County's current demands are served by either groundwater or Red River surface water sources, and these supplies are reasonably expected to continue to meet those demands in the future. A large future irrigation/livestock demand is anticipated in Lamar County with the addition of a Daisy Farms facility. This facility is anticipated to use Sulphur Basin surface water supplies. This demand has been included in the demand projections presented in this report.

- It is important to note that two of the largest cities in the Sulphur Basin –Paris and Commerce - were not included in this analysis because they were not anticipated to need Sulphur Basin surface water in the future.
  - The City of Paris is located in Lamar County on the divide between the Red and Sulphur Basins, and the city's current supply is from Pat Mayse Lake (owned and operated by the U.S. Army Corps of Engineers, Tulsa District) and Crook Lake, both in the Red River Basin. Paris' current permitted diversion from Lake Pat Mayse is 61,610 ac-ft./yr. (for municipal and industrial purposes). Based on a recent study by HDR Engineering, the firm yield of Pat Mayse is 59,670 ac-ft./yr. The Region D plan shows Pat Mayse Lake and Crook Lake will provide Paris with adequate future supplies with surpluses. As a part of this study, this information was confirmed with the City of Paris' consulting engineer, Hayter Engineering.
  - The City of Commerce is located in Hunt County in the upper Sulphur Basin near the divide with the Sabine Basin. The city's current supply is from Lake Tawakoni in the Sabine Basin, with a small amount of local groundwater. The Region D Plan shows this current supply to be adequate through the 50 year planning period, even with the population of Commerce more than doubling over that period. The City of Commerce has a contract with the Sulphur River Municipal Water District (SRMWD) for 16,000 ac-ft./yr. of supply from Jim Chapman Lake in the Sulphur Basin, but is not currently utilizing this supply. The Upper Trinity Regional Water District has a long-term (50 year) lease with the City of Commerce to use this water.
- Although not part of any Texas county, Texarkana, Arkansas was included in this analysis because it is partially located in the Sulphur Basin, is served by the Texarkana Water Utility, and is partially supplied by Sulphur River Basin supplies located in Texas (Wright Patman Lake). The 2010 Census population of Texarkana, Arkansas was 29,919.

B. Municipal Water Demand

Municipal water demand projections are developed using two components: population and per capita water use. Once the WUGs to be included in this study were identified, a range of population and municipal demand projections were developed by decade for the period of 2010 through 2060.

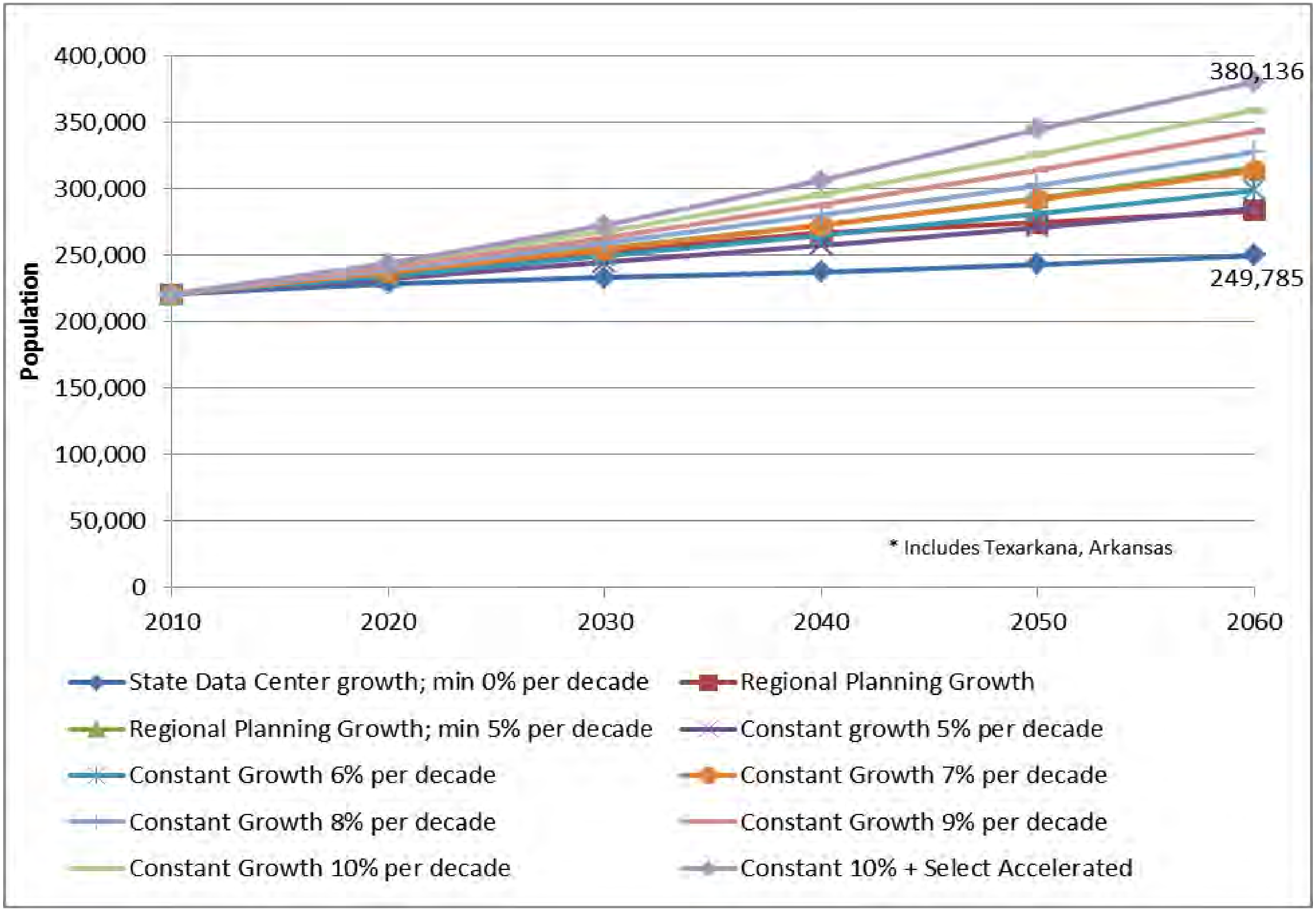
Population Projections

For this project, ten separate scenarios were developed to identify a full range of future population projections. All scenarios used 2010 census data for city populations. Growth rates from available State Data Center and TWDB Regional Planning (Regions C and D) population projections were used to develop three of the scenarios. (Most of the Sulphur Basin lies within Region D. A small portion of Fannin County is in the Sulphur Basin but lies in Region C.) These scenarios disregarded any decline in population projected by the State Data Center or Regional Water Planning groups. Six additional scenarios were developed using constant growth percentages for each decade, ranging from 5% growth per decade to 10% growth per decade. One last scenario was developed using a growth rate of 10% per decade with select WUGs anticipating accelerated growth in some decades. This scenario reflects the feedback of several of the water managers in the basin interviewed as part of the data collection for this study and represents the most aggressive growth scenario evaluated. The 2010 population for entities using Sulphur Basin water supplies is approximately 221,000. Figure 3-4 shows the range of population projections developed for this study, which by 2060 range from around 250,000 people to a little over 380,000 people. A detailed breakdown of the ten population scenarios is included in Appendix A. A summary of discussions with Sulphur River Basin water managers/stakeholders is included in Appendix B.

Per Capita Water Demand Projections

Per capita water use is the average amount of water used per person on a daily basis. It is typically measured in gallons per capita per day (gpcd) and can differ greatly from WUG to WUG. The only available projections of per capita water use for the Sulphur Basin are those developed by Regions C and D during the 2011 Regional Planning process. It should be noted that the Regional Planning process uses dry year per capita demands which is intended to represent what water use would be in drought or dry-year conditions. This is typically higher use than in normal years. The Region D Plan set a minimum consumption of 115 gpcd for all municipal WUGs. (Region D did not set a limit on the maximum gpcd amount for WUGs.) The Region D Plan also stated its objection to the use of projections that include reductions in future use due to implementation of the state plumbing code. These reductions reflect the water savings that will be realized with the routine replacement of holder high-use plumbing fixtures with new water efficient fixtures over time.

Figure 3-4: Population Scenarios for Sulphur Basin Entities using Sulphur Basin Supplies



Both of those Region D preferences were used to develop the first two scenarios for this study. A total of three scenarios of per capita demands were developed based on the Region D projections:

- Regional Plan - This scenario uses gpcd values for each WUG from the Region C and D Plans (without plumbing code decreases), which is based on historical gpcd using a minimum of 115 gpcd.
- Regional Plan 140 Minimum - This scenario uses gpcd values for each WUG from the Region C and D Plans (without plumbing code decreases), but applies a lower limit of 140 gpcd rather than 115 gpcd. The 140 gpcd value is based on the goal of the Water Conservation Task Force for maximum municipal per capita water use in Texas. This scenario does not "lock in" historically lower per capita water users at their historically low use rates, but allows the potential for them to increase use up to what Region D defines as "a reasonable upper municipal level consumption goal". This scenario yielded the highest per capita projections and therefore the highest water demand projections.
- Regional Plan 140 minimum with Plumbing Code - This scenario uses gpcd values for each WUG from the Region C and D Plans, but applies a lower limit of 140 gpcd. In addition, for any WUGs with gpcd higher than 140, a modest decrease of 2 gpcd per decade was applied for plumbing code conservation. The higher plumbing code conservation from the Region D Plan was not used due to the objection expressed in the Region D Plan.

Historical water use information for WUGs is available from TWDB and in some cases can be helpful in determining historical per capita and projecting future per capita water use. That information was obtained and compared to the Region C and D per capita projections. Many of the WUGs were found to have very low historical per capita water use (in the range of 70-90 gpcd), but for the purpose of this study, the Region D minimum gpcd of 115 was retained. No basis for any changes to the Regional Planning per capita projections was found based on the TWDB historical use data.

2. Conservation Assumptions

The 2011 Region D Plan does not include any water conservation strategies for any WUGs. The plan states that "For each WUG with a shortage and consumption greater than 140 gpcpd, a water conservation strategy was considered …. Costs [of conservation strategies] are relatively high due to the small size of the entities and the small amounts of water involved. The conservation savings were not adequate to alleviate the shortage for any of the entities." [Page ES-11 of 2011 Northeast Texas Regional Water Plan]

To maintain consistency with the desires of the local and regional planning efforts, no conservation was included in this study except for the one per capita scenario with the modest plumbing code savings.

3. Municipal Demand Projects

Based on the ten population scenarios and the three per capita demand scenarios, 30 scenarios of municipal demand projections were developed. Figure 3-5 shows those projections for the municipal demand of entities supplied from the Sulphur Basin, which range from almost 39,000 ac-ft./yr. to almost 64,000 ac-ft./yr. in 2060. The lowest scenario (almost 39,000 ac-ft./yr.) represents the State Data Center population growth rates paired with the Regional Plan per capita demands. The highest scenario (almost 64,000 ac-ft./yr) represents the 10% per decade population growth with selected accelerated population growth paired with the per capita demands from the Region D Plan with a 140 gpcd minimum.

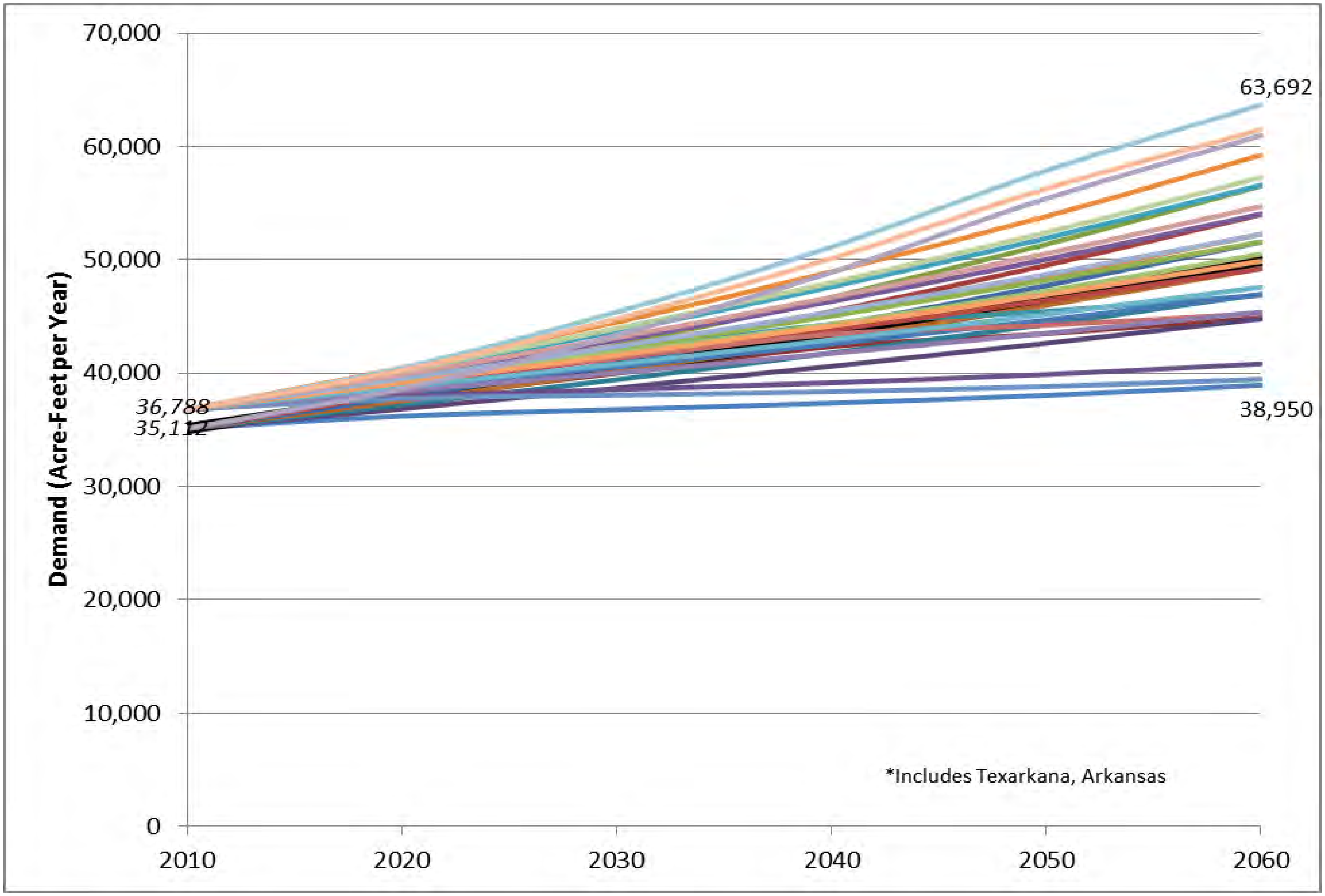
4. Non-Municipal Water Demand

The only currently available source of non-municipal demand projections for the Sulphur Basin is from the 2011 Region D Plan. These non-municipal demands are separated by county and basin and include the categories of Irrigation, Livestock, Manufacturing, Mining, and Steam Electric Power.

In the Region D Plan, the total 2010 non-municipal demand within the Sulphur Basin was projected to be 129,217 ac-ft/yr, increasing to 166,416 ac-ft/yr. by 2060. By far the largest demand in the basin is manufacturing in Cass County, which goes from 107,417 ac-ft/yr in 2010 to 141,276 ac-ft/yr in 2060 (83-85% of all non-municipal use). The Region D projections served as the basis for the projections in this study, with some modifications which are outlined below.

Some of the Sulphur Basin non-municipal demand is currently served by either groundwater or out-of-basin supplies, most notably Lamar County Manufacturing which is served by Red River Basin sources through the City of Paris. For the purpose of this study, some of the demand that is met groundwater or out-of-basin sources was not included in the projections. The amount deducted was around 8,400 ac-ft./yr. in 2010.

Figure 3-5: Municipal Demand Project Scenarios



There is a potential for some local out-of-basin demands to be met in the future by Sulphur Basin surface supplies, particularly in counties surrounding Wright Patman Lake and Jim Chapman Lake (Bowie, Red River, Cass, and Hopkins Counties). Some of those demands were included, adding around 9,500 ac-ft./yr. in 2010 to the projections.

A major adjustment that was made to the Region D projections was for Cass County manufacturing. Since Cass County manufacturing was projected to be such a large portion of the overall Sulphur Basin demand, meetings were held with local stakeholders to identify and refine these demands. The project team met with representatives from International Paper (IP), whose paper mill in Cass County is the largest single water user in the Sulphur Basin. IP has a long-term contract with the City of Texarkana for 120,000 ac-ft./yr. of supply from Wright Patman Lake. IP confirmed that their future demand projections should be equal to their contracted amount, with no increase beyond that demand anticipated. The Region D projections also had a significant demand beyond IP's 120,000 ac-ft./yr. for Cass County manufacturing (over 20,000 ac-ft./yr. by 2060). According to IP, there are currently no other manufacturers in Cass County that use significant amounts of water. Based on that information, the remaining Cass County manufacturing demand was decreased. In order to still provide for the potential of new industry to move into the county, a future manufacturing demand was included for Cass County which reaches 5,600 ac-ft./yr. by 2060.

Other significant non-municipal water users in the Sulphur Basin are the Red River Army Depot and the industrial park located on the property of the former Lone Star Ammunition Plant, both located in Bowie County west of the City of Texarkana. The former Lone Star property is now managed by TexAmericas Center (formerly Red River Redevelopment Authority), which is actively recruiting new industry to the area. TexAmericas' business plan estimates a baseline water use of 2 MGD currently, which will double in the next 15 years and then double again in another 15 years (to a total of 8 MGD, or 8,960 ac-ft./yr., by 2040). This demand was included in the Bowie County manufacturing projections. TexAmericas also indictaed there is potential for additional large water users to locate at their facility. An additional 10 MGD (11,200 ac-ft./yr.) has been added to the baseline demand to account for this possibility, for a total of 18 MGD by 2040.

The project team also met with the City of Sulphur Springs (in Hopkins County), which expressed concern that the Hopkins County manufacturing demand had been underestimated in the Region D Plan. Sulphur Springs anticipates future growth based on their proximity to the Dallas Metroplex area and their location on Interstate 30. Based on that information, a demand of 5,600 ac-ft./yr. (5 MGD) by 2060 was added to the projections in Hopkins County. This provides for the potential of new industry to move into the Sulphur Springs area.

Livestock and Mining demands in the Sulphur Basin portion of Franklin County are currently being served by local groundwater. Stakeholder meetings revealed that these uses may need to convert to Sulphur Basin surface water supplies. Those demands, which are fairly small, were added to the non-municipal demand projections.

As mentioned previously, a large-scale agricultural facility is being planned in Lamar County. Daisy Farms is constructing a leading edge production dairy which will employ up to 160 workers. The projected demand for Daisy Farms is 15,000 acre-feet per year for irrigation demand and 1,500 acre-feet per year for livestock demand beginning in 2020. In a letter dated January 11, 2012, Lamar County officially requested that Region D include these demands in the next round of regional planning.

This study attempted to address concerns presented in the Region D Plan regarding restrictions placed on future manufacturing growth. Region D's concern was that the Regional Planning process did not allow the projections to include the possibility of additional industry moving into the region. To address this, these changes outlined above were made. A summary of those changes is below:

- 5 MGD demand in Cass County
- 8 MGD baseline demand in Bowie County for TexAmericas
- 10 MGD additional demand in Bowie County for TexAmericas
- 5 MGD demand for Sulphur Springs in Hopkins County
- 14.7 MGD additional irrigation/livestock demand for Daisy Farms

To further address Region D's concern, three additional demands of 5 MGD at unspecified locations were added for unknown future development. All totaled, 57.7 MGD (64,700 ac-ft./yr.) of future demand has been included for non-municipal purposes.

Under the "aggressive growth" scenario outlined above, the total projected non-municipal demands on Sulphur Basin surface supplies from within (or immediately adjacent to) the basin is estimated to be just over 210,000 ac-ft./yr. by 2060. The breakdown of demands is shown in Table 3-4.

Table 3-4: Non-Municipal Demand Projects for the Sulphur Basin

-Values in Acre-feet-

(Based on Region D Projections, with changes as outlined in text of this report)

Non-Municipal		TOTAL Demand					
WUG Name	Basin	2010	2020	2030	2040	2050	2060
BOWIE COUNTY							
IRRIGATION	RED	2,314	2,314	2,314	2,254	2,104	1,964
LIVESTOCK	RED	559	559	559	508	435	373
LIVESTOCK	SULPHUR	951	951	951	864	741	635
MANUFACTURING	RED	8	9	10	11	12	13
MANUFACTURING	SULPHUR	2,279	2,534	2,751	2,961	3,141	3,394
TexAmericas (8 MGD)	SULPHUR	2,240	4,480	6,720	8,960	8,960	8,960
MINING	RED	19	19	18	18	18	18
MINING	SULPHUR	23	22	22	21	21	21
CASS COUNTY							
IRRIGATION	CYPRESS	6	6	6	6	6	6
LIVESTOCK	CYPRESS	584	584	584	584	584	584
LIVESTOCK	SULPHUR	250	250	250	250	250	250
INTERNATIONAL PAPER	SULPHUR	120,000	120,000	120,000	120,000	120,000	120,000
Future Manufacturing (5 MGD)	SULPHUR	0	1,120	2,240	3,360	4,480	5,600
MANUFACTURING	CYPRESS	17	19	20	21	21	23
MINING	CYPRESS	351	370	380	389	399	408
MINING	SULPHUR	457	481	494	507	518	531
HOPKINS COUNTY							
IRRIGATION	SULPHUR	50	50	50	50	50	50
LIVESTOCK	CYPRESS	146	146	146	146	146	146
LIVESTOCK	SABINE	1,457	1,457	1,457	1,457	1,457	1,457
LIVESTOCK	SULPHUR	3,254	3,254	3,254	3,254	3,254	3,254
MANUFACTURING	SULPHUR	1,039	1,111	1,168	1,222	1,268	1,357
Future Manufacturing (5 MGD)	SULPHUR	2,240	2,240	3,360	3,360	4,480	5,600
MINING	SULPHUR	175	189	197	205	213	221
RED RIVER COUNTY							
IRRIGATION	RED	2,024	2,003	1,982	1,961	1,941	1,921
IRRIGATION	SULPHUR	1,689	1,672	1,655	1,638	1,621	1,603
LIVESTOCK	RED	660	660	660	660	660	660
LIVESTOCK	SULPHUR	949	949	949	949	949	949
MANUFACTURING	SULPHUR	6	7	7	7	7	8

-Values in Acre-feet-

(Based on Region D Projections, with changes as outlined in text of this report)

Non-Municipal		TOTAL Demand					
WUG Name	Basin	2010	2020	2030	2040	2050	2060
STEAM ELECTRIC POWER	SULPHUR	614	489	572	673	796	946
DELTA COUNTY							
IRRIGATION	SULPHUR	578	572	566	559	553	547
LIVESTOCK	SULPHUR	344	344	344	344	344	344
HUNT COUNTY							
IRRIGATION	SABINE	1,492	1,492	1,492	1,492	1,492	1,492
IRRIGATION	SULPHUR	446	446	446	446	446	446
MORRIS COUNTY							
LIVESTOCK	SULPHUR	155	155	155	155	155	155
FANNIN COUNTY							
LIVESTOCK	SULPHUR	292	292	292	292	292	292
FRANKLIN COUNTY							
LIVESTOCK	SULPHUR	560	560	560	560	560	560
MINING	SULPHUR	439	419	409	401	392	384
FUTURE DEVELOPMENT							
TexAmericas (10 MGD)	SULPHUR	5,600	5,600	5,600	11,200	11,200	11,200
Daisy Farms (14.7 MGD)	SULPHUR	0	16,500	16,500	16,500	16,500	16,500
FUTURE (5 MGD)	SULPHUR	1,120	1,120	2,240	3,360	4,480	5,600
FUTURE (5 MGD)	SULPHUR	1,120	1,120	2,240	3,360	4,480	5,600
FUTURE (5 MGD)	SULPHUR	1,120	1,120	2,240	3,360	4,480	5,600
Total Non-Municipal Demand Projections		**157,627**	**177,685**	**185,860**	**198,325**	**203,906**	**209,672**

C. Total Projected Demand of Sulphur River Basin Surface Water Users

Based on the municipal and non-municipal projections presented above, the highest total projected water demand reasonably expected for Sulphur Basin Surface water supplies from within (or immediately adjacent to) the basin is just under 274,000 ac-ft./yr., as presented in Figure 3-6. The municipal demand shown in Figure 3-6 is the highest scenario of demands from Figure 3-5, and the figure includes all scenarios of potential non-municipal growth, as discussed in the previous section.

As stated above, Figure 3-6 represents the highest future demand scenario evaluated in this analysis. The actual future demand will likely be lower than presented in this figure. It is important to note that the Sulphur Basin needs are highly dependent on non-municipal water uses. In order to avoid inhibiting he future growth of the regional economy due to lack of available water, this study has included almost 40,000 ac-ft./yr. for potential future industrial water demands and 16,500 ac-ft./yr. for future irrigation/livestock demands.

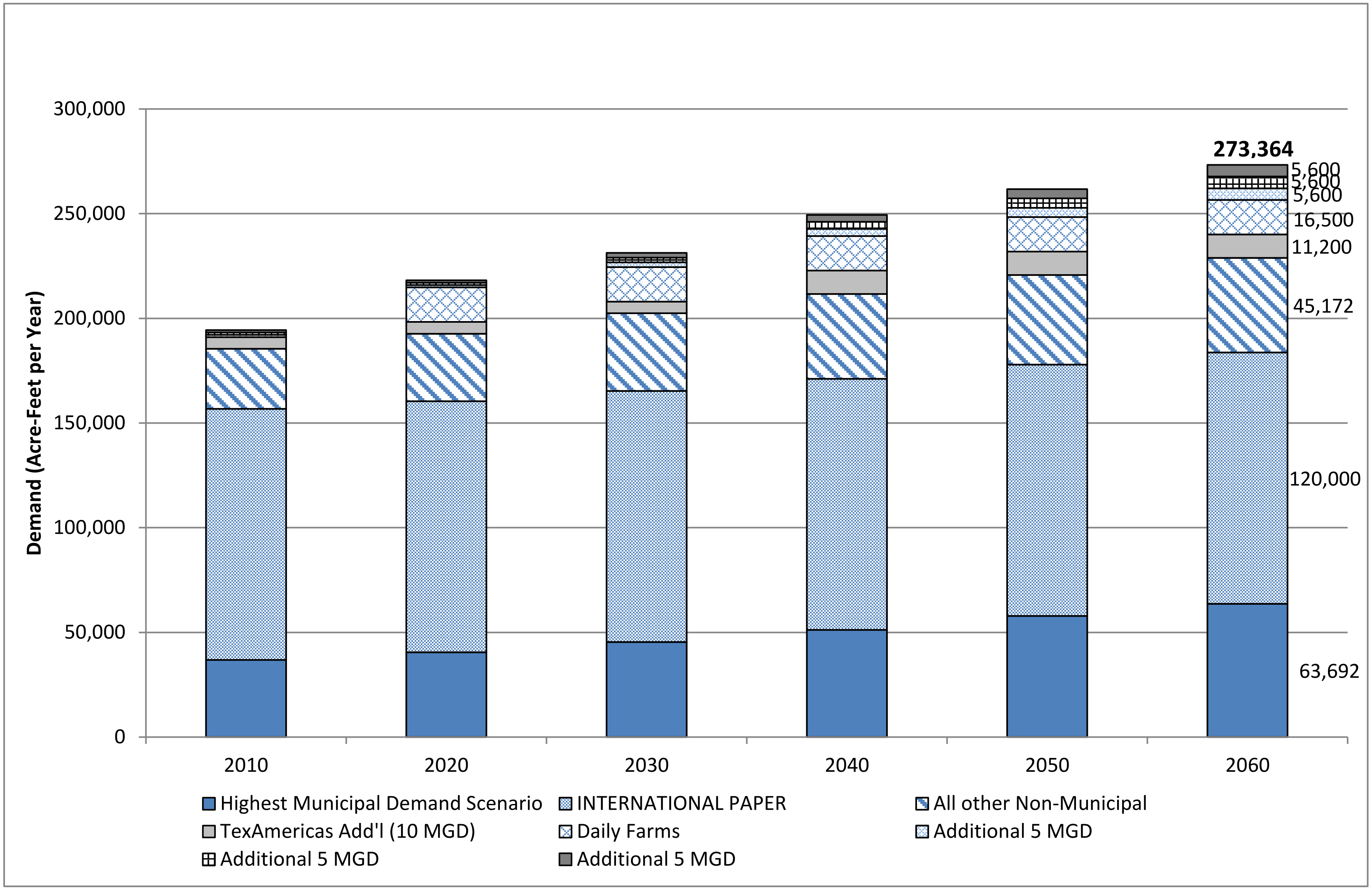
3.2.2 Demand for Sulphur River Basin Water from Outside the Basin

There are a number of water suppliers located outside (and not immediately adjacent to) the Sulphur Basin that depend on Sulphur Basin surface supply, specifically on Jim Chapman Lake. Both the North Texas Municipal Water District (NTMWD) and the City of Irving hold water rights in Jim Chapman Lake (see Section 5.2.2 for more information), and the Upper Trinity Regional Water District (UTRWD) has a long term contract for use from Jim Chapman Lake. These suppliers are located in the Dallas-Fort Worth Metroplex area and currently serve over 1.5 million people. Jim Chapman Lake is an integral part of the current water supply for these suppliers and will continue to be in the future.

As the Metroplex area continues to grow, both conservation and reuse will be important elements of future water supply. In the 2011 Region C Plan, conservation and reuse strategies account for 25% of the strategies to meet the future needs of the region. The NTMWD has two large scale reuse projects that will provide over 170,000 ac-ft/yr of reuse supply by year 2060, and UTRWD has existing and planned reuse projects that will provide over 25,000 ac-ft./yr. of reuse supply by year 2060. Additionally, the Region C Plan estimates a combined municipal conservation savings of over 97,500 ac-ft./yr. by 2060 for NTMWD, UTRWD, and Irving customers. Even with these conservation and reuse strategies, the needs of the NTMWD, Irving, and UTRWD will continue to increase due to population growth, and those suppliers will continue to depend on their current supply from Jim Chapman Lake into the future.

According to the Region C Plan, conservation and reuse are not sufficient to meet the projected water supply needs of the region. The Region C plan identifies an additional 1.5 million ac-ft/yr of new supply to meet projected growth. The Region C plan evaluates a number of alternate sources for this additional supply and includes development of 618,350 ac-ft./yr. from the Sulphur River Basin to meet 2060 needs.

Figure 3-6: Highest Total Demand Projections Scenario - Sulphur Basin Entities using Sulphur Surface Supplies



3.3 WATER AVAILABILITY

3.3.1 Aggregate Water Availability

A. Sulphur River Water Availability Modeling

In order to assess of the overall availability of surface water in the Sulphur River Basin under current conditions, the Water Availability Model (WAM) for the Sulphur River Basin was updated to reflect several important considerations. The WAM, a computer model based on the Texas A&M Water Rights Analysis Package (WRAP), is used by the Texas Commission on Environmental Quality (TCEQ) to determine surface water availability and forms the basis of water rights decisions by that agency. The Sulphur Basin WAM was originally developed under contract to TCEQ by R.J. Brandes Company in 1999 and includes a period of record from 1940 through 1996. The Sulphur WAM, as modified for the 2011 Region C plan, forms the basis of this analysis. However, three significant modifications were made in order to reflect aggregate water availability under current conditions.

The first significant modification made to the WAM was to update the storage capacity of both Wright Patman Lake and Jim Chapman Lake to account for sedimentation. Specifically, the WAM was updated using volumetric surveys conducted by the Texas Water Development Board for Jim Chapman Lake (2007) and Wright Patman Lake (2003). These surveys showed that some degree of storage capacity had been lost to sedimentation.

Secondly, the analysis deviates from the Region C analysis regarding current operations at Wright Patman Lake. The top of the conservation pool at Wright Patman varies seasonally; the specific elevation at a given time of the year is specified in a "rule curve." The contract between the Corps of Engineers and the project's local sponsor, the City of Texarkana, as well as the Texas water right, allow for the lake to be operated using the "Ultimate Rule Curve". This rule curve allows the top of the conservation pool to vary from elevation228.64 feet to 224.89 feet. However, that contract has never been fully executed by the local sponsor, and Wright Patman Lake is actually operated under an "Interim" Rule Curve. Under this rule curve, the top of the conservation pool varies from elevation 227.5 feet to 220.6 feet. Operation at these lower target elevations has an impact on the reliable yield, as calculated in the WAM. The Region C version of the WAM evaluated Wright Patman under the Ultimate Rule Curve, whereas this analysis is based on the interim Rule Curve.

The yield of Wright Patman Lake does not include any mandatory releases from conservation storage. Although these releases are specified in the Interim Rule Curve, they are primarily used by International Paper. Since these releases are considered part of International Paper's supply from the reservoir, we believe it is appropriate to account for these releases as part of the yield of the reservoir. The yield is also limited to the storage in the reservoir above elevation 220 feet msl. Additional supplies could be made available if storage below 220 feet were used. These assumptions were used both for this study and the Region C analysis.

Finally, the WAM was updated to include Lake Ralph Hall. This reservoir, located in Fannin County, is proposed by the Upper Trinity Regional Water District (UTRWD). UTRWD has applied to the TCEQ for a water right to divert 45,000 acre-feet for municipal purposes and impound 180,000 acre-feet. This permit was issued by TCEQ on September 24, 2013. Because portions of this analysis were conducted prior to the permit issuance, scenarios both with and without Lake Ralph Hall are presented for comparison.

The concept of "naturalized flows" is fundamental to the WAM's structure. "Naturalized flows" are synthesized from a wide variety of historical data, and represent historical streamflow conditions without water right diversions, major reservoirs and return flows. The WAM then supplies existing water rights, consistent with their priority under the Prior Appropriation doctrine of water use, from those naturalized flows. This process is repeated on a monthly basis for the 56 years in the period of record to estimate the availability of water at each point in time (and location) to meet the demands of existing water rights. Water in excess of those demands is "unappropriated" and theoretically available for the granting of additional water rights by the State.

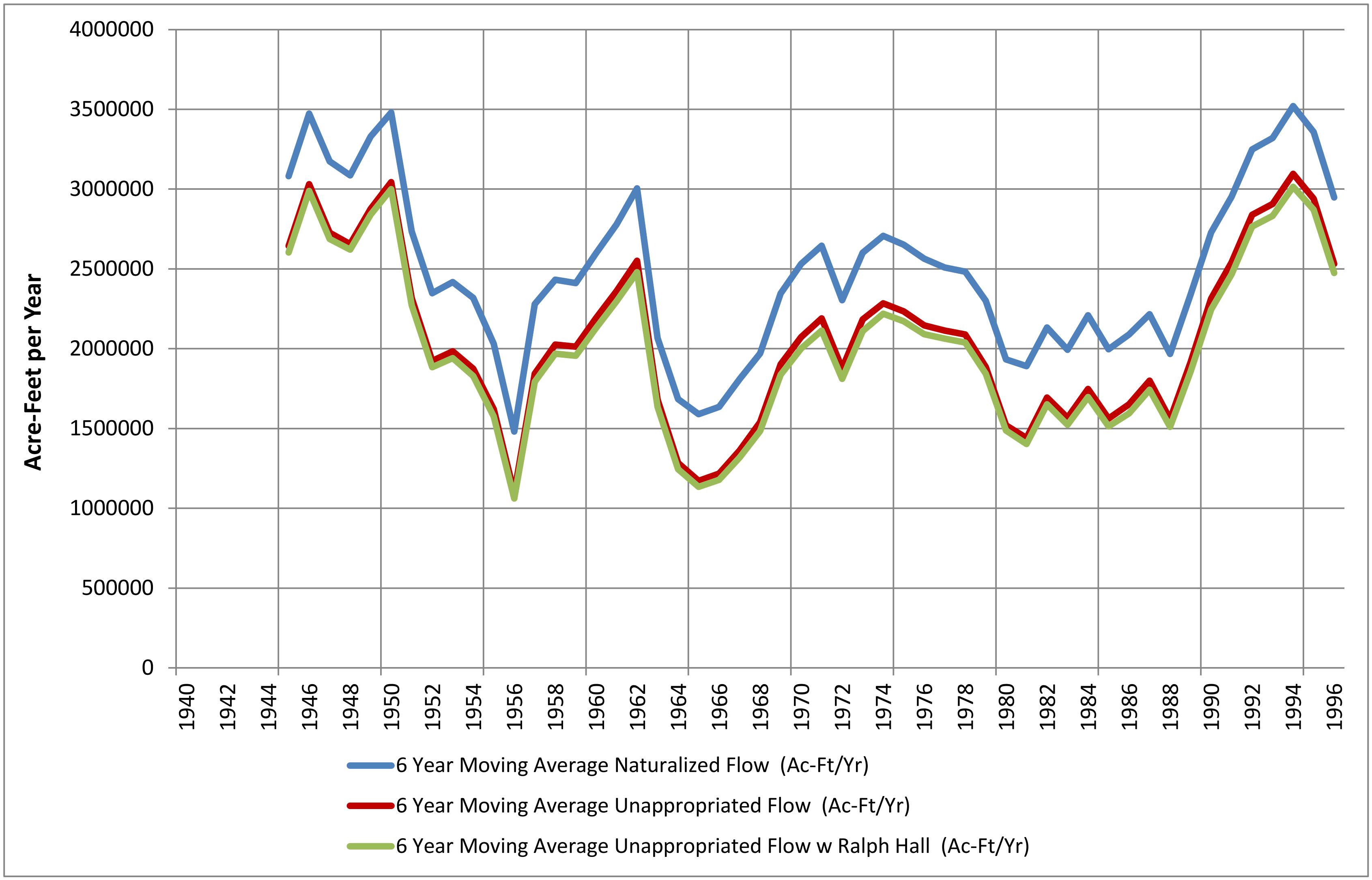
Table 3-5 summarizes the analysis of water availability in the Sulphur River at the Texas border for each year in the period of record. This location shows the maximum amount of unappropriated flow for the basin. This table also includes the average water availability over the period of record, availability in the wettest and in the driest year, and the average annual availability during 1951-1956, the most severe drought in the WAM period-of-record. Figure 3-7 presents the annual information graphically using a six-year moving average to help identify trends in the data. As indicated by the WAM analysis, the Sulphur Basin has an average naturalized flow of approximately 2 million ac-ft./yr., with an estimated 1.1 million ac-ft./yr. of unappropriated flow during the drought of record. Additional information describing the water availability modeling is contained in Appendix C.

Table 3-5: Sulphur River at Texas Border Flow (Ac-Ft/Yr)

Year	Naturalized Flow (Ac-Ft/Yr.)	Unappropriated Flow (Ac-Ft/Yr.)	Unappropriated Flow w Ralph Hall (Ac-Ft/Yr.)
1940	2,323,768	1,897,397	1,858,918
1941	3,610,138	3,237,657	3,193,880
1942	2,600,614	2,145,245	2,087,088
1943	1,133,313	764,878	757,225
1944	3,000,218	2,477,773	2,437,099
1945	5,819,794	5,337,494	5,287,159
1946	4,677,989	4,224,659	4,167,768
1947	1,807,737	1,413,480	1,389,042
1948	2,076,589	1,709,971	1,688,957
1949	2,602,198	2,092,774	2,073,034
1950	3,892,674	3,487,804	3,395,153
1951	1,353,248	973,864	927,678
1952	2,349,846	1,866,195	1,830,708
1953	2,228,510	1,773,275	1,729,806
1954	1,487,448	1,057,105	1,018,216
1955	874,389	564,504	548,978
1956	593,166	327,994	315,018
1957	6,145,262	5,472,555	5,313,229
1958	3,264,870	2,959,639	2,887,453
1959	2,102,019	1,690,667	1,647,311
1960	2,612,942	2,135,007	2,071,771
1961	1,956,997	1,579,248	1,545,659
1962	1,948,741	1,473,098	1,414,179
1963	516,675	248,067	244,445
1964	969,093	577,921	546,319
1965	1,536,859	1,022,445	988,623
1966	2,883,810	2,407,024	2,335,509
1967	3,005,734	2,448,178	2,378,226
1968	2,906,017	2,529,377	2,412,312
1969	2,776,434	2,428,318	2,358,153
1970	2,083,201	1,606,512	1,537,597
1971	2,219,730	1,719,274	1,660,586

Year	Naturalized Flow (Ac-Ft/Yr.)	Unappropriated Flow (Ac-Ft/Yr.)	Unappropriated Flow w Ralph Hall (Ac-Ft/Yr.)
1972	832,337	527,244	519,226
1973	4,790,128	4,287,199	4,174,415
1974	3,540,858	3,137,287	3,066,272
1975	2,447,727	2,121,523	2,077,789
1976	1,552,838	1,085,631	1,045,896
1977	1,893,006	1,518,087	1,491,071
1978	668,948	388,114	381,702
1979	3,702,247	3,062,227	3,002,389
1980	1,328,735	940,173	927,900
1981	2,197,365	1,644,483	1,569,815
1982	3,010,521	2,611,174	2,532,831
1983	1,053,441	752,404	721,291
1984	1,960,525	1,476,828	1,432,621
1985	2,429,992	1,950,873	1,892,228
1986	1,886,385	1,475,030	1,417,252
1987	2,953,903	2,527,866	2,459,578
1988	1,522,517	1,160,930	1,139,190
1989	3,282,538	2,897,670	2,794,700
1990	4,296,498	3,872,804	3,769,742
1991	3,775,323	3,315,888	3,216,894
1992	3,659,680	3,261,341	3,218,143
1993	3,386,893	2,930,213	2,854,844
1994	2,720,040	2,300,233	2,234,821
1995	2,309,568	1,958,347	1,937,342
1996	1,839,318	1,421,118	1,387,258
Average	**2,498,269**	**2,074,984**	**2,023,023**
Maximum	**6,145,262**	**5,472,555**	**5,313,229**
Minimum	**516,675**	**248,067**	**244,445**
Average Annual 51-56	**1,481,101**	**1,092,823**	**1,061,734**

Figure 3-7: Sulphur River at Texas Border Flow (Ac-Ft/Yr)



The Water Availability Model was used to estimate the reliable supply available from Sulphur Basin water rights in light of the specific assumptions included in this analysis. For Jim Chapman Lake and Wright Patman Lake, the reliable supply is based on the calculated firm yield of the reservoir as currently operated. For the other reservoirs and run-of-river water rights, the reliable supply is defined as the minimum annual diversions in the period of record, and approximates the reliable supply. This value is shown for each impoundment in the WAM in Table 3-6 below.

Table 3-6: Reliable Supply – Sulphur Basin Water Rights

Reservoir or Stream Name	Reliable Supply (Ac-Feet/Year)
Reservoirs	
Jim Chapman Lake (Cooper Reservoir)[a]	116,910
Wright Patman Lake[b]	46,000
Langford Creek Lake	421
Lake Sulphur Springs	9,800
Wolfe City Reservoir	96
City Lake	63
Terry Lake	314
South Lake	0
Magic Valley Lake	140
Lake Coleman	35
Lake Romal	0
Kennedy Lake	80
Supervisor's Club Reservoir	0
Cross Timber Ranch Lake No 1	0
Gordon Lake	0
Turkey Creek Lake	0
Streams	
Old Channel S Sulphur River	9,120
Sulphur River	10,216
Big Creek	0
S Sulphur River	0
Brushy Creek	5
Barnard Draw	30
Rock Creek	26
Wolfpen Creek	17
Mitchell Creek	0
Denton Creek	48
Bear Pen Creek	0
Campbell Creek	0
Ripley Creek	11
McCullough Creek	18
Piney Creek	6

Reservoir or Stream Name	Reliable Supply (Ac-Feet/Year)
E Piney Creek	11
E Piney Creek & Piney Creek	0
Murphy Creek	0
Village Creek	0
Eds Creek	1
Anderson Creek	69
Rice Creek	31
Holly Creek	55
Brooks Creek	19
Moss Creek	0
Caney Creek	945
Caney Creek	1,879
White Oak Creek	8
Toyah Creek	0
Total	**196,374**

a. Firm yield of the conservatino pool of the reservoir

b. Firm yield using the Interim Rule Curve, limited to storage above 220 feet, and with no downstream releases from conservation storage

B. Water Availability from Out of Basin Sources

As identified in the basin overview, there are seven sources of surface water that are imported for use in the Sulphur Basin. The seven sources include Lake Tawakoni, Bob Sandlin Lake, Bonham Lake, Crook Lake, Cypress Springs Lake, Pat Mayse Lake, and Millwood Lake. WAM modeling was not performed for these sources as part of this analysis. However, existing analyses were utilized, including the Region D Plan and a number of follow-up interviews, to confirm that the assumption of continued reliance on these sources would be appropriate. This review is discussed further below.

Sabine Basin sources include Lake Tawakoni (owned by the Sabine River Authority) which supplies water to a number of water users in the Sulphur River Basin, with the City of Commerce being the largest. Other users are North Hunt WSC, manufacturing uses in Hunt County and rural populations in Hunt and Delta Counties. According to the Region D Plan, Lake Tawakoni has a firm yield of 229,807 ac-ft./yr. in the year 2010, decreasing to 221,240 ac-ft./yr. by year 2060 due to sedimentation. (The Region D Plan cites the Sabine WAM as the source of this yield.) Based on the information in the Region D plan, these Sulphur Basin entities currently use around 7,900 ac-ft./yr. of Lake Tawakoni supply and will continue to utilize the supply through the 2060 planning period.

Cypress Bayou Basin sources include Lake Bob Sandlin and Lake Cypress Springs. Lake Bob Sandlin provides a small amount of supply (less than 600 ac-ft./yr.) to areas in rural Titus County and small areas of rural Franklin County. According to the Region D Plan, Lake Bob Sandlin has a firm yield of 60,430 ac-ft./yr. (The Region D Plan cites the Cypress WAM as the source of this yield and shows no decrease in the future yield due to sedimentation.) The supply in Lake Bob Sandlin will continue to be available to these Sulphur Basin users in the future. However, there is the potential that these Sulphur Basin users could convert to Sulphur Basin surface water in the future so they have been included in the demand projections presented in Section 4 of this report. Cypress Springs Lake supplies water for two entities in the Sulphur River Basin (Cypress Springs SUD and the City of Mount Vernon). According to the Region D Plan, Cypress Springs Lake has a firm yield of 10,737 ac-ft./yr., decreasing to 9,537 ac-ft./yr. by year 2060 due to sedimentation. (The Region D Plan cites the Cypress WAM as the source of this yield.) The entities in the Sulphur River Basin use approximately 3,500 ac-ft./yr. out of Cypress Springs Lake.

Red River Basin sources for Sulphur Basin users include Bonham Lake, Crook Lake, and Pat Mayse Lake. Bonham Lake supplies a very small amount of supply for water users in rural Fannin County (sold through the City of Bonham). According to the 2011 Region C Water Plan, Bonham Lake has a firm yield of 5,340 ac-ft./yr. The Region C Plan shows this supply to continue to be available to these rural Fannin County water users through the 2060 planning period. Crook Lake supplies water for the City of Paris. According to the Region D Plan, Crook Lake has a firm yield of 7,290 ac-ft./yr. (The Region D Plan cites the Red River WAM as the source of this yield and shows no decrease in the future yield due to sedimentation.) Paris is permitted to use 12,000 ac-ft./yr. out of Crook Lake, but this permit exceeds the yield of the lake. Lake Crook is primarily used as back-up supply by Paris, and is not currently used at its full permit amount. Pat Mayse Lake supplies water for several entities in the Sulphur River Basin, including the City of Paris (including its customers), Lamar County WSD, and Lamar County manufacturing uses. The City of Paris holds water rights from Pat Mayse Lake totaling 61,610 ac-ft./yr. According to the Region D Plan, Lake Pat Mayse has a firm yield of 59,670 ac-ft./yr. through 2060. (The Region D Plan cites a recent study by HDR Engineering performed for the City of Paris as the source of this yield. It was verified with the City of Paris' consulting engineer (Hayter Engineering) that this yield estimate reflects currently permitted operating conditions of the lake.) Based on information from the Region D plan, it is estimated that approximately 18,000 ac-ft/yr of supply from Crook Lake and Pat Mayse Lake is currently being used by the portion of Paris (and its customers) that is located in the Sulphur Basin.

The Texarkana Water Utilities (TWU) system provides integrated water and sewer services to the combined cities of Texarkana, Texas and Texarkana, Arkansas. In addition to Wright Patman Lake, TWU uses raw water from Millwood Lake, located on the Little River in Hempstead, Howard, Little River, and Sevier Counties in Southwestern Arkansas. The City of Texarkana, Arkansas has a contract with the Southwest Arkansas Water District for 15 MGD from Millwood Lake and consistently exercises that contract. The Southwest Arkansas Water District has an additional 35 MGD available under their storage contract with the Corps of Engineers and is actively marketing that water. Data collection activities identified concerns about the sustainability of Millwood Lake as a long-term water source due to high rates of sedimentation. The Corps of Engineers (Little Rock District) has indicated a desire to assess sedimentation concerns empirically, and is seeking cost-shared support for a watershed study which would include a current bathymetric survey (email, Trish Anslow, Chief, Planning and Environmental Branch, Little Rock District, COE). This evaluation assumes that the current contract amount of 15 MGD from Millwood Lake is sustainable through 2060.

The total amount of out-of-basin supplies used in the Sulphur Basin is approximately 30,000 ac-ft./yr. from Texas sources, with an additional 16,800 ac-ft./yr. (15 MGD) contracted from Millwood Lake in Arkansas. This gives a total out-of-basin supply of 46,800 ac-ft./yr.

3.3.2 Appropriated Water within the Sulphur River Basin

The sum of all water rights (appropriated/permitted) within the Sulphur River Basin authorized by the State of Texas is approximately 382,000 ac-ft./yr. The vast majority of these water rights are for supply from Wright Patman Lake and Jim Chapman Lake, although there are a number of smaller reservoirs in the basin for which water rights have been granted. Table 3-7 provides a detailed list of water rights from Sulphur River Basin Impoundments.

As can be seen from Table 3-7 not all the water right holders are located in the Sulphur River Basin. Excluding the integrated system of Texarkana Water Utilities (see below) , approximately 108,000 ac-ft./yr. is permitted to be exported out-of-basin, virtually all from Jim Chapman Lake, and virtually all to entities in the Dallas-Fort Worth Metroplex. In addition, several in-basin water rights holders in Jim Chapman (e.g. City of Commerce, Sulphur River Municipal Water District) sell some or all of their permitted water to Metroplex entities.

Table 3-7: Sulphur River Basin Water Rights with Permitted Diversions

Reservoir Name/ Stream	Water Right #	Authorized Impoundment (ac-ft)	Use	Permit Amount (ac-ft/yr)	Water Right Holder	Sulphur River Basin Users	Outside Basin User
Jim Chapman Lake (Cooper Reservoir)	CA 03-4797B	81,470	Municipal	26,960	Sulphur River MWD	Commerce (Gafford Chapel WSC, Maloy WSC, North Hunt WSC, Texas A&M West Delta WSC), Cooper, Sulphur Springs, Brashear WSC, Brinker WSC, Martin Springs WSC, Livestock, Pleasant Hill WSC	Upper Trinity Regional WD, Lake Cities Municipal Utility Authority Argyle, Argyle WSC, Aubrey, Bartonville, Bartonville WSC, Celina, Cooper Canyon, Corinth, County-Other, Cross Roads, Denton County FWSD#1A, Double Oak, Hebron, Hickory Creek, Highland Village, Irving, Justin, Krugerville, Krum, Lake Dallas, Lincoln Park, Manufacturing, Mustang SUD, Oak Point, Pilot Point, Sanger, Shady Shores
			Industrial	11,560		Manufacturing	Manufacturing
	CA 03-4798	114,265	Municipal	54,000	North Texas MWD	None	Allen, Anna, Blackland WSC, Caddo Basin SUD, Cash SUD, College Mound WSC, County-Other, Crandall, Culleoka WSC, East Fork SUD, Fairview, Farmersville, Fate, Forney, Forney Lake WSC, Frisco, Garland, Gastonia-Scurry SUD, Hackberry, Heath, Howe, Irrigation, Josephine, Kaufman, Lavon WSC, Little Elm, Lowry Crossing, Lucas, Manufacturing, McKinney, McClendon-Chisholm, Mesquite, Milligan WSC, Mining, Murphy, Nevada, New Hope, North Collin WSC, Oak Grove, Parker, Plano, Post Oak Bend City, Princeton, Prosper, Richardson, Rockwall, Rowlett, Royse City, Sachse, Saint Paul, Scurry, Sunnyville, Terrell, The Colony, Van Alstyne, Wylie
	CA 03-4799C	114,265	Municipal	44,820	City of Irving	None	Irving

Reservoir Name/ Stream	Water Right #	Authorized Impoundment (ac-ft)	Use	Permit Amount (ac-ft/yr)	Water Right Holder	Sulphur River Basin Users	Outside Basin User
			Mun & Industrial	9,180		None	Irving & Manufacturing
Wright Patman Lake	CA 03-4836	386,900	Municipal	45,000	Texarkana, TX	Central Bowie WSC, County-Other (Avery, Annona, Domino), De Kalb, Federal Correction Institution, Macedonia-Eylau MUD #1, Manufacturing, Maud, Nash, New Boston, Red Lick, Red River County WSC, Redwater, Texarkana TX, Texarkana AR, Wake Village, Atlanta, Mandeville, AR	County-Other, Hooks, Leary, Manufacturing
			Industrial	135,000	Texarkana, TX	International Paper, Manufacturing	None
Langford Creek Lake	CA 03-4809	1,225	Municipal	1,119.5	Red River County WCID 1	Clarksville	None
			Industrial	0.5		Manufacturing	None
Lake Sulphur Springs	CA 03-4811B	17,838	Municipal & Industrial	9,800	City of Sulphur Springs	Sulphur Springs	None
						Livestock, Manufacturing	None
Wolfe City Reservoir[1]	CA 03-4795	855	Municipal	300	City of Wolfe City	Wolfe City	None
City Lake	CA 03-4800	164	Municipal	273	City of Cooper	No longer used	None
Terry Lake	CA 03-4803	328	Irrigation	1,900	Helmut Hermann ET AL	No reported use	None
Magic Valley Lake	CA 03-4810	200	Irrigation	200	Perry R Bass Inc	No reported use	None
Lake Coleman	CA 03-4812	408	Municipal	408	City of Sulphur Springs	Emergency supply – Sulphur Springs	None
Kennedy Lake	CA 03-4837	550	Irrigation	80	Leon S Kennedy Jr	No reported use	None
Old Channel S Sulphur River	P 03-3845A	7498	Irrigation	8,328	Sulphur Bluff Ranch LLC	Irrigation	None
	P 03-3845B	2,925	Irrigation	11,312			
Sulphur River	P 03-3890	152	Municipal	102	City of Pecan Gap	Delta county[2]	None
Sulphur River	CA 03-4802	300	Irrigation	278	Alexander Frick ET AL	Irrigation	None

Reservoir Name/ Stream	Water Right #	Authorized Impoundment (ac-ft)	Use	Permit Amount (ac-ft/yr)	Water Right Holder	Sulphur River Basin Users	Outside Basin User
Rivercrest Lake	CA 03-4804	7,100	Industrial	10,000	Luminant Generation Co LLC	Rivercrest Steam Electric Power[3]	None
Sulphur River	CA 03-4805	2,063	Irrigation	3,000	E P Land & Cattle Co Inc	No reported use	None
Big Creek Lake	P 03-4060	4,890	Municipal	1,518	City of Cooper	City of Cooper	None
S Sulphur River	CA 03-4796	60	Irrigation	80	Webb Hill Country Club	Irrigation	None
Brushy Creek	CA 03-4801	0	Irrigation	5	Delta Country Club Inc	Irrigation	None
Barnard Draw	CA 03-4806	0	Irrigation	8	Mary Margaret Vaughan	No reported use	None
	CA 03-4807	0	Irrigation	22	Mary Margaret Vaughan	No reported use	None
Rock Creek	CA 03-4813	0	Irrigation	113	Sulphur Springs Country Club	Irrigation	None
Rock Creek	P 03-5906	1,002	Mining	220	Luminant Mining CO LLC	Mining	None
Wolfpen Creek	CA 03-4814	26	Irrigation	30	Jerry N Jordan Trustee ET AL	Irrigation	None
Denton Creek	CA 03-4816	434	Municipal	400	City of Mount Vernon	No longer used[4]	None
Bear Pen Creek	CA 03-4817	0	Irrigation	333	Hans Weiss ET UX	No reported use	None
Campbell Creek	CA 03-4818	24	Irrigation	11	Robert W Campbell ET AL	No reported use	None
Ripley Creek	CA 03-4820	0	Irrigation	22	Unknown	No reported use	None
	CA 03-4821	1	Industrial	1	Anna Pearl Lewis	None	None
Ripley Creek	P 03-5562	0	Industrial	125	Luminant Mining CO LLC	Mining	None
McCullough Creek	CA 03-4822	195	Irrigation	100	John E & Bernice Baldwin	No reported use	None

Reservoir Name/ Stream	Water Right #	Authorized Impoundment (ac-ft)	Use	Permit Amount (ac-ft/yr)	Water Right Holder	Sulphur River Basin Users	Outside Basin User
Piney Creek	CA 03-4823	24	Irrigation	23	Ardelia Gauntt	No reported use	None
	CA 03-4824	0	Irrigation	8	Walter W Lee	No reported use	None
E Piney Creek	CA 03-4825	30	Irrigation	20	Robert Crooks ET AL	No reported use	None
E Piney Creek & Piney Creek	P 03-12099	513	Mining	200	Luminant Mining CO LLC	Monticello lignite mining	None
Eds Creek	CA 03-4829	0	Irrigation	4	William E Johnson Jr ET AL	No reported use	None
Anderson Creek	CA 03-4830	0	Irrigation	378	William E Johnson Jr ET AL	No reported use	None
Rice Creek	CA 03-4831A	259	Municipal	31	City of New Boston	Emergency supply	None
	CA 03-4833	14	Industrial	8	H C Prange Jr	No reported use	None
Holly Creek	CA 03-4832B	8	Municipal	325	City of New Boston	No reported use	None
Brooks Creek	CA 03-4834	15	Irrigation	39	William E Johnson Jr ET AL	No reported use	None
Caney Creek	P 01-5873	1,340	Municipal	1,032	Red River Redevelopment Authority	RRDA service area	RRDA service area in Red River Basin
		2,734		1,928			
White Oak Creek	P 03-12145	0	Irrigation	35	Los Senderos Cattle and Ranch Company	Irrigation	None
Toyah Creek	P 03-5449	504	Other, wildlife habitats	863	Texas Parks & Wildlife Dept	Texas Parks & Wildlife Dept	None
		436		436			
		195		195			
		232		232			

Table 3-8: Sulphur River Basin Water Rights with Permitted Diversions

Reservoir Name/ Stream	Water Right #	Authorized Impoundment (ac-ft)	Use	Permit Amount (ac-ft/yr)	Water Right Holder	Sulphur River Basin Users	Outside Basin User
Jim Chapman Lake (Cooper Reservoir)	CA 03-4797B	81,470	Municipal	26,960	Sulphur River MWD	Commerce (Gafford Chapel WSC, Maloy WSC, North Hunt WSC, Texas A&M West Delta WSC), Cooper, Sulphur Springs, Brashear WSC, Brinker WSC, Martin Springs WSC, Livestock, Pleasant Hill WSC	Upper Trinity Regional WD, Lake Cities Municipal Utility Authority Argyle, Argyle WSC, Aubrey, Bartonville, Bartonville WSC, Celina, Cooper Canyon, Corinth, County-Other, Cross Roads, Denton County FWSD#1A, Double Oak, Hebron, Hickory Creek, Highland Village, Irving, Justin, Krugerville, Krum, Lake Dallas, Lincoln Park, Manufacturing, Mustang SUD, Oak Point, Pilot Point, Sanger, Shady Shores
			Industrial	11,560		Manufacturing	Manufacturing
	CA 03-4798	114,265	Municipal	54,000	North Texas MWD	None	Allen, Anna, Blackland WSC, Caddo Basin SUD, Cash SUD, College Mound WSC, County-Other, Crandall, Culleoka WSC, East Fork SUD, Fairview, Farmersville, Fate, Forney, Forney Lake WSC, Frisco, Garland, Gastonia-Scurry SUD, Hackberry, Heath, Howe, Irrigation, Josephine, Kaufman, Lavon WSC, Little Elm, Lowry Crossing, Lucas, Manufacturing, McKinney, McClendon-Chisholm, Mesquite, Milligan WSC, Mining, Murphy, Nevada, New Hope, North Collin WSC, Oak Grove, Parker, Plano, Post Oak Bend City, Princeton, Prosper, Richardson, Rockwall, Rowlett, Royse City, Sachse, Saint Paul, Scurry, Sunnyville, Terrell, The Colony, Van Alstyne, Wylie
	CA 03-4799C	114,265	Municipal	44,820	City of Irving	None	Irving
			Mun & Industrial	9,180		None	Irving & Manufacturing

Reservoir Name/ Stream	Water Right #	Authorized Impoundment (ac-ft)	Use	Permit Amount (ac-ft/yr)	Water Right Holder	Sulphur River Basin Users	Outside Basin User
Wright Patman Lake	CA 03-4836	386,900	Municipal	45,000	Texarkana, TX	Central Bowie WSC, County-Other (Avery, Annona, Domino), De Kalb, Federal Correction Institution, Macedonia-Eylau MUD #1, Manufacturing, Maud, Nash, New Boston, Red Lick, Red River County WSC, Redwater, Texarkana TX, Texarkana AR, Wake Village, Atlanta, Mandeville, AR	County-Other, Hooks, Leary, Manufacturing
			Industrial	135,000	Texarkana, TX	International Paper, Manufacturing	None
Langford Creek Lake	CA 03-4809	1,225	Municipal	1,119.5	Red River County WCID 1	Clarksville	None
			Industrial	0.5		Manufacturing	None
Lake Sulphur Springs	CA 03-4811B	17,838	Municipal & Industrial	9,800	City of Sulphur Springs	Sulphur Springs	None
						Livestock, Manufacturing	None
Wolfe City Reservoir[1]	CA 03-4795	855	Municipal	300	City of Wolfe City	Wolfe City	None
City Lake	CA 03-4800	164	Municipal	273	City of Cooper	No longer used	None
Terry Lake	CA 03-4803	328	Irrigation	1,900	Helmut Hermann ET AL	No reported use	None
Magic Valley Lake	CA 03-4810	200	Irrigation	200	Perry R Bass Inc	No reported use	None
Lake Coleman	CA 03-4812	408	Municipal	408	City of Sulphur Springs	Emergency supply – Sulphur Springs	None
Kennedy Lake	CA 03-4837	550	Irrigation	80	Leon S Kennedy Jr	No reported use	None
Old Channel S Sulphur River	P 03-3845A	7498	Irrigation	8,328	Sulphur Bluff Ranch LLC	Irrigation	None
	P 03-3845B	2,925	Irrigation	11,312			
Sulphur River	P 03-3890	152	Municipal	102	City of Pecan Gap	Delta county[2]	None
Sulphur River	CA 03-4802	300	Irrigation	278	Alexander Frick ET AL	Irrigation	None

Reservoir Name/ Stream	Water Right #	Authorized Impoundment (ac-ft)	Use	Permit Amount (ac-ft/yr)	Water Right Holder	Sulphur River Basin Users	Outside Basin User
Rivercrest Lake	CA 03-4804	7,100	Industrial	10,000	Luminant Generation Co LLC	Rivercrest Steam Electric Power[3]	None
Sulphur River	CA 03-4805	2,063	Irrigation	3,000	E P Land & Cattle Co Inc	No reported use	None
Big Creek Lake	P 03-4060	4,890	Municipal	1,518	City of Cooper	City of Cooper	None
S Sulphur River	CA 03-4796	60	Irrigation	80	Webb Hill Country Club	Irrigation	None
Brushy Creek	CA 03-4801	0	Irrigation	5	Delta Country Club Inc	Irrigation	None
Barnard Draw	CA 03-4806	0	Irrigation	8	Mary Margaret Vaughan	No reported use	None
	CA 03-4807	0	Irrigation	22	Mary Margaret Vaughan	No reported use	None
Rock Creek	CA 03-4813	0	Irrigation	113	Sulphur Springs Country Club	Irrigation	None
Rock Creek	P 03-5906	1,002	Mining	220	Luminant Mining CO LLC	Mining	None
Wolfpen Creek	CA 03-4814	26	Irrigation	30	Jerry N Jordan Trustee ET AL	Irrigation	None
Denton Creek	CA 03-4816	434	Municipal	400	City of Mount Vernon	No longer used[4]	None
Bear Pen Creek	CA 03-4817	0	Irrigation	333	Hans Weiss ET UX	No reported use	None
Campbell Creek	CA 03-4818	24	Irrigation	11	Robert W Campbell ET AL	No reported use	None
Ripley Creek	CA 03-4820	0	Irrigation	22	Unknown	No reported use	None
	CA 03-4821	1	Industrial	1	Anna Pearl Lewis	None	None
Ripley Creek	P 03-5562	0	Industrial	125	Luminant Mining CO LLC	Mining	None
McCullough Creek	CA 03-4822	195	Irrigation	100	John E & Bernice Baldwin	No reported use	None
Piney Creek	CA 03-4823	24	Irrigation	23	Ardelia Gauntt	No reported use	None

Reservoir Name/ Stream	Water Right #	Authorized Impoundment (ac-ft)	Use	Permit Amount (ac-ft/yr)	Water Right Holder	Sulphur River Basin Users	Outside Basin User
	CA 03-4824	0	Irrigation	8	Walter W Lee	No reported use	None
E Piney Creek	CA 03-4825	30	Irrigation	20	Robert Crooks ET AL	No reported use	None
E Piney Creek & Piney Creek	P 03-12099	513	Mining	200	Luminant Mining CO LLC	Monticello lignite mining	None
Eds Creek	CA 03-4829	0	Irrigation	4	William E Johnson Jr ET AL	No reported use	None
Anderson Creek	CA 03-4830	0	Irrigation	378	William E Johnson Jr ET AL	No reported use	None
Rice Creek	CA 03-4831A	259	Municipal	31	City of New Boston	Emergency supply	None
	CA 03-4833	14	Industrial	8	H C Prange Jr	No reported use	None
Holly Creek	CA 03-4832B	8	Municipal	325	City of New Boston	No reported use	None
Brooks Creek	CA 03-4834	15	Irrigation	39	William E Johnson Jr ET AL	No reported use	None
Caney Creek	P 01-5873	1,340	Municipal	1,032	Red River Redevelopment Authority	RRDA service area	RRDA service area in Red River Basin
		2,734		1,928			
White Oak Creek	P 03-12145	0	Irrigation	35	Los Senderos Cattle and Ranch Company	Irrigation	None
Toyah Creek	P 03-5449	504	Other, wildlife habitats	863	Texas Parks & Wildlife Dept	Texas Parks & Wildlife Dept	None
		436		436			
		195		195			
		232		232			

1. This facility is also referred to as Turkey Creek Lake. TCEQ records show no reported use with this water right from 2003 to 2007.
2. TCEQ reports state that Delta County Water took over the Pecan Gap water treatment facilities. No reported use from Pecan Gap.
3. Rivercrest power facilities have been retired and were imploded in 2011.
4. City of Mount Vernon now receives water from Lake Cypress Springs.

A. Wright Patman Lake

Wright Patman Lake is located in Cass and Bowie Counties near the Texas/Arkansas state line. The only water right in Wright Patman Lake is held by the City of Texarkana, Texas. The City of Texarkana, Texas has the right to impound 386,900 acre-feet of water in Wright Patman Lake and is permitted to use 180,000 ac-ft./yr. The City of Texarkana, Texas is permitted to use this water for municipal and industrial purposes. Municipal use is permitted for 45,000 ac-ft./yr., while industrial is permitted for 135,000 ac-ft./yr. Texarkana serves a number of municipal customers in the Sulphur River Basin. Those customers are listed in Table 3-7. Texarkana also serves several out-of-basin users, including Cass County-Other, Hooks, Leary, and Manufacturing, Queen City. By far the largest of Texarkana's customers is International Paper, which has a contract for 120,000 ac-ft./yr. The towns of Atlanta and Queen City have the ability to purchase drinking water from Texarkana through the potable water treatment plant located at the International Paper Mill and operated by International Paper on behalf of Texarkana. Atlanta exercises this option; however Queen City primarily relies on groundwater. This plant also supplies water to a small amount of out-of-basin manufacturing users in Cass County.

B. Jim Chapman Lake

Jim Chapman Lake is located in Delta and Hopkins Counties. Four entities currently obtain water from the reservoir: the Upper Trinity Regional Water District (UTRWD), the City of Irving (Irving), the North Texas Municipal Water District (NTMWD), and the City of Sulphur Springs (Sulphur Springs). Certificate of Adjudication (CA) 03-4797 belongs to the Sulphur River Municipal Water District (SRMWD). 16,106 acre-feet per year of the SRMWD authorization is used by UTRWD, and 3,214 acre-feet per year is used by NTMWD. As a result NMTWD's total authorized diversions from the reservoir is 57,214 acre-feet per year. Of the remaining SRMWD authorizations, 18,128 acre-feet per year are assigned to the Sulphur Springs and 1,072 acre-feet per year are assigned to the City of Cooper. The City of Cooper currently does not use water from the reservoir, instead selling to UTMWD.

The Sulphur River MWD has the right to impound 81,470 acre-feet of water in Lake Chapman (including 71,750 acre-feet in the conservation pool) and is permitted to use 38,520 ac-ft./yr. annually (26,960 ac-ft./yr. for municipal use and 11,560 ac-ft./yr. for industrial use). The City of Commerce has contracted for 16,106 acre-feet per year of the use permitted to the Sulphur River MWD, 11,274 ac-ft./yr. municipal use and 4,832 ac-ft./yr. industrial use. The cities of Sulphur Springs and Cooper have the rest of the Sulphur River MWD water rights. The North Texas MWD has the right to impound 114,265 acre-feet in

Lake Chapman (including 100,625 acre-feet in the conservation pool) and is permitted to use 54,000 ac-ft./yr. The City of Irving has the right to impound 114,265 acre-feet in Lake Chapman (including 100,625 acre-feet in the conservation pool) and is permitted to use 54,000 ac-ft./yr. (44,820 ac-ft./yr. for municipal and 9,180 ac-ft./yr. for industrial). The entities using water from Jim Chapman Lake are listed in Table 3-8.

C. Minor Reservoirs/Sources

There are fifty eight water rights associated with minor reservoirs, small lakes, rivers, and creeks in the Sulphur River Basin. The water right holders for minor reservoirs in the Sulphur River Basin are shown in Table 3-7. The combined impoundment right for the minor reservoirs is 61,169 acre-feet with a combined permitted diversion amount of 55,844 ac-ft/yr.

3.3.3 Unappropriated Water within the Sulphur Basin

Based on the WAM output and a rollup of the existing water rights which have been granted by TCEQ for Sulphur Basin waters, there is a significant volume of unappropriated water in the Basin. The average flow over the most severe drought in the historical record provides a rough estimate of the amount of water that can be reliably developed in a river basin. Using the naturalized flows form the Sulphur Basin Water Availability Model, the Texas portion of the Sulphur River Basin produced an average of 1.5 million ac-ft/yr from 1951 to 1956, the historical drought-of-record for the basin. The amount of unappropriated water potentially available for development in the basin is roughly 1.1 million ac-ft./yr. Development of additional storage, as well as other infrastructure, would be required in order to make this supply available for municipal or other economic uses.

3.3.4 Water Availability Concerns

Our analysis demonstrates that the Sulphur River Basin, taken as a whole, can provide abundant surface water, in addition to existing water rights. However, this abundance is not necessarily available uniformly across the basin. Not all municipalities or industries have a surplus or - in some cases - an adequate supply for the period of analysis for this study. This analysis does not assess water availability as segmented by each user group; however, data collection efforts identified several specific instances of availability concerns which are discussed below.

A. Wright Patman Lake

As noted earlier in the report, the State of Texas has permitted 180,000 ac-ft./yr. for municipal and industrial use from Wright Patman Lake. Water Availability modeling indicates that sufficient surface water is available in all but the driest years to meet this water right. However, in light of current actual conditions relative to sedimentation, the elevation of pump station intakes on the lake, and the Interim Rule Curve which limits conservation storage, this analysis suggests that the reliable supply from Wright Patman Lake under current conditions is approximately 46,000 ac-ft./yr. Access to additional available yield is certainly possible, but would require either a modification to Texarkana's contract for storage with the Corps of Engineers, a significant infrastructure investment (discussed further below), or both.

B. Jim Chapman Lake

The 2011 Region D Water Plan identifies the dependable yield for Jim Chapman Lake as 127,000 ac-ft./yr. This analysis reduces that estimate to approximately 117,000 ac-ft./yr. The difference is largely due to the more explicit accounting for sedimentation incorporated into this analysis. However, the total permitted right to Jim Chapman Lake is 146,500 ac-ft./yr. Under severe drought conditions, the ability of Jim Chapman Lake to provide sufficient water to meet all permitted water rights may be limited. An accounting plan developed by R.J. Brandes governs allocation of water use from Lake Chapman. Dr. Brandes maintains the accounting plan in an Excel spreadsheet. Whenever the reservoir begins a significant drought, Dr. Brandes updates the spreadsheet each month. The accounting plan divides the conservation storage in the reservoir among the five authorized water users (UTRWD, Irving, NTMWD, Sulphur Springs and Cooper). These divisions are called storage accounts. The maximum volume in each account is based on the percentage of total conservation storage available to each user. If the reservoir is full, the storage accounts are full. As storage in the reservoir begins to drop, diversions are subtracted from each user's account. Inflows, evaporative losses and the 5 cfs constant release are divided among the accounts based on that account's percentage of the total water in conservation storage. As long as a user has storage in their account, they can use water from the reservoir up to their authorized diversion (less an allotment for future evaporative losses.) Once the account has been depleted, a user cannot use any moe water from the reservoir unless inflows partially or entirely fill their account.

C. Red River County

The City of Clarksville draws its supply from Lake Langford and a system of three municipal wells. One well is currently out of service. The groundwater source exceeds state drinking water standards for chlorides while the surface water exceeds state standards for turbidity. The two sources are mixed at a 60% surface water/40% groundwater ratio in order to provide water meeting drinking water standards. Under drought conditions, such as 2006 and 2011, the reliability of the Lake Langford source is significantly stressed, and aggregate supply is barely adequate for the current population. One way to supply additional surface water to Red River County would be to build a water supply pipeline from Annona and upsize existing pipelines from Dekalb in eastern Red River County to Clarksville (approximately 30 miles). Due to the high cost of the project, this option is not being pursued. Population-driven demand for water from Red River County is included in our analysis of in-basin demand; however, there is no currently-developed or contemplated Sulphur Basin source to supply this demand. The Red River Water Supply Corporation receives most water from a series of municipal wells and a connection to the TWU system near Annona.

D. City of Sulphur Springs

The City of Sulphur Springs draws its supply from both Jim Chapman Lake and Lake Sulphur Springs. The city participated with North Texas Municipal Water District, and the City of Irving to serve as local sponsors for the construction of Jim Chapman Lake, and their portion of the water right is approximately 12,000 ac-ft./yr. The water right in Lake Sulphur Springs is 9,800 ac-ft./yr. Lake Sulphur Springs is currently used as a backup supply only, primarily due to quality concerns. Sulphur Springs faces several infrastructure challenges limiting full use of this supply which are discussed further in subsequent sections of this report. In addition, they have expressed concern relative to the adequacy of their basic supply from Jim Chapman Lake in light of potential future growth scenarios. Sulphur Springs is aggressively seeking to augment their supply with a variety of options including reuse and additional Sulphur River basin water rights. (Personal conversation, Marc Maxwell, City Manager, City of Sulphur Springs.) While various scenarios for growth in water demand by the City of Sulphur Springs were included in our analysis of in-basin demand, there is no currently-developed Sulphur Basin source identified to meet this demand.

E. Titus County

The northern portion of Titus County is within the Sulphur River Basin. Water use is a mix of ground and surface water. Surface water for all Titus County is provided by the Titus County Freshwater Supply District (TCFSD), which owns and operates Lake Bob Sandlin. TCFSD has diversion rights of 48,500 ac-ft./yr. from Lake Bob Sandlin, of which 38,500 ac-ft./yr. is for steam electric generation (Luminant) and 10,000 for municipal and industrial use (Mount Pleasant). It is expected that Lake Bob Sandlin can reliably supply these entities for the next 50 years. However, Mount Pleasant and its wholesale customers currently use 7,000 ac-ft./yr., approximately half of which is industrial. Thus, Titus County FSD has only 3,000 ac-ft./yr. of supply beyond their current use. Because Mount Pleasant, and Titus County as a whole, are growing at rates faster than anticipated by the Region D water planning process, TCFSD has indicated a need to explore development of additional surface water sources in order to sustain service levels and support industrial growth, and is interested in developing additional supply from within the Sulphur River Basin. (Personal conversation, Daryl Grubbs, General Manager, TCFSD.) A portion of this need is included in our demand projections for within-basin use; however there is no currently-developed Sulphur Basin source identified to support this demand.

3.3.5 Infrastructure Constraints

In addition to basic availability concerns discussed above, water availability in the Sulphur River Basin is constrained by a variety of infrastructure inadequacies. The discussion below does not represent a comprehensive catalog of infrastructure constraints, but is illustrative of the types of issues encountered in our data collection.

A. Intake Structures

1. Texarkana Intake Structure

The current operational rules for Wright Patman Lake, known as the Interim Rule Curve, provide for a seasonally varying conservation storage pool and variable low-flow releases, summarized as follows:

- The reservoir has a constant top of conservation storage of 220.6 feet National Vertical Datum of 1929 (NGVD 29) from the beginning of November to the beginning of April;
- After April 1, the top of conservation storage rises to a maximum of 227.5 feet NGVD 29 by the beginning of June

- After June 1, the top of conservation storage is gradually reduced to 225.0 feet NGVD 29 at the beginning of October; and
- From there the top of conservation storage falls to 221.2 feet NGVD 29 on November 1 and afterwards the top of conservation is 220.6 feet NGVD 29.

Wright Patman Lake is a relatively shallow lake, operated for flood control in accordance with the rule curve described above. Siltation is a problem throughout Wright Patman Lake, particularly at the existing City of Texarkana Intake. Cause for concern is presented in “Volumetric Survey of Wright Patman Lake,” prepared for the U.S. Army Corps of Engineers, Fort Worth District, in cooperation with the City of Texarkana, by the Texas Water Development Board (TWDB), dated March 10, 2003. This report indicates that the original volume of the conservation pool was estimated to be 145,300 acre-feet with a surface area of 20,300 acres. At elevation 230.0 feet, the volume was estimated to be 437,250 acre-feet with a surface area of 38,600 acres. During the period of December 16 - January 16, 1997, a hydrographic survey of Wright Patman Lake was performed by the Texas Water Development Board's Hydrographic Survey Program. Results indicate that the lake's capacity at the conservation pool elevation of 220.0 feet was 110,900 acre-feet and the area was 18,994 acres. At elevation 230.0 feet, the volume was determined to be 392,740 acre-feet with an area of 34,882 acres. The estimated reduction in storage capacity at elevation 220.0 feet since 1956 was 34,400 acre-feet or 1,147 acre-feet per year. The average annual deposition rate of sediment in the conservation pool of the reservoir was further estimated in this report to be 0.34 acre-feet per square mile of drainage area. It should be noted that a more recent volumetric survey of Wright Patman has been performed by TWDB.

The City of Texarkana raw water intake structure is located on the north shore of Wright Patman Lake. The top of the intake structure is set at 218.2 feet NGVD and the structure has a “bottom of conduit” elevation of 210 feet. This intake structure is subject to serious siltation problems, particularly at and below elevation 223 ft. NGVD 29. (Personal conversation, Mr. Bill King, Executive Director, TWU.) This elevation is above the top of the conservation pool for October through April under the Interim Rule Curve that governs current operations. In 2006, the intake channel was dredged to address this siltation problem. The improvement in operation was temporary, as additional siltation continues. The most recent volumetric survey of Wright Patman Lake, conducted by the Texas Water Development Board in 2010 indicates that sedimentation since 2005 amounts to approximately 2 feet at this location.

TWU has considered several options to address the siltation issue at their intake structure. Extension of the structure into deeper water, additional dredging, and relocation of the structure have all been considered. The Riverbend Water District, formed by the State Legislature in 2009 and comprised of Texarkana, Texas as well as a number of entities in Bowie and Red River Counties, has undertaken a feasibility study of an alternate location for a new intake structure in conjunction with other potential infrastructure improvements. However, no current proposal to remedy or improve the problem has been selected or endorsed.

2. International Paper Company

Although International Paper Company does not hold a water right from Wright Patman Lake, they hold a long-term contract with the City of Texarkana for a substantial portion of Texarkana's water right. International Paper uses water under this contract for both process water at the plant, and, when needed, to augment flows in the Sulphur River and meet the conditions of their effluent discharge permit from TCEQ. International Paper has a separate intake structure, located on the south shore of Wright Patman Lake. This location is in a deeper area of the lake and not as susceptible to siltation problems as is the Texarkana Intake, and International Paper does not report any planned changes to their raw water system for the foreseeable future.

3. Jim Chapman Lake

The intake structure shared by the City of Sulphur Springs, North Texas Municipal Water District, the City of Irving, and Upper Trinity Regional Water District at Jim Chapman Lake is likewise subject to significant siltation constraints. A silt barrier has formed between the intake structure and the main body of the lake, preventing full access to water in the conservation pool. If the current drought continues, the City of Sulphur Springs is predicting a loss of access to their Chapman water as early as the spring of 2012. The Upper Trinity Municipal Water District, North Texas Municipal Water District, and the City of Irving have undertaken a feasibility study to assess alternative proposals for modifications to the shared infrastructure so that access to water from the reservoir can be maintained.

B. Raw Water Treatment

The Texarkana Water Utilities (TWU), a joint water utility for the Cities of Texarkana, Texas and Texarkana, Arkansas, treats Wright Patman water at the treatment plant located on New Boston Road in Texarkana, Texas. This plant was constructed in 1959 and later expanded in 1970. The current reliable capacity is estimated to be 20 MGD, due in part to the restricted capacity of an aging and sediment-impaired raw water delivery system. The ability of the TWU to supply treated water from this plant is augmented by the purchase and treatment of water from Millwood Lake from the Southwest Arkansas Water District.

TWU currently provides approximately 1-2 MGD (summer peak of 2- 2.5 MGD) of treated Wright Patman water to the northeast portion of the TexAmericas Center, the redevelopment authority for the former Lone Star Army Ammunition Plant. The adjacent Red River Army Depot (RRAD) is served by one of two on-site reservoirs (Lake Caney). An estimated 5,000 ac-ft./yr. (or 4.5 MGD) is available from Lake Caney. The other lake (Elliott) is not connected to the RRAD WTP and is not utilized. The City of Texarkana has committed to reserve an additional 25,000 ac-ft./yr. for use by the TexAmericas Center and/or Red River Army Depot to support future industrial growth and sustain the military presence.

Current treatment capacity is not sufficient to support this commitment or to expand the Texarkana system to other member cities of the Riverbend Water Resources District west of Bowie County. The Riverbend Water District has contracted for a feasibility study to evaluate a potential new treatment and distribution system for Wright Patman water having with an initial capacity of 35 MGD. (Personal conversation, Bill Cork, Executive Director, TexAmericas Center.)

C. Distribution

As discussed previously, Red River County (City of Clarksville and Red River Water Supply Corporation) faces an immediate and serious water shortage. Shortfalls in the existing distribution system for treated water prevent addressing that shortage from the TWU system. An estimated 27 miles of new and replacement pipeline, as well as a new pressure booster station would be needed to address this shortage. A rough estimate of the cost to provide such a system exceeds $9 million.

In Bowie County, additional distribution is also needed to support the TexAmericas Center redevelopment plan. Currently, only the northeast portion of the 15,000-acre industrial site is served by the TWU system. The longer term plan calls for abandonment of the internal TAC/RRAD system with a shift to the more dependable Wright Patman source. Distribution needs associated with this shift may be addressed by implementation of the as-yet-undeveloped Riverbend Water District proposal.

3.3.6 Water Availability Summary

The Sulphur River Basin possesses abundant water resources. Using the naturalized flows form the Sulphur Basin Water Availability Model, the Texas portion of the Sulphur River Basin produced an average of 1.5 million ac-ft./yr. from 1951 to 1956, the historical drought-of-record for the basin. Based on the TCEQ database of water rights, approximately 26 percent of this average drought flow (382,000 ac-ft/yr) is appropriated by existing water rights. An estimated 108,000 ac-ft/yr of the appropriated water leaves the basin for users in the Dallas-Fort Worth Metroplex. The Sulphur Basin imports an estimated 46,800 ac-ft/yr from sources in the Red, Sabine, Cypress, and Little River Basins.

3.4 SUMMARY

The demand for water within the Sulphur River Basin is expected to grow significantly through 2060. As documented by the 2010 Census, portions of the region are currently growing at rates faster than expected in the regional water planning process. The region possesses potential for significant economic growth, and water availability (or lack thereof) is a primary consideration in whether or not that potential is achieved. This analysis reviewed ten population growth scenarios for surface water users in the Sulphur River Basin, and three scenarios of per capita water use in order to develop a range of 30 municipal water demand projections. The total municipal demand for surface water within the basin by the year 2060 is projected to be between 39,000 ac-ft./yr. to 64,000 ac-ft./yr.

Industrial demand within the Sulphur River Basin currently accounts for approximately 70% of the total water demand in the basin. Under the aggressive growth scenarios evaluated for this analysis, that proportion of water use increases by 2060. In most aggressive industrial growth scenario, the industrial water demand in the basin increases to 210,000 ac-ft./yr.

Estimates of potential future water demand in this analysis are significantly higher than predicted in the Region D Water planning process; the difference lies in the varying assumptions of future population growth and variety of hypothetical industrial development incorporated in the various scenarios. Total surface water demand in the Sulphur River Basin by 2060 under the maximum growth scenario is predicted to be approximately 274,000 ac-ft./yr.

Using the naturalized flows from the Sulphur Basin Water Availability Model, the Texas portion of the Sulphur River Basin produced an average of 1.5 million ac-ft./yr. from 1951 to 1956, the historical drought-of-record for the basin. Based on the TCEQ database of water rights, approximately 26 percent of this average drought flow (382,000 ac-ft./yr.) is appropriated by existing water rights. An estimated 108,000 ac-ft./yr. of the appropriated water leaves the basin for permit holders in the Metroplex. The amount of unappropriated water in the basin is estimated at approximately 1.1 million ac-ft./yr. on a reliable basis.

Sulphur River Basin users currently import approximately 46,800 ac-ft./yr. of surface water from sources in the Red, Sabine, Cypress, and Little River Basins. Those sources appear to be sustainable in those amounts over the period of analysis. Accordingly, there is a total of approximately 1.1 million ac-ft./yr. of water potentially available to meet in-basin needs of 274,000 ac-ft/yr.

This abundance of available and unappropriated water in the Sulphur Basin should not be construed to imply that the Sulphur River Basin is without water resources problems and needs. Sufficient storage and/or treatment and distribution infrastructure is lacking in many instances. Some water user groups have an immediate and critical need to develop additional sources or infrastructure, while others have sufficient capacity for now but develop constraints at a future time.

4.0 WRIGHT PATMAN LAKE YIELD SCENARIOS

As currently operated, Wright Patman Lake provides over 2.5 million acre-feet of storage for floodwaters. Consistent with that mission, water captured in the flood storage space is release as quickly as practicable. Prior studies have suggested that significant additional water supply yield could be generated if the flood storage in Wright Patman Lake were instead managed for water conservation. Resignation of existing storage in this manner is termed a storage reallocation, and was described conceptually in Chapter 2 of this report. This chapter presents the results of analysis conducted to evaluate a wide variety of possible reallocation scenarios at Wright Patman Lake.

4.1 UNMODIFIED WATERSHED SEDIMENTATION CONDITION

4.1.1 Current Watershed Conditions

The dependable yield of a reservoir is largely a function of the amount of inflows and the volume of storage. A reallocation at Wright Patman Lake would be intended to increase the amount of storage dedicated to water supply (also called conservation storage), with a commensurate decrease in the storage dedicated to other purposes. Increasing the volume of conservation storage in a reservoir can result from raising the top of the conservation pool, lowering the bottom of the conservation pool, or both. A variety of combinations of the two variables was investigated to evaluate the potential increase in yield resulting from a hypothetical reallocation at Wright Patman.

With respect to the top of the conservation pool, the initial evaluation considers the Interim Rule curve (monthly variation in the top of the conservation pool between 220.6 ft and 227.5 ft) to be the Existing Condition. Changing to the Ultimate Rule curve (monthly variation in the top of conservation pool between 224.89 ft and 228.64 ft) was evaluated, as were eight scenarios having the top of the conservation pool at a flat elevation (no monthly variation) increasing from 227.5' in five foot increments until the top of the flood pool (259.5 ft) is reached.

Four scenarios for the bottom of the conservation pool were considered. The first of these is the scenario set by the City of Texarkana's existing storage contract with the U.S. Army Corps of Engineers, which limits withdrawals from Wright Patman Lake to the storage above 220.0 ft. (The contract allows withdrawals below 220 feet under "exceptional conditions", but this was not considered in this scenario.) The second scenario considers the preferred minimum operating level for Texarkana's current intake structure and constrains effective storage as a result of those limitations. Based on input from Texarkana Water Utilities (TWU), this scenario considers the effective bottom of conservation pool to be 223.0 ft. The third scenario recognizes that the City of Texarkana has commissioned a study to evaluate a new intake structure that would be located in a deeper part of the lake, less susceptible to siltation and effective over a wider range of conditions. This scenario considers the effective bottom of the conservation pool to be 217.5 ft. Finally, a scenario was evaluated that eliminates the dedicated sediment storage and considers the bottom of the conservation pool to be essentially the bottom of the reservoir.

There are forty possible combinations of the maximum and minimum elevations for the conservation pool described above. The firm yields based on Water Availability Model (WAM) runs for each of these forty scenarios are shown in Table 4-1. A complete description of the WAM modifications associated with each scenario is contained in Appendix C. The data shown in Table 4-1 are representative of current sediment conditions in Wright Patman, with the assumption that Lake Ralph Hall has been built upstream. Lake Ralph Hall is included as a conservative assumption so that the estimated yields for Wright Patman do not include use of flows that would be captured by that reservoir. The WAM yields portrayed in Table 4-1 have been reduced by 7,247 ac-ft/yr to account for a constant release of 10 cfs from Wright Patman Dam, consistent with the requirements of the City's contract with the Corps of Engineers.

Figure 4-1 portrays the firm yield of the eight flat elevation scenarios graphically. Each line represents one of the four bottom-of-conservation-pool scenarios. As expected, the lower the bottom of the conservation pool, the higher the dependable yield, all other things being equal.

Table 4-1: Wright Patman Lake Various Conservation Pool Elevations

Maximum Conservation Pool Elevation (feet)/Curve	Minimum Conservation Pool Elevation	Sediment Condition	Firm Yield (ac-ft/yr)[1]	Yield above Current Contract[2] (ac-ft/yr)
Interim	Current pump station (223 ft)	Current	0	0
Ultimate	Current pump station (223 ft)	Current	172,753	0
227.5	Current pump station (223 ft)	Current	174,873	0
232.5	Current pump station (223 ft)	Current	385,753	205,753
237.5	Current pump station (223 ft)	Current	620,623	440,623
242.5	Current pump station (223 ft)	Current	748,833	568,833
247.5	Current pump station (223 ft)	Current	868,203	688,203
252.5	Current pump station (223 ft)	Current	1,011,113	831,113
257.5	Current pump station (223 ft)	Current	1,137,533	957,533
259.5	Current pump station (223 ft)	Current	1,191,083	1,011,083
Interim	Texarkana Contract (220 ft)	Current	40,263	0
Ultimate	Texarkana Contract (220 ft)	Current	201,413	21,413
227.5	Texarkana Contract (220 ft)	Current	255,693	75,693
232.5	Texarkana Contract (220 ft)	Current	460,963	280,963
237.5	Texarkana Contract (220 ft)	Current	658,273	478,273
242.5	Texarkana Contract (220 ft)	Current	772,663	592,663
247.5	Texarkana Contract (220 ft)	Current	891,913	711,913
252.5	Texarkana Contract (220 ft)	Current	1,034,363	854,363
257.5	Texarkana Contract (220 ft)	Current	1,155,013	975,013
259.5	Texarkana Contract (220 ft)	Current	1,208,533	1,028,533

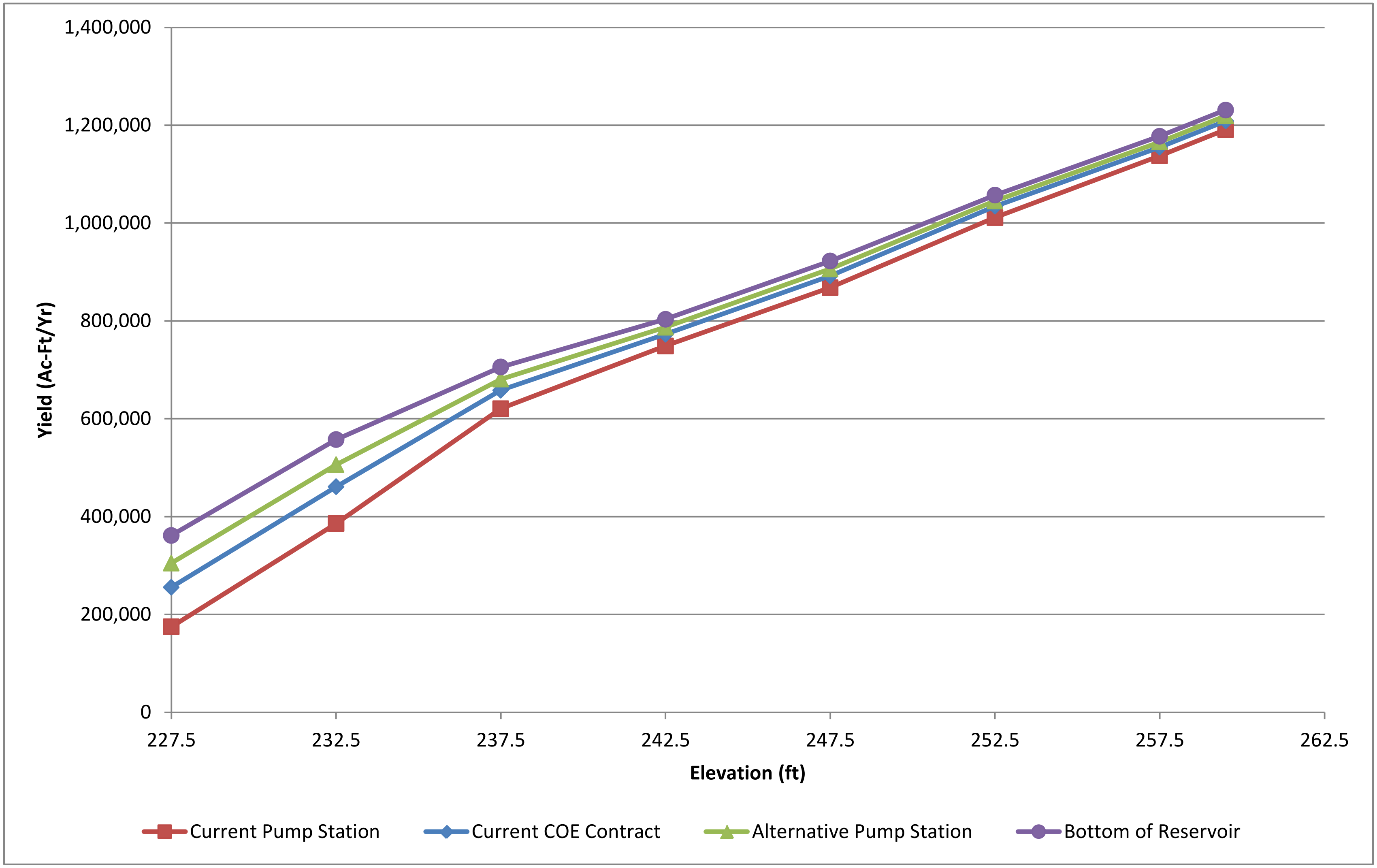
Maximum Conservation Pool Elevation (feet)/Curve	Minimum Conservation Pool Elevation	Sediment Condition	Firm Yield (ac-ft/yr)[1]	Yield above Current Contract[2] (ac-ft/yr)
Interim	Proposed pump station (217.5 ft)	Current	123,743	0
Ultimate	Proposed pump station (217.5 ft)	Current	263,303	83,303
227.5	Proposed pump station (217.5 ft)	Current	304,883	124,883
232.5	Proposed pump station (217.5 ft)	Current	505,873	325,873
237.5	Proposed pump station (217.5 ft)	Current	680,773	500,773
242.5	Proposed pump station (217.5 ft)	Current	787,163	607,163
247.5	Proposed pump station (217.5 ft)	Current	906,263	726,263
252.5	Proposed pump station (217.5 ft)	Current	1,045,033	865,033
257.5	Proposed pump station (217.5 ft)	Current	1,165,623	985,623
259.5	Proposed pump station (217.5 ft)	Current	1,219,123	1,039,123

Interim	Full Conservation	Current	205,513	25,513
Ultimate	Full Conservation	Current	331,403	151,403
227.5	Full Conservation	Current	361,643	181,643
232.5	Full Conservation	Current	557,353	377,353
237.5	Full Conservation	Current	705,783	525,783
242.5	Full Conservation	Current	803,483	623,483
247.5	Full Conservation	Current	922,583	742,583
252.5	Full Conservation	Current	1,057,183	877,183
257.5	Full Conservation	Current	1,177,713	997,713
259.5	Full Conservation	Current	1,231,183	1,051,183

[1] Firm yield estimates incorporate a constant downstream release of 10 cfs per the City of Texarkana's contract with the Corps of Engineers.

[2] The current contract between the Corps of Engineers and Texarkana allows for the diversion of 180,000 acre-feet per year, as does Texarkana's Texas water right.

Figure 4-1: Wright Patman Yield vs. Top of Conservation Pool Elevation



It is worth noting that the yield curve in Figure 4-1 does not "break" in the traditional sense. Generally, the rate of increase in yield with increasing storage decreases as the amount of storage increases, and the curve flattens--becoming almost horizontal for very large increases in storage. This is because the watershed generates only so much runoff, and eventually the reservoir storage becomes large enough to effectively capture the maximum amount of runoff. However, in the case of the Sulphur River watershed, Figure 4-1 shows that even with the entire flood pool of Wright Patman reallocated to conservation storage, firm yield is still increasing significantly with increasing in storage. This suggests that a reallocation at Wright Patman would not be constrained by watershed runoff.

Figure 4-1 also shows that the minimum elevation of the conservation pool makes a noticeable difference in dependable yield when the top-of-conservation-pool elevation ranges from current conditions to approximately 237.5 ft. For larger reallocations, where the maximum conservation pool elevation is raised to levels higher than 237.5 ft, the difference in yield attributable to lowering the bottom of the conservation pool becomes less significant.

This study also assessed the effects on Wright Patman of a hypothetical modification to the seniority of water rights between Wright Patman Lake and Jim Chapman Lake. Where the Texas priority rights system requires that Jim Chapman Lake pass inflows to Wright Patman Lake because of its senior water right, the hypothetical scenario would allow Jim Chapman Lake to retain inflows as long as there is empty storage in the conservation pool (440.0 ft). If Jim Chapman Lake and Wright Patman Lake were to be operated as a system, it is unlikely that inflows to Jim Chapman would be passed downstream, and this scenario is intended to reflect that concept. This scenario essentially subordinates the Wright Patman water right to the water rights associated with operation of Jim Chapman Lake. Note that this is a strictly a hypothetical scenario and would only be considered as part of a broader plan for water resources development that included appropriate protection and consideration for downstream users. Results of this subordination on Wright Patman yields, under several scenarios, are compared with values from Table 4-1 in Table 4-2, below.

In general, the modified priority for the water right does reduce the firm yield of Wright Patman Lake; however the affect ranges only from about 1 to 11%. The reason for this lies in the overlap between the critical drought periods for the two reservoirs. Currently, the Wright Patman water right may make a senior water right call on inflows to Jim Chapman Lake (up to the specified amount.) During the critical drought period when the Wright Patman water right is most likely to make such a call, Jim Chapman

Lake is also in its critical drought period and has little or no inflows to release --notwithstanding the seniority of the Wright Patman call. (Priority calls do not apply to previously stored inflows, only inflows into the reservoir during the priority call.)

Table 4-2: Firm Yield of Wright Patman Lake with Modified Water Right Seniority

Maximum Conservation Pool Elevation	Minimum Conservation Pool Elevation	Firm Yield (ac-ft/yr)[1] w/o Modified Water Right	Firm Yield (ac-ft/yr)[1] with Modified Water Right	Difference in Firm Yield (ac-ft/yr)
Per Interim Rule Curve	220 ft	40,263	39,843	420
Per Ultimate Rule Curve	220 ft	201,413	188,513	12,900
Per Interim Rule Curve	223 ft	0	0	0
Per Interim Rule Curve	217.5 ft	123,743	110,253	13,490
Per Interim Rule Curve	Bottom of Reservoir	205,513	195,203	10,310

[1] Firm yield estimates incorporate a constant downstream release of 10 cfs per the City of Texarkana's contract with the Corps of Engineers

Under these conditions, the seniority of the Wright Patman water right does not necessarily result in a release from Jim Chapman Lake. The effect of reducing the seniority of the Wright Patman water right is diminished by the inflow constraint. However, notice that the difference in yield is more significant with reallocation. This is because the higher demand levels and associated additional storage increase the frequency at which priority releases are made from Jim Chapman Lake, increasing the impact of the Lake Chapman releases on the yield of Wright Patman Lake.

4.2.2 Future Watershed Conditions

In order to evaluate the effect of watershed sedimentation on the firm yield of Wright Patman Lake over the period of analysis (50 years) a set of time-series graphs were developed. Time-series graphs were developed only for the scenarios having a minimum conservation pool elevation of 220.ft. Primarily, this is because--as discussed above-- for reallocations generating additional yield on the scale necessary to justify a stand-alone reallocation project, the effect of raising the maximum conservation pool elevation dominates the effect of lowering the minimum conservation pool elevation. Time series data were likewise run for only three of the nine scenarios for increasing the maximum conservation pool elevation. As shown in Table 4-1, reallocations above 252.5 ft generate significantly more dependable yield than the 600,000 to 700,000 acre-feet targeted in this study. It would be difficult, if not impossible, to justify completely eliminating flood storage from Wright Patman in order to gain additional yield for which there is not a demonstrated need. Accordingly, the largest two reallocation scenarios (maximum elevation of 257.5 and 259.5 ft) were dropped from the time series analysis.

Because Figure 4-1 shows that the yield curve has an inflection point at elevation 237.5 ft but is essentially a straight line between elevations 237.5 and 257.5 ft, we did not run all six scenarios between 227.5 and 252.5 ft. Reallocation scenarios with maximum conservation pool elevations of 227.5, 237.5 and 252.5 ft were felt to be indicative of the full range of scenarios. The scenarios for maximum elevations of 232.5, 242.5 and 247.5 ft can be inferred from the time series analysis.

Time series data were developed by analyzing the effect of diminished reservoir storage resulting from sustained sedimentation on reservoir yields at various points in the future. The storage volume lost due to sedimentation was estimated by modeling sediment yields and loads from each sub-basin in the Sulphur Watershed using the Soil and Water Assessment Tool (SWAT) in metric tons per year. The predicted sediment loads were converted to a volume using density data collected from Wright Patman sediment deposits as part of this analysis. The analytical process is described in detail in Appendix D.

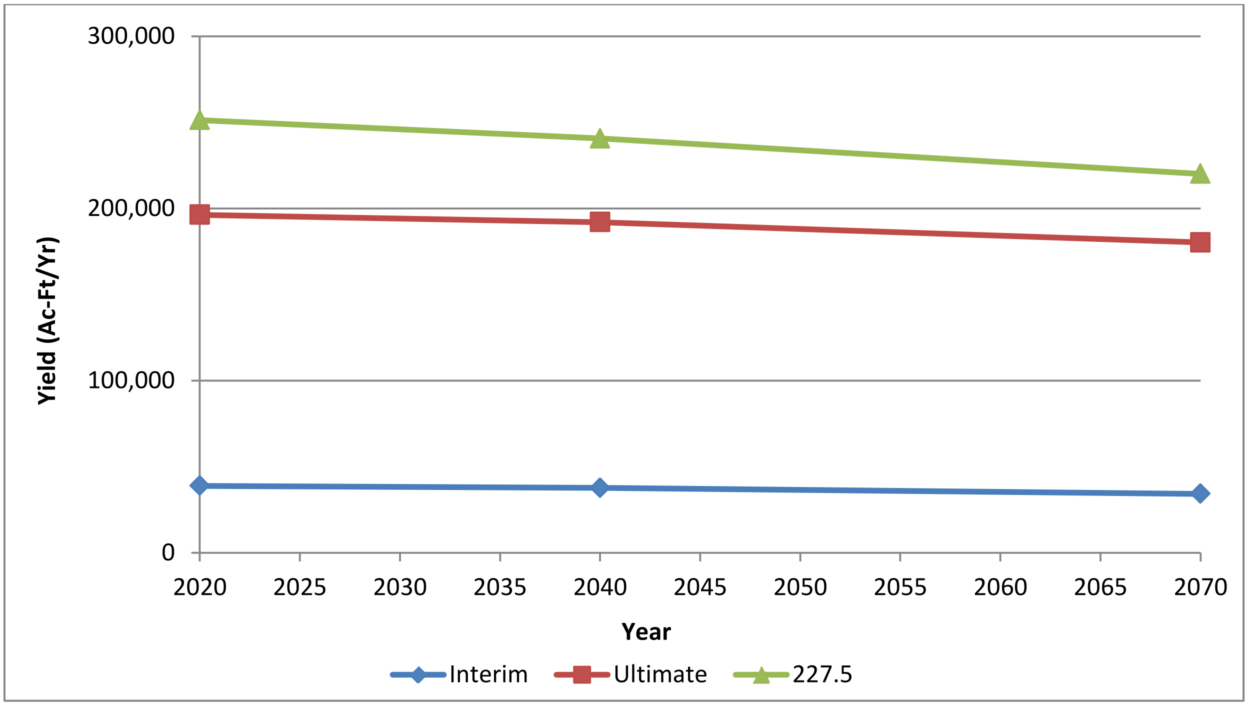
Using the SWAT as discussed above, current sedimentation rates were extrapolated into the future. The effect of future sedimentation on storage and dependable yield was explicitly modeled in the WAM for the years 2020, 2040 and 2070. The results are displayed in Table 4- 3. Interpolating between these points, Figure 4-2 provides a picture of the effect of watershed sedimentation on storage and yield in Wright Patman over time. Each scenario for the top of conservation pool is a different line. Because of the large difference in yield between the two highest storage levels and the other reallocation scenarios, the yields have been put on two different graphs so that the changes in yield can be seen. Note that this analysis assumes that Lake Ralph Hall starts to affect sediment loads at Wright Patman Lake by the year 2020.

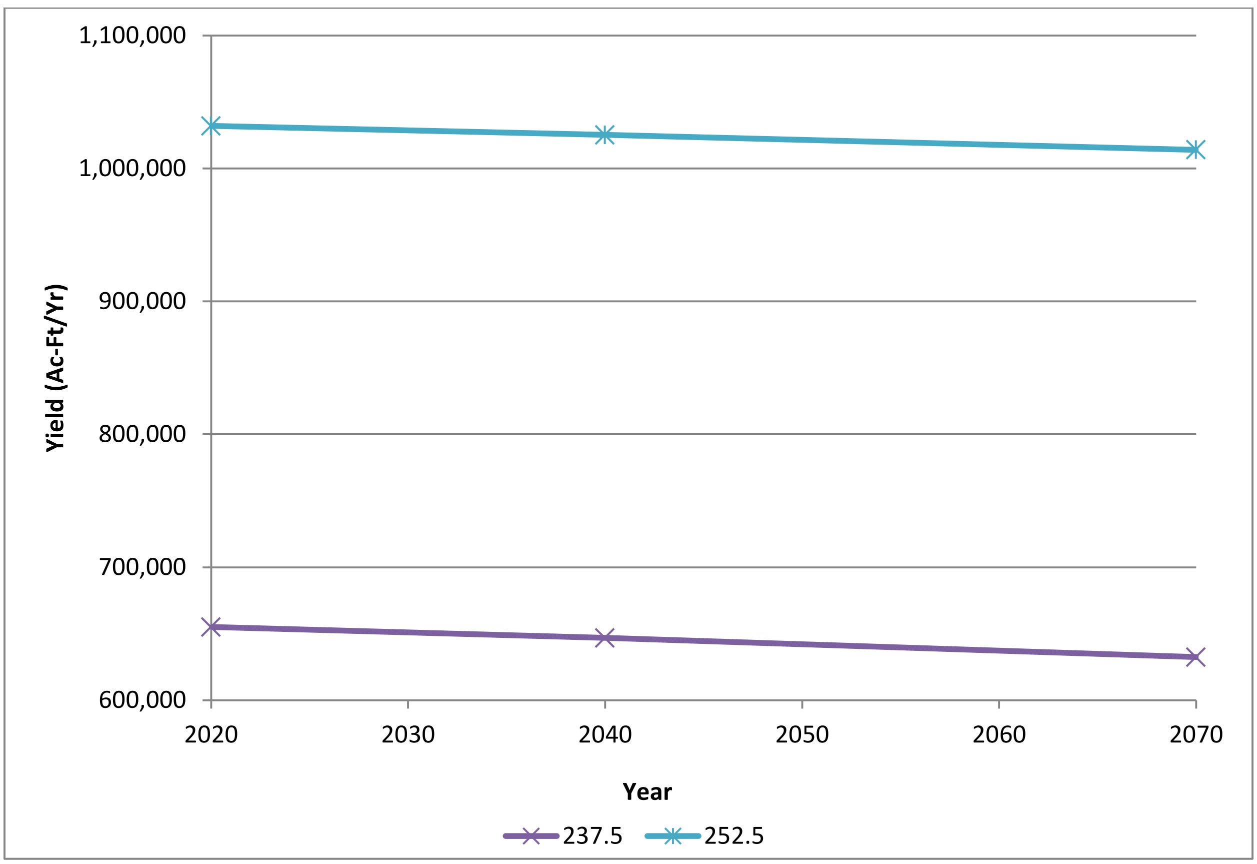
Table 4-3: Firm Yield of Wright Patman Lake in Selected Future Years Considering the Impact of Projected Sedimentation (ac-ft/yr)[1]

Top of Conservation Pool	2020	2040	2070	Reduction 2020-2070
Per the Interim Rule Curve	38,953	37,713	34,283	12%
Per the Ultimate Rule Curve	196,293	192,033	180,283	8.2%
227.5 ft	251,313	240,633	220,153	12%
237.5 ft	655,023	646,873	632,373	3.5%
252.5 ft	1,031,993	1,025,243	1,014,063	1.7%

[1]Firm yield estimates incorporate a constant downstream release of 10 cfs per the City of Texarkana's contract with the Corps of Engineers. Bottom of conservation pool at 220.0 ft for all scenarios.

Figure 4-2: Firm Yield at Wright Patman Lake over Time [1]





4.2 POTENTIAL MODIFICATIONS TO WATERSHED SEDIMENT CONDITION

The next phase of the analysis evaluated the effects of a hypothetical program to reduce erosion and subsequent sedimentation across the Sulphur River watershed. This hypothetical program was developed by identifying Best Management Practices (BMPs) which have been documented to reduce sediment loadings, and evaluating, through the use of Geographic Information Systems (GIS), their relevance in specific sub-basins of the Sulphur River watershed. With-BMP scenarios were then replicated within the SWAT model to predict the reduction in sedimentation attributable to BMP application.

The foundation of this work is two studies conducted in the Cedar Creek watershed in 2009-2010. Lee, et al. (2010) investigated the potential adoption rates of 21 BMPs whose effectiveness for sediment and nutrient reduction in the Cedar Creek watershed was first assessed by Rister et al. (2009). Lee et al. (2010) reduced this list to eight BMPs based on total phosphorus reduction at 100% application rate and the cost of BMP implementation per ton of total phosphorus reduction, with cost effectiveness having the highest priority. Four of the eight BMPs recommended by Lee for reducing phosphorus loads were also the most effective at reducing sediment loads. These BMPs were adopted for the current study. The Cedar Creek watershed and the Sulphur River watershed have similar climate, geology, and soils, and reasonably similar agricultural practices. This analysis assumes that conditions and trends in the Sulphur River watershed can be considered similar to those observed in the Cedar Creek watershed for BMP implementation purposes.

Two BMP's not evaluated by Lee, et al (2010) were added to the analysis based on FNI's experience. FNI noted channel erosion in the majority of sites visited (48 total) during a watershed reconnaissance trip in March 2012 (FNI, 2012). Channel grade control structures have been observed to decrease channel erosion in other streams and rivers in North Texas. It was theorized that they could have the same effect on channel erosion in the Sulphur River watershed. Riparian buffer strips were documented by Narashimhan, et al (2007) to significantly reduce sediment loads, but were eliminated by Lee, et al. (2010) because they were not cost-effective for reducing phosphorus. Because the focus of this effort was sediment reduction, riparian buffer strips were included in the With-BMP evaluation.

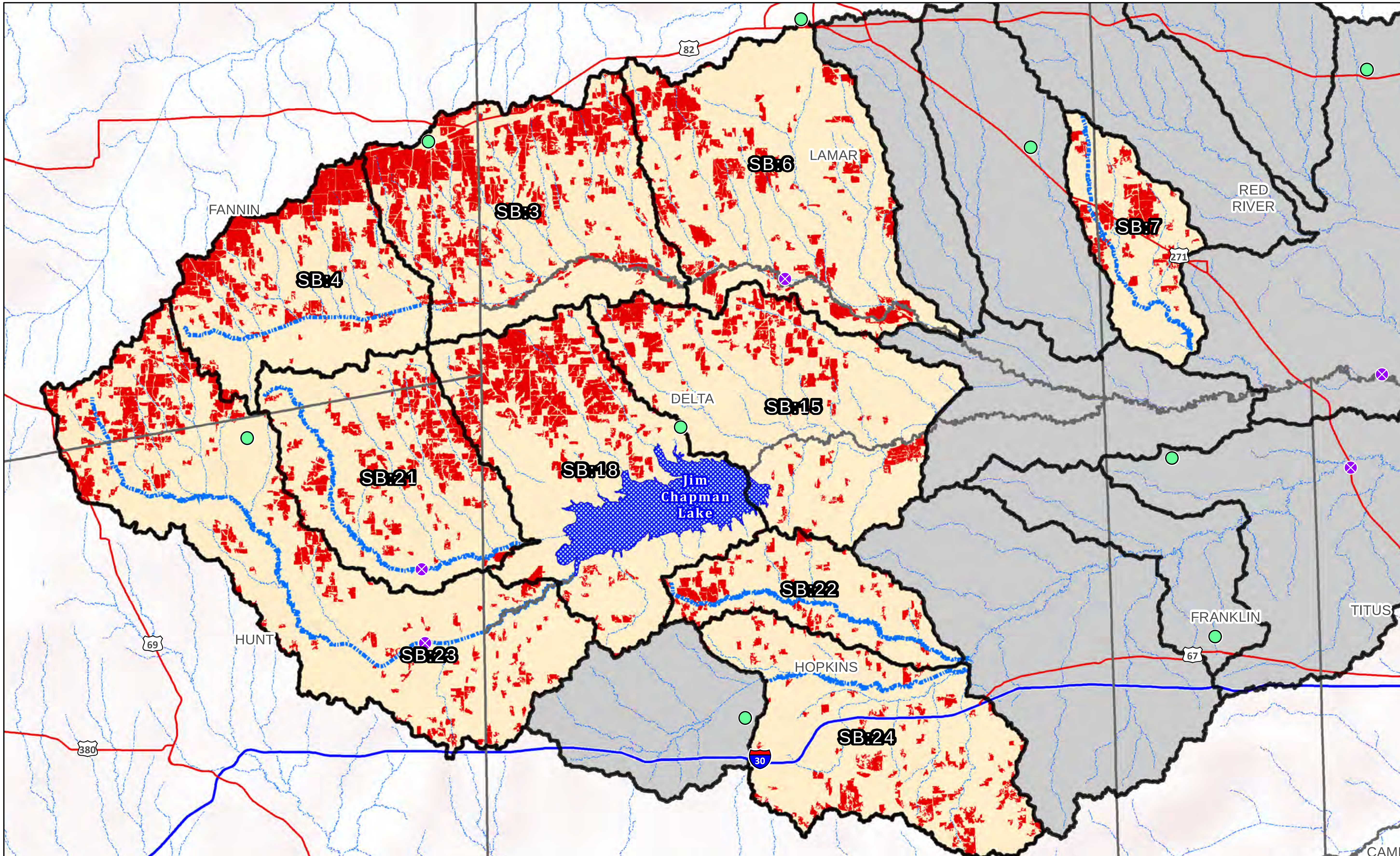
The BMP's assessed for hypothetical implementation within the Sulphur River Basin are as follows:

- Filter Strips
  - Strips of dense vegetation located between agricultural fields and adjacent water bodies. The filter strip intercepts runoff from the upslope sediment source (field with crop, pasture, disturbance, etc.) and filters it before it enters the water body. The vegetation in the filter strip slows the flow velocity of the runoff causing suspended sediment to settle out.
- Terrace
  - An embankment within a field designed to intercept runoff and prevent erosion. Terraces are constructed across the field slope, on a contour. Terraces reduce slope length, thereby reducing surface runoff velocity. Terracing also promotes infiltration of surface water runoff.
- Cropland to Pasture
  - Fields that have traditionally been used for row crop agriculture are converted to improved pasture. Improved pasture is pasture where crops such as hay are planted and grazing is permitted. Runoff rates and volumes are typically higher in row crop agriculture than in any other rural land use. Increased ground cover in an improved pasture reduces surface runoff rates and promotes infiltration.
- Critical Pasture Planting
  - Existing drainage swales in agricultural fields are planted with perennial grasses to decrease erosion and increase roughness. Increased roughness decreases flow velocities, which promotes settling of suspended sediment and increases infiltration.
- Channel Grade Control
  - Channel grade control involves the placement of grade (slope) stabilization structures in stream or river channels. Channel grade control structures are typically constructed of concrete, rock, and/or compacted earth and artificially decrease the slope of the channel. Decreased channel slopes (flatter slopes) produce lower flow velocities, which generate less erosive forces. Slower velocity flow also promotes settling of suspended sediment and increased infiltration through the channel bed and banks.

- Riparian Buffer Strip
    - An area of predominantly trees and/or shrubs located adjacent to a water body (stream, river, lake, etc.). Riparian buffer strips, also known as riparian corridors and riparian forest buffers, reduce the sediment load to a stream from the surround landscape by reducing runoff velocity, causing suspended sediment to drop out.

Additional discussion of BMP selection is included in Appendix B, Technical Memorandum: Sulphur Basin SWAT Model – Sediment BMP Analysis.

BMPs were not modeled across the entire Sulphur River watershed. BMP simulations were focused on the subbasins that produced the highest sediment yields in the baseline SWAT analysis. Using GIS capability, appropriate locations within each of these sub-basins for each BMP were identified. For example, land surface BMPs (filter strips, terraces, converting cropland to pasture, and critical pasture planting) were simulated only on cropland in the target sub-watersheds. In-channel BMPs (channel grade control and riparian buffer strips) were applied only to the target subbasins with an average main channel slope steeper than 0.0008 ft/ft. (Harvey, et al. (2007) reported that the slope of the channel of the North Sulphur River was 0.0008 feet/foot prior to channelization activities starting early in the 20th century. It was assumed that this channel slope was representative of a stable channel slope for the main channels.) Figures 4-3 through 4-7 identify the location of BMP simulation within the target sub-basins, while Table 4-4 displays the extent or number of BMPs simulated.



U.S. ARMY CORPS OF ENGINEERS, FORT WORTH DISTRICT

Sulphur River Watershed Overview - SWAT Model

Filter Strips and Cropland to Pastureland Conversion within Target Subbasins

FN PROJECT NO.	MHP11453
DATE CREATED	1/9/2013
DATUM & COORDINATE SYSTEM	NAD83 State Plane (feet) Texas North Central
FILE NAME	SubbasinCropland
PREPARED BY	JAW

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4500 International Plaza Suite 200
Fort Worth, Texas 76109-4895
(817) 735-7300

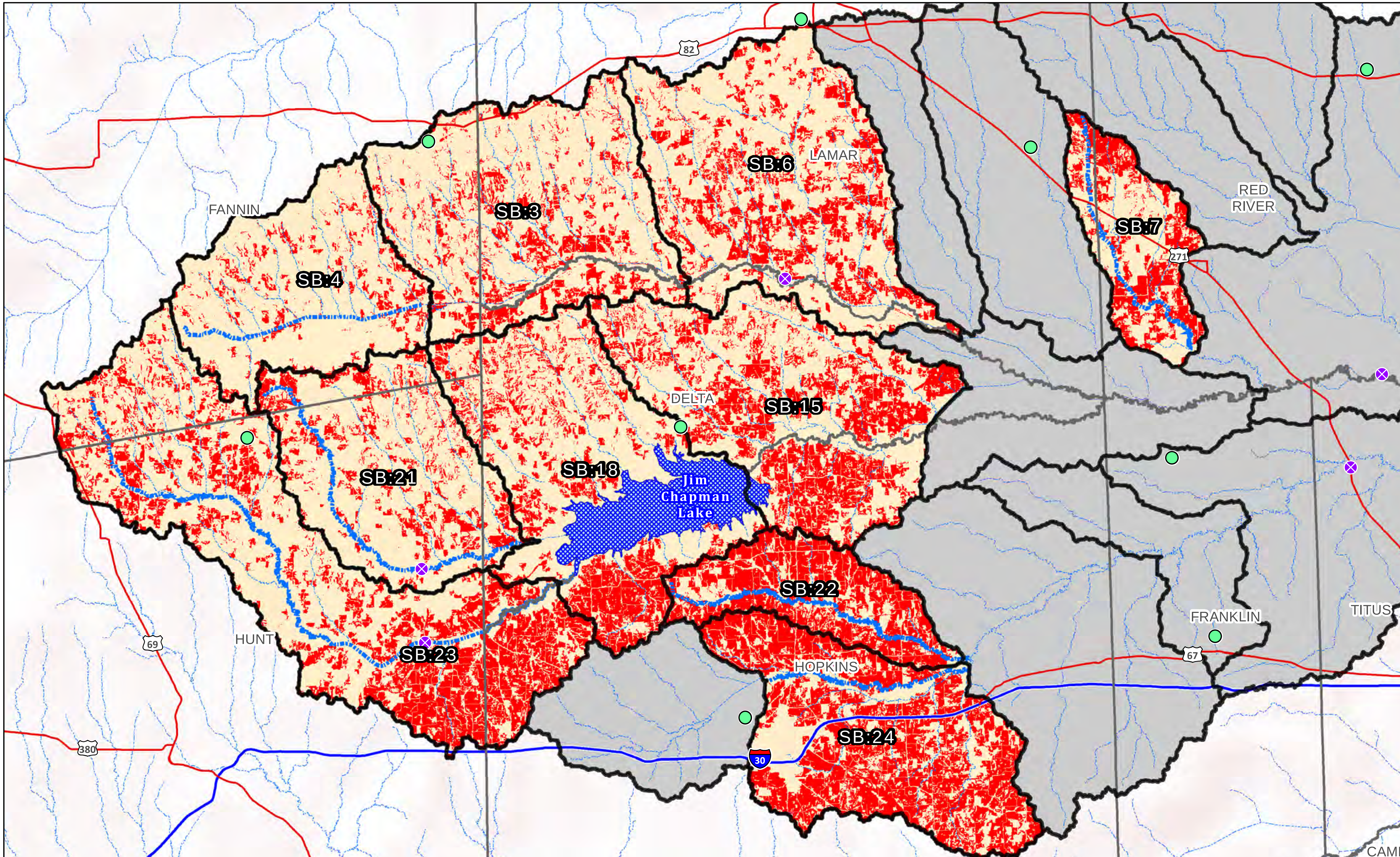
Stream Gage
Weather Station
Existing Lake
Cropland
NHD Flowline
Subbasin Main Channel

1:300,000
0 4.5 9 Miles
1 inch = 5 miles

N S E W

FIGURE 3

Path: H:\ENVIRONMENTAL\FROM_MTG\MXD\SubbasinCropland.mxd



U.S. ARMY CORPS OF ENGINEERS, FORT WORTH DISTRICT

Sulphur River Watershed Overview - SWAT Model

Terracing Applied to Cropland and Pastureland with Slopes Greater than 2% within Target Subbasins

FN PROJECT NO. MHP11453
DATE CREATED 1/9/2013
DATUM & COORDINATE SYSTEM NAD83 State Plane (feet) Texas North Central
FILE NAME SubbasinTerracing 2Perc slopes
PREPARED BY JAW

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Fort Worth, Texas 76109-4895
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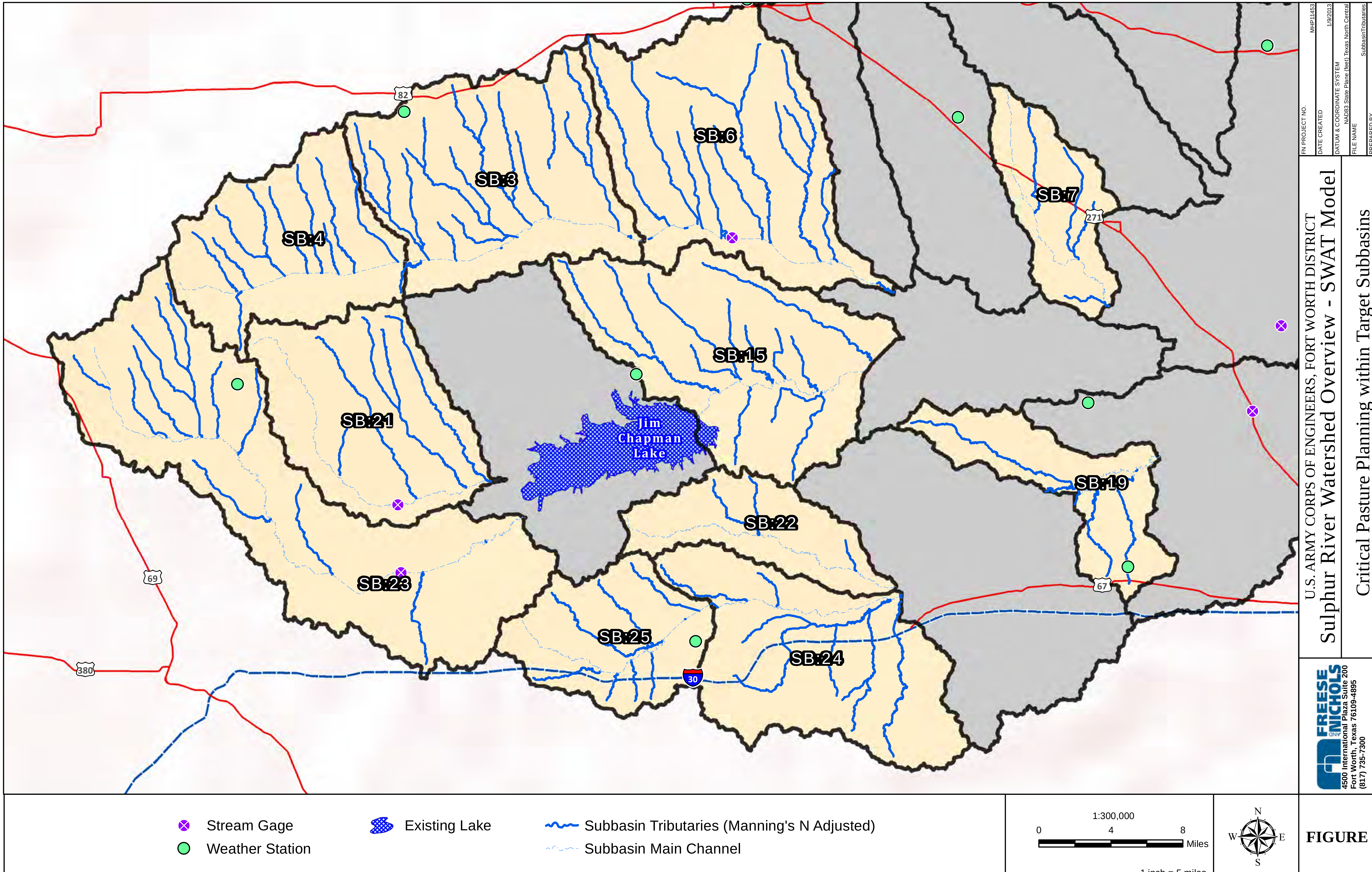
Stream Gage
Weather Station
Existing Lake
Agricultural/Pasture Land, > 2% Slope
NHD Flowline
Subbasin Main Channel

1:300,000
0 4.5 9 Miles
1 inch = 5 miles

N W E S

FIGURE 4

Path: H:\ENVIRONMENTAL\FROM_MTG\MXD\SubbasinTerracing 2Perc slopes.mxd



Path: H:\ENVIRONMENTAL\FROM_MTG\MXD\SubbasinTributaries.mxd

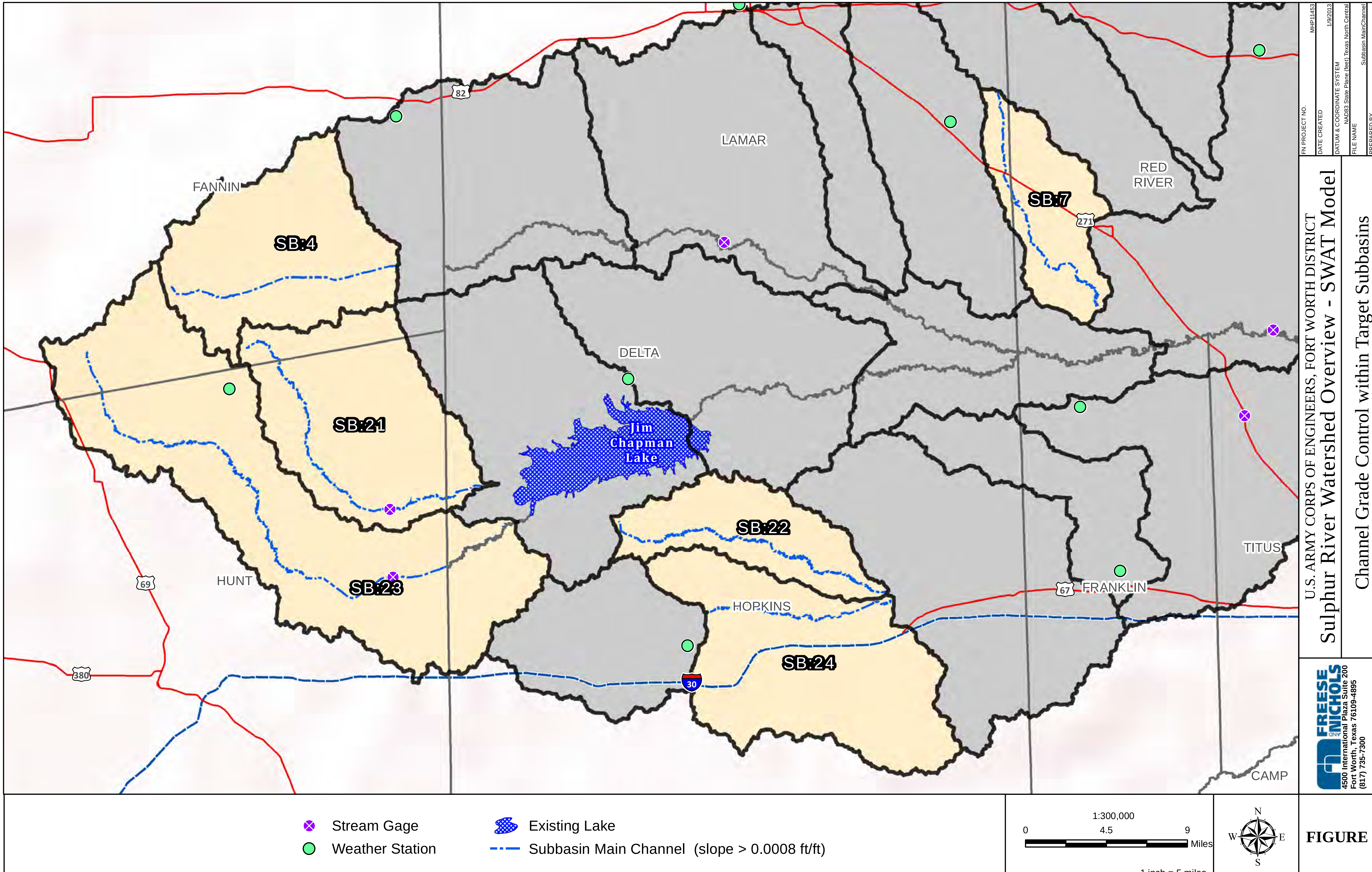
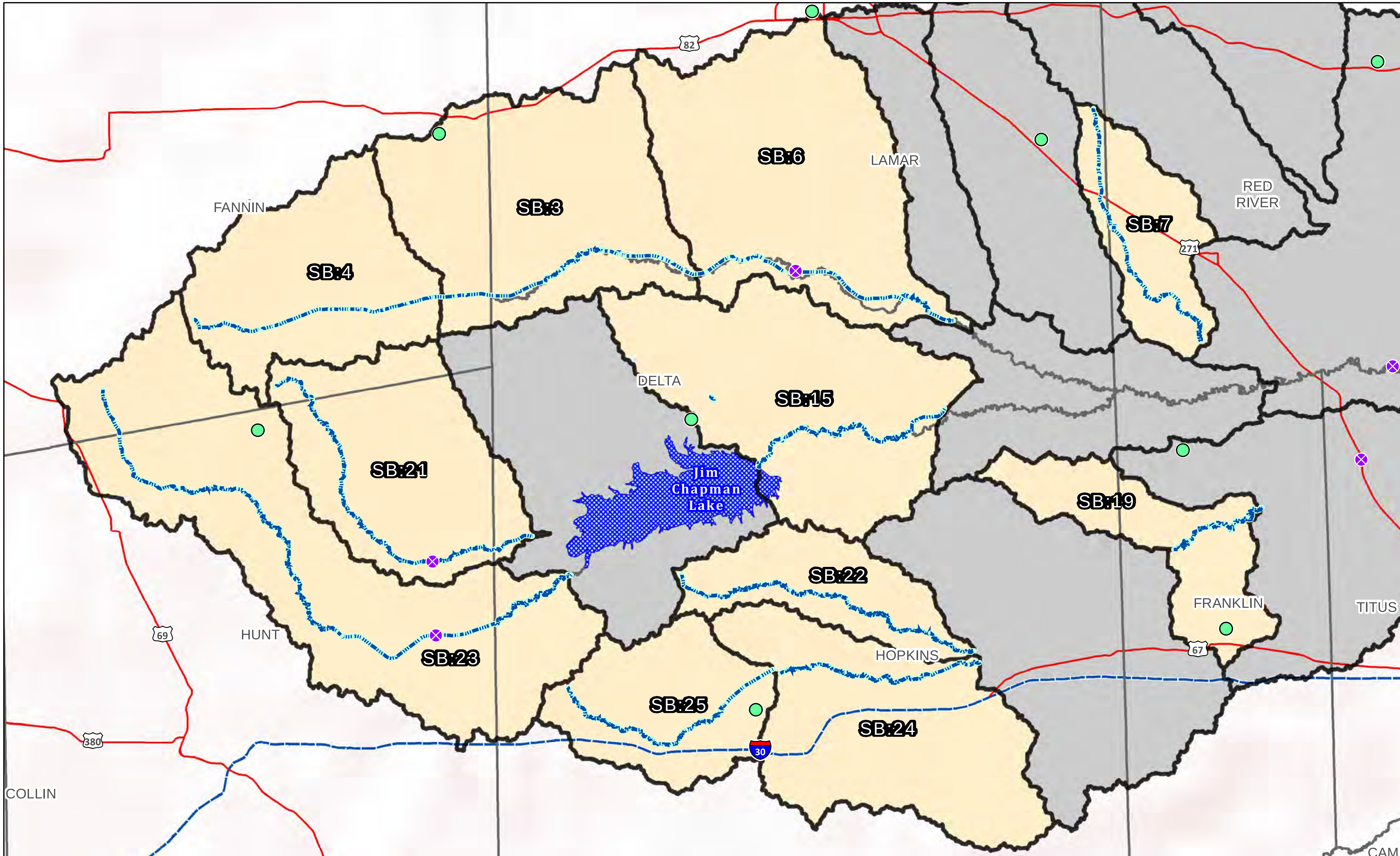


FIGURE 6

Path: H:\ENVIRONMENTAL\FROM_MTG\MXD\Subbasin MainChannel.mxd



U.S. ARMY CORPS OF ENGINEERS, FORT WORTH DISTRICT

Sulphur River Watershed Overview - SWAT Model

Applied Riparian Buffer Strips within Target Subbasins

FN PROJECT NO.	MHP11453
DATE CREATED	1/9/2013
DATUM & COORDINATE SYSTEM	NAD83 State Plane (feet) Texas North Central
FILE NAME	Subbasin Riparian
PREPARED BY	JAW

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Fort Worth, Texas 76109-4895
(817) 735-7300

Stream Gage
Weather Station
Existing Lake
Riparian Buffer Strips (Along Subbasin Main Channel)

1:300,000
0 4.5 9 Miles
1 inch = 5 miles

N W E S

FIGURE 7

Path: H:\ENVIRONMENTAL\FROM_MTG\MXD\Subbasin Riparian.mxd

Table 4-4: Number and/or Extent of BMP's included in the Sulphur River SWAT Model

Subbasin	Total Subbasin Area (acres)	Filter Strips (acres)[1]	Terrace (acres)[2]	Cropland to Pasture (acres)[3]	Critical Pasture Planting (linear feet)[4]	Channel Grade Control[5]		Riparian Buffer Strip (linear feet)[6]
						Linear feet	Number of 3-foot drops	
3	93,650	293	10,056	28,990	130,840	--	--	78,740
4	64,339	182	802	17,946	86,352	38,451	9.6	38,451
6	102,034	175	9,433	17,319	147,441	--	--	84,679
7	33,747	64	2,572	6,364	93,832	19,587	1.4	19,587
15	93,060	131	16,973	12,972	159,088	--	--	95,243
18	100,171	207	14,191	20,406	144,849	--	--	90,846
21	70,111	120	3,931	11,857	126,837	40,617	2.3	40,617
22	35,306	60	7,814	5,961	102,822	31,791	2.4	31791
23	137,734	221	22,017	21,847	224,475	156,791	1.6	156,791
24	809,731	111	31,102	10,957	93,930	65,551	4.4	65,551

[1] Filter strip acreage represents the area of cropland that would be taken out of production and converted to filter strips in each subbasin.

[2] Terrace acreage represents the area of cropland and pasture where terraces would be installed in each subbasin.

[3] Cropland to pasture acreage is the total number of acres in each watershed that would be converted from cropland to pasture. At the 100% adoption rate, the cropland to pasture acreage is equal to the total acres of cropland in each subbasin.

[4] Critical pasture planting linear footage is the length of tributary channel in each subsbasin that was affected by the critical pasture planting BMP.

[5] Channel grade control linear footage is a measure of the total channel length impacted in each subbasin that would be affected by grade control practices under a 100% adoption rate. The number of 3-foot drops is provided as an example of how many 3-foot high drop structures would be needed to artificially lower the existing channel slope the equilibrium channel slope of 0.0008 ft/ft. The difference between the existing and equilibrium channel slopes was multiplied by the total main channel length to calculate the expected amount of downcutting need for the channel to reach the equilibrium slope. It is a standard engineering practice to limit drop structure height to three feet in order to avoid dangerous hydraulic conditions that can be generated with greater drop heights.

[6] The riparian buffer strip linear footage represents the number of feet of channel in each subbasin where riparian buffer strips would be established. At the assumed 100% adoption rate, this value is equal to the total main channel length in each subbasin.

BMPs were simulated for 100% of the land cover within each of the target subbasins meeting the application criteria discussed above. It is recognized that a 100% adoption rate is not likely. Factors influencing BMP adoption would be expected to include the cost of implementation, cost of implementation as compared to economic benefit, willingness of landowners to participate, availability of government assistance funding and other variables. Rister, et al. (2009) estimated marginal (expected) rates of BMP adoption in the Cedar Creek watershed through a program of extensive surveys and interviews with local stakeholders including landowners, government agencies, and academics. A similar study would need to be performed in the Sulphur River Basin in order to develop more precise predictions of expected BMP implementation in the face of an actual sediment reduction program. The purpose of this study was rather to identify whether or not such a program could reasonably be expected to have a meaningful effect on the rate of sedimentation in Wright Patman Lake; evaluation of the performance or cost-effectiveness of such a program is beyond the scope of this effort. It is likely that the sediment loads generated using marginal rates of BMP implementation would be higher and more realistic than those generated under assumed 100% BMP application rates.

The scenario simulating application of the six BMPs as described above was labeled the Intensive scenario. In addition to the Intensive scenario, a second sediment reduction scenario was developed and evaluated. This scenario used four of the BMPs judged to be the most feasible, based on evaluation of the initial BMP scenario. This scenario, labeled the Feasible Scenario consisted of simulating four BMPs – Filter Strips, Cropland to Pasture Conversion, Channel Grade Control, and Riparian Buffer Strips- across the watershed in the same manner as for the Intensive scenario.

The average annual sediment load, sediment yield, and total sediment yield results in Tables4- 5,4- 6, and 4- 7 include the percentage reduction from the baseline (non-BMP scenario) to the two alternative BMP scenarios. The differences between terms “sediment load” and “sediment yield” are described in the following bullet points:

- Sediment load
    - Sediment load is the total amount of sediment that passes through the outlet of each sub-basin, carried by flowing water in the channel; also known as sediment discharge.
    - Units = mass per unit time

- Sediment yield
  - Sediment yield is the amount of sediment that enters the main channel in each individual sub-basin per unit area of the sub-basin, originating from overland erosion.
  - Units = mass per unit area per unit time
- Total sediment yield
  - Total sediment yield is the total amount of sediment entering the main channel from overland erosion in each individual sub-basin.
  - Total sediment yield is calculated by multiplying the SWAT-calculated sediment yield by the total area of the individual sub-basin.
  - Units = mass per unit time

Sediment load, sediment yield, and total sediment yield are presented by individual sub-basin.

Figures 4-8 through 4-10 illustrate the changes in sediment loads as reported by the model. The Intensive BMP scenario reduced sediment loads to Wright Patman Lake by 31% (240,767 metric tons) while the Feasible BMP scenario reduced sediment loads to Wright Patman Lake by 28% (223,518 metric tons). Additional information on this analysis is contained in Appendix D.

Table 4-5: Average annual sediment load comparison – Baseline scenario, Intensive BMP scenario and Feasible BMP scenario

Subbasin	Existing Condition Scenario(metric tons)	Intensive BMP Scenario (metric tons)	Intensive BMP Scenario (percent reduction)	Feasible BMP Scenario (metric tons)	Feasible BMP Scenario (percent reduction)
1	2,943	2,943	0%	2,943	0%
2	2,629	2,629	0%	2,629	0%
3	190,004	10,497	94%	14,969	92%
4	80,977	7,293	91%	9,919	88%
5	2,454	2,454	0%	2,454	0%
6	292,656	16841	94%	24,118	92%
7	23,799	579	98%	939	96%
8	3,002	3,002	0%	3002	0%
9	526,960	204,875	61%	216,191	59%
10	444,534	96,785	78%	107,148	76%
11	3,361	3,361	0%	3361	0%
12*	785,823	545,056	31%	562,305	28%
14	3,897	3,897	0%	3,897	0%
15	123,909	31,387	75%	34,149	72%
16	290,776	77,647	73%	104,094	64%
17	267,021	208,859	22%	217,446	19%
18	368,655	12,700	97%	20861	94%
19	212,831	34,655	84%	39,617	81%
20	208,544	26,221	87%	31,179	85%
21	89,022	3127	96%	4,981	94%
22	48,756	295	99%	1,246	97%
23	164,456	3,605	98%	7,876	95%
24	143,982	5,230	96%	9,232	94%
25	2,207	2,207	0%	2,207	0%

*Location of Wright Patman Lake

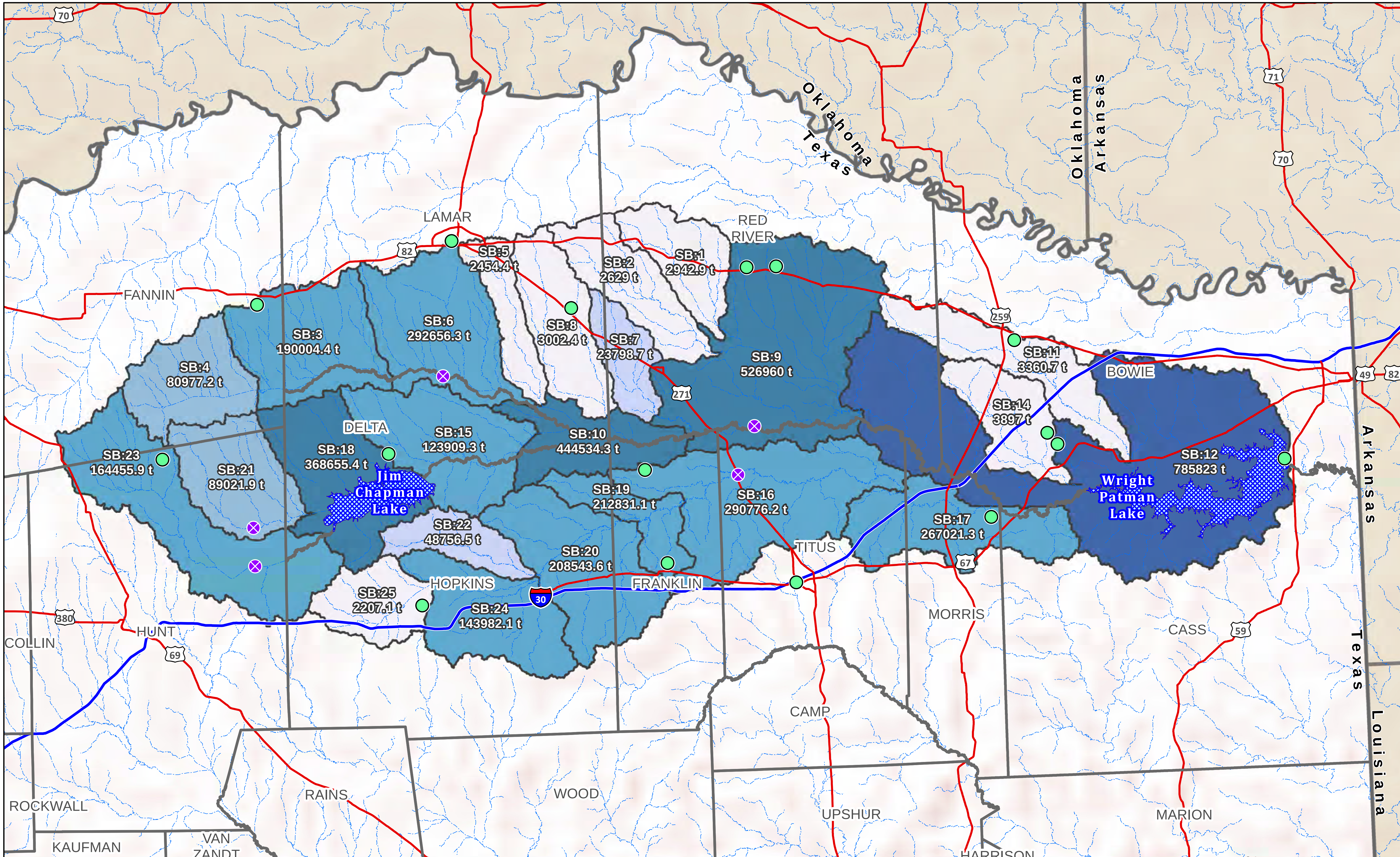
Table 4-6: Average Annual Sediment Yield Comparison – Baseline Scenario, Intensive BMP Scenario and Feasible BMP Scenario

Subbasin	Existing Condition Scenario (metric tons/hectare)	Intensive BMP Scenario (metric tons/hectare)	Intensive BMP Scenario (percent reduction)	Feasible BMP Scenario (metric tons/hectare)	Feasible BMP Scenario (percent reduction)
1	0.147	0.147	0%	0.147	0%
2	0.110	0.110	0%	0.110	0%
3	4.932	0.161	97%	0.280	94%
4	3.110	0.280	91%	0.381	88%
5	0.169	0.169	0%	0.169	0%
6	2.256	0.091	96%	0.161	93%
7	1.743	0.042	98%	0.069	96%
8	0.112	0.112	0%	0.112	0%
9	0.220	0.220	0%	0.220	0%
10	0.123	0.123	0%	0.123	0%
11	0.121	0.121	0%	0.121	0%
12*	0.154	0.154	0%	0.154	0%
14	0.182	0.182	0%	0.182	0%
15	2.263	0.077	97%	0.138	94%
16	0.213	0.213	0%	0.213	0%
17	0.435	0.435	0%	0.435	0%
18	3.449	0.074	98%	0.125	96%
19	0.128	0.128	0%	0.128	0%
20	0.220	0.220	0%	0.220	0%
21	3.138	0.110	96%	0.176	94%
22	3.413	0.020	99%	0.087	97%
23	3.194	0.072	98%	0.155	95%
24	4.531	0.065	99%	0.187	96%
25	0.121	0.121	0%	0.121	0%

Table 4-7: Average annual total sediment yield comparison – Baseline scenario, intensive BMP scenario, and feasible BMP scenario

Subbasin	Existing Condition Scenario(metric tons)	Intensive BMP Scenario (metric tons)	Intensive BMP Scenario (percent reduction)	Feasible BMP Scenario (metric tons)	Feasible BMP Scenario (percent reduction)
1	2,944	2,944	0%	2,944	0%
2	2,263	2,663	0%	2,663	0%
3	186,904	6,094	97%	10,612	94%
4	80,980	7,285	91%	9,918	88%
5	2,451	2,451	0%	2,451	0%
6	93,149	3,775	96%	6,666	93%
7	23,804	573	98%	942	96%
8	3,018	3,018	0%	3,018	0%
9	18,404	18,404	0%	18,404	0%
10	3,026	3,026	0%	3,026	0%
11	3,472	3,472	0%	3,472	0%
12*	21,811	21,811	0%	21,811	0%
14	3,905	3,905	0%	3,905	0%
15	85,218	2,884	97%	5,213	94%
16	12,427	12,427	0%	12,427	0%
17	14,861	14,861	0%	14,861	0%
18	139,823	2,980	98%	5,047	96%
19	2,020	2,020	0%	2,020	0%
20	9,458	9,458	0%	9,458	0%
21	89,024	3,123	96%	4,979	94%
22	48,758	290	99%	1,246	97%
23	178,023	4,013	98%	8,659	95%
24	148,468	2,114	99%	6,130	96%
25	2,199	2,199	0%	2,199	0%

*Location of Wright Patman Lake



Stream Gage
Weather Station
Existing Lake
NHD Flowline

Baseline Scenario
Average Annual Sediment Load (tons)
Between 1997-2010

0 - 20000	20001 - 50000
50001 - 100000	100001 - 300000
300001 - 600000	600001+

1:575,000
0 4.5 9 18 Miles
1 inch = 9 miles

N W E S

FIGURE 8

U.S. ARMY CORPS OF ENGINEERS, FORT WORTH DISTRICT

Sulphur River Watershed Overview - SWAT Model

Baseline Scenario - Average Annual Sediment Load (tons)

FN PROJECT NO. MHP11453
DATE CREATED 1/11/2013
DATUM & COORDINATE SYSTEM NAD83 State Plane (feet) Texas North Central
FILE NAME Fig8_Sed_Load_Baseline_MTG
PREPARED BY JAW

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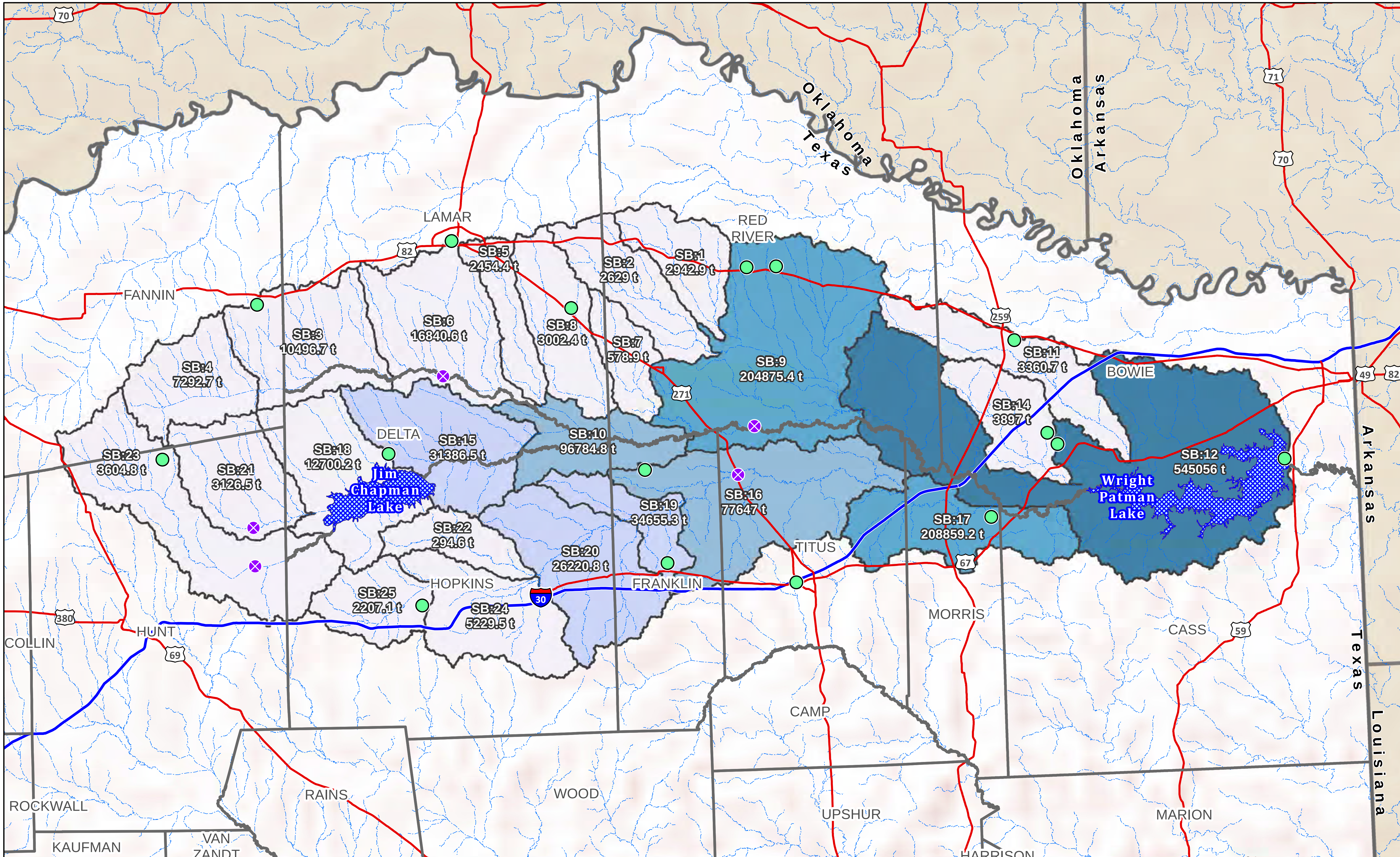
Path: H:\ENVIRONMENTAL\FROM_MTG\MXD\Arc10\For_Becky\Fig8_Sed_Load_Baseline_MTG.mxd



U.S. ARMY CORPS OF ENGINEERS, FORT WORTH DISTRICT

Sulphur River Watershed Overview - SWAT Model

Intensive BMP Scenario- Average Annual Sediment Load (tons)

FN PROJECT NO.	MHP11453
DATE CREATED	1/11/2013
DATUM & COORDINATE SYSTEM	NAD83 State Plane (feet) Texas North Central
FILE NAME	Fig9_Sed_Load_Intensive_MTG
PREPARED BY	JAW

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Stream Gage
Weather Station
Existing Lake
NHD Flowline

Intensive BMP Scenario
Average Annual Sediment Load (tons)
Between 1997-2010

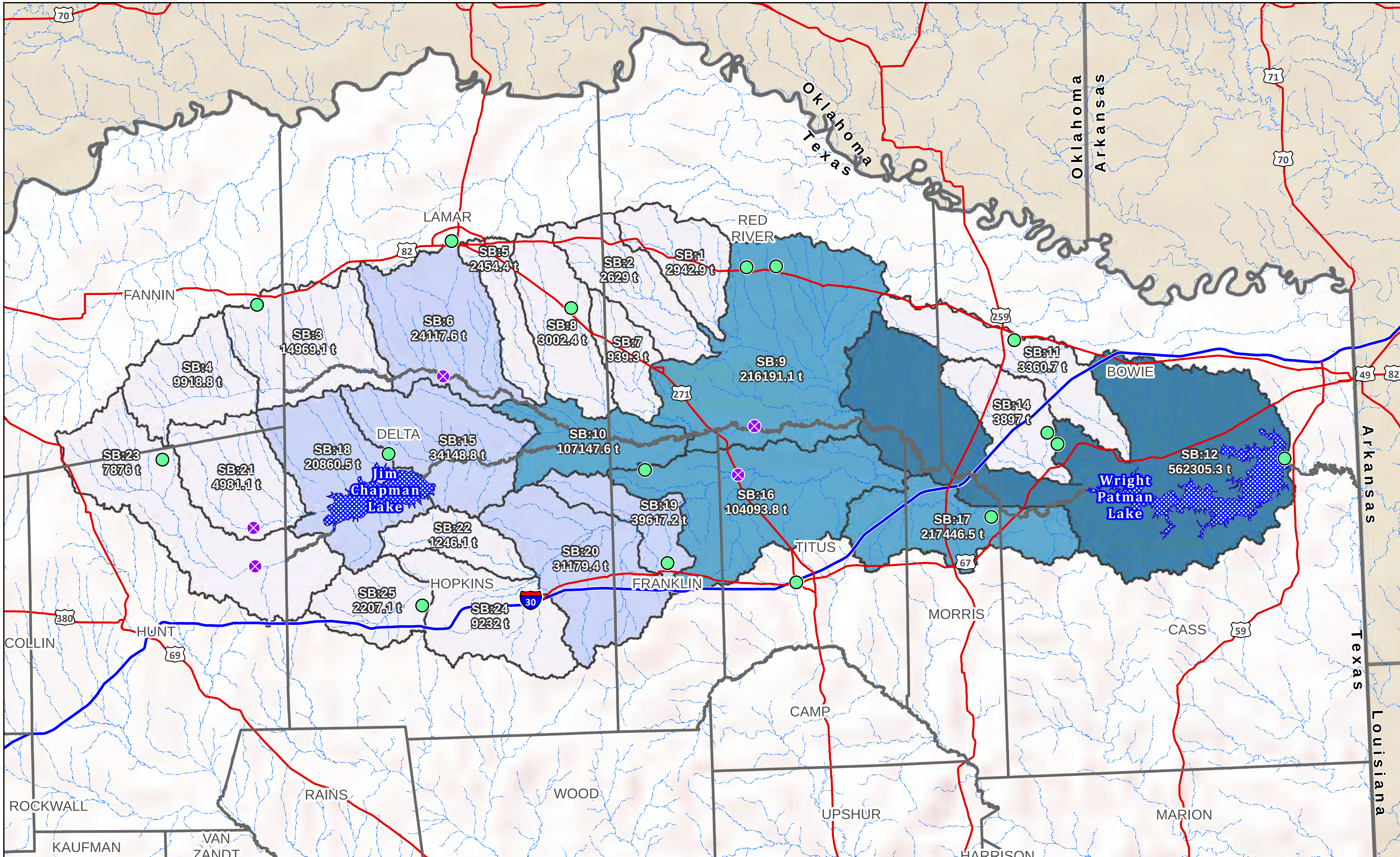
0 - 20000
200001 - 50000
50001 - 100000
100001 - 300000
300001 - 600000
600001+

1:575,000
0 4.5 9 18 Miles
1 inch = 9 miles

N W E S

FIGURE 9

Path: H:\ENVIRONMENTAL\FROM_MTG\MXD\Arc10\For_Becky\Fig9_Sed_Load_Intensive_MTG.mxd



Stream Gage
Weather Station
Existing Lake
NHD Flowline

Feasible BMP Scenario
Average Annual Sediment Load (tons)
Between 1997-2010

0 - 20000	50001 - 100000
20001 - 50000	100001 - 300000
300001 - 600000	600001+

1:575,000

0 4.5 9 18 Miles

1 inch = 9 miles

N W E S

U.S. ARMY CORPS OF ENGINEERS, FORT WORTH DISTRICT

Sulphur River Watershed Overview - SWAT Model

Feasible BMP Scenario- Average Annual Sediment Load (tons)

FN PROJECT NO.	MHP11453
DATE CREATED	1/11/2013
DATUM & COORDINATE SYSTEM	NAD83 State Plane (feet) Texas North Central
FILE NAME	Fig10_Sed_Load_Feasible_MTG
PREPARED BY	JAW

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FIGURE 10

Path: H:\ENVIRONMENTAL\FROM_MTG\MXD\Arc10\For_Becky\Fig10_Sed_Load_Feasible_MTG.mxd

4.3 EFFECT OF MODIFIED SEDIMENT CONDITION ON WRIGHT PATMAN YIELDS

In order to evaluate the effect of reduced sediment loading to Wright Patman Lake on the dependable yield thereof, the WAM analysis described in Section 4.1 was revised. Specifically, values within the WAM that a) relate the storage volume in the reservoir to the surface area and b) the storage available in the reservoir at a given top-of-conservation-pool elevation were modified to reflect the changes predicted by the SWAT model. Specifically, the reduction in sediment load, measured in tons per year, was converted to a volume (acre-feet) using the measured density from Wright Patman sediment core samples obtained during development and calibration of the SWAT model. Table 4-8 reflects the firm yield of Wright Patman Lake over the 50-year period of analysis under several reallocation scenarios as modified by predicted sediment reductions using the Feasible BMP scenario. All scenarios shown in Table 4-8 assume the minimum (bottom) elevation of the conservation pool to be 220.0 ft and likewise assume a minimum constant release of 10 cfs downstream of Wright Patman per the existing Corps contract.

Figures 4-11 through 4-13 compare the firm yield of Wright Patman Lake over time with and without the sediment mitigation program for each of three reallocation scenarios. In each case, the blue line represents the firm yield associated with anticipated watershed conditions absent a sediment mitigation program whereas the red line reflects the firm yield with the Feasible BMP scenario in place.

Table 4-9 indicates the cumulative increase in dependable yield over the 50-year period of analysis resulting from sediment mitigation for each of three reallocation scenarios portrayed in Figures 4-8 through 4-10 as predicted by the model. The results presented in Table 4-9 are consistent with the observations presented in Figure 4-1 in that the improvement in yield associated with storage generally at the bottom of the reservoir pool is most pronounced for the smaller reallocations and diminishes in relative importance for larger reallocation scenarios.

Table 4-8: Cumulative Savings Resulting from Sediment Mitigation Program Applied over a 50-year Period

Reallocation Scenario – Top of Conservation Pool	Cumulative Savings (Ac-Ft)
227.5 ft	240,000
237.5 ft	170,000
252.5 ft	130,000

Table 4-9: Firm Yield of Wright Patman Lake with Sediment Reduction Program

Conservation Pool Max. Elevation (ft)/Curve	Sediment Condition	Firm Yield (ac-ft/yr)[1]	Sediment Condition[1]	Firm Yield (ac-ft/yr)[2]	Increase in Firm Yield due to BMPs (ac-ft/yr)
Interim	2020	38,953	2020	38,953	0
Ultimate	2020	196,293	2020	196,293	0
227.5	2020	251,313	2020	251,313	0
237.5	2020	655,023	2020	655,023	0
252.5	2020	1,031,993	2020	1,031,993	0
Interim	2040	37,713	2040 with Feasible BMPs	38,303	590
Ultimate	2040	192,033	2040 with Feasible BMPs	194,013	1,980
227.5	2040	240,633	2040 with Feasible BMPs	244,113	3,480
237.5	2040	646,873	2040 with Feasible BMPs	649,323	2,450
252.5	2040	1,025,243	2040 with Feasible BMPs	1,027,243	2,000
Interim	2070	34,283	2070 with Feasible BMPs	35,983	1,700
Ultimate	2070	180,283	2070 with Feasible BMPs	186,113	5,830
227.5	2070	220,153	2070 with Feasible BMPs	230,303	10,150
237.5	2070	632,373	2070 with Feasible BMPs	639,533	7,160
252.5	2070	1,014,063	2070 with Feasible BMPs	1,019,333	5,270

[1]The analysis assumes Lake Ralph Hall will be in place by 2020. Sediment conditions between the current time period and 2020 do not have Ralph Hall in place; after 2020 the sediment conditions includes the effect of Lake Ralph Hall

[2] Firm yield estimates incorporate a constant downstream release of 10 cfs per the City of Texarkana's contract with the Corps of Engineers

Figure 4-11: Yield with Maximum Conservation Elevation at 227.5 Feet

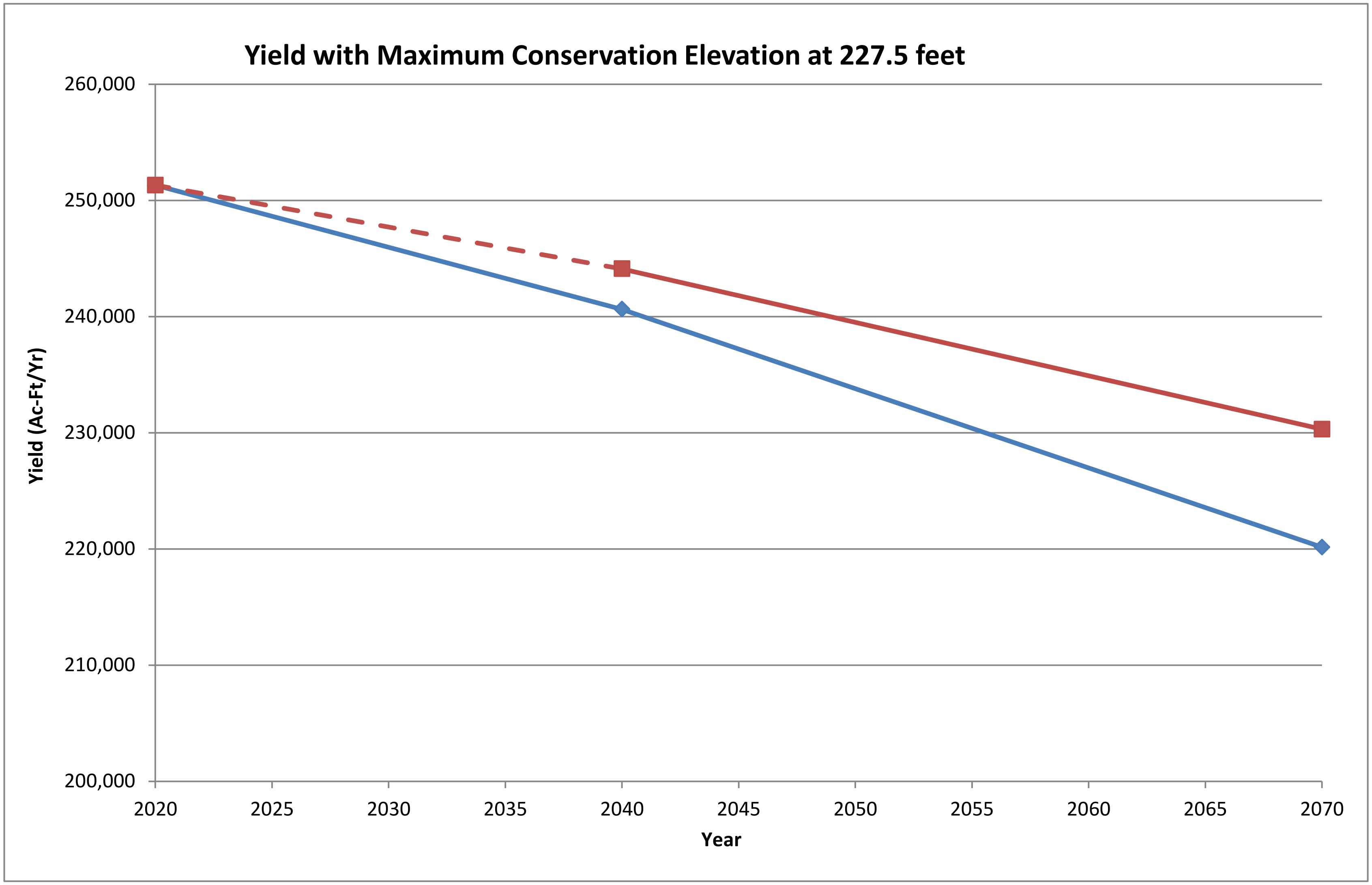


Figure 4-12: Yield at Maximum Conservation Pool Elevation 237.5

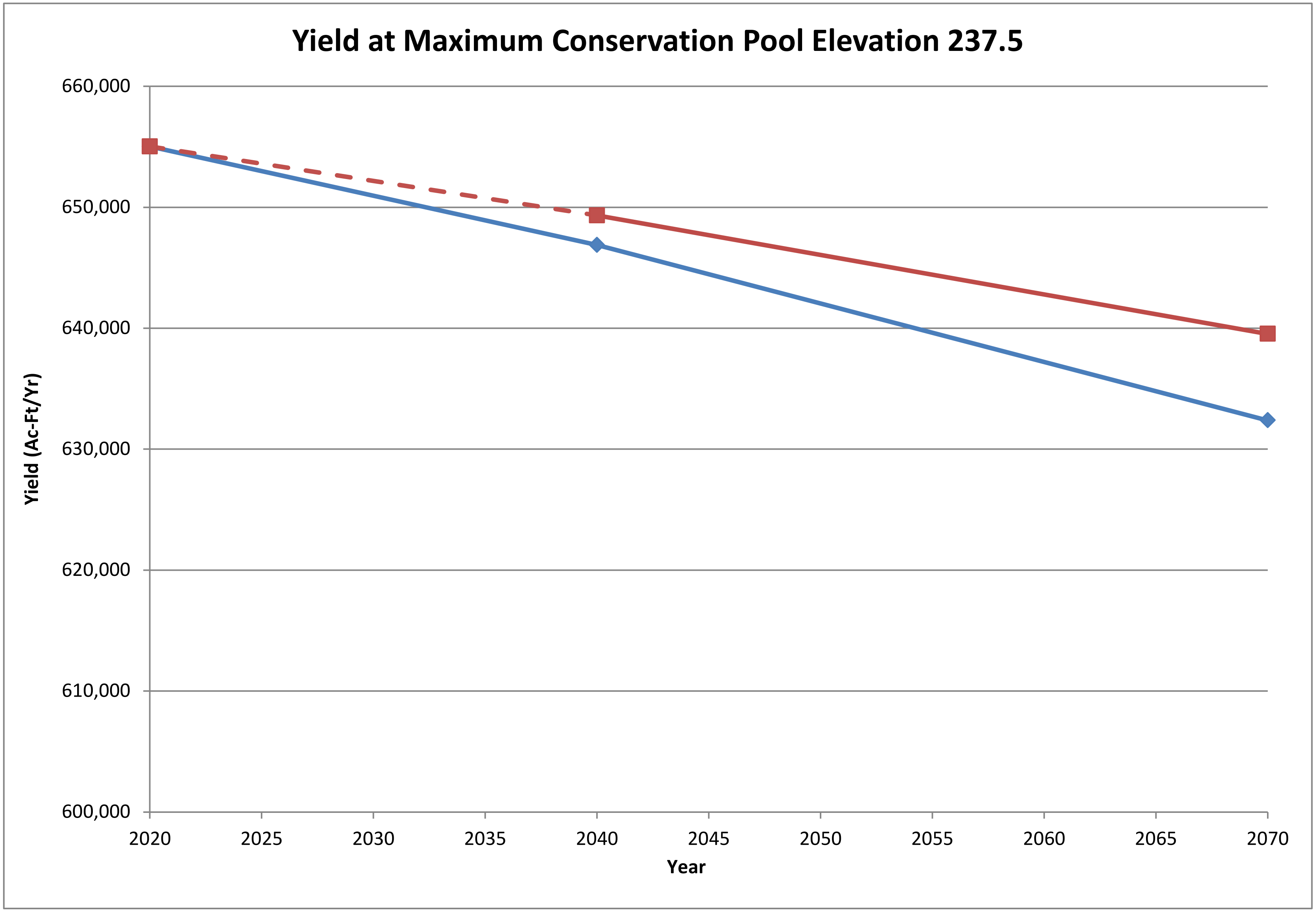
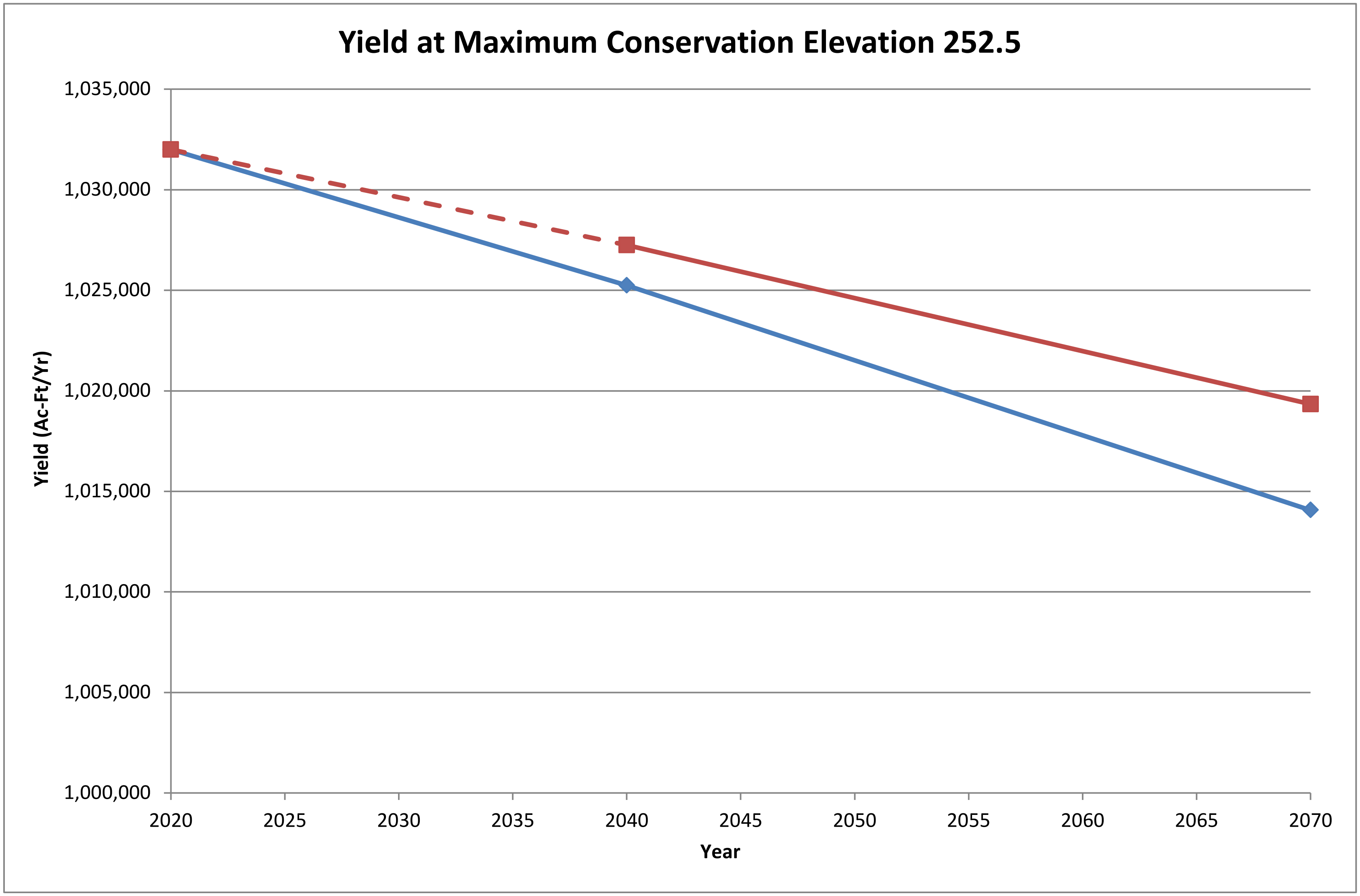


Figure 4-13: Yield at Maximum Conservation Elevation 252.5



The results presented in this section are specific to the predicted effect of a sediment reduction program on firm yields at Wright Patman Lake. The additional benefits which would be realized at other existing, planned, or potential water resources projects in the basin, and to riparian landowners in the basin, were not addressed.

4.4 SUMMARY

In general, the analysis demonstrates that reallocation of storage from flood control or sediment storage to water conservation storage at Wright Patman Lake could substantially increase the firm yield of the project. For scenarios raising the top of the conservation pool (reallocating storage from flood control to water supply), the modeling indicates that firm yield continues to increase significantly with the increase in storage at all elevations. Increasing storage by lowering the bottom of the conservation pool (reallocating dead storage to water supply) also increases yield substantially. With the entire reservoir storage dedicated to water conservation (no sediment storage or flood control storage), the firm yield of the reservoir exceeds 1.2 million acre-feet per year.

Simulation of subordination of the senior Wright Patman right to the more junior Jim Chapman right reduced the firm yield of Wright Patman Lake by an estimated 1-11 % depending on the bottom elevation chosen for the conservation pool (whether or not sediment storage is reallocated) and on whether the Interim or Ultimate rule curve is used as the top of the conservation pool.

Storage in Wright Patman Lake is predicted to decline over time due to ongoing sedimentation from the watershed. Absent a reallocation or other change to Wright Patman Lake operations, the firm yield of the reservoir would be reduced by approximately 12% by the year 2070, even with Lake Ralph Hall in place upstream. The SWAT model indicates that sediment yields and loads within the watershed could be substantially reduced by a program of Best Management Practices. Implementation of four practices at 100% of the applicable locations within ten of the basin's sub-watersheds is predicted to reduce sedimentation at Wright Patman by 28% (223,518 metric tons per year.) The reduced loss of storage has a beneficial effect on the predicted firm yield of Wright Patman Lake, generally in the 1-5% range depending on the scenario. On a cumulative basis, the additional water supply available as a result of the reduction in sediment may be several hundred thousand acre-feet.

5.0 YIELD ANALYSIS - ALTERNATIVE SITES

In addition to the multiple scenarios for reallocation at Wright Patman Lake, the Scope of Work calls for evaluation of up to five additional alternative strategies to develop additional water supply in the Sulphur River Basin. Numerous prior studies have identified and evaluated potential reservoir sites in the Sulphur River Basin, and this this study built on previous analyses. A partial list of prior studies is contained in the References section of this report.

Suitable reservoir sites are located on the main stem of the Sulphur River, as well as on the North and South Sulphur River, Cuthand Creek, and White Oak Creek. The Sulphur River Basin Reservoir Study conducted by FNI in 2000 identified almost 20 alternative locations suitable for dam site construction, many of which have been under study for decades. In general, more upstream sites are characterized by lower total cost, smaller yields, and higher unit costs for water while the more downstream sites are characterized by higher total costs, greater yield and lower unit costs. (FNI, 2000) More recent studies, including the *2006 Region C Regional Water Plan* (TWDB, 2006) and the *Reservoir Site Protection Study* (TWDB, 2008) have focused on sites near the vicinity of the South Sulphur River/Sulphur River confluence (various configurations of the George Parkhouse site) and sites near the vicinity of the White Oak Creek/Sulphur River confluence (various configurations of the Marvin Nichols site.)

5.1 SELECTION RATIONALE

In selecting alternatives for inclusion in this study, emphasis was placed on taking advantage of prior work where appropriate and on evaluating the full range of geographic locations suitable for the development of new storage or yield.

The George Parkhouse project is representative of an upstream storage location within the Sulphur River Basin. Three dam sites have studied in detail on multiple occasions. The George Parkhouse I site (George Parkhouse South) is located on the South Sulphur River downstream of Jim Chapman Dam and upstream of the South Sulphur River's confluence with the Sulphur River. The George Parkhouse II site (George Parkhouse North) is located on the North Sulphur River upstream of the South Sulphur Confluence, and the George Parkhouse III site is located on the Sulphur River downstream of the confluence of the North and South Sulphur Rivers. (See Figure 5-1) The Parkhouse I and II sites are included in the *2006 Region C Regional Water Plan* as alternative strategies for North Texas Municipal

U.S. ARMY CORPS OF ENGINEERS, FORT WORTH DISTRICT

Sulphur River Watershed Overview

Alternative Locations, George Parkhouse Site

FN PROJECT NO.	DATE CREATED	DATUM & COORDINATE SYSTEM	FILE NAME	PREPARED BY
MHP11453	5/22/2013	NAD83 State Plane (feet) Texas North Central	FIGURE 1	JAW

FREESE NICHOLS
4500 International Plaza Suite 200
Fort Worth, Texas 76109-4895
(817) 735-7300

PARKHOUSE DAM SITES
SULPHUR BASIN

0 0.75 1.5 3 4.5 6 Miles

1 in = 3 miles

N W E S

FIGURE 1

Path: X:\2011 Projects\116076.01 FNI - Water Shed Study – Sulphur River Basin\03 GIS\FIGURE 1.mxd

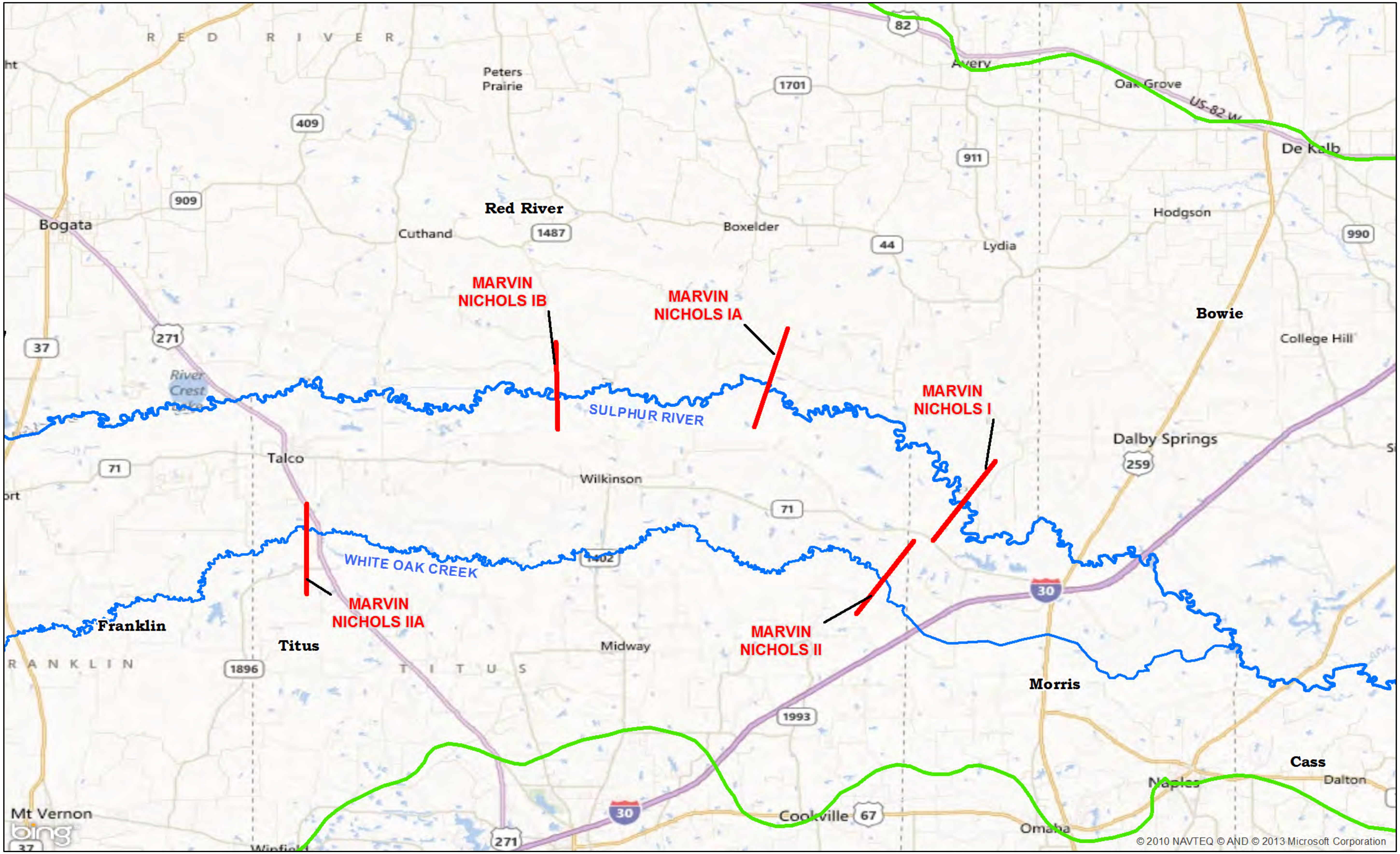
Water District (NTMWD), the Upper Trinity Regional Water District (UTRWD) and/or Tarrant Regional Water District (TRWD). The Parkhouse I site is recommended as an alternative strategy for Dallas Water Utilities, NTMWD, UTRWD and the City of Irving in the *2011 Region C Regional Water Plan.* Both sites were recommended for protection in the *Reservoir Site Protection Study*. The Parkhouse I and Parkhouse II sites are included as alternatives in this analysis.

The Marvin Nichols project is representative of a more downstream location for new storage within the Sulphur River Basin. At least five locations for this dam have been considered. The Marvin Nichols project has been evaluated as an impoundment at multiple locations on White Oak Creek and multiple locations on the Sulphur River (FNI, 2000). (See Figure 5-2) In general, these alternative sites represent an attempt to locate the impoundment so as to minimize conflicts with Priority 1 bottomland hardwood habitats and oilfield activity while maintaining yield. A reservoir at the Marvin Nichols IA site is a recommended strategy for North Texas Municipal Water District, the Upper Trinity Regional Water District, and Tarrant Regional Water District in the 2006 and 2011 *Region C Regional Water Plan* and an alternative strategy for Dallas Water Utilities and the City of Irving in the 2011 plan. The Marvin Nichols IA site is designated as a unique reservoir site by the Texas legislature and is included as an alternative in this analysis.

Jim Chapman Lake is located in the western portion of the Sulphur River Basin on the South Sulphur River. As discussed in Chapter 2,, Jim Chapman Lake includes flood storage between elevations 440 and 446.2 feet NGVD. This storage has a volume of 130,361 acre-feet. Possible reallocation of this flood storage to conservation storage was included in this analysis as an alternative water supply source.

White Oak Creek has a significant drainage area and is a major tributary of the Sulphur River. In addition to the two Marvin Nichols sites on White Oak Creek identified in Figure 5-2, there are suitable dam locations further upstream on White Oak Creek. In particular, a site upstream of the City of Talco near the Talco gage presents the opportunity for an on-channel reservoir that could be hydraulically connected to the main stem of the Sulphur River to take advantage of flows from both the White Oak Creek and Sulphur River. This concept was defined further (see Section 5.2.5) and included in this analysis as an alternative.

Figure 5-3 portrays the full suite of alternatives identified for consideration in this analysis.



FN PROJECT NO. MHP11453
DATE CREATED 5/21/2013
DATUM & COORDINATE SYSTEM NAD83 State Plane (feet) Texas North Central
FILE NAME FIGURE 2
PREPARED BY JAW

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Sulphur River Watershed Overview

Alternative Locations, Marvin Nichols Site

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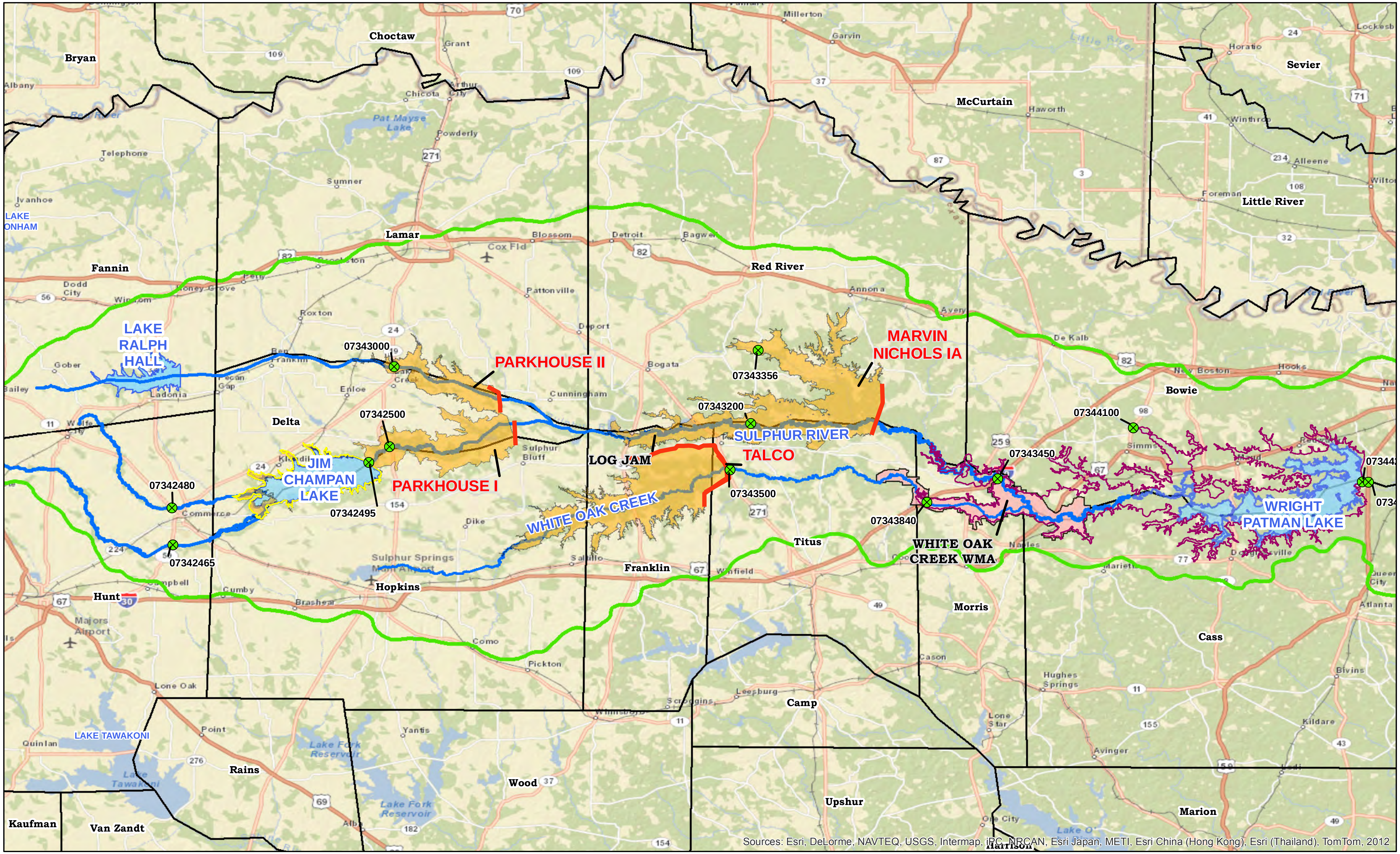
Marvin_Nichols_Dam_Sites
SULPHUR BASIN

0 0.75 1.5 3 4.5 6 Miles
1 in = 3 miles

N W E S

FIGURE 2

Path: X:\2011 Projects\116076.01 FNI - Water Shed Study – Sulphur River Basin\03 GIS\FIGURE 2.mxd



U.S. ARMY CORPS OF ENGINEERS, FORT WORTH DISTRICT

Sulphur River Watershed Overview

Alternative Storage Sites, Sulphur River Basin

FN PROJECT NO. MHP11453
DATE CREATED 5/22/2013
DATUM & COORDINATE SYSTEM NAD83 State Plane (feet) Texas North Central
FILE NAME CHAMPAN-PATMAN-HALL 5-16-13
PREPARED BY JAW

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USGS STREAM GAUGE
CHAPMAN FLOOD POOL-446.2'
PATMAN FLOOD POOL-259.5'
DAM SITES
ALTERNATIVE SITE LOCATIONS
SULPHUR_BASIN

0 2.25 4.5 9 13.5 18 Miles

1 in = 9 miles

N W E S

FIGURE 3

Path: X:\2011 Projects\116076.01 FNI - Water Shed Study – Sulphur River Basin\03 GIS\CHAMPAN-PATMAN-HALL 5-16-13.mxd

5.2 DESCRIPTIONS OF ALTERNATIVES EVALUATED

5.2.1 George Parkhouse I Alternative

As shown in Figure 5-1, the George Parkhouse I project would be located on the South Sulphur River in Delta and Hopkins counties, about 18 miles northeast of the City of Sulphur Springs. The top of the conservation pool would be at elevation 401 feet NGVD. At this elevation, the reservoir would have a storage capacity of 651,712 acre-feet. At this location, the reservoir would have a total drainage area of 654 square miles (of which 479 square miles are above Jim Chapman Lake.)

As evaluated herein, George Parkhouse I would inundate 28,362 acres. The amount of each land use/cover type inundated is shown in Table 5-1, below. The land use classification providing the basis for Table 5-1, as well as Tables5-2 through 5-5, was performed by Freese and Nichols, Inc. as part of a related study and does not exactly match the land classification information contained in earlier reports for the same reservoir sites. Data sources utilized in this classification system included the Farm Service Agency (FSA) National Agriculture Imagery Program (NAIP) aerial imagery, satellite imagery, 10-meter digital elevation models (DEM), U.S. Department of Agriculture (USDA) Soil Survey Geographic (SSURGO) soil data types, TPWD vegetational areas, U.S. Geologic Survey (USGS) National Hydrolography Dataset (NHD) layers, USGS Geologic Atlas of Texas, as well as field verified site data. A detailed explanation of the methodology used in this classification is contained in FNI Interim Report, "Comparative Environmental Assessment, Sulphur River Basin." (See References)

Table 5-1: Land Use/Cover Type Inundated by the George Parkhouse 1 Reservoir (acres)

Barren	1
Bottomland Hardwood Forest	4,267
Forested Wetland	5,487
Grassland/Old field	12,133
Herbaceous Wetland	432
Open Water	181
Row Crops	3,987
Shrub/Wetland	278
Shrubland	65
Upland Forest	1,521
Urban	10
	28,362

5.2.2 George Parkhouse II Alternative

The George Parkhouse II project is an impoundment on the North Sulphur in Lamar and Delta counties, approximately 15 miles southeast of the City of Paris. The top of the conservation pool would be at elevation 410 feet NGVD. At this elevation, the reservoir would have a storage capacity of 330,871 acre-feet. At this location, the reservoir would have a total drainage area of 421 square miles, of which approximately 101 square miles is above the proposed Lake Ralph Hall.

The George Parkhouse II project would inundate 15,359 acres. The amount of each land use/cover type inundated is shown in Table 5-2, below.

Table 5-2: Land Use/Cover Type Indundated by the George Parkhouse 2 Reservoir (acres)

Barren	1
Bottomland Hardwood Forest	1,960
Forested Wetland	1,116
Grassland/Old field	7,718
Herbaceous Wetland	91
Open Water	182
Row Crops	3,626
Shrub/Wetland	28
Shrubland	19
Upland Forest	602
Urban	14
	15,357

5.2.3 Marvin Nichols 1A Alternative

The Marvin Nichols 1A project would be located on the Sulphur River and Red River and Titus counties approximately halfway between the cities of Clarksville and Mount Pleasant. The top of the conservation pool would be at elevation 328 feet NGVD. At this elevation, the reservoir would have a storage capacity of 1,532,031 acre-feet. At this location, the reservoir would have a total drainage area of 1,889 square miles (of which 479 square miles are above Jim Chapman Lake.)

The Marvin Nichols IA project would inundate 66,103 acres. The amount of each land use/cover type inundated is shown in Table 5-3, below.

Table 5-3: Land Use/Cover Type Inundated by the Marvin Nichols 1A Reservoir (acres)

Barren	<1
Bottomland Hardwood Forest	10,156
Forested Wetland	21,444
Grassland/Oldfield	18,241
Herbaceous Wetland	1,244
Open Water	1,162
Row Crops	706
Shrub/Wetland	1,405
Shrubland	444
Upland Forest	11,223
Urban	78
	66,103

5.2.4 Jim Chapman Reallocation Alternative

Jim Chapman Lake is an existing reservoir owned and operated by the Corps of Engineers on the South Sulphur River in Hopkins County. The flood pool of Jim Chapman Lake is located between elevations 440 and 446.2 feet NGVD. This storage has a volume of 130,000 acre-feet and a footprint of 4,905 acres. The analysis considered reallocation of the entire volume of the flood storage pool (130,000 acre-feet) to conservation storage. The amount of each land use/cover type that would be inundated under this configuration is shown in Table 5-4, below.

Table 5-4: Land Use/Cover Type Indundated by Full Reallocation of Jim Chapman Flood Control Storage (acres)

Barren	1
Bottomland Hardwood Forest	2,264
Forested Wetland	736
Grassland/Oldfield	373
Herbaceous Wetland	94
Open Water	42
Row Crops	2
Shrub/Wetland	109
Shrubland	241
Upland Forest	1,029
Urban	9
	4,900

5.2.5 White Oak Creek/Talco Alternative

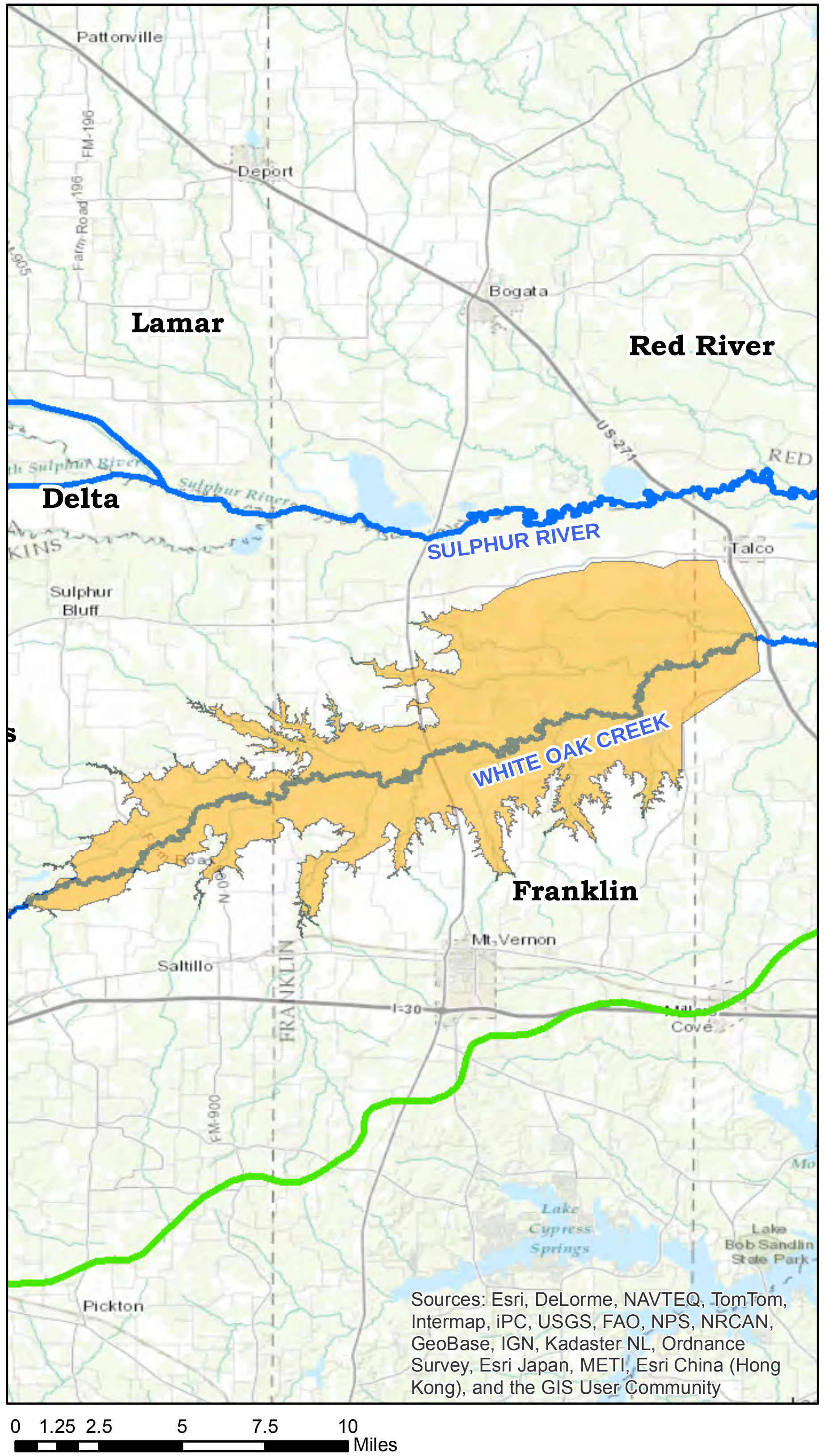
The White Oak Creek/Talco alternative was modeled in three configurations. The first configuration consists of a storage reservoir located on White Oak Creek upstream of the U.S. Highway 271 bridge, near the western boundary of Titus County. At this location, the reservoir would have a total drainage area of 538 square miles. Five scales of storage were modeled from a maximum storage elevation of 328 feet to 370 feet NGVD. Above 370 feet, water would begin to spill over into the adjacent Sulphur River drainage. At the 370 foot elevation, the reservoir would inundate 48,916 acres. The amount of each land use/cover type inundated is shown in Table 5-5, below.

Table 5-5: Land Use/Cover Type Indundated by Talco Storage Reservoir (acres)

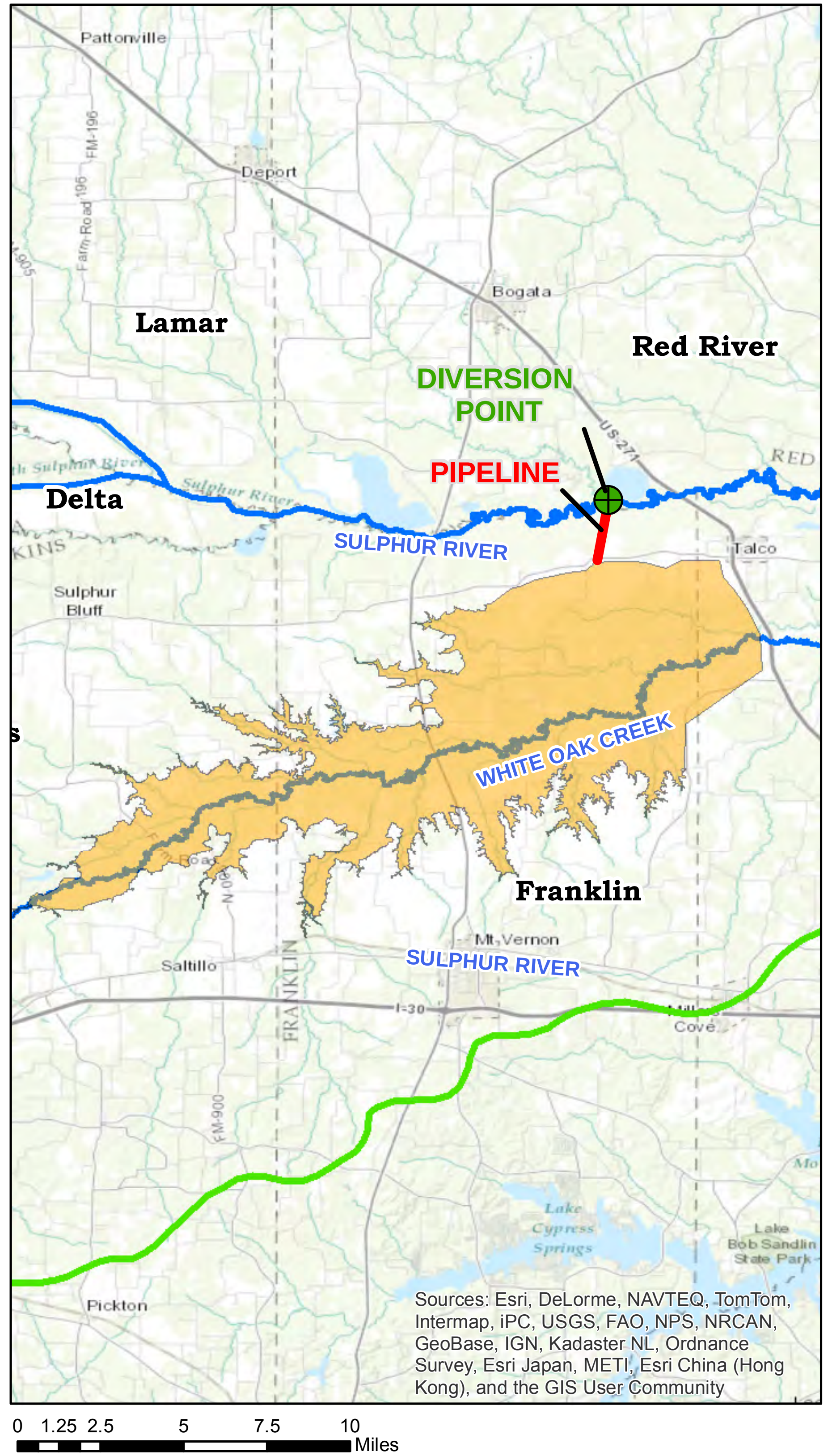
Barren	<1
Bottomland Hardwood Forest	7,251
Forested Wetland	10,316
Grassland/Oldfield	18,107
Herbaceous Wetland	276
Open Water	394
Row Crops	1,989
Shrub/Wetland	468
Shrubland	288
Upland Forest	9,803
Urban	23
	48,915

The second configuration modeled for the Talco alternative adds a diversion component to the storage reservoir described above. The diversion component would consist of an intake structure on the Sulphur River near the Talco gage and a pipeline between the diversion location and the Talco impoundment. Diversion rates of 500 and 2,500 cfs were evaluated. See Figure 5-4 for a schematic of this concept. The diversion component would "scalp" high flows from the Sulphur River during flood events and store them in the Talco impoundment. This configuration takes advantage of the additional drainage area of the Sulphur River above the diversion location (1,365 square miles) to increase yield without adding additional storage. The third configuration for this alternative adds a pipeline between the Talco impoundment and Jim Chapman Lake, allowing water to be pumped to Jim Chapman Lake to take advantage of any incidental storage available, when conditions allow. Pipeline capacity was assumed to be 500 cfs. This configuration is also shown on Figure 5-4.

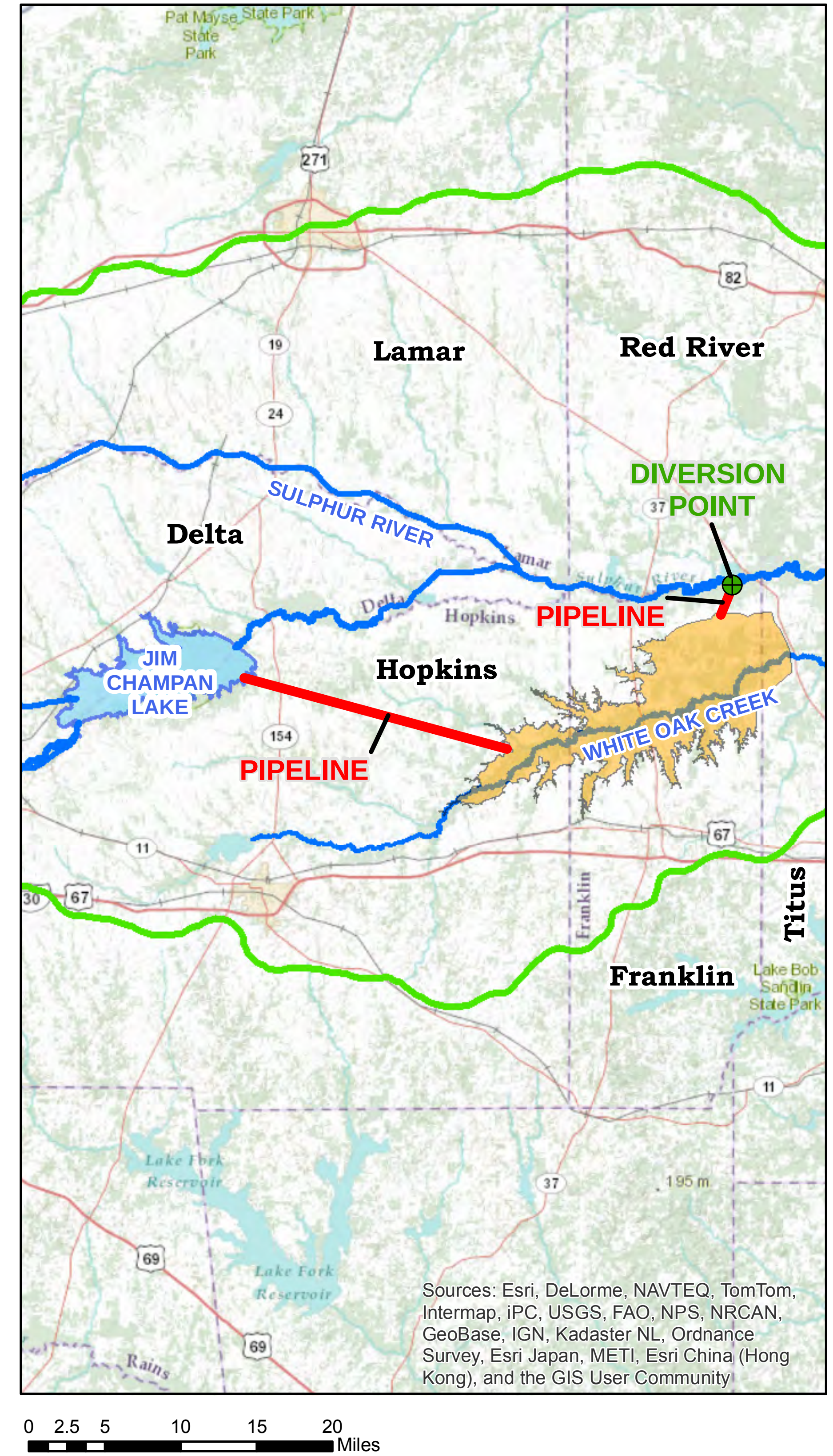
CONFIGURATION 1



CONFIGURATION 2



CONFIGURATION 3



WHITE OAK CREEK/TALCO RESERVOIR
SULPHUR BASIN

FN PROJECT NO.	MHP11453
DATE CREATED	5/22/2013
DATUM & COORDINATE SYSTEM	NAD83 State Plane (feet) Texas North Central
FILE NAME	FIGURE 4
PREPARED BY	JAW

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Sulphur River Watershed Overview

Alternative Configurations, Talco Site

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FIGURE 4

Path: X:\2011 Projects\116076.01 FNI - Water Shed Study – Sulphur River Basin\03 GIS\FIGURE 4.mxd

5.3 ADDITIONAL DESCRIPTION OF ALTERNATIVES

To further describe the alternatives under consideration, a high-level evaluation was conducted of real estate requirements and major relocations within the reservoir footprint. In order to approximate the number of homeowners or business owners that might be affected by each alternative, digital parcel maps were compared to the digital map of the reservoir footprint and the number of parcels extending into the reservoir footprint were counted. This “table-top” evaluation, portrayed in Table 5-6, provides a general comparison between the alternatives as to the number of landowners that might be affected but does not represent a definitive assessment. Table 5-6 also identifies the number of school districts having a portion of their tax base within in each reservoir footprint. Note: Hopkins County parcel data was not available electronically as of the time of this writing. As a result, the number of parcels which may intersect with the relevant reservoir footprint was simply estimated from a review of the tax roll, and is likely to be overstated in comparison with the estimates from other counties. More detailed information is found in Appendix E.1, Alternative Site Parcel Analysis.

Similarly, an assessment was made of the major relocations which would be likely to be required for each alternative. The appropriate conservation pool was delineated on 2012 aerial imagery from the Microsoft Bing Maps Service to indicate the potentially-impacted area. The imagery was then reviewed at a scale small enough to discern individual structures, such as houses, barns, well pads, and other features. A summary of the results is provided in Table 5-7. Additional details and copies of the maps used to conduct this analysis are provided in Appendix E.2, Qualitative Assessment of Sulphur Basin Alternatives.

Table 5-6: Estimate of Real Estate Requirements / Relocations

	Parkhouse I Site			Parkhouse II Site			Marvin Nichols 1A Site				Jim Chapman Reallocation			Talco Site			
	Delta County	Hopkins County	TOTAL	Lamar County	Delta County	TOTAL	Red River County	Titus County	Franklin County	TOTAL	Delta County	Hopkins County	TOTAL	Titus County	Franklin County	Hopkins County	TOTAL
No. of Parcels	343	457	800	290	137	427	598	170	162	930	183	226	409	65	1285	323	1673
Owners	131	368	499	146	59	205	280	94	42	416	42	145	187	39	439	181	659
Business Owners	11	7	18	8	8	16	20	10	3	33	4	2	6	3	24	10	37
Home Owners	60	162	222	67	20	87	58	25	6	89	15	77	92	10	143	102	255
Churches	--	1	1	--	--	--	--	--	--	--	--	--	--	--	1	--	1
Cemeteries	--	2	2	--	--	--	--	--	--	--	--	--	--	--	1	--	--
School Districts	3	2	5	1	2	2	5	2	1	5	1	1	2	1	2	3	4

Table 5-7: Major Relocations (Estimated)

	George Parkhouse I	George Parkhouse II	Jim Chapman Re-Allocation[1]	Marvin Nichols 1A	Talco Reservoir[2]	Wright Patman Re-Allocation[3]
Proposed Cons. Pool	401.0 ft.	410.0 ft.	446.2 ft.	328.0 ft.	370.0 ft.	259.5 ft.
Inundated Area	28,362 ac	15,359 ac	4,902 ac	66,102	48,404 ac	77,332 ac
	44.3 m^2	24.0 mi^2	7.7 mi^2	103.3 mi^2	75.6 mi^2	120.8 mi^2
Natural/Wildlife Areas[4]	--	--	--	--	--	24,710 ac
Impacted Structures	48	91	21	112	294	64
O&G Facilities[5]	--	--	--	54	93	2
Pipeline	--	--	--	--	6.2 mi	--
Elec. Trans. Lines	--	--	--	--	10.8 mi	19.9 mi
Railroad	--	--	--	--	--	14.9 mi
Total Roads	39.5 mi	24.2 mi	1.0 mi	69.4 mi	94.3 mi	66.8 mi
Major Highways[6]	5.3 mi	2.8 mi	--	18.3 mi	9.9 mi	21.3 mi
Potential Bridges	State Hwy 19, FM 1536	State Hwy 19, State Hwy 24	--	US 271, State Hwy 37, FM 412, FM 909, FM 910, FM 1487	State Hwy 37, FM 900, FM 71	Interstate 30, US 67, US 259, State Hwy 8, State Hwy 77

[1] *All impacts associated with Cooper Lake State Park (boat ramps, parking lots, pavilions, etc.)*
[2] *US Highway 271 is assumed to remain as-is at the downstream toe of the dam*
[3] *Many impacted structures associated with State Park (boat ramps, parking lots, pavilions, etc.)*
[4] *White Oak Creek Mitigation Area*
[5] *Oil & Gas (O&G) Facilities include Well Pads, Storage Tanks, and Other Facilities*
[6] *Indicates potential bridge locations*

5.4 INITIAL YIELD ANALYSIS

The yield of each alternative described above was estimated using the State of Texas' Water Availability Model (WAM). As discussed earlier in this report, modifications were made to the WAM to reflect conditions relevant to this analysis. Specifically, storage volumes in Jim Chapman Lake and Wright Patman Lake were updated to reflect the most recent sediment surveys for those impoundments, minor corrections were made to the drainage area ratios at specific locations in order to address known inaccuracies, and Lake Ralph Hall was considered to be in place.

Estimates of the initial yields of each alternative are based on the current capacities for Wright Patman Lake and Jim Chapman Lake. Operation of Lake Wright Patman influences the predicted yield of upstream reservoirs because it has a senior water right. This senior water right allows the storage and diversion of up to 180,000 acre-feet per year for municipal and industrial purposes. Texarkana's current contract with the Corps does not allow for sufficient storage to dependably generate that yield. The Interim Rule curve governing current operations limits conservation storage in Wright Patman Lake and reduces the dependable yield to 47,510 acre-feet per year (FNI, 2013). Water availability estimates were made consistent with the legal priority ascribed to the full Patman water right. However, the reliability of this water right is limited by the available storage associated with the Interim Rule Curve under which the reservoir is operated. In addition, all analyses assume a continuous release of at least 10 cfs from Wright Patman Lake per the requirements of the contract with the Corps of Engineers. Availability estimates also assume a continuous release of 5 cfs from Jim Chapman Lake, per the water right. However, prediction of estimated environmental flow requirements or their effect on reservoir yield are explicitly outside the scope for this effort and will be estimated separately. As those estimates become available, yield estimates would be reduced accordingly. Table 5-8, below, provides the estimate of the annual yield (rounded to the nearest 100 acre-feet per year) from the Marvin Nichols site, Parkhouse I and II sites, and the Jim Chapman reallocation scenario based on these assumptions. Yields for the various Talco configurations/scenarios are shown in Table 5-9. Additional information is contained in Attachment C.3.

Table 5-8: Initial Yield Estimates, Alternative Storage Sites (acre-feet/year)

George Parkhouse I	124,300
George Parkhouse II	124,200
Marvin Nichols 1A	590,000
Jim Chapman Lake Reallocation (increase)	25,000

Jim Chapman Lake is currently over-permitted and the reliability of its water rights is less than 100%. While a reallocation of storage improves the reliability of the existing water rights, its contribution of “new “water is small. Cost estimates for a reallocation of the flood storage have not been made, but it seems clear that these costs would be substantial in comparison to the limited increase in supply that could be made available. Based on this information, a reallocation at Jim Chapman Lake was not considered further.

Table 5-9: Initial Yield Estimates, Talco Configurations (acre-feet/year)

Maximum Elevation	Configuration 1	Configuration 2		Configuration 3	
		500 cfs Pumping Rate	2500 cfs Pumping Rate	500 cfs Pumping Rate	2500 cfs Pumping Rate
328	66,200	81,700	96,100	100,900	121,400
350	169,600	204,200	231,000	204,400	240,900
360	226,400	273,800	314,900	273,200	315,900
370	265,100	320,800	392,000	329,700	397,400

Neither the pumping rate for the Sulphur River Division (Talco Configurations 2 and 3) nor the Jim Chapman pipeline (Talco Configuration 3) has been optimized. The two pumping rates are simply intended to be indicative of a “reasonably sized” and “very large” diversion in order to gain a basic understanding of how yield might change over the range of possible diversion scales. The information in Table 9 tells us that increasing the Sulphur River division to a very large scale adds to yield, generally in the range of 13-22%. Adding the additional storage in Jim Chapman Lake (Configuration 3) adds only a small increment of additional yield. This is in part due to the same over-permitting/reliability issue discussed previously, and partly attributable to the fact that the operation of the Talco/Chapman “system” defined by Configuration 3 has not been optimized. A series of optimization runs might allow this estimate to be increased somewhat, but is not likely to significantly modify the relative outcome.

To simplify the analysis, only Configuration 2 (500 cfs) for the Talco site at maximum elevation 350 and 370 were carried forward into the time-series analysis.

5.5 ANALYSIS OF YIELD OVER TIME

As discussed in previous chapters, erosion and sedimentation in the Sulphur River Basin are an ongoing concern and have the potential to affect reservoir yields over time as reservoir storage is reduced by sediment deposits. The effects of reduced storage on Wright Patman Lake yield, under a variety of scenarios, were discussed in Chapter Four. Any new reservoir upstream of Wright Patman Lake would be likewise expected to be affected by ongoing sedimentation. Using the SWAT for the Sulphur River Basin developed for this study, each potential reservoir was modeled individually to assess expected sedimentation impacts on the reservoir. Because these impoundments are all upstream of Wright Patman Lake, a significant amount of the sediment they would trap would otherwise have traveled further downstream and been deposited in Wright Patman Lake. Thus, the upstream reservoirs would be expected to reduce sediment loads to Wright Patman Lake. The predicted reduction in sediment loads to Wright Patman Lake, in combination with each new reservoir, was also estimated. All model runs assume Lake Ralph Hall is constructed and fully operational. A detailed explanation of evaluation process is contained in Appendix D. Estimated annual sediment loads for each site are portrayed in Table 5-10 below.

Table 5-10: Average Annual Sediment Load (metric tons)

Reservoir	Sediment Load	Wright Patman Sediment Load
Parkhouse 1	123,902	729,025
Parkhouse 2	292,656	637,610
Marvin Nichols 1A	526,960	477,250
Talco	212,831	760,683

For comparison purposes, the annual sediment load for Wright Patman without any additional upstream reservoirs (except Lake Ralph Hall) was estimated in Chapter 4 to be 785,823 metric tons.

The predicted annual sediment loads were utilized to estimate decreased reservoir storage over time, along with the resultant effect on yield. Each reservoir was assumed to be constructed and operational by 2030. Yield estimates, rounded to the nearest 100 acre-feet, for the years 2030 and 2070 are shown in Table 5-11. Yield estimates over time were calculated for two Talco scenarios – “Maximum Conservation Pool elevation 350, Configuration 2” and “Maximum Conservation Pool elevation 370, Configuration 2.” Revised yields for Wright Patman Lake were not estimated, but to the degree that sedimentation in Wright Patman Lake would be reduced by the construction of an upstream reservoir, storage and yield for Wright Patman would be increased as compared to the condition without the upstream reservoir. Depending on the specific parameters of the scenario, this increase in storage would either improve the reliability of the current reservoir yield or contribute to an increase in yield.

Two water rights scenarios were evaluated – the first assumes the new reservoir would have a junior water right commensurate with its application date, and that the Wright Patman water right is senior. This scenario is labeled "Priority" in Table 5-11. The second scenario subordinates the Wright Patman Lake water right to that of the new reservoir. This scenario is hypothetical only, and is indicative of a condition wherein the two reservoirs would be voluntarily operated as a system in order to increase the overall yield and decrease overall costs. This scenario is labeled "Patman Subordination" in Table 5-11.

Table 5-11: Alternate Project Yields Over Time (acre-feet/year)

Reservoir	2030 Yield		2070 Yield	
	Priority	Patman Subordination	Priority	Patman Subordination
Parkhouse I	124,300	135,300	123,500	134,500
Parkhouse II	124,200	135,300	121,000	132,000
Marvin Nichols 1A	590,000	659,600	581,300	650,200
Talco (350) *	204,200	227,000	200,000	222,700
Talco (370)*	320,800	335,000	321,400	333,900

* Yield with 500 cfs pumping rate from main stem of Sulphur River

Note that in most cases the yield is 2070 is lower than the yield in 2030 because of the lost storage due to sedimentation. The exception is the 2070 yield for the Talco site with a maximum pool elevation of 370 feet. For this alternative, the 2070 yield under priority analysis is 600 acre-feet per year higher than the 2030 yield. Under the subordination analysis, the yield of the Talco alternative is 1,100 acre-feet per year less in 2070 than in 2030. At elevation 370 feet, the Talco alternative has well over 1 million acre-feet of storage. The sediment accumulation in the reservoir is a relatively small portion of the overall storage in the reservoir. Lake Wright Patman, which is located downstream and senior in priority to the Talco alternative, is able to store less water and therefore makes fewer priority calls on the Talco alternative. The reduction in water passed to Wright Patman's senior water right is more than the yield lost due to sediment accumulation, so the yield is slightly more in 2070 than in 2030. This is not true for the subordination analysis, which assumes that no water is passed for Wright Patman's senior water right. As a result there is slightly less yield for the Talco alternative in 2070.

Cumulative storage losses over the forty-one year period of analysis for each reservoir are shown in Table 5-12. Over this same period 23,968 acre-feet of storage would be lost in Lake Jim Chapman and

5,396 acre-feet in Lake Ralph Hall (same for all scenarios). For comparative purposes 52,365 of storage would be lost in Wright Patman Lake without construction of any additional upstream storage.

Table 5-12: Cumulative Storage Loss (2030 to 2070) (acre-feet)

Reservoir	Storage Lost in Main Reservoir	Storage Lost in Wright Patman
Parkhouse 1	8,056	47,396
Parkhouse 2	19,024	41,452
Marvin Nichols 1A	34,258	31,028
Talco	13,836	49,453

5.6 MODIFIED WATERSHED SEDIMENT CONDITION

As described in detail in the previous chapter of this report, a hypothetical program to reduce sedimentation in the Sulphur River Basin was synthesized using the Soil and Water Assessment Tool (SWAT). The "Feasible" scenario consisted of simulating four Best Management Practices (Filter strips, Cropland to pasture conversion, Channel grade control and Riparian buffer strips) in the sub-watersheds with the highest sediment yields. The predicted average annual sediment loads for each alternative reservoir, and for Wright Patman in combination with each reservoir, under this modified condition are shown in Table 5-13 below.

Table 5-13: Average Annual Sediment Load Feasible Scenario (metric tons)

Reservoir	Sediment Load	Reduction in Comparison with Baseline	Wright Patman Sediment Load	Reduction in Comparison with Baseline
Parkhouse I	34,149	89,753	550,702	178,323
Parkhouse II	24,118	268,538	546,294	91,316
Marvin Nichols 1A	216,191	310,769	447,696	338,127
Talco	39,617	173,214	566,742	193,941

Over time, the reduction in loss of storage attributable to the BMP implementation would be expected to improve reservoir yield as compared to the un-modified sediment condition. Yields for each reservoir for the years 2030 and 2070 were estimated based on the revised storage capacities and are shown in Table 5-14 below. As before, the yields are shown with both the "Priority" and "Patman Subordination" water rights scenarios

Table 5-14: Reservoir Yield under Mitigated Sediment Condition (acre-feet/year)

Reservoir	2030 Yield		2070 Yield		Improvement in 2070 Yield over Current Sedimentation	
	Priority	Patman Subordination	Priority	Patman Subordination	Priority	Patman Subordination
Parkhouse I	124,300	135,300	123,900	134,950	400	400
Parkhouse II	124,200	135,300	123,900	135,000	2,900	2,900
Marvin Nichols 1A	589,900	659,600	586,400	655,500	5,100	5,200
Talco (350) *	204,200	227,00	203,900	226,400	3,900	3,700
Talco (370)*	320,800	335,000	321,700	334,700	300	800

* Yield with 500 cfs pumping rate from main stem of Sulphur River

The change in yield over time attributable to the Feasible BMP scenario is shown graphically in Figures 5-5 through 5-10 for the Parkhouse and Marvin Nichols alternatives. Over the forty year period (between 2030 and 2070), the cumulative savings resulting from the reduction in sedimentation is represented by the area between the two lines. The amount of this cumulative savings in acre-feet is shown in Table 5-15 below. Once, again, these savings are in addition to savings at Wright Patman, which have not been estimated for this set of scenarios. Other benefits across the watershed to riparian landowners, for example, have likewise not been estimated but could be significant.

Table 5-15: Cumulative Savings – Feasible BMP Scenario (acre-feet)

Reservoir	Priority	Patman Subordination
Parkhouse I	8,000	8,000
Parkhouse II	59,000	60,000
Marvin Nichols 1A	104,000	106,000
Talco (350)	76,000	74,000
Talco (370)	6,000	16,000

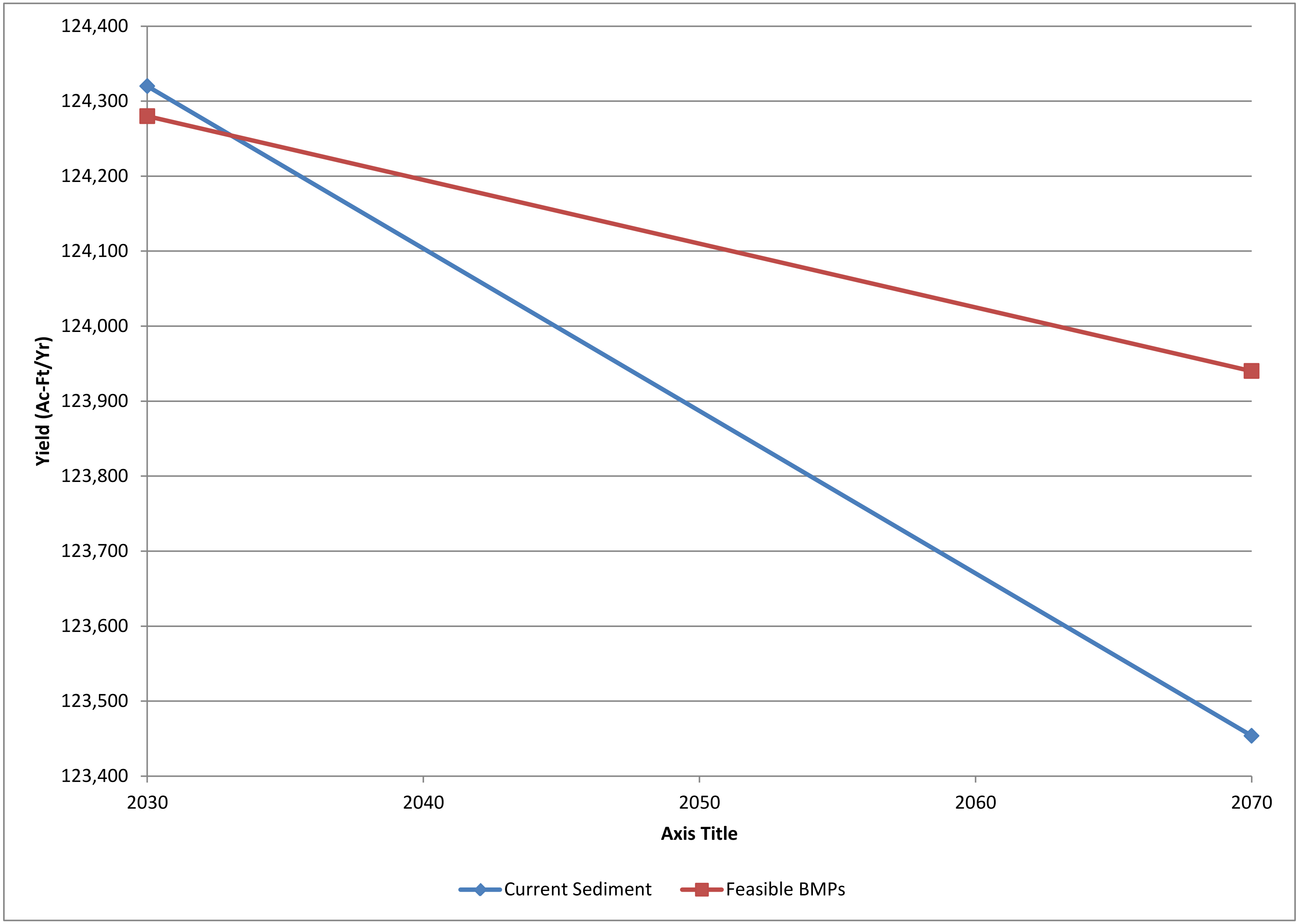

Figure 5-5: Parkhouse I Yield – Priority Order

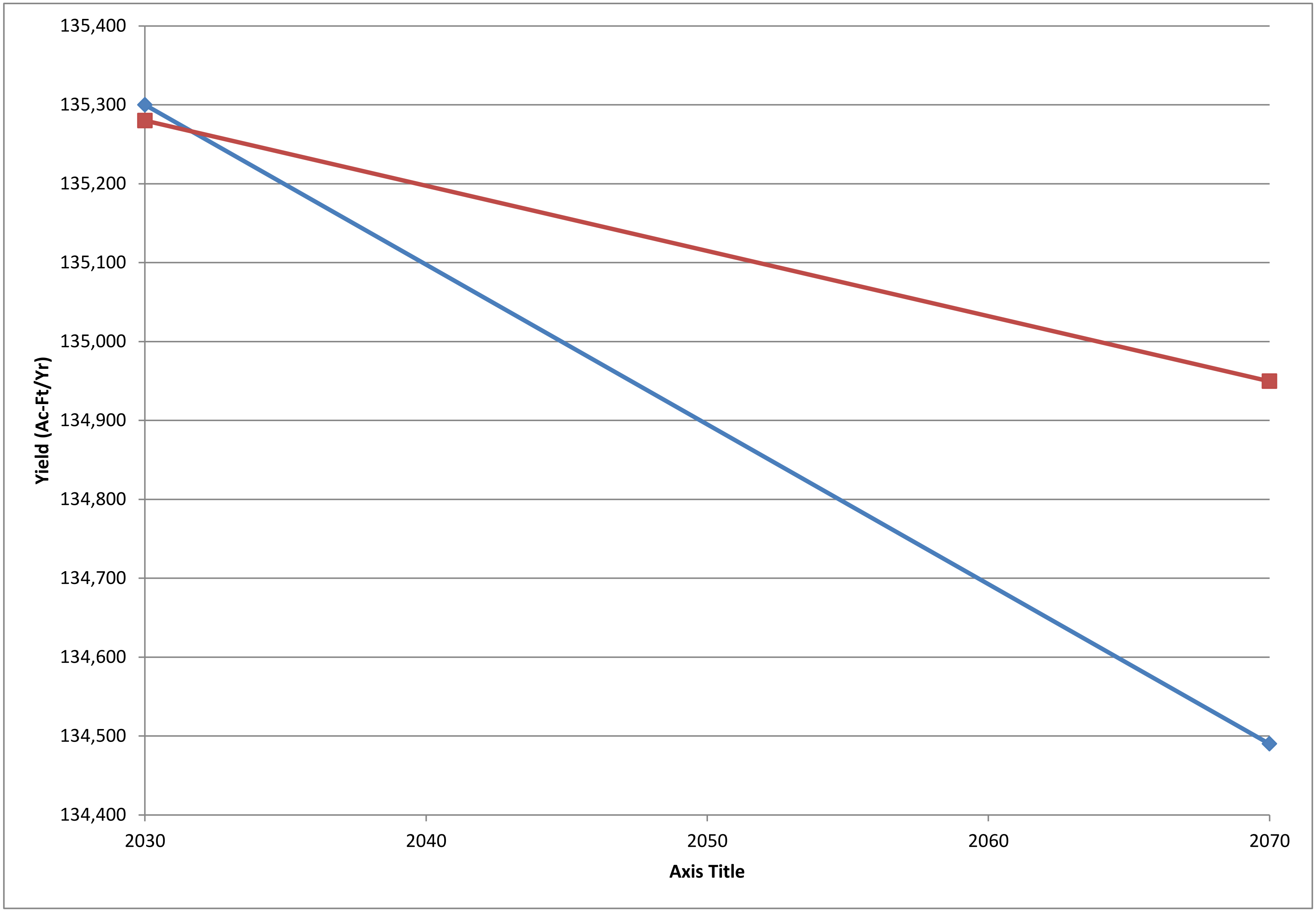

Figure 5-6: Parkhouse I Yield – Patman Subordination

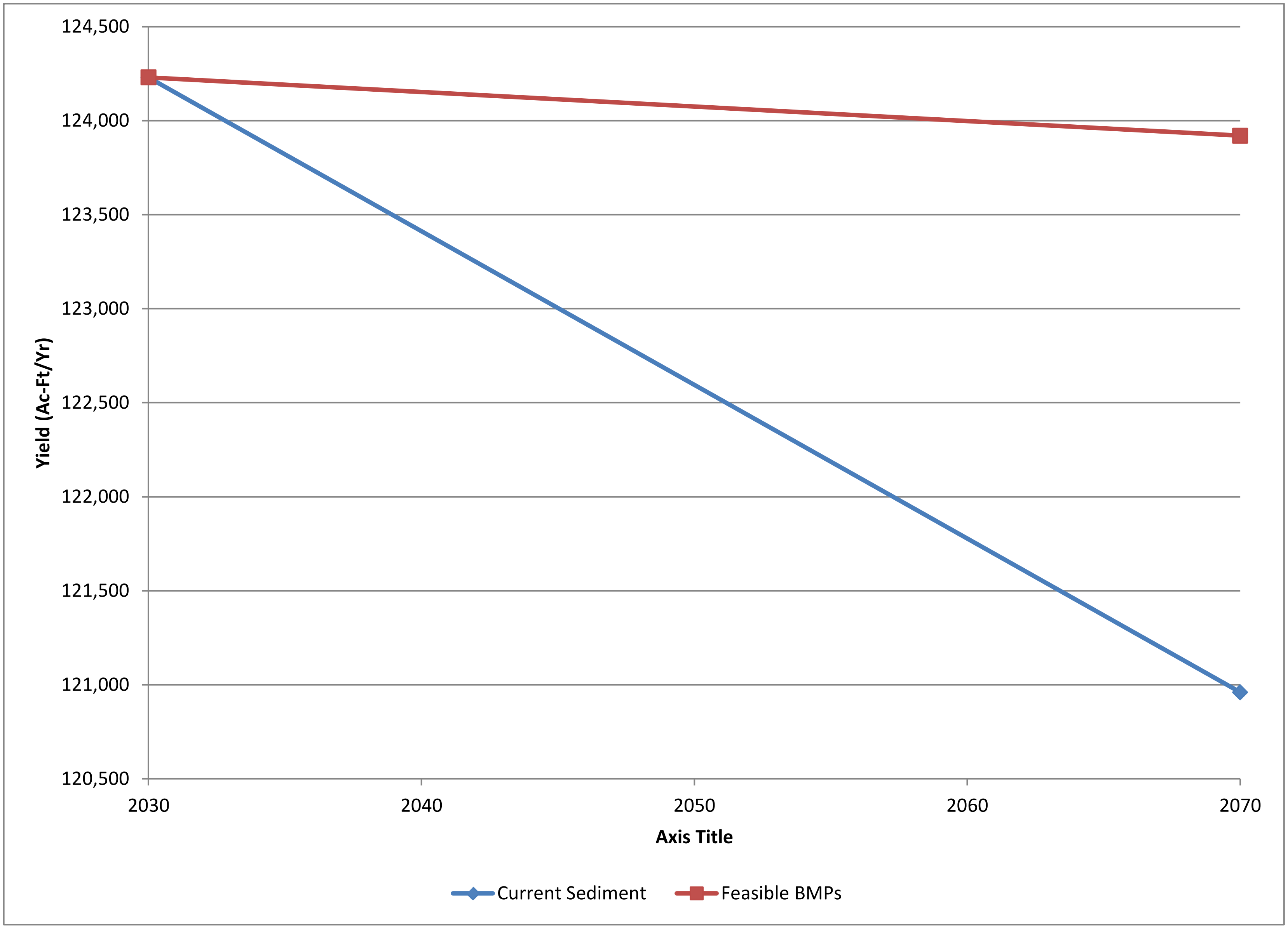

Figure 5-7: Parkhouse II Yield – Priority Order

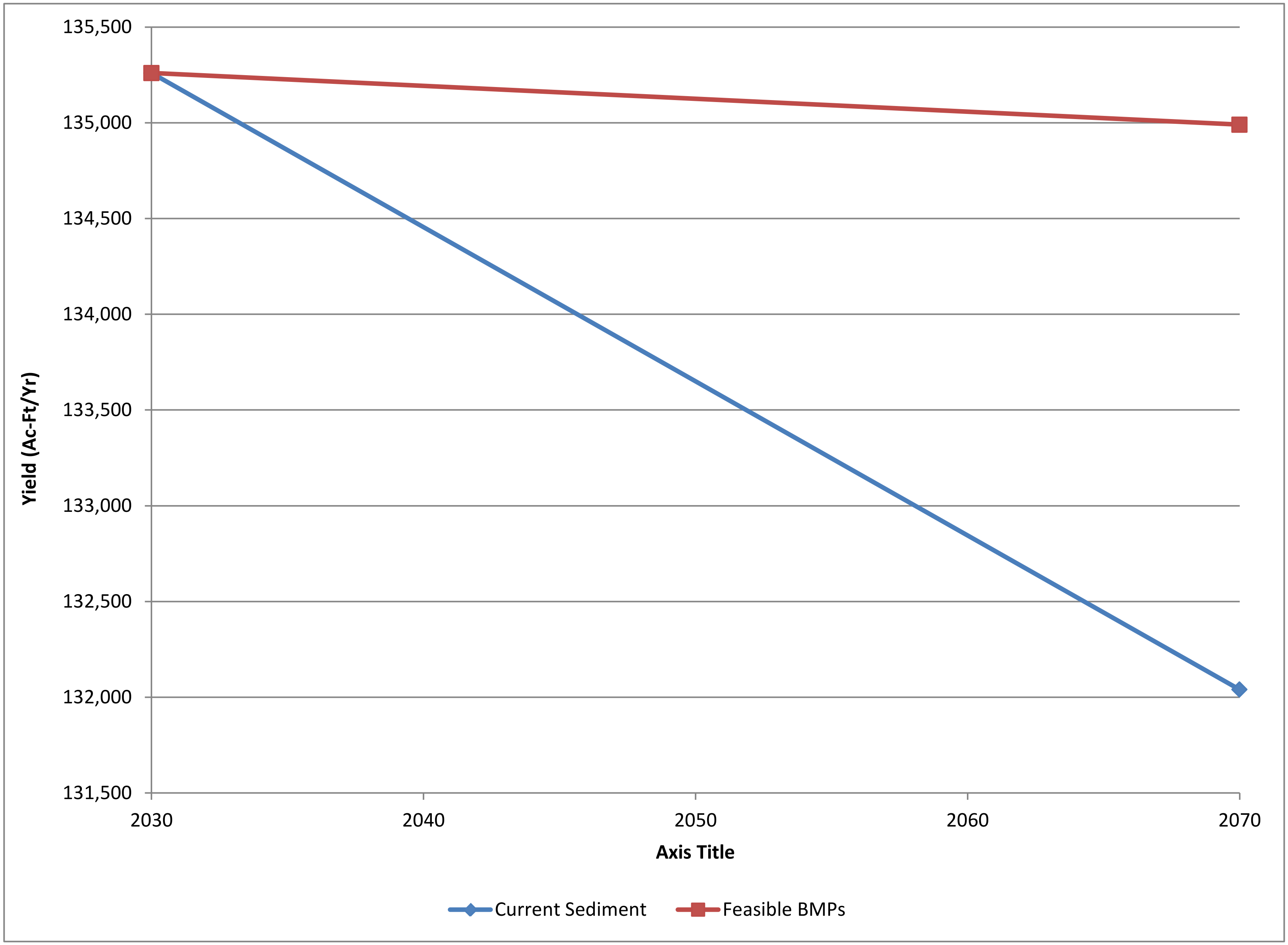

Figure 5-8: Parkhouse II Yield – Patman Subordination

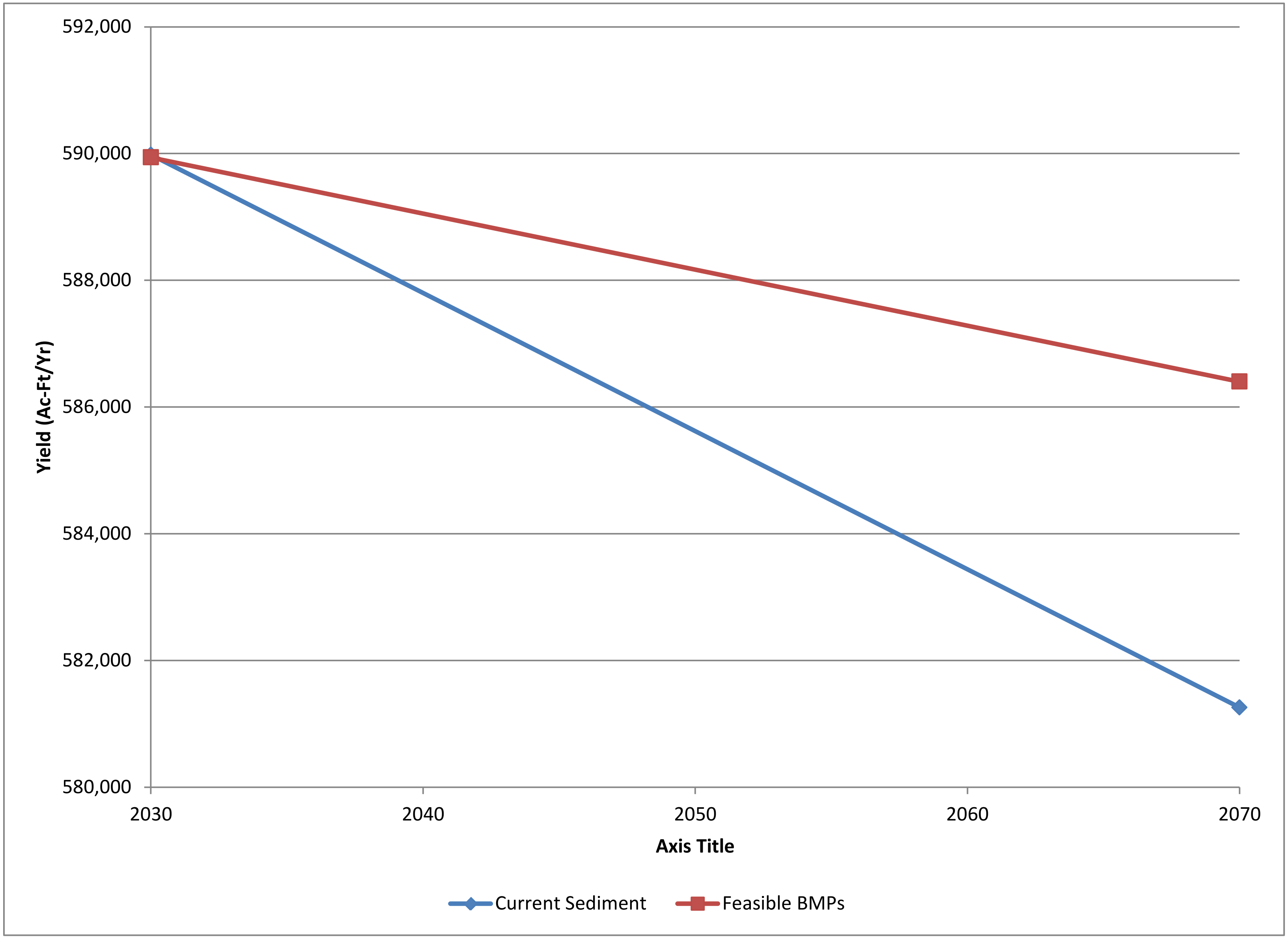

Figure 5-9: Marvin Nichols Yield – Priority Order

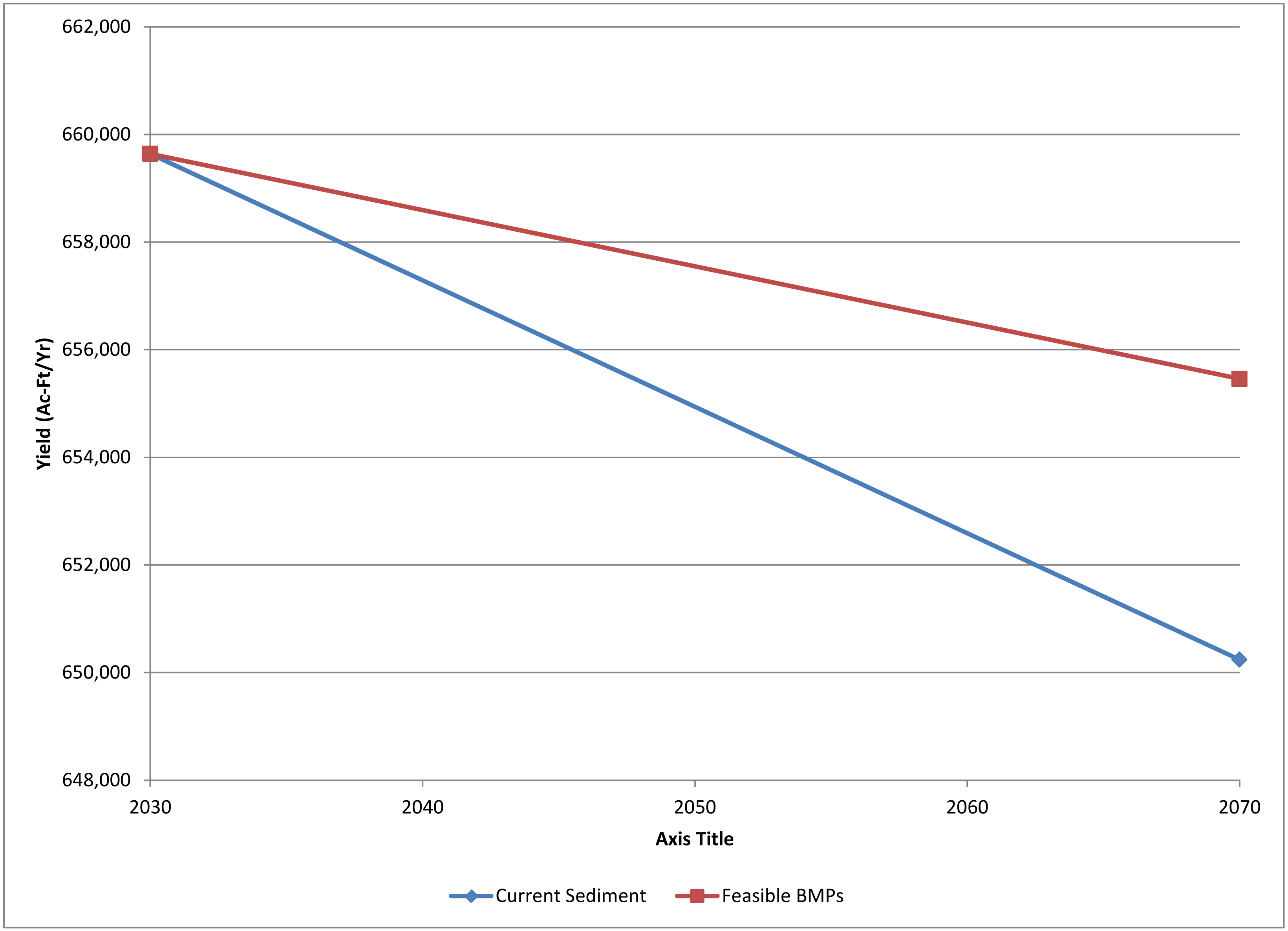

Figure 5-10: Marvin Nichols Yield – Patman Subordination

5.7 SUMMARY

In summary, alternative storage locations in the Sulphur River Basin have the potential to generate new water supply for the region. Some alternatives generate substantial annual yields on their own and appear to have merit as stand-alone alternatives (e.g. Marvin Nichols IA and the larger Talco configurations) while others (Parkhouse I and Parkhouse II) may be more attractive as a component of a project in combination with another storage feature. While reallocation at Jim Chapman Lake would increase the reliability of the water rights held by existing users, it does not appear to generate a substantial amount of "new" water supply.

Likewise, Talco Configuration 3 (adding storage in Jim Chapman reservoir to the Talco storage configuration) does not appear promising, most likely for the same reasons as discussed above. Configuration 3 is not recommended for future evaluation.

Construction of upstream reservoirs, particularly Parkhouse II or Marvin Nichols IA, has a substantial effect on the sediment load to Wright Patman Lake. As compared to the existing condition, rates of sedimentation in Wright Patman would be reduced, with a beneficial effect over time on storage capacity in the reservoir. As expected, however, sedimentation affects the yield over time of any upstream reservoir. The magnitude of this effect varies, but is in general relatively minor.

Synthesis of Best Management Practices to reduce sediment yields throughout the basin results in predicted sediment loads for each reservoir site significantly below the rate predicted for the unmodified watershed condition. Reductions in load range from 59% for Marvin Nichols IA to 92% for Parkhouse II. These reductions in sediment load are in addition to reductions in sediment loads to Wright Patman Lake ranging from 14% to 70% as compared to the unmodified watershed scenario. The reduction in annual sediment load over time has a generally small but beneficial effect on yield and results in cumulative savings over 40 years ranging from 6,000 acre-feet to over 100,000 acre-feet.

6.0 SUMMARY AND CONCLUSIONS

The demand for water within the Sulphur River Basin is expected to grow significantly through 2060. The region possesses potential for significant economic growth, and water availability (or lack thereof) is a primary consideration in whether or not that potential is achieved. This analysis developed a wide variety of population growth and per capita water use scenarios in order to develop a range of municipal water demand projections. The total municipal demand for surface water within the basin by the year 2060 is projected to be between 39,000 ac-ft./yr. to 64,000 ac-ft./yr. Industrial demand within the Sulphur River Basin currently accounts for approximately 70% of the total water demand in the basin. Under the aggressive growth scenarios evaluated for this analysis, that proportion of water use increases by 2060. In the most aggressive industrial growth scenario, the industrial water demand in the basin increases to 210,000 ac-ft./yr. by 2060, with total surface water demand in the Sulphur River Basin predicted to be approximately 274,000 ac-ft./yr.

Using the naturalized flows from the Sulphur Basin Water Availability Model, the Texas portion of the Sulphur River Basin produced an average of 1.5 million ac-ft./yr. from 1951 to 1956, the historical drought-of-record for the basin. Based on the TCEQ database of water rights, approximately 26 percent of this average drought flow (382,000 ac-ft./yr.) is appropriated by existing water rights. An estimated 108,000 ac-ft./yr. of the appropriated water leaves the basin for permit holders in the Metroplex. The amount of unappropriated water in the basin is estimated at approximately 1.1 million ac-ft./yr. on a reliable basis. Sulphur River Basin users currently import approximately 46,800 ac-ft./yr. of surface water from sources in the Red, Sabine, Cypress, and Little River Basins. Those sources appear to be sustainable in those amounts over the period of analysis. Accordingly, there is a total of approximately 1.1 million ac-ft./yr. of water potentially available to meet in-basin needs of 274,000 ac-ft/yr.

This abundance of available and unappropriated water in the Sulphur Basin does not mean that the Sulphur River Basin is without water resources problems and needs. Sufficient storage and/or treatment and distribution infrastructure is lacking in many instances. Some water user groups have an immediate and critical need to develop additional sources or infrastructure, while others have sufficient capacity for now but develop constraints at a future time.

Additional water supply could be developed from the Sulphur River Basin from a variety of sources. Reallocation of storage from flood control or sediment storage to water conservation storage at Wright Patman Lake could substantially increase the firm yield of the project. For scenarios raising the top of the conservation pool (reallocating storage from flood control to water supply), the modeling indicates that firm yield continues to increase significantly with the increase in storage at all elevations. Increasing storage by lowering the bottom of the conservation pool (reallocating dead storage to water supply) also increases yield substantially. With the entire reservoir storage dedicated to water conservation (no sediment storage or flood control storage), the firm yield of the reservoir exceeds 1.2 million acre-feet per year.

Storage in Wright Patman Lake is predicted to decline over time due to ongoing sedimentation from the watershed. Absent a reallocation or other change to Wright Patman Lake operations, the firm yield of the reservoir would be reduced by approximately 12% by the year 2070, even with Lake Ralph Hall in place upstream. The SWAT indicates that sediment yields and loads within the watershed could be substantially reduced by a program of Best Management Practices. Implementation of four practices at 100% of the applicable locations within ten of the basin's sub-watersheds is predicted to reduce sedimentation at Wright Patman by 28% (223,518 metric tons per year.) The reduced loss of storage has a beneficial effect on the predicted firm yield of Wright Patman Lake, generally in the 1-5% range depending on the scenario. On a cumulative basis, the additional water supply available as a result of the reduction in sediment may be several hundred thousand acre-feet.

Alternative storage locations in the Sulphur River Basin also have the potential to generate new water supply for the region. Some alternatives generate substantial annual yields on their own and appear to have merit as stand-alone alternatives (e.g. Marvin Nichols IA and the larger Talco configurations) while others (Parkhouse I and Parkhouse II) may be more attractive as a component of a project in combination with another storage feature. While reallocation at Jim Chapman Lake would increase the reliability of the water rights held by existing users, it does not appear to generate a substantial amount of "new" water supply. Likewise, Talco Configuration 3 (adding storage in Jim Chapman reservoir to the Talco storage configuration) does not appear promising, most likely for the same reasons as discussed above.

Construction of upstream reservoirs, particularly Parkhouse II or Marvin Nichols IA, has a substantial effect on the sediment load to Wright Patman Lake. As compared to the existing condition, rates of sedimentation in Wright Patman would be reduced, with a beneficial effect over time on storage capacity in the reservoir. As expected, however, sedimentation affects the yield over time of any upstream reservoir. The magnitude of this effect varies, but is in general relatively minor.

Synthesis of Best Management Practices to reduce sediment yields throughout the basin results in predicted sediment loads for each reservoir site significantly below the rate predicted for the unmodified watershed condition. Reductions in load range from 59% for Marvin Nichols IA to 92% for Parkhouse II. These reductions in sediment load are in addition to reductions in sediment loads to Wright Patman Lake ranging from 14% to 70% as compared to the unmodified watershed scenario. The reduction in annual sediment load over time has a generally small but beneficial effect on yield and results in cumulative savings over 40 years ranging from 6,000 acre-feet to over 100,000 acre-feet.

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