US Army Corps
of Engineers ®
Fort Worth District

Lake Columbia
Regional Water Supply Reservoir Project
Draft Environmental Impact Statement
Volume 2 - Appendices

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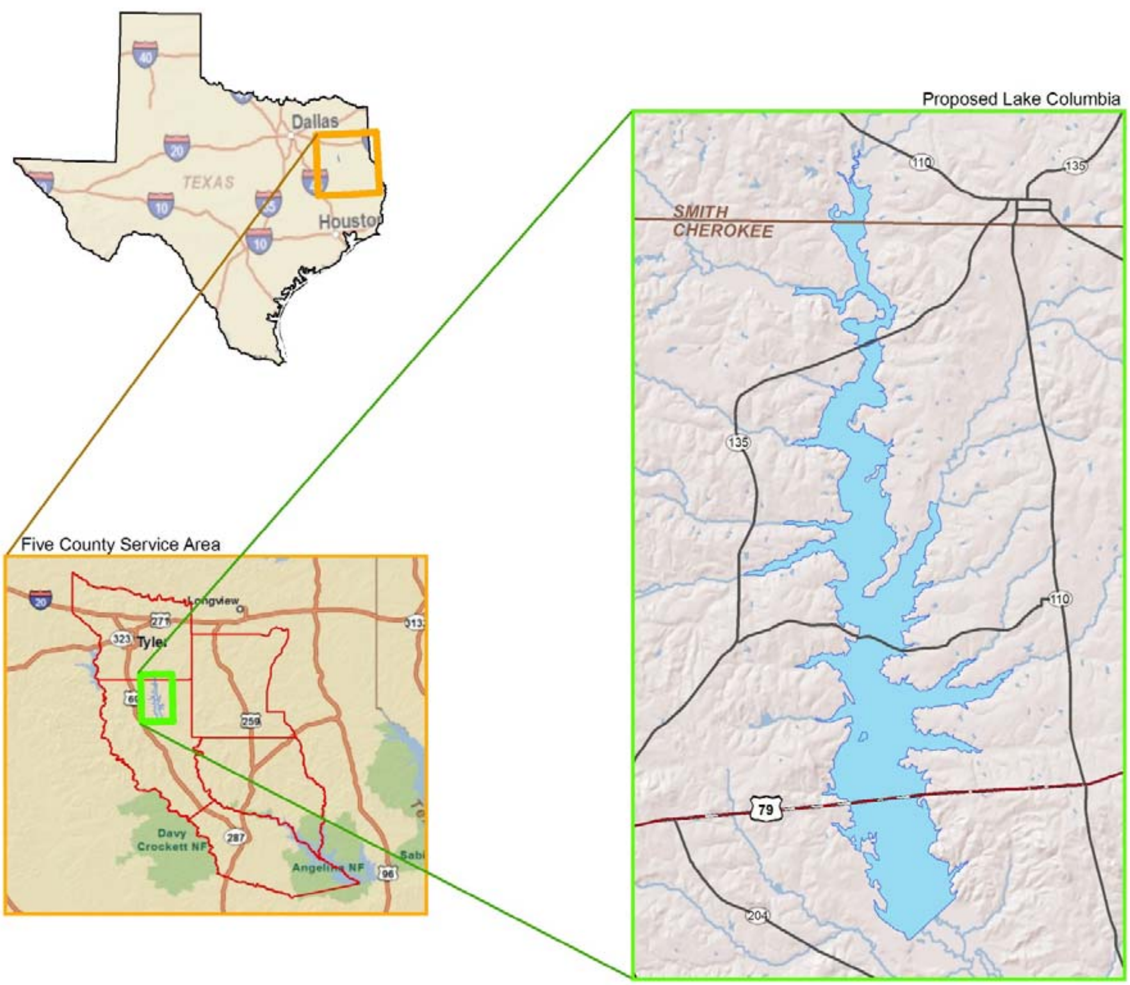

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LAKE EASTEX NEEDS ANALYSIS AND ALTERNATIVES EVALUATION (EPA, 2003)

July 2003

Final

LAKE EASTEX NEEDS ANALYSIS AND ALTERNATIVES EVALUATION

United States Environmental Protection Agency

Dallas, Texas

Gulf Engineers & Consultants

July 2003

Final

Contract No. GS-10F0180K
GEC Project No. 22505101

LAKE EASTEX
NEEDS ANALYSIS AND ALTERNATIVES EVALUATION

Prepared for

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EXECUTIVE SUMMARY

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Lake Eastex is a proposed 85,507 acre feet per year (AFY) water supply reservoir that would serve five East Texas counties (Angelina, Cherokee, Nacogdoches, Rusk, and Smith). Twenty entities (cities, water supply corporations, a manufacturer, and a county) are presently participating in the development of the lake, which would be built under the auspices of the Angelina & Neches River Authority (ANRA). A Clean Water Act Section 404 permit application for the reservoir has been submitted to the Fort Worth District Corps of Engineers. The Region 6 (Dallas) office of the U.S. Environmental Protection Agency (EPA) has a responsibility for reviewing the application pursuant to the 404(b)(1)Guidelines [40CFR Part 230] (Guidelines). One of EPA's primary regulatory review requirements under the Guidelines is whether there are any practicable, less environmentally damaging alternatives to the lake, including the no action alternative. This report provides background information to EPA with regard to an alternatives analysis.

The report discusses the purpose of the analysis, prior planning reports concerning Lake Eastex, information in the State Water Plan concerning water supply needs in the five-county region, and potential alternative water sources. Appendices contain information from the State Water Plan relevant to water supply needs in the five-county region and the engineering cost estimation worksheets for the various alternatives.

The needs analysis in this report is based on secondary data obtained from the East Texas Region report of the 2002 State Water Plan. The regional report covers 20 counties, including the five counties that would be served by Lake Eastex. The regional report provides supply, demand, and deficit figures for every city and category of use (e.g., steam electric power) in the five-county region that would sustain a deficit during at least one decennial year during the 50-year planning period from 2000 to 2050. The regional report analyzes alternatives and related costs for meeting those deficits and provides recommended strategies for meeting those deficits. No attempt was made to verify or enhance these data because they are recent and were generated by local water supply planners using state planning criteria.

According to the regional report, the 2050 deficit (which is the highest deficit) in the five-county region is 58,078 AFY. There are many cities and categories of use in the five-county region that will not have water supply deficits through 2050. Of those that do, there are many for which Lake Eastex is not the recommended strategy because nearby, reliable, lower-cost sources are readily available. Precision with respect to the entities and deficits for which Lake Eastex is the recommended strategy is not possible, primarily because water supply corporations (some of which would benefit from Lake Eastex) are lumped in a county-other category.

The highest estimated 2050 deficit for which Lake Eastex is the recommended strategy in the regional report is 20,908 AFY, and the most likely estimate is 19,778 AFY. Lake Eastex would meet about a third of the five-county deficit. Smith County has no deficits that would be met by Lake Eastex. The deficits for Rusk, Nacogdoches, and Angelina counties are negligible (509 AFY) and do not begin until 2050. Almost all of the deficits for which Lake Eastex is the recommended strategy occur in Cherokee County, and most of those deficits are sustained by a power company that is not an ANRA participant and whose plans are not firm.

Lake Eastex is not the recommended strategy for about half of the current Lake Eastex participants. Further, there are other existing sources of water for meeting the identified deficits. These alternatives are identified and costed out in the regional report and cumulatively would be less environmentally damaging than Lake Eastex because they would concentrate on the use of existing sources.

Alternatives for supplying the 85,507 AFY yield of Lake Eastex are analyzed in the present report. These analyses are essentially concerned with the practicality and costs of obtaining and transporting by pipeline from other sources to the Lake Eastex site the amount of water that would be yielded by Lake Eastex. Split distribution systems are also considered, mimicking the original planning reports on Lake Eastex that assume 60 percent distribution to a southern delivery point and 40 percent distribution to a northern delivery point (although there is no current basis for such an assumption). In addition, consideration is given to supplying from one source the 2050 deficit of 19,778 AFY recommended for satisfaction by Lake Eastex in the State Water Plan.

Proposed reservoirs are not considered because of their uncertainty. Groundwater was considered as a potential source but was rejected because of quantity and quality problems. B. A. Steinhagen Lake was considered but rejected because of its distance from the Lake Eastex site and because its use would involve complicated water rights issues. That left Toledo Bend Reservoir, Sam Rayburn Reservoir, and Lake Palestine as existing sources of additional water to be analyzed in this report.

Sam Rayburn Reservoir could supply the required amount of water. However, in order to obtain this water, it would be necessary to reallocate flood control storage in the reservoir to water supply storage. This would raise the lake level, disrupting existing facilities and usages and causing environmental damages, and would require an Act of Congress. Use of Sam Rayburn Reservoir to secure the yield of Lake Eastex is a possible, but not a practical, alternative.

Toledo Bend Reservoir could supply the required amount of water. The construction and operation and maintenance (O&M) cost for a pipeline from Toledo Bend Reservoir to the Lake Eastex site would be $176,030,440 and the total annual cost would be $19,204,570, providing the Lake Eastex yield at 69 cents per thousand gallons. The split-delivery version of this alternative would supply water to the region at a cost of 66 cents per thousand gallons. Both of these are viable alternatives and would be less environmentally damaging than Lake Eastex.

Lake Palestine could supply the required amount of water, but would require the purchase of water rights from an existing holder. The construction and O&M cost for a pipeline from Lake Palestine to the Lake Eastex site would be $36,314,850 and the total annual cost would be $10,396,016, providing the Lake Eastex yield at a cost of 37 cents per thousand gallons. The Lake Eastex yield would be available from Lake Palestine only if Dallas would be willing to sell its water rights. Because Dallas is currently developing plans to use these water rights, use of Lake Palestine to obtain the Lake Eastex yield is a possible, but not a practical, alternative.

Lake Palestine could supply the 2050 deficit of 19,778 AFY that the East Texas Region report recommends for satisfaction by Lake Eastex. The construction and O&M cost for this alternative would be $16,699,980 and the total annual cost would be $3,086,372, providing 21,000 AFY at a cost of 45 cents per thousand gallons. This alternative would require the acquisition of the portion of the City of Palestine's water rights in Lake Palestine that is presently not being used. Lake Palestine is a potential alternative for meeting the deficits for which Lake Eastex was the recommended strategy in the East Texas Region report, and this alternative would be less environmentally damaging than Lake Eastex. Cost estimates for all alternatives do not include compensatory mitigation costs because such costs are not known at this time.

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I. INTRODUCTION

LAKE EASTEX

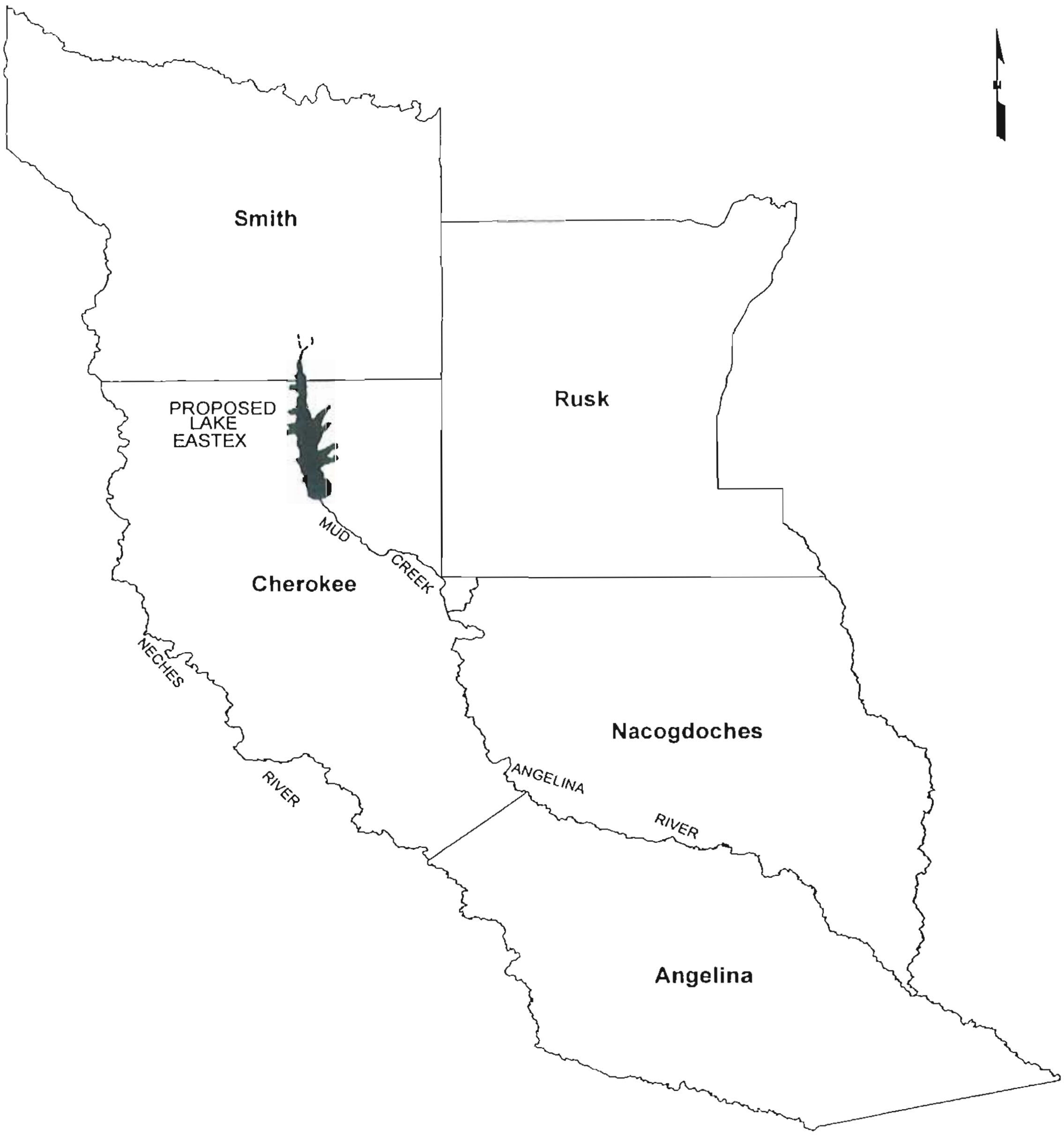
Lake Eastex (Figure 1) is a proposed lake that would be constructed under the auspices of the Angelina & Neches River Authority (ANRA). ANRA's webpage indicates that "The primary purpose of Lake Eastex is water supply. Lake Eastex is not a flood control reservoir nor is it envisioned to have any hydroelectric capabilities. The lake will be located in the Mud Creek floodplain, approximately 10 miles northeast of Jacksonville, Texas, primarily in Cherokee County, with the northern limits of the lake extending into Smith County. It will be 14 miles in length, 1.5 miles wide; cover 10,000 acres; contain 187,839 acre feet of water; and provide 85,507 acre feet of water per year to water supply customers."

Lake Eastex is envisioned as a water supply source for five counties in the 20-county East Texas Region water planning area, which is designated by the Texas Water Development Board (TWDB) as Region I. The five counties that are identified for servicing by the lake are Angelina, Cherokee, Nacogdoches, Rusk, and Smith. The lake is not envisioned in any planning documents to meet all of the water supply needs in the five-county region. Entities that might use the lake for water supply include 20 that are presently participating with ANRA in the development of the project. The 20 entities are comprised of nine cities, nine water supply corporations (WSCs), one county, and one manufacturing facility. Other entities that might use the lake are identified in the East Texas Region report, which is an integral part of the 2002 State Water Plan.

PURPOSE OF THE ANALYSIS

ANRA submitted a 404 permit application for Lake Eastex to the Fort Worth District Corps of Engineers in October 2000. The Environmental Protection Agency (EPA) has a responsibility for reviewing the application. To assist in its review of the application, EPA contracted G.E.C., Inc. (GEC) to provide information on whether the lake is needed for water supply and whether there are any practical, less environmentally damaging alternatives. The environmental concern arises from the preliminary estimates that the lake would inundate about 4,500 acres of U. S. waters, including 3,800 acres of forested wetlands.

There are many different reasons why a lake might be needed, including such things as recreation. However, ANRA indicates (published information and personal communication) that the purpose of the lake is water supply. For a water supply lake, need is generally understood as water supply deficits projected over a 50-year project planning period, with justification provided by an explanation of how the lake would contribute to meeting those needs. Deficits for the five-county region and an explanation of how Lake Eastex could contribute to meeting those needs are presented in the East Texas Region report. As a consequence, the present analysis is largely concerned with a review of the existing information.



Source: G.E.C., Inc.

Figure 1. Lake Eastex Region

Alternatives to Lake Eastex have been analyzed in prior reports and are summarized in the 404 permit application. The analyses were directed toward a regional distribution system that would meet total projected deficits for the five-county region and used combinations of six sources and two delivery points corresponding to the distribution of total deficits in the five-county region and found that Lake Eastex was the least-cost alternative. The present analysis includes a similar dual delivery approach, but focuses on a simpler approach, which is to determine whether there are any sources that could provide the 85,507 acre feet per year (AFY) that would be yielded by Lake Eastex and to analyze the costs of transporting that water to the Lake Eastex site. The cost estimates for these alternatives will provide a ready comparison to the cost estimates for Lake Eastex once they have been developed in a final form.

II. PRIOR REPORTS

1991 LAKE EASTEX REPORT

The two-volume *Lake Eastex Regional Water Supply Planning Study* was prepared by Lockwood, Andrews & Newnam for ANRA in August 1991. Volume 1, the Engineering and Financial Analysis, is concerned with the project background, water supply alternatives for the five-county region, and the engineering and financial issues associated with the proposed Lake Eastex. Volume 2, Environmental Inventory and Issues, describes the baseline environment and potential environmental impacts.

The introduction indicates that Lake Eastex was conceived in 1978 by Cherokee County community leaders (primarily Jacksonville) in conjunction with ANRA to satisfy long-term municipal and industrial water supply needs and particularly to meet an immediate opportunity for the establishment of a lignite mine that would use between 20,000 and 30,000 AFY. Although the opportunity for the lignite mine soon disappeared, the idea of the lake as an important factor for county development did not; and it was assumed by ANRA that haste was required because of increasing difficulties in developing water projects.

Financial support for obtaining a permit from the Texas Water Commission was consolidated by ANRA from 1981 to 1983, at which time there were 14 project participants: the cities of Jacksonville and Rusk in Cherokee County; the City of Lufkin in Angelina County; the cities of New London, Overton, and Henderson in Rusk County; the cities of Arp and Troup in Smith County; Cherokee County; Reklaw WSC; Angelina County; Angelina County WSC; Texas Utility Services; and Leo Childs. Lake Eastex had developed into a regional project.

A permit application was submitted in September 1984 and approved in June 1985. When it became time to obtain financial commitments for project planning, Texas Utility Services and Angelina County withdrew, and the remaining 12 were joined by 11 new participants: the City of Nacogdoches in Nacogdoches County; Temple-Inland Forest Products in Angelina County; Blackjack WSC; Craft-Turney WSC; Jackson WSC; New Summerfield WSC;

Redland WSC; Star Mountain WSC; Walnut Grove WSC; Woodlawn WSC; and Wright City WSC. The project had assumed its present five-county regional dimension.

Water demand projections are presented in the Lake Eastex report for the five-county region for the decennial years from 1990 to 2040. These projections are generally in keeping with Texas Water Development Board projections, using the high per capita use without additional conservation high population series (October 1989 draft). The major departure was the inclusion under industrial demand estimates of needs for industries not currently in the region or with plans to expand or locate in the region, which was done in recognition that surface water can be an economic development tool. A minimum regional demand for new industries of 10,000 AFY and a maximum regional demand of 20,000 AFY was projected for each decennial year, producing a minimum total demand in 2040 of 304,526 AFY and a maximum total demand of 314,526 AFY.

Groundwater problems are discussed in the Lake Eastex report. Groundwater use is projected to be 85,207 AFY at a minimum in 2040 and 104,338 AFY at a maximum, depending on availability assumptions. Surface water demand is defined as the portion of total water demand that cannot be met by groundwater sources, with the maximum surface water demand determined by subtracting the minimum groundwater use projection from the maximum total demand. This produces a minimum surface water demand of 200,188 AFY and a maximum demand of 229,319 AFY.

Reservoirs within or near the five-county region had the capacity at the time the report was developed to supply through permits or contracts 222,825 AFY to entities within the region. Although part of this water was not used, the study did not consider this unused water as available for use. As a consequence, the 2040 minimum demand that could be met by existing supplies (assuming minimum groundwater supply) was 118,006 AFY, and the maximum was 119,217 AFY. Subtracting these numbers from the minimum and maximum demands for 2040 for the five-county region produced a minimum surface water deficit of 82,182 AFY and a maximum deficit of 110,102 AFY.

Because of groundwater limitations, deficits of this magnitude could only be met by surface water according to the report, either through a new project such as Lake Eastex or other existing or proposed surface water sources. A thorough analysis was made of the availability of supplies in existing surface water sources. The results are presented in Table III.8 of the report and are re-presented here as Table 1.

Most of the existing sources are eliminated in the report because of prior commitments, and most of the proposed sources are eliminated because they are not currently being pursued, could not be developed within 10-15 years, or would produce unacceptable environmental damages. That leaves the existing sources of Toledo Bend Reservoir (375,000 AFY uncommitted), Sam Rayburn Reservoir by way of B. A. Steinhagen Lake (370,000 AFY uncommitted), and Lake Palestine (5,000 AFY uncommitted) and the proposed sources Lake

Table 1. Existing Surface Water Alternatives

Basin and Reservoir	Owner	Permitted Diversion (ac-ft/yr)	Uncommitted Water (ac-ft/yr)	Status/Comments
NECHES BASIN				
Sam Rayburn Reservoir/B.A. Steinhagen Lake	LNVA/COE	820,000	370,000	Available from LNVA via Lake Steinhagen
Lakes Jacksonville & Acker	City of Jacksonville	6,200	0	Committed to Jacksonville
Lake Nacogdoches	City of Nacogdoches	22,000	0	Committed to Nacogdoches
Lake Palestine	UNMWA	238,110	5,000	Available with approval of UNMWA
Lakes Tyler & Tyler East	City of Tyler	40,325	0	Committed to Tyler
Lake Athens	Athens MWA	8,500	0	Committed to Athens
Lake Striker	Angelina-Nacogdoches Cos. WCID #1	20,600	5,600	Not Available-TP&L & Champion have first options to buy
Lake Pinkston	City of Center	3,800	0	Committed to Center
Lake Kurth	Champion International Corp.	19,100	0	Committed to Champion
SABINE BASIN				
Lake Cherokee	Cherokee Water Company	62,400	0	Committed to Longview & SW Electric Co.
Lake Gladewater	City of Gladewater	1,679	0	Committed to Gladewater
Lake Martin	Texas Utilities Elec. Co.	25,000	0	Committed to TU Electric
Lake Tawakoni	SRA	230,750	N/A	Some small amount uncommitted but is reserved for local needs
Toledo Bend Reservoir	SRA	750,000	375,000	Available with approval from SRA
Lake Fork	SRA	164,940	0	Committed to Dallas, Longview, Tenneco, TUGO, and Phillips Coal
Lake Murvaul	Panola County FWSD	22,400	0	Committed to Carthage
TRINITY BASIN				
Cedar Creek Reservoir	Tarrant County WCID #1	175,000	N/A	Some amount uncommitted, but reserved for in-basin needs
Richland-Chambers Reservoir	Tarrant County WCID #1	210,000	N/A	Some amount uncommitted, but reserved for in-basin needs
Bardwell Lake	TRA/COE	9,600	0	Committed to Ennis, Flood Control
Benbrook Lake	City of Fort Worth/COE	2,371	0	Committed to Benbrook WSA & Fort Worth, Flood Control
Grapevine Lake	Grapevine, Dallas COE	161,250	0	Committed to Grapevine & Dallas, Flood Control
Joe Pool Lake	TRA/COE	17,000	0	Committed to local needs, Flood Control
Lavon Lake	Texas MWD/COE	104,000	0	Committed to Texas MWD, Flood Control
Lewisville Lake	Dallas and Denton/COE	598,900	0	Committed to Dallas & Denton, Flood Control
Navarro Mills Lake	TRA/COE	19,400	0	Committed to Dawson, Corsicana, Post Oak WSC, Texas Industries
Ray Roberts Lake	Dallas & Denton/COE	799,600	0	Committed to Dallas and Denton
Lake Brideport	Tarrant County WCID #1	93,000	0	Committed to Brideport, Texas Industries, Wise Co. WSD, West Wise Rural WSC, Gifford-Hill
Eagle Mountain	Tarrant County WCID #1	159,600	0	Committed to Tarrant Utility Co., Tarrant Co. MUD #1, Tesco, Lone Star Ind., Community WSC
Lake Livingston	TRA & City of Houston	1,254,000	0	Committed to TP&L & Houston
Mountain Creek Lake	TP&L	6,400	0	Committed to TP&L
Lake Ray Hubbard	City of Dallas	89,700	0	Committed to Dallas
Lake Worth	City of Fort Worth	13,393	0	Committed to General Dynamics
Houston County Reservoir	Houston County WCID #1	7,000	0	Committed to Crockett, Grapeland, Lovelady, Southwest Chemical & Consolidated WSC
Lake Fairfield	TP&L, DP&L, TESCO	14,150	0	Committed to Power Generation
Forest Grove	Texas Utilities Services	9,500	0	Committed to Texas Utilities for Power Generation

Source: Table III.8 in *Lake Eastex Regional Water Supply Planning Study*, Volume 1.

Eastex (85,507 AFY), Little Cypress Reservoir (40,000 AFY uncommited), and Sam Rayburn Reservoir through reallocation of flood storage to water supply storage.

Eleven alternatives are evaluated for meeting the 110,102 AFY maximum 2040 deficit. Cost estimates were prepared for eight, with three eliminated from consideration because of obvious cost considerations. Most of the eight carried forward are combinations of sources because only Toledo Bend Reservoir and Sam Rayburn Reservoir (by way of B. A. Steinhagen Lake and by way of storage reallocation) have uncommited yields that could meet the maximum deficit. The alternatives are evaluated in terms of delivery of raw water by pipeline of 44,214 AFY to a northern delivery point west of New Summerfield at the lower end of the Lake Eastex site and 65,888 AFY to a southern delivery point near the Angelina River at U.S. 59.

Lake Eastex would not have a sufficient yield to meet the 110,102 AFY deficit by itself. The two alternatives involving Lake Eastex are the lowest-cost alternatives, largely because Lake Eastex would provide much of the water to the southern delivery point by way of the Angelina River (rather than by pipeline, as with the other alternatives). The least-cost alternative (10a) is Lake Eastex with Sam Rayburn Reservoir through storage reallocation, incorporating aspects of the Angelina County Regional Water Supply Plan, in which Lufkin would obtain water from Sam Rayburn and act as the distribution point for a portion of the southern delivery point. This alternative would deliver 110,102 AFY to the two delivery points at 51 cents per thousand gallons. The next lowest-cost alternative is 10 (Lake Eastex with Sam Rayburn Reservoir through storage reallocation), which would deliver water to the two delivery points at 53 cents per thousand gallons. Sam Rayburn Reservoir through storage reallocation alone would deliver water by pipeline at 70 cents per thousand gallons to the two delivery points, and Toledo Bend Reservoir alone would deliver water by pipeline at 96 cents per thousand gallons to the two delivery points. The report also points out (p. III-49) that if the regional deficit fell below the 85,507 AFY that could be supplied by Lake Eastex, Lake Eastex alone would be the least-cost alternative.

In considering the needs of the then-participants in the Lake Eastex project, the Lake Eastex report does not provide an analysis of deficits for each participant or attempt to demonstrate that Lake Eastex is the least-cost alternative for each participant. Rather, it presents a table of demands (rather than deficits) for the participants (Table IV.6, re-presented here as Table 2), develops four delivery systems for meeting those demands, and provides costs per thousand gallons for each participant so that the participants can make their own determinations as to whether Lake Eastex would be the least-cost alternative. Consequently, the report does not clarify whether the lake would satisfy any deficits or whether it would be used by anyone.

At the time of the analysis, the City of Nacogdoches with a 2040 demand of 15.5 MGD (one MGD is equal to about 1,120 AFY) accounted for one-third of the total 46.73 MGD demand for the 23 participants, which included a number of small WSCs. Other significant demands were registered by Temple-Inland (9.19 MGD), the City of Jacksonville (5.38 MGD), the City of Henderson (3.87 MGD), the City of Lufkin (3.79 MGD, which is the portion of this city's demand that would be supplied by Lake Eastex), Walnut Grove WSC (1.30 MGD), and the City of Rusk (1.00 MGD). The other 17 participants had demands of under 1.00 MGD, including

Cherokee County with zero demand because it is not a water user or supplier. Sixteen participants were placed in a northern distribution system, four were placed in a southern system, and separate systems were developed for the City of Nacogdoches and Temple-Inland because of their geographic isolation from the clusters.

Table 2. Projected Demands for Project Participants
Average Day Projected Demands in MGD

Entity	Year				
	2000	2010	2020	2030	2040
Angelina WSC[3]	0	0	0.04	0.12	0.17
City of Arp	0.23	0.26	0.30	0.35	0.37
Blackjack WSC	0.10	0.10	0.11	0.12	0.12
Cherokee County[2]	0	0	0	0	0
Leo F. Childs	0.08	0.08	0.08	0.08	0.08
Craft-Turney WSC	0.50	0.54	0.59	0.62	0.64
City of Henderson	2.78	3.03	3.32	3.63	3.87
Jackson WSC	0.28	0.32	0.37	0.43	0.45
City of Jacksonville	4.26	4.70	4.95	5.24	5.38
City of Lufkin[1]	0	0	0.97	2.58	3.79
City of Nacogdoches	9.86	11.36	12.87	14.29	15.05
City of New London	0.42	0.45	0.53	0.62	0.66
New Summerfield WSC	0.13	0.14	0.16	0.17	0.17
City of Overton	0.50	0.54	0.60	0.66	0.70
Redland WSC[1]	0	0	0.03	0.08	0.12
Reklaw WSC	0.05	0.06	0.06	0.06	0.07
City of Rusk	0.79	0.87	0.92	0.97	1.00
Star Mountain WSC	0.22	0.25	0.29	0.34	0.36
Temple-Inland, Inc.	9.19	9.19	9.19	9.19	9.19
City of Troup	0.41	0.46	0.50	0.55	0.59
Walnut Grove WSC	0.79	0.91	1.05	1.22	1.30
Woodlawn WSC[3]	0	0	0.03	0.09	0.13
Wright City WSC	0.45	0.51	0.59	0.69	0.73
Subtotal	31.04	33.77	37.55	42.10	44.94
Other Angelina County Regional System Demands	0	0	0.43	1.13	1.79
Total Demand on Lake Eastex	31.04	33.77	37.98	43.23	46.73

1 As stated in Section IV.C.2., the delivery systems for the participants have been sized to convey all of the year 2040 demands. This approach was taken in order to provide a consistent basis for economic comparison between current sources and a Lake Eastex supply. Exceptions have been noted.

2 This participant is also a participant or is recommended to be a participant in the Angelina County Regional System. Demand which is shown is the portion of the total demand, which has been assumed as being supplied from Lake Eastex. Total 2040 demands which were used for sizing the Southern distribution system are as follows: Angelina WSC = 0.55 mgd; Lufkin = 11.81 mgd; Redland WSC = 0.37; and Woodlawn WSC = 0.40 mgd.

3 Cherokee County, as an entity, is not a water user and will not be diverting water out of Lake Eastex; therefore, no demand is shown.

Source: Table IV.6 in *Lake Eastex Regional Water Supply Planning Study*, Volume 1.

Construction cost estimates were prepared for Lake Eastex and for the delivery systems. Four alternative construction costs are presented for the lake, depending on mitigation cost assumptions and whether FM 2064 would be replaced or abandoned. These estimates range from $85,357,000 to $103,193,000 (in 1990 dollars). The least-cost alternative would produce raw water at a cost of 37 cents per 1,000 gallons. The highest-cost alternative would produce raw water at a cost of 45 cents per 1,000 gallons. The project financing plan was based on the assumption that 60 percent of the reservoir yield would be purchased by project participants and 40 percent by the State of Texas.

The second volume of the 1991 report contains an environmental inventory and discusses environmental impacts. Socioeconomic impacts of lake construction are summarized on page III-13:

1. The potential economic growth projected for the region cannot be achieved apart from the development of an adequate water supply.

2. Construction of the lake would provide a short-term boost to the local economy through construction employment and attendant housing, food, and service needs.

3. The lake would provide an opportunity for the attraction of manufacturers (particularly those that are water intensive), which if achieved would provide a large boost to the local and regional economy.

4. The only adverse impact would be a small short-term decrease in ad valorem tax income for Cherokee and Smith counties.

In addition, the report states that the lake would have a positive impact on housing development, recreational opportunities, and economic activities related to recreation.

1992 LAKE EASTEX REFORMULATION

In 1992, the alternatives were reformulated by Lockwood, Andrews & Newnam in the *Revised Surface Water Alternatives Analysis*. The reformulation looks at Lake Eastex as a stand-alone project rather than as a component of a regional water plan. Alternatives were identified and costed out for providing the 85,507 AFY that would be supplied by Lake Eastex rather than the originally identified deficit of 110,102 AFY. These were almost the same alternatives as those considered in the 1991 report. However, Alternative 10 (Lake Eastex with Sam Rayburn Reservoir with storage reallocation) was modified to Lake Eastex only. In addition, Alternative 10a (Lake Eastex with Sam Rayburn Reservoir through storage reallocation, incorporating aspects of the Angelina County Water Supply Plan), which was the least-cost alternative in the 1991 report, was excluded (p. 1) because "it is a variation on the utilization of a supplement to Lake Eastex." The same delivery points and pump stations were assumed.

As shown in Table 3, in most cases the revised estimates of the costs of delivered water are slightly higher than the original estimates (partly because the cost per thousand gallons delivered increases as the quantity delivered decreases). The cost figures for Alternative 10 are not comparable because they refer to two different projects. The revised costs for Alternative 10 exclude the original costs connected with the use of Sam Rayburn Reservoir, including the costs for reallocation, pumps, and a transmission line to the southern delivery point. The remaining costs (Table 4, which appear to be in 1991 dollars) provide an estimate of the construction cost for Lake Eastex (reflected in the raw water cost) and the cost of transmitting the water from the northern delivery point at Lake Eastex to the Angelina River. The Lake Eastex only alternative was found to be the least-cost alternative, delivering water to the regional system at 49 cents per thousand gallons (again, largely because a pipeline would not be needed for conveyance to the southern delivery point). The next lowest-cost alternative (at 72 cents per thousand gallons) was Sam Rayburn Reservoir with storage reallocation (Table 5 and Figure 2). The Toledo Bend Reservoir alternative (Table 6 and Figure 3) would provide water at 97 cents per thousand gallons.

Table 3. Cost of Delivered Water Comparisons
(cost per 1,000 gallons)

Alternative	1991	1992
1 Sam Rayburn Reservoir (via B. A. Steinhagen Lake)	1.1198	1.1266
2 Toledo Bend Reservoir	0.9608	0.9667
3 Toledo Bend Reservoir with Lake Palestine	0.9493	1.0079
4 Toledo Bend Reservoir with Lake Palestine and Little Cypress Reservoir	0.9134	0.9816
6 Sam Rayburn Reservoir via Storage Reallocation	0.7028	0.7166
7 Sam Rayburn Reservoir (via storage reallocation) with Lake Palestine and Little Cypress Reservoir	0.7216	0.7690
10 Lake Eastex with Sam Rayburn Reservoir/Lake Eastex Only	0.5286	0.4907

Source: *Revised Surface Water Alternatives Analysis.*

Table 4. Alternative 10: Lake Eastex

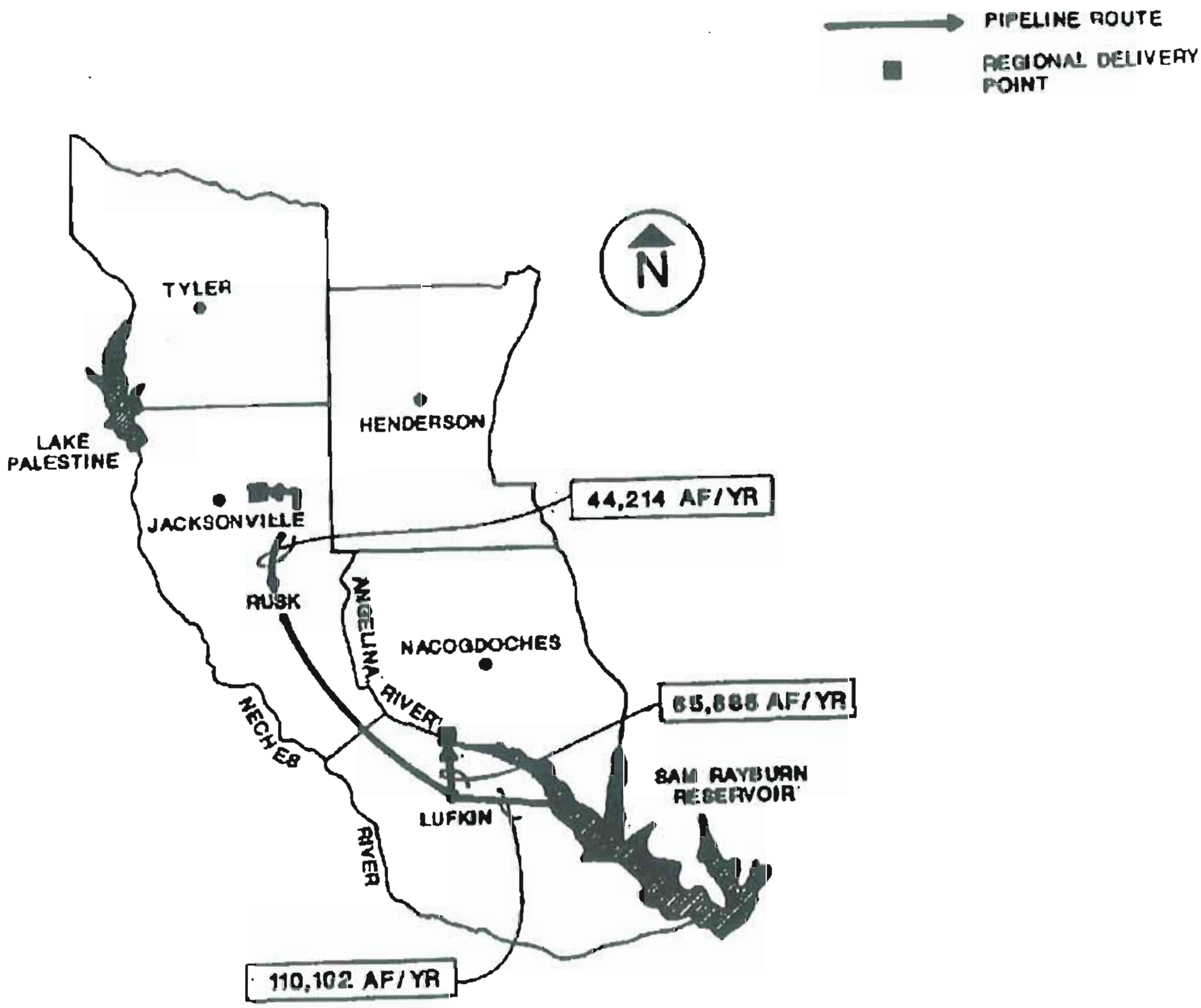
CAPITAL COSTS	
Intake/Pump Stations	$4,012,040
Intake – 1 @ 45.81 MGD	
Intake – 1 @ 30.54 MGD	
Transmission Line	
0.19 MI of 54"	$1,500,576
2 MI of 42"	
Subtotal	$5,512,616
Engineering and Contingency (25%)	$1,378,154
Total	$6,890,770
ANNUAL COSTS	
Raw Water ($0.45/1,000 Gal)	$12,537,289
O&M (5% of Capital Cost)	$344,539
Amortized Capital Cost (includes financing costs)	
Total	$13,671,179
COST PER 1,000 GALLONS	0.4907

Source: *Revised Surface Water Alternatives Analysis.*

Table 5. Alternative 6: Sam Rayburn Reservoir via Storage Reallocation

CAPITAL COSTS	
Intake/Pump Stations	$7,878,272
Intake – 1 @ 76.33 MGD	
Booster – 1 @ 76.33 MGD	
Booster – 3 @ 30.54 MGD	
Transmission Line	$74,289,600
21 MI of 66"	
10 MI of 54"	
57 MI of 42"	
Subtotal	$82,167,872
Engineering and Contingency (25%)	$20,541,968
Total	$102,709,840
ANNUAL COSTS	
Raw Water	
COE ($0.10/1,000 Gal)	$2,786,064
LNVA ($0.01/1,000 Gal)	$278,606
O&M (5% of Capital Cost)	$5,135,492
Amortized Capital Cost (includes financing costs)	$11,765,618
Total	$19,965,780
COST PER 1,000 GALLONS	0.7166

Source: *Revised Surface Water Alternatives Analysis.*



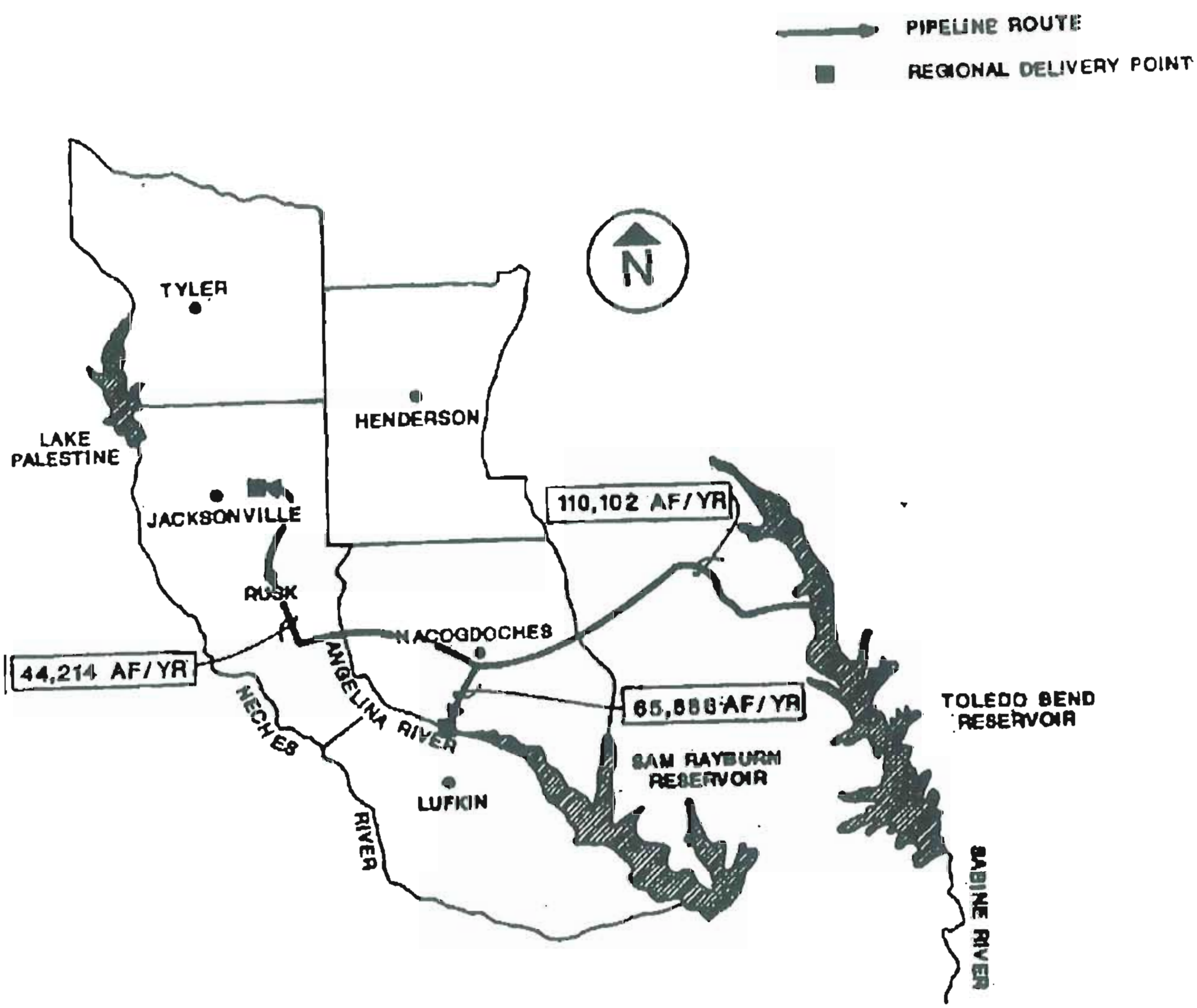
Source: Exhibit III.10 in *Lake Eastex Regional Water Supply Planning Study*, Volume 1.

Figure 2. Alternative 6: Sam Rayburn Reservoir via Storage Reallocation

Table 6. Alternative 2: Toledo Bend Reservoir

CAPITAL COSTS	
Intake/Pump Stations	$9,052,859
Intake – 1 @76.33 MGD	
Booster – 1 @ 76.33 MGD	
Booster – 2 30.54 MGD	
Transmission Line	$111,724,800
53 MI of 66"	
10 MI of 54"	
51 MI of 42"	
Subtotal	$120,777,659
Engineering and Contingency (25%)	$30,194,415
Total	$150,972,074
ANNUAL COSTS	
Raw Water ($0.075/1,000 Gal)	$2,089,548
O&M (5% of Capital Cost)	$7,548,604
Amortized Capital Cost (includes financing costs)	$17,294,153
Total	$26,932,305
COST PER 1,000 GALLONS	0.9667

Source: *Revised Surface Water Alternatives Analysis*.



Source: Exhibit III.7 in *Lake Eastex Regional Water Supply Planning Study*, Volume 1.

Figure 3. Alternative 2: Toledo Bend Reservoir

III. 404 PERMIT APPLICATION

A 404 permit application was submitted by ANRA to the Fort Worth District in October 2000. The purpose of Lake Eastex, according to the application, is "to supplement current and projected water supply demands in the region" (p. 1) or "to meet current and projected water supply demands within the adjacent five-county region" (p. 4). The latter wording occurs in the section on Proposed Project Purpose and is probably a better expression of purpose, as long as "meet" is understood to refer to partial rather than total fulfillment of demands.

The meaning of "demand" is unclear in the application and may refer to demand per se or to deficits (i.e., net demand). A demand table is not presented for the five-county region. The three tables that are presented as evidence of need (all on p. 6) are county population projections, water surplus/shortage, and water surplus/shortage as percent of demand. The textual reference to the two latter tables says that "The region is expected to experience increasing water demands, with water shortages projected for some counties by the year 2010 and becoming more widespread during the 50-year planning period 2000 to 2050." This suggests that the five-county deficit is considered to be the indicator of the need for the lake.

The surplus/shortage table (Table 4 in the permit application, which is re-presented here as Table 7) provides surplus and shortage figures for the decennial years from 2000 to 2050. The table shows a 2050 deficit of 46,492 AFY for the five-county region, constituted by a Smith County surplus of 10,316 AFY and deficits of 13,566 AFY in Angelina County, 18,703 AFY in Cherokee County, 10,944 AFY in Nacogdoches County, and 13,595 AFY in Rusk County. The cited source for this table is Shaumburg & Polk's 2000 *Regional Water Plan for East Texas Region I*, which was obviously an early draft of the East Texas Region report for the 2002 State Water Plan. It should be noted that these are general deficits rather than the surface water deficits presented in the 1991 report.

Table 7. Net Water Surplus/(Shortage) in Acre-Feet Per Year Based on the Regional Water Plan for East Texas Region I (Shaumburg & Polk *et al.*, 2000)

	Year					
County	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**
Angelina	8,220	5,048	1,447	(3,026)	(8,015)	(13,566)
Cherokee	345	(244)	(6,114)	(12,090)	(12,872)	(18,703)
Nacogdoches	14,762	12,270	9,499	(1,878)	(6,092)	(10,944)
Rusk	615	(3,789)	(8,377)	(13,444)	(13,476)	(13,595)
Smith	23,727	20,794	17,999	16,909	13,522	10,316
Total	**47,669**	**34,079**	**14,454**	**(13,529)**	**(40,455)**	**(46,492)**

Note: Shortages shown in parentheses.

Source: Table 4 in 404 permit application.

The East Texas Region report contains a surplus/shortage table (Table 4.4) for the 20 counties in the region. The figures for the five counties have been extracted and are re-presented here as Table 8. As can be seen from this table, the numbers for each county for each decennial year are different from those in Table 4 in the permit application (present Table 7). The most dramatic change is a move from a suplus to a deficit for Smith County. Such changes are not uncommon in water resources planning. The 2050 deficits for the five counties are 5,044 AFY for Angelina County, 18,395 AFY for Cherokee County, 12,315 AFY for Nacogdoches County, 16,912 AFY for Rusk County, and 5,412 AFY for Smith County. This produces a five-county 2050 deficit of 58,078. These are the figures that should appear in the permit application if it is updated.

Table 8. Net Water Surplus/(Shortage)
(acre-feet per year)

County	Year					
	2000	**2010**	**2020**	**2030**	**2040**	**2050**
Angelina	16,742	13,570	9,969	5,496	507	(5,044)
Cherokee	446	(109)	(5,939)	(11,875)	(12,612)	(18,395)
Nacogdoches	13,391	10,899	8,128	(3,249)	(7,445)	(12,315)
Rusk	(2,673)	(7,082)	(11,676)	(16,749)	(16,786)	(16,912)
Smith	7,999	5,066	2,271	1,181	(2,206)	(5,412)
Total	**35,905**	**22,344**	**2,753**	**(25,196)**	**(38,542)**	**(58,078)**

Source: Table 4.4 in East Texas Region report.

The permit application does not attempt to show the part that Lake Eastex might play in meeting these deficits. Rather, a list of Lake Eastex participants is presented as Table 6 in the permit application and is re-presented here as Table 9. This list excludes some of the participants in 1991 and includes some new participants. The exclusions are Angelina WSC, Leo F. Childs, City of Henderson, City of Lufkin, City of Overton, Redland WSC, Star Mountain WSC, Walnut Grove WSC, Woodlawn WSC, and Wright City WSC. The inclusions are Afton Grove WSC, North Cherokee WSC, Rusk Rural WSC, Stryker Lake WSC, Caro WSC, City of Tyler, and City of Whitehouse. These exclusions and inclusions result in a list of 20 participants.

The table correctly indicates that Lake Eastex was not the recommended strategy in the draft East Texas Region plan for six of the listed entities. (Although not a water user, Cherokee County appears in the county-other category for Cherokee County in the regional plan, with Lake Eastex as the recommended strategy, which is why it is checked in the table.) No deficits appear in that plan by 2050 for the City of Jacksonville, the City of Troup, and the City of Arp; Lake Eastex is not the least-cost strategy for Jackson WSC and the City of Whitehouse; and the City of Tyler has plans to meet its deficits from a source other than Lake Eastex. The permit application points out that "these entities have elected to participate in the Lake Eastex project in order to secure an adequate water supply for the future," apparently meaning as a contingency or after the 2050 planning period. A footnote to the table points out that the participants account for 66 percent of the Lake Eastex water rights.

Table 9. Participants in the Development of Lake Eastex

County	Participant	Senate Bill 1 Water User Group (WUG) Category	Lake Eastex is a Recommended Regional Water Planning Strategy
Current Participants			
Angelina	Temple Inland	Manufacturing	✔
Cherokee	Cherokee County	County-Other	✔
Cherokee	Craft Turney WSC	County-Other	✔
Cherokee	Afton Grove WSC	County-Other	✔
Cherokee	Blackjack WSC	County-Other	✔
Cherokee	North Cherokee WSC	County-Other	✔
Cherokee	Rusk Rural WSC	County-Other	✔
Cherokee	Reklaw WSC	County-Other	✔
Cherokee	Stryker Lake WSC	County-Other	✔
Cherokee	City of Jacksonville	Jacksonville	
Cherokee	City of New Summerfield	New Summerfield	✔
Cherokee	City of Rusk	Rusk	✔
Smith	City of Troup	Troup	
Nacogdoches	Caro WSC	County-Other	✔
Nacogdoches	City of Nacogdoches	Nacogdoches	✔
Rusk	City of New London	New London	✔
Smith	City of Arp	Arp	
Smith	Jackson WSC	County-Other	
Smith	City of Tyler	Tyler	
Smith	City of Whitehouse	Whitehouse	

Note: 1. Total Participation = 66 percent of Lake Eastex Water Rights.
2. Total ANRA Water Right for Lake Eastex = 85,507 acre-feet per year.

Source: Table 6 in 404 permit application.

The obvious course of action for showing a relationship between Lake Eastex and the needs expressed in the county deficit figures would be to present deficit projections for the Lake Eastex participants, as well as any other entities or categories of use that might benefit from the construction of the lake. These projections were available for presentation in the permit application. The only indications that there is relationship between need and Lake Eastex are the instances in Table 6 (present Table 9) where Lake Eastex is identified as the recommended strategy, the statement on page 8 that "Lake Eastex is recommended in the draft regional water plan as a water planning strategy for most of the 20 current Lake Eastex participants with ANRA," and the statement on page 11 that "Lake Eastex is a recommended strategy by the East Texas Water Planning Group for meeting future water shortages for the ANRA and many of its customers."

The permit application contains a section on alternatives to Lake Eastex. The information presented is a repetition of the information presented in the 1991 report and in the 1992 reformulation, without updating to costs that were current when the application was submitted. It is obvious from the information presented in the 404 permit application that Lake Eastex is the least-cost alternative. However, the point is not made explicit and is not used as a justification for construction of the lake.

All of the alternatives are dismissed on the basis that they are not the recommended alternatives for Lake Eastex participants in the State Water Plan and that (p. 15) "Strategies that are not 'recommended' are not eligible for Texas Water Development Board funding." A secondary consideration, which applies only to the alternatives involving interbasin transfers, is that (p. 16) "Currently out-of-basin water rights are considered 'junior' by state law and are not considered reliable water sources and therefore are not a good risk for obtaining funding by selling of bonds."

IV. STATE WATER PLAN

The East Texas Region report is an integral part of the 2002 State Water Plan, which appears under the title *Water for Texas--2002*. The East Texas Region report is concerned with the 20 counties in Region I, including the five counties in the Lake Eastex service area. It was prepared by the East Texas Regional Water Planning Group with the assistance of Schaumburg & Polk as the lead engineering firm in keeping with Texas' newly instituted bottom-up water planning process.

The East Texas Region report presents strategies for meeting the water supply needs of every entity in the 20 counties that is expected to have a deficit by 2050 even with water conservation measures in place. The strategies for each entity are costed out, and the best strategies (that is, the least-cost strategies) for meeting the deficits are recommended. Lake Eastex is not presented as a strategy for meeting any of the deficits outside of the five-county service area.

Cities (over 1,000 population) are treated separately. WSCs are combined in a county-other category that makes it difficult to determine the situation of individual entities. Other categories of use include steam electric power, manufacturing, irrigation, mining, and livestock, the latter two of which are irrelevant to the present analysis. Water supply contracts that expire during the planning period are registered as deficits, as they are throughout the State Water Plan, and contract renewal is treated as an alternative for meeting deficits.

LAKE EASTEX PARTICIPANTS

Table 3.2 of the East Texas Region report contains a list of ANRA participants in the development of Lake Eastex, which is re-presented here as Table 10. The only difference between this list and the participant list in the permit application is that John Moore in Cherokee County replaces Craft-Turney WSC in Cherokee County. ANRA's webpage lists Craft-Turney WSC as a participant and does not list John Moore. However, the report states in the county-other analysis for Cherokee County on page 5-16 that John Moore has a contract with ANRA

Table 10. ANRA Participants in the Development of Lake Eastex

Participant	WUG	County	Percentage	Amount (ac-ft/yr)
Afton Grove WSC	County-Other	Cherokee	1.00%	855
City of Arp	Arp	Smith	0.05%	43
Blackjack WSC	County-Other	Cherokee	1.00%	855
Caro WSC	County-Other	Nacogdoches	1.50%	1,283
Cherokee County	County-Other	Cherokee	3.00%	2,565
Jackson WSC	County-Other	Smith	1.00%	855
City of Jacksonville	Jacksonville	Cherokee	5.00%	4,275
John Moore	County-Other	Cherokee	1.00%	855
City of Nacogdoches	Nacogdoches	Nacogdoches	10.00%	8,551
City of New London	New London	Rusk	1.00%	855
New Summerfield WSC	New Summerfield	Cherokee	1.00%	855
North Cherokee WSC	County-Other	Cherokee	1.00%	855
Reklaw WSC	County-Other	Cherokee	0.50%	428
City of Rusk	Rusk	Cherokee	1.00%	855
Rusk Rural WSC	County-Other	Cherokee	1.00%	855
Stryker Lake WSC	County-Other	Cherokee	0.50%	428
Temple Inland	Manufacturing	Angelina	10.00%	8,551
City of Troup	Troup	Smith	5.00%	4,275
City of Tyler	Tyler	Smith	10.00%	8,551
City of Whitehouse	Whitehouse	Smith	10.00%	8,551
Total Participation			64.55%	55,195
Total ANRA Water Right for Lake Eastex				85,507

Source: Table 3.2 in East Texas Region report.

with an option for water from Lake Eastex if developed and mentions Craft-Turney without that designation. ANRA (personal communication) indicates that the report was mistaken and that Craft-Turney rather than John Moore is the Lake Eastex participant.

The table is important because it shows the percentage of participation in the development of Lake Eastex and the allocated amount of the Lake Eastex yield that would be provided on the basis of the percentage of participation. These allocations are not water rights, but rather reflect the level of participation in the planning study and will need to be formalized by contracts in the future. The allocation numbers are important because they were used in the East Texas Region analysis of alternatives to meet deficits. In every case in which Lake Eastex is the recommended alternative, the recommended amount of water is the allocation amount rather than the amount that would be needed to meet the deficit.

Again, there are differences between the report and the webpage, with the latter indicating percentage of participation as 0.50 (rather than 0.05) for the City of Arp, 0.50 (rather than 1.50) for Caro WSC, 3.00 (rather than 1.00) for New Summerfield, and 2.00 (rather than 1.00) for North Cherokee WSC. ANRA (personal communication) indicates that the webpage is correct.

However, the report numbers were the ones used in the strategies analysis. The total percentage participation is fairly close for the permit application (66 percent of the Lake Eastex yield), the report (64.55 percent), and the webpage (67 percent) and has no implications for the present analysis.

SHORTAGES

Table 4.6 in the East Texas Region report (Water Shortages During the Planning Period for East Texas Water User Groups) presents the 2000-2050 decennial shortages and surpluses for each city and category of use in the 20 counties that is expected to have a deficit at some time during the planning period. These numbers were derived from TWDB Table 7, which was the basis for planning throughout the state. Table 11 extracts the relevant numbers for the cities and categories in the five-county region and provides county and regional totals. This table does not include the Lake Eastex participants Jacksonville, Arp, and Troup because they did not have any expected deficits during the planning period.

These are almost the same deficit numbers that appear in the tables devoted to the analyses of each city and category of use. The exceptions are minor and occur in the 2050 deficit for manufacturing in Rusk County and for all decennial years in the steam electric power category for Rusk County. The exceptions have no relevance for the present analysis.

It should be noted that the deficits shown in the county and regional totals in Table 11 are higher than those shown in Table 8 presented in the previous section. This is because Table 11 excludes cities and use categories that registered surpluses throughout the planning period. Table 11 presents a much better perspective on the actual needs of the region, which tend to be depreciated in simple comparisons between surpluses and shortages.

Table 11 also contains two check lists. The first list shows whether the city is a Lake Eastex participant or whether the category contains Lake Eastex participants. The second list shows whether the report recommends Lake Eastex as the strategy for meeting the deficit. Both lists provide an overview of the role that Lake Eastex and its participants would play in meeting regional water needs. It should be noted that Lake Eastex is not the recommended strategy for meeting the deficits of most of the entities in the five-county service area (a generalization that remains true if the components of the county-other categories are disaggregated). This situation could, of couse, change in subsequent renditions of the State Water Plan.

Table 11. Water Shortages During the Planning Period (acre-feet per year)

County	Entity	Year 2000	2010	2020	2030	2040	2050	Lake Eastex Participant	Lake Eastex Recommended
Angelina	Lufkin	39	(747)	(1,673)	(2,995)	(4,544)	(5,949)		
	Huntington	137	99	66	28	(12)	(60)		
	Livestock	(1)	(22)	(46)	(75)	(108)	(146)		
	Manufacturing	14,519	12,229	9,642	6,701	3,381	(481)	✔	✔
	Mining	(14)	(18)	(23)	(29)	(35)	(42)		
	Total	14,680	11,541	7,966	3,630	(1,318)	(6,678)		
Cherokee	Alto	35	28	22	11	(2)	(16)		
	Bullard	(25)	(28)	(43)	(47)	(53)	(65)		
	New Summerfield	37	29	18	7	(6)	(21)	✔	✔
	Rusk	40	16	5	(54)	(96)	(134)	✔	✔
	Wells	(11)	(16)	(22)	(27)	(32)	(37)		
	County-Other	(1,542)	(2,000)	(3,076)	(4,068)	(4,459)	(4,800)	✔	✔(P)
	Irrigation	(1,312)	(1,312)	(1,312)	(1,312)	(1,312)	(1,312)	✔	✔(P)
	Mining	7	32	(183)	(485)	(629)	(799)		
	Steam Electric Power	343	343	(4,657)	(9,657)	(9,657)	(14,657)		✔
	Total	(2,428)	(2,908)	(9,248)	(15,632)	(16,246)	(21,841)		
Nacogdoches	Nacogdoches	13,725	11,872	9,844	7,079	3,938	(24)	✔	✔
	County-Other	(641)	(972)	(1,350)	(2,014)	(2,577)	(2,901)		
	Livestock	0	(287)	(621)	(1,008)	(1,457)	(1,978)		
	Mining	(41)	(60)	(92)	(125)	(158)	(195)		
	Steam Electric Power	0	0	0	(7,505)	(7,505)	(7,505)		
	Total	13,043	10,553	7,781	(3,573)	(7,759)	(12,603)		
Rusk	Henderson	(212)	(173)	(65)	9	23	(19)		
	New London	9	12	21	15	7	(4)	✔	✔
	Tatum	(13)	(6)	5	11	16	18		
	County-Other	(143)	(184)	(427)	(724)	(839)	(980)		
	Livestock	39	23	5	(16)	(41)	(69)		
	Steam Electric Power	(4,960)	(9,960)	(14,960)	(19,960)	(19,960)	(19,960)		
	Manufacturing	(47)	(52)	(58)	(64)	(69)	(35)		
	Irrigation	(62)	(62)	(62)	(62)	(62)	(62)		
	Total	(5,389)	(10,402)	(15,541)	(20,791)	(20,925)	(21,111)		
Smith	Lindale	3	(3)	(2)	(7)	(10)	(14)		
	Whitehouse	(22)	(236)	(378)	(403)	(386)	(382)	✔	
	Tyler	6,708	4,913	3,251	3,291	1,103	(866)	✔	
	County-Other	966	78	(901)	(1,996)	(3,198)	(4,422)	✔	
	Total	7,655	4,752	1,970	885	(2,491)	(5,684)		
GRAND TOTAL		27,561	8,784	(7,072)	(35,481)	(48,739)	(67,958)		

Note: P = partial (Lake Eastex would meet part of the deficit)

Source: Table 4.6 in East Texas Region report.

DEFICIT ANALYSIS

The following is a county-based summary of what the East Texas Region report says about the deficits for every entity or category of use for which Lake Eastex was considered a possible strategy for meeting a deficit, which includes Lake Eastex participants and potential users of Lake Eastex. The analysis concentrates on the features that are important for understanding the overall situation, rather than attempting to duplicate the complexity of the report's analysis. The report's full analysis for each entity or category of use is included as Appendix A.

Rusk County

The City of New London is a Lake Eastex participant at 855 AFY. New London, which uses groundwater, shows a deficit of 4 AFY beginning in 2050. New London could obtain water from Lake Eastex, Henderson, or Tyler. Lake Eastex is the least-cost strategy and the recommended strategy, with 885 AFY (apparently should be 855 AFY) as the recommended amount.

Nacogdoches County

The City of Nacogdoches is a Lake Eastex participant at 8,551 AFY. Nacogdoches, which uses ground and surface water (from Lake Nacogdoches), shows a deficit of 24 AFY beginning in 2050. Caro WSC is a Lake Eastex participant at 1,283 AFY. It is not analyzed as a separate entity in the report, but rather within the context of the alternatives for Nacogdoches. Nacogdoches could obtain water from Lake Eastex or Toledo Bend. Lake Eastex is the least-cost strategy and the recommended strategy, with 9,843 AFY (apparently Nacogdoches plus Caro) as the recommended amount.

Angelina County

The manufacturing category shows a deficit of 481 AFY beginning in 2050. The category includes the Lake Eastex participant (at 8,551 AFY) Temple-Inland, a forest products company in Diboll. However, the category also contains other entities that are not Lake Eastex participants, such as manufacturers that are supplied by the City of Lufkin. Consequently, it is uncertain whether the deficit is for Temple-Inland. It is probable that the deficit is not related to Temple-Inland, because this company indicated a static demand in the 1991 report (see Table 2), rather than an increasing demand that could result in a deficit. ANRA (personal communication) indicates that this interpretation is correct. Two strategies are recommended for meeting the deficit: (1) contract renewal with the City of Lufkin, which would supply 6,400 AFY; and (2) Lake Eastex, which would supply 8,551 AFY through Temple-Inland. It is uncertain which of the recommended strategies is meant to cover the deficit.

Smith County

The City of Whitehouse, which is a Lake Eastex participant at 8,551 AFY, receives 95 percent of its supply from Tyler and 5 percent from groundwater. Whitehouse shows a deficit beginning at 22 AFY in 2000 and rising to 382 AFY in 2050. Whitehouse could expand its contract with Tyler to meet the deficit or use Lake Eastex water. Lake Eastex is not the least-cost strategy and is not the recommended strategy.

Jackson WSC uses groundwater and is a Lake Eastex participant at 855 AFY. It is a component of the county-other category, which shows a deficit of 901 AFY in 2020, rising to 4,422 AFY in 2050. It is uncertain whether any portion of the total county-other deficit is sustained by Jackson WSC. The strategy for the total deficit is to obtain additional groundwater beginning at 160 AFY in 2020 and rising to 3,520 in 2050 and supplement these amounts by 885

AFY from Tyler. The 885 AFY could also be obtained from Lake Eastex through Jackson WSC. Lake Eastex is not the least-cost strategy and is not the recomended strategy.

The cities of Arp and Troup are Lake Eastex project participants at 43 AFY and 4,275 AFY, respectively. They do not appear in the Smith County analysis because they do not expect deficits through 2050. Tyler is a Lake Eastex project participant at 8,551 AFY with a deficit of 866 AFY beginning in 2050. Lake Eastex is not analyzed as an alternative for Tyler because Tyler is constructing a 30 MGD facilty to obtain water from Lake Palestine.

Cherokee County

The City of Rusk is a Lake Eastex participant at 855 AFY. Rusk shows a deficit beginning at 54 AFY in 2030 and rising to 134 AFY in 2050. The current supply is from groundwater and Rusk City Lake. Water could be obtained from Lake Eastex or the City of Jacksonville. Lake Eastex is the least-cost strategy and the recommended strategy, with 855 AFY as the recommended amount.

The City of New Summerfield is a Lake Eastex participant at 855 AFY. The city intends to use 787 AFY for resale to meet plant farm irrigation demands (as reflected in the analyis for that category). The current supplies for the city are from groundwater. New Summerfield shows a deficit of 6 AFY beginning in 2040 and rising to 21 AFY in 2050. Water can be obtained from Lake Eastex, Jacksonville, or Tyler. Lake Eastex is the least-cost strategy and the recommended strategy, with 855 AFY as the recommended amount.

The City of Jacksonville is a Lake Eastex participant at 4,275 AFY but is not included in the Cherokee County analysis because it does not expect any deficits through 2050.

The county-other category includes the Lake Eastex participants Afton Grove WSC, Blackjack WSC, North Cherokee WSC, Reklaw WSC, Rusk Rural WSC, Stryker Lake WSC, Craft-Turney (as corrected), and Cherokee County. These entities have a combined Lake Eastex allocation of 7,696 AFY. The category contains three WSCs that are not participants in the Lake Eastex project: John Moore (as corrected), Gum Creek, and West Jacksonville. Current supplies are from groundwater and Lake Jacksonville (through Jacksonville). The total deficit is 1,524 AFY in 2000, rising to 4,800 in 2050. Afton Grove WSC, Craft-Turney WSC, Gum Creek WSC, North Cherokee WSC, and West Jacksonville WSC could renew contracts with Jacksonville for water from Lake Jacksonville. There are two recommended strategies for meeting the 2050 deficit: (1) renew contracts with Jacksonville, with 1,130 AFY as the recommended amount; and (2) obtain water from Lake Eastex, with 7,696 AFY as the recommended amount. Because contract renewal would supply water at a lower cost than Lake Eastex, it is apparent that the 2050 deficit that would be met by Lake Eastex is 3,670 AFY (4,800 AFY minus 1,130 AFY). For the Lake Eastex participants that are presently using groundwater, expansion of groundwater supplies does not appear to be a viable long-term strategy. Blackjack WSC could obtain water from the City of Tyler; and Blackjack WSC, Stryker Lake WSC, and Rusk Rural WSC could obtain water from the City of Jacksonville, but the cost would be higher than the cost of water from Lake Eastex.

The irrigation category shows a deficit of 1,312 AFY beginning in 2000 and remaining at that level through 2050. Current supplies are from groundwater and are used for plant farms in the New Summerfield area. More than 90 percent of the irrigation shortage is attributed to plant farm demand. It is assumed that 40 percent of the deficit can be met by additional groundwater and 60 percent from Lake Eastex. Two strategies are recommended for meeting the deficit: (1) obtain additional water from aquifer, with 565 AFY as the recommended amount; and (2) obtain water from Lake Eastex through the New Summerfield allocation of 855 AFY, with 787 AFY as the recommended amount. The Lake Eastex water is more costly than the groundwater because it is treated water through New Summerfield. The portion of the deficit that would met by Lake Eastex is 787 AFY (i.e., 60 percent of the 2050 total irrigation deficit of 1,312 AFY).

The steam-electric power category shows a deficit of 4,657 AFY beginning in 2020 and rising to 14,657 AFY in 2050. The deficit is based on a constant supply from 2000 to 2050 of 5,343 AFY and a current demand of 5,000 AFY, rising to 10,000 AFY in 2020 and 20,000 AFY in 2050. Although a facility is not named, the 2000 demand is 5,000 AFY, the 2000 supply is 5,343, and the water source is groundwater and Striker Creek Lake. This indicates that the current demand and the constant supply refers to Texas Utilities, which is located on the west side of Striker Creek Lake, has a permit for the withdrawal of 5,000 AFY from the lake, and uses 343 AFY of groundwater. Texas Utilities is not a Lake Eastex participant. The source of the increased demand is not identified. Subsequent contacts with ANRA indicate that the source of the increased demand is a power company (a foreign enterprise) whose plans are not firm. The 14,657 AFY deficit in 2050 can be met by Lake Eastex or by a combination of alternatives (increased withdrawals of 5,600 AFY from Striker Creek Lake and reuse of wastewater from Jacksonville and Tyler). Lake Eastex is lower in cost (65 cents per thousand gallons) than the combination of alternatives, but shows the same cost as Stryker Creek Lake (which could not supply all of the 2050 deficit).

DEFICIT SUMMARY

Table 12 shows the deficits by decennial year for the cases in which Lake Eastex is a recommended solution, with the year 2000 left blank because Lake Eastex was not expected to come online until 2010. The numbers are acquired from the respective tables for each city and category of use contained in Appendix A. There are two problematic cases.

Two strategies are recommended for covering the manufacturing deficit in Angelina County (Lake Eastex through Temple-Inland and renewal of contracts with Lufkin). It is possible that the deficit would be met by Temple-Inland because the water that would be available from Lake Eastex through Temple-Inland is less costly ($1.14 per thousand gallons) than the water that would be available through Lufkin ($1.98 per thousand gallons). This is because the water that would be available through Lufkin to meet the deficit is treated water.

Table 12. Deficits for which Lake Eastex is the Recommended Solution (acre-feet per year)

County	Entity	Year					
		2000	2010	2020	2030	2040	2050
Angelina	Manufacturing	--	0	0	0	0	(481)
Cherokee	New Summerfield	--	-	-	-	(6)	(21)
	Rusk	--	0	0	(54)	(96)	(134)
	County-Other	--	(2,000) [2,000]	(2,514) [3,076]	(2,938) [4,068]	(3,326) [4,459]	(3,670) [4,800]
	Irrigation	--	(787)	(787)	(787)	(787)	(787)
	Steam Electric Power	--	0	(4,657)	(9,657)	(9,657)	(14,657)
Nacogdoches	Nacogdoches	--	0	0	0	0	(24)
Rusk	New London	--	0	0	0	0	(4)
Smith	--	--	0	0	0	0	0
TOTAL			(2,787) [2,787]	(7,958) [8,520]	(13,382) [14,512]	(13,872) [15,005]	(19,778) [20,908]

Source: County analytical tables in East Texas Region report.

The county-other category for Cherokee County does not provide a disaggregated analysis for its various components. Two strategies are recommended for meeting the deficit (Lake Eastex and contract renewal with Jacksonville). Contract renewal with Jacksonville does not have the capacity to meet all of the deficit. However, it is lower in cost ($1.48 per thousand gallons) than Lake Eastex ($1.61 per thousand gallons). This suggests that the portion of the deficit that would be met by Lake Eastex can be computed by subtracting the recommended amounts for contract renewal from the total deficits for each decennial year. The reduced amounts are presented in the table, with the full deficits underneath in brackets for comparison.

It should also be noted that the numbers for the irrigation category in Cherokee County have been adjusted to reflect the 60 percent portion of the deficit that would be met by Lake Eastex.

ALTERNATIVES

For every case in which Lake Eastex was the recommended strategy, at least one alternative strategy was presented and costed out. Lake Eastex was the recommended strategy because it was found to be the least-cost strategy. This means that alternatives to Lake Eastex do not need to be sought outside the confines of the report. These alternatives are presented in the analytical tables for each entity in Appendix A.

The City of Rusk in Cherokee County, which is a Lake Eastex participant at 855 AFY, may be used as an example. Tables 13 and 14 present the analytical tables for Rusk, which presently uses groundwater. The first table shows that Rusk is expected to have a deficit of 54 AFY in 2030, increasing to 96 AFY in 2040 and 134 AFY in 2050. Lake Eastex is the recommended strategy, and the amount recommended (855 AFY) is Rusk's allocation from Lake Eastex. The second table shows that obtaining water from Jacksonville was considered as an alternative, but that it was not recommended because it was more costly than Lake Eastex. It should be noted that the cost analyses for the alternatives are based on the provision of the Lake Eastex allocation amount rather than the deficit amounts in the first table.

Table 13. Rusk Deficit and Recommendation

Category	Year					
	2000	2010	2020	2030	2040	2050
Population	4,645	4,945	5,237	5,651	5,952	6,182
Water Demand (ac-ft/year)	1,051	1,075	1,086	1,145	1,187	1,225
Current Supply (ac-ft/year)	1,091	1,091	1,091	1,091	1,091	1,091
Supply (+)-Demand (-) (ac-ft/yr)	40	16	5	-54	-96	-134
Recommended Strategy RU-1 (ac-ft/yr): Obtain water from Lake Eastex				855	855	855

Source: Page 5-15 in East Texas Region report.

Table 14. Rusk Alternatives

Strategy	Firm Yield (ac-ft/yr)	Total Capital Cost	Total Annualized Cost	Unit Cost ($/ac-ft)	Unit Cost ($/1,000 gal)
RU-1: Obtain water from Lake Eastex	855	$5,630,000	$518,985	$607	$1.86
RU-2: Obtain water from City of Jacksonville	855	$4,915,000	$940,500	$1,100	$3.36

Source: Page 5-15 in East Texas Region report.

V. ALTERNATIVE WATER SOURCES

POTENTIAL ALTERNATIVES

The 1991 Lake Eastex report projected a 2040 surface water deficit of 110,102 AFY for the five-county region and identified and costed out alternatives to Lake Eastex that would transport from various sources 60 percent of the required amount of water (sustained by Angelina and Nacogdoches counties) to a southern delivery point north of Lufkin on the Angelina River and 40 percent (sustained by Cherokee, Rusk, and Smith counties) to a northern delivery point west of New Summerfield at the Lake Eastex site. The required amount was reduced in 1992 to 85,507 AFY on the basis that if 110,102 AFY of surface water was projected in 1991 to be needed in 2040, it was not unreasonable to assume in 1992 that at least 85,507 AFY would be needed. The same alternative delineations and delivery points were used, but the costs changed because lesser amounts were delivered and pipe and pump sizes were reduced.

The costs per thousand gallons of delivered water through these alternatives were carried forward in the 404 permit application as a basis for comparison to the cost of Lake Eastex water. However, the projected deficits for 2040 and even 2050 for the five-county region in the East Texas Region report (see present Table 8) are substantially below those of the 1991 Lake Eastex report (particularly in light of the fact that they contain deficits that are not surface water deficits); and the regional distribution of the deficits has changed dramatically, with Angelina and Nacogdoches counties now accounting for only 30 percent of the projected deficits. As a consequence, the costs per thousand gallons of delivered water for the alternatives in the permit application do not offer a valid comparison to Lake Eastex in the current planning context.

Performance of a surface water deficit analysis like the one conducted in 1991 would not demonstrate that there is need for an 85,507 AFY reservoir. The regional deficit numbers in the East Texas Region report are only partly correlated with a need for Lake Eastex (that is, in those cases where Lake Eastex is the recommended strategy). Insofar as they are correlated, they are heavily concentrated in Cherokee County and do not provide a context for the transport of large volumes of water in a regional system. The present allocations for Lake Eastex could be used to design alternatives, but this would decouple the alternatives from need and would not demonstrate that the yield of Lake Eastex is needed. More importantly, the participants are expected to change to some degree (ANRA, personal communication). Indeed, participation might change significantly once the current participants are required to sign contracts for the purchase of water, with the East Texas Region report indicating (p. 3-4) that current commitments extend only through the completion of the 404 permit process. Consequently, there is no reasonable basis for reanalyzing the previous alternatives with their weighted delivery points.

Nevertheless, alternatives assuming a 60 percent south/40 percent north delivery system are included in the present analysis in order to maintain continuity with the previous reports, whose results have been incorporated into the 404 permit application. It should be noted that the pipeline routes for the alternatives that use two delivery points are not the same as those in the previous reports. In addition, the delivery points differ to some degree because of hydrologic and efficiency considerations. The present analysis uses Henderson for the northern delivery point rather than the Lake Eastex site as in the previous reports and Rusk in one alternative rather than the Angelina River north of Lufkin.

The present analysis also uses an approach that was not included in the previous reports. This approach does not attempt to demonstrate that 85,507 AFY of surface water are needed in the five-county region. Rather, it asks if such an amount is needed whether there are alternative sources that could supply that amount and at what cost.

Groundwater as a potential source is analyzed in this report. The only surface water sources within the East Texas Region that could supply 85,507 AFY of water are Toledo Bend Reservoir, Sam Rayburn Reservoir, Lake Palestine, and B. A. Steinhagen Lake. Only Toledo

Bend Reservoir is free of complications. All of Sam Rayburn Reservoir has already been allocated to various purposes, and to obtain the required amount, it would be necessary to reallocate flood control storage to water supply. Most of the water in Lake Palestine is already permitted, but much of the permitted water is not currently being used. Acquisition of that water would require a willing seller.

Toledo Bend Reservoir, Sam Rayburn Reservoir, and Lake Palestine are analyzed in this report, but B. A. Steinhagen Lake is not. B. A. Steinhagen Lake is downstream of Sam Rayburn Reservoir, from which it receives its water. Because of its location, B. A. Steinhagen Lake was the most costly of the alternatives considered in the 1991 Lake Eastex report, and acquisition of the required amount would involve complicated water rights issues.

Potential reservoirs are not analyzed in this report because they are uncertain and because the determination of the practical availability of water from such sources is complex. According to the East Texas Region report, there are 13 sites in Region I with features that make them desirable for reservoir construction, but only Lake Eastex is recommended as a strategy at this time. Little Cypress Reservoir, which was the only proposed reservoir considered in the 1991 Lake Eastex report, is listed in the North East Texas Region report as one of 14 potential reservoir sites in the region. However, only Marvin Nichols I on the Sulphur River is recommended, and it is too distant from the five-county Lake Eastex region to merit analysis.

COST ESTIMATES

Preliminary analysis indicated that groundwater was not a feasible alternative to Lake Eastex. As a consequence, this report develops costs for obtaining and transporting (by pipeline) 85,500 AFY from Toledo Bend Reservoir, Sam Rayburn Reservoir, and Lake Palestine and a lesser amount from Lake Palestine. These costs include raw water costs for Toledo Bend and Lake Palestine, water rights purchase costs for Lake Palestine, reallocation costs for Sam Rayburn, construction and operations and maintenance (O&M) costs for the pipelines, and other costs such as those associated with environmental effects.

Alignments were largely delineated in-field, using primarily highway rights-of-way (but also pipeline and railroad rights-of-way), which was the same procedure used in the 1991 Lake Eastex report. The developed raw water costs are costs of delivered (and therefore ready to use) water at the Lake Eastex site. A storage facility at the site is not assumed, which is the same procedure that was used in the 1991 Lake Eastex report to delineate the two delivery points. The raw water costs should not be compared to any numbers in the current 404 permit application, but rather to the raw water costs for Lake Eastex that will appear in the preliminary design and cost analysis that is presently being prepared for ANRA.

The construction and O&M cost estimates are based on cost data furnished by material and equipment suppliers, published cost data, and construction experience. Concrete pressure pipe is used throughout at dimensions ranging from 36 to 66 inches. Booster pump stations are placed at various locations along the pipelines to maintain system pressure. Use of existing rights-of-way reduces costs and interference with traffic and lowers gradients where pipelines cross over hills. Steel casings are used beneath all railroad and major highway crossings. Disrupted pavement surfaces are replaced in-kind. The construction and O&M cost estimates include a 25 percent escalation for engineering and contingencies and 5 percent for O&M.

Annual costs were determiend by calculating: (1) the annual amortiziation of total construction cost at 5.875 percent (the current discounting rate for Federal projects) over a 50-year project life; (2) annual operation and maintenance cost, including labor and materials at 5 percent of total construction cost, and annual power cost; (3) raw water cost where purchased from Toledo Bend Reservoir and Lake Palestine; (4) environmental mitigation costs associated with pipeline construction; (5) reallocation cost (Sam Rayburn); and (6) water rights purchase cost (Lake Palestine). All appropriate annual costs were totaled for each alternative. The annual yield in acre-feet was multiplied by 325.851 to convert water volumes to thousand gallon increments. The total annual cost of each alternative was divided by the yield of each alternative to provide an estimate of the cost per 1,000 gallon.

Mitigation costs were developed on the basis of a review of topographic maps and therefore are estimates, with $5,000 per acre assumed as the value. Because they are estimates, the mitigation costs include costs for wetland delineation studies.

TOLEDO BEND RESERVOIR

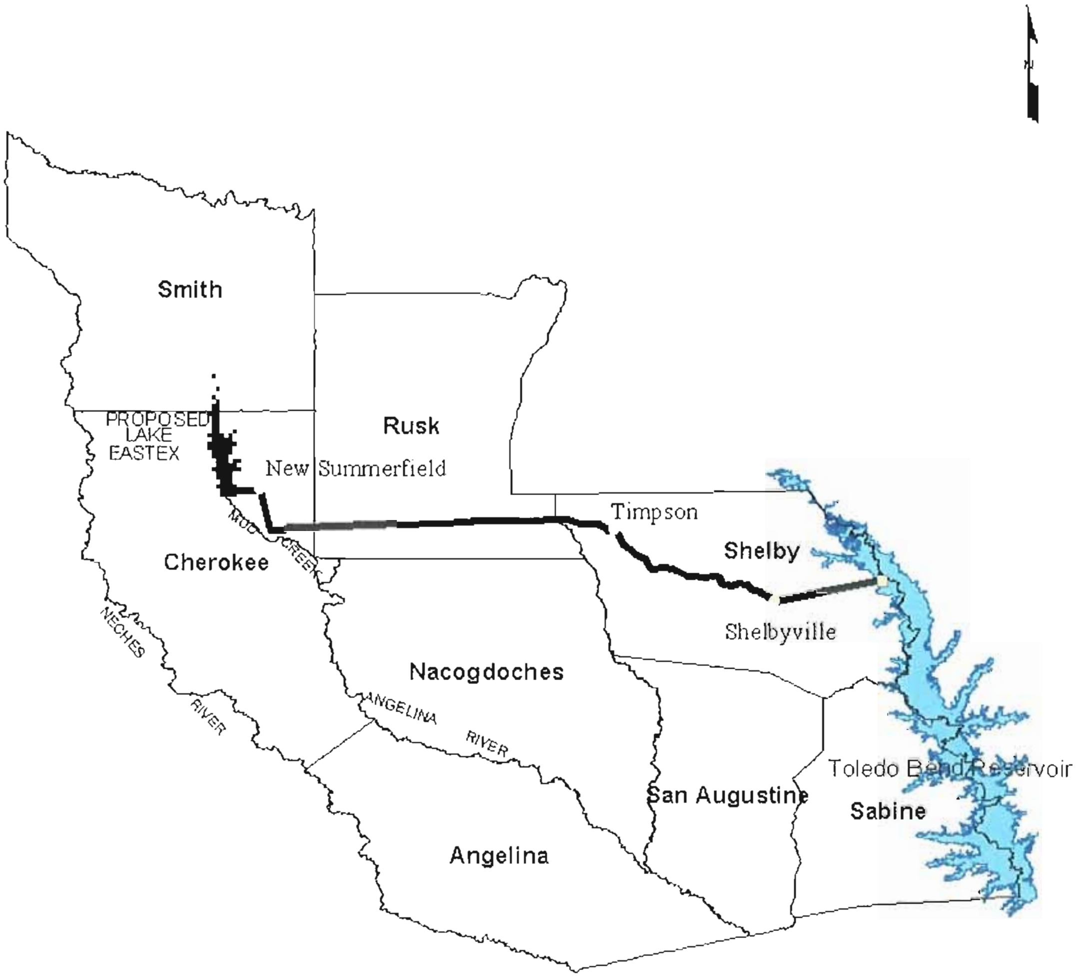
Two alternatives are considered for the use of Toledo Bend Reservoir water. The first involves a line directly from Toledo Bend to the Lake Eastex site. The second involves the use of northern and southern delivery points. The costs for both of these alternatives involve construction and O&M costs and raw water costs.

Direct Line

This alternative (Figure 4) would involve a concrete pressure pipeline running in a generally westerly direction that would transport 85,500 AFY from an intake structure at Toledo Bend Reservoir to the Lake Eastex site and would include pump stations at the intake structure and two booster stations along the line.

The line would begin at Toledo Bend Reservoir and would run westwardly parallel to State Route (SR) 2694 for 14 miles to Shelbyville, thence northwestwardly parallel to SR 87 for 22 miles to Timpson, thence westwardly parallel to U. S. 84 for 35 miles to its intersection with SR 204, thence northwardly along SR 204 and SR 110 for 10.7 miles to a point about two miles south of New Summerfield, thence west across country 4.7 miles to the Lake Eastex site.

The total length of the pipeline is 86.4 miles. Booster pump stations would be located at Timpson and on U.S. 84 about 6.5 miles northeast of Reklaw. The intake structure and both pump stations would each have four pumps, two of which are rated at 16,800 gallons per minute (GPM) and two at 10,000 GPM. A diesel generator for standby power in the event of power failure is included in the pump station estimates. The estimated construction and O&M cost of



Source: G.E.C., Inc.

Figure 4. Toledo Bend Reservoir Direct Line

this alternative is $176,030,440. A detailed construction and O&M cost estimate is included as Appendix B.

The construction and O&M costs, environmental mitigation costs, annual costs, and costs per thousand gallons of water for this alternative are shown in Table 15. The raw water cost was obtained (written communication) from the Sabine River Authority of Texas, which has jurisdiction over the Texas portion of Toledo Bend Reservoir. The total annual cost for this alternative is $19,204,570, providing 85,500 AFY at a cost of 69 cents per thousand gallons.

Table 15. Cost Summary for Toledo Bend Reservoir Direct Line (85,500 AFY)

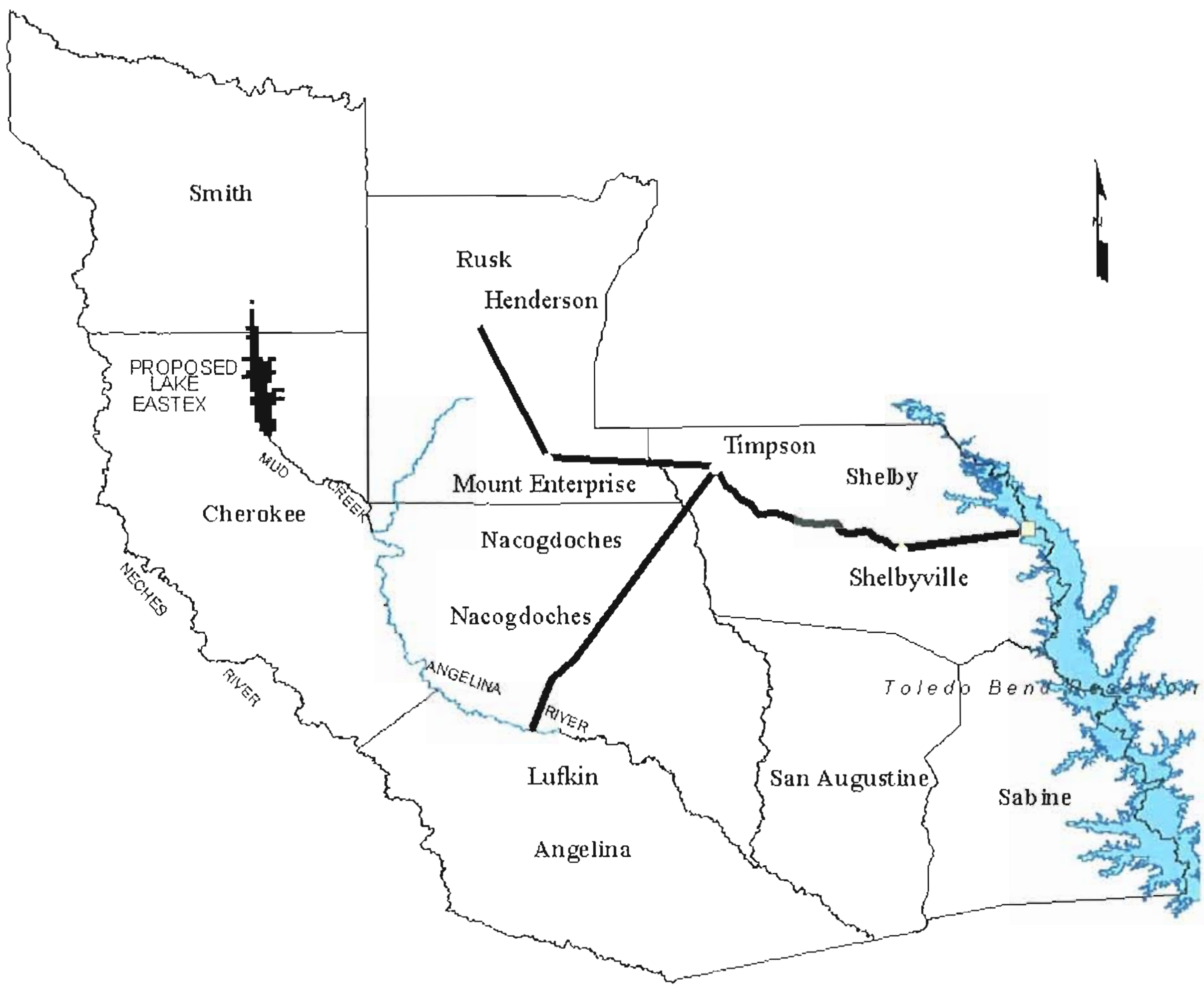
Construction and O&M Cost	
Intake Structure and Pump Station	$2,608,100
Pipeline, Toledo Bend to Pump Station No. 1	$83,178,940
Pump Station No. 1	$2,153,570
Pipeline, Pump Station No. 1 to Pump Station No. 2	$55,947,880
Pump Station No. 2	$2,153,570
Pipeline, Pump Station No. 2 to Lake Eastex Site	$29,988,380
Total Construction and O&M Cost	**$176,030,440**
Environmental Mitigation Cost	**$100,000**
Annual Cost	
Ammortized Construction Cost	$10,973,739
Operation and Maintenance Cost	$6,022,630
Raw Water Cost (@ $0.079/1,000 gallons)	$2,201,967
Environmental Mitigation	$6,234
Total Annual Cost	**$19,204,570**
Cost Per 1,000 Gallons	$0.69

Sources: G.E.C., Inc.

Split Delivery

This alternative (Figure 5) involves a line from Toledo Bend Reservoir that would split at Timpson, with 40 percent of the 85,500 AFY delivered to Henderson and 60 percent delivered to a point on the Angelina River north of Rusk.

The route of this pipeline begins at the same location on Toledo Bend Reservoir and follows the same route for 36 miles to the booster pump station at Timpson. It is sized to deliver85,500 AFY to this point. The intake structure at the reservoir and the booster pump



Source: G.E.C., Inc.

Figure 5. Toledo Bend Reservoir Split Delivery

station at Timpson have four pumps each, two rated at 16,800 GPM and two rated at 10,000 GPM.

From Timpson, a pipeline extends southwardly for 37.4 miles to a delivery point on U.S. 59 where it crosses the Angelina River. The route of this pipeline follows the route of an existing gas transmission pipeline from Timpson to SR 21 east of Nacogdoches. It then follows the 224 Loop around the south side of Nacogdoches to U.S. 59. From there, it runs south along U.S. 59 to the delivery point. No booster pump station is required for this pipeline. This pipeline delivers 51,300 AFY to the southern delivery point.

A second pipeline begins at the booster pump station at Timpson and extends westwardly along U.S. 84 to a booster pump station at Mt. Enterprise near the intersection of U.S. 259, a distance of 17.6 miles. This booster pump station has two pumps, each rated at 12,500 GPM. From this point, it runs northwardly along U.S. 259 a distance of 20.5 miles to a delivery point at Henderson. This pipeline delivers 34,200 AFY to the northern delivery point and is 38.1 miles long.

The intake structure and both booster pump stations have provision for standby power in the event of a power failure. The estimated construction and O&M cost of this alternative is $181,952,810. A detailed construction and O&M cost estimate is included as Appendix C.

The construction and O&M costs, environmental mitigation costs, annual costs, and costs per thousand gallons of water for this alternative are shown in Table 16. The total annual cost for this alternative is $18,370,098, providing 85,500 AFY at a cost of 66 cents per thousand gallons.

SAM RAYBURN RESERVOIR

Two alternatives are considered for the use of Sam Rayburn Reservoir water. The first involves a line directly from Sam Rayburn to the Lake Eastex site. The second involves the use of northern and southern delivery points. The costs for both of these alternatives involve construction and O&M costs and reallocation costs.

Direct Line

This alternative (Figure 6) involves a concrete pressure pipeline running in a westerly and northerly direction that would transport 85,500 AFY from an intake structure at Sam Rayburn Reservoir to the Lake Eastex site and would include pump stations at the intake structure and two booster stations along the line.

The line begins at the Sam Rayburn Reservoir near Etoile and runs in a westerly direction paralleling SR 103 for 13.4 miles to the 287 Loop around Lufkin, thence northwestwardly around Lufkin to U.S. 59 and northwardly along U.S. 59 a distance of 16.1 miles to a booster pump station at Nacogdoches. From that point, it runs northwardly 23.7 miles along U.S. 59/259 and SR 204 to a second booster pump station located about one mile west of Cushing on SR 204, thence northwestwardly 17.7 miles along SR 204/110 to a point

Table 16. Cost Summary for Toledo Bend Reservoir Split Delivery (85,500 AFY)

Construction and O&M Cost	
Intake Structure and Pump Station	$2,608,100
Pipeline, Toledo Bend to Pump Station No. 1	$83,178,940
Pump Station No. 1	$2,153,570
Pipeline, Pump Station No. 1 to Angelina River	$52,249,630
Pipeline, Pump Station No. 1 to Pump Station No. 2	$18,899,250
Pump Station No. 2	$979,690
Pipeline to Henderson	$21,883,630
Total Construction and O&M Cost	**$181,952,810**
Environmental Mitigation Cost	**$150,000**
Annual Cost	
Ammortized Construction	$11,342,940
Operation and Maintenance Cost	$4,815,840
Raw Water Cost (@$0.079/1,000 gallons)	$2,201,967
Environmental Mitigation Cost	$9,351
Total Annual Cost	**$18,370,098**
Cost Per 1,000 Gallons	**$0.66**

Source: G.E.C., Inc.

Source: G.E.C., Inc.

Figure 6. Sam Rayburn Reservoir Direct LIne

about two miles south of New Summerfield, thence west across country 4.7 miles to the Lake Eastex site.

The total length of the pipeline is 75.6 miles. The intake structure and both pump stations would each have four pumps, two of which are rated at 16,800 GPM and two at 10,000 GPM. A diesel generator for stanby power in the event of power failure is included in the pump station estimates. The estimated construction and O&M cost of this alternative is $144,448,040. A detailed construction and O&M cost estimate is included as Appendix D.

Sam Rayburn Reservoir contains three pools. The lower pool is the sedimentation pool, which is allocated for the storage of sediment. The middle pool is the conservation pool, which stores water for use, including water supply. Most of the water supply is used downriver by the Lower Neches Valley Authority for distribution to customers by way of B. A. Steinhagen Lake. The upper pool is the flood control pool, essentially an empty area that is available for the storage of flood waters as needed.

In order to secure additional water supply from the reservoir, it would be necessary to reallocate a portion of the flood storage capacity to water supply. Securing 85,500 AFY of additional water supply from the reservoir would require raising the lake level about one foot. A lake raise of this amount would affect the contiguous shoreline, environment, facilities, and cultural resources and would require mitigation, replacement, relocation, and real estate acquisition. These are reallocation costs, which, as initial costs, may be thought of as similar to raw water costs.

An analysis of reallocation costs is far beyond the scope of the present analysis. To compute a reallocation cost, the cost designated as "COE raw water cost" in the 1991 Lake Eastex report was updated to current price levels.

The construction and O&M costs, environmental mitigation costs, annual costs, and costs per thousand gallons of water for this alternative are shown in Table 17. The total annual cost for this alternative is $17,961,572, providing 85,500 AFY at a cost of 64 cents per thousand gallons.

Reallocations involving water level changes are generally difficult to achieve because of the disruptions they would cause to existing facilities and usages. Raising the water level on Sam Rayburn Reservoir would involve such problems, the dimensions of which are reflected to some degree in the high estimated cost of reallocation. To this should be added the difficulties that would be involved in pursuing a reallocation, including a need for an Act of Congress. Most importantly, the quality of the habitat that would be inundated is higher than the quality of the habitat that would be destroyed through the creation of Lake Eastex. Consequently, use of Sam Rayburn Reservoir to secure the yield of Lake Eastex is a possible, but not a practical, alternative.

Table 17. Cost Summary for Sam Rayburn Reservoir Direct Line (85,500 AFY)

Construction and O&M Cost	
Intake Structure and Pump Station	$2,608,100
Pipeline, Sam Rayburn to Pump Station No. 1	$63,858,320
Pump Station No. 1	$2,153,570
Pipeline, Pump Station No. 1 to Pump Station No. 2	$40,316,350
Pump Station No. 2	$2,153,570
Pipeline to Lake Eastex Site	$33,358,130
Total Construction and O&M Cost	**$144,448,040**
Environmental Mitigation Cost	**$100,000**
Annual Cost	
Ammortized Construction Cost	$9,004,892
Operation and Maintenance Cost	$5,105,730
Reallocation Cost (COE @ $0.138/1,000 gallons)	$3,844,716
Environmental Mitigation Cost	$6,234
Total Annual Cost	**$17,961,572**
Cost Per 1,000 Gallons	**$0.64**

Source: G.E.C., Inc.

Split Delivery

The route of this pipeline (Figure 7) begins at the same location on Sam Rayburn Reservoir and follows the same route for 29.5 miles to the booster pump station at Nacogdoches. This pipeline is sized to deliver 85,500 AFY to Lufkin, where 51,300 AFY is conveyed to a southern delivery point. From this delivery point, it is sized to deliver 34,200 AFY to Henderson. The intake structure and the first booster pump station each have four pumps, two rated at 16,800 GPM and two rated at 10,000 GPM. From here, a pipeline extends northwardly along U.S. 59 and 259 a distance of 21.3 miles to a second booster pump station about 3.5 miles south of Mt. Enterprise. This pump station has two pumps rated at 12,500 GPM each. From here, it continues along U.S. 259 for 22.3 miles to Henderson, where 34,200 AFY is delivered. The estimated construction and O&M cost of this alternative is $100,626,100. A detailed construction and O&M cost estimate is included as Appendix E.

The construction and O&M costs, environmental mitigation costs, annual costs, and costs per thousand gallons of water for this alternative are shown in Table 18. The total annual cost for this alternative is $13,246,499, providing 85,500 AFY at a cost of 48 cents per thousand gallons.

Source: G.E.C., Inc.

Figure 7. Sam Rayburn Reservoir Split Delivery

Table 18. Cost Summary for Sam Rayburn Reservoir Split Delivery (85,500 AFY)

Construction and O&M Cost	
Intake Structure and Pump Station	$2,608,100
Pipeline, Sam Rayburn to Pump Station No. 1	$48,034,570
Pump Station No. 1	$979,690
Pipeline, Pump Station No. 1 to Pump Station No. 2	$24,053,980
Pump Station No. 2	$979,690
Pipeline to Henderson	$23,970,070
Total Construction and O&M Cost	**$100,626,100**
Environmental Mitigation Cost	**$150,000**
Annual Cost	
Ammortized Construction Cost	$6,273,032
Operation and Maintenance Cost	$3,119,400
Reallocation Cost (COD @ $0.138/1,000 gallons)	$3,844,716
Environmental Mitigation Cost	$9,351
Total Annual Cost	**$13,246,499**
Cost Per 1,000 Gallons	**$0.48**

Source: G.E.C., Inc.

The objections to this alternative are the same as those enumerated for the direct delivery of Sam Rayburn Reservoir water.

LAKE PALESTINE

Lake Palestine is about 17 miles from the Lake Eastex site. According to the East Texas Region report, Lake Palestine has a yield of 238,110 AFY, of which 600 AFY is allocated for irrigation, 23,000 AFY for industrial use, and 214,510 for municipal use. The irrigation and industrial allocations are currently being used. Almost all of the municipal allocation has been permitted. The City of Dallas has acquired rights to 114,337 AFY, the City of Tyler to 67,200 AFY, and the City of Palestine to 28,000 AFY, for a total of 209,537 AFY, leaving only 4,973 AFY unpermitted.

Appendix C of the report indicates that only 3,045 AFY of the municipal allocation was being used in 1995, suggesting that large quantities of unused water are available from Lake Palestine. The report also indicates that Tyler is presently constructing a 30 MGD (33,600 AFY) facility to make use of its Lake Palestine water, which would still leave a substantial quantity of unused water.

Lake Palestine would be able to supply the required 85,500 AFY only if Dallas would be willing to sell its water. Costs are developed for this "Full Amount" alternative. Costs are also developed for a "Reduced Amount" alternative, which assumes that an amount less than 85,500 AFY would be available from other permittees. The costs for both of these alternatives include construction and O&M costs, water rights costs, and raw water costs.

Full Amount

This alternative (Figure 8) involves a concrete pressure pipeline running in an easterly direction that would transport 85,500 AFY from an intake structure at Lake Palestine to the Lake Eastex site.

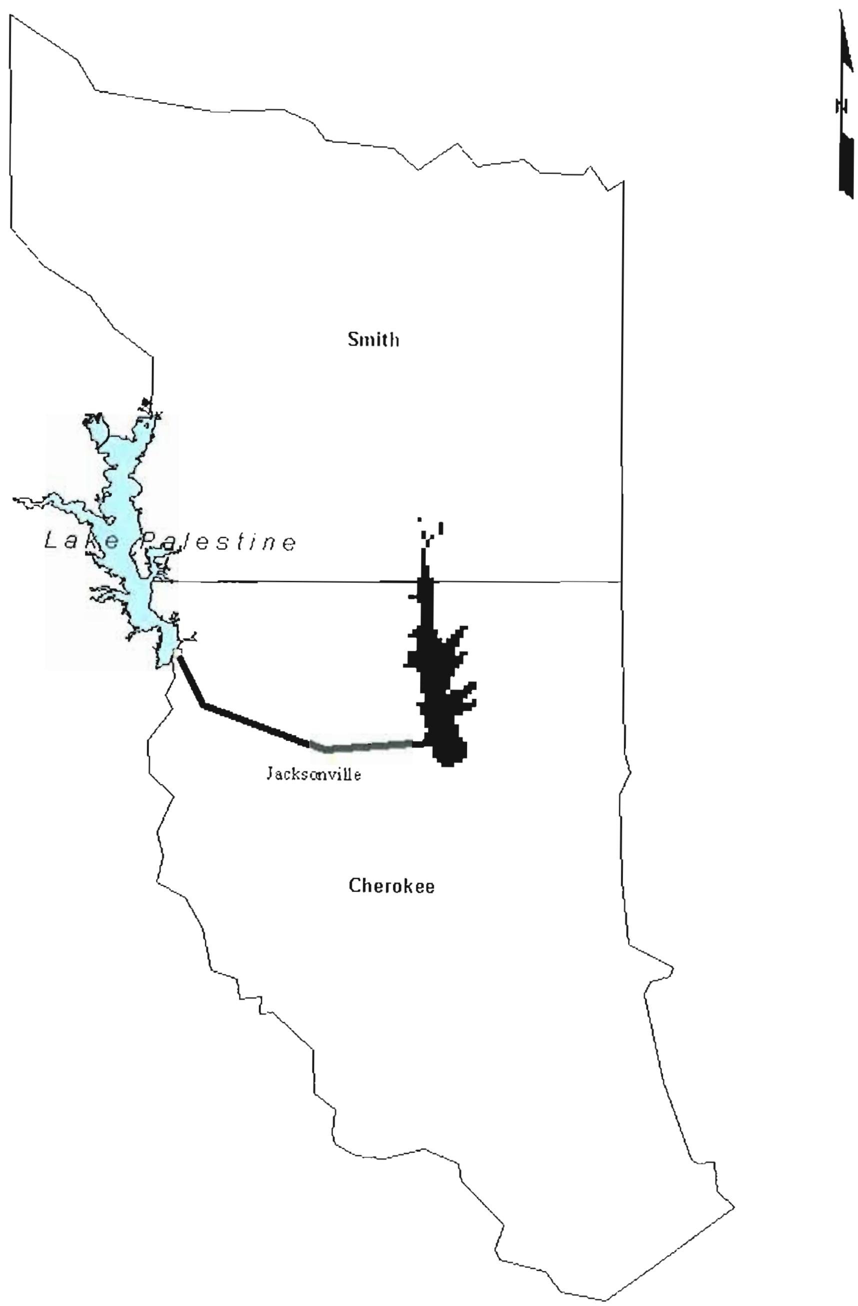
The pipeline begins at an intake structure at Cherokee Landing on the east side of Lake Palestine approximately one-half mile northeast of the dam and runs southeastwardly about three miles to a pipeline right-of-way, thence southeastwardly along the north side of the pipeline right-of-way for about four miles to an electric transmission line right-of-way, thence southeastwardly along the north side of the power line right-of-way for about five miles to near an electric substation in the northeast corner of Jacksonville, thence east along the north side of the power line right-of-way for about five miles to the Lake Eastex site.

The intake structure has four pumps, two rated at 16,800 GPM and two at 10,000 GPM, with provision for standby power in the event of power failure. The estimated construction and O&M cost of this alternative is $36,314,850. A detailed construction and O&M cost estimate is included as Appendix F.

The cost of water under this alternative would also depend on the price for which it could be purchased from Dallas Water Utilities. The Utility paid $10,000,000 for its Lake Palestine water rights in the 1970s. This price equals $87.46 per acre foot, or $5.48 per acre foot per year based on a 50-year project life and 6 percent interest, or 1.7 cents per thousand gallons.

Information on water rights transactions in East Texas is not readily available. In March 2002, the Georgia Water Planning and Policy Center published *The Sale and Leasing of Water Rights in Western States: An Overview for the Period 1990-2001*. According to the data presented in this report, water rights transactions in Texas have concentrated in the Rio Grande Valley and in the San Antonio region. Statewide, the average sales price of water is $442 per acre foot, and the average lease price is $45 per acre foot per year. Based on a 50-year project life at 6 percent interest, the annual cost of water purchased for $442 per acre foot is $28 per acre foot per year, or 8.6 cents per thousand gallons.

The San Antonio Water System has been a consistent purchaser of water rights in Texas and is the nearest major purchaser to Lake Palestine. Municipal water systems are generally able to pay more for water than industrial users or agricultural users. The San Antonio Water System paid $700 per acre foot for water rights to the Edwards aquifer in 1999, which equals $46 per acre foot per year, or approximately 14 cents per thousand gallons. The City of Laredo purchased



Source: G.E.C., Inc.

Figure 8. Lake Palestine Full Amount

surface water rights during the past 10 years for amounts ranging from $288 to $600 per acre foot, which equals approximately 6 to 12 cents per thousand gallons.

Because Dallas Water Utilities is not offering its Lake Palestine water for sale or lease, a hypotethical sales price of 12 cents per thousand gallons is assumed, which is the highest price that has been paid for surface water in Texas during the past ten years.

The cost of this alternative would also depend on the cost of raw water from Lake Palestine, which is under the jurisdiction of the Upper Neches River Municipal Water Authority. Information on the cost of raw water from Lake Palestine is not readily available. It was 7.67 cents per thousand gallons in 1991, when Toledo Bend water was selling for 7.5 cents per thousand gallons. Because the current price of Toledo Bend water is 7.9 cents per thousand gallons, 8 cents per thousand gallons is a reasonable estimate for the current price of Lake Palestine raw water.

The construction and O&M costs, environmental mitigation costs, annual costs, and costs per thousand gallons of water for this alternative are shown in Table 19. The total annual cost for this alternative is $10,396,016, providing 85,500 AFY at a cost of 37 cents per thousand gallons.

Table 19. Cost Summary for Lake Palestine Full Amount (85,500 AFY)

Construction and O&M Cost	
Intake Structure and Pump Station	$2,608,100
Pipeline, Lake Palestine to Lake Eastex Site	$33,706,750
Total Construction and O&M	**$36,314,850**
Environmental Mitigation Cost	**$50,000**
Water Allocation Purchase Cost (@ $700 per acre foot)	**$59,850,000**
Annual Cost	
Ammortized Construction Cost	$2,263,868
Operation and Maintenance Cost	$2,169,160
Water Rights Purchase Cost (@ $0.12/1,000 gallons)	$3,731,050
Raw Water Cost (@ $0.08/1,000 gallons)	$2,228,821
Environmental Mitigation Cost	$3,117
Total Annual Cost	**$10,396,016**
Cost Per 1,000 Gallons	**$0.37**

Source: G.E.C., Inc.

The Region D report for the State Water Plan indicates (p. 5.36) that Dallas Water Utilities plans to develop facilities to connect its Lake Palestine water supply to its system at a cost of $300 million by 2020 as part of a plan to meet a 2050 demand of 855,485 AFY. Contact with Dallas Water Utilities indicates that an additional $200 million will be invested in a treatment plant, that rights-of-way are currently being obtained, that the pipeline will be constructed by 2015, and that the probability of construction is 100 percent. Consequently, purchase of Lake Palestine water from Dallas Water Utilities might be considered a theoretical possibility until the pipeline is actually built, but it is not a practical alternative.

Reduced Amount

The City of Tyler and the City of Palestine combined have permits for 95,200 AFY from Lake Palestine.

Tyler has a permit for 67,200 AFY from Lake Palestine. The East Texas Region report indicates that Tyler is constructing a 30 MGD (33,600 AFY) facility to obtain half of its water from Lake Palestine. Contact with the Tyler Water Utilities indicates that the city intends to use its remaining half in 2020-2025 based on projected demand. Consequently, this water is not practically available.

Palestine has a permit for 28,000 AFY from Lake Palestine. Palestine's webpage indicates that it withdraws 3.25 MGD (3,640 AFY) from the Neches River below the Lake Palestine dam, with a 6 MGD maximum withdrawal. Contact with the City of Palestine Utilities indicates that Palestine uses an average of 5 MGD (5,600 AFY), with an 8 MGD maximum withdrawal, that municipal demand is not expected to increase, and that the remaining water might be used for industry, including a prospective power plant whose plans are not firm. It should also be kept in mind that there is 4,973 AFY of uncommitted water in Lake Palestine.

There is sufficient water in Lake Palestine potentially available for use that could meet the 2050 deficit of 19,778 AFY that the East Texas Region report recommends for satisfaction by Lake Eastex. A residual (21,000 AFY) of Palestine's permitted usage (28,000 AFY) will be used for the costing of the "Reduced Amount" alternative.

This alternative involves a 36-inch concrete pressure pipeline running in an easterly direction that would transport 21,000 AFY from an intake structure at Lake Palestine to the Lake Eastex site. The pipeline route would be the same as that for the "Full Amount" scenario, as shown in Figure 8. The intake structure has two pumps rated at 13,000 GPM, with provision for standby power in the event of power failure. The estimated construction and O&M cost of this alternative is $16,699,980. A detailed construction and O&M cost estimate is included as Appendix G.

The construction and O&M costs, environmental mitigation costs, annual costs, and costs per thousand gallons of water for this alternative are shown in Table 20. The total annual cost for this alternative is $3,086,372, providing 21,000 AFY at a cost of 45 cents per thousand gallons.

Table 20. Cost Summary for Lake Palestine Reduced Amount (21,000 AFY)

Construction and O&M Cost	
Intake Structure and Pump Station	$1,519,230
Pipeline to Lake Eastex Site	$15,180,750
Total Construction and O&M Cost	**$16,699,980**
Environmental Mitigation Cost	**$50,000**
Annual Cost	
Ammortized Construction Cost	$1,041,077
Operation and Maintenance Cost	$578,350
Water Rights Purchase Cost (@ $0.12/1,000 gallons)	$916,398
Raw Water Cost (@ $0.08/1,000 gallons)	$547,430
Environmental Mitigation Cost	$3,117
Total Annual Cost	**$3,086,372**
Cost Per 1,000 Gallons	**$0.45**

Source: G.E.C., Inc.

GROUNDWATER

In 1991, TWDB published an *An Evaluation of Ground Water Resources in the Vicinity of the Cities of Henderson, Jacksonville, Kilgore, Lufkin, Nacogdoches, Rusk and Tyler in East Texas*, which deals with historic groundwater usage in six counties, including the five counties in the Lake Eastex service area. The present analysis of groundwater as an alternative to Lake Eastex is based on this report.

There are three principal groundwater aquifers in the six-county area. The shallowest is the Sparta, with an estimated annual recharge rate of 31,000 acre-feet. At greater depth is the Queen City with an estimated annual recharge rate of 208,000 acre-feet; and at even greater depth is the Carrizo-Wilcox with an estimated annual recharge rate of 105,000 acre-feet.

Most of the groundwater that has been used is from the Carrizo-Wilcox aquifer, because the quality of its water is higher than that of the water in the Sparta and Queen City aquifers. Generally, the water quality of all three aquifers is well within the recommended limits for concentrations of primary and secondary constituents for drinking water. However, quality deteriorates with depth. In the Sparta and Queen City aquifers, this is significant and may occur just below their outcrops. These two aquifers rarely contain fresh water below depths of 600 to 700 feet, whereas in the Carrizo-Wilcox aquifer fresh water occurs in depths of up to 3,000 feet. Although the water quality in all three aquifers is generally good, low well yields and high concentrations of iron and dissolved solids in the upper aquifers result in much higher production costs because of the number of wells required to achieve the volume desired and the required treatment process.

The six-county area has experienced significant historic groundwater level declines because of long-term heavy pumpage and insufficient well spacing. This is particularly true in the vicinity of Tyler, Nacogdoches, and Lufkin. In these areas, the drop of water levels in many wells has exceeded 300 to 400 feet and, in some instances, as much as 500 feet. The areas of significant water level decline are characterized by long-term pumping of high-capacity wells that are spaced too close together. However, there has been a leveling-off and/or reduction of annual water level decline rates in the Lufkin-Nacogdoches area since Nacogdoches began using surface water from Lake Nacogdoches as a major source of its water supply in 1979.

According to the report, relatively large amounts of groundwater are recoverable from the underlying aquifers, but much of this water is not economical or dependable for recovery in the large amounts required for the projected demand, particularly from the Sparta and Queen City aquifers. The Sparta aquifer has a maximum thickness of about 200 feet and averages about 100 feet in thickness. Also, it has a significant threat of surface pollution because it is very close to the ground surface. The Queen City aquifer has a maximum thickness of about 600 feet and an average thickness in the range of 300 to 400 feet.

The reason that these aquifers are not dependable and economical sources of water supply is that a large number of small-capacity wells would be required to meet the projected demand. In addition, the high concentration of iron and dissolved solids would require a more expensive degree of treatment. There is still a significant amount of water available from the Carrizo-Wilcox aquifer, but not in the vicinity of the population centers. The larger cities would have to supplement their water supply from surface sources because of the cost of well spacing and hudraulic problems associated with conveying groundwater from remote areas, where water is available, to their treatment facilities.

In 1985, the total groundwater usage in the six-county area was 74,618 acre-feet, of which 91 percent (68,029 acre-feet) was from the Carrizo-Wilcox aquifer. The annual recharge for this aquifer is 105,000 acre-feet, leaving 36,971 acre-feet for future use. In 1991, the projected usage for the area in 2010 was 135,425 acre-feet. The volume recovered from the Carrizo-Wilcox aquifer has averaged in the range of 63 percent to 66 percent. Assuming that 60 percent of the 2010 demand is groundwater, the total usage from this source is 81,255 acre-feet, leaving 23,745 acre-feet available for future use.

Additional large-volume wells in the vicinity of the population centers would severely lower groundwater levels, ruling this out as a source of future water supply in these areas. This additional capacity can be used in small population centers without affecting groundwater levels. Because there will be very little water available from the Carrizo-Wilcox aquifer and because of the problems associated with recovering water from the other aquifers, groundwater is not a viable alternative for the provision of the Lake Eastex yield.

LEGAL ISSUES

The 404 permit application states that there can be no practical alternatives to Lake Eastex because: (1) only the alternatives recommended in the State Water Plan for Lake Eastex participants and other potential users are eligible for state funding; and (2) any alternative involving interbasin transfers would encounter difficulties with respect to priority of water rights and therefore would be a bad risk for bond sales. If both of these statements are true, it is obvious that the present analysis of Toledo Bend Reservior, Sam Rayburn Reservoir, and Lake Palestine as alternatives to Lake Eastex is not viable. Sam Rayburn Reservoir and Lake Palestine would violate the first point, and Toledo Bend Reservoir would violate both points because it would involve an interbasin transfer.

With respect to the issue of state funding, Senate Bill 1, which was enacted in 1997 and established the procedures under which the regional plans were developed, indicates (Section 1.02 – Regional Water Plans) that projects are normally eligible for state funding only if they are compatible with the State Water Plan, but that a waiver may be granted. This directive and the waiver provision are reiterated on page 70 of *Water for Texas--2002*. In implementing this directive, TWDB as a practical matter is not funding projects that are not included in the State Water Plan (TWDB, personal communication). This is as it should be, for to do otherwise would subvert the whole intent of the state planning process.

However, the directive is not applicable to projects for which state funding is not sought. More importantly, the law does not say that only projects that appear in the 2002 State Water Plan are eligible for state funding. A new plan is developed every five years, and any alternatives described in the 1991 Lake Eastex report and in the present report could be included in future renditions. Taken at face value, the argument in the permit application suggests severe limitations on the inclusion of any new participants in the Lake Eastex project and, should the project not be built, that entities with needs currently recommended for satisfaction by Lake Eastex would never be eligible for state funding. Texas water law places no barriers to the type of formal analysis of alternatives presented in the 1991 Lake Eastex report and in the present report.

Texas water law authorizes the taking of water from one basin to another, but protects the interest of the source basin. Table 5-7 in *Water for Texas--2002* contains a list of 99 existing interbasin transfers in Texas, and Table 8-1 contains a list of major water conveyances proposed by the regional water planning groups, many of which involve interbasin transfers. Prior appropriation is a fundamental principle of Texas water law. During times of shortage, seniority with respect to water allocations is established by the order in time in which water rights were secured, with all subsequently established rights being junior in priority. Section 2.08 (Interbasin Transfers) of Senate Bill 1 provides that any new application for an interbasin transfer would be junior in relation to existing rights in the water source during times of shortage. This provision contributes to the practical (but not prohibitive) difficulties connected with interbasin transfers.

Texas water policy also protects the interests of the source basin. Permits for interbasin transfers are generally not granted if it is determined that the source basin has significant needs over 50 years that could be met by the source and that the granting of the permit would be detrimental to the satisfaction of those needs (TWDB, personal communication). However, even in these cases the law is not prohibitive because Senate Bill 1 contains provisions under Section 2.08 for compensation and mitigation if they are needed. The *Comprehensive Sabine Watershed Management Plan* shows a net 2050 surplus of 755,780 AFY for the 21 counties in its region, suggesting that there would be no difficulties in securing water from Toledo Bend.

VI. SOURCES

Angelina & Neches River Authority. Meeting with Kenneth Reneau and John Stover on December 19, 2002, to discuss Lake Eastex.

Angelina & Neches River Authority. Webpage, www.anra.org.

City of Palestine, Texas. Webpage, www.palestine-online.org.

City of Palestine Utilities. Telephone conversation with Brian Socia concerning City of Palestine's use of Lake Palestine water.

Czetwertynski, Mariella, 2002. *The Sale and Leasing of Water Rights in Western States: An Overview for the Period 1990-2001.* Georgia Water Planning and Policy Center, Georgia State University.

Dallas Water Utilities. Telephone conversation with Charles Stringer on January 31, 2003, concerning Dallas' use of Lake Palestine water.

Fort Worth District Corps of Engineers. Meeting with Jennifer Walker on November 7, 2002, to obtain planning documents.

Fort Worth District Corps of Engineers. Meeting with Corps personnel organized by Kevin Craig on January 14, 2003, to discuss issues connected with Sam Rayburn Reservoir reallocation.

Fort Worth District Corps of Engineers. Telephone conversation with Presley Hatcher on November 8, 2002, concerning Corps criteria for reservoir need.

Freese and Nichols, Inc., 2000 (for Anglina & Neches River Authority). "404 Permit Application." Submitted to Fort Worth District Corps of Engineers.

Freese and Nichols, Inc. (for Sabine River Authority of Texas), 1999. *Comprehensive Sabine Watershed Management Plan.*

Kaiser, Ronald A., 1998. "A Primer on Texas Surface Water Law for the Regional Planning Process." Available on www.bickerstaff.com/waterlawfeature/kaiser.htm.

Lockwood, Andrews & Newnam, Inc., 1992. "Revised Surface Water Alternatives Analysis." Copy obtained from ANRA.

Lockwood, Andrews & Newnam, Inc., 1991. *Lake Eastex Water Supply Planning Study, Volume 1, Engineering and Financial Analysis.*

Lockwood, Andrews & Newnam, Inc., 1991. *Lake Eastex Water Supply Planning Study, Volume 2, Environmental Inventory and Issues.*

Sabine River Authority of Texas. Telephone conversation with Jack Tatum on November 21, 2002, concerning availability of water from Toledo Bend Reservoir.

Sabine River Authority of Texas. Letter from SRA on January 2, 2003, concerning costs of raw water from Toledo Bend Reservoir.

"Senate Bill 1," 1997. Available through Texas Legislature Online, Seventy-Eighth Congress, Regular Session.

Texas Water Development Board. Telephone conversations with Bill Roberts and Chris Martinez on November 4, November 29, December 2, and December 8, 2002, and January 9, 2003, concerning State Water Plan, reports, interpretation of data, and reservoir development issues.

Texas Water Development Board, 1991. *An Evaluation of Ground Water Resources in the Vicinity of the Cities of Henderson, Jacksonville, Kilgore, Lufkin, Nacogdoches, Rusk and Tyler in East Texas.*

Texas Water Development Board, 2002. *Water for Texas – 2002.*

Texas Water Development Board, 2002. "Region I (East Texas) report for 2002 State Water Plan."

Texas Water Developmennt Board, 2002. "Region D (North East Texas) report for 2002 State Water Plan."

Texas Water Development Board, 2002. "Region C report for 2002 State Water Plan."

Texas Water Resources Research Institute, n.d., *Handbook of Texas Water Law.*

Tyler Water Utilities. Telephone conversation with Greg Moran on February 5, 2003, concerning Tyler's use of Lake Palestine water.

Appendix A

DEFICITS AND STRATEGIES

5.2.2 Angelina County

City of Lufkin

The City of Lufkin currently receives all of its supply form the Carrizo-Wilcox Aquifer. The City is currently planning construction of a surface water treatment plant on Sam Rayburn Reservoir (where it will contract with the LNVA for 28,000 acre-feet/year). The City's existing well field will continue to be operated at or near its current capacity, but the proposed surface water plant will be expanded in a series of phases to meet rising future demands. The most recent plans for the timing of the phased development is as follows:

Year	Capacity (ac-ft/yr)
2006	11,200
2015	16,800
2025	22,400
2035	28,000

It is proposed that the future expansions will enable the City to service additional surrounding county water suppliers and to meet increasing manufacturing demands.

The following is a summary of the demands and supply provided by the selected strategy. The selected strategy is to construct a proposed surface water plant and transfer line to supply water from Sam Rayburn Reservoir. The general location of the improvements is indicated on the county map.

	2000	2010	2020	2030	2040	2050
Population	36,684	44,281	53,452	64,521	77,883	94,013
Water Demand (ac-ft/year)	5,712	6,498	7,424	8,746	10,295	11,700
Current Supply (ac-ft/year)	5,751	5,751	5,751	5,751	5,751	5,751
Supply(+)-Demand(-) (ac-ft/yr)	39	-747	-1,673	-2,995	-4,544	-5,949
Recommended Strategy LU-1 (ac-ft/year): Construct conveyance pipeline to Rayburn Reservoir and associated water treatment plant.		5,600	6,384	6,272	7,560	7,560

The supplies provided by recommended strategy are cumulative totals based on construction of phases as discussed above and do not include quantities supplied to meet manufacturing needs.

Only one strategy was considered to meet the future water demands. Expansion of groundwater was not considered to be a realistic alternative due to the demand required. The cost of the strategy is presented in the following table.

Strategy	Firm Yield (AF/Y)	Total Capital Cost	Total Annualized Cost	Unit Cost ($/AF)	Unit Cost ($/Thou. Gal.)
LU-1: Construct conveyance pipeline to Rayburn Reservoir and associated water treatment plant.	7,560	$50,409,000	$4,064,256	$648	$ 1.98

City of Huntington

The City of Huntington currently receives supplies from the Yegua aquifer. The shortage shown in the year 2040 and beyond is based on limiting current supply to 50% of the current well pumping capacity. The shortage can be most easily met by additional wells if needed.

	2000	2010	2020	2030	2040	2050
Population (number of persons)	2,273	2,756	3,202	3,670	4,120	4,601
Water Demand (ac-ft/year)	298	336	369	407	447	495
Current Supply (ac-ft/year)	435	435	435	435	435	435
Supply(+)-Demand(-) (ac-ft/yr)	137	99	66	28	-12	-60
Recommended Strategy HU-1 (ac-ft/year): Expand current supplies					60	60

The existing wells, with proper management and maintenance, are expected to continue servicing the needs of the City.

Strategy	Firm Yield (AF/Y)	Total Capital Cost	Total Annualized Cost	Unit Cost ($/AF)	Unit Cost ($/Thou. Gal.)
HU-1: Expand current supply	60	$176,773	$16,954	$283	$ 0.87

Livestock

Livestock is supplied from Queen City and Sparta and local supplies. The recommended strategy is to continue expansion of the current supplies.

	2000	2010	2020	2030	2040	2050
Water Demand (ac-ft/year)	628	649	673	702	735	773
Current Supply (ac-ft/year)	627	627	627	627	627	627
Supply(+)-Demand(-) (ac-ft/yr)	-1	-22	-46	-75	-108	-146
Recommended Strategy ANL-1 (ac-ft/year): Expand current supplies	49	49	49	98	147	147

Only one strategy was considered to meet the future water demands. The cost of the strategy is presented in the following table.

Strategy	Firm Yield (AF/Y)	Total Capital Cost	Total Annualized Cost	Unit Cost ($/AF)	Unit Cost ($/Thou. Gal.)
ANL-1 (ac-ft/year): Expand current supplies	145	$66,570	$8,604	$69.49	$ 0.21

Manufacturing

Current supplies are from several sources with the following approximate distribution; 14,668 acre-feet/year from the Carrizo-Wilcox Aquifer, 851 acre-feet/year from the Yegua and 29,000 acre-feet/year from surface water sources. The City of Lufkin currently supplies approximately 12% of the current needs, however, it would be expected that the City's percentage of the supply would increase. The 19,000 acre-feet of surface water is controlled by a single manufacturing entity, Donohue. It is not expected that all of the growth will be limited to Donohue, which has the largest source of water supply. It is anticipated that growth will be supplied by the City of Lufkin and possibly Temple-Inland, which is currently under contract with ANRA for supply from Lake Eastex. It is expected that Temple-Inland would use the Lake Eastex supply as it became available.

	2000	2010	2020	2030	2040	2050
Water Demand (ac-ft/year)	30,000	32,290	34,877	37,818	41,138	45,000
Current Supply (ac-ft/year)	44,519	44,519	44,519	44,519	44,519	44,519
Supply(+)-Demand(-) (ac-ft/yr)	14,519	12,229	9,642	6,701	3,381	-481
Recommended Strategy ANM-1 (ac-ft/year): Renew Contract with City of Lufkin.			2,006	4,947	6,400	6,400
Recommended Strategy ANM-2 (ac-ft/year): Obtain supply from Lake Eastex					8,551	8,551

The supply from the City of Lufkin is based on supplies available after meeting municipal demands by the City of Lufkin.

Strategy	Firm Yield (AF/Y)	Total Capital Cost	Total Annualized Cost	Unit Cost ($/AF)	Unit Cost ($/Thou. Gal.)
ANM-1 (ac-ft/year): Renew Contract with City of Lufkin.	6,400	$42,944,000	$3,193,344	$648	$ 1.98
ANM-2 (ac-ft/year): Obtain supply from Lake Eastex	8,551	$32,992,000	$3,180,972	$372	$ 1.14

Note: Cost reflect treated water for ANM-1 and raw water for ANM-2. ANM-1 is industrial portion of cost for water from City of Lufkin.

Mining

Water for mining is supplied from the Carrizo-Wilcox. Water strategy would be to continue use of the Carrizo-Wilcox.

	2000	2010	2020	2030	2040	2050
Water Demand (ac-ft/year)	36	40	45	51	57	64
Current Supply (ac-ft/year)	22	22	22	22	22	22
Supply(+)-Demand(-) (ac-ft/yr)	-14	-18	-23	-29	-35	-42
Recommended Strategy ANN-1 (ac-ft/year):Increase supply from wells.	42	42	42	42	42	42

Only one strategy was considered to meet the future water demands. The cost of the strategy is presented in the following table.

Strategy	Firm Yield (AF/Y)	Total Capital Cost	Total Annualized Cost	Unit Cost ($/AF)	Unit Cost ($/Thou. Gal.)
ANN-1:Increase supply from wells	42	$33,936	$4,081	$96.00	$ 0.29

5.2.3 Cherokee County

The Carrizo-Wilcox Aquifer is almost fully allocated in Cherokee County. There are substantial amounts of additional water available from the Queen City and Sparta Aquifers, but these aquifers do not cover the entire county. Where feasible, water from the Queen City or Sparta Aquifers may be substituted for Carrizo-Wilcox water in the following potential water management strategies. However, the ETRWPG has made a policy decision that water from the Queen City and Sparta Aquifers will be used primarily for Livestock and Irrigation uses because of the unreliable supply and quantity. No proposed management strategies for municipal water shortages involve the Queen City and Sparta Aquifers.

Water obtained from the Queen City Aquifer may be acidic and may have levels of iron and manganese greater than TNRCC secondary drinking water standards. Water obtained from the Sparta Aquifer may have levels of sulfates greater than the TNRCC secondary drinking water standards, especially in far southern Cherokee County. Water quality in the Sparta Aquifer is best on the outcrop.

Alto

The City of Alto's water supply is currently from groundwater wells in the Carrizo-Wilcox Aquifer. Future population growth is expected to increase the demand for water. The strategy selected to meet the future demands is to increase additional supplies from the Carrizo-Wilcox.

	2000	2010	2020	2030	2040	2050
Population (number of persons)	1,137	1,235	1,335	1,443	1,556	1,656
Water Demand (ac-ft/year)	205	212	218	229	242	256
Current Supply (ac-ft/year)	240	240	240	240	240	240
Supply(+)-Demand(-) (ac-ft/yr)	35	28	22	11	-2	-16
Recommended Strategy Al-1 (ac-ft/year): Increase supply from Carrizo-Wilcox					121	121

Only one strategy was considered to meet the future water demands. The cost of the strategy is presented in the following table.

Strategy	Firm Yield (AF/Y)	Total Capital Cost	Total Annualized Cost	Unit Cost ($/AF)	Unit Cost ($/Thou. Gal.)
Al-1: Increase supply from Carrizo-Wilcox	121	$201,025	$32,181	$266	$ 0.81

Bullard

The City of Bullard's water supply is currently from groundwater wells in the Carrizo-Wilcox Aquifer, with some of the wells in Smith County. Future population growth is expected to increase the demand for water. The strategy selected to meet the future demands is to increase additional supplies from the Carrizo-Wilcox in Smith County.

	2000	2010	2020	2030	2040	2050
Population (number of persons)	661	737	875	942	1,033	1,130
Water Demand (ac-ft/year)	141	144	159	163	169	181
Current Supply (ac-ft/year)	116	116	116	116	116	116
Supply(+)-Demand(-) (ac-ft/yr)	-25	-28	-43	-47	-53	-65
Recommended Strategy BU-1 (ac-ft/year): Increase supply from Carrizo-Wilcox	121	121	121	121	121	121

Only one strategy was considered to meet the future water demands. The cost of the strategy is presented in the following table.

Strategy	Firm Yield (AF/Y)	Total Capital Cost	Total Annualized Cost	Unit Cost ($/AF)	Unit Cost ($/Thou. Gal.)
BU-1 (ac-ft/year): Increase supply from Carrizo-Wilcox	121	$214,725	$35,126	$290	$ 0.89

New Summerfield

The City of New Summerfield currently obtains water supply from Carrizo-Wilcox Aquifer. Although near term needs are adequate, the City has a contract with ANRA for water from Lake Eastex, if it is developed. Development of plant farms in the New Summerfield area, with the City being the supplier of the water, will impact the City's need for new sources. The selected strategy is to obtain water from Lake Eastex. Improvements used in the evaluation of strategies are shown on the county map.

	2000	2010	2020	2030	2040	2050
Population (number of persons)	604	681	767	864	974	1,097
Water Demand (ac-ft/year)	81	89	100	111	124	139
Current Supply (ac-ft/year)	118	118	118	118	118	118
Supply(+)-Demand(-) (ac-ft/yr)	37	29	18	7	-6	-21
Recommended Strategy SU-1 (ac-ft/year): Obtain water from Lake Eastex for support of local plant farm.		855	855	855	855	855

Most of the supply from Eastex (787 ac-ft/yr) is for resale to plant farm irrigation demands.

In addition to the recommended alternative, alternatives were also investigated for purchase of water through Cities of Jacksonville and Tyler. The evaluation of alternatives was based on providing a supply equal to the Lake Eastex contract amounts.

Strategy	Firm Yield (AF/Y)	Total Capital Cost	Total Annualized Cost	Unit Cost ($/AF)	Unit Cost ($/Thou. Gal.)
SU-1: Obtain water from Lake Eastex	855	$5,630,000	$518,985	$607	$ 1.86
SU-2: Obtain water from City of Jacksonville	855	$4,267,441	$839,610	$982	$ 3.00
SU-3: Obtain water from City of Tyler	855	$1,280,394	$692,550	$810	$ 2.48

Rusk

Current supplies are obtained from Carrizo-Wilcox Aquifer and Rusk City Lake. The City presently has a contract with ANRA for water from Lake Eastex, if constructed. The selected strategy is to obtain water from Lake Eastex. _Improvements used in the evaluation of strategies are shown on the county map.

	2000	2010	2020	2030	2040	2050
Population	4,645	4,945	5,237	5,651	5,952	6,182
Water Demand (ac-ft/year)	1,051	1,075	1,086	1,145	1,187	1,225
Current Supply (ac-ft/year)	1,091	1,091	1,091	1,091	1,091	1,091
Supply(+)-Demand(-) (ac-ft/yr)	40	16	5	-54	-96	-134
Recommended Strategy RU-1 (ac-ft/year): Obtain water from Lake Eastex				855	855	855

In addition to the selected alternatives, a supplementary alternative of strategy RU-2, will be to obtain water from the City of Jacksonville. The evaluation of alternatives were based on providing a supply equal to the Lake Eastex contract amounts

Strategy	Firm Yield (AF/Y)	Total Capital Cost	Total Annualized Cost	Unit Cost ($/AF)	Unit Cost ($/Thou. Gal.)
RU-1: Obtain water from Lake Eastex	855	$5,630,000	$518,985	$607	$ 1.86
RU-2: Obtain water from City of Jacksonville	855	$4,915,000	$940,500	$1,100	$ 3.36

Wells

Current supply is from Carrizo-Wilcox Aquifer. Due to the small quantity of projected future demand the selected strategy is to continue development of current supply.

	2000	2010	2020	2030	2040	2050
Population	824	874	929	976	1,026	1,078
Water Demand (ac-ft/year)	124	129	135	140	145	150
Current Supply (ac-ft/year)	113	113	113	113	113	113
Supply(+)-Demand(-) (ac-ft/yr)	-11	-16	-22	-27	-32	-37
Recommended Short Term Strategy WE-1 (ac-ft/year): Use additional water from Carrizo-Wilcox.	121	121	121	121	121	121

Only one strategy was considered to meet the future water demands. The cost of the strategy is presented in the following table.

Strategy	Firm Yield (AF/Y)	Total Capital Cost	Total Annualized Cost	Unit Cost ($/AF)	Unit Cost ($/Thou. Gal.)
WE-1: Increase supply from Carrizo-Wilcox	121	$233,146	$35,090	$290	$ 0.89

County-Other

Current supplies are from Carrizo-Wilcox Aquifer, Queen City Aquifer, Sparta Aquifer and Lake Jacksonville. Afton Grove WSC, Craft-Turney WSC, Gum Creek WSC, North Cherokee WSC, and West Jacksonville WSC could potentially renew contracts with Jacksonville for water from Lake Jacksonville. Afton Grove WSC, Blackjack WSC, Cherokee County, John Moore, North Cherokee WSC, Reklaw WSC, Rusk Rural WSC, and the Stryker Lake WSC have existing contracts with ANRA with option for water from Lake Eastex if developed. These contracts are sufficient to meet remaining County-Other demands.

	2000	2010	2020	2030	2040	2050
Population	27,594	30,767	34,070	36,654	39,042	41,279
Water Demand (ac-ft/year)	5,441	5,917	6,431	6,855	7,246	7,587
Current Supply (ac-ft/year)	3,917	3,917	3,355	2,787	2,787	2,787
Supply(+)-Demand(-) (ac-ft/yr)	-1,524	-2,000	-3,076	-4,068	-4,459	-4,800
Recommended Strategy CHC-1 (ac-ft/year): Use additional water from Carrizo-Wilcox	404					
Recommended Strategy CHC-2 (ac-ft/year): Overdraft Carrizo-Wilcox until sustainable supply obtained	1,211					
Recommended Strategy CHC-3 (ac-ft/year): Renew contracts with City of Jacksonville			562	1,130	1,130	1,130
Recommended Strategy CHC-4 (ac-ft/year): Obtain water from Lake Eastex		7,696	7,696	7,696	7,696	7,696

In addition to the above recommended strategies evaluation was also made of supplies from the Cities of Jacksonville and Tyler. The evaluation of alternatives were based on providing a supply equal to the Lake Eastex contract amounts

Strategy	Firm Yield (AF/Y)	Total Capital Cost	Total Annualized Cost	Unit Cost ($/AF)	Unit Cost ($/Thou. Gal.)
CHC-1: Use additional water from Carrizo-Wilcox	404	$637,740	$107,968	$268	$ 0.82
CHC-2: Overdraft Carrizo-Wilcox until sustainable supply obtained	1,211	$1,913,200	$323,905	$268	$ 0.82
CHC-3: Renew contracts with City of Jacksonville	1,130	$0	$548,050	$485	$ 1.48
CHC-4: Obtain water from Lake Eastex	7,696	$44,680,000	$4,055,792	$527	$ 1.61
CHC-5: Obtain water from City of Jacksonville for certain Lake Eastex participants	1,283	$6,403,657	$1,259,906	$982	$ 3.00
CHC-6: Obtain water from City of Tyler for Lake Eastex participants	855	$1,280,394	$692,530	$810	$ 2.48
CHC-7: Obtain water from City of Jacksonville for certain Lake Eastex participants	855	$4,915,000	$940,500	$1,100	$ 3.36

Notes: Eastex participants in various alternatives as noted below:
CHC-5: New Summerfield, Blackjack WSC, Stryker Lake WSC
CHC-6: Blackjack WSC and New Summerfield on extension of line from Whitehouse and Troup.
CHC-7: City of Rusk and Rusk Rural WSC

Irrigation

Current supply is from Carrizo-Wilcox Aquifer, Queen City Aquifer, Sparta Aquifer and Irrigation Local Supply. More than 90% of the irrigation water shortage is attributable to plant farm demands. Based on conversation with Joe Daniels of Powell Brothers Plant Farm and geographical extent of the Queen City Aquifer, it is assumed that 40% of the shortage can be met using additional supply from the Queen City Aquifer. The remaining 60% of the shortage can be met with water from Lake Eastex. There appears to be sufficient water in the New Summerfield contract with ANRA, and much of the plant farm demand is centered around New Summerfield.

	2000	2010	2020	2030	2040	2050
Water Demand (ac-ft/year)	1,753	1,753	1,753	1,753	1,753	1,753
Current Supply (ac-ft/year)	441	441	441	441	441	441
Supply(+)-Demand(-) (ac-ft/yr)	-1,312	-1,312	-1,312	-1,312	-1,312	-1,312
Recommended Strategy CHR-1(ac-ft/year) Use additional water from the Queen City Aquifer	565	565	565	565	565	565
Recommended Strategy CHR-2(ac-ft/year) Overdraft Carrizo-Wilcox Aquifer until sustainable supply obtained	807					
Recommended Strategy CHR-3 (ac-ft/year) Obtain water from Lake Eastex (from New Summerfield)		787	787	787	787	787

Strategy	Firm Yield (AF/Y)	Total Capital Cost	Total Annualized Cost	Unit Cost ($/AF)	Unit Cost ($/Thou. Gal.)
CHR-1: Use additional water from the Queen City Aquifer	565	$1,130,800	$155,026	$274	$ 0.84
CHR-2 : Overdraft Carrizo-Wilcox Aquifer until sustainable supply obtained	807	$993,616	$92,866	$236	$ 0.72
CHR-3 : Obtain water from Lake Eastex	787	$0	$468,265	$607	$ 1.86

NOTE: CHI-3 is treated water supplied thru New Summerfield.

Mining

Current supply is from Carrizo-Wilcox Aquifer and Mining Local Supply. Recommended strategy is to obtain water from the Queen City Aquifer.

	2000	2010	2020	2030	2040	2050
Water Demand (ac-ft/year)	77	52	267	569	713	883
Current Supply (ac-ft/year)	84	84	84	84	84	84
Supply(+)-Demand(-) (ac-ft/yr)	7	32	-183	-485	-629	-799
Recommended Strategy CHN-1 (ac-ft/year): Use water from Queen City.			807	807	807	807

Only one strategy was considered to meet the future water demands. The cost of the strategy is presented in the following table.

Strategy	Firm Yield (AF/Y)	Total Capital Cost	Total Annualized Cost	Unit Cost ($/AF)	Unit Cost ($/Thou. Gal.)
CHN-1: Use water from Queen City.	807	$1,723,838	$231,367	$287	$ 0.88

Steam Electric Power

Current supplies are from the Carrizo-Wilcox Aquifer and Striker Creek Lake. Construction of Lake Eastex could meet the entire future demand.

	2000	2010	2020	2030	2040	2050
Water Demand (ac-ft/year)	5,000	5,000	10,000	15,000	15,000	20,000
Current Supply (ac-ft/year)	5,343	5,343	5,343	5,343	5,343	5,343
Supply(+)-Demand(-) (ac-ft/yr)	343	343	-4,657	-9,657	-9,657	-14,657
Recommended Strategy CHS-1 (ac-ft/year): Obtain water from Lake Eastex.		14,657	14,657	14,657	14,657	14,657

Besides Lake Eastex, no single alternative can provide the entire demand. A review of the supply from alternative strategies is as follows:

Alternative	Approx. Qty. (ac-ft/yr)
Lake Striker	5,600
Reuse of wastewater from Jacksonville	1,934
Reuse of wastewater from Tyler	7,123

The comparison of the alternatives is as follows:

Strategy	Firm Yield (AF/Y)	Total Capital Cost	Total Annualized Cost	Unit Cost ($/AF)	Unit Cost ($/Thou. Gal.)
CHI-S: Obtain water from Lake Eastex.	14,657	$30,857,000	$3,136,598	$214	$ 0.65
CHS-2: Striker Creek Lake	5,600		$1,187,200	$212	$ 0.65
CHS-3: Reuse from City of Jacksonville	1,934	$4,618,000	$555,982	$302	$ 0.92
CHS-4: Reuse from City of Tyler, South	7,123	$15,689,000	$1,942,276	$497	$ 1.52
CHS-5: Reuse from City of Tyler, West	5,862	$26,855,000	$3,546,518	$605	$ 1.85

5.2.9 Nacogdoches County

City of Nacogdoches

The City of Nacogdoches obtains water from both ground and surface water sources. The City has eight water wells which tap the Carrizo-Wilcox Aquifer. The City also operates a surface water plant located on Lake Nacogdoches. The current water plant is rated for 6.75 mgd. Plans are currently in process to expand the surface water facility to a capacity of 15 to 18 MGD. In addition to its own demands, the City of Nacogdoches provides almost all manufacturing demands and provides water to surrounding water supply corporations.

The numbers indicated in the supply table (TWDB Table 5) included all water rights to Lake Nacogdoches even though the City cannot currently treat the entire water rights. The City will need to construct wells and improve the water surface treatment plant to meet demands. The table does indicate the City should consider other sources of water, in addition to Lake Nacogdoches, in the later portions of the planning period. The selected strategy to obtain long-term water supplies is to obtain water from Lake Eastex. The current plant is to release water from Lake Eastex into the Angelina River and divert the flows from the Angelina River to Lake Nacogdoches.

	2000	2010	2020	2030	2040	2050
Population (number of persons)	36,709	42,959	50,274	58,834	68,851	80,574
Water Demand (ac-ft/year)	9,033	10,551	12,264	14,622	17,366	20,780
Current Supply (ac-ft/year)	22,758	22,423	22,108	21,701	21,286	20,756
Supply(+)-Demand(-) (ac-ft/yr)	13,725	11,872	9,844	7,079	3,938	-24
Recommended Strategy NA-1 (ac-ft/year): Obtain supply from Lake Eastex						9,834

Note: Strategy NA-1 includes 1,283 ac-ft/yr for Caro WSC located just north of Nacogdoches

Other strategies evaluated included obtaining water from Toledo Bend with a regional treatment facility located at Center.

Strategy	Firm Yield (AF/Y)	Total Capital Cost	Total Annualized Cost	Unit Cost ($/AF)	Unit Cost ($/Thou. Gal.)
NA-1 (ac-ft/year): Obtain supply from Lake Eastex	9,834	$121,727,275	$11,929,660	$853	$ 2.61
NA-2 (ac-ft/year): Obtain supply from Toledo Bend in conjunction with Center and San Augustine	9,834	$155,686,675	$15,188,457	$1,544.48	$ 4.72

NOTE: Strategy cost includes water treatment and transport cost to treat additional water from Lake Nacogdoches in addition to water from Lake Eastex.

County-Other

Appleby WSC, Caro WSC, D&M WSC, Etoile WSC, Libby WSC, Lilbert-Looneyville WSC, Lilly Grove WSC, Melrose WSC, Sacul WSC, Swift WSC, and Woden WSC obtain their groundwater from the Carrizo Wilcox Aquifer. The remaining supplies are from the Queen City, Sparta Sands, or other *undifferentiated* aquifers. The City of Nacogdoches provides wholesale water to D&M, Lilly Grove, Appleby, Woden, Timber Ridge Association, Woodland Hills and Central Heights, and Nacogdoches County MUD. For the majority of the County-Other entities, the best means for supply is to continue use of groundwater and expansion of contracts with the City of Nacogdoches.

	2000	2010	2020	2030	2040	2050
Population (number of persons)	24,923	28,622	32,635	37,904	42,717	45,337
Water Demand (ac-ft/year)	4,199	4,530	4,908	5,572	6,135	6,459
Current Supply (ac-ft/year)	3,558	3,558	3,558	3,558	3,558	3,558
Supply(+)-Demand(-) (ac-ft/yr)	-641	-972	-1,350	-2,014	-2,577	-2,901
Recommended Strategy NAC-1 (ac-ft/year): Use additional groundwater	780	1,040	1,300	1,820	2,340	2,600
Recommended Strategy NAC-2: Expand contract with City of Nacogdoches	77	116	162	241	309	343

Other strategies included for evaluation are determining the feasibility of developing surface water sources in the area (such as apply to State agencies for potable use of Lake Naconiche). Cost for this alternative was not developed. Caro WSC has an existing contract with ANRA with option from water for Lake Eastex if developed. The cost for Caro WSC was analyzed within the City of Nacogdoches water management strategies.

Strategy	Firm Yield (AF/Y)	Total Capital Cost	Total Annualized Cost	Unit Cost ($/AF)	Unit Cost ($/Thou. Gal.)
NAC-1: Use additional groundwater	2,600	$3,997,095	$204,100	$157	$ 0.48
NAC-2: Expand contract with City of Nacogdoches	348	$0.00	$227,923	$654.95	$ 2.00

Livestock

Supply is from the Carrizo-Wilcox, Sparta and Queen City Aquifers. Expansion of current supplies by drilling new wells and/or constructing ponds for livestock is the best strategy. Livestock producers that currently obtain water from public water suppliers (either as an emergency back-up or primary provider) should continue to renew their contracts.

	2000	2010	2020	2030	2040	2050
Water Demand (ac-ft/year)	2,150	2,437	2,771	3,158	3,607	4,128
Current Supply (ac-ft/year)	2,150	2,150	2,150	2,150	2,150	2,150
Supply(+)-Demand(-) (ac-ft/yr)	0	-287	-621	-1,008	-1,457	-1,978
Recommended Strategy NAL-1 (ac-ft/year): Expand current supplies		287	861	1,148	1,722	2,009

Strategy	Firm Yield (AF/Y)	Total Capital Cost	Total Annualized Cost	Unit Cost ($/AF)	Unit Cost ($/Thou. Gal.)
Strategy NAL-1: Expand current supplies	2,009	$481,058	$67,732	$59	$ 0.18

Mining

	2000	2010	2020	2030	2040	2050
Water Demand (ac-ft/year)	261	280	312	345	378	415
Current Supply (ac-ft/year)	220	220	220	220	220	220
Supply(+)-Demand(-) (ac-ft/yr)	-41	-60	-92	-125	-158	-195
Recommended Strategy NAN-1 (ac-ft/year): Increase groundwater usage	96	96	96	195	195	195

Only one strategy was considered to meet the future water demands. The cost of the strategy is presented in the following table.

Strategy	Firm Yield (AF/Y)	Total Capital Cost	Total Annualized Cost	Unit Cost ($/AF)	Unit Cost ($/Thou. Gal.)
NAN-1: Increase groundwater usage	195	$146,880	$10,176	$106	$ 0.32

Steam Electric Power

No current supply exists and no immediate need was identified. The largest and closest source of water is from Rayburn Reservoir.

	2000	2010	2020	2030	2040	2050
Water Demand (ac-ft/year)	0	0	0	7,505	7,505	7,505
Current Supply (ac-ft/year)	0	0	0	0	0	0
Supply(+)-Demand(-) (ac-ft/yr)	0	0	0	-7,505	-7,505	-7,505
Recommended Strategy NAI-1: (ac-ft/year): Obtain water from Sam Rayburn				7,505	7,505	7,505

Alternative source of supply is for the construction of a pipeline from Toledo Bend Reservoir. However, transportation distance is farther than Sam Rayburn Reservoir.

Strategy	Firm Yield (AF/Y)	Total Capital Cost	Total Annualized Cost	Unit Cost ($/AF)	Unit Cost ($/Thou. Gal.)
NAI-1: Obtain water from Sam Rayburn	7,505			$28.14	$ 0.09

Note: Unit cost include only estimate of cost for raw water supply.

5.2.14 Rusk County

Much of the supply is groundwater taken from the Carrizo-Wilcox. However, the City of Henderson is in the process of construction of a surface water treatment plant. Surface water is also used for Steam Electric Power.

County-Other

Current supply is from Carrizo-Wilcox with the exception of surface water from Upper Neches Municipal Water Authority provided to New Salem WSC and sales to Cross Roads WSC from the City of Kilgore. Development of groundwater from Carrizo Wilcox is favorable except in areas of existing well field development appears to be at a maximum. This area is around the Henderson, New London and Mount Enterprise areas. Well fields could be developed at further distances (3-10 miles) outside these developed areas. In addition, both the City of Kilgore and the City of Henderson are currently developing new surface water systems. This may be a potential source for new water.

	2000	2010	2020	2030	2040	2050
Population (number of persons)	27,291	29,609	34,210	38,058	41,484	43,009
Water Demand (ac-ft/year)	3,362	3,403	3,646	3,943	4,058	4,199
Current Supply (ac-ft/year)	3,219	3,219	3,219	3,219	3,219	3,219
Supply(+)-Demand(-) (ac-ft/year)	-143	-184	-427	-724	-839	-980
Recommended Strategy: RUC-1: Increase supplies from groundwater	350	350	350	500	500	640
Recommended Strategy: RUC-2: Expand services from Kilgore and Henderson	0	590	590	590	590	590

Strategy	Firm Yield (AF/Y)	Total Capital Cost	Total Annualized Cost	Unit Cost ($/AF)	Unit Cost ($/Thou. Gal.)
Recommended Strategy: RUC-1: Increase supplies from groundwater	480	$718,494	$49,920	$156	$ 0.48
Recommended Strategy: RUC-2: Expand services from Kilgore and Henderson	590	$4,028,647	$698,560	$1,184	$ 3.62

City of Henderson

The City of Henderson is presently constructing a 3 mgd water treatment plant. Supply is taken from the Sabine River near Longview. The City shares a portion of the raw water supply line with the City of Kilgore. The City has a contract with the Sabine River Authority for a 4.5 mgd supply. This project will meet the demands for the City in the planning period.

	2000	2010	2020	2030	2040	2050
Population (number of persons)	12,006	12,161	11,866	11,584	11,554	11,524
Water Demand (ac-ft/year)	2,461	2,384	2,233	2,115	2,058	2,053
Current Supply (ac-ft/year)	2,249	2,211	2,168	2,124	2,081	2,034
Supply(+)-Demand(-) (ac-ft/year)	-212	-173	-65	9	23	-19
Recommended Strategy: HE-1 Construct transfer and treatment facilities from Sabine River.	1680	1680	1680	1680	1680	1680

Strategy	Firm Yield (AF/Y)	Total Capital Cost	Total Annualized Cost	Unit Cost ($/AF)	Unit Cost ($/Thou. Gal.)
Recommended Strategy HE-1 (ac-ft/year): Construct transfer and treatment facilities from Sabine River.	1680	$19,300,000	$1,653,120	$984	$ 3.01

City of New London

Current supply is from Carrizo-Wilcox. The City has an existing contract with ANRA for water from Lake Eastex if developed. The recommended strategy is for the City to continue pursuit of supplies from Lake Eastex.

	2000	2010	2020	2030	2040	2050
Population	1,039	1,069	1,079	1,127	1,191	1,256
Water Demand (ac-ft/year)	233	230	221	227	235	246
Current Supply (ac-ft/year)	242	242	242	242	242	242
Supply(+)-Demand(-) (ac-ft/yr)	9	12	21	15	7	-4
Recommended Strategy NL-1 (ac-ft/year): Obtain water from Lake Eastex		885	885	885	885	885

Alternate strategies include obtaining treated supplies from the City of Henderson or Tyler. The financially feasibility will depend on the cost of treated water from these sources.

Strategy	Firm Yield (AF/Y)	Total Capital Cost	Total Annualized Cost	Unit Cost ($/AF)	Unit Cost ($/Thou. Gal.)
Strategy NL-1: Obtain water from Lake Eastex	885	$5,630,000	$537,195	$607	$ 1.86
Strategy NL-2: Obtain water from City of Henderson	885	$3,857,175	$867,546	$979	$ 2.99
Strategy NL-3 Obtain water from City of Tyler	885	$7,252,954	$1,115,815	$1322	$ 4.04

City of Tatum

Current supply is from Carrizo-Wilcox. Use additional water from Carrizo-Wilcox.

	2000	2010	2020	2030	2040	2050
Population (number of persons)	1,063	1,077	1,053	1,031	1,029	1,027
Water Demand (ac-ft/year)	141	134	123	117	112	110
Current Supply (ac-ft/year)	128	128	128	128	128	128
Supply(+)-Demand(-) (ac-ft/yr)	-13	-6	5	11	16	18
Recommended Strategy TA-1 (ac-ft/year): Increase supply from Carrizo-Wilcox	41	41	41	41	41	41

Strategy	Firm Yield (AF/Y)	Total Capital Cost	Total Annualized Cost	Unit Cost ($/AF)	Unit Cost ($/Thou. Gal.)
TA-1: Increase supply from Carrizo-Wilcox	30	$181,458	$11,820	$394	$ 1.21

Livestock

Current supply is groundwater and surface water. Use additional groundwater from Carrizo-Wilcox.

	2000	2010	2020	2030	2040	2050
Water Demand (ac-ft/year)	1,237	1,253	1,271	1,292	1,317	1,345
Current Supply (ac-ft/year)	1,276	1,276	1,276	1,276	1,276	1,276
Supply(+)-Demand(-) (ac-ft/yr)	39	23	5	-16	-41	-69
Recommended Strategy RUL-1 (ac-ft/year): Increase supply from Carrizo-Wilcox				41	41	82

Strategy	Firm Yield (AF/Y)	Total Capital Cost	Total Annualized Cost	Unit Cost ($/AF)	Unit Cost ($/Thou. Gal.)
RUL-1: Increase supply from Carrizo-Wilcox	82	$37,900	$6,068	$74	$ 0.23

Steam Electric Power

Current demands are being met by Lake Martin based on historical data. Immediate future demands are related to construction of the Tanaska/Coral plant in southern Rusk County which have expected water demands of 12,900 acre-feet/year. This demand will be met with construction of raw water line from Toledo Bend. Provide surface water from Toledo Bend.

	2000	2010	2020	2030	2040	2050
Water Demand (ac-ft/year)	30,000	35,000	40,000	45,000	45,000	45,000
Current Supply (ac-ft/year)	25,179	25,179	25,179	25,179	25,179	25,179
Supply(+)-Demand(-) (ac-ft/yr)	-4,821	-9,821	-14,821	-19,821	-19,821	-19,821
Recommended Strategy RUI-1 (ac-ft/year): Surface water from Toledo Bend	4,960	9,960	14,960	19,960	19,960	19,960

Strategy	Firm Yield (AF/Y)	Total Capital Cost	Total Annualized Cost	Unit Cost ($/AF)	Unit Cost ($/Thou. Gal.)
Surface water from Toledo Bend	19,960	$0.00	$638,720	$32	$ 0.10

NOTE: Cost does not include transportation cost of water.

Manufacturing

Supplies are from local surface water surfaces or the City of Henderson. With the construction of the new surface water plant, it would be expected that growth would occur in the Henderson area.

	2000	2010	2020	2030	2040	2050
Water Demand (ac-ft/year)	344	382	425	469	512	559
Current Supply (ac-ft/year)	297	330	367	405	443	483
Supply(+)-Demand(-) (ac-ft/yr)	-47	-52	-58	-64	-69	-76
Recommended Strategy RUM-1 (ac-ft/year): Increase groundwater supply	81	81	81	81	81	81

Strategy	Firm Yield (AF/Y)	Total Capital Cost	Total Annualized Cost	Unit Cost ($/AF)	Unit Cost ($/Thou. Gal.)
RUM-1: Increase groundwater supplies	81	$51,323	$7,047	$87	$ 0.27

Irrigation

Water from the Neches Basin portion of the County has been used to meet needs in the Sabine portion of the County. It is assumed this will continue. The table shows a shortage in the Sabine Basin that can be adequately supplied by the Neches Basin. The selected strategy is to transfer surplus from the Neches to the Sabine Basin.

5.2.18 Smith County

With the exception of the City of Tyler, Resort Water Service, Inc and local sources for mining and livestock, water is supplied from the Carrizo-Wilcox. The City of Tyler currently utilizes groundwater to fulfill 15% of its needs. The City of Tyler also provides approximately 75% of the manufacturing demands. The City of Tyler currently has underway a project to supply treated water from Lake Palestine. The initial phase of construction will add approximately 30 mgd capacity.

County-Other

Most of the supply is from Carrizo-Wilcox with the exception of surface water provided to Resort Water Services by the Upper Neches Municipal Water Authority and some sales by the City of Tyler. Demands could be provided by increasing production from Carrizo-Wilcox or through water contracts with City of Tyler.

	2000	2010	2020	2030	2040	2050
Population (number of persons)	51,862	60,338	69,524	79,568	89,431	99,531
Water Demand (ac-ft/year)	7,757	8,645	9,624	10,719	11,921	13,145
Current Supply (ac-ft/year)	8,723	8,723	8,723	8,723	8,723	8,723
Supply(+)-Demand(-) (ac-ft/yr)	966	78	-901	-1,996	-3,198	-4,422
Recommended Strategy SMC-1 (ac-ft/year): Use additional water from Carrizo-Wilcox			160	1,120	2,400	3,520
Recommended Strategy SMC-2 (ac-ft/year): Supply from City of Tyler			885	885	885	885

Jackson WSC has a contract with ANRA for water from Lake Eastex if developed.

Strategy	Firm Yield (AF/Y)	Total Capital Cost	Total Annualized Cost	Unit Cost ($/AF)	Unit Cost ($/Thou. Gal.)
SMC-1: Use additional water from Carrizo-Wilcox	3520	$5,397,060	$496,800	$207	$ 0.63
Strategy SMC-2 (ac-ft/year): Obtain water from City of Tyler.	885	$3,299,552	$489,405	$553.00	$ 1.69
Strategy SMC- 3(ac-ft/year): Obtain water from Lake Eastex.	885	$5,630,000	$525,690	$594.00	$ 1.82

City of Lindale

Supply is from Carrizo-Wilcox. Increase supply from Carrizo-Wilcox.

	2000	2010	2020	2030	2040	2050
Population (number of persons)	1,372	1,490	1,565	1,625	1,676	1,709
Water Demand (ac-ft/year)	261	267	266	271	274	278
Current Supply (ac-ft/year)	264	264	264	264	264	264
Supply(+)-Demand(-) (ac-ft/yr)	3	-3	-2	-7	-10	-14
Recommended Strategy LI-1 (ac-ft/year): Increase supply from Carrizo-Wilcox			40	40	40	40

Strategy	Firm Yield (AF/Y)	Total Capital Cost	Total Annualized Cost	Unit Cost ($/AF)	Unit Cost ($/Thou. Gal.)
Strategy LI-1: Increase supply from Carrizo-Wilcox	40	$82,333	$8,160	$204	$ 0.62

City of Whitehouse

City of Whitehouse receives approximately 95% through City of Tyler and 5% through groundwater. Increase from City of Tyler supplies

	2000	2010	2020	2030	2040	2050
Population (number of persons)	7,230	9,535	11,289	11,724	11,806	11,889
Water Demand (ac-ft/year)	972	1,186	1,328	1,353	1,336	1,332
Current Supply (ac-ft/year)	950	950	950	950	950	950
Supply(+)-Demand(-) (ac-ft/yr)	-22	-236	-378	-403	-386	-382
Recommended Strategy WH-1 (ac-ft/year): Renew and expand contract with City of Tyler	22	236	378	403	386	382

Has a contract with ANRA for water from Lake Eastex, if developed.

Strategy	Firm Yield (AF/Y)	Total Capital Cost	Total Annualized Cost	Unit Cost ($/AF)	Unit Cost ($/Thou. Gal.)
WH-1 (ac-ft/year): Renew and expand contract with City of Tyler	382	$0	$185,270	$485	$ 1.48
WH-2 (ac-ft/year): Obtain supply from Lake Eastex	8,551	$56,306,000	$5,087,845	$595	$ 1.82

City of Tyler

The City of Tyler currently has underway a project to supply treated water from Lake Palestine. The initial phase of construction will add approximately 30 mgd capacity.

	2000	2010	2020	2030	2040	2050
Population (number of persons)	86,694	98,647	111,146	123,995	136,968	149,806
Water Demand (ac-ft/year)	17,577	19,006	20,418	20,139	22,093	23,828
Current Supply (ac-ft/year)	24,285	23,919	23,669	23,430	23,196	22,962
Supply(+)-Demand(-) (ac-ft/yr)	6,708	4,913	3,251	3,291	1,103	-866
Recommended Strategy TY-1 (ac-ft/year): Increase supply from Lake Palestine		16,800	16,800	16,800	16,800	16,800

Strategy	Firm Yield (AF/Y)	Total Capital Cost	Total Annualized Cost	Unit Cost ($/AF)	Unit Cost ($/Thou. Gal.)
TY-1: Increase supply from Lake Palestine	16,800	$60,000,000	$7,089,600	$422	$ 1.29

Appendix B

TOLEDO BEND DIRECT

ESTIMATE OF COST

This estimate of cost is for pumping 85,500 acre-feet of water annually from Toledo Bend Reservoir to the proposed Eastex Reservoir site near New Summerfield, Texas.

85,500 acre-feet = 76.32 million gallons per day (MGD) = 53,000 gallons per minute (GPM)

Eastex Reservoir New Summerfield		Toledo Bend Reservoir
←	85,500 acre-feet 76.32 MGD (53,000 GPM)	

Detailed Cost Worksheet – Toledo Bend Alternative

Reach 1
Demand Center Pump Station No. 1
Water Source Toledo Bend
Page 1 of 13

I. Intake Structure and Pump Station

A	Excavation		
	8,000 CY @ $8.11/CY		$ 64,880
B.	Concrete		
	350 CY @ $400/CY		$ 140,000
C.	Pumps		
	Total design head 461 ft. (200 psi)		
	Pump and motor	2 – 16,800 GPM @ $335,000 2 – 10,000 GPM @ $206,400	$1,082,800
D.	Valves		$ 174,000
E.	Pipework		$ 237,800
F.	Electrical Controls		$ 150,000
G.	Pump Building		
	600 Sq. Ft. @ $40/Sq. Ft.		$ 24,000
H.	Sluice Gates	2 Ea. @ $10,250	$ 20,500
I.	Standby Power (Diesel generator)		$ 32,500
J.	Dewatering		$ 115,000
K.	Miscellaneous (Handrails, ladders, plumbing, etc.)		$ 45,000
L.	Construction Cost (Items A-K)		$2,086,480
M.	Engineering and Contingencies (25% of Line K)		$ 521,620
N.	Total Construction Cost (Line L + Line M)		$2,608,100

Detailed Cost Worksheet – Toledo Bend Alternative

Reach 1
Demand Center Pump Station No. 1
Water Source Toledo Bend

O. Operation and Maintenance

1.	Labor and Materials (0.5% of Line N)	$ 13,100
2.	Annual Power Cost ($0.025/KWH)	$ 2,022,610

Detailed Cost Worksheet – Toledo Bend Alternative

Reach 1
Demand Center Pump Station No. 1
Water Source Toledo Bend.

II. Pipeline

A. Pipeline Design Information

1. From Toledo Bend to Pump Station No. 1 (Timpson)
2. Pipeline Capacity: 76.32 MGD (53,000 GPM)
3. Length: 191,000 feet
4. Diameter: 66 inch
5. Type of pipe: Concrete pressure pipe (200 psi)
6. Pump Station No. 1 Head

a. Static

High point elevation	-	470 msl
Intake water elevation	-	165 msl
Static head	-	305 feet

b. Friction head loss in pipe - 155 feet

c. Total pump head - 461 feet (200 psi)

B. Pipeline Construction Cost Data

1. Transmission Pipe — $65,513,000

a. Concrete pressure pipe

191,000 L.F. 66" pipe @ $343/LF

2. Special Items

a. Clearing and grubbing — $ 335,400

78 acres @ $4,300/acre

b. Bored highway crossings — $ 184,000

96" steel pipe casing – 160 LF @ $1,150/LF

c. Bored Railroad Crossings — $ 100,000

96" steel pipe casing – 80 LF @ $1,250/LF

Detailed Cost Worksheet – Toledo Bend Alternative

Reach 1
Demand Center Pump Station No. 1.
Water Source Toledo Bend.
Page 4 of 15

	d.	Highway and roadway crossings	$ 31,550
		Highway - 8 crossings @ $1,600 Ea. Roadway - 15 crossings @ $1,250 Ea.	
	e.	Stream crossings	$ 69,400
		Major crossings - 2 @ $25,600 Ea. Minor crossings - 7 @ $2,600 Ea.	
	f.	Pipeline crossings	$ 87,500
		96" steel pipe casing – 140 LF @ $625/LF	
3.	Land for right-of-way- 78 acres @ $2,850/acre		$ 222,300
4.	Construction Cost (Items 1 – 3)		$66,543,150
5.	Engineering and Contingencies (25% of Line 4)		$16,635,790
6.	Total Construction Cost (Line 4 + Line 5)		$83,178,940
7.	Operation and Maintenance		
	a.	Labor and Materials (.5% of Line 6)	$ 415,900

Detailed Cost Worksheet – Toledo Bend Alternative

Reach 2
Demand Center Pump station No. 2.
Water Source Toledo Bend.
Page 5 of 13.

III. Pump Station No. 1

A Excavation

250 CY @ $15/CY — $ 3,750

B. Concrete

20 CY @ $400/CY — $ 8,000

C. Pumps — $1,082,800

Total design head 408 ft (177 psi).

Pump and motor 2 – 16,800 GPM @ $335,000
2- 10,000 GPM @ $206,400

D. Valves — $ 174,000

E. Pipework — $ 237,800

F. Electrical Controls — $ 150,000

G. Pump Building

600 Sq. Ft. @ $40/Sq. Ft. — $ 24,000

H. Standby Power (Diesel generator) — $ 32,500

I. Miscellaneous (Handrails, ladders, plumbing, etc.) — $ 10,000

J. Construction Cost (Items A-I) — $1, 722,850

K. Engineering and Contingencies (25% 0f Line J) — $ 430,720

L. Total Construction Cost (Line J + Line K) — $ 2,153,570

Detailed Cost Worksheet – Toledo Bend Alternative

Reach 2
Demand Center Pump Station No. 2
Water Source Toledo Bend

M. Operation and Maintenance

1.	Labor and Materials (0.5% of Line L)	$ 10,900
2.	Annual Power Cost ($0.025/KWH)	$ 1,790,080

Detailed Cost Worksheet – Toledo Bend Alternative

Reach 2
Demand Center Pump Station No. 2
Water Source Toledo Bend .

IV. Pipeline

A. Pipeline Design Information

1. From Pump Station No. 1 (Timpson) to Pump Station No. 2
2. Pipeline Capacity: 76.32 MGD (53,000 GPM)
3. Length: 159,000 feet
4. Diameter: 60-inch
5. Type of pipe: Concrete pressure pipe (200 psi)
6. Pipeline Head

a.	Static		
	High point elevation	-	590 msl
	P. S. No. 1 elevation	-	389 msl
	Static head	-	201 feet
b.	Friction head loss in pipe	-	207 feet
c.	Total pump head	-	408 feet (177 psi)

B. Pipeline Construction Cost Data

1. Transmission Pipe $44,202,000

a. Concrete pressure pipe

159,000 L.F. 60" pipe @ $278/LF

2. Special Items

a. Clearing and grubbing $ 47,300

11 acres @ $4,300/acre

b. Bored highway crossings $ 374,000

84" steel pipe casing: 340 LF @ $1,100/LF

c. Highway and roadway crossings $ 26,250

Roadway – 21 crossings @ $1,250 Ea.

	d.	Stream crossings	$ 13,000
		Minor crossings - 5 @ $2,600 Ea.	
	e.	Pipeline crossings	$ 64,400
		84" steel pipe casing – 140 LF @ $460/LF	
3.	Land for right-of-way - 11 acres @ $2,850/acre		$ 31,350
4.	Construction Cost (Items 1 - 3)		$44,758,300
5.	Engineering and Contingencies (25% 0f Line 4)		$11,189,580
6.	Total Construction Cost (Line 4 + Line 5)		$55,947,880
7.	Operation and Maintenance		
	Labor and Materials (0.5% of Line 6)		$ 279,740

Detailed Cost Worksheet – Toledo Bend Alternative

Reach 3
Demand Center Lake Eastex.
Water Source Toledo Bend.

III. Pump Station No. 2

A Excavation

250 CY @ $15/CY — $ 3, 750

B. Concrete

20 CY @ $400/CY — $ 8,000

C. Pumps — $1,082,800

Total design head 303 ft. (132 psi)

Pump and motor cost 2 – 16,800 GPM @ $335,000
2 – 10,000 GPM @ $206,400

D. Valves — $ 174,000

E. Pipework . — $ 237,800

F. Electrical Controls — $ 150,000

G. Pump Building

600 Sq. Ft. @ $40/Sq. Ft. — $ 24,000

H. Standby Power (Diesel Generator) — $ 32,500

I. Miscellaneous (Handrails, ladders, plumbing, etc.) — $ 10,000

J. Construction Cost (Items A-I) — $1,722,850

K. Engineering and Contingencies (25% of Line J) — $ 430,720

L. Total Construction Cost (Line J + Line K) — $2,153,570

M. Operation and Maintenance

a.	Labor and Materials (0.5% of Line L)	$ 10,900
b.	Annual Power Cost	$ 1,329,400

VI. Pipeline

A. Pipeline Design Information

1. From Pump Station No. 2 to Lake Eastex near New Summerfield
2. Pipeline Capacity: 76.32 MGD (53,000 GPM)
3. Length: 106,000 feet
4. Diameter: 54 inch
5. Type of pipe: Concrete pressure pipe (150 psi)
6. Pump Station Head

a. Static

High point elevation	- 545 msl
Pump Sta. No. 2 elevation	- 470 msl
Static head	- 75 feet
b. Friction head loss in pipe	- 228 feet
c. Total pump head	- 303 feet (132 psi)

B. Pipeline Construction Cost Data

1. Transmission Pipe $23,532,000

a. Concrete pressure pipe

106,000 L.F. 54" pipe @ $222/LF

2. Special Items

a. Clearing and grubbing $ 47,300

11 acres @ $4,300/acre

b. Bored highway crossings $ 289,000

66" steel pipe casing: 340 LF @ $850/LF

c. Highway and roadway crossings $ 26,250

Roadway – 21 crossings @ $1,250 Ea.

Detailed Cost Worksheet – Toledo Bend Alternative

	d.	Stream crossings	$ 13,000
		Minor crossings – 5 @ $2,600 Ea.	
	e.	Pipeline crossings	$ 51,800
		66" steel pipe casing – 140 LF @ $370/LF	
3.	Land for right-of-way - 11 acres @ 2,850/acre		$ 31,350
4.	Construction Cost (Items 1 - 3)		$23,990,700
5.	Engineering and Contingencies (25% Of Line 4)		$ 5,997,680
6.	Total Construction Cost (Line 4 + Line 5)		$29,988,380
7.	Operation and Maintenance		
	Labor and Materials (0.5% of Line 6)		$ 150,000

Detailed Cost Worksheet – Toledo Bend Alternative

Reach 1 – 3
Demand Center Lake Eastex
Water Source Toledo Bend

Project Summary Cost Sheet

Project Feature		Construction and O&M Cost	Amortized Construction Cost	Annual O&M Cost	System Annual Cost
I.	Intake Structure and Pump Station	$ 2,608,100	$ 162,589	$ 2,035,710	$ 2,198,299
II.	Pipeline Toledo Bend Bend to P.S. No. 1	$ 83,178,940	$ 5,185,376	$ 415,900	$ 5,601,276
III.	Pump Station No. 1	$ 2,153,570	$ 134,253	$ 1,800,980	$ 1,935,233
IV.	Pipeline P.S. No. 1 to P.S. No. 2	$ 55,947,880	$ 3,487,791	$ 279,740	$ 3,767,531
V.	Pump Station No. 2	$ 2,153,570	$ 134,254	$1,340,300	$ 1,474,554
VI.	Pipeline P.S. No. 2 to Lake Eastex Site	$ 29,988,380	$ 1,869,476	$ 150,000	$ 2,019,476
VIII.	Total	$176,030,440	$10,973,739	$6,022,630	$16,996,369

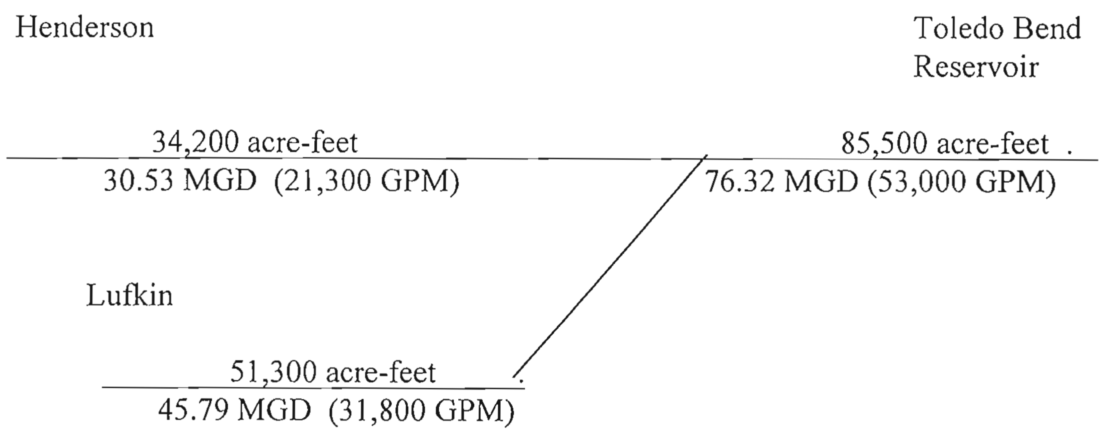
Appendix C

TOLEDO BEND DELIVERY

ESTIMATE OF COST

This estimate of cost is for pumping 85,500 acre-feet of water annually from Toledo Bend Reservoir to delivery points near Lufkin (51,300 acre-feet) and Henderson (34,200 acre-feet).

85,500 acre-feet = 76.32 million gallons per day (MGD) = 53,000 gallons per minute (GPM)



Detailed Cost Worksheet – Toledo Bend Alternative

Reach 1
Demand Center Pump Station No. 1
Water Source Toledo Bend .
Page 2 of 15 .

O. Operation and Maintenance

1.	Labor and Materials (0.5% of Line N)	$ 13,100
2.	Annual Power Cost ($0.025/KWH)	$ 2,013,840

Detailed Cost Worksheet – Toledo Bend Alternative

Reach 1
Demand Center Pump Station No. 1
Water Source Toledo Bend .

II. Pipeline

A. Pipeline Design Information

1. From Toledo Bend to Pump Station No. 1 (Timpson)
2. Pipeline Capacity: 76.32 MGD (53,000 GPM)
3. Length: 191,000 feet
4. Diameter: 66 inch
5. Type of pipe: Concrete pressure pipe (200 psi)
6. Pump Station No. 1 Head

a.	Static		
	High point elevation	-	470 msl
	Intake water elevation	-	165 msl
	Static head	-	305 feet
b.	Friction head loss in pipe	-	154 feet
c.	Total pump head	-	459 feet (199 psi)

B. Pipeline Construction Cost Data

1. Transmission Pipe $65,513,000

a. Concrete pressure pipe

191,000 L.F. 66" pipe @ $343/LF

2. Special Items

a. Clearing and grubbing $ 335,400

78 acres @ $4,300/acre

b. Bored highway crossings $ 184,000

96" steel pipe casing – 160 LF @ $1,150/LF

c. Bored Railroad Crossings $ 100,000

96" steel pipe casing – 80 LF @ $1,250/LF

Detailed Cost Worksheet – Toledo Bend Alternative

	d.	Highway and roadway crossings	$ 31,550
		Highway - 8 crossings @ $1,600 Ea. Roadway - 15 crossings @ $1,250 Ea.	
	e.	Stream crossings	$ 69,400
		Major crossings - 2 @ $25,600 Ea. Minor crossings - 7 @ $2,600 Ea.	
	f.	Pipeline crossings	$ 87,500
		96" steel pipe casing – 140 LF @ $625/LF	
3.	Land - 78 acres @ $2,850/acre		$ 222,300
4.	Construction Cost (Items 1 – 3)		$66,543,150
5.	Engineering and Contingencies (25% of Line 4)		$16,635,790
6.	Total Construction Cost (Line 4 + Line 5)		$83,178,940
7.	Operation and Maintenance		
	a.	Labor and Materials (0.5% of Line 6)	$ 415,900

III. Pump Station No. 1

A.	Excavation		
	250 CY @ $15/CY		$ 3,750
B.	Concrete		
	20 CY @ $400/CY		$ 8,000
C.	Pumps		$1,082,800
	Total design head 338 ft. (146 psi)		
	Pump and motor	2 – 16,800 GPM @ $335,000 2 - 10,000 GPM @ $206,400	
D.	Valves		$ 174,000
E.	Pipework		$ 237,800
F.	Electrical Controls		$ 150,000
G.	Pump Building		
	600 Sq. Ft. @ $40/Sq. Ft.		$ 24,000
H.	Standby Power (Diesel generator)		$ 32,500
I.	Miscellaneous (Handrails, ladders, plumbing, etc.)		$ 10,000
J.	Construction Cost (Items A-I)		$1, 722,850
K	Engineering and Contingencies (25% 0f Line J)		$ 430,720
L.	Total Construction Cost (Line J + Line K)		$ 2,153,570

Detailed Cost Worksheet – Toledo Bend Alternative

Reach 2.
Demand Center Angelina River/Henderson
Water Source Toledo Bend

M. Operation and Maintenance

1.	Labor and Materials (0.5% of Line L)	$ 10,900
2.	Annual Power Cost ($0.025/KWH)	$ 1,482,960

IV. Pipeline

A. Pipeline Design Information

1. From Timpson to delivery point at the Angelina River near Lufkin
2. Pipeline Capacity: 31.8 MGD (31,800 GPM)
3. Length: 60,000 feet of 48" & 137,500 feet of 54"
4. Diameter: 34 inch & 54 inch
5. Type of pipe: Concrete pressure pipe (150 psi)
6. Intake station pump head

a. Static		
	High point elevation	- 510 msl
	Intake water elevation	- 389 msl
	Static head	- 121 feet
b. Friction head loss in pipe		- 217 feet
c. Total pump head		- 338 feet (146 psi)

B. Pipeline Construction Cost Data – Timpson to Angelina River

1. Transmission Pipe — $40,845,000

a. Concrete pressure pipe

60,000 L.F. 48" pipe @ $172/LF
137,500 L.F. 54" pipe @ $222/LF

2. Special Items

a. Clearing and grubbing — 468,700

109 acres @ $4,300/acre

b. Bored highway crossings — 95,000

84" steel pipe casing: 40 LF @ $1,100/LF
66" steel pipe casing: 60 LF @ $850/LF

c.	Highway and roadway crossings	$ 25,150
	Highway - 4 crossings @ $1,600 Ea. Roadway - 15 crossings @ $1,250 Ea.	
d.	Stream crossings	$ 25,600
	Major crossing - 1 @ $25,600 Ea.	
f.	Pipeline crossings	$ 29,600
	66" steel pipe casing – 80 LF @ $370/LF	
3.	Land for right-of-way	$ 310,650
	109 acres @ $2,850/acre	
4.	Construction Cost (Items 1 – 2)	$ 41,799,700
5.	Construction Contingency (25% of Line 4)	$ 10,449,930
6.	Total Construction Cost (Line 4 + Line 5)	$52,249,630
7.	Operation and Maintenance	
	Labor and Materials (0.5% of Line 9)	$ 261,250

V. Pipeline

A. Pipeline Design Information

1. From Pump Station No. 1 (Timpson) to Pump Station No. 2
2. Pipeline Capacity: 30.53 MGD (21,200 GPM)
3. Length: 93,000 feet
4. Diameter: 42 inch
5. Type of pipe: Concrete pressure pipe (150 psi)
6. Intake station pump head

a. Static

	High point elevation	- 590 msl
	P. S. No. 1 elevation	- 389 msl
	Static head	- 201 feet
b.	Friction head loss in pipe	- 133 feet
c.	Total pump head	- 334 feet (145 psi)

B. Pipeline Construction Cost Data – Toledo Bend to Timpson

1. Transmission Pipe $14,787,000

a. Concrete pressure pipe

93,000 L.F. 42" pipe @ $159/LF

2. Special Items

a. Clearing and grubbing $ 47,300

11 acres @ $4,300/acre

b. Bored highway crossings $ 170,000

66" steel pipe casing: 200 LF @ $850/LF

c. Highway and roadway crossings $ 13,750

Roadway – 11 crossings @ $1,250 Ea.

Detailed Cost Worksheet – Toledo Bend Alternative

Reach 4
Demand Center Pump Station No. 2
Water Source Toledo Bend.

	d.	Stream crossings	$ 18,200
		Minor crossings - 7 @ $2,600 Ea.	
	e.	Pipeline crossings	$ 51,800
		66" steel pipe casing – 140 LF @ $370/LF	
3.	Land - 11 acres @ 2,850/acre		$ 31,350
4.	Construction Cost (Items 1 - 3)		$15,119,400
5.	Engineering and Contingencies (25% Of Line 4)		$ 3,779,850
6.	Total Construction Cost (Line 4 + Line 5)		$18,899,250
7.	Operation and Maintenance		
	Labor and Materials (0.5% of Line 6)		$ 94,500

VI. Pump Station No. 2

A	Excavation	
	250 CY @ $15/CY	$ 3,750
B.	Concrete	
	20 CY @ $400/CY	$ 8,000
C.	Pumps	$ 516,000
	Total design head 233 ft. (101 psi)	
	Pump and motor cost 2 – 12,500 GPM @ $258,000	
D.	Valves	$ 90,000
E.	Pipework	$ 30,500
F.	Electrical Controls	$ 75,000
G.	Pump Building	
	450 Sq. Ft. @ $40/Sq. Ft.	$ 18,000
H.	Standby Power (Diesel Generator)	$ 32,500
I.	Miscellaneous (Handrails, ladders, plumbing, etc.)	$ 10,000
J.	Construction Cost (Items A-I)	$ 783,750
K.	Engineering and Contingencies (25% of Line J)	$ 195,140
L.	Total Construction Cost (Line J + Line K)	$ 979,690

Detailed Worksheet – Toledo Bend Alternative

Reach 3.
Demand Center Henderson.
Water Source Toledo Bend.

M. Operation and Maintenance

a. Labor and materials (0.5% of Line L) $ 5,030

b. Annual Power Cost $ 408,940

VII. Pipeline

A. Pipeline Design Information

1. From Pump Station No. 2 to delivery point at Henderson
2. Pipeline Capacity: 30.53 MGD (21,200 GPM)
3. Length: 108,000 feet
4. Diameter: 42 inch
5. Type of pipe: Concrete pressure pipe (150 psi)
6. Pump Station Head

a. Static

High point elevation	- 558 msl
Pump Sta. No. 2 elevation	- 480 msl
Static head	- 78 feet

b. Friction head loss in pipe - 155 feet

c. Total pump head - 233 feet (101 psi)

B. Pipeline Construction Cost Data

1. Transmission Pipe — $17,172,000

a. Concrete pressure pipe

108,000 L.F. 42" pipe @ $159/LF

2. Special Items

a. Clearing and grubbing — $ 47,300

11 acres @ $4,300/acre

b. Bored highway crossings — $ 221,000

66" steel pipe casing: 260 LF @ $850/LF

c. Highway and roadway crossings — $ 13,750

Roadway – 11 crossings @ $1,250 Ea.

	d.	Stream crossings	$ 10,400
		Minor crossings - 4 @ $2,600 Ea.	
	e.	Pipeline crossings	$ 11,100
		66" steel pipe casing – 30 LF @ $370/LF	
3.	Land for right-of-way - 11 acres @ 2,850/acre		$ 31,350
4.	Construction Cost (Items 1 - 3)		$17,506,900
5.	Engineering and Contingencies (25% 0f Line 4)		$ 4,376,730
6.	Total Construction Cost (Line 4 + Line 5)		$21,883,630
7.	Operation and Maintenance		
	Labor and Materials (0.5% of Line 6)		$ 109,420

Detailed CostWorksheet – Toledo Bend Alternative

Reach 1 – 3
Demand Center Angelina River & Henderson
Water Source Toledo Bend
Page 15 of 15

Project Summary Cost Sheet

Project Feature		Construction and O&M Cost	Amortized Construction Cost	Annual O&M Cost	System Annual Cost
I.	Intake Structure and Pump Station	$ 2,608,100	$ 162,589	$2,026,940	$ 2,189,529
II.	Pipeline Toledo Bend Bend to P.S. No. 1	$ 83,178,940	$ 5,185,376	$ 415,900	$ 5,601,276
III.	Pump Station No. 1	$ 2,153,570	$ 134,254	$ 1,493,860	$ 1,628,114
IV.	Pipeline P.S. No. 1 to Angelina River	$ 52,249,630	$ 3,257,242	$ 261,250	$ 3,518,492
V.	Pipeline P.S. No. 1 to P.S. No. 2	$ 18,899,250	$ 1,178,179	$ 94,500	$ 1,272,679
VI.	Pump Station No. 2	$ 979,690	$ 61,074	$ 413,970	$ 475,044
VII.	Pipeline to Henderson	$ 21,883,630	$ 1,364,226	$ 109,420	$ 1,473,646
VIII.	Total	$181,952,810	$11,342,940	$ 4,815,840	$16,158,780

Detailed Cost Worksheet – Toledo Bend Alternative

Reach 1
Demand Center Pump Station No.1
Water Source Toledo Bend

I. Intake Structure and Pump Station

A Excavation

8,000 CY @ $8.11/CY — $ 64,880

B. Concrete

350 CY @ $400/CY — $ 140,000

C. Pumps

Total design head 459 ft. (199)

Pump and motor 2 – 16,800 GPM @ $335,000; 2 – 10,000 GPM @ $206,400 — $1,082,800

D. Valves — $ 174,000

E. Pipework — $ 237,800

F. Electrical Controls — $ 150,000

G. Pump Building

600 Sq. Ft. @ $40/Sq. Ft. — $ 24,000

H. Sluice Gates 2 Ea. @ $10,250 — $ 20,500

I. Standby Power (Diesel generator) — $ 32,500

J. Dewatering — $ 115,000

K. Miscellaneous (Handrails, ladders, plumbing, etc.) — $ 45,000

L. Construction Cost (Items A-K) — $2,086,480

M. Engineering and Contingencies (25% of Line K) — $ 521,620

N. Total Construction Cost (Line L + Line M) — $2,608,100

Appendix D

SAM RAYBURN DIRECT

ESTIMATE OF COST

This estimate of cost is for pumping 85,500 acre-feet of water annually from Sam Rayburn Reservoir to the proposed Eastex Reservoir site near New Summerfield, Texas.

85,500 acre-feet = 76.32 million gallons per day (MGD) = 53,000 gallons per minute (GPM)

Eastex Reservoir
New Summerfield

Sam Rayburn
Reservoir

85,500 acre-feet

76.32 MGD (53,000 GPM

Detailed Cost Worksheet – Sam Rayburn Alternative

Reach 1
Demand Center Pump Station No. 1
Water Source Sam Rayburn .
Page 1 of 13

I. Intake Structure and Pump Station

A	Excavation	
	8,000 CY @ $8.11/CY	$ 64,880
B.	Concrete	
	350 CY @ $400/CY	$ 140,000
C.	Pumps	$1,082,800
	Total design head 342 ft. (142 psi)	
	Pump and motor 2 – 16,800 GPM @ $335,000 2 – 10,000 GPM @ $206,400	
D.	Valves	$ 174,000
E.	Pipework	$ 237,800
F.	Electrical Controls	$ 150,000
G.	Pump Building	
	600 Sq. Ft. @ $40/Sq. Ft.	$ 24,000
H.	Sluice Gates 2 Ea. @ $10,250	$ 20,500
I.	Standby Power (Diesel Generator)	$ 32,500
J.	Dewatering	$ 115,000
K.	Miscellaneous (Handrails, ladders, plumbing, etc.)	$ 45,000
L.	Construction Cost (Items A-K)	$ 2,086,480
M.	Engineering and Contingencies (25% of Line L)	$ 521,620

Detailed Cost Worksheet – Sam Rayburn Alternative

Reach 1.
Demand Center Pump Station No. 1
Water Source Sam Rayburn.

N.	Total Construction Cost (Line L + Line M)	$ 2,608,100
O.	Operation and Maintenance	
1.	Labor and Materials (0.5% of Line O)	$ 13,100
2.	Annual Power Cost	$ 1,500,510

II. Pipeline

A. Pipeline Design Information

1. From Sam Rayburn to Pump Station No. 1
2. Pipeline Capacity: 76.32 MGD
3. Length: 155,700 feet
4. Diameter: 66 inch
5. Type of pipe: Concrete pressure pipe (150 psi)
6. Intake station pump head

a. Static

	High point elevation	-	380 msl
	Intake water elevation	-	164 msl
	Static head	-	216 feet
b.	Friction head loss in pipe	-	126 feet
c.	Total pump head	-	342 feet (148 psi)

B. Pipeline Construction Cost Data – Sam Rayburn to Pump Station No. 1

1. Transmission Pipe $50,135,400

a. Concrete pressure pipe

155,700 L.F. 66" pipe @ $322/LF

2. Special Items

a. Clearing and grubbing $ 335,400

78 acres @ $4,300/acre

b. Bored highway crossings $ 126,500

96" steel pipe casing - 110 LF @ $1,150/LF

Detailed Cost Worksheet – Sam Rayburn Alternative

Reach 1
Demand Center Pump Station No.1
Water Source Sam Rayburn .

	c.	Bored railroad crossings	$ 200,000
		96" steel pipe casing 160 LF @ $1,250/LF	
	d.	Highway and roadway crossings	$ 17,500
		Roadway - 14 crossings @ $1,250 Ea.	
	e.	Stream crossings	$ 30,800
		Major crossings - 1 @ $25,600 Ea. Minor crossings - 2 @ $2,600 Ea.	
	f.	Pipeline crossings	$ 18,750
		96" steel pipe casing – 30 LF @ $625/LF	
3.	Land - 78 acres @ $2,850/acre		$ 222,300
4.	Construction Cost – (Items 1 – 3)		$51,086,650
5.	Engineering and Contingencies (25% of Line 4)		$12,771,670
6.	Total Construction Cost (Line 4 + Line 5)		$63,858,320
7.	Operation and Maintenance		
	a.	Labor and Materials (0.5% of Line 7)	$ 319,300

Reach 2
Demand Center Pump Station No. 2
Water Source Sam Rayburn

III. Pump Station No. 1

A	Excavation	
	250 CY @ $15/CY	$ 3, 750
B.	Concrete	
	20 CY @ $400/CY	$ 8,000
C.	Pumps	$ 1,082,800
	Total design head 339 ft. (147 psi)	
	Pump and motor cost 2 – 16,800 GPM @ $335,000; 2 – 10,000 GPM @ $206,400	
D.	Valves	$ 174,000
E.	Pipework	$ 237,800
F.	Electrical Controls	$ 150,000
G.	Pump Building	
	600 Sq. Ft. @ $40/Sq. Ft.	$ 24,000
H.	Standby Power (Diesel Generator)	$ 32,500
I.	Miscellaneous (Handrails, ladders, plumbing, etc.)	$ 10,000
J.	Construction Cost (Items A-I)	$ 1,772,850
K.	Engineering and Contingencies (25% of Line I)	$ 430,720
L.	Total Construction Cost (Line J + Line K)	$ 2,153,570

Detailed Cost Worksheet – Sam Rayburn Alternative

M. Operation and Maintenance

a. Labor and Materials (0.5% of Line L) $ 10,960

b. Annual Power Cost $1,461,020

Detailed Cost Worksheet – Sam Rayburn Alternative

Reach 2
Demand Center Pump Sta.No. 2
Water Source Sam Rayburn

IV. Pipeline

A. Pipeline Design Information

1. Pipeline from Pump Station No. 1 to Pump Station No. 2
2. Pipeline Capacity: 76.32 MGD (53,000 GPM)
3. Length: 125,300 feet
4. Diameter: 60 inch
5. Type of pipe: Concrete pressure pipe (150 psi)
6. Booster pump station head

a.	Static		
	High point elevation	-	558 msl
	Low point elevation	-	380 msl
	Static head	-	178 feet
b.	Friction head loss in pipe	-	161 feet
c.	Total pump head	-	339 feet (147 psi)

z

B. Pipeline Construction Cost Data

1. Transmission Pipe — $30,698,500

a. Concrete pressure pipe

125,300 L.F. 60" pipe @ $245/LF

2. Special Items

a. Clearing and grubbing — $ 120,400

28 acres @ $4,300/acre

b. Bored highway crossings — $ 308 000

84" steel pipe casing - 280 LF @ $1,100/LF

Detailed Cost Worksheet – Sam Rayburn Alternative

Reach 2
Demand Center Pump Station No. 2
Water Source Sam Rayburn .

	c.	Bored railroad crossings	$ 72,000
		84" steel pipe casing 60 LF @ $1,200/LF	
	d.	Highway and roadway crossings	$ 18,550
		Highway - 3 crossings @ $1,600 Ea. Roadway - 11 crossings @ $1,250 Ea.	
	e.	Stream crossings	$ 105,000
		Major crossings - 4 @ $25,600 Ea. Minor crossings – 1 @ $ 2,600 Ea.	
	f.	Pipeline crossings	$ 22,200
		66" steel pipe casing – 60 LF @ $370/LF	
	g.	Asphalt street removed and replaced	$ 828,630
		40,500 Sq. Yds. @ 20.46/Sq. Yd.	
3.	Land - 28 acres $ $2,850/acre		$ 79,800
4.	Construction Cost (Items 1 – 3)		$32,253,080
5.	Engineering and Contingencies (25% of Line 4)		$ 8,063,270
6.	Total Construction Cost (Line 4 + Line 5)		$40,316,350
7.	Operation and Maintenance		
	a.	Labor and Materials (0.5% of Line 6)	$ 201,600

Detailed Cost Worksheet – Sam Rayburn Alternative

Reach 3
Demand Center Lake Eastex
Water Source Sam Rayburn

V. Pump Station No. 2

A	Excavation	
	250 CY @ $15/CY	$ 3, 750
B.	Concrete	
	20 CY @ $400/CY	$ 8,000
C.	Pumps	$1, 082,800
	Total design head 341 ft. (148 psi)	
	Pump and motor 2 – 16,8500 GPM @ $335,000 2 - 10,000 GPM @ $206,400	
D.	Valves	$ 174,000
E.	Pipework	$ 237, 800
F.	Electrical Controls	$ 150,000
G.	Pump Building	
	600 Sq. Ft. @ $40/Sq. Ft.	$ 24,000
H.	Standby Power (Diesel Generator)	$ 32,500
I.	Miscellaneous (Handrails, ladders, plumbing, etc.)	$ 10,000
J.	Construction Cost (Items A-I)	$1,722,850
K.	Engineering and Contingencies (25% of Line J)	$ 430,720
L.	Total Construction Cost (Line J + Line K)	$2,153,570

M. Operation and Maintenance

a.	Labor and materials (0.5% of Line L)	$ 10,900
b.	Annual Power Cost	$ 1,421,540

Detailed Cost Worksheet – Sam Rayburn Alternative

Reach 3
Demand Center Lake Eastex
Water Source Sam Rayburn
Page 11 of 13

VI. Pipeline

A. Pipeline Design Information

1. From Pump Station No. 2 to Lake Eastex (New Summerfield)
2. Pipeline Capacity: 76.32 MGD (53,000 GPM)
3. Length: 118,200 feet
4. Diameter: 54 inch
5. Type of pipe: Concrete pressure pipe (150 psi)
6. Pipeline Head

a. Static

High point elevation	-	545 msl
Low point elevation	-	458 msl
Static head	-	87 feet

b. Friction head loss in pipe - 254 feet

c. Total pump head - 341 feet (148 psi)

B. Pipeline Construction Cost Data

1. Transmission Pipe $26,240,400

a. Concrete pressure pipe

118,200 L.F. 54" pipe @ $222/LF

2. Special Items

a. Clearing and grubbing $ 116,100

27 acres @ $4,300/acre

b. Bored highway crossings $ 220,000

72" steel pipe casing - 220 LF @ $1,000/LF

Detailed Cost Worksheet – Sam Rayburn Alternative

	c.	Highway and roadway crossings	$ 12,500
		Roadway - 10 crossings @ $1,250 Ea.	
	e.	Stream crossings	$ 7,800
		Minor crossings – 3 @ $2,600 Ea.	
	f.	Pipeline crossings	$ 12,750
		72" steel pipe casing – 30 LF @ $425/LF	
3.	Land for right-of-way		$ 76,950
		27 acres @ $2,850/acre	
4.	Construction Cost (Items 1 – 3)		$26,686,500
5.	Engineering and Contingencies (25% 0f Line 4)		$ 6,671,630
6.	Total Construction Cost (Line 4 + Line 5)		$33,358,130
7.	Operation and Maintenance		
	a.	Labor and Materials (0.5% of Line 6)	$ 166,800

Detailed CostWorksheet – Sam Rayburn Alternative

Reach 1 – 3
Demand Center Lake Eastex
Water Source Sam Rayburn
Page 13 of 13

Project Summary Cost Sheet

	Project Feature	Construction and O&M Cost	Amortized Construction Cost	Annual O&M Cost	System Annual Cost
I.	Intake Structure and Pump Station	$ 2,608,100	$ 162,589	$1,513,610	$ 1,676,199
II.	Pipeline Sam Rayburn to Pump Station No. 1	$ 63,858,320	$3,980,928	$ 319,300	$ 4,300,228
III.	Pump Station No. 2	$ 2,153,570	$ 134,254	$1,471,980	$ 1,606,234
IV.	Pipeline P.S. No. 1 to P.S. No. 2	$ 40,316,350	$2,513,322	$ 201,600	$ 2,714,922
V.	Pump Station No. 2	$ 2,153,570	$ 134,254	$1,432,440	$ 1,566,694
VI.	Pipeline to Lake Eastex Site	$ 33,358,130	$2,079,546	$ 166,800	$ 2,246,346
VII.	Total Estimated Cost	$144,448,040	$9,004,893	$5,105,730	$14,110,623

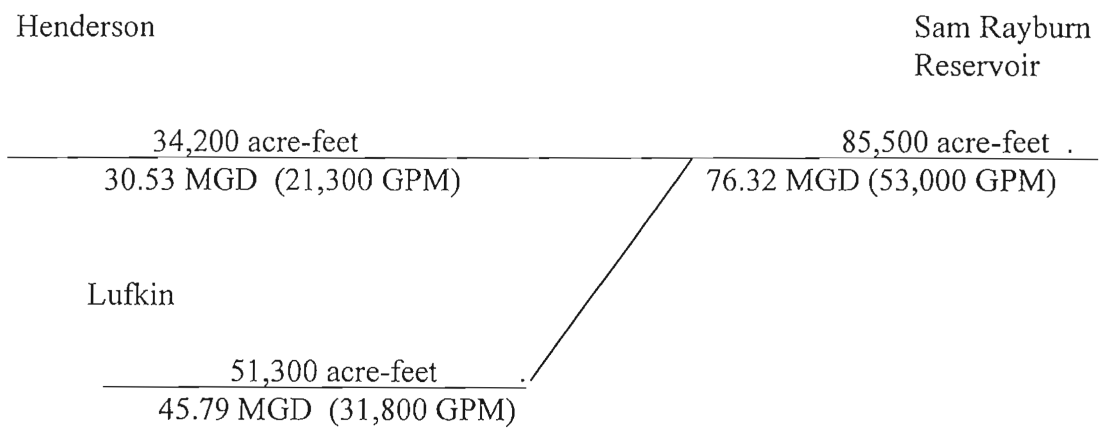
Appendix E

SAM RAYBURN SPLIT DELIVERY

ESTIMATE OF COST

This estimate of cost is for pumping 85,500 acre-feet of water annually from Sam Rayburn Reservoir to delivery points near Lufkin (51,300 acre-feet) and Henderson (34,200 acre-feet).

85,500 acre-feet = 76.32 million gallons per day (MGD) = 53,000 gallons per minute (GPM)



Detailed Cost Worksheet – Sam Rayburn Alternative

Reach 1
Demand Center Pump Station No. 1
Water Source Sam Rayburn.
Page 1 of 13

I. Intake Structure and Pump Station

A Excavation

8,000 CY @ $8.11/CY — $ 64,880

B. Concrete

350 CY @ $400/CY — $ 140,000

C. Pumps — $1,082,800

Total design head 337 ft. (146 psi)

Pump and motor 2 – 16,800 GPM @ $335,000
2 – 10,000 GPM @ $206,400

D. Valves — $ 174,000

E. Pipework — $ 237,800

F. Electrical Controls — $ 150,000

G. Pump Building

600 Sq. Ft. @ $40/Sq. Ft. — $ 24,000

H. Sluice Gates 2 Ea. @ $10,250 — $ 20,500

I. Standby Power (Diesel Generator) — $ 32,500

J. Dewatering — $ 115,000

K. Miscellaneous (Handrails, ladders, plumbing, etc.) — $ 45,000

L. Construction Cost (Items A-K) — $1,086,480

M. Engineering and Contingencies (25% of Line L) — $ 521,620

Detailed Cost Worksheet – Sam Rayburn Alternative

Reach 1
Demand Center Pump Station No. 1
Water Source Sam Rayburn
Page 2 of 13

N.	Total Construction Cost (Line L + Line M)	$ 2,608,100
O.	Operation and Maintenance	
	1. Labor and Materials (0.5% of Line Q)	$ 13,100
	2. Annual Power Cost	$ 1,478,570

Detailed Cost Worksheet – Sam Rayburn Alternative

II. Pipeline

A. Pipeline Design Information

1. From Sam Rayburn to Pump Station No. 1
2. Pipeline Capacity: 66" - 76.32 MGD (53,000 GPM)
   48" – 30.53 MGD (21,200 GPM)
3. Length: 71,000 Feet OF 66" & 84,700 Feet of 48"
4. Diameter: 66-inch & 48-Inch
5. Type of pipe: Concrete pressure pipe (150 psi)
6. Intake station pump head

a. Static

High point elevation	-	380 msl
Intake water elevation	-	164 msl
Static head	-	216 feet

b. Friction head loss in pipe - 121 feet

c. Total pump head - 337 feet (146 psi)

B. Pipeline Construction Cost Data – Sam Rayburn to Pump Station No. 1

1. Transmission Pipe $37,430,400

a. Concrete pressure pipe

71,000 L.F. 66" pipe @ $322/LF
84,700 L.F. 48" pipe @ $172/LF

2. Special Items

a. Clearing and grubbing $ 335,400

78 acres @ $4,300/acre

b. Bored highway crossings $ 126,500

96" steel pipe casing - 110 LF @ $1,150/LF

	c.	Bored railroad crossings	$ 248,500
		96" steel pipe casing 170 LF @ $1,250/LF 66" steel pipe casing 40 LF @ $ 900/LF	
	d.	Highway and roadway crossings	$ 15,000
		Roadway - 12 crossings @ $1,250 Ea.	
	e.	Stream crossings	$ 30,800
		Major crossings - 1 @ $25,600 Ea. Minor crossings - 2 @ $2,600 Ea.	
	f.	Pipeline crossings	$ 18,750
		96" steel pipe casing – 30 LF @ $625/LF	
3.	Land for right-of-way 78 acres @ $2,850/acre		$ 222,300
4.	Construction Cost – (Items 1 – 3)		$38,427,650
5.	Engineering and Contingencies (25% of Line 4)		$ 9,606,920
6.	Total Construction Cost (Line 4 + Line 5)		$48,034,570
7.	Operation and Maintenance		
	a.	Labor and Materials (0.5% of Line 9)	$ 240,180

III. Pump Station No. 1

A Excavation

250 CY @ $15/CY — $ 3, 750

B. Concrete

20 CY @ $400/CY — $ 8,000

C. Pumps — $ 516,000

Total design head 339 ft. (147 psi)

Pump and motor cost 2 - 12,500 GPM @ $258,000

D. Valves — $ 90,000

E. Pipework — $ 30,500

F. Electrical Controls — $ 75,000

G. Pump Building

450 Sq. Ft. @ $40/Sq. Ft. — $ 18,000

H. Standby Power (Diesel Generator) — $ 32,500

I. Miscellaneous (Handrails, ladders, plumbing, etc.) — $ 10,000

J. Construction Cost (Items A-I) — $ 783,750

K. Engineering and Contingencies (25% of Line J) — $ 195,940

L. Total Construction Cost (Line J + Line K) — $ 979,690

Detailed Cost Worksheet – Sam Rayburn Alternative

M. Operation and Maintenance

a.	Labor and Materials (0.5% of Line L)	$ 5,030
b.	Annual Power Cost	$ 595,000

IV. Pipeline

A. Pipeline Design Information

1. Pipeline from Pump Station No. 1 to Pump Station No. 2
2. Pipeline Capacity: 30.53 MGD (21,200 GPM)
3. Length: 112,300 feet
4. Diameter: 42 inch
5. Type of pipe: Concrete pressure pipe (150 psi)
6. Booster pump station head

a. Static

High point elevation	-	558 msl
Low point elevation	-	380 msl
Static head	-	178 feet

b. Friction head loss in pipe - 161 feet

c. Total pump head - 339 feet (147 psi)

B. Pipeline Construction Cost Data

1. Transmission Pipe $17,855,700

a. Concrete pressure pipe

112,300 L.F. 42" pipe @ $159/LF

2. Special Items

a. Clearing and grubbing $ 120,400

28 acres @ $4,300/acre

b. Bored highway crossings $ 170,000

66" steel pipe casing - 200 LF @ $850/LF

Detailed Cost Worksheet – Sam Rayburn Alternative

c.	Bored railroad crossings	$ 54,000
	66" steel pipe casing 60 LF @ $900/LF	
d.	Highway and roadway crossings	$ 18,550
	Highway - 3 crossings @ $1,600 Ea. Roadway - 11 crossings @ $1,250 Ea.	
e.	Stream crossings	$ 105,000
	Major crossings - 4 @ $25,600 Ea. Minor crossings – 1 @ $ 2,600 Ea.	
f.	Pipeline crossings	$ 11,100
	66" steel pipe casing – 30 LF @ $370/LF	
g.	Asphalt street removed and replaced	$ 828,630
	40,500 Sq. Yds. @ 20.46/Sq. Yd.	

3.	Land - 28 acres $ $2,850/acre	$ 79,800
4.	Construction Cost (Items 1 – 3)	$19,243,180
5.	Engineering and Contingencies (25% of Line 4)	$ 4,810,800
6.	Total Construction Cost (Line 4 + Line 5)	$24,053,980
7.	Operation and Maintenance	
a.	Labor and Materials (0.5% of Line 6)	$ 120,270

Reach 3
Demand Center Henderson
Water Source Sam Rayburn

VI. Pump Station No. 2

A	Excavation	
	250 CY @ $15/CY	$ 3, 750
B.	Concrete	
	20 CY @ $400/CY	$ 8,000
C.	Pumps	$ 516,000
	Total design head 309 ft. (134 psi)	
	Pump and motor cost 2 – 12,500 GPM @ $258,000	
D.	Valves	$ 90,000
E.	Pipework	$ 30,500
F.	Electrical Controls	$ 75,000
G.	Pump Building	
	450 Sq. Ft. @ $40/Sq. Ft.	$ 18,000
H.	Standby Power (Diesel Generator)	$ 32,500
I.	Miscellaneous (Handrails, ladders, plumbing, etc.)	$ 10,000
J.	Construction Cost (Items A-I)	$ 783,750
K.	Engineering and Contingencies (25% of Line J)	$ 195,940
L	Total Construction Cost (Line K + Line L)	$ 979,690

Detailed Worksheet – Sam Rayburn Alternative

M. Operation and Maintenance

a.	Labor and materials (0.5% of Line M)	$ 5,070
b.	Annual Power Cost	$ 542,330

VI. Pipeline

A. Pipeline Design Information

1. From Pump Station No. 2 to Henderson
2. Pipeline Capacity: 30.53 MGD (21,200 GPM)
3. Length: 118,000 feet
4. Diameter: 42 inch
5. Type of pipe: Concrete pressure pipe (150 psi)
6. Pipeline Head

a. Static

High point elevation	-	552 msl
Low point elevation	-	412 msl
Static head	-	140 feet

b. Friction head loss in pipe - 169 feet

c. Total pump head - 309 feet (134 psi)

B. Pipeline Construction Cost Data

1. Transmission Pipe $18,762,000

a. Concrete pressure pipe

118,000 L.F. 42" pipe @ $159/LF

2. Special Items

a. Clearing and grubbing $ 116,100

27 acres @ $4,300/acre

b. Bored highway crossings $ 187,000

66" steel pipe casing - 220 LF @ $850/LF

	c.	Highway and roadway crossings	$ 12,500
		Roadway - 10 crossings @ $1,250 Ea.	
	e.	Stream crossings	$ 10,400
		Minor crossings – 4 @ $2,600 Ea.	
	f.	Pipeline crossings	$ 11,100
		66" steel pipe casing – 30 LF @ $370/LF	
3.	Land		$ 76,950
		27 acres @ $2,850/acre	
4.	Construction Cost (Items 1 – 3)		$19,176,050
5.	Engineering and Contingencies (25% 0f Line 4)		$ 4,794,020
6.	Total Construction Cost (Line 4 + Line 5)		$23,970,070
7.	Operation and Maintenance		
	a.	Labor and Materials (0.5% of Line 6)	$ 119,850

Detailed CostWorksheet – Sam Rayburn Alternative

Reach 1 – 3
Demand Center Henderson
Water Source Sam Rayburn

Project Summary Cost Sheet

Project Feature		Construction and O&M Cost	Amortized Construction Cost	Annual O&M Cost	System Annual Cost
I.	Intake Structure and Pump Station	$2,608,100	$162,589	$1,491,670	$1,654,259
II.	Pipeline Sam Rayburn to Pump Station No. 1	$48,034,570	$2,994,476	$240,180	$3,234,656
III.	Pump Station No. 1	$979,690	$61,074	$600,030	$661,104
IV.	Pipeline P.S. No. 1 to P.S. No. 2	$24,053,980	$1,499,525	$120,270	$1,619,795
V.	Pump Station No. 2	$979,690	$61,074	$547,400	$608,474
VI.	Pipeline to Henderson	$23,970,070	$1,494,294	$119,850	$1,614,144
VII.	Total	$100,626,100	$6,273,032	$3,119,400	$9,392,432

Appendix F

LAKE PALESTINE FULL AMOUNT

ESTIMATE OF COST

This estimate of cost is for pumping 85,500 acre-feet of water annually from Lake Palestine Reservoir to the proposed Eastex Reservoir site near New Summerfield, Texas.

85,500 acre-feet = 76.32 million gallons per day (MGD) = 53,000 gallons per minute (GPM)

Palestine Reservoir

Lake Eastex Reservoir
New Summerfield

85,500 acre-feet

76.32 MGD (53,000 GPM)

Detailed Cost Worksheet – Lake Palestine Alternative

Reach 1
Demand Center Lake Eastex
Water Source Lake Palestine

I. Intake Structure and Pump Station

A Excavation

8,000 CY @ $8.11/CY — $ 64,880

B. Concrete

350 CY @ $400/CY — $ 140,000

C. Pumps — $1,082,800

Total design head 453 ft. (197 psi)

Pump and motor 2 – 16,800 GPM @ $335,000
2 – 10,000 GPM @ $206,400

D. Valves — $ 174,000

E. Pipework — $ 237,800

F. Electrical Controls — $ 150,000

G. Pump Building

600 Sq. Ft. @ $40/Sq. Ft. — $ 24,000

H. Sluice Gates 2 Ea. @ $10,250 — $ 20,500

I. Standby Power (Diesel Generator) — $ 32,500

J. Dewatering — $ 115,000

K. Miscellaneous (Handrails, ladders, plumbing, etc.) — $ 45,000

L. Construction Cost (Items A-K) — $2,086,480

M. Engineering and Contingencies (25% of Line L) — $ 521,620

Detailed Cost Worksheet – Lake Palestine Alternative

Reach 1.
Demand Center Lake Eastex.
Water Source Lake Palestine.

N.	Total Construction Cost (Line L + Line M)	$ 2,608,100
O.	Operation and Maintenance	
	1. Labor and Materials (0.5% of Line O)	$ 13,100
	2. Annual Power Cost	$ 1,987,520

Detailed Cost Worksheet – Lake Palestine Alternative

Reach 1
Demand Center Lake Eastex .
Water Source Lake Palestine .
Page 3 of 5 .

II. Pipeline

A. Pipeline Design Information

1. From Lake Palestine to Lake Eastex near New Summerfield
2. Pipeline Capacity: 76.32 MGD (53,000 GPM)
3. Length: 65,000 feet of 60 inch & 24,000 feet of 54 inch
4. Diameter: 60 inch and 66 inch
5. Type of pipe: Concrete pressure pipe (200 psi)
6. Intake Pump Station Head:

a.	Static		
	High point elevation	-	695 msl
	Intake water elevation	-	345 msl
	Static head	-	350 feet
b.	Friction head loss in pipe	-	103 feet
c.	Total pump head	-	453 feet (197 psi)

B. Pipeline Construction Cost Data

1. Transmission Pipe $26,302,000

a. Concrete pressure pipe

65,000 L.F. 60" Pipe @ $278/LF
24,000 L.F. 66" pipe @ $343/LF

2. Special Items

a. Clearing and grubbing $ 107,500

25 acres @ $4,300/acre

b. Bored highway crossings $ 132,000

84" steel pipe casing – 120 LF @ $1,100/LF

c. Bored Railroad Crossings $ 120,000

84" steel pipe casing – 100 LF @ $1,200/LF

Detailed Cost Worksheet – Lake Palestine Alternative

Reach 1
Demand Center Lake Eastex
Water Source Lake Palestine
Page 4 of 5

	d.	Highway and roadway crossings	$ 11,600
		Highway - 1 crossings @ $1,600 Ea. Roadway - 8 crossings @ $1,250 Ea.	
	e.	Stream crossings	$ 5,200
		Minor crossings - 2 @ $2,600 Ea.	
	f.	Pipeline crossings	$ 110,400
		84" steel pipe casing – 240 LF @ $460/LF	
3.	Land for right-of-way - 62 acres @ $2,850/acre		$ 176,700
4.	Construction Cost (Items 1 – 3)		$26,965,400
5.	Engineering and Contingencies (25% of Line 4)		$ 6,741,350
6.	Total Construction Cost (Line 4 + Line 5)		$33,706,750
7.	Operation and Maintenance		
	a.	Labor and Materials (.5% of Line 6)	$ 168,540

Detailed CostWorksheet – Lake Palestine Alternative

Reach 1 – 3
Demand Center Lake Eastex
Water Source Lake Palestine
Page 5 of 5

Project Summary Cost Sheet

Project Feature		Construction and O&M Cost	Amortized Construction Cost	Annual O&M Cost	System Annual Cost
I.	Intake Structure and Pump Station	$ 2,608,100	$ 162,589	$ 2,000,620	$2,163,209
II.	Pipeline Lake Palestine to Lake Eastex Site	$33,706,750	$2,101,279	$168,540	$2,269,819
III.	Total	$36,314,850	$2,263,868	$ 2,169,160	$4,433,028

Appendix G

LAKE PALESTINE REDUCED AMOUNT

ESTIMATE OF COST

This estimate of cost is for pumping 21,000 acre-feet of water annually from Lake Palestine Reservoir to the proposed Eastex Reservoir site near New Summerfield, Texas.

21,000 acre-feet = 18.75 million gallons per day (MGD) = 13,000 gallons per minute (GPM)

Palestine Reservoir

Lake Eastex Reservoir
New Summerfield

21,000 acre-feet

18.75 MGD (13,000 GPM)

Detailed Cost Worksheet – Lake Palestine Alternative

Reach 1
Demand Center Lake Eastex .
Water Source Lake Palestine .

I. Intake Structure and Pump Station

A	Excavation	
	8,000 CY @ $8.11/CY	$ 64,880
B.	Concrete	
	350 CY @ $400/CY	$ 140,000
C.	Pumps	$ 578,000
	Total design head 459 ft. (199 psi)	
	Pump and motor 2 – 13,000 GPM @ $289,000	
D.	Valves	$ 90,000
E.	Pipework	$ 30,500
F.	Electrical Controls	$ 75,000
G.	Pump Building	
	600 Sq. Ft. @ $40/Sq. Ft.	$ 24,000
H.	Sluice Gates 2 Ea. @ $10,250	$ 20,500
I.	Standby Power (Diesel Generator)	$ 32,500
J.	Dewatering	$ 115,000
K.	Miscellaneous (Handrails, ladders, plumbing, etc.)	$ 45,000
L.	Construction Cost (Items A-K)	$1,215,380
M.	Engineering and Contingencies (25% of Line L)	$ 303,850

Detailed Cost Worksheet – Lake Palestine Alternative

Reach	1
Demand Center	Lake Eastex
Water Source	Lake Palestine
Page 2	of 5

N.	Total Construction Cost (Line L + Line M)		$1,519,230
O.	Operation and Maintenance		
	1.	Labor and Materials (0.5% of Line O)	$ 7,600
	2.	Annual Power Cost	$ 494,750

Detailed Cost Worksheet – Lake Palestine Alternative

Reach 1
Demand Center Lake Eastex .
Water Source Lake Palestine .
Page 3 of 5 .

II. Pipeline

A. Pipeline Design Information

1. From Lake Palestine to Lake Eastex near New Summerfield
2. Pipeline Capacity: 18.75 MGD (13,000 GPM)
3. Length: 89,000
4. Diameter: 36 inch
5. Type of pipe: Concrete pressure pipe (200 psi)
6. Intake Pump Station Head:

a. Static

High point elevation	-	695 msl
Intake water elevation	-	345 msl
Static head	-	350 feet

b. Friction head loss in pipe - 109 feet

c. Total pump head - 459 feet (199 psi)

B. Pipeline Construction Cost Data

1. Transmission Pipe $11,659,000

a. Concrete pressure pipe

89,000 L.F. 36" Pipe @ $131/LF

2. Special Items

a. Clearing and grubbing $ 107,500

25 acres @ $4,300/acre

b. Bored highway crossings $ 66,000

54" steel pipe casing – 120 LF @ $550/LF

c. Bored Railroad Crossings $ 61,000

54" steel pipe casing – 100 LF @ $610/LF

	d.	Highway and roadway crossings	$ 11,600
		Highway - 1 crossings @ $1,600 Ea. Roadway - 8 crossings @ $1,250 Ea.	
	e.	Stream crossings	$ 5,200
		Minor crossings - 2 @ $2,600 Ea.	
	f.	Pipeline crossings	$ 57,600
		54" steel pipe casing – 240 LF @ $240/LF	
3.		Land for right-of-way - 62 acres @ $2,850/acre	$ 176,700
4.		Construction Cost (Items 1 – 3)	$12,144,600
5.		Engineering and Contingencies (25% of Line 4)	$3,036,150
6.		Total Construction Cost (Line 4 + Line 5)	$15,180,750
7.		Operation and Maintenance	
	a.	Labor and Materials (.5% of Line 6)	$ 76,000

Detailed Cost Worksheet – Lake Palestine Alternative

Reach 1 – 3
Demand Center Lake Eastex
Water Source Lake Palestine

Project Summary Cost Sheet

Project Feature		Construction and O&M Cost	Amortized Construction Cost	Annual O&M Cost	System Annual Cost
I.	Intake Structure and Pump Station	$ 1,519,230	$ 94,709	$502,350	$ 597,059
II.	Pipeline Lake Palestine to Lake Eastex Site	$15,180,750	$ 946,368	$ 76,000	$1,022,368
III.	Total	$16,699,980	$1,041,077	$578,350	$1,619,427

Appendix H

ENGINEERING COST ESTIMATING METHODOLOGY

ENGINEERING COST ESTIMATING METHODOLOGY

These estimates are based on cost data furnished by material and equipment suppliers, published cost data, and construction experience. Concrete pressure pipe is used throughout. Friction head loss was developed using the parameters set out in the American Waterworks Association's *Manual of Water Supply Practices, Concrete Pressure Pipe, Second Edition* and *Cameron Hydraulic Data*. Both of these publications are widely used in the design of water systems. Static head loss is based on profiles taken from *USGS Quadrangle Maps, 7.5 Minute Series.* To achieve pipe economy, 150 psi pipe is used where practical, and 200 psi pipe is used where head loss exceeds 150 psi. Booster pump stations are placed at locations along the pipelines to keep system pressure within these constraints. Total head loss used to size pipelines and pumps is the sum of static head and friction head. Estimated annual maintenance and operating costs and power costs are included in the detailed estimates.

Highway, street, railroad, pipeline, and stream crossing locations were obtained from the quadrangle maps. Generally, the routes of the pipelines follow area highways, but in some reaches they parallel railroads, electric transmission lines, and pipelines or run across country. Most of area highways have broad rights-of-way, and the four-lane highways have wide grass medians. Where space permits, the pipelines are placed on highway rights-of-way, because very little clearing will be required, which will result in less interference with traffic. This results in purchasing less right-of-way and lower gradients where pipelines cross over hills. Steel casings are bored beneath all railroad crossings and major highway crossings. These casings are a minimum of six inches larger than the outside diameter of the pipeline. Water lines crossing beneath pipelines also are in steel pipe casings, but are open cut. Secondary highways, streets, county roads and private roads are open cut. The unit costs for these facilities include replacing the pavement surfaces in-kind.

REFERENCES

Cameron Hydraulic Data, 14th Edition, published by the Compressed Air Magazine Company.

Manual of Water Supply Practices, Concrete Pressure Pipe, American Water Works Association, 2nd Edition.

SOURCES OF COST DATA

Building Construction Cost Data, 2002. R. S. Means Company, Inc., Kingston, MA.

Hansen Pipe and Products, Inc., Grand Prairie, TX. Concrete pressure pipe.

Hydraulic Engineering Tables Engineering Information. Hersey – Sparling Meter Company.

Layne Central Company, Memphis, TN. Pumps and motors.

Memphis Road Boring Company, Olive Branch, MS. Pipe boring.

Van Brocklin & Associates, Inc. Valves.

APPENDIX B

EPA ALTERNATIVES ANALYSIS-UPDATED REVIEW (FNI, 2007b)

FREESE • NICHOLS

SIMONE FREY KIEL 93615 STATE OF TEXAS LICENSED PROFESSIONAL ENGINEER

Simone Kiel 2-8-2007

MEMORANDUM

TO: ANRA, File, ANR00164

FROM: Simone Kiel, P.E.

SUBJECT: EPA Alternatives Analysis – Updated review

DATE: February 8, 2007

The Lake Eastex Needs Analysis and Alternatives Evaluation Report, prepared by G.E.C., Inc. for the EPA, was published in July 2003. Data used to develop this report relied on previous studies and recommendations in the 2001 East Texas Regional Water Plan and 2002 State Water Plan. Since 2003, Texas has continued the regional water planning process, with new regional water plans and a new state water plan being published in 2006 and 2007, respectively.

The alternatives analysis in the G.E.C. report focused on potential water supplies from existing surface water sources in the East Texas Region. Sources considered include Toledo Bend Reservoir, Sam Rayburn Reservoir, and Lake Palestine. As noted in the alternatives analysis (page ES-iii), the feasibility of using Lake Palestine water as an alternate for Lake Columbia is low because most of the water in this lake is committed to the City of Dallas. There is potential for some entities to contract with the cities of Tyler or Palestine, but the amount that would be available is much less than the full yield of Lake Columbia. Also, if water is determined to be available from Lake Palestine, it is likely that the City of Dallas would be interested in contracting for additional supplies to meet its projected 650,000 acre-feet per year deficit.

The alternatives analysis states that use of water from Sam Rayburn Reservoir is a possible, but not a practical, alternative to Lake Columbia. We agree with this assessment. In addition to current users of water form this source, the 2006 regional water plan shows additional demand on Sam Rayburn Reservoir that was not included in the 2002 plan. These additional demands total over 650,000 acre-feet per year by 2020. Without a major new strategy for the Lower Neches Valley Authority, there is not available supply from Sam Rayburn Reservoir for Lake Columbia participants.

Toledo Bend Reservoir is a major water source in the Sabine River Basin. It is currently permitted for 750,000 acre-feet per year (Texas' share). Based on the 2006 regional water plans, there would be supply available to Lake Columbia participants. To use this water, the participants would need to obtain an interbasin water right permit. The cost estimates prepared for this alternative appear low and do not comply with standards used for a project of this type. Specifically, the concerns on the cost estimates are:

- The pipelines are undersized for amount of flow in the analysis (76.3 MGD). It appears that the pipes were sized based on head loss, which results in moving the same amount of flow from larger to smaller pipelines. This is not standard practice and would have impacts to the life cycle costs of the transmission system.

- The cost estimates do not provide for peaking capacities in the sizing of the pipelines.
- No storage is provided at the pump stations.
- No terminal storage is included. Terminal storage is needed for two reasons: 1) to provide reserve storage if the single pipeline requires maintenance, and 2) provide additional peaking capacity. Without terminal storage, the transmission line must provide all of the peaking capacity for its users, and no peaking capacity was provided in the analysis by G.E.C.
- The annual costs for the alternative strategies are amortized over 50 years. Most pipeline projects are financed over 30 years, and that is Texas' standard in regional water planning.

A revised cost estimate for the Toledo Bend to New Summerfield alternative was prepared using updated unit costs and sizing sufficient to move 85,500 acre-feet per year of water, with a peak capacity of 110 MGD. Consistent with Senate Bill 1 costing requirements, engineering and contingencies are 35% of the construction costs for pump stations and 30% for pipelines. Debt service is amortized over 30 years, and O&M costs are 1% for pipelines, 2.5% for pump stations and storage tanks, and 1.5% for dams or earthen dikes. Interest during construction is based on 6% interest with a 4% return on unused funds. Construction unit costs are updated to third quarter 2006 dollars to compare to the latest cost estimates developed for Lake Columbia.

Since the GEC report was published, construction costs for large transmission projects have increased considerably. Using G.E.C.'s original design with updated unit costs, the capital costs increase by over 50 percent. Correcting the deficiencies in the cost assumptions and updating unit costs, the total capital cost to move 85,500 acre-feet per year of water from Toledo Bend to New Summerfield is $398 million. The unit cost of water per 1,000 gallons is $1.65. The total capital cost for the construction of Lake Columbia is estimated at $191 million. The updated Toledo Bend cost estimate is shown in Table 1.

Table 1
Updated Cost Estimate for Toledo Bend to New Summerfield

STRATEGY:			**Toledo Bend to New Summerfield, TX**		
AMOUNT: Raw water (ac-ft/yr):			**85,500**	Peak capacity = 110 MGD	
Construction Costs	**Size**	**Amount**	**Unit**	**Unit cost**	**Cost**
72" Water Line	72 in	191,000	LF	$470	$89,770,000
72" Water Line	72 in	159,000	LF	$470	$74,730,000
72" Water Line	72 in	106,000	LF	$470	$49,820,000
Bore & encasement			LS	$2,000,000	$2,000,000
Intake Structure	110 MGD	1	EA	$5,100,000	$5,100,000
Pump Station at Toledo Bend	15,306 HP	1	EA	$15,232,000	$15,232,000
Booster station	11,424 HP	1	EA	$12,320,000	$12,320,000
Booster station	6,184 HP	1	EA	$7,548,000	$7,548,000
Ground storage tank	8 MG	4	EA	$1,900,000	$7,600,000
Terminal storage (5 days) w/ discharge structure	1,200 AF	1	EA	$13,400,000	$13,400,000
Subtotal - Construction Costs					*$277,520,000*
Engineering and Contingencies					$86,061,000.00
Mitigation and Permitting (1%)					$3,330,240
ROW purchase		419	AC	$3,500.00	$1,465,565
Subtotal					*$368,376,805*
Interest During Construction					$30,096,385
Total Capital Project Costs					**$398,473,190**
Annual Costs					
Debt Service - Total Capital					$28,948,643
Water Purchase ($0.10/kgal)					$2,786,026
Operation and Maintenance					
Pipelines					$2,571,840
Pump stations					$1,434,000
Terminal storage					$241,200
Pumping Costs					$9,966,300
Total Annual Costs					**$45,948,010**
Annual Cost ($ per acre-foot)					**$537**
Annual Cost ($ per 1000 gallons)					**$1.65**

APPENDIX C

MITIGATION PLAN FOR
THE ANGELINA & NECHES RIVER AUTHORITY'S
LAKE COLUMBIA REGIONAL WATER SUPPLY RESERVOIR PROJECT
(FNI, 2009b)

Mitigation Plan

For the

Angelina and Neches River Authority's

Lake Columbia Regional Water Supply Reservoir Project

Prepared by

Freese and Nichols, Inc.

December 3, 2009

U.S. Army Corps of Engineers Project Number 198700524

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Figures are contained in Appendix A

APPENDICES

1.0 Introduction

The purpose of this mitigation plan (the "Plan") is to identify and describe in detail the mitigation measures proposed by the Angelina and Neches River Authority (ANRA) to compensate for the impacts to aquatic resources related to the Lake Columbia project. This Plan was prepared in accordance with the guidelines established by the U.S. Army Corps of Engineers (USACE) and published in the following documents:

- Compensatory Mitigation for Losses of Aquatic Resources; Final Rule (33 Code of Federal Regulations, Parts 325 and 332, as published in the Federal Register, Vol. 73, No. 70, April 10, 2008) (the "Mitigation Rule")
- Mitigation Guidelines, Regulatory Program, Fort Worth District U.S. Army Corps of Engineers, Draft – December 24, 2003

2.0 Mitigation Goals and Objectives

The goal of ANRA's proposed mitigation Plan is to replace and/or restore aquatic functions and services in waters of the U.S. that are expected to be lost due to the development of Lake Columbia. In keeping with federal wetlands policy, this mitigation goal includes no overall net loss of wetland functions and services within the Neches River watershed. The intent of the Plan is also to achieve no overall net loss of stream functions but, as streams are described as "hard to replace" in the Mitigation rule, this goal may not be achievable. Detailed descriptions of the impacts of the proposed project to waters of the U.S. were described in the *Lake Columbia Regional Water Supply Reservoir Project Draft Environmental Impact Statement*, prepared by the USACE and published in December 2009, and they are outlined in applicable section of this Plan.

2.1 Mitigation Sequencing

2.1.1 Impact Avoidance and Minimization

This mitigation plan was conceived to compensate for the estimated unavoidable impacts to waters of the U.S. due to development of the proposed Lake Columbia. As described in the environmental impact statement for the project (USACE, 2009), ANRA has followed the USACE required sequencing process whereby impacts to waters of the

U.S. were avoided to the extent practicable while addressing the purpose and need for the project, impacts that could not be avoided were minimized to the extent practicable, and finally mitigation actions were identified in this Plan to compensate for the remaining unavoidable but minimized impacts to waters of the U.S.

ANRA proposes the following actions to minimize impacts of the proposed project on the aquatic environment.

a. **Land and Flowage Easement Acquisitions.** ANRA will purchase land around Lake Columbia up to elevation 318 feet NGVD and prohibit unpermitted development within this area. This would avoid indirect impacts to 1,029 acres of land contiguous with the conservation pool. In addition, flowage easements would be purchased for land from 318 ft NGVD up to elevation 326 ft NGVD. Approximately 3,350 acres would be included. Development restrictions would minimize the secondary impacts of development in the vicinity of the reservoir and avoid flood damage to habitable structures. Permitted activities are described in detail in Appendix B. ANRA has not calculated specific functional credit units for this area or claimed any preservation credits. However, these restrictions would minimize water quality and secondary development impacts.

b. **Water Quality Regulations.** ANRA adopted Lake Columbia Water Quality Regulations on August 7, 2007 (Appendix B). These regulations apply to the lake itself and to an area immediately surrounding the lake shore known as the "No Discharge Zone" (NDZ). The NDZ is defined by the regulation as "the land located horizontally 2,000 feet from the 315 feet [NGVD] elevation. The NDZ as well as the 318 foot and 326 foot NGVD contours are depicted in Figure 5.

   The NDZ encompasses approximately 15,500 acres, and it includes approximately 35 miles of intermittent stream channels and 10 miles of perennial stream channels. ANRA's Water Quality Regulations specifically prohibit the following:

1) Construction and installation of pipelines and utility lines within the lake.
2) Construction or enlargement of existing hazardous or municipal solid waste facilities within the Lake Columbia watershed (except for such facilities owned, operated, or within the incorporated limits of Tyler, Jacksonville, New Summerfield, Troup, Whitehouse, and Bullard).
3) Petroleum storage tanks greater than 100 gallons within the NDZ.
4) Onsite sewerage facilities (OSSF) in the NDZ on lots: less than 0.75 acre if connected to a public water supply; less than 1.25 acres if not connected to public water supply; which can be served practicably by a sewage collection system. (NOTE: All OSSFs in the NDZ must be permitted by ANRA.)
5) Human-induced erosion.
6) Construction of any structure that would decrease the storage capacity of the lake, be a source of contamination, or significantly impact aquatic or terrestrial habitat.
7) Modification of the shoreline (up to the 100-year flood elevation, 322.59 feet NGVD) without prior written consent of ANRA.

In addition, ANRA's regulations require the following measures to protect water quality in Lake Columbia:

1) Forestry best management practices (BMPs) for all forestry activities within the NDZ. (Section 4 of the WQRs makes the Best Management Practices established by the Texas Forest Service mandatory for all forestry operations within the No Discharge Zone. The BMPs are applicable to all property regardless of acreage. Part Three of the BMPs specifically addresses forestry operations in wetlands. One of the principal procedures to protect wetlands is the establishment of Streamside Management Zones (SMZs) which should be at least 50 feet in width near perennial streams. The BMPs do not allow for clear cutting in the SMZs and

require at least a minimum of 50% of original crown cover or 50 square feet of basal area per acre to be maintained. ANRA has the authority under current law to enforce the WQR. Texas Water Code Section 49.216 even authorizes it to contract for or employ peace officers to enforce its rules.).

2) OSSFs must be designed by a P.E. or registered professional sanitarian.
3) OSSF plan approval by ANRA prior to construction.
4) ANRA approval of plans to construction piers, docks and other water front facilities.

2.1.2 Analysis of Alternative Mitigation Approaches

ANRA first proposed its multi-faceted mitigation approach for the Lake Columbia project in its Section 404 permit application to the USACE Fort Worth District on October 31, 2000. That proposed approach encompassed both permittee-responsible mitigation, which was the regulatory preference at that time, and purchase of mitigation bank credits and payment of in-lieu fee.

ANRA further refined its compensatory mitigation strategy in the 2003 Lake Eastex [Columbia] Planning Studies Report (FNI, 2003). The components of that strategy, which included on-site, near-site, and off-site permittee-responsible activities, were published in the USACE Joint Public Notice issued on September 5, 2003.

More recently, the USACE issued its Mitigation Rule which essentially reversed the USACE preference for implementing mitigation by making the purchase of mitigation bank credits and in-lieu fee payment methods as preferred over permittee-responsible mitigation. Also during the period between submittal of the Lake Columbia 404 permit application and publication of the Mitigation Rule, the USACE approved a number of mitigation banks in East Texas that could potentially provide opportunities to compensate for the loss of waters of the U.S. Meanwhile, prior to publication of the Mitigation Rule, ANRA had already made tentative commitments to secure off-site, threatened private lands associated with the Big Thicket National Preserve (BTNP) that could be restored or preserved to compensate for some of the loss of wetlands and streams at the Lake Columbia site.

After publication of the Mitigation Rule, ANRA evaluated the alternative of purchasing mitigation bank credits to compensate for all or a portion of the impacts to waters of the U.S. at the Lake Columbia site. Results of that evaluation included the following:

No single mitigation bank would have enough credits to offset the wetlands impacts identified by the Hydrogeomorphic Methodology (HGM) study conducted on Lake Columbia. Consequently, compensatory mitigation through bank credit purchase would be geographically fragmented.

A proposal from a mitigation bank brokerage company proposed stacking credits from nine mitigation banks from East Texas, only two of which are currently permitted, to address ANRA's compensatory mitigation need. Lake Columbia lies within the primary service area of only two of the banks, while the remaining seven banks are outside of the Neches River basin. Credit purchase requirements increase for projects outside of the primary service area of a bank. The number of credits currently available would not meet ANRA's need, and there is no certainty that additional banks would be approved and enough additional credits made available to compensate for the impacts of Lake Columbia. Thus, additional mitigation actions would be required.

The largest bank within close proximity to the Lake Columbia site has a total land area of approximately 19,000 acres (nearly two times the area of the lake Columbia project). The bank would have a total of 29,939 credits for forested wetlands mitigation when fully authorized. According to the credit/debit determination process described in the bank's mitigation banking instrument, ANRA would have to purchase 61,236 credits. Thus, the number of credits available would not meet ANRA's compensatory mitigation need, so additional mitigation action beyond the bank would be necessary. Furthermore, the estimated cost of purchasing all of the bank's credits would far exceed the entire estimated cost of the Lake Columbia project. Therefore, purchasing credits from this bank was considered not practicable.

Large on-channel reservoir projects in general, because of their size and location and the typically large area of aquatic resources impacts, may require more complex (i.e., multi-faceted) mitigation approaches than other types of non- water dependent development projects. After reviewing the practicability of satisfying Lake Columbia mitigation requirements solely through purchase of mitigation bank credits (in-lieu fee compensation is not an available mitigation strategy for the project area), ANRA concluded that continuing its efforts to mitigate through a multi-faceted permittee-responsible approach would keep the mitigation activities within the Neches River basin where the impacts would occur, and it would be more cost effective than pursuing mitigation primarily through credit purchase. ANRA still proposes to use mitigation bank credit purchase as a supplemental mitigation strategy, if needed, to fulfill mitigation requirements.

Recognizing the USACE mandate and desirability of compensating for impacts as close to the impact source as practicable, ANRA proposes to mitigate the adverse effects of the Lake Columbia project on aquatic resources in a stepwise fashion by first identifying and implementing mitigation measures on-site, followed next by near-site mitigation actions, and finally by off-site actions in the vicinity of the Big Thicket National Preserve (BTNP), a federally-protected resource recognized internationally for its unique ecological importance. In the event that additional mitigation credit still remains after implementing mitigation measures on-site, near-site, and off-site near BTNP, ANRA will also seek other off-site lands within the Neches River watershed as well as the purchase of mitigation bank credits if necessary to offset the losses of aquatic habitat. ANRA's proposed on-site, near-site, and off-site approach to achieve the no-net-loss goal affords flexibility among these mitigation locations to allow for land availability at the time the mitigation plan is implemented. It is ANRA's intent to mitigate as much of the impacts as practicable either at or near the reservoir site. In this context, "practicable" is defined as "available and capable of being done after taking into consideration cost, existing technology, and logistics in light of overall project purposes" (40 CFR 230.3(q)). In addition, ANRA's primary goal is to acquire mitigation properties (fee simple or easement) by willing buyer/willing seller agreements. However, if necessary to fulfill its compensatory mitigation requirements, ANRA will exercise its power of eminent domain to acquire mitigation land in the absence of readily identifiable willing sellers.

2.2 Impact Site

Lake Columbia will have a surface area of 10,133 acres and is situated in the Pineywoods vegetation area in East Texas. The area is typified by pine and mixed pine/hardwood forest and is dissected with bottomland hardwood forest associated with rivers, streams, swamps, and reservoirs. There are areas of pasture land and some areas of crop cultivation. Early timber harvesting principally involved cutting large trees. Subsequently, clear cutting practices have dominated timber harvesting and have resulted in replanting of pine stands producing even-aged monotypic communities which are generally referred to as pine plantations. Timberlands which have been converted to pasture use are dominated by coastal Bermuda grass (*Cynodon dactylon*) and bahia grass (*Paspalum notatum*). Mud Creek, the stream on which the dam will be located, is a tributary of the Angelina River which is a tributary of the Neches River. Mud Creek, at the dam site, is a broad fluvial flood plain with a stream bed elevation of 265 ft. NGVD. The topography is generally rolling to hilly with broad, flat floodplains.

A total of 5,746.5 acres of waters of the U. S., including wetlands were delineated in the Permit Area (Table 2.1). The Permit Area includes the footprint of the conservation pool of the reservoir below elevation 315 NGVD and the limits of construction in the vicinity of the dam. The location and boundaries of waters of the U.S. at the site were delineated by Freese and Nichols, Inc. (FNI) as described in the Joint Public Notice of 404 permit application issued by the USACE and the Texas Commission on environmental Quality on September 4, 2003.

Table 2.1 Waters of The US Within the Permit Area

Water of the U.S. Classification	Area (acres)
Forested Wetlands	3,689
Shrub-scrub Wetlands	144
Herbaceous Wetlands	1,518
Intermittent Streams (204,864 linear feet)	47
Perennial Streams (370,128 linear feet)	255
Open Water	63
Hillside Bog	0.5
New Channel (14,256 linear feet)	30
TOTAL	5,746.5

2.3 Mitigation Site

As noted in Table 2.1, the aquatic resources impacted by Lake Columbia consist of wetlands, streams, and open water. The ANRA proposes to mitigate the impacts of the proposed Lake Columbia on waters of the U.S. by implementing mitigation activities at the following locations, in priority order:

1. On-site, at the reservoir site: Within the reservoir itself or land immediately surrounding the reservoir
2. Near-site: Land connected immediately downstream, including the 100 year floodplain from the dam to the mouth of Mud Creek.
3. Off-site: Land that is not on-site or near-site, including the following:
   a. Land adjacent to the BTNP that meets the following criteria:
      i. Is in imminent danger of disturbance or has high potential for residential, commercial, industrial, or other intensive use that would be detrimental to BTNP property.
      ii. Is undeveloped and exhibits high quality habitat or aquatic ecosystem functions based on a Habitat Evaluation Procedure (HEP) or Hydrogeomorphic (HGM) assessment.
   b. Other land suitable for wetland restoration or preservation that is within the Mud Creek or Neches River watersheds.
   c. Mitigation bank credit purchase.

ANRA has received a financial commitment from the Texas Water Development Board (TWDB) which will provide funding for the purchase of land. However, funds for land acquisition will not be released until the 404 permit is issued. ANRA will commence efforts to acquire land for mitigation in the prioritized areas upon receipt of the 404 permit.

3.0 Baseline Information

3.1 Impact Site Location

The proposed reservoir would be located on Mud Creek, a tributary to the Angelina River and would extend into Smith and Cherokee Counties (Figure 1). The proposed dam site would be located approximately three miles downstream (south) of U.S. Highway 79 in Cherokee County, approximately at Universal Transverse Mercator (UTM) coordinates 297304.242 East and 3535573.434 North (Zone 15) on the Troup West, Tecula, Griffin, Jacksonville East, and new Summerfield 7.5-minute USGS quadrangle map in the USGS Hydrologic Unit 12020004.

The location and distribution of waters of the U.S. within the Lake Columbia footprint are shown in Figures 2a through 2g. The total area of affected waters of the U.S. is 5,746.5 acres (Table 2.1).

3.2 Assessment Methods

Wetland functions within the footprint of Lake Columbia were assessed using a modified, rapid HGM approach known as *HGM Interim*. The methodology has been employed commonly by the Fort Worth District USACE in recent years, especially to evaluate the functional uplift potential of mitigation bank sites. For the Lake Columbia site, two models were selected by the USACE: *Riverine Herbaceous/Shrub HGM Interim* and *Riverine Forested HGM Interim*. Each of these models is used to evaluate the capacity of either riverine herbaceous/shrub-scrub or riverine forested wetlands to perform three wetland functions, as follows:

- Temporary storage and detention of surface water
- Maintain Plant and animal community
- Removal and sequestration of elements and compounds

The model yields a dimensionless functional capacity index (FCI) value ranging between 0 and 1.0 for each function, with 1.0 indicating perfect functional capacity and 0 indicating no capacity or value for that wetland function. The FCI is used to calculate functional capacity units (FCU) by multiplying the FCI value by the number of acres of wetland type (i.e., forested, shrub-scrub, or herbaceous wetland). The FCU values represent the units of functional impacts at the reservoir site, and they represent the units of mitigation credit that must be achieved at the mitigation site, or that must be purchased from a mitigation bank in order to balance or compensate for project impacts. A detailed discussion of the method and the HGM analysis conducted for the Lake Columbia site is presented in the Draft EIS.

3.3 Existing Hydrology

Mud Creek, on which the proposed Lake Columbia would be located, is a tributary of the Angelina River and has a total drainage area of approximately 554 square miles. There is one streamflow gaging station on Mud Creek, USGS No. 08034500 (Mud Creek near Jacksonville). The gaging record extends from 1939 to 1979 and 2001 to present. The drainage area of Mud Creek and its tributaries above this gage covers 376 square miles. The average mean daily flow for 1940 through 1979 is 258 cubic feet per second (cfs), and the median is 74 cfs. The minimum mean daily flow is 0 cfs and the maximum is 22,700 cfs. The proposed dam site would be located immediately upstream of the Coon Creek confluence and the drainage area at this point is approximately 384 square miles.

3.4 Existing Vegetation

The location and distribution of vegetative cover types within the Lake Columbia Reservoir site are depicted in Figures 3a through 3g. Following are descriptions of the typical species that occur within each cover type.

Herbaceous Wetland

Herbaceous wetlands within the Permit Area are dominated by wetland obligates such as rushes, sedges, smartweed, and lizard’s tail (FNI, 2003). Common forbs include goldenrod and morning glory (*Ipomoea* sp.). Native grasses such as switch grass (*Panicum virgatum*) and bluestems (*Andropogon* sp.) are common.

Shrub Wetland

Shrub wetlands within the Permit Area are wetlands in successional transition between herbaceous wetlands and forested wetlands (FNI, 2003). Dominant shrubs include eastern false-willow (*Baccharis halimilifolia*), deciduous holly (*Ilex decidua*), and buttonbush (*Cephalanthus occidentalis*). Trees include overcup oak (*Quercus lyrata*), willow oak (*Q. phellos*), loblolly pine (*Pinus taeda*), and red maple (*Acer rubrum*). Vines include green briar (*Smilax* spp.), wisteria (*Wisteria* spp.), blackberry (*Rubus* spp.), and pepper vine (*Ampelopsis arborea*). Soft rush (*Juncus effusus*), American snowbell (*Styrax americana*), lizard's tail (*Saururus cernuus*), sedges (e.g., *Carex* spp., *Cyperus* spp.), and smartweed (*Polygonum* spp.) dominated the herbaceous species present.

Bottomland Hardwood Forest (Deciduous Forested Wetland)

Bottomland hardwood forest in the proposed Lake Columbia project area is associated with the Mud Creek floodplain (FNI, 2003). Dominant trees include willow oak, overcup oak, American elm (*Ulmus americana*), sweet gum (*Liquidambar styraciflua*), sugar hackberry (*Celtis laevigata*), and water oak (*Q. nigra).* Dominant plants in the shrub strata are often small trees, such as those listed above, and may also include swamp tupelo (*Nyssa sylvatica*), deciduous holly (*Ilex decidua*), and American beautyberry (*Callicarpa americana*). Common vines in the bottomland hardwood forest include green briar (*Smilax* spp.), poison ivy (*Toxicodendron radicans*), trumpet creeper (*Campsis radicans*), and Japanese honeysuckle (*Lonicera japonica*), while common herbaceous plants include lizard's tail, sedges, goldenrod (*Solidago* spp.), and smartweed.

Riverine

Emergent, floating, and submergent aquatic vegetation is noticeably absent from the Mud Creek channel (FNI, 2003). Vegetation overhanging the stream channel typically includes herbs and grasses such as sedges, smartweed, and Indian sea-oats (*Chasmanthium latifolia*). Common tree and shrub species include planer-tree (*Planera aquatica),* water oak, swamp privet (*Forestiera acuminata*), and water tupelo (*Nyssa aquatica*).

Upland Forest (Deciduous Upland Forest)

Upland forests in the Permit Area are typically mixed hardwood/pine stands with thick sub-canopies of young trees, shrubs, and vines (FNI, 2003). Dominant tree species include water oak, post oak (*Quercus stellata*), southern red oak (*Quercus falcata*), loblolly pine, short leaf pine (*Pinus echinata*), sweet gum, winged elm (*Ulmus alata*), and eastern red cedar (*Juniperus virginiana*). Common shrub and vine species include common persimmon (*Diospyros virginiana*), American beautyberry, blackberry, Japanese honeysuckle, and green briar. Common herbs include joe-pye weed (*Eupatorium* sp.), corn salad (*Valerianella* sp.), sweet clover (*Melilotus* spp.), and dock (*Rumex* sp.).

Shrubland

Shrubland in the Permit Area represents a midpoint in the successional transition from pasture to forest (FNI, 2003). Most of the shrub stratum is made up of small trees (e.g., elms, oaks, sweet gum, and pines). Actual shrub species include eastern false-willow (*Baccharis halimilifolia*), sumac (*Rhus coriaria),* Mexican plum (*Prunus mexicana*), and rusty black-haw (*Viburnum rufidulum*). Common vines include blackberry, honeysuckle, and grape (*Vitis* sp.), and common herbaceous species include sedges, corn salad, rabbit tobacco (*Evax verna*), and sweet clover.

Grassland

Grassland within the Permit Area is generally represented by upland improved Bermuda grass (*Cynodon dactylon*) pastures that have typically followed from forest clearing (FNI, 2003). Common forbs include nettles (*Solanum* sp.), yankeeweed (*Eupatorium compostifolium*), corn salad, and goldenrod.

3.5 Existing Soils

Soils within the proposed footprint of Lake Columbia are presented in Table 3.1. Descriptions of the soil series are available online from the following:

Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Official Soil Series Descriptions [Online WWW]. Available URL: “http://soils.usda.gov/technical/classification/osd/index.html” [Accessed 10 February 2008]. USDA-NRCS, Lincoln, NE.

Table 3.1 Soils in the Proposed Lake Columbia Footprint

Area (ac.)	Percent of Footprint Area	Description	Geomorphology	Prime Farmland	Erodibility	Drainage
4,289	40.38	Mantachie clay loam	floodplains		Not highly erodible	Somewhat poorly drained
1,703	16.03	Iuka fine sandy loam	floodplains		Not highly erodible	Moderately well drained
1,667	15.70	Marietta clay loam	floodplains		Not highly erodible	Moderately well drained
317	2.98	Bienville loamy fine sand, nearly level	stream terraces		Not highly erodible	Somewhat excessively drained
308	2.90	Sacul fine sandy loam, strongly sloping	interfluves		Highly erodible	Moderately well drained
298	2.80	Mantachie fine sandy loam	floodplains		Not highly erodible	Somewhat poorly drained
221	2.08	Bowie fine sandy loam, sloping	interfluves		Potentially highly erodible	Well drained
220	2.08	Bienville loamy fine sand	stream terraces		Not highly erodible	Somewhat excessively drained
204	1.92	Sacul fine sandy loam, sloping	interfluves		Potentially highly erodible	Moderately well drained
196	1.84	Mantachie loam, frequently flooded	floodplains		Not highly erodible	Somewhat poorly drained
114	1.07	Ochlockonee loamy fine sand	floodplains		Not highly erodible	Well drained
102	0.96	Sacul fine sandy loam, gently sloping	interfluves		Potentially highly erodible	Moderately well drained
95	0.89	Bowie fine sandy loam, gently sloping	interfluves	X	Potentially highly erodible	Well drained
89	0.83	Bienville loamy fine sand, sloping	stream terraces		Potentially highly erodible	Somewhat excessively drained
76	0.72	Sacul fine sandy loam, sloping, eroded	interfluves		Potentially highly erodible	Moderately well drained
63	0.60	Cuthbert fine sandy loam, strongly sloping	interfluves		Highly erodible	Well drained
53	0.50	Percilla soils	depressions on interfluves		Not highly erodible	Poorly drained
53	0.50	Hannahatchee fine sandy loam	floodplains		Not highly erodible	Well drained
45	0.43	Betis loamy fine sand, sloping	interfluves		Potentially highly erodible	Somewhat excessively drained
44	0.42	Lilbert loamy fine sand, sloping	interfluves		Potentially highly erodible	Well drained
39	0.37	Darco loamy fine sand, strongly sloping	interfluves		Highly erodible	Somewhat excessively drained
38	0.36	Darco loamy fine sand, sloping	interfluves		Potentially highly erodible	Somewhat excessively drained
38	0.36	Nacogdoches fine sandy loam, sloping, eroded	interfluves		Potentially highly erodible	Well drained
38	0.36	Trawick fine sandy loam, strongly sloping, eroded	interfluves		Highly erodible	Well drained

Area (ac.)	Percent of Footprint Area	Description	Geomorphology	Prime Farmland	Erodibility	Drainage
34	0.32	Angelina	floodplains		Not highly erodible	Very poorly drained
34	0.32	Sacul fine sandy loam, strongly sloping, eroded	interfluves		Highly erodible	Moderately well drained
32	0.30	Darco loamy fine sand, strongly sloping	interfluves		Highly erodible	Somewhat excessively drained
28	0.27	Elrose fine sandy loam, strongly sloping	interfluves		Highly erodible	Well drained
26	0.25	Elrose fine sandy loam, sloping	interfluves		Potentially highly erodible	Well drained
26	0.24	Woodtell fine sandy loam, gently sloping	interfluves		Potentially highly erodible	Well drained
26	0.24	Briley loamy fine sand, sloping	interfluves		Potentially highly erodible	Well drained
19	0.18	Alazan fine sandy loam, level	stream terraces	X	Not highly erodible	Moderately well drained
16	0.15	Tenaha loamy fine sand, strongly sloping	interfluves		Highly erodible	Well drained
15	0.14	Water				
11	0.10	Woodtell fine sandy loam, sloping	interfluves		Highly erodible	Well drained
6	0.06	Briley loamy fine sand, gently sloping	interfluves		Not highly erodible	Well drained
6	0.06	Elrose fine sandy loam, gently sloping	interfluves	X	Potentially highly erodible	Well drained
6	0.05	Ruston fine sandy loam, sloping	interfluves	X	Potentially highly erodible	Well drained
5	0.05	Bub-Trawick complex	interfluves		Highly erodible	Well drained
4	0.03	Owentown loamy fine sand, occasionally flooded	floodplains	X	Not highly erodible	Moderately well drained
2	0.02	Woodtell fine sandy loam, sloping, eroded	interfluves		Highly erodible	Well drained
2	0.02	Darco loamy fine sand, nearly level	interfluves		Not highly erodible	Somewhat excessively drained
2	0.02	Darco loamy fine sand, strongly sloping	interfluves		Highly erodible	Somewhat excessively drained
2	0.02	Lilbert loamy fine sand, gently sloping	interfluves		Not highly erodible	Well drained
2	0.02	Alazan fine sandy loam, sloping	stream terraces	X	Potentially highly erodible	Moderately well drained
2	0.02	Ruston fine sandy loam, gently sloping	interfluves	X	Potentially highly erodible	Well drained
1	0.01	Darco loamy fine sand, 1 to 6 percent slopes	interfluves		Potentially highly erodible	Somewhat excessively drained
1	0.01	LaCerda clay loam, sloping	interfluves		Potentially highly erodible	Moderately well drained
1	0.01	Gallime fine sandy loam, 1 to 5 percent slopes	stream terraces	X	Potentially highly erodible	Well drained
1	0.01	Bowie fine sandy loam, sloping, eroded	interfluves		Potentially highly erodible	Well drained

Source: NRCS, 2007

3.6 Existing Wildlife Usage

Bottomland Hardwood Forest (Deciduous Forested Wetlands)

This habitat type is situated along slopes and lowlands bordering Mud Creek and its tributaries. Cover is young to mature hardwood forest with many mast and fruit producing species. Understory and ground cover habitat structure are usually limited due to the dense overstory. The highly variable hydrologic regime of this habitat ranging from mesic to hydric, along with it being frequently associated with aquatic habitats, provides excellent habitat diversity. Characteristic fauna of bottomland hardwoods are white-tailed deer, (*Odocoileus virginianus*), fox squirrel (*Sciurus niger*), gray squirrel (*Sciurus carolinensis*), swamp rabbit (*Sylvilagus aquaticus*), raccoon (*Procyon lotor*), beaver (*Castor canadensis*), three-toed box turtle (*Terrapene Carolina*), western cottonmouth (*Agkistrodon piscivorus*), ground skink (*Leiolopisma laterale*), green anole (*Anolis carolinensis*), fence lizard (*Sceloporus undulates*), green tree frog (*Hyla cinera*), gray tree frog (*Hyla chrysoscelis*), gulf coast toad (*Bufo valiceps*), barred owl (*Strix varia*), hairy woodpecker (*Dendrocopos villosus*), downy woodpecker (*Dendrocopos pubescens*), wood thrush, (*Hylocichla mustelina*), and wood duck (*Aix sponsa*). Signs of white-tailed deer, bobcats (*Lynx rufus*), and raccoons are common in the bottomlands of the Permit Area, and common avian species include pileated woodpecker (*Dryocopus pileatus*), eastern-tufted titmouse (*Parus bicolor*), wood duck, Carolina wren (*Thryothorus ludovicianus*), red shouldered hawk (*Buteo lineatus*), and yellow-crowned night heron (*Nycticroax violaceus*) (FNI, 2003).

Herbaceous Wetlands

Herbaceous wetlands (hydric habitats) typically exhibit a relatively high species diversity and habitat structure. These areas may also be associated with aquatic habitats (ponds and streams), thus increasing habitat diversity. Typical wildlife inhabiting herbaceous wetland areas include raccoon, beaver, cricket frog (*Acris crepitans*), spring peeper (*Hyla crucifer*), Strecker's chorus frog (*Pseudacris streckeri*), southern leopard frog (*Rana utricularia*), green anole, western cottonmouth, water snake (*Nerodia erythrogaster*), great blue heron (*Ardea herodias*), snowy egret (*Leucophoyx thula*), and red-winged blackbird (*Agelaius phoeniceus*). Marsh wrens (*Cistothorus palustris*), common yellow throats (*Geothlypis trichas*), and turkey (*Meleagris galopavo*), along with beaver and a variety of frogs, can be found within the herbaceous wetlands of the Permit Area (FNI, 2003).

Shrub-Scrub Wetlands

Shrub-scrub wetlands are in successional transition between herbaceous wetlands and bottomland hardwood forests. Shrub-scrub wetlands can also be associated with aquatic habitats (ponds and streams), thus increasing habitat diversity. Characteristic wildlife included those occurring in both herbaceous wetlands and bottomland hardwood forests. A variety of songbirds, including yellow-breasted chat (*Icteria virens*), along with evidence of beaver activity have been observed in shrub-scrub wetlands within the Permit Area (FNI, 2003).

Riverine (Streams and Ponds)

Characteristic wildlife associated with streams and ponds are raccoon, opossum (*Didelphis virginiana*), beaver, cricket frog, bullfrog (*Rana catesbeana*), southern leopard frog, red-eared turtle (*Chyrsemys sp.*), snapping turtle (*Chelydra serpentina*), diamond-backed water snake (*Nerodia rhombifera*), western cottonmouth, mallard (*Anas platyrhynchos*), wood duck, great blue heron, and green heron (*Butorides virescens*).

Grassland

Characteristic wildlife of the grassland habitat are nine-banded armadillo (*Dasypus novemcinctus*), eastern cottontail (*Sylvilagus floridanus*), hispid cotton rat (*Sigmodon hispidus*), long-tailed harvest mouse (*Reithrodontomys fulvescens*), plains pocket gopher (*Geomys bursarius*), six-lined racerunner (*Cnemidophorus sexlinatus*), racer (*Coluber constrictor*), painted bunting (*Passerina ciris*), lark sparrow (*Chondestes grammacus*), eastern meadowlark (*Sturnella ma*gna), mockingbird (*Mimus polyglottos*), scissor-tailed flycatcher (*Muscivora forfic*), mourning dove (*Zenaidura macroura),* bobwhite quail (*Colinus virginianus*), red tailed hawk (*Buteo lineatus*), and turkey vulture (*Cathartes aura*).

Upland Forest (Deciduous Upland Forest)

Characteristic wildlife of the upland hardwood forest habitat type are white-tailed deer, fox squirrel, raccoon, white-footed mouse (*Peromyscus leucopus*), eastern cottontail, three-toed box turtle, green anole, Texas rat snake (*Elaphe obsoleta*), downy woodpecker, red-bellied woodpecker (*Centurus carolinus*), cardinal (*Richmondena cardinalis*), Carolina chickadee (*Parus carolinensis*), Carolina wren (*Thryothorus ludovicianus*), mourning dove, black and white warbler (*Mniotilta varia*), pine warbler (*Dendroica pinus*), and blue jay (*Cyanocitta cristata*). Eastern bluebirds (*Sialia sialis*), pine warblers, tufted-titmouse (*Baeolophus bicolor*), broad-headed and five-lined skinks (*Eumeces laticeps* and *E. faciatus*, respectively), gray tree frogs (*Hyla* sp.), and armadillos (*Dasypus novemcinctus*) have been observed in upland forests within the Permit Area (FNI, 2003).

Shrub-Scrub Upland

Wildlife species inhabiting shrub-scrub uplands include white-tailed deer, raccoon, opossum, eastern cottontail, coyote (*Canis latrans*), six-lined racerunner, green anole, racer, and copperhead (*Akistrodon contortrix*). Bird species observed in this habitat type within the Permit Area included indigo bunting (*Passerina cyanea*), blue grosbeak (*Guiraca caerulea*), red-tailed hawk, cardinal, mourning dove, eastern kingbird (*Tyrannus tyrannus*), and common crow (*Corvus brachyrhynchos*).

4.0 Mitigation Site Selection and Credit Determination

4.1 Site Selection Process

ANRA proposes to mitigate the impacts of the proposed Lake Columbia on waters of the U.S. by implementing mitigation activities on-site first, then near-site (downstream) to the extent possible, and then off-site as necessary to compensate for the unmitigated impacts that remain after on-site and near-site mitigation actions are completed.

On-site mitigation actions are those that would occur within the normal pool footprint of the reservoir. Near-site and off-site mitigation activities would be implemented on lands that ANRA proposes to purchase in fee simple or acquire through conservations easement. Proposed mitigation activities and restrictions on uses of these lands include:

1. Limiting timber harvesting and clearing to wetland restoration
2. Eliminating livestock grazing
3. Limitations on public access and consumptive uses
4. Restoration of degraded forested wetlands
5. Preservation of intermittent streams and riparian buffers
6. Preservation of perennial streams and riparian buffers

The first three actions will minimize future disturbances to wetlands and adjacent habitats and will allow natural succession processes to occur. This will improve the quality of the habitat and are expected to improve existing wetland functions.

As the trees in forested wetlands grow and mature herbaceous cover will likely decrease as result of increased canopy cover and shading. Tree density usually decreases in mature forests as the size (diameter at breast height, or dbh) of the trees increase. This will result in higher basal area and density of tree stems. As large trees mature and die there will be an increase in the number of snags and coarse woody debris. These predictions will be measured during monitoring activities to show the results of these compensatory mitigation actions.

Some areas downstream have been clearcut or heavily harvested for timber. Any such areas acquired will be restored by minor topographic enhancements and vegetation plantings. Wetland hydrology would be improved or restored by removing restrictive culverts, roads, and levees, and filling drainage ditches or swales. These actions will increase wetland functions by increasing the number and types of topographic features and frequency and duration of flooding.

The most important restoration feature will be revegetating the area with appropriate herbaceous, shrub, and tree species. Particular attention will be paid to providing functional riparian buffers along streams and channel sloughs.

No specific mitigation land has been purchased, leased or otherwise selected for the Lake Columbia project. However, there are logged, clearcut, farmed, or otherwise degraded formerly forested wetlands within the region of the proposed project that will be targeted for acquisition as mitigation land.

The proposed Lake Columbia wetland restoration components for mitigating impacts of the project would encompass a wide variety of potential activities depending on the amount and type of degradation at the selected restoration sites. Wetland restoration involves returning wetland characteristics such as hydrology and vegetation to a level of a functioning wetland.

Sites that have been ditched, tiled or leveed or degraded from excessive logging; uncontrolled cattle grazing, or unrestricted off-road vehicle use are all candidates for restoration. Mitigation activities could span the spectrum from curtailing these or other damaging practices to restoring the water source and/or other wetland properties. Because the degree of current damage would vary, the effort needed to restore sites will also vary. For instance, a partially drained wetland may be fairly simple to restore to its natural water level, but others could require site preparation to restore hydrology and topographic features; vegetation plantings for trees, shrubs and herbaceous plants. The site characteristics described in the HGM Subindex Criteria Descriptions in Tables 4.1 through 4.4 would serve as a "road map" to guide restoration. If conditions existed that resulted in a low Subindex value then actions could be taken to create conditions that would result in a higher score and therefore increase the wetland functions of the site.

Examples of typical conservation practices on wetland restoration projects are listed below:

Wetland wildlife habitat management

Water-control structure

Earthen dike

Upland wildlife habitat management

Use exclusion/access control

Ditch plug or drain tile removal

Microtopography enhancement

Road/dike breach, rock-fill or stream crossing

Tree/shrub planting

Shallow-water management for wildlife

Before any restoration activities are conducted, ANRA will identify prospective mitigation tracts near the Lake Columbia site or in off-site locations. Each prospective site will undergo a thorough evaluation that will include wetland delineations, HGH assessment of functions, inventorying existing vegetation, and quantifying existing hydrology, existing topography, and soil conditions as depicted in the wetlands restoration flow chart in Figure 4 (WRTC, 1992). After this review sites would be selected that have greater chances for mitigation success and more functional uplift potential.

As indicated in the descriptions of the HGM Subindex variables much of the opportunities for functional uplift involves vegetation planting of herbaceous, shrub, and tree species.

As examples of potential opportunities that exist in the Mud Creek, Angelina River and Neches River watershed, ANRA presents the following four possible scenarios for wetland restoration to compensate for project impacts:

EXAMPLE SCENARIO 1: Prior Converted farmland without wetland hydrology

Photograph 1. Prior Converted farmland without wetland hydrology

Table 4.1 Comparison of hypothetical HGM variables for restoration site represented by Prior Converted Farmland without existing wetland hydrology showing projected subindex values with and without restoration. Planned restoration is to be a functioning forested wetland as assessed using the HGM Interim method.

Subindex Baseline	Subindex After Restoration	Subindex Name	Subindex Value	Subindex Criteria Description
0.1	**0.75**	**Vdur**	1.00	In average year, at least 80% of site either floods or ponds for at least 14 days
			0.75	In average year, at least 80% of site either floods or ponds for at least 7 days
			0.50	In average year, 50 to 79% of site floods or ponds for at least 7 days
			0.25	In average year, 25 to 49% of site floods or ponds for at least 7 days
			0.10	In average year, all or portions floods or ponds from 1 - 7 days
			0.00	The area is not subject to flooding or ponding
0.25	**0.75**	**Vfrq**	1.00	Floods or ponds annually 5 out of 5 years
			0.75	Floods or ponds 3 of 5 years or 4 of 5 years
			0.50	Floods or ponds 2 of 5 years

Subindex Baseline	Subindex After Restoration	Subindex Name	Subindex Value	Subindex Criteria Description
			0.25	Floods or ponds less than 2 of 5 years
			0.00	The area is not subject to flooding or ponding
0.1	**0.70**	**Vtopo**	1.00	> 30% of the site is represented by rises, dips, hummocks, channel sloughs, and other topographic features
			0.70	15 to 30% of the site is represented by rises, dips, hummocks, channel sloughs, and other topographic features
			0.40	< 15% of the site is represented by rises, dips, hummocks, channel sloughs, and other topographic features
			0.10	Smooth, flat, or very gently undulating with little or no topographic relief
0.1	**0.50**	**Vcwd**	1.00	> 7 pieces of cwd > 3" diameter along 100' transect
			0.50	3 to 7 pieces of cwd > 3" diameter along 100' transect
			0.30	< 3 pieces of cwd > 3" diameter along 100' transect
			0.10	Area is openland (pasture or cropland)
0.10	**0.75**	**V wood**	1.00	> 90% of area is covered by woody vegetation
			0.75	67 to 89% of area is covered by woody vegetation
			0.50	34 to 66% of area is covered by woody vegetation
			0.25	11 to 33% of area is covered by woody vegetation
			0.10	1 to 10% of area is covered by woody vegetation
0.10	**1.00**	**Vtree**	1.00	At least 60% of stand is oak, hickory, or elm (black willow, cottonwood, tallow, and sycamore = < 5% of stand)
			0.80	> 40% of stand is oak, hickory, or elm (black willow, cottonwood, tallow, and sycamore = < 10% of stand)
			0.50	> 20% of stand is oak, hickory, or elm (black willow, cottonwood, tallow, and sycamore = < 15% of stand)
			0.30	< 20% of stand is oak, hickory, or elm
			0.10	The area is openland
0.10	**1.00**	**Vrich**	1.00	5 or more tree species present
			0.80	4 tree species present
			0.60	3 tree species present
			0.40	1 or 2 species present
			0.10	The site is openland
0.10	**0.80**	**Vbasal**	1.00	The basal area (DBH) of site averages > 100 sq ft/acre
			0.80	The basal area of site averages 80 to 100 sq ft/acre
			0.60	The basal area of the site averages 60 to 79 sq ft/acre
			0.40	The basal area of the site averages < 60 sq ft/acre
			0.10	The site is openland
0.10	**1.00**	**Vdensity**	1.00	The site averages a tree density of 100 to 250 trees/acre
			0.60	The site averages a tree density of 250 to 500 trees/acre OR 50 to 100 trees/acre
			0.40	The site averages < 50 trees/acre or > 500 trees/acre
			0.10	The site is openland

Subindex Baseline	Subindex After Restoration	Subindex Name	Subindex Value	Subindex Criteria Description
0.10	**0.75**	**Vmid**	1.00	Midstory cover averages > 50%
			0.75	Midstory cover averages 31 to 50%
			0.50	Midstory cover averages 11 to 30%
			0.30	Midstory cover < 10%
			0.10	The site is openland
0.10	**1.00**	**Vherb**	1.00	Herbaceous cover averages 5 to 30%
			0.50	Herbaceous cover averages 31 to 50%
			0.30	Herbaceous cover < 5% OR > 50%
			0.10	The site is dominated by tame pasture species or is cropland
0.50	**0.75**	**Vconnect**	1.00	Wetland plus four habitats and/or surrounded by forested
			0.75	Wetland plus two or more habitat type (other than forested) OR three or more habitat types
			0.50	Wetland plus one other habitat types or two other habitat types
			0.25	One other habitat types other than urban habitat
			0.10	Surround by urban (homes, lawns, concrete, etc.)
0.10	**0.50**	**Vdetritus**	1.00	> 85% of the area possesses an O or A horizon
			0.50	From 11 to 84% of the area possesses an O or A horizon
			0.30	< 10% of the area possesses an O or A horizon
			0.10	Site is plowed
1.00	**1.00**	**Vredox**	1.00	Redox features represent > 20% of the pedon within the top 4" of soil surface (mottles = many)
			0.10	Redox features < 20% (mottles = common or few)
0.50	**0.50**	**Vsorp**	1.00	Site is dominated by clays (clay, clay loam, silty clay loams) or highly organic (valu =2/chroma=1; 2/2; 3/1)
			0.50	Site is dominated by loams (silt loams, very fine sandy loams, fine sandy loams, loams) OR non-montmorillonitic clays
			0.10	Site is dominated by sands (sands, loamy fine sands, loamy sands)

Using the subindex variable values listed above, the functional capacity index for each of the three Interim HGM method functions were calculated to predict the functional uplift resulting from the proposed restoration. For this analysis the restoration area was assumed to encompass 2,500 acres of wetland restoration.

Formulas for calculating Functional Capacity Indexes are listed below:
Function No. 1. Temporary Storage and Detention of Surface Water (Storage)
(FCI)=sqrt((sqrt(Vdur*Vfrq))*((Vtopo+Vcwd+Vwood)/3))

Function No. 2. Maintenance of Plant and Animal Communities (Maintenance) (FCI) = (Vtree+Vcwd+Vrich+((Vbasal+Vdensity)/2+((Vmid+Vherb)/2+Vconnect)/6

Function No. 3. Removal and Sequestration of Elements and Compounds (Removal)
(FCI)=(Vwood+vfrq+vdur+((Vtopo+Vcwd+Vwood)/3)+((Vdetritus+Vredox+Vsorp)/3))/5

CALCULATIONS

BASELINE CONDITIONS

Storage Coefficient (FCI) = 0.13
Functional Unit (FCU) = Coefficient (FCI) * Acres **=** 0.13 ***** 2500 acres =**314 FCUs** for Function No. 1

Maintenance Coefficient (FCI) = 0.17
Functional Unit (FCU) = Coefficient (FCI) * Acres = 0.17 * 2,500 acres = **417 FCUs** for Function No. 2

Removal Coefficient (FCI) = 0.22
Functional Unit (FCU) = Coefficient (FCI)*Acres = 0.22 * 2,500 = **524 FCUs** for Function No. 3

RESTORED FUNCTIONS

Storage Coefficient (FCI) = 0.70
Functional Unit (FCU) = Coefficient (FCI) * Acres = 0.70 * 2,500 **= 1746 FCUs** for Function No. 1

Maintenance Coefficient (FCI) = 0.84
Functional Unit (FCU) = Coefficient (FCI) * Acres = 0.84 * 2,500 = **2094 FCUs** for Function No. 2

Removal Coefficient (FCI) = 0.71
Functional Unit (FCU) = Coefficient (FCI)*Acres = 0.71 * 2,500 = **1783 FCUs** for Function No. 3

The next step for calculating the effectiveness of the proposed mitigation activities is to determine the functional uplift produced by the restoration. This uplift is calculated by subtracting the baseline FCUs from the restored FCUs to calculate a net gain of wetland functions. In this example the following illustrates this calculation for each function:

For **Function No. 1**, Restored FCUs (1746 FCUs) minus Baseline FCUs (314 FCUs) equals a **NET GAIN** of **1432 FCU Uplift.**

For **Function No. 2**, Restored FCUs (2094 FCUs) minus Baseline FCUs (417 FCUs) equals a **NET GAIN** of **1677 FCU Uplift.**

For **Function No. 3**, Restored FCUs (1783 FCUs) minus Baseline FCUs (524 FCUs) equals a **NET GAIN** of **1259 FCU Uplift.**

The next step in the mitigation calculation process is to compare the proposed FCU uplift values to the FCU values impacted by the proposed project. This will indicate the effectiveness of this restoration component in meeting the goal of no net loss of wetland functions. The calculations for this component of forested wetlands restoration from prior converted cropland without wetland hydrology are as follows:

Impacted FCUs for Forested wetland Function No. 1 (3532 FCUs) minus FCU uplift (1432 FCUs) = 2100 FCUs. The 2100 FCUs in this calculation are the remaining FCUs that would need to be compensated for by another mitigation component.

Impacted FCUs for Forested wetland Function No. 2 (3612 FCUs) minus FCU uplift (1677 FCUs) = 1935 FCUs. The 1935 FCUs in this calculation are the remaining FCUs that would need to be compensated for by another mitigation component.

Impacted FCUs for Forested wetland Function No. 3 (3062 FCUs) minus FCU uplift (1259 FCUs) = 1803 FCUs. The 1803 FCUs in this calculation are the remaining FCUs that would need to be compensated for by another mitigation component.

As proposed this restoration strategy would compensate for 40.5, 46.4, and 41.1 percent, for Function No. 1, Function No. 2, and Function No. 3, respectively.

EXAMPLE SCENARIO 2: Clearcut wetland with wetland hydrology

Photograph 2. Clearcut forested wetland with wetland hydrology.

Table 4.2 Comparison of hypothetical HGM variables for restoration site represented by **Clearcut wetland with wetland hydrology** showing projected subindex values with and without restoration. Planned restoration is to be a functioning forested wetland as assessed using the HGM Interim method.

Subindex Baseline	Subindex After Restoration	Subindex Name	Subindex Value	Subindex Criteria Description
0.75	**0.75**	**Vdur**	1.00	In average year, at least 80% of site either floods or ponds for at least 14 days
			0.75	In average year, at least 80% of site either floods or ponds for at least 7 days
			0.50	In average year, 50 to 79% of site floods or ponds for at least 7 days
			0.25	In average year, 25 to 49% of site floods or ponds for at least 7 days
			0.10	In average year, all or portions floods or ponds from 1 - 7 days
			0.00	The area is not subject to flooding or ponding
0.75	**0.75**	**Vfrq**	1.00	Floods or ponds annually 5 out of 5 years
			0.75	Floods or ponds 3 of 5 years or 4 of 5 years
			0.50	Floods or ponds 2 of 5 years
			0.25	Floods or ponds less than 2 of 5 years

Subindex Baseline	Subindex After Restoration	Subindex Name	Subindex Value	Subindex Criteria Description
			0.00	The area is not subject to flooding or ponding
0.1	**0.70**	**Vtopo**	1.00	> 30% of the site is represented by rises, dips, hummocks, channel sloughs, and other topographic features
			0.70	15 to 30% of the site is represented by rises, dips, hummocks, channel sloughs, and other topographic features
			0.40	< 15% of the site is represented by rises, dips, hummocks, channel sloughs, and other topographic features
			0.10	Smooth, flat, or very gently undulating with little or no topographic relief
0.30	**0.30**	**Vcwd**	1.00	> 7 pieces of cwd > 3" diameter along 100' transect
			0.50	3 to 7 pieces of cwd > 3" diameter along 100' transect
			0.30	< 3 pieces of cwd > 3" diameter along 100' transect
			0.10	Area is openland (pasture or cropland)
0.10	**0.75**	**V wood**	1.00	> 90% of area is covered by woody vegetation
			0.75	67 to 89% of area is covered by woody vegetation
			0.50	34 to 66% of area is covered by woody vegetation
			0.25	11 to 33% of area is covered by woody vegetation
			0.10	1 to 10% of area is covered by woody vegetation
0.10	**1.00**	**Vtree**	1.00	At least 60% of stand is oak, hickory, or elm (black willow, cottonwood, tallow, and sycamore = < 5% of stand)
			0.80	> 40% of stand is oak, hickory, or elm (black willow, cottonwood, tallow, and sycamore = < 10% of stand)
			0.50	> 20% of stand is oak, hickory, or elm (black willow, cottonwood, tallow, and sycamore = < 15% of stand)
			0.30	< 20% of stand is oak, hickory, or elm
			0.10	The area is openland
0.10	**1.00**	**Vrich**	1.00	5 or more tree species present
			0.80	4 tree species present
			0.60	3 tree species present
			0.40	1 or 2 species present
			0.10	The site is openland
0.10	**0.80**	**Vbasal**	1.00	The basal area (DBH) of site averages > 100 sq ft/acre
			0.80	The basal area of site averages 80 to 100 sq ft/acre
			0.60	The basal area of the site averages 60 to 79 sq ft/acre
			0.40	The basal area of the site averages < 60 sq ft/acre
			0.10	The site is openland
0.10	**1.00**	**Vdensity**	1.00	The site averages a tree density of 100 to 250 trees/acre
			0.60	The site averages a tree density of 250 to 500 trees/acre OR 50 to 100 trees/acre
			0.40	The site averages < 50 trees/acre or > 500 trees/acre
			0.10	The site is openland
0.10	**1.00**	**Vmid**	1.00	Midstory cover averages > 50%

Subindex Baseline	Subindex After Restoration	Subindex Name	Subindex Value	Subindex Criteria Description
			0.75	Midstory cover averages 31 to 50%
			0.50	Midstory cover averages 11 to 30%
			0.30	Midstory cover < 10%
			0.10	The site is openland
0.30	**0.50**	**Vherb**	1.00	Herbaceous cover averages 5 to 30%
			0.50	Herbaceous cover averages 31 to 50%
			0.30	Herbaceous cover < 5% OR > 50%
			0.10	The site is dominated by tame pasture species or is cropland
0.75	**0.75**	**Vconnect**	1.00	Wetland plus four habitats and/or surrounded by forested
			0.75	Wetland plus two or more habitat type (other than forested) OR three or more habitat types
			0.50	Wetland plus one other habitat types or two other habitat types
			0.25	One other habitat types other than urban habitat
			0.10	Surround by urban (homes, lawns, concrete, etc.)
0.50	**0.50**	**Vdetritus**	1.00	> 85% of the area possesses an O or A horizon
			0.50	From 11 to 84% of the area possesses an O or A horizon
			0.30	< 10% of the area possesses an O or A horizon
			0.10	Site is plowed
1.00	**1.00**	**Vredox**	1.00	Redox features represent > 20% of the pedon within the top 4" of soil surface (mottles = many)
			0.10	Redox features < 20% (mottles = common or few)
0.50	**0.50**	**Vsorp**	1.00	Site is dominated by clays (clay, clay loam, silty clay loams) or highly organic (valu =2/chroma=1; 2/2; 3/1)
			0.50	Site is dominated by loams (silt loams, very fine sandy loams, fine sandy loams, loams) OR non-montmorillonitic clays
			0.10	Site is dominated by sands (sands, loamy fine sands, loamy sands)

Using the subindex variable values listed above, the functional capacity index for each of the three Interim HGM method functions were calculated to predict the functional uplift resulting from the proposed restoration. For this analysis the restoration area was assumed to encompass 2,500 acres of wetland restoration.

Formulas for calculating Functional Capacity Indexes are listed below:

Function No. 1. Temporary Storage and Detention of Surface Water (Storage)
(FCI)=sqrt((sqrt(Vdur*Vfrq))*((Vtopo+Vcwd+Vwood)/3))
Function No. 2. Maintenance of Plant and Animal Communities (Maintenance) (FCI) = (Vtree+Vcwd+Vrich+((Vbasal+Vdensity)/2+((Vmid+Vherb)/2+Vconnect)/6

Function No. 3. Removal and Sequestration of Elements and Compounds (Removal)
(FCI)=(Vwood+vfrq+vdur+((Vtopo+Vcwd+Vwood)/3)+((Vdetritus+Vredox+Vsorp)/3))/5

CALCULATIONS

BASELINE CONDITIONS

Storage Coefficient (FCI) = 0.35
Functional Unit (FCU) = Coefficient (FCI) * Acres **=** 0.35 ***** 2500 acres =**884 FCUs** for Function No. 1

Maintenance Coefficient (FCI) = 0.26
Functional Unit (FCU) = Coefficient (FCI) * Acres = 0.26 * 2,500 acres = **646 FCUs** for Function No. 2

Removal Coefficient (FCI) = 0.49
Functional Unit (FCU) = Coefficient (FCI)*Acres = 0.49 * 2,500 = **1217 FCUs** for Function No. 3

RESTORED FUNCTIONS

Storage Coefficient (FCI) = 0.66
Functional Unit (FCU) = Coefficient (FCI) * Acres = 0.66 * 2,500 **= 1654 FCUs** for Function No. 1

Maintenance Coefficient (FCI) = 0.78
Functional Unit (FCU) = Coefficient (FCI) * Acres = 0.78 * 2,500 = **1958 FCUs** for Function No. 2

Removal Coefficient (FCI) = 0.70
Functional Unit (FCU) = Coefficient (FCI)*Acres = 0.70 * 2,500 = **1750 FCUs** for Function No. 3

The next step for calculating the effectiveness of the proposed mitigation activities is to determine the functional uplift produced by the restoration. This uplift is calculated by subtracting the baseline FCUs from the restored FCUs to calculate a net gain of wetland functions. In this example the following illustrates this calculation for each function:

For **Function No. 1**, Restored FCUs (1654 FCUs) minus Baseline FCUs (884 FCUs) equals a **NET GAIN** of **770 FCU Uplift.**
For **Function No. 2**, Restored FCUs (1958 FCUs) minus Baseline FCUs (646 FCUs) equals a **NET GAIN** of **1312 FCU Uplift.**
For **Function No. 3**, Restored FCUs (1750 FCUs) minus Baseline FCUs (1217 FCUs) equals a **NET GAIN** of **533 FCU Uplift.**

The next step in the mitigation calculation process is to compare the proposed FCU uplift values to the FCU values impacted by the proposed project. This will indicate the effectiveness of this restoration component in meeting the goal of no net loss of wetland functions. The calculations for this component of forested wetlands restoration from prior converted cropland without wetland hydrology are as follows:

Impacted FCUs for Forested wetland Function No. 1 (3532 FCUs) minus FCU uplift (770 FCUs) = 2762 FCUs. The 2762 FCUs in this calculation are the remaining FCUs that would need to be compensated for by another mitigation component.

Impacted FCUs for Forested wetland Function No. 2 (3612 FCUs) minus FCU uplift (1312 FCUs) = 2300 FCUs. The 2300 FCUs in this calculation are the remaining FCUs that would need to be compensated for by another mitigation component.

Impacted FCUs for Forested wetland Function No. 3 (3062 FCUs) minus FCU uplift (533 FCUs) = 2529 FCUs. The 2529 FCUs in this calculation are the remaining FCUs that would need to be compensated for by another mitigation component.

As proposed this restoration strategy would compensate for 21.8, 36.3, and 17.4 percent, for Function No. 1, Function No. 2, and Function No. 3, respectively.

EXAMPLE SCENARIO 3: Agricultural site with wetland hydrology

Photograph 3. Agricultural site with wetland hydrology

Table 4.3 Comparison of hypothetical HGM variables for restoration site represented by **Agricultural Site with Hydrology** showing projected subindex values with and without restoration. Planned restoration is to be a functioning forested wetland as assessed using the HGM Interim method.

Subindex Baseline	Subindex After Restoration	Subindex Name	Subindex Value	Subindex Criteria Description
0.50	**0.75**	**Vdur**	1.00	In average year, at least 80% of site either floods or ponds for at least 14 days
			0.75	In average year, at least 80% of site either floods or ponds for at least 7 days
			0.50	In average year, 50 to 79% of site floods or ponds for at least 7 days
			0.25	In average year, 25 to 49% of site floods or ponds for at least 7 days
			0.10	In average year, all or portions floods or ponds from 1 - 7 days
			0.00	The area is not subject to flooding or ponding
0.50	**0.75**	**Vfrq**	1.00	Floods or ponds annually 5 out of 5 years
			0.75	Floods or ponds 3 of 5 years or 4 of 5 years
			0.50	Floods or ponds 2 of 5 years
			0.25	Floods or ponds less than 2 of 5 years

Subindex Baseline	Subindex After Restoration	Subindex Name	Subindex Value	Subindex Criteria Description
			0.00	The area is not subject to flooding or ponding
0.10	**0.40**	**Vtopo**	1.00	> 30% of the site is represented by rises, dips, hummocks, channel sloughs, and other topographic features
			0.70	15 to 30% of the site is represented by rises, dips, hummocks, channel sloughs, and other topographic features
			0.40	< 15% of the site is represented by rises, dips, hummocks, channel sloughs, and other topographic features
			0.10	Smooth, flat, or very gently undulating with little or no topographic relief
0.10	**0.50**	**Vcwd**	1.00	> 7 pieces of cwd > 3" diameter along 100' transect
			0.50	3 to 7 pieces of cwd > 3" diameter along 100' transect
			0.30	< 3 pieces of cwd > 3" diameter along 100' transect
			0.10	Area is openland (pasture or cropland)
0.10	**0.75**	**V wood**	1.00	> 90% of area is covered by woody vegetation
			0.75	67 to 89% of area is covered by woody vegetation
			0.50	34 to 66% of area is covered by woody vegetation
			0.25	11 to 33% of area is covered by woody vegetation
			0.10	1 to 10% of area is covered by woody vegetation
0.10	**1.00**	**Vtree**	1.00	At least 60% of stand is oak, hickory, or elm (black willow, cottonwood, tallow, and sycamore = < 5% of stand)
			0.80	> 40% of stand is oak, hickory, or elm (black willow, cottonwood, tallow, and sycamore = < 10% of stand)
			0.50	> 20% of stand is oak, hickory, or elm (black willow, cottonwood, tallow, and sycamore = < 15% of stand)
			0.30	< 20% of stand is oak, hickory, or elm
			0.10	The area is openland
0.10	**1.00**	**Vrich**	1.00	5 or more tree species present
			0.80	4 tree species present
			0.60	3 tree species present
			0.40	1 or 2 species present
			0.10	The site is openland
0.10	**0.80**	**Vbasal**	1.00	The basal area (DBH) of site averages > 100 sq ft/acre
			0.80	The basal area of site averages 80 to 100 sq ft/acre
			0.60	The basal area of the site averages 60 to 79 sq ft/acre
			0.40	The basal area of the site averages < 60 sq ft/acre
			0.10	The site is openland
0.10	**1.00**	**Vdensity**	1.00	The site averages a tree density of 100 to 250 trees/acre
			0.60	The site averages a tree density of 250 to 500 trees/acre OR 50 to 100 trees/acre
			0.40	The site averages < 50 trees/acre or > 500 trees/acre
			0.10	The site is openland
0.10	**0.75**	**Vmid**	1.00	Midstory cover averages > 50%

Subindex Baseline	Subindex After Restoration	Subindex Name	Subindex Value	Subindex Criteria Description
			0.75	Midstory cover averages 31 to 50%
			0.50	Midstory cover averages 11 to 30%
			0.30	Midstory cover < 10%
			0.10	The site is openland
0.30	**1.00**	**Vherb**	1.00	Herbaceous cover averages 5 to 30%
			0.50	Herbaceous cover averages 31 to 50%
			0.30	Herbaceous cover < 5% OR > 50%
			0.10	The site is dominated by tame pasture species or is cropland
0.75	**0.75**	**Vconnect**	1.00	Wetland plus four habitats and/or surrounded by forested
			0.75	Wetland plus two or more habitat type (other than forested) OR three or more habitat types
			0.50	Wetland plus one other habitat types or two other habitat types
			0.25	One other habitat types other than urban habitat
			0.10	Surround by urban (homes, lawns, concrete, etc.)
0.50	**0.50**	**Vdetritus**	1.00	> 85% of the area possesses an O or A horizon
			0.50	From 11 to 84% of the area possesses an O or A horizon
			0.30	< 10% of the area possesses an O or A horizon
			0.10	Site is plowed
1.00	**1.00**	**Vredox**	1.00	Redox features represent > 20% of the pedon within the top 4" of soil surface (mottles = many)
			0.10	Redox features < 20% (mottles = common or few)
0.50	**0.50**	**Vsorp**	1.00	Site is dominated by clays (clay, clay loam, silty clay loams) or highly organic (valu =2/chroma=1; 2/2; 3/1)
			0.50	Site is dominated by loams (silt loams, very fine sandy loams, fine sandy loams, loams) OR non-montmorillonitic clays
			0.10	Site is dominated by sands (sands, loamy fine sands, loamy sands)

Using the subindex variable values listed above, the functional capacity index for each of the three Interim HGM method functions were calculated to predict the functional uplift resulting from the proposed restoration. For this analysis the restoration area was assumed to encompass 2,500 acres of wetland restoration.

Formulas for calculating Functional Capacity Indexes are listed below:

Function No. 1. Temporary Storage and Detention of Surface Water (Storage)
(FCI)=sqrt((sqrt(Vdur*Vfrq))*((Vtopo+Vcwd+Vwood)/3))
Function No. 2. Maintenance of Plant and Animal Communities (Maintenance) (FCI) = (Vtree+Vcwd+Vrich+((Vbasal+Vdensity)/2+((Vmid+Vherb)/2+Vconnect)/6

Function No. 3. Removal and Sequestration of Elements and Compounds (Removal)
(FCI)=(Vwood+vfrq+vdur+((Vtopo+Vcwd+Vwood)/3)+((Vdetritus+Vredox+Vsorp)/3))/5

CALCULATIONS

BASELINE CONDITIONS

Storage Coefficient (FCI) = 0.22
Functional Unit (FCU) = Coefficient (FCI) * Acres **=** 0.22 ***** 2500 acres =**550 FCUs** for Function No. 1

Maintenance Coefficient (FCI) = 0.23
Functional Unit (FCU) = Coefficient (FCI) * Acres = 0.23 * 2,500 acres = **575 FCUs** for Function No. 2

Removal Coefficient (FCI) = 0.37
Functional Unit (FCU) = Coefficient (FCI)*Acres = 0.37 * 2,500 = **925 FCUs** for Function No. 3

RESTORED FUNCTIONS

Storage Coefficient (FCI) = 0.64
Functional Unit (FCU) = Coefficient (FCI) * Acres = 0.64 * 2,500 **= 1600 FCUs** for Function No. 1

Maintenance Coefficient (FCI) = 0.84
Functional Unit (FCU) = Coefficient (FCI) * Acres = 0.84 * 2,500 = **2100 FCUs** for Function No. 2

Removal Coefficient (FCI) = 0.69
Functional Unit (FCU) = Coefficient (FCI)*Acres = 0.690 * 2,500 = **1725 FCUs** for Function No. 3

The next step for calculating the effectiveness of the proposed mitigation activities is to determine the functional uplift produced by the restoration. This uplift is calculated by subtracting the baseline FCUs from the restored FCUs to calculate a net gain of wetland functions. In this example the following illustrates this calculation for each function:

For **Function No. 1**, Restored FCUs (1600 FCUs) minus Baseline FCUs (550 FCUs) equals a **NET GAIN** of **1050 FCU Uplift.**
For **Function No. 2**, Restored FCUs (2100 FCUs) minus Baseline FCUs (575 FCUs) equals a **NET GAIN** of **1525 FCU Uplift.**
For **Function No. 3**, Restored FCUs (1725 FCUs) minus Baseline FCUs (925 FCUs) equals a **NET GAIN** of **800 FCU Uplift.**

The next step in the mitigation calculation process is to compare the proposed FCU uplift values to the FCU values impacted by the proposed project. This will indicate the effectiveness of this restoration component in meeting the goal of no net loss of wetland functions. The calculations for this component of forested wetlands restoration from prior converted cropland without wetland hydrology are as follows:

Impacted FCUs for Forested wetland Function No. 1 (3532 FCUs) minus FCU uplift (1050 FCUs) = 2482 FCUs. The 2482 FCUs in this calculation are the remaining FCUs that would need to be compensated for by another mitigation component.

Impacted FCUs for Forested wetland Function No. 2 (3612 FCUs) minus FCU uplift (1525 FCUs) = 2087 FCUs. The 2087 FCUs in this calculation are the remaining FCUs that would need to be compensated for by another mitigation component.

Impacted FCUs for Forested wetland Function No. 3 (3062 FCUs) minus FCU uplift (800 FCUs) = 2262 FCUs. The 2262 FCUs in this calculation are the remaining FCUs that would need to be compensated for by another mitigation component.

As proposed this restoration strategy would compensate for 29.7, 42.2, and 26.1 percent, for Function No. 1, Function No. 2, and Function No. 3, respectively.

- **EXAMPLE SCENARIO 4:** Pine plantation on wetland site

Photograph 4. Pine plantation on wetland site

Table 4.4 Comparison of hypothetical HGM variables for restoration site represented by **Pine Plantation in a previously forested wetland** showing projected subindex values with and without restoration. Planned restoration is to be a functioning forested wetland as assessed using the HGM Interim method.

Subindex Baseline	Subindex After Restoration	Subindex Name	Subindex Value	Subindex Criteria Description
0.50	**0.50**	**Vdur**	1.00	In average year, at least 80% of site either floods or ponds for at least 14 days
			0.75	In average year, at least 80% of site either floods or ponds for at least 7 days
			0.50	In average year, 50 to 79% of site floods or ponds for at least 7 days
			0.25	In average year, 25 to 49% of site floods or ponds for at least 7 days
			0.10	In average year, all or portions floods or ponds from 1 - 7 days
			0.00	The area is not subject to flooding or ponding
0.50	**0.50**	**Vfrq**	1.00	Floods or ponds annually 5 out of 5 years
			0.75	Floods or ponds 3 of 5 years or 4 of 5 years
			0.50	Floods or ponds 2 of 5 years
			0.25	Floods or ponds less than 2 of 5 years

Subindex Baseline	Subindex After Restoration	Subindex Name	Subindex Value	Subindex Criteria Description
			0.00	The area is not subject to flooding or ponding
0.70	**0.70**	**Vtopo**	1.00	> 30% of the site is represented by rises, dips, hummocks, channel sloughs, and other topographic features
			0.70	15 to 30% of the site is represented by rises, dips, hummocks, channel sloughs, and other topographic features
			0.40	< 15% of the site is represented by rises, dips, hummocks, channel sloughs, and other topographic features
			0.10	Smooth, flat, or very gently undulating with little or no topographic relief
0.30	**1.00**	**Vcwd**	1.00	> 7 pieces of cwd > 3" diameter along 100' transect
			0.50	3 to 7 pieces of cwd > 3" diameter along 100' transect
			0.30	< 3 pieces of cwd > 3" diameter along 100' transect
			0.10	Area is openland (pasture or cropland)
0.25	**0.75**	**V wood**	1.00	> 90% of area is covered by woody vegetation
			0.75	67 to 89% of area is covered by woody vegetation
			0.50	34 to 66% of area is covered by woody vegetation
			0.25	11 to 33% of area is covered by woody vegetation
			0.10	1 to 10% of area is covered by woody vegetation
0.30	**1.00**	**Vtree**	1.00	At least 60% of stand is oak, hickory, or elm (black willow, cottonwood, tallow, and sycamore = < 5% of stand)
			0.80	> 40% of stand is oak, hickory, or elm (black willow, cottonwood, tallow, and sycamore = < 10% of stand)
			0.50	> 20% of stand is oak, hickory, or elm (black willow, cottonwood, tallow, and sycamore = < 15% of stand)
			0.30	< 20% of stand is oak, hickory, or elm
			0.10	The area is openland
0.40	**1.00**	**Vrich**	1.00	5 or more tree species present
			0.80	4 tree species present
			0.60	3 tree species present
			0.40	1 or 2 species present
			0.10	The site is openland
0.40	**1.00**	**Vbasal**	1.00	The basal area (DBH) of site averages > 100 sq ft/acre
			0.80	The basal area of site averages 80 to 100 sq ft/acre
			0.60	The basal area of the site averages 60 to 79 sq ft/acre
			0.40	The basal area of the site averages < 60 sq ft/acre
			0.10	The site is openland
0.40	**1.00**	**Vdensity**	1.00	The site averages a tree density of 100 to 250 trees/acre
			0.60	The site averages a tree density of 250 to 500 trees/acre OR 50 to 100 trees/acre
			0.40	The site averages < 50 trees/acre or > 500 trees/acre
			0.10	The site is openland
0.30	**1.00**	**Vmid**	1.00	Midstory cover averages > 50%

Subindex Baseline	Subindex After Restoration	Subindex Name	Subindex Value	Subindex Criteria Description
			0.75	Midstory cover averages 31 to 50%
			0.50	Midstory cover averages 11 to 30%
			0.30	Midstory cover < 10%
			0.10	The site is openland
0.30	**1.00**	**Vherb**	1.00	Herbaceous cover averages 5 to 30%
			0.50	Herbaceous cover averages 31 to 50%
			0.30	Herbaceous cover < 5% OR > 50%
			0.10	The site is dominated by tame pasture species or is cropland
0.75	**0.75**	**Vconnect**	1.00	Wetland plus four habitats and/or surrounded by forested
			0.75	Wetland plus two or more habitat type (other than forested) OR three or more habitat types
			0.50	Wetland plus one other habitat types or two other habitat types
			0.25	One other habitat types other than urban habitat
			0.10	Surround by urban (homes, lawns, concrete, etc.)
0.50	**0.50**	**Vdetritus**	1.00	> 85% of the area possesses an O or A horizon
			0.50	From 11 to 84% of the area possesses an O or A horizon
			0.30	< 10% of the area possesses an O or A horizon
			0.10	Site is plowed
1.00	**1.00**	**Vredox**	1.00	Redox features represent > 20% of the pedon within the top 4" of soil surface (mottles = many)
			0.10	Redox features < 20% (mottles = common or few)
0.50	**0.50**	**Vsorp**	1.00	Site is dominated by clays (clay, clay loam, silty clay loams) or highly organic (valu =2/chroma=1; 2/2; 3/1)
			0.50	Site is dominated by loams (silt loams, very fine sandy loams, fine sandy loams, loams) OR non-montmorillonitic clays
			0.10	Site is dominated by sands (sands, loamy fine sands, loamy sands)

Using the subindex variable values listed above, the functional capacity index for each of the three Interim HGM method functions were calculated to predict the functional uplift resulting from the proposed restoration. For this analysis the restoration area was assumed to encompass 2,500 acres of wetland restoration.

Formulas for calculating Functional Capacity Indexes are listed below:

Function No. 1. Temporary Storage and Detention of Surface Water (Storage)
(FCI)=sqrt((sqrt(Vdur*Vfrq))*((Vtopo+Vcwd+Vwood)/3))

Function No. 2. Maintenance of Plant and Animal Communities (Maintenance) (FCI) = (Vtree+Vcwd+Vrich+((Vbasal+Vdensity)/2+((Vmid+Vherb)/2+Vconnect)/6

Function No. 3. Removal and Sequestration of Elements and Compounds (Removal)

(FCI)=(Vwood+vfrq+vdur+((Vtopo+Vcwd+Vwood)/3)+((Vdetritus+Vredox+Vsorp)/3))/5

CALCULATIONS

BASELINE CONDITIONS

Storage Coefficient (FCI) = 0.46
Functional Unit (FCU) = Coefficient (FCI) * Acres **=** 0.46 ***** 2500 acres =**1150 FCUs** for Function No. 1

Maintenance Coefficient (FCI) = 0.41
Functional Unit (FCU) = Coefficient (FCI) * Acres = 0.41 * 2,500 acres = **1025 FCUs** for Function No. 2

Removal Coefficient (FCI) = 0.47
Functional Unit (FCU) = Coefficient (FCI)*Acres = 0.47 * 2,500 = **1175 FCUs** for Function No. 3

RESTORED FUNCTIONS

Storage Coefficient (FCI) = 0.64
Functional Unit (FCU) = Coefficient (FCI) * Acres = 0.64 * 2,500 **= 1600 FCUs** for Function No. 1

Maintenance Coefficient (FCI) = 0.96
Functional Unit (FCU) = Coefficient (FCI) * Acres = 0.96 * 2,500 = **2400 FCUs** for Function No. 2

Removal Coefficient (FCI) = 0.65
Functional Unit (FCU) = Coefficient (FCI)*Acres = 0.65 * 2,500 = **1625 FCUs** for Function No. 3

The next step for calculating the effectiveness of the proposed mitigation activities is to determine the functional uplift produced by the restoration. This uplift is calculated by subtracting the baseline FCUs from the restored FCUs to calculate a net gain of wetland functions. In this example the following illustrates this calculation for each function:

For **Function No. 1**, Restored FCUs (1600 FCUs) minus Baseline FCUs (1150 FCUs) equals a **NET GAIN** of **450 FCU Uplift.**

For **Function No. 2**, Restored FCUs (2400 FCUs) minus Baseline FCUs (1025 FCUs) equals a **NET GAIN** of **1375 FCU Uplift.**

For **Function No. 3**, Restored FCUs (1625 FCUs) minus Baseline FCUs (1175 FCUs) equals a **NET GAIN** of **450 FCU Uplift.**

The next step in the mitigation calculation process is to compare the proposed FCU uplift values to the FCU values impacted by the proposed project. This will indicate the effectiveness of this restoration component in meeting the goal of no net loss of wetland functions. The calculations for this component of forested wetlands restoration from prior converted cropland without wetland hydrology are as follows:

Impacted FCUs for Forested wetland Function No. 1 (3532 FCUs) minus FCU uplift (450 FCUs) = 3082 FCUs. The 3082 FCUs in this calculation are the remaining FCUs that would need to be compensated for by another mitigation component.

Impacted FCUs for Forested wetland Function No. 2 (3612 FCUs) minus FCU uplift (1025 FCUs) = 2587 FCUs. The 2587 FCUs in this calculation are the remaining FCUs that would need to be compensated for by another mitigation component.

Impacted FCUs for Forested wetland Function No. 3 (3062 FCUs) minus FCU uplift (450 FCUs) = 2612 FCUs. The 2612 FCUs in this calculation are the remaining FCUs that would need to be compensated for by another mitigation component.

As proposed this restoration strategy would compensate for 12.7, 28.4, and 14.7 percent, for Function No. 1, Function No. 2, and Function No. 3, respectively.

As summarized below for four hypothetical scenarios, there can be considerable variation in the potential for functional uplift. The maximum expected uplift for each function is highlighted in **Bold**, while the minimum expected uplift is shown in *Italics*.

- **Pine Plantation**
  - Function No. 1, *450 FCU Uplift.*
  - Function No. 2, 1375 FCU Uplift.
  - Function No. 3, *450 FCU Uplift*.
- **Agriculture land with wetland hydrology**
  - Function No. 1, 1050 FCU Uplift.
  - Function No. 2, 1525 FCU Uplift.
  - Function No. 3, 800 FCU Uplift.

- **Clearcut with wetland hydrology**
    - Function No. 1, 770 FCU Uplift.
    - Function No. 2, *1312 FCU Uplift*.
    - Function No. 3, 533 FCU Uplift.
- **Prior converted farmland without wetland hydrology**
    - Function No. 1, **1432 FCU Uplift**.
    - Function No. 2, **1677 FCU Uplift.**
    - Function No. 3, **1259 FCU Uplift.**

4.2 Mitigation Credit Determination Process

ANRA proposes to mitigate impacts to waters of the U.S. at the Lake Columbia site by *initially* targeting the mitigation measures presented in Tables 4.5 through 4.8 to compensate for losses. The detailed rationale for these initial mitigation targets is described in subsequent paragraphs. Tables 4.5 through 4.8 serve as mitigation balance sheets to afford an accounting of aquatic impacts (debits) versus mitigation credits. These tables reflect the amount of compensation gained from on-site, near-site and off-site mitigation actions, and they will serve as a tracking mechanism for adaptive mitigation strategies. For example, if the near-site downstream forested wetland restoration area turns out to be less or more than the initially proposed 2,500 acres, then the balance sheet will provide a method of identifying potential adjustments to the targeted on-site or off-site mitigation areas to effect a balance of the impacts and compensatory mitigation.

Table 4.5 Lake Columbia Mitigation Balance Sheet for Forested Wetlands

3-Dec-09

Impact Type and Amount			Mitigation Measures: On-site		Mitigation Measures: Near-site		Mitigation Measures: Off-site			
			Lake Columbia (Full compensation of Functions 1 & 2)	Standing Timber in Reservoir (3500 ac.)*	Downstream Conservation Easement (preservation) (500 ac)	Downstream Restoration (wetlands uplift per 2500 acres)	Big Thicket Restoration (2500 acres)	Big Thicket Preservation Conservation Easement (3500 acres)		
Resource Impacted		FCUs	FCUs	FCUs	FCUs	FCUs	FCUs	FCUs		
Forested Wetlands (3,689 ac)										
	Functions								Mitigation Total FCUs	Net Gain FCUs
	1. Storage/Detention	3,532	3,532		45	770	770	1,575	6,692	3,160
	2. Maintenance	3,612		686	45	1,312	1,312	1,575	4,930	1,318
	3. Removal/Sequestration	3,061	3,061		45	533	533	1,575	5,747	2,686

Table 4.6 Lake Columbia Mitigation Balance Sheet for Herbaceous Wetlands

3-Dec-09

			Mitigation Measure				
			On-site		Near-site		
Impact Type and Amount			Lake Columbia (Full compensation of Functions 1 & 2)	Fringe Wetlands Created (1,195 acres)	Downstream Restoration (wetlands uplift per 400 acres)		
Resource Impacted		FCUs	FCUs	FCUs	FCUs		
Herbaceous Wetlands (1518 acres)							
	Functions					**Mitigation Total FCUs**	**Net Gain FCUs**
	1. Storage/Detention	1368	1,368		280	1,648	280
	2. Maintenance	1012		801	280	1,081	69
	3. Removal/Sequestration	1027	1,027		280	1,307	280

Table 4.7 Lake Columbia Mitigation Balance Sheet for Shrub Wetlands

3-Dec-09

Impact Type and Amount					Mitigation Measure: On-site	Mitigation Measure: Near-site		
					Lake Columbia (Full compensation of Functions 1 & 2)	Downstream Restoration (wetlands uplift per 200 acres)		
Resource Impacted		Linear Feet	Acres	FCUs	FCUs	FCUs	Mitigation Total FCUs	Net Gain FCUs
Shrub-Scrub Wetlands			144					
	Functions							
	1. Storage/Detention****			135	135	120	255	120
	2. Maintenance			108		120	120	12
	3. Removal/Sequestration			108	108	120	228	120

Table 4.8 Lake Columbia Mitigation Balance Sheet for Non-Wetland Waters of the U.S.

3-Dec-09

Impact Type and Amount			Mitigation Measure: Onsite		Mitigation Measure: Near-site		Mitigation Measure: Off-site			
			Lake Columbia (Full Compensation of All Functions)	Stream Buffer Preservation (perimeter of Lake)	Stream Buffer Preservation Downstream	Downstream Restoration (Streams) Fee Simple	Big Thicket Streams			
Resource Impacted	Linear Feet	Acres	Acres	Linear Feet	Linear Feet	Linear Feet	Linear Feet	**Mitigation Total LF**	**Net Gain LF**	**Net Gain Acres**
New Channel (Unpermitted Activity by Others)	14,256									
Intermittent Stream	204,864			182,746	10,000	110,000	120,000	422,746	217,882	
Perennial Streams	370,128			52,594	18,500	203,500	222,000	496,594	126,466	
Open Water (63 acres)		63	10,133							10,070

The estimated project impacts, expressed in units of linear feet for streams, functional capacity units (FCU) for wetlands, and acres for open water and hillside bogs, are compared to proposed mitigation measures and presented in Table 4.5 through 4.8. Hence, the Tables are balance sheets comparing the impacts of waters of the U.S. with the mitigation measures that are proposed to compensate for those impacts. Values within the net gain/loss column that are equal to or greater than zero indicate that the impacts for the indicated water resource would be mitigated by the proposed mitigation measures in the on-site, near-site, and off-site columns . Following are descriptions of ANRA's proposed mitigation measures.

1. Onsite: Proposed onsite mitigation consists of actions that take place within the reservoir footprint. These are described as follows:
    a. Wetland fringe development in shallow areas on the margin of the lake. The USACE and its EIS contractor conducted a field evaluation of fringe wetland development in several representative East Texas reservoirs and estimated that 1,195 acres of fringe wetlands will develop in certain shallow (i.e., 4-foot deep or less), gently sloping portions of the reservoir (USACE, 2009). The expected location and distribution of these wetlands are depicted in Figure 4A. ANRA estimates that the 1,195 acres of fringe wetlands will provide 801 FCUs toward the Maintenance function for herbaceous wetlands (Table 4.6) Wetland fringe areas will be protected under the authority of ANRA's Water Quality Regulations (WQRs), as described under the *Site Protection* section of this Mitigation Plan. A typical cross-sectional view of the wetland fringe area relative to shoreline zones protected under the WQRs is presented in Figure 4B.
    b. The lake will have a surface area of 10,133 acres. Subtracting 1,195 acres of expected fringe wetlands, the total area of open water to be created in the lake is 8,926 acres of open water. It is expected that this area will compensate fully for the inundation of 63 acres of open water within the reservoir footprint (Table 4.8).
    c. The reservoir is expected to compensate for the lost wetland function of "temporary storage and detention of surface water." On a watershed scale the flood detention and storage functions of reservoirs can be analogous to flood detention functions of wetlands (AWWA 1994). Most reservoirs are designed to have some amount of flood storage capacity. Lake Columbia, a water su*pply reservoir*, would function as temporary storage of flood waters. For

example, with the reservoir at normal pool elevation (315 ft NGVD), a 2-year storm event would have a peak inflow of 13,034 cfs with a corresponding peak discharge out of the reservoir of 3,478 cfs (FNI report). The difference of these two values is temporary storage and detention of flood waters. The amount of storage and the length of time for detention would vary with the magnitude of any given flood and the reservoir pool stage (water elevation). For example, this function in the existing wetlands is limited to the total area of 5,351 acres of wetlands (herbaceous, shrub-scrub, forested) (Tables 4.5, 4.6, and 4.7). Lake Columbia's surface area will be nearly twice that of the existing wetlands and is expected to provide this function in an amount that is proportional to the surface area of the lake. Water will be released from the dam to provide supply to downstream users thereby making water storage temporary. Thus, the value of this function in the lake in terms of FCUs is expected to be at least equal to the value of FCUs present in the existing wetlands (i.e., 5,090 FCUs) as noted from the sum of Storage/Detention on-site Lake Columbia FCUs in Tables 4.5, 4.6, and 4.7.[1]

Again, on a watershed basis, the reservoir is expected to compensate for the lost wetland function of "removal and sequestration of elements and compounds." Reservoirs are documented to be efficient settling basins or sinks for suspended solids and nutrients and compounds that are attached to colloidal clays and other settleable materials. Reservoirs retain significant percentages of inflowing sediment with some reservoirs exhibiting trapping efficiencies up to over 90 percent (AWWA 1994). Elements and compounds such as heavy metals are removed from water by adsorption to clays and

[1] Reservoirs indisputably perform the functions of "temporary storage and detention of surface water" and "removal and sequestration of elements and compounds." Although the proposed Lake Columbia would not be a wetland, per se, the aforementioned functions would be performed on an ecosystem basis. This concept is compatible with the definition of functions in the final compensatory mitigation rule in 33 CFR Parts 325 and 332 and 40 CFR Part 230 – "Functions means the physical, chemical, and biological processes that occur in ecosystems." This concept of function not being restricted to wetland functions is further explained in the preamble to the Final Rule. The two aquatic ecosystem functions ("temporary storage and detention of surface water" and "removal and sequestration of elements and compounds") will still be provided by the proposed Lake Columbia.

organic compounds and then settle out of suspension (sedimentation), precipitated as oxides, hydroxides, etc.; and removed by plant uptake. AWWA (1994) cited instances where metal retention coefficients range from 93 - 96 percent for iron; 21-57 percent for copper; 26-78 percent for zinc and 73-89 percent for lead. Nitrogen and phosphorous would be assimilated by the proposed reservoir's algae, plankton, and macrophytes. Clearly the proposed Lake Columbia would perform this function of removal and sequestration of elements and compounds. Therefore, Lake Columbia is expected to be at least as effective as the existing wetlands at removing and sequestering elements and compounds, and ANRA proposes to take credit for 4,229 FCUs in the lake for this function (Tables 4.5, 4.6, and 4.7).

d. As part of the proposed action, ANRA proposes to acquire 3,500 acres of land within the reservoir footprint with standing mature forest that would not be cleared (Table 4.5). Such standing timber would provide cover for fish in the lake, and it would provide nesting, roosting and perching habitat for birds where the snags are exposed above the water level. Thus, leaving standing timber within the reservoir relates to the wetland function, "maintenance of plant and animal communities," as it would benefit fish and avian species. ANRA proposes to take credit for 686 FCUs based on the assumptions that 1) they will be able to keep 3,500 acres of timber standing in the reservoir prior to inundation and that 2) it will be worth 20 percent of the value of forested wetlands having an FCI value of 0.98.

Inundated standing timber (examples are shown in photographs ST 1 and ST 2) within the conservation pool area of the proposed Lake Columbia would provide some of the habitat functions of forested wetlands and upland forests. These functions would include nesting habitat for cavity nesting birds such as eastern bluebird, downy woodpecker, pileated woodpecker, wood duck, tufted titmouse, Carolina chickadee, Carolina wren, great crested flycatcher, and prothonatary warbler (USDA 1977); nesting and perching habitats for red-tailed hawk and American kestrel; and potential rookery areas for cattle egret and other colonial waterbirds.

The cavity nesting birds utilize snags in forested wetlands and upland forests. The downy woodpecker was representative of this cavity nesting guild for forested wetland and upland forests as part of the Habitat Evaluation Procedure conducted for the proposed Lake Columbia. As trees are inundated and eventually die a larger number of snags would be created than would be found in the existing forested areas. The number of snags per acre and availability of potential nest sites were HEP variables measured for the downy woodpecker and wood duck, respectively. Although difficult to quantify, these habitat variable would certainly increase as a result of the flooded/inundated timber. This inundated timber would provide snag habitat for decades as evidence by the remaining trees in nearby reservoirs such as Sam Rayburn and Toledo Bend.

Photograph ST1. Example of inundated timber along lacustrine shoreline.

Photograph ST2. Example of inundated timber along lacustrine shoreline.

The existing forested and scrub/shrub wetland habitat that would be inundated by the proposed Lake Columbia would provide spawning and nursery habitat for some fishes and provides habitat for amphibians, reptiles, mammals, and birds. Aquatic invertebrates, plankton and aquatic macrophytes contribute to the aquatic food chain.

The proposed standing timber in the reservoir, depending on whether it is in shallow or deep water, would replace some of these affected functions. Some of the "Maintenance of Plant and Animal Community" wetland functions of forested and shrub/scrub wetlands would continue to be provided by the standing timber within the proposed reservoir. These functions include:

Cavity nesting habitat for birds (e.g., red-headed woodpeckers)

Foraging habitat for birds – insect feeders

Roosting and nesting areas for water birds such as herons and egrets

Underwater substrate for invertebrates and periphyton

2. Near-site: Proposed near-site mitigation includes actions on lands immediately surrounding the reservoir; in the upstream watershed including Mud Creek and its tributaries; and the 100-year floodplain downstream from the dam.

    a. ANRA has contracted with the City of Jacksonville, Texas to ensure that the City will continue to return its reclaimed municipal effluent to Keys Creek which is a tributary of Mud Creek just downstream of the Lake Columbia proposed dam site. This action will provide a continuous flow of the City's permitted discharge of up to 2.75 million gallons per day into Keys Creek and thence to Mud Creek. The entire length of Mud Creek from Keys Creek to its confluence with the Angelina River (120,384 linear feet) is expected to benefit from this action.
    b. **Stream Buffer Preservation in NDZ.** ANRA proposes to partially mitigate impacts to intermittent and perennial streams based on the protection afforded the stream channels in the NDZ by the Lake Columbia Water Quality Regulations. As indicated in Table 4.1, there are 182,746 linear feet of intermittent streams and 52,594 linear feet of perennial streams that would benefit from such protection.
    c. **Upstream Conservation Easement.** ANRA expects to obtain conservation easements on up to 250 acres of land upstream of Lake Columbia in the Mud Creek corridor downstream of Lake Tyler. As these lands are identified and the habitat characterized in terms of existing functional capacity, ANRA proposes to update the mitigation balance sheet (Table 4.1) to reflect the appropriate mitigation credit due to these lands. No specific parcel has been selected, but if this option is exercised, there will be a separate conservation easement to protect the land in perpetuity. The conservation easements proposed in the Mitigation Plan are in addition to the WQRs and the flowage easements that will be required. Texas law does not allow ANRA to overflow private lands without consent of the property owner. This consent usually takes the form of a "Flowage Easement." The conservation easements will be in addition to such Flowage Easements.
    d. **Downstream Restoration**. ANRA proposes to secure land in fee simple and in conservation easements within the 100-year floodplain downstream of the dam to mitigate a portion of the losses of waters of the U.S. due to the project (Figure 6). As noted in Table 4.1, ANRA's goal is to purchase 2,500 acres in the floodplain downstream of the dam for forested wetlands restoration.

       Assuming that functional capacities indices (FCI) for the wetland functions including temporary water storage, maintenance of plant and animal communities, and removal and sequestration of elements and compounds can be improved by factors of 0.35, 0.7, and 0.29, respectively, ANRA proposes to compensate for impacts to these three functions by providing 879 FCUs for temporary storage; 1,750 FCUs for plant and animal community maintenance; and 717 FCUs for removal and sequestration (Table 4.1, Downstream Restoration Wetlands Uplift per 2,500 acres column).

Further, ANRA's goal for downstream mitigation is to acquire 500 acres of bottomland pasture or cropland and convert it to 200 acres of shrub-scrub wetland and 300 acres of herbaceous wetlands. Assuming a functional uplift of 0.9 for these conversions, ANRA proposes to compensate for impacts to the three functions by providing 180 FCUs each for shrub-scrub wetlands mitigation and 270 FCUs each for herbaceous wetlands (Table 4.1, Downstream Restoration Wetlands Uplift per 500 acres column.).
In addition to the fee simple land, ANRA proposes to secure an additional 500 acres of high quality (FCI=0.90) forested wetlands in the downstream floodplain to protect by conservation easement (preservation credit). Protection of such land will yield a small number of FCUs for forested and herbaceous wetlands mitigation (Table 4.1, Downstream Conservation Easement (preservation) column).

The acquisition of both the fee simple and easement land downstream will provide additional stream mitigation by buffering stream channels on those properties and protecting them through deed restrictions or conservation easements. As noted in Table 4.1 (Stream Buffer Preservaton Downstream column), the downstream fee simple and easement properties are expected to compensate for impacts to 10,000 linear feet of intermittent streams and 18,500 linear feet of perennial streams.

3. Off-site: Proposed off-site mitigation consists of actions involving land acquisition adjacent to the Big Thicket National Preserve (BTNP), mitigation bank credit purchases from USACE approved wetland mitigation banks, and restoration of wetlands on other off-site lands besides the BTNP.
    a. **BTNP.** ANRA proposes to conduct a portion of its mitigation in the vicinity of the BTNP based on the fact that the Lake Columbia impacts would occur in the BTNP watershed (Figures 7 and 8); the project site is hydrologically connected to the BTNP by way of Mud Creek, the Angelina River, Sam Rayburn Reservoir, the Neches River, B.A. Steinhagen Lake, and the Neches River; the BTNP is recognized as a resource of national and international importance for its unique ecological attributes; and portions of the BTNP face threats from the sale of adjacent

lands by timber companies and others that could be developed for purposes that are incompatible with the preservation goals of the BTNP. Congress has authorized the National Park Service to purchase lands within the BTNP proclamation areas, but no funding has been allocated to accomplish additional land acquisition. Land acquired for the BTNP augmentation would have to meet the following criteria in order to be considered eligible for purchase:

- It must be contiguous with the BTNP.
- Restoration lands must be in a degraded state (e.g., clearcut or cropland) or otherwise managed to preclude development of wetlands (e.g., pine plantation, bermed, dewatered by ditching, etc.).
- Preservation lands must have an potential threat of disturbance (e.g., logging) or have a high potential for residential, commercial, industrial, or other intensive use that would be detrimental to adjacent BTNP property.
- Preservation land must be undeveloped and exhibit high quality aquatic ecosystem functions (FCI=0.90 or greater) based on a Hydrogeomorphic (HGM Interim) assessment.

ANRA proposes to acquire 2,500 acres of land adjacent to the BTNP on which to restore wetlands functions. Such restoration efforts are estimated to provide 879 FCUs for temporary storage; 1,750 FCUs for plant and animal community maintenance; and 717 FCUs for removal and sequestration (Table 4.1, Big Thicket Restoration (2,500 acres) column). These lands would be donated to the National Park Service for perpetual management and protection upon concurrence from the USACE that the restored areas are functioning as intended. ANRA's responsibility for protection of the mitigation lands would be conveyed to the National Park Service along with the land ownership.

ANRA also proposes to purchase up to 3,500 acres of high quality forested wetland adjacent to the existing BTNP and donate it to the National Park Service for incorporation into the preserve for perpetual management and protection (Table 4.5, Big Thicket Preservation column). These high quality wetlands to be preserved are expected to have a FCI of 0.9 and at a mitigation ratio of 5:1, would yield 1,575 FCUs for storage, maintenance and removal/sequestration function (Table 4.5).

The typical preservation ratio for wetlands is 10:1 (10 acres preserved for 1 acre impacted). ANRA has proposed using this typical ratio for FCU credit for the preservation of forested wetlands in the Mud Creek corridor downstream of proposed Lake Columbia. In addition, ANRA is seeking concurrence to use a more generous ratio, 5:1, for preservation of wetlands that would be associated with the Big Thicket National Preserve. Such lands would expand the area of protected wetlands and unique wildlife habitat associated with the BTNP. The BTNP has been recognized by Congress as a resource of national importance and has charged the National Park Service with the responsibility of managing these lands. In fact, the BTNP is recognized internationally as an ecologically unique place. If wetlands preserved in places that are not adjacent to such ecologically important resources are afforded 10:1 preservation credit, then the preservation of lands that would expand the extent of nationally/internationally recognized resources such as the BTNP should warrant additional, non-trivial credit. ANRA proposes that the mitigation credit value of currently vulnerable land set aside to augment the BTNP be afforded a 5:1 credit ratio in recognition of the juxtaposition of such lands to this important ecological resource.

Based on the importance of the BTNP in terms of the services it provides to society and the ecological functions that exist, ANRA proposes that donating 3,500 acres of high quality forested wetlands that are contiguous with existing BTNP lands warrants a 5:1 mitigation credit ratio (as compared to a 10:1 ratio for lands not associated with the BTNP) which would result in the preservation of 1,575 FCUs for each of the three wetland functions.

It is estimated that the acquisition of 2,500 acres of restoration lands and 3,500 acres of preservation lands would provide compensation for 120,000 linear feet of intermittent streams and 222,000 linear feet of perennial streams that would fall within the mitigation lands (Table 4.1, Big Thicket Preservation/Restoration Streams column).

b. ANRA proposes to purchase one mitigation credit from an approved mitigation bank to compensate for the loss of 0.5 acre of hillside bog (Table 4.1, Purchase Mitigation Bank Credits column).

c. The ANRA proposes to acquire additional off-site mitigation properties within the Neches River watershed to supplement on-site, near-site, and other off-site mitigation measures as necessary to compensate for the impacts summarized in Table 4.1.

ANRA has received a financial commitment from the TWDB which will allow the purchase of land, but the funds for land purchase will not be released until the 404 permit is issued. ANRA will commence efforts to acquire land for mitigation in the prioritized areas upon receipt of the 404 permit. As prospective wetland mitigation lands are identified, they will be assessed using the HGM Interim method, and Table 4.1 will be adjusted with the actual compensation values in terms of acres of wetlands, FCUs, and linear feet of streams. As the net gain/loss for each resource type reaches or exceeds zero, compensation for that aquatic resource will be complete. ANRA proposes to acquire mitigation lands and conduct the work necessary to balance the impacts within ten years of receiving the 404 permit for Lake Columbia.

5.0 Mitigation Work Plans

ANRA will provide restoration, protection, and maintenance of a bottomland forested wetland ecosystem by developing native, self-sustaining mosaics of forest types indigenous to the Angelina-Neches River Basin on near-site and off-site mitigation tracts. The dominant forest type would be a closed-to-partially-open canopy layer dominated by desirable tree species including water hickory, blackgum, water elm, white oak, laurel oak, overcup oak, swamp chestnut oak, water oak, cherrybark oak, willow oak, and bald cypress. Associated midstory species include American hornbeam, *Crataegus* spp., common persimmon, deciduous holly, American holly, Eastern hop-hornbeam, coral berry, *Vaccinium* spp., and possum-haw viburnum. This forest type will be supplemented by scrub/shrub wetlands, emergent wetlands, and open water areas, indigenous to the Basin. These are species anticipated to occur naturally or will be planted to achieve the desired vegetation alliance. The purpose of this mitigation work plan is to restore the desired native, bottomland hardwood wetland forest, continue to provide flood storage and sediment/element/compound retention, and increase wetland functions from their present levels on the mitigation sites.

5.1 Tree and Shrub Plantings

A variety of tree species will be planted at varying densities and age classes with the goal of establishing the base conditions for establishment of a deciduous forested wetland on the mitigation site(s). Species selections will include fast growing species such as sycamore and cottonwood; soft mast species such as elm, red mulberry, and green ash; and hard mast such as oaks, pecan, and hickories. Species will be selected based on actual site conditions of topography, hydrology and soils.

Fast growing species will accelerate the production of canopy cover, nesting habitat for some bird species and snag habitats as the trees age and die. These species will also provide biodiversity function for the mitigation site.

Soft mast and hard mast species will be important for providing food sources for a variety of wetland species and species that utilize wetlands, including gray squirrels, white-tailed deer, cottontail and swamp rabbits, and waterfowl (wood duck, mallard, etc.). As these trees age, they will provide snags and large woody debris for nesting and refuge habitat.

A representative planting and site preparation plan for a floodplain site located along Mud Creek is presented in Table 5.1. When specific mitigation sites are selected details plans and specifications describing locations, seasons, and species to plant will be prepared for contractors to follow and comply with.

Table 5.1 Typical tree and shrub planting plan for selected habitats at a Mud Creek floodplain mitigation site.

Riparian Corridor	**Shrubs**	**Species**	**No./acre**	**Plantings**	**Comment ***
		Swamp Privet	50	Shrubs shall be planted within 25' of channel	S
		Redbud	35		H
		Buttonbush	75		S
		False Indigo	50		H
	Trees	**Species**	**No./acre**	**Plantings**	**Comment ***
		Green Ash	35		S
		Sycamore	30	Live stakes	F,S
		Pecan	25	3" B/B	H
		Bur Oak	10	3" B/B	H
		Chinquapin Oak	15	3" B/B	H
		Water Oak	30		H
		Hickory	10		H
		Mulberry	10		S
			165		
Floodplain	**Shrubs**	**Species**	**No./acre**	**Plantings**	**Comment ***
		Possum Haw	15		S
		Swamp privet	25		S
		Buttonbush	20		S
		Dogwood	25		S
		Redbud	10		H
	Trees	**Species**	**No./acre**	**Plantings**	**Comment ***
		Green Ash	25		S
		Willow Oak	40		H
		Bur Oak	30	3" B/B	H
		Sugarberry	25		F,S
		Sycamore	30	Live stakes	F,S
		Cottonwood	15	Live stakes	F,S
		Swamp Oak	10		H
		Sweetgum	5		F,S
			180		
Pond/slough	**Shrubs**	**Species**	**No./acre**	**Plantings**	**Comment ***
		American Beautyberry	10	Shrubs clumped around pond/slough edges	S
		Dogwood	25		S
		Swamp Privet	20		S

		Cherry Laurel	15		S
	Trees	**Species**	**No./acre**	**Plantings**	**Comment ***
		Green Ash	20		S
		Cottonwood	15	Live stakes	F,S
		Bur Oak	12		H
		Water Oak	25		H
Hummock	**Shrub**s	**Species**	**No./acre**	**Plantings**	**Comment ***
		Redbud	15		H
		Cherry Laurel	20		S
		Dogwood	15		H
	Trees	**Species**	**No./acre**	**Plantings**	**Comment ***
		Bur Oak	15		H
		Overcup Oak	20		H
		American Elm	10		S
		Pecan	15		H
		Hickory	10		H
		Sweetgum	5		F,S

* S=soft mast; H=hard mast; F=fast growing

6.0 MAINTENANCE PLAN

Once initial construction is completed, the Mitigation Land will be monitored as provided in the *Monitoring Requirements* and *Performance Standards* sections of this plan. In addition to corrective action as may be required, maintenance of the property will include:

- Protection from encroachment by neighboring landowners;
- Protection from timber thefts;
- Maintaining boundary markings;
- Providing for usages which do not interfere with the achieving and maintaining wetland functions;
- Replacing vegetation planted as needed to achieve survival goals;
- Controlling invasive species; and
- Taking such other action as may be necessary under the Adaptive Management Plan set out below.

The cost of the maintenance will be included in the cost for operating and maintaining Lake Columbia Reservoir which the Participants will be obligated to pay.

7.0 Performance Standards

7.1 Target Values

The following vegetation characteristics are indices of the highest function (FCI) values for "Maintenance of plant and animal communities" in the HGM Interim model. These will be used as indicators of the effectiveness of mitigation site success..

- >90% of area is covered by woody vegetation
- At least 60% of stand is oak, hickory, or elm (black willow, cottonwood, tallow, and sycamore = < 5% of stand)
- 5 or more tree species present
- The basal area (DBH) of site averages > 100 sq ft/acre
- The site averages a tree density of 100 to 250 trees/acre
- Midstory cover averages > 50%

7.2 Vegetative Cover Survival Goals

Goals for tree and shrub planting survival will be monitored annually in September and October for years 1 through 5 after the site restoration is completed and then at years 7 and 10. The overall goal will be to have a functioning early-successional stage forested wetland established at the end of 10 years. The 10-year goal is based on growth and yield models for southern hardwoods (McTague et al.). For a moderate quality site (site index =50 based on 25 years base age) a mixed southern hardwood site should have trees with a mean height of approximately 25 feet at the end of 10 years. Part of the monitoring would be to document tree height, stem density, basal area, shrub and tree canopy cover.

The survival goals will be used as indicators of the relative success of planting and any discrepancies will be addressed as part of the Adaptive Management Plan.

7.3 Functions Goals

In addition to the survival goals, the primary goal of the overall compensatory mitigation plan is to restore and/or create a functioning forested wetland that will ***replace the lost functions and services*** of those lost by the proposed Lake Columbia Project.

At years 5 and 10, the HGM Interim model variables used for the Lake Columbia HGM Interim baseline would be sampled, calculated and compared to the mitigation sites baseline to document success. If after 10 years the mitigation site(s) have achieved net gain/loss of zero or greater as described in Table 4.1, the plan will be considered a success and mitigation implementation will be deemed complete.

Wildlife use of the mitigation site will be documented (quantitatively if practicable) during monitoring events.

8.0 Site Protection

Mitigation Lands acquired by ANRA to compensate for impacts of the reservoir project will be protected from modification in perpetuity by establishing USACE approved conservation easement upon those properties.

In 2003, the Texas Legislature enacted Senate Bill 1362 which, among other things, gave ANRA the legal authority to adopt rules around the Lake Columbia site to protect it from sources of pollution and other activities necessary to protect the water quality of the reservoir. It is under that authority that ANRA adopted the Water Quality Regulations (WQRs).

One of the important features of the WQRs is the control over land development within the fringe areas of the reservoir. As provided in Section 6.01 of the WQR: "The general rules are that nothing can be constructed in this zone which will decrease the storage capacity of the lake, be a source of contamination, or significantly impact aquatic or terrestrial habitat." Section 6.02 restricts the construction of piers, docks, and other waterfront facilities in the Construction Regulated Zone and provides for prior approval and licensing by ANRA on a case by case basis. Before a property owner can subdivide shoreline property, the owner must prepare and submit to ANRA a "Shoreline Habitat Plan." At least 60 % of the shoreline within 50 feet of 315 msl level is required to be maintained in a natural condition. In considering shoreline modification, ANRA specifically will consider those areas identified as wetland fringe under the Mitigation Plan.

Mitigation land that is acquired by ANRA which is adjacent or proximate to the BTNP will be conveyed to the United States of America to be made part of the Preserve. Todd Brindle, Park Superintendent, has advised ANRA that the National Park Service has the legal authority to accept donated land. The conveyance will be made after it has been determined by ANRA that the restoration or other action to benefit lands has been successful.

9.0 Monitoring Requirements

A detailed monitoring plan will be developed for each mitigation tract. ANRA will be responsible for retaining a qualified staff or entity to conduct monitoring at mitigation sites at years 1 through 5 and years 7 and 10 following implementation of planting. Monitoring will be conducted by evaluating plant survival rates based 5-percent surveys of mitigation tracts using 0.1-acre plots. The HGM Interim model as employed to quantify impacts at the Lake Columbia site will be used to assess the improvement of the three wetland functions on mitigation tracts. Monitoring reports shall be prepared in letter format and will include maps, data, and photographs necessary to allow the USACE to evaluate the performance and success of mitigation efforts.

10.0 Long-Term Management Plan

Mitigation land owned by ANRA will be monitored on a periodic basis by making visual observations after year 10 to insure that the land has continued to develop in accordance with the applicable Desired Mitigation Condition.

The East Texas area is subject to a number of events which could be detrimental to the Mitigation Land including hurricanes, floods, wildfires, tornados, and other similar types of occurrences. The impacts from these events may require corrective actions in order to maintain or obtain the appropriate functions. Any corrective action taken will be consistent with this Mitigation Plan. Any proposed action which will result in a modification of a mitigation site will be submitted to the Corps for its prior approval. Corrective actions consistent with the Texas Forest Service BMPs will not require prior approval.

The cost of the maintenance shall be included in the cost for operating and maintaining Lake Columbia Reservoir. In the contracts between ANRA and the Participants, the Participants will be obligated to pay the annual operating and maintenance expenses.

Long term management may also require prescribed burns of forest lands, control of invasive species, and maintenance of topographic features to control hydrology. Likewise, cost of insuring compliance with conservation restrictions will be a part of the operation and maintenance expense payable by the Participants.

Upon a determination that a Big Thicket preservation tract meets the compensatory mitigation requirements, the tract of Big Thicket mitigation land will be conveyed to the United States of America to become part of the BTNP. Once Big Thicket mitigation land has been transferred to the United States of America, the BTNP will provide for the long term management. For other Mitigation Land, the long term costs will be included in the operation and management costs of Lake Columbia which will be an obligation of the Lake Participants.

ANRA will give the District Engineer sixty (60) days written advanced notification before any action is taken to void or modify Conservation Restrictions, this Mitigation Plan, or to transfer the legal title to the Mitigation Lands other than to the United States of America. Upon the transfer of title to the United States of America, ANRA shall give the District Engineer a copy of the recorded conveyance.

11.0 Adaptive Management Plan

The following elements will be monitored and evaluated during monitoring events to determine whether any corrective action needs to be implemented.

11.1 Hydrology

If baseline hydrological conditions or modified conditions created as part of the mitigation plan are not supporting the conditions need for a functioning forested wetland, then the problem will be assessed using hydrological/hydraulic modeling, on the ground surveys, etc. to provide solutions.

The creation of beaver dams or other natural events modifying hydrology will not be considered a problem unless the event is detrimental to the overall functioning of the site.

11.2 Topography

Any topographical modifications made as part of the mitigation plan will be monitored for effectiveness. If there is evidence that features created (ponds, swales berm/hummocks, etc.) are not “working” attempts to modify them will be made to the extent practicable without damaging the other features of the site.

11.3 Biology – Plant and Animal Communities

The functioning of the site will be monitored using HGM Interim as described above. If a site is not performing as expected, then the results of the HGM Interim sampling can be used to identify variables that need to be improved. This will be the basis of any additional habitat treatments such as additional planting, selectively cutting trees, modifying topography, etc.

11.4 Invasive Species

The presence of invasive species is unwanted and to the extent that other desirable species would not be harmed, plans will be developed and implemented to control invasives.

12.0 Financial Assurances

The funds to carry out this Mitigation Plan will come from the proceeds of bonds which will be issued only after ANRA has entered into contracts with the State of Texas, cities, water supply corporations, industries, and other entities for the sale and purchase of water from Lake Columbia. The money to purchase mitigation land and/or easements will be borrowed as part of the funding for reservoir site acquisition. ANRA and the TWDB have previously entered into a Master Agreement for the Lake Columbia Project, to provide the terms and conditions for the TWDB involvement.

In May 2004, the Texas Water Development Board (Board) adopted a resolution whereby it committed to ANRA up to $10,000,000 to finance the planning, design, and construction of Lake Columbia. As a result of the commitment, ANRA and the Board entered into a Master Agreement under which the Board became a co-owner of the project with ANRA. Subsequently, in 2007, the Texas Water Development Board approved and additional $5,735,000 for the acquisition of the ownership interest in Lake

Columbia. In July 2009, the Texas Water Development Board increased its financial commitment to ANRA by $48,530,000 for a total of $64,265,000. ANRA and the Board have agreed to amend the Master Agreement and a First Amended Master Agreement.

The first $1,980,000 of the Board funds is being used by ANRA for the cost associated with the Environmental Impact Statement and the 404 permit. The Board is obligated to deliver to ANRA $52,785,000 for the acquisition of the land and the easements for the reservoir site and the mitigation land. There is an additional $9,500,000 allocated for surveying, appraisal, title and site assessments.

ANRA has also included in its development budget, funds ("Mitigation Fund") to be used for restoring, establishing, and/or preserving tracts to produce the required mitigation.

13.0 References

Freese and Nichols. 2003. Lake Eastex [Columbia] Planning Studies Final Report. Prepared for Angelina and Neches River Authority and Texas Water Development Board. May 2003. Fort Worth, Texas

McTague, John Paul, Daniel J. Robison, David O'Loughlin, Joseph Roise, and Robert Kellison. 2006. Development of Growth and Yield Models for Southern Hardwoods: Site Index Determinations. In, Connor, Kristina F., ed. 2006. Proceedings of the 13th Biennial Southern Silvicultural Research CConference.

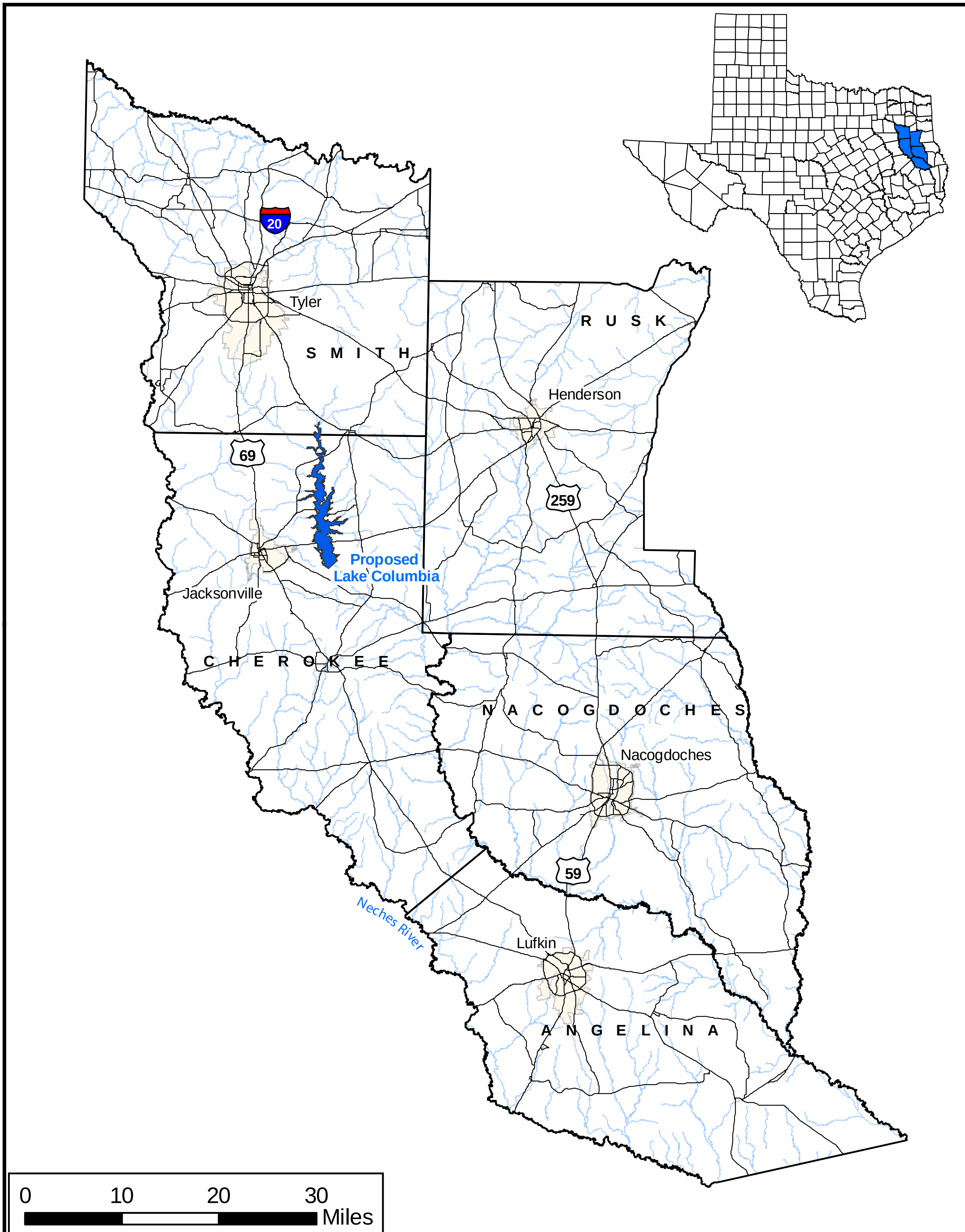
Gen. Tech. Rep. SRS–92. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 640 p.

U.S. Army Corps of Engineers. 2010. Lake Columbia Regional Water Supply Project Draft Environmental Impact Statement. Fort Worth, Texas.

U. S. Department of Agriculture (USDA). 1977. Cavity-nesting birds of North American forests. U. S. Forest Service. Agriculture Handbook No. 511.

Wetlands Research & Technology Center (WRTC). 1992. WRP Technical Note. WG-RS-3.1 Wetlands Engineering: Design Sequence for Wetlands Restoration and Establishment. May 1992.

Appendix A
Maps and Figures



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Location Map

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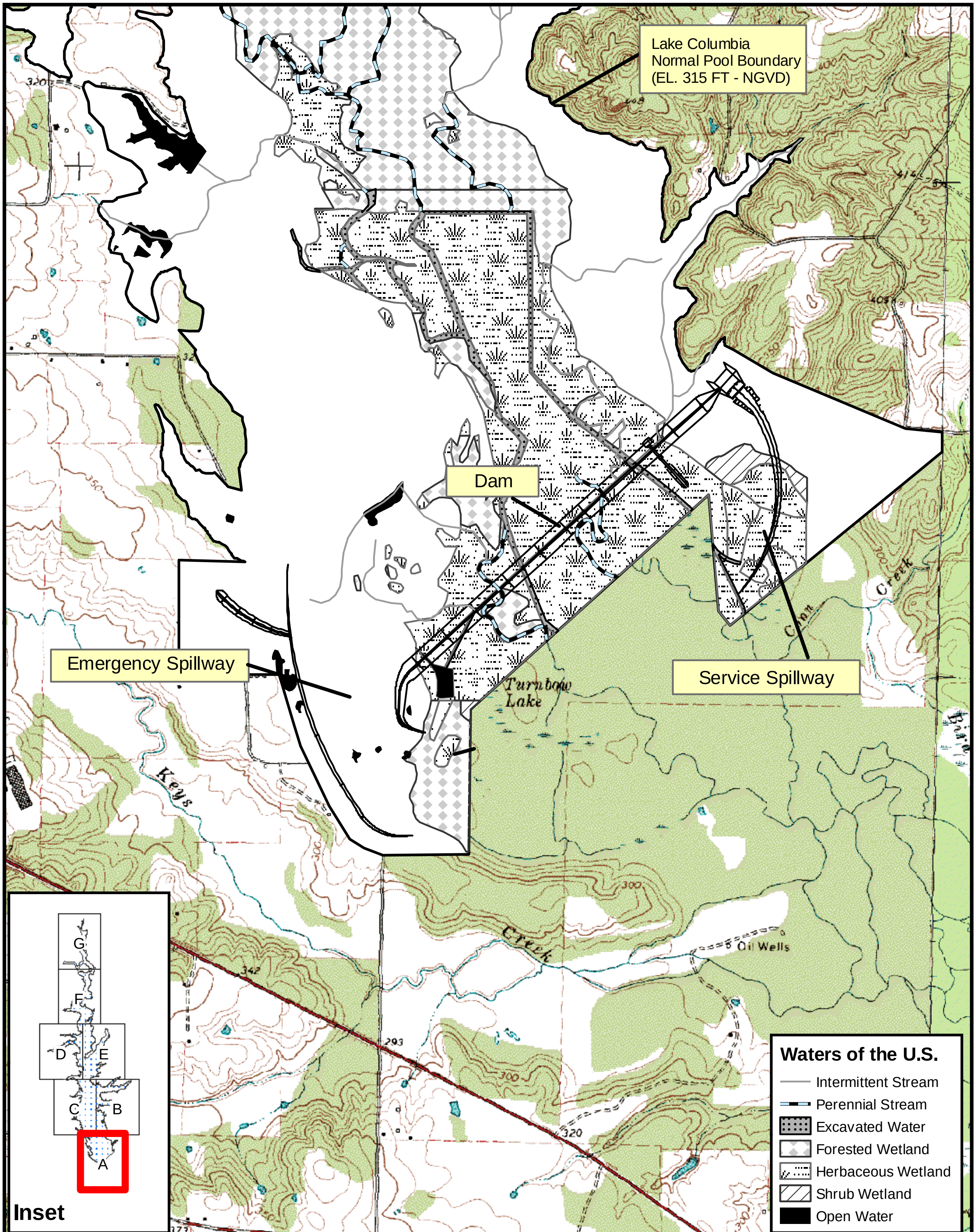

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Waters of the U.S. Within the Normal Pool

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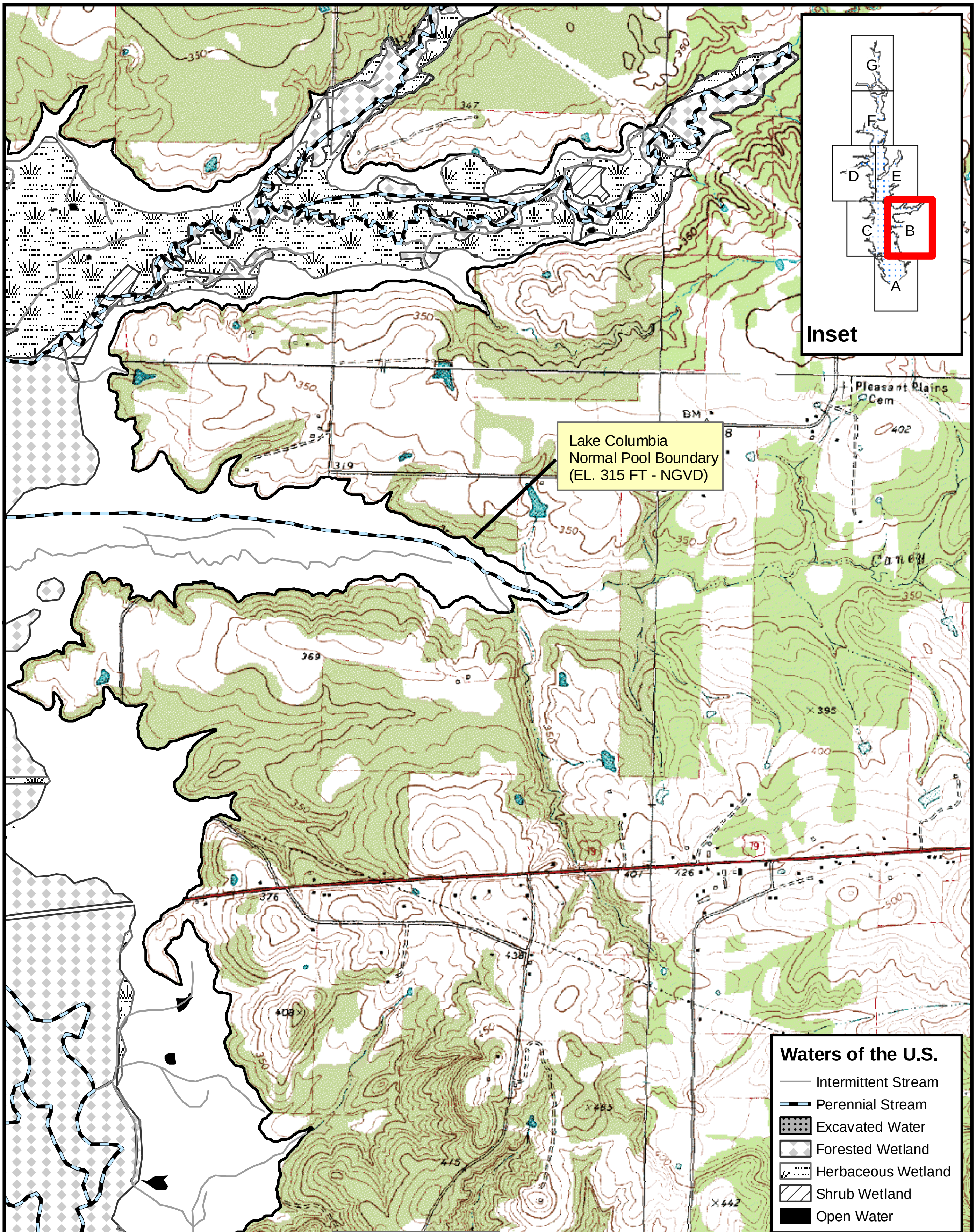
FIGURE 2A



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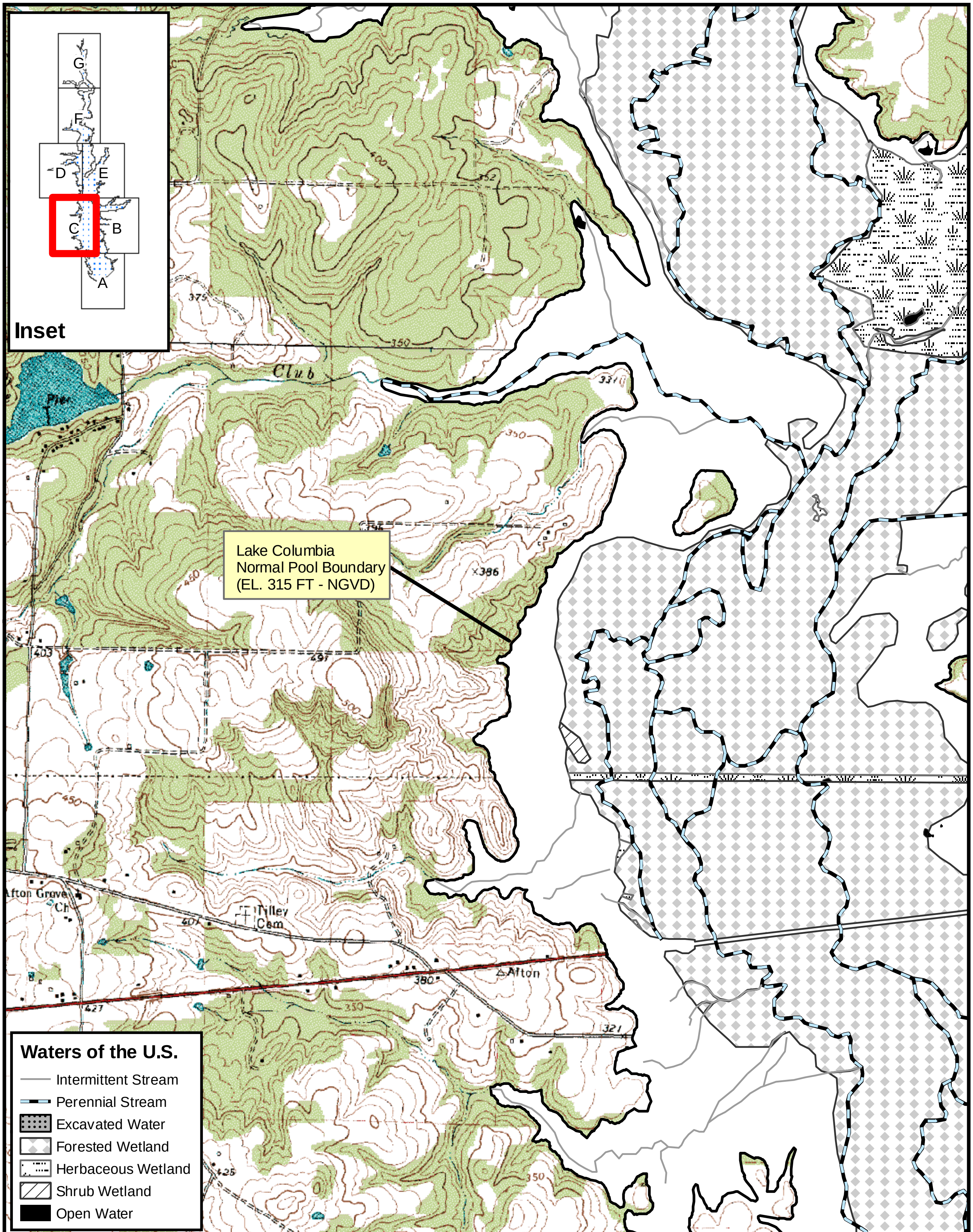

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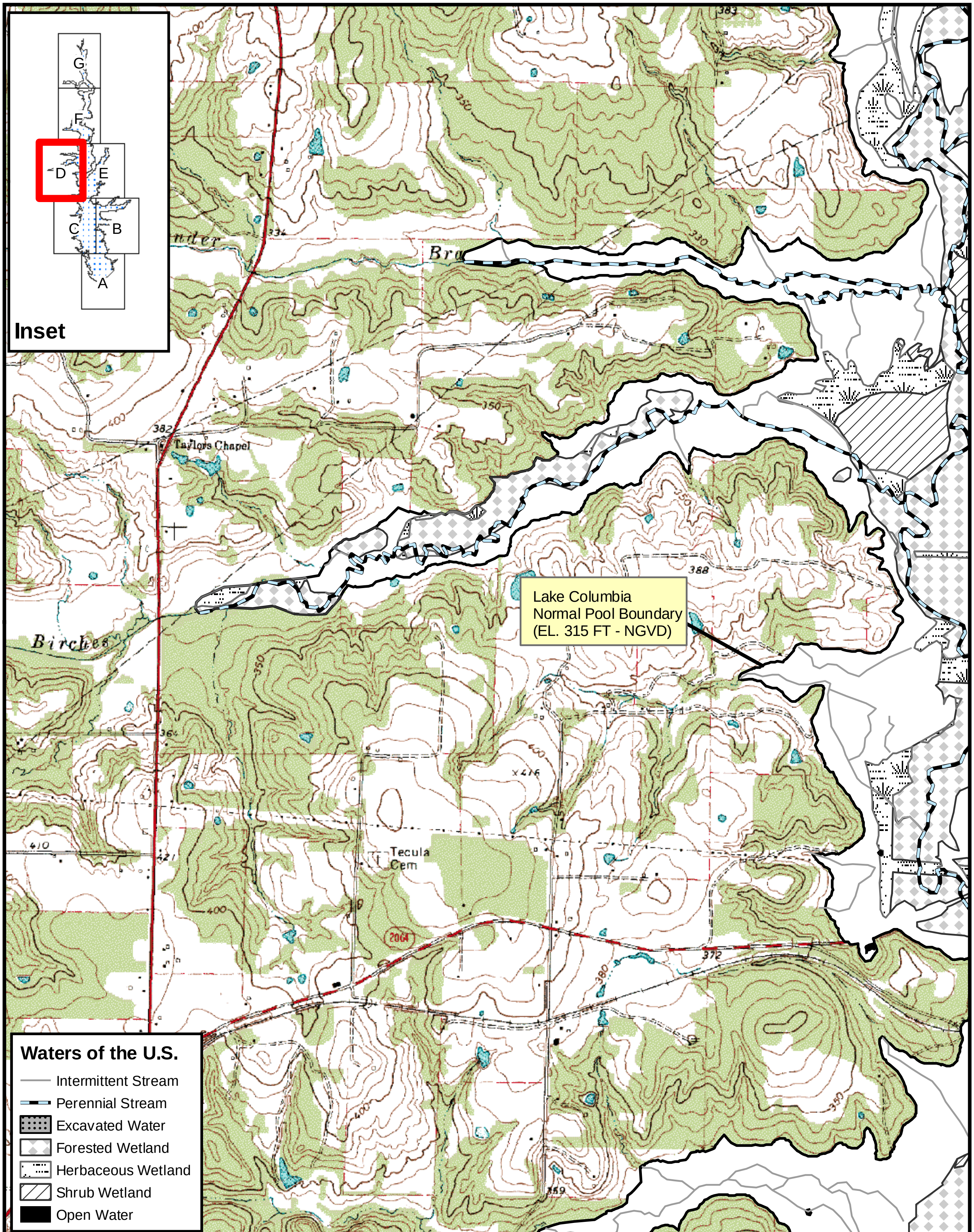

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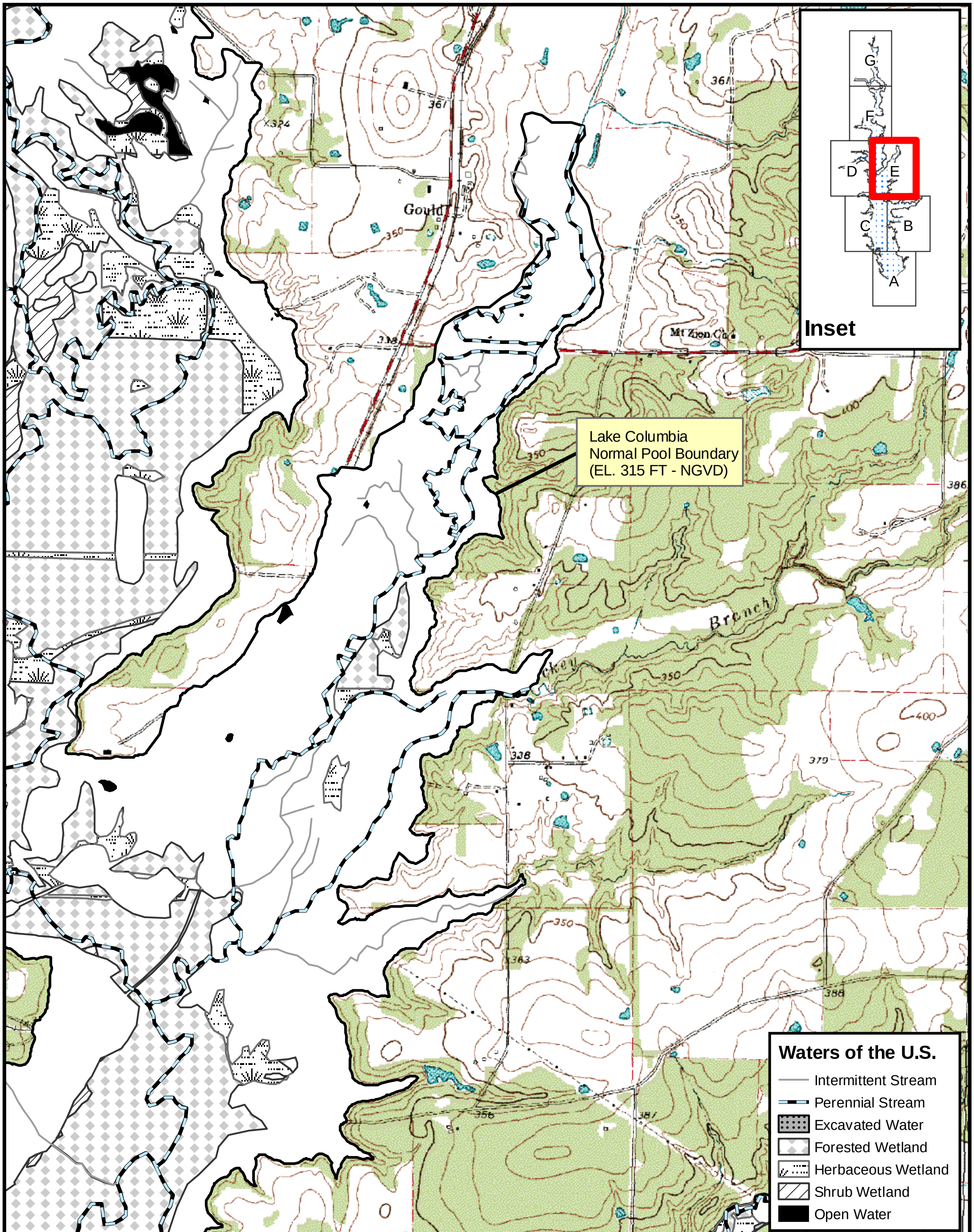

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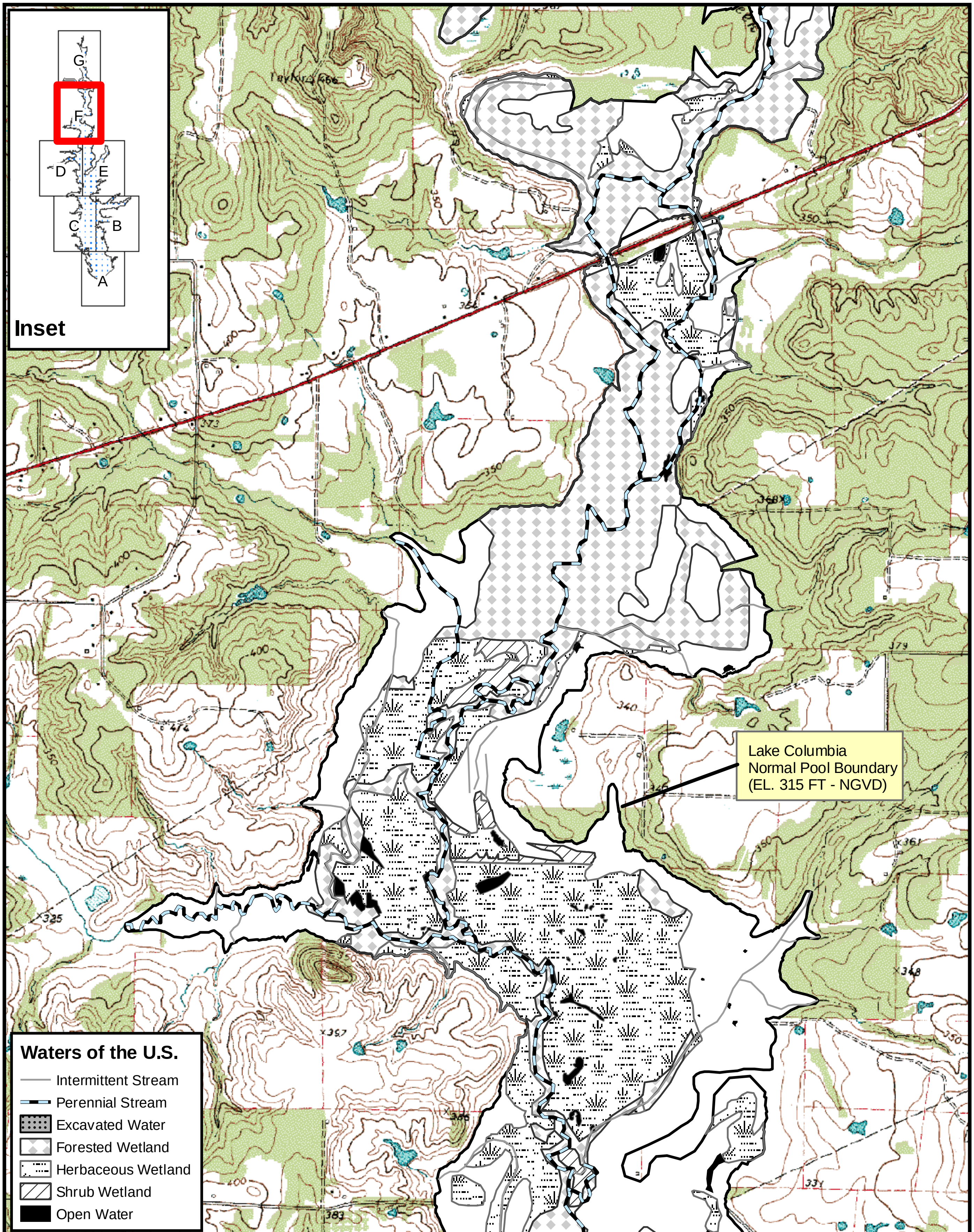

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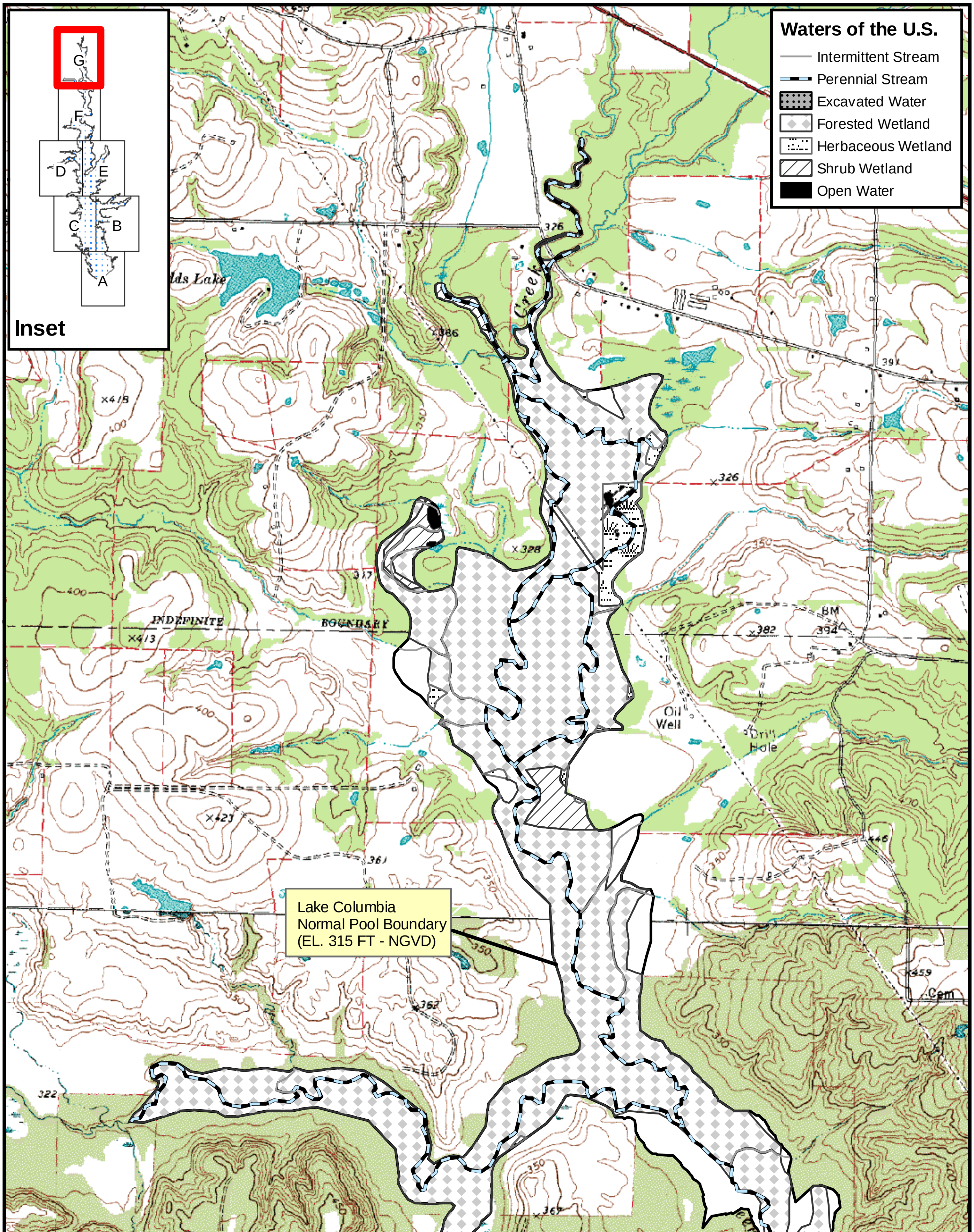

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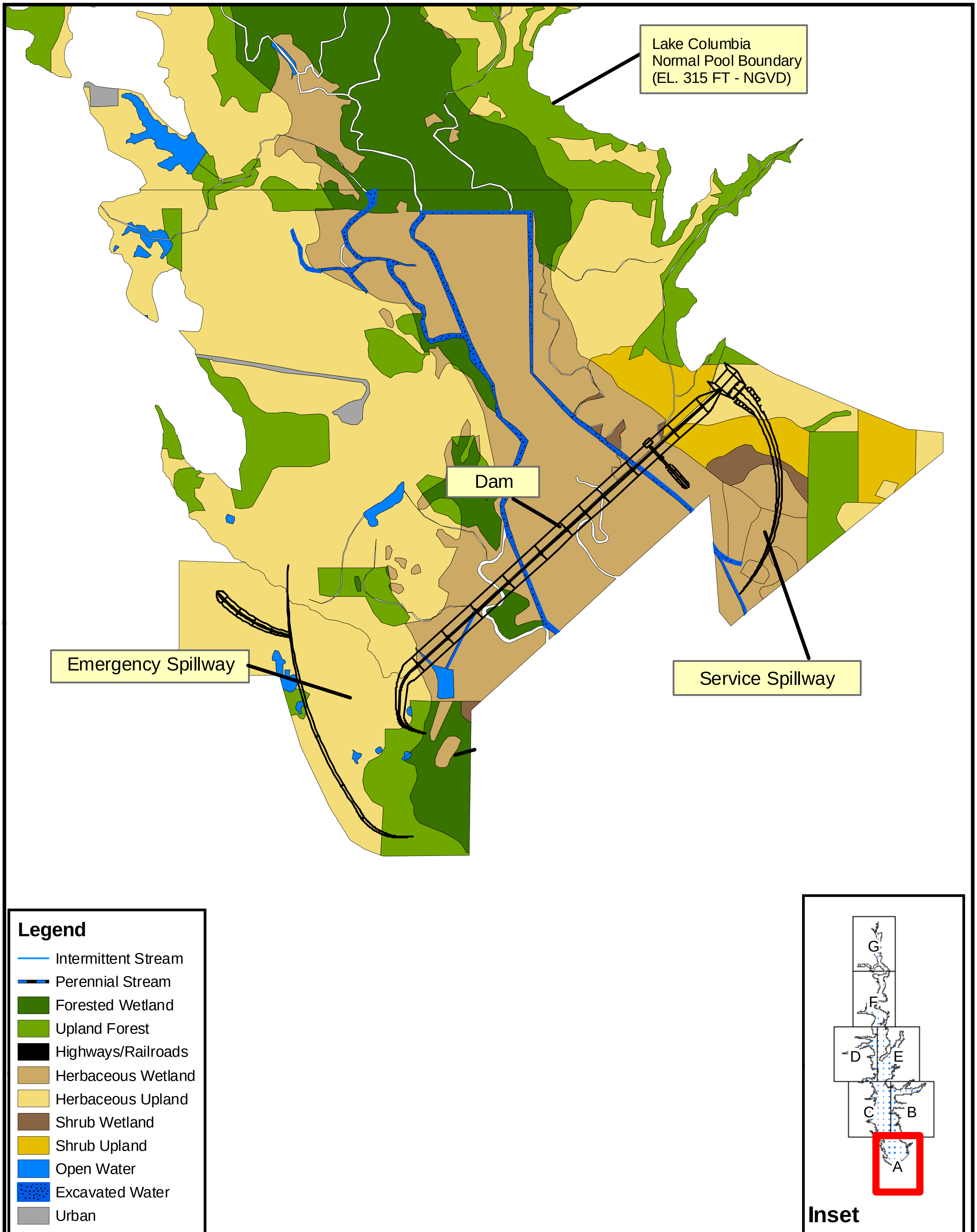

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Cover Types Within the Normal Pool

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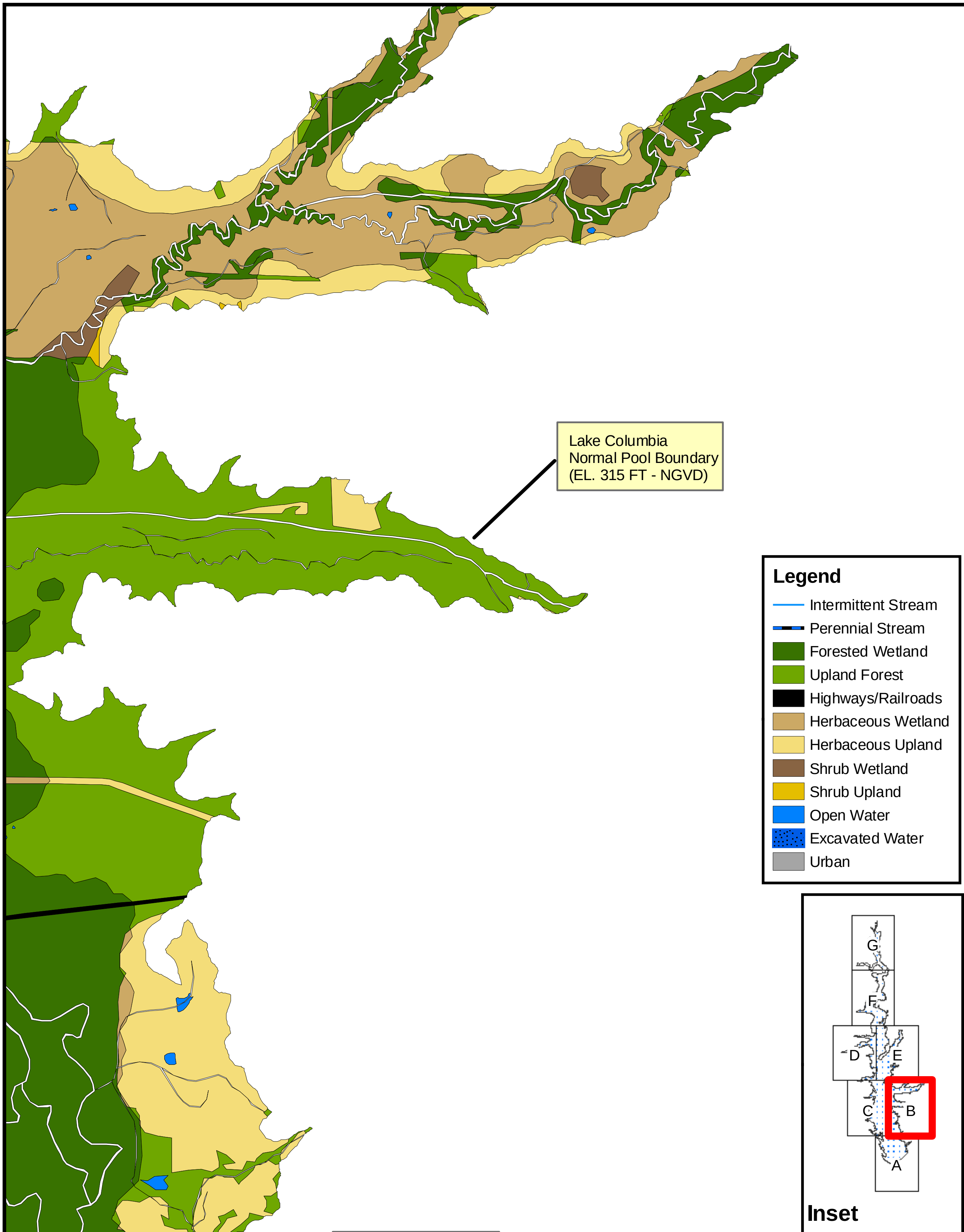

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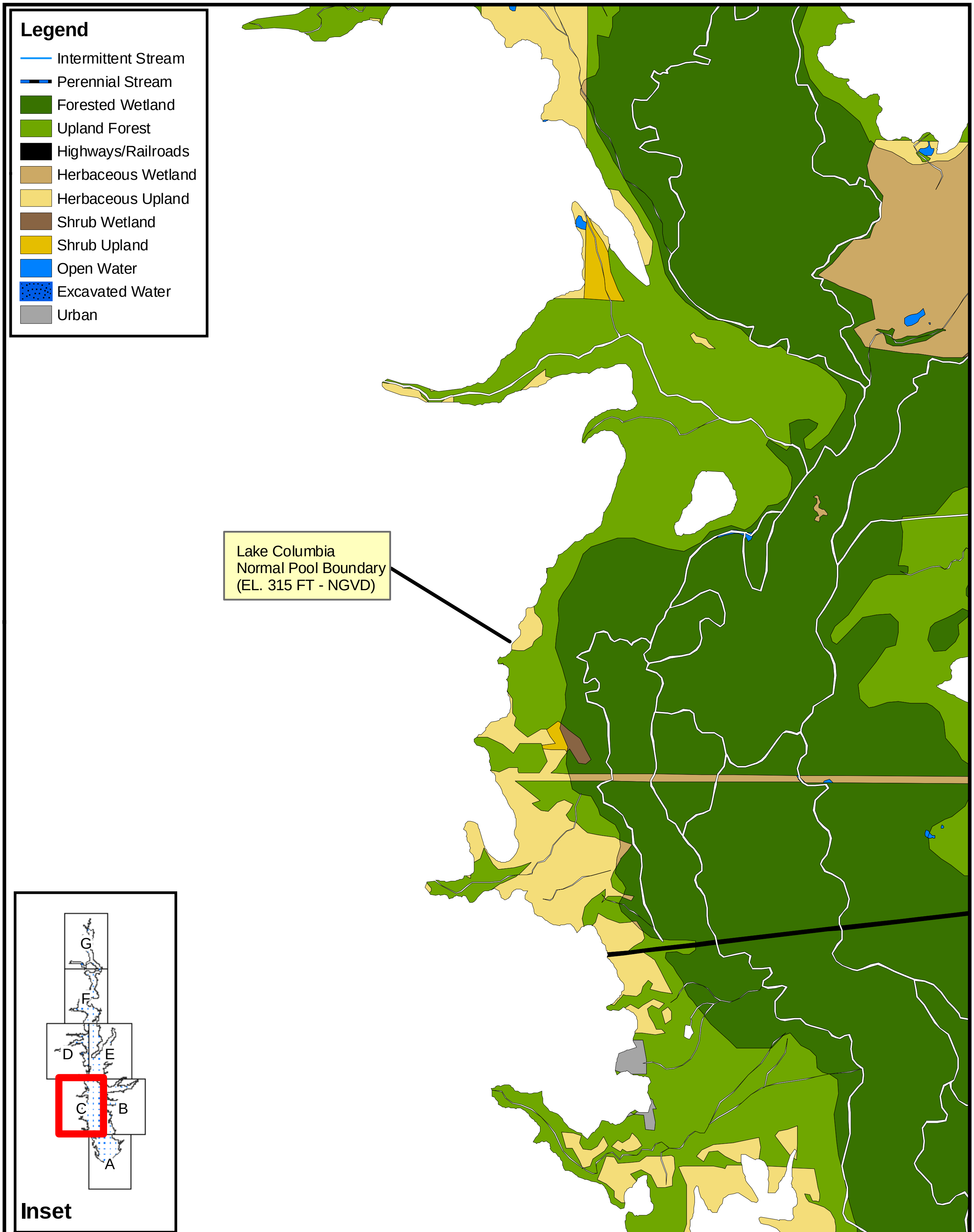

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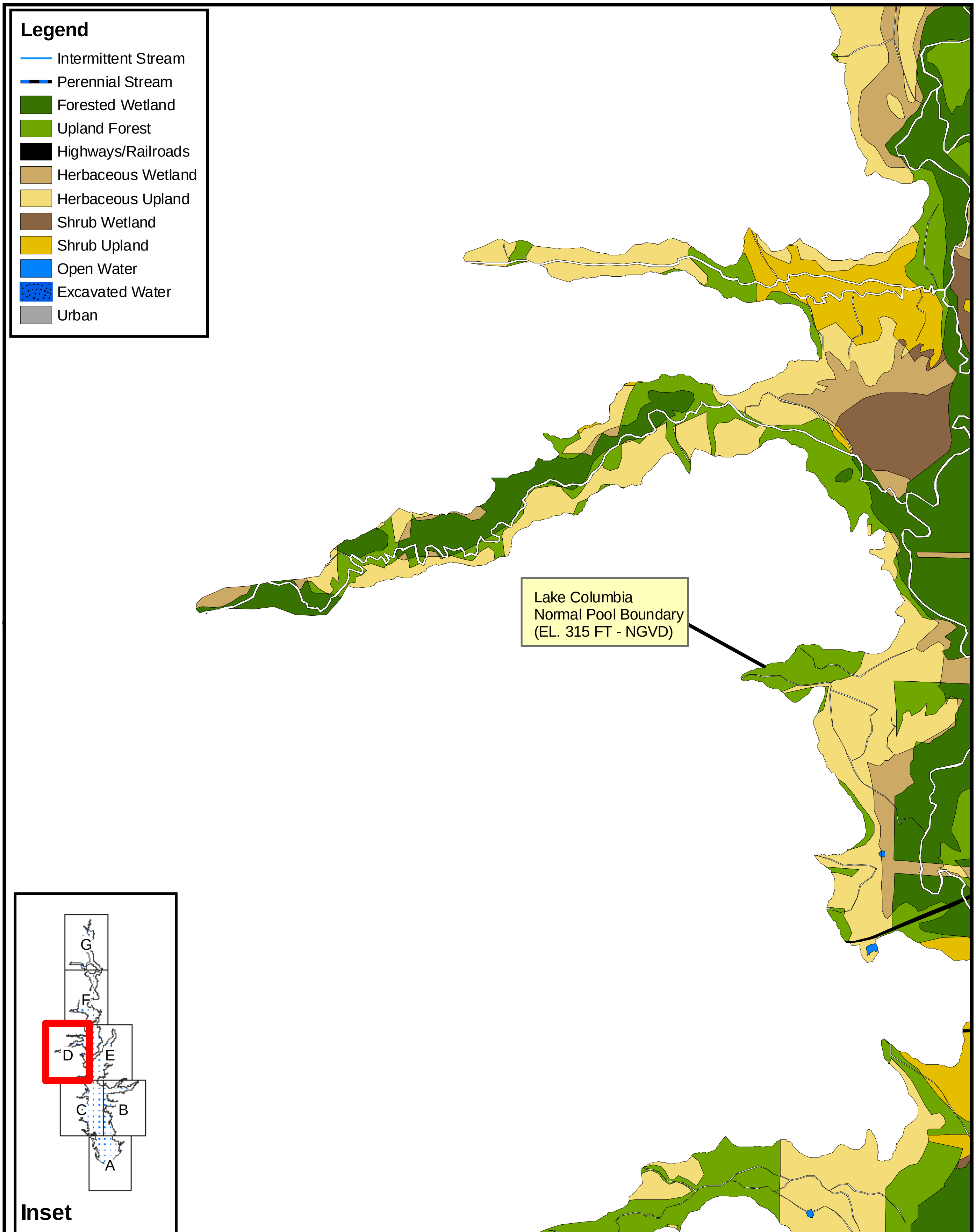

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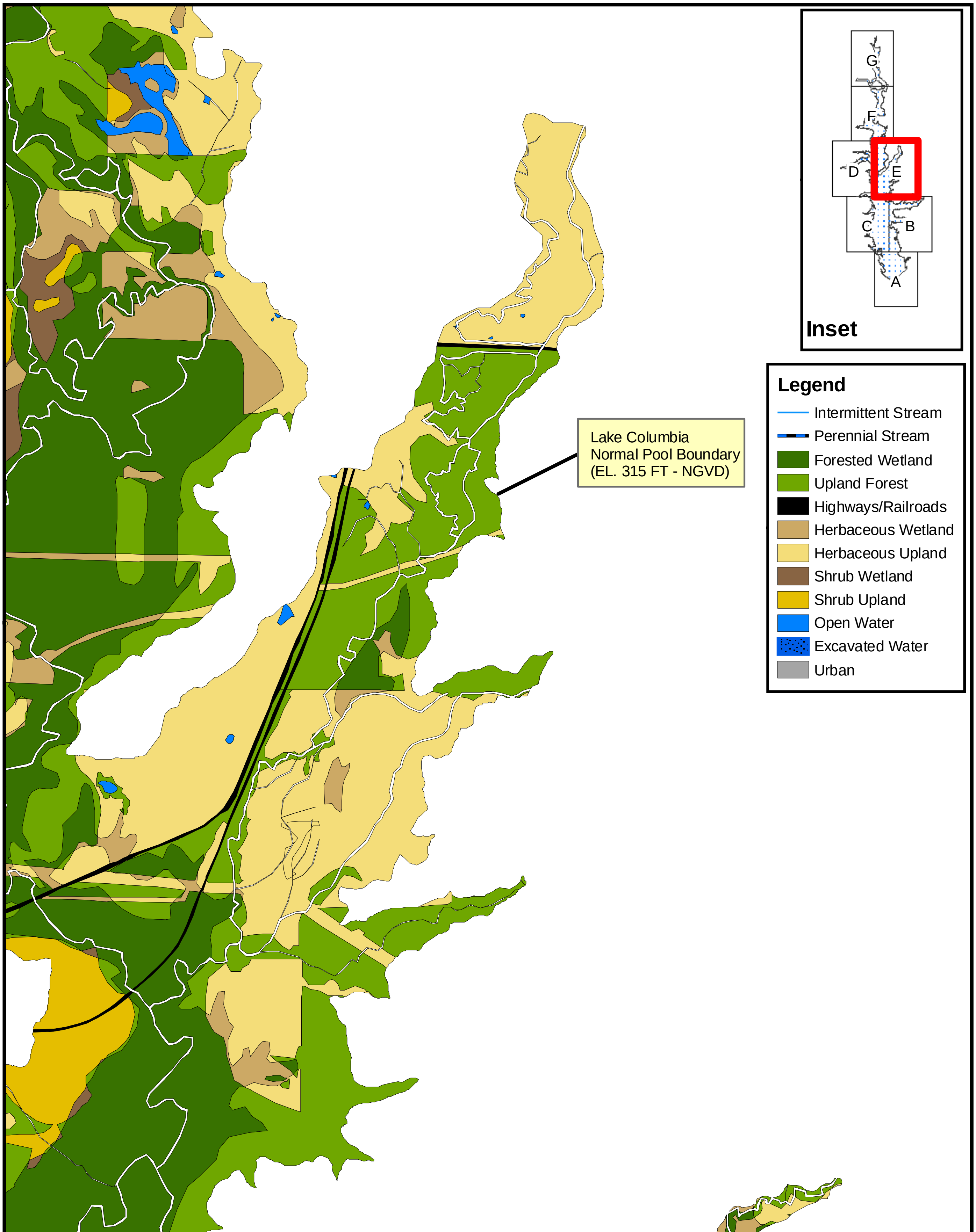

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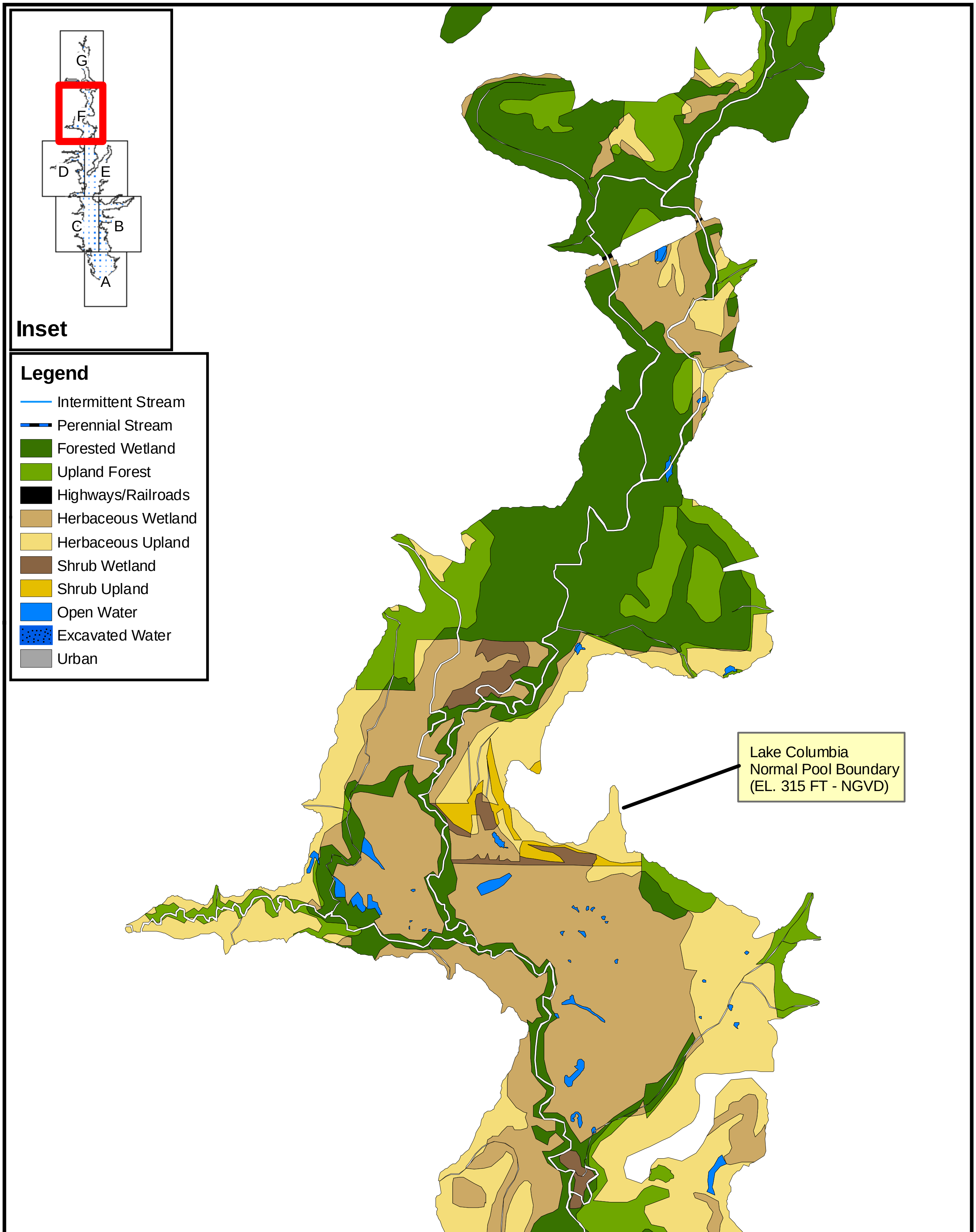
FIGURE 3E



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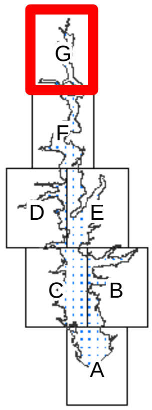
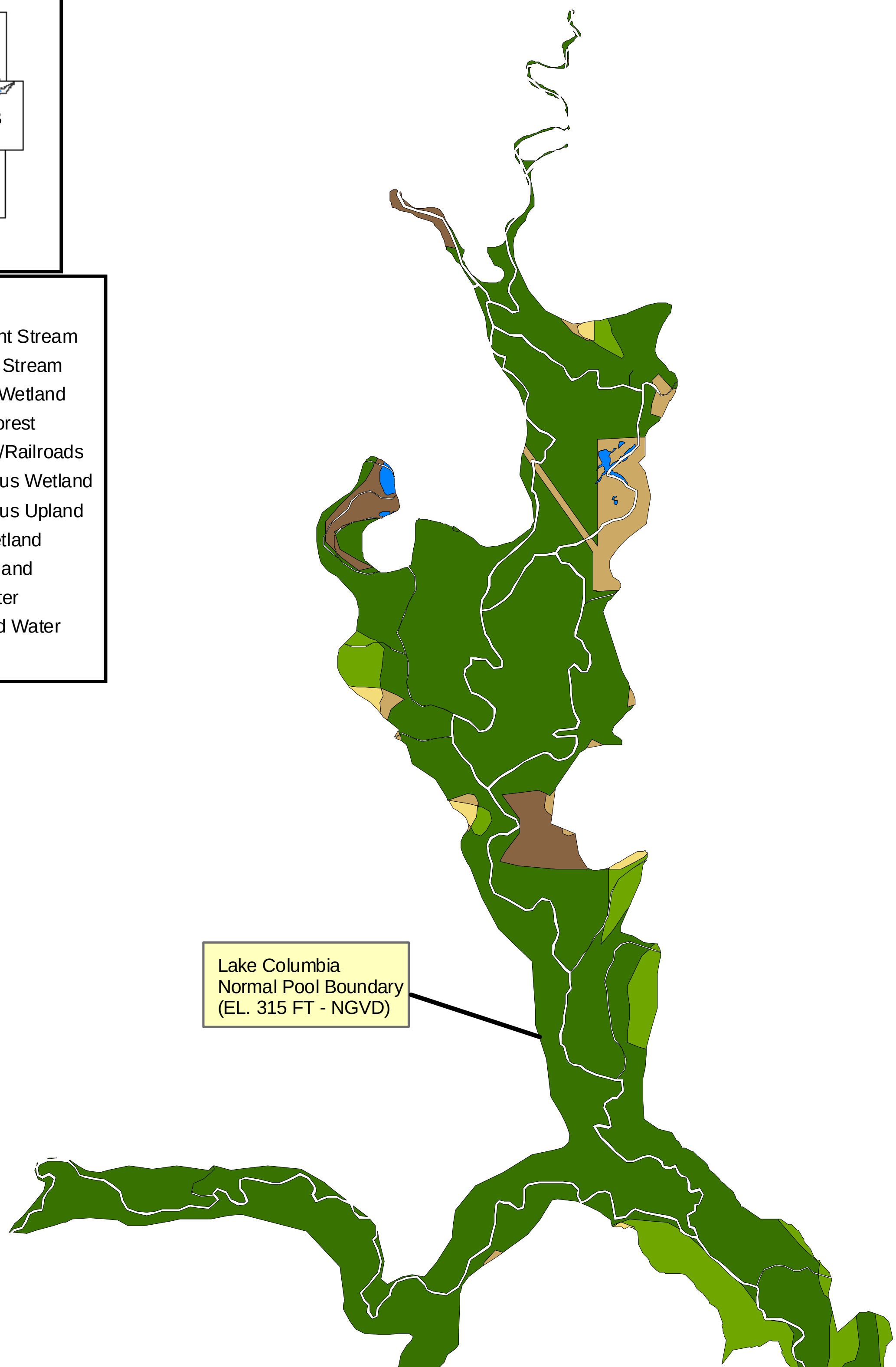


Inset

Legend

- Intermittent Stream
- Perennial Stream
- Forested Wetland
- Upland Forest
- Highways/Railroads
- Herbaceous Wetland
- Herbaceous Upland
- Shrub Wetland
- Shrub Upland
- Open Water
- Excavated Water
- Urban



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DATE	August 2009
SCALE	1:24,000
DESIGNED	SPW
DRAFTED	BME

3G

FIGURE

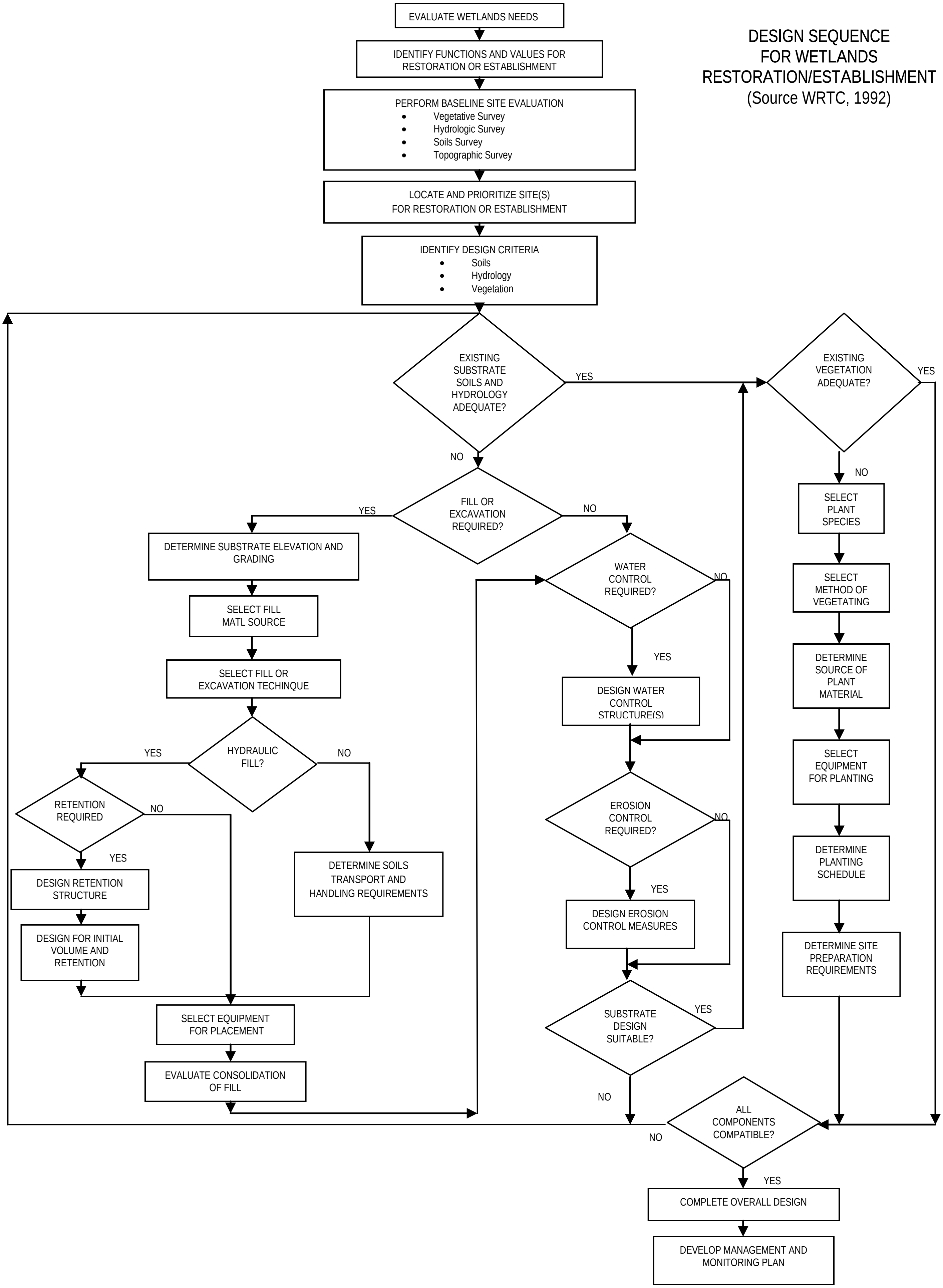
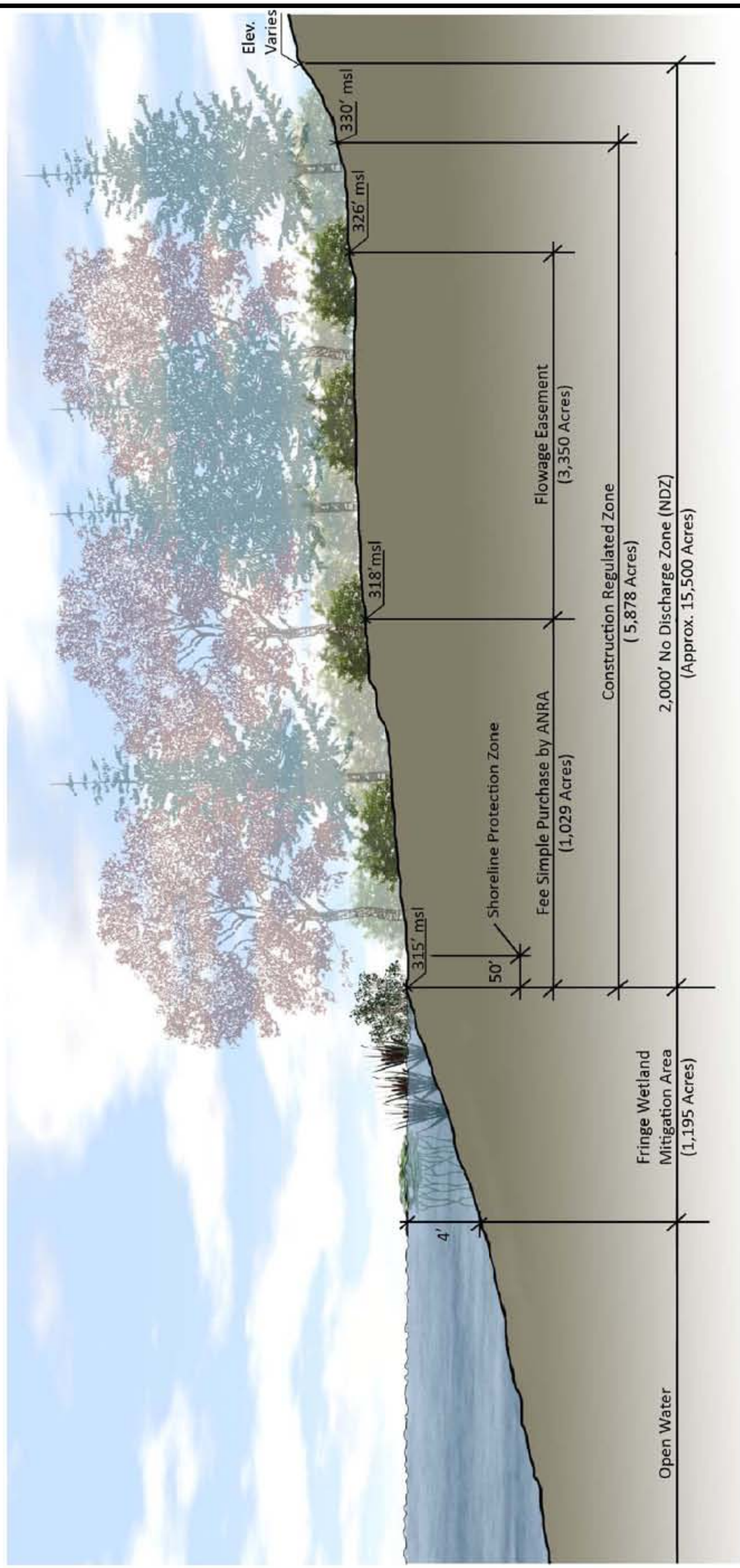


Figure 4 Flowchart illustrating design sequence for wetlands restoration and establishment projects



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Fort Worth, TX 76109 - 4895
Phone - (817) 735 - 7300

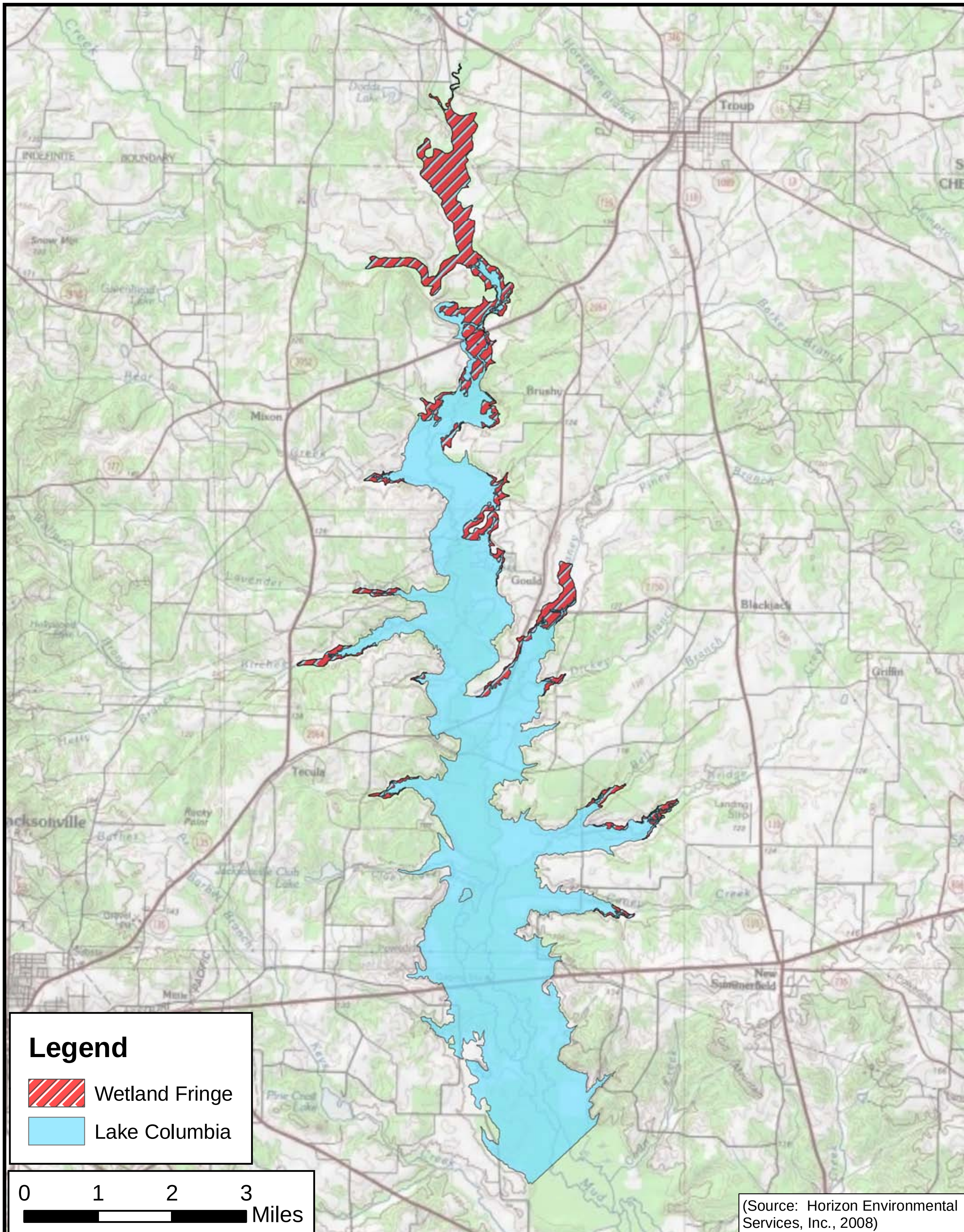
Angelina and Neches River Authority
Lake Columbia Mitigation Plan

Typical Cross-Section View of Fringe Wetlands and ANRA's Water Quality Regulations Protection Zones

FN JOB NO	ANR00164
FILE	Figure4B.mxd
DATE	November 2009
SCALE	Not to Scale
DESIGNED	SPW
DRAFTED	BME

4B

FIGURE



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Angelina and Neches River Authority
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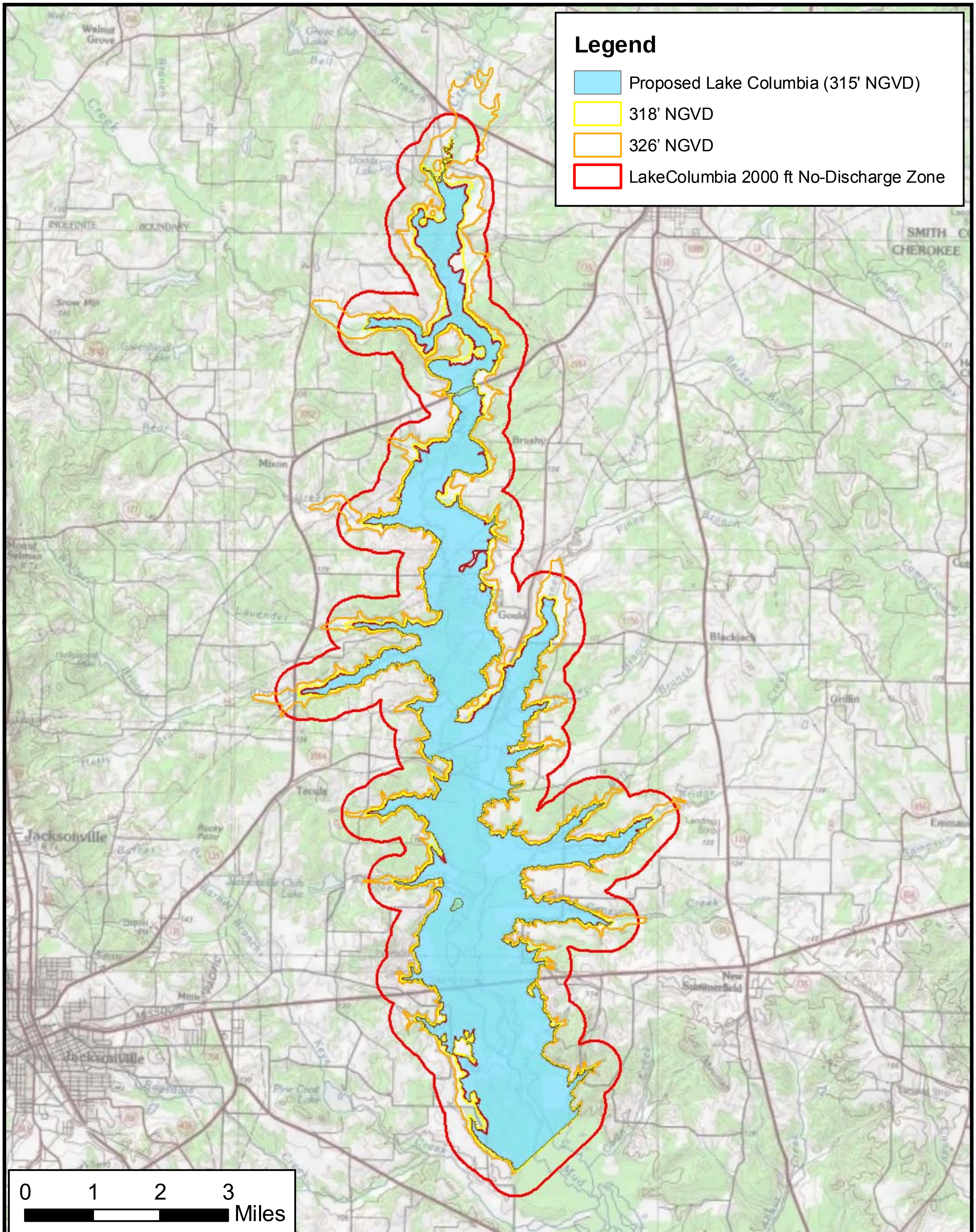
Wetland Fringe Areas

FN JOB NO	ANR00164
FILE	Figure5A.mxd
DATE	August 2009
SCALE	1:115,000
DESIGNED	SPW
DRAFTED	BME

5A

FIGURE



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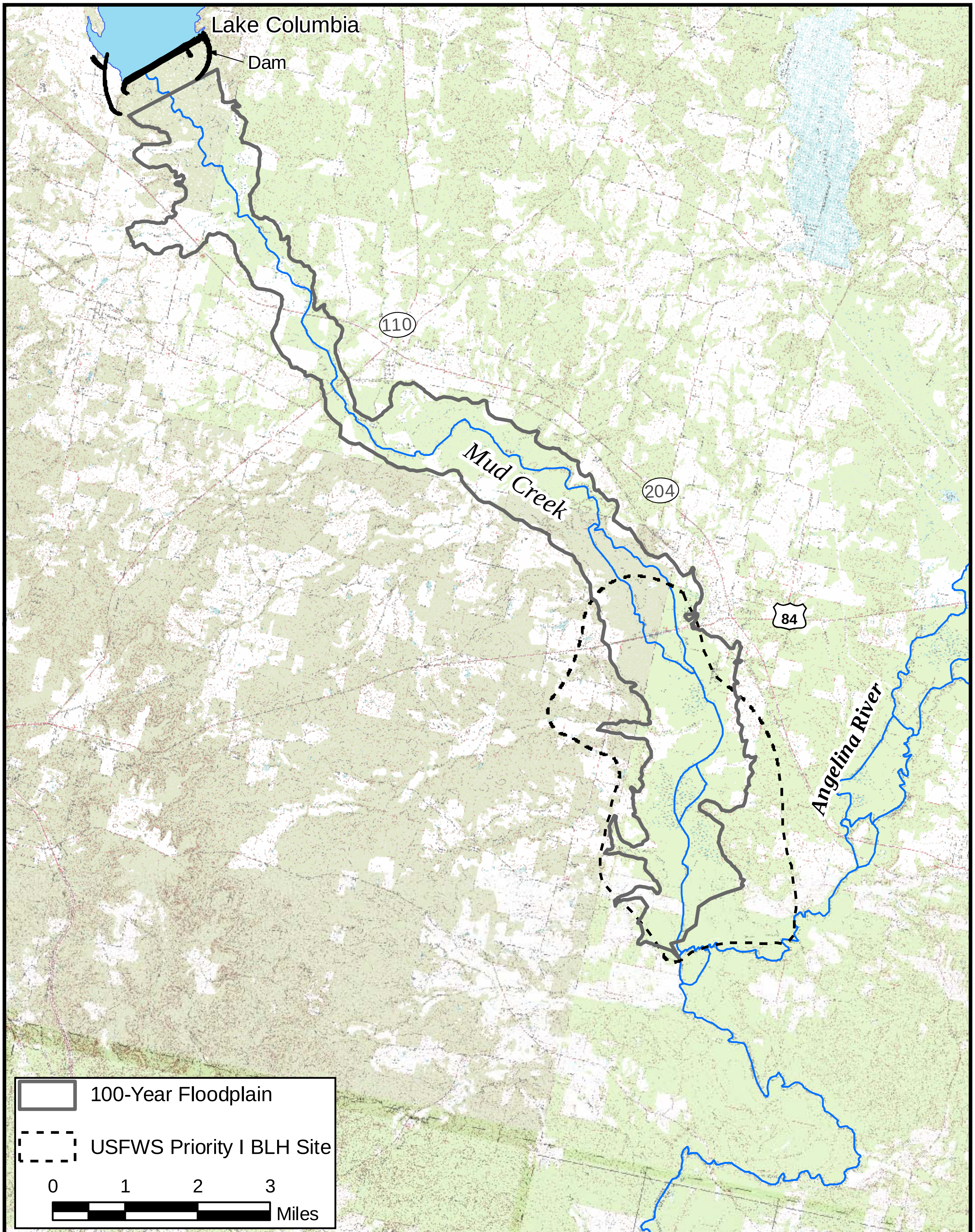
Angelina and Neches River Authority
Lake Columbia Mitigation Plan

No Discharge Zone

FN JOB NO	ANR00164
FILE	Figure6.mxd
DATE	August 2009
SCALE	1:125,000
DESIGNED	SPW
DRAFTED	BME

6

FIGURE



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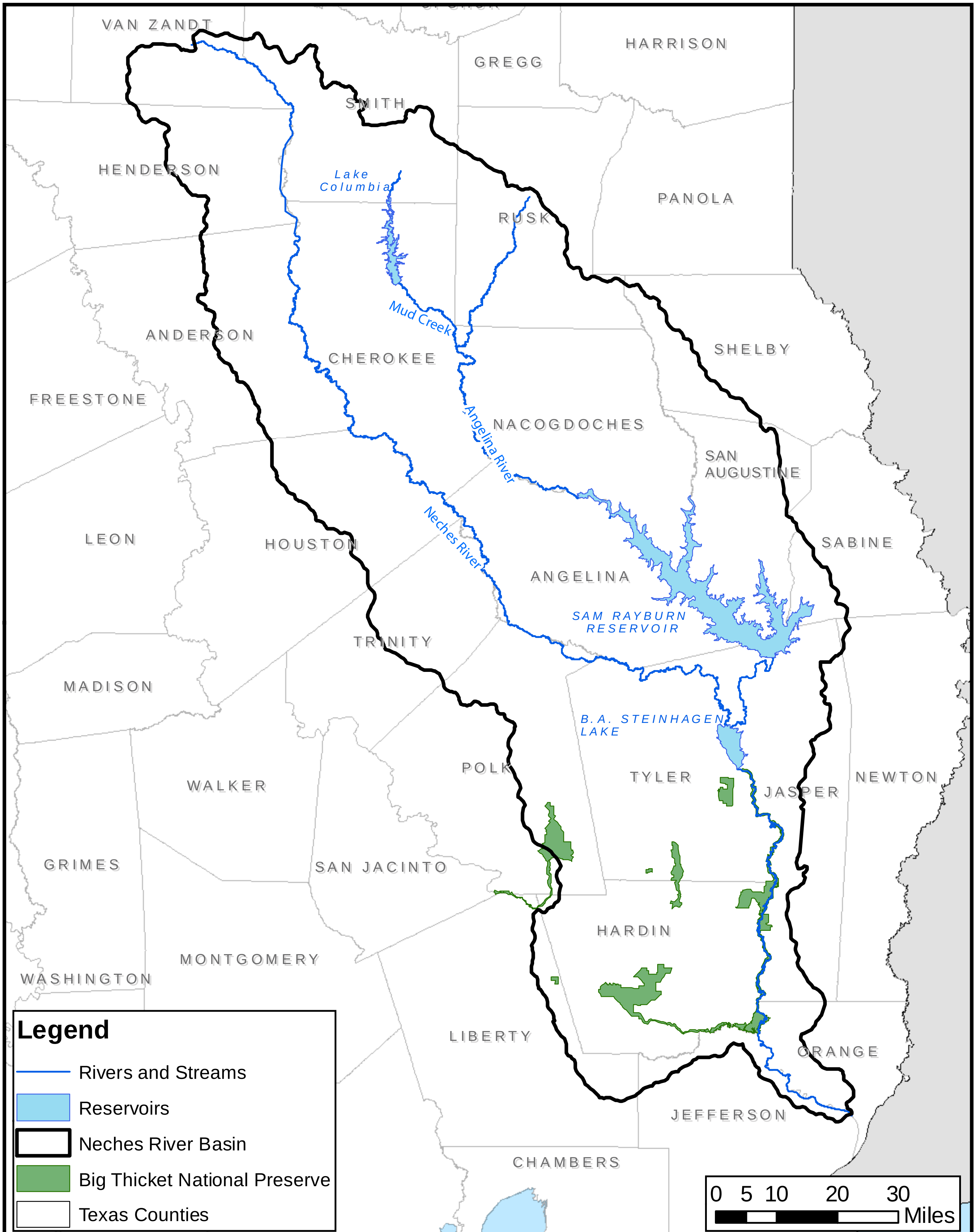
Angelina and Neches River Authority
Lake Columbia Mitigation Plan

100-Year Floodplain Downstream from Dam Site

FN JOB NO	ANR00164
FILE	Figure7.mxd
DATE	August 2009
SCALE	1:117,000
DESIGNED	BME
DRAFTED	BME

7
FIGURE



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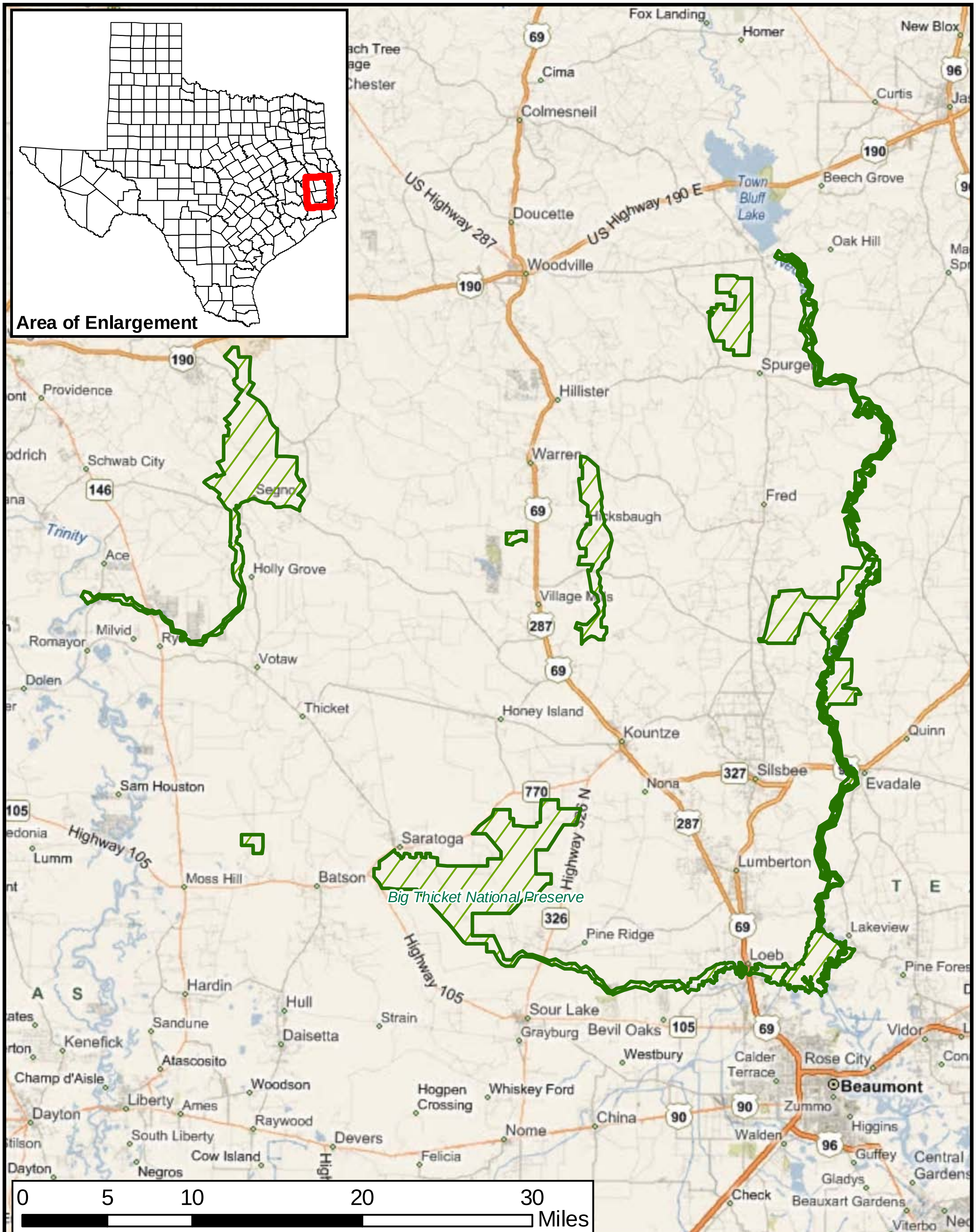
Angelina and Neches River Authority
Lake Columbia Mitigation Plan

Location of Big Thicket National Preserve

FN JOB NO	ANR00164
FILE	NechesBasin.mxd
DATE	August 2009
SCALE	1:500,000
DESIGNED	SPW
DRAFTED	BME

FIGURE 8



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Angelina and Neches River Authority
Lake Columbia Mitigation Plan

Big Thicket National Preserve

FN JOB NO	ANR00164
FILE	BigThicket.mxd
DATE	August 2009
SCALE	1:500,000
DESIGNED	SPW
DRAFTED	BME

9

FIGURE

Appendix B
Lake Columbia Water Quality Regulations

LAKE COLUMBIA

WATER QUALITY REGULATIONS

The State of Texas has conferred on the Angelina and Neches River Authority ("ANRA") the authority and responsibility to develop and maintain Lake Columbia so that the quality of water flowing into, stored, and diverted from it will be of the highest quality. This authority and responsibility is derived from Senate Bill 1362 (78th Leg. Ch. 1230), Texas Water Code Chapter 26, Texas Special Local Districts Code Chapter 8501, Texas Constitution Article 16, Section 59, and other laws. After public notice and hearing, ANRA has adopted the regulations set out below, which it may amend from time to time, in order to protect water quality while at the same time provide for the use and enjoyment of Lake Columbia..

SECTION 1

Definitions. The following definitions are used in these Regulations unless another meaning is specifically stated. All locations are in relation to the shores of Lake Columbia.

1.01 "MSL" means an elevation with reference to mean sea level.

1.02 "Construction Regulated Zone" means land located at or above 315 feet MSL and below 330 MSL and in the locations shown on the attachments labeled "Construction Limits."

1.03 "No Discharge Zone" means the land located horizontally 2000 feet from the 315 feet MSL elevation.

1.04 "100 Year Flood Level" means 323.4 feet MSL.

1.05 "On-site Sewage Facility" ("OSSF") means a system defined in Texas Health and Safety Code Sec 366.

1.06 "Effective Date or Effective Dates" means the day or days established in an Order adopted by ANRA after which compliance with these Regulations will be required. The Order, as may be amended, will be recorded in the Real Property Records of both Smith and Cherokee Counties.

1.07 "Forestry BMPs" mean the Best Management Practices established, from time to time, by the Texas Forest Service

1.08 "Lake Columbia Watershed" means all land draining into Lake Columbia.

1.09 "Lake Columbia" means the reservoir project authorized by Permit to Appropriate State Water Number 4228 (Application No. 4537) held by ANRA.

1.10 "Large or Significant Development" means a development that ANRA believes may have a direct water quality impact on Lake Columbia.

1.11 "Nonpoint Source Pollution" ("NPS") means pollution that is caused by or attributable to diffused sources such as land runoff, precipitation, or percolation.

1.12 "Best Management Practices" ("BMPs") mean those practices, including but not limited to Forestry BMPs, that prevent or control nonpoint source pollution.

1.13 "Pollution" has the same meaning as given in Texas Water Code Chapter 26, as amended.

1.14 "Lake Columbia Water Quality Regulations" mean these regulations adopted and as may be amended, by ANRA for the protection and preservation of the water in Lake Columbia.

1.15 "Shoreline Habitat Plan" means a plan that addresses the Shoreline and/or the Streamside Management Zone in the Forestry BMPs.

1.16 "Shoreline Habitat Zone" means the area along the Shoreline.

1.17 "Subdivided" means the division of land into two or more tracts which is not exempt under Texas Local Government Code Chapter 232.

1.18 "Subdivision" means land which has been subdivided.

1.19 "Shoreline" means the extended point where the plane of the surface of water stored in Lake Columbia touches land up to the 100 year Flood Level.

1.20 "Commission" means the Texas Commission on Environmental Quality or its successor or agency.

1.21 "Agricultural Activities" means all activities associated with the production of livestock or use of land for planting, growing, cultivation and harvesting crops, or participation in a wildlife management plan.

1.22 "Utility Line" means any wire, cable, pipe or any other type of conveyance for the transmission of gas, liquid, electronic signal, electricity, telephone service, cable television service or any other type of service whether public or private.

1.22 "Development" means all land modification activity, including the construction of buildings, roads, paved storage areas and parking lots. Development also includes, but is not limited to, any land disturbing construction activities or human-caused change of the land surface including clearing of vegetative cover, excavating, leveling, grading, contouring, mining and the deposit of refuse, waste, or fill. Care and maintenance of lawns, gardens and landscape vegetation, agricultural activities and activities subject to "Forestry BMPs" are not included within this definition.

SECTION 2

Pipelines and Utilities

The construction and installation of pipelines and utility lines in Lake Columbia is prohibited.

APPROVED 8/7/07

SECTION 3

Solid or Hazardous Waste Facilities

3.01 Construction of or enlargement of existing Hazardous or Municipal Solid Waste facilities including receiving and transfer facilities are prohibited within the Lake Columbia Watershed except for Municipal Solid Waste within the incorporated limits of the Cities of Tyler, Jacksonville, New Summerfield, Troup, Whitehouse, and Bullard or owned by or operated by one of said cities.

3.02 Petroleum storage tanks ("PST") with a capacity greater than 100 gallons are prohibited in the No Discharge Zone without the approval of ANRA.

SECTION 4

Forestry Activities:

Forestry BMPs are mandatory for all forestry activities in the No Discharge Zone.

SECTION 5

No Discharge Zone.

5.01 After the Effective Date, OSSF are not allowed in the No Discharge Zone on: (1) a lot less than 0.75 acres in size if the improvements are connected to a public water supply; (2) a lot less than 1.25 acres that is not connected to a public water supply; or (3) on any lot which can practicably be served by a sewage collection and treatment system permitted by the Texas Commission on Environmental Quality (the"Commission") .

5.02 OSSF may be allowed in the No Discharge Zone, except as provided in 5.01 above, provided the OSSF has received a permit as provided below and it does not discharge pollution.

5.03 All On-Site Sewage Facilities must be designed by either a registered professional engineer or a registered professional sanitarian. Plans for an OSSF, along with all applicable fees and other information which may be required by ANRA, must be submitted to ANRA for its review and approval prior to beginning construction. Upon its review and approval, ANRA shall issue a permit to the property owner for the system. ANRA shall make available to the public the forms and design criteria for OSSF.

5.04 All OSSF permits shall remain subject to the continued jurisdiction of ANRA and shall be cancelable upon reasonable notice for failure to comply with applicable laws, regulations and requirements.

5.05 ANRA shall adopt application forms, design criteria, maintenance requirements, fee schedules, and other requirements from time to time which shall be incorporated by reference into these Regulations. The requirements may be more stringent and restrictive than those established by the Commission, Cherokee County or Smith County for OSSF.

5.06 Erosion is prohibited in the No Discharge Zone. Property owners are required to take action to prevent erosion from occurring on their property and to immediately abate any erosion on it. Property owners may be relieved of the duty to abate erosion occurring on their property if they can show to ANRA's satisfaction that the erosion is caused by natural forces.

SECTION 6

Construction Regulated Zone.

6.01 Owners of property adjacent to the Construction Regulated Zone ("Adjacent Owners") may be granted permission to use this Zone but are limited in what can be constructed on it. The general rules are that nothing can be constructed in this Zone which will decrease the storage capacity of the Lake, be a source of contamination, or significantly impact aquatic or terrestrial habitat.

6.02 Adjacent Owners may construct piers, docks, and other water front facilities in the Construction Regulated Zone after applying to and receiving from ANRA a license to do so. Each application will be evaluated on a case by case basis consistent with applicable construction regulations.

SECTION 7

Land Development

7.01. Any person who proposes to subdivide land within the Construction Regulated Zone, except for land within the municipal limits or extraterritorial jurisdiction of the Cities of Tyler, Whitehouse, and Troup, must submit to ANRA the plat or plats required under the Subdivision Regulations of Smith County or Cherokee County.

7.02 In addition to the County Requirements, the Subdivider must provide a Non-point Source Pollution control plan for both the construction of any roads, utilities, parking lots, or other improvements associated with the development and any impervious cover that will remain on the property.

7.03 Any Shoreline property that is to be Subdivided must contain a Shoreline Habitat Plan that states how the Shoreline habitat will be maintain, restored and protected as well as means and methods of stabilizing the Shoreline to prevent erosion. At least sixty percent (60%) of all Shoreline within 50 feet of the 315 MSL Level must be maintained in a natural condition. No modification within the Shoreline as defined in these Regulations is permitted without prior written consent from ANRA. The purpose of the Shoreline Habitat Plan is to prevent sedimentation within the lake, prevent erosion along the shoreline, to filter and remove nutrients from runoff into the lake and to provide a productive wildlife habitat. Shoreline Habitat Plans shall be reviewed on a case by case basis as necessary, consistent with the purpose stated herein, and any such review shall be based upon the following considerations:

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c. Use of native species over non-native species.

d. Use of non-natural shoreline materials such as sea walls, bulkheads, rip rap and other hard shoreline materials will be considered on a case by case basis.

e. Any other factors peculiar to the site being considered and determined, by ANRA, to be relevant.

7.04 In determining whether Development is a "large or significant development" as defined by Rule 1.10 ANRA shall consider the following:

a. the size of the development;

b. the character of the development (residential, commercial, industrial, etc.);

c. the amount of impervious cover;

d. proximity to Lake Columbia and/or streams, rivers or creeks draining into Lake Columbia; and

e. other factors the ANRA considers relevant.

7.05 All Development within the No Discharge Zone equal to or greater than one (1) acre, must comply with TCEQ TPDES General Permit No. TXR150000. Development of less than one (1) acre must control run-off and sedimentation from the Development so as to prevent discharges that would cause or contribute to a violation of water quality standards or that would fail to protect and maintain all existing designated uses of Lake Columbia.

ADOPTED this ___ day of ___________, 2007.

____

President

ATTEST:

____

Secretary

APPROVED 8/7/07

APPENDIX D

ANRA'S LAKE COLUMBIA WATER QUALITY REGULATIONS

LAKE COLUMBIA WATER QUALITY REGULATIONS

(Approved 8/7/2007 by ANRA Board of Directors)

The State of Texas has conferred on the Angelina and Neches River Authority ("ANRA") the authority and responsibility to develop and maintain Lake Columbia so that the quality of water flowing into, stored, and diverted from it will be of the highest quality. This authority and responsibility is derived from Senate Bill 1362 (78th Leg. Ch. 1230), Texas Water Code Chapter 26, Texas Special Local Districts Code Chapter 8501, Texas Constitution Article 16, Section 59, and other laws. After public notice and hearing, ANRA has adopted the regulations set out below, which it may amend from time to time, in order to protect water quality while at the same time provide for the use and enjoyment of Lake Columbia.

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APPENDIX E

PRELIMINARY LAKE COLUMBIA DEPARTMENT OF THE ARMY PERMIT APPLICATION
SECTION 404 (B)(1) GUIDELINE ANALYSIS

January 2010

TABLE OF CONTENTS

LIST OF TABLES

1.0 INTRODUCTION AND PURPOSE OF THE PROJECT

The applicant, Angelina & Neches River Authority (ANRA) proposes to construct, operate, and maintain a dam and reservoir known as Lake Columbia (the "Project") on Mud Creek, a tributary of the Angelina River, in Cherokee and Smith counties, Texas. The basic project purpose is water supply. The overall purpose is to provide water supply for Angelina, Cherokee, Nacogdoches, Rusk, and Smith counties in east Texas ("Five-County Area") to meet projected needs through the year 2060 and beyond. Water from the proposed project would be used primarily to meet future municipal, industrial, and steam electric power demands.

ANRA began initial planning for Lake Columbia (formerly Lake Eastex or Mud Creek) in 1978. ANRA's early efforts led to the issuance of a water right by the Texas Water Commission in 1985 (Permit to Appropriate State Water No. 4228). This permit authorizes the development and construction of the dam and reservoir on Mud Creek in Cherokee and Smith counties, with capacity to impound up to 195,500 acre-feet of water. The permit also authorizes the diversion of up to 85,507 acre-feet of water per year from the reservoir for municipal and industrial uses.

The proposed Project requires authorization from under Section 404 of the Clean Water Act and Section 10 of the Rivers and Harbors Act of 1899. Jurisdictional activities would include the discharge of approximately 672,000 cubic yards of dredged and fill material into the waters of the U.S. under Section 404 of the Clean Water Act. Evaluation of a standard individual permit is a federal action subject to review under the National Environmental Policy Act of 1969 (NEPA). Overall this proposal would result in adverse impacts to approximately 5,746.5 acres of waters of the U.S. Further it has been determined that this permit decision is a major federal action with the potential to significantly affect the quality of the human environment. As such, under the provisions of NEPA and the Council on Environmental Quality's implementing regulations (40 CFR 1500-1508), preparation of an Environmental Impact Statement (EIS) is necessary. The Notice of Intent to prepare an EIS for this project was published in the June 28, 2005, Federal Register, Volume 70, No. 123, page 37094.

1.1 LOCATION

The proposed Lake Columbia dam would be constructed on Mud Creek approximately 5 miles southeast of the city of Jacksonville, in Cherokee County, Texas, and approximately 3 miles downstream from the U.S. Highway 79 (US 79) bridge over Mud Creek. The proposed center of the dam necessary for the creation of the Lake Columbia Reservoir would be located approximately at Universal Transverse Mercator (UTM) coordinates, zone 15; NAD83, 297409.82 East and 353625.25 North on the Jacksonville East, Texas, 7.5-minute US Geological Survey (USGS) quadrangle map in the USGS Hydrologic Unit 12020004.

1.2 PROJECT DESCRIPTION

The creation of Lake Columbia would require the construction of a dam on Mud Creek that would impound water approximately 14 miles upstream in Cherokee and Smith counties at an average width of approximately 1.1 miles. The reservoir created by the dam would inundate approximately 10,133 acres at the top of the conservation pool, i.e., at an elevation of 315 feet National Geodetic Vertical Datum (NGVD) (FNI, 2003a).

Construction of the proposed dam and spillway is estimated to take 2.5 years after a construction contract is awarded. The construction of the proposed dam and spillway, in conjunction with other construction-related activities, would result in the discharge of fill into approximately 220 acres of waters of the U.S. The actual footprint of the dam and spillway structure would be 164 acres with the total amount of above-grade fill estimated at 3.6 million cubic yards. The proposed dam would be an earth fill structure with an impervious clay core and cutoff, a bentonite slurry trench approximately 40 to 100 feet deep to control seepage under the dam, and soil cement to control erosion on the upstream face of the dam. The applicant has indicated that large quantities of clay suitable for the core and sand suitable for the soil cement are likely present within two miles of the dam at a location proposed to be impounded. Portions of the reservoir footprint including the borrow area would be cleared, but in most areas, trees would be left standing to provide additional habitat for fish and other aquatic life. Concrete would also be used for some of the structural features of the dam, including the service spillway and the outlet works.

The outlet works for Lake Columbia would likely consist of a vertical intake tower located within the reservoir near the toe of the dam, a conduit through or below the base of the embankment, and control valves. The intake tower would have selective withdrawal capabilities to facilitate the release of water from near the surface, at mid-depth, or near the bottom, depending on lake level. The service spillway for the dam would be an uncontrolled overflow structure 200 feet wide constructed in a cut through the left (east) abutment. It would have vertical reinforced concrete sidewalls and a concrete ogee section, with a stilling basin downstream. Approach and outlet channels would be excavated through the abutment with sloping sides and protected with a combination of soil-cement and grass. Floods up to the 50-year event would pass through the service spillway. The emergency spillway, which would pass larger flood flows up to the probable maximum flood, would be a grassed earth channel 1100 feet wide excavated through the right abutment. The side slopes may be protected with soil cement. An 8-foot deep concrete cutoff wall at the crest is planned for a control section.

Construction would also include access roads, equipment staging areas, and borrow areas. Borrow areas would be located in the reservoir pool upstream of the dam. The total cost of reservoir construction is approximately $191 million in 2006 dollars (not including mitigation).

The applicant currently owns State Permit No. 4228, which authorizes ANRA to divert and use 85,507 acre-feet of water per year from Lake Columbia, should it be constructed. The firm yield of the reservoir has been estimated at 75,700 acre-feet per year using the February 2005 version of the Texas Commission on Environmental Quality (TCEQ) Neches Water Availability Model (WAM) under the assumption of no upstream return flows (SPI, 2006). When upstream return flows are included, the full 85,507 acre-feet per year of authorized diversion is available as a firm supply (FNI, 2005a). The lake would contain 195,500 acre-feet of water at the conservation pool elevation of 315 feet NGVD.

The 100-year flood would rise to an elevation of 322.59 feet NGVD. The probable maximum flood (PMF), an extreme event used for dam design, would reach an elevation of 334.08 feet NGVD (FNI, 2007c).

1.3 REGULATORY AUTHORITY

This document fulfills the requirements of Section 404(b)(1) of the Clean Water Act (CWA). The purpose of this analysis is to identify and evaluate practicable alternatives as defined in 33 Code of Federal Regulations (CFR) 230.3 that minimize the impacts to the aquatic resource. The Section 404(b)(1) guidelines are the substantive criteria with which discharges must comply before a Section 404 permit may be issued by the USACE. These guidelines have been developed by the US Environmental Protection Agency (USEPA) in coordination with the USACE.

The fundamental precept of the guidelines is that discharges of dredged or fill material into waters of the US, including wetlands, should not occur unless it can be demonstrated that such discharges, either individually or cumulatively, will not result in unacceptable adverse effects on the aquatic ecosystem. Discharge of dredged or fill material from the proposed project must comply with restrictions set forth in the guidelines. These restrictions include the following:

1. No discharge of dredged or fill material shall be permitted if there is a practicable alternative to the proposed discharge which would have less adverse impact on the aquatic ecosystem, so long as the alternative does not have other significant environmental consequences.
2. Discharge is not permitted if it causes or contributes to violation of applicable state water quality standards; violates toxic effluent standards; jeopardizes the continued existence of species listed under the Endangered Species Act of 1973; adversely affects designated critical habitat; or adversely affects any designated marine sanctuary under the Marine Protection, Research, and Sanctuaries Act of 1972.

3. Discharge is not permitted that would cause or contribute to significant degradation of the waters of the United States, including significant adverse effects on aquatic organisms and ecosystems.
4. No discharge of dredged or fill material shall be permitted unless appropriate and practicable steps have been taken that will minimize potential adverse impacts of the discharge on the aquatic ecosystem.

These restrictions provide the general basis for the subsequent sections of the Section 404(b)(1) analysis.

1.4 PRACTICABILITY

Pursuant to Section 404(b)(1) of the CWA, the USACE defines practicable alternatives as those that are "available and capable of being done after taking into consideration cost, existing technology, and logistics in light of overall project purposes" (*ibid*). ANRA has provided industry-specific information with regard to cost, existing technology, and logistics on which to base practicability criteria for the proposed project. The USACE has verified that information and developed practicability criteria against which the preferred project and the identified alternatives can be compared.

1.4.1 Cost

The cost of the project or any alternatives considered must be evaluated in terms of final cost of developed water to the users in the Five-County Area. In terms of practicability for a water supplier relating to cost, there is no single standardized upper limit for a regional multi-participant project at which point a new supply would become unaffordable based solely on cost. It relates more to which new supply is the most cost effective for the individual supplier. The criteria that would be used to evaluate the cost effective component is unique to each water supplier based on a number of factors ranging from geography to financial ability of the utility to obtain funding. Therefore, the least cost alternative is considered the most practicable from the standpoint of cost.

1.4.2 Existing Technology

Technological considerations include the ability to acquire water of sufficient quantities from sources other than the proposed reservoir, such as development of groundwater or transport of water from other existing reservoirs.

1.4.3 Logistics

Logistical considerations include the availability of other water sources, the quantity of other water sources, and the legal access to other sources.

1.4.4 Practicability Criteria

For purposes of this evaluation, an alternative will be considered practicable with regard to cost if it can deliver water to users in the Five-County Area at a rate comparable to or less than other available supply alternatives.

An alternative will be considered practicable with regard to technology if sufficient water to meet projected demands for the Five-County Area is available and is feasible to deliver to a central holding reservoir.

To be considered practicable from the standpoint of logistics, water rights for alternative sources must be capable of being acquired or there must be adequate supplies available for use to meet projected demand.

1.5 Alternatives Considered

The USACE has three alternatives available relative to its consideration of ANRA's application for an individual permit pursuant to Section 404 of the CWA: 1) issue the permit, 2) issue the permit with special conditions, or 3) deny the permit. Permit denial is referred to as the No-Action Alternative as describe below in Section 1.5.1.

ANRA considered a variety of alternatives during feasibility studies for Lake Columbia, including the No-Action Alternative. In addition, the USACE identified potential alternatives to Lake Columbia based on issues identified during the scoping process and evaluation. Alternatives to the proposed project are described below.

1.5.1 No-Action

Under the No-Action Alternative, the USACE would deny the Section 404 and Section 10 permit for this project. As a result, the proposed Lake Columbia reservoir would not be constructed, and the potential impacts to the natural or human environment indentified for the Proposed Action would not occur as a result of the project.

Implementation of the No-Action Alternative would not meet the defined purpose and need for the Project. However, the No-Action Alternative still must be addressed in the EIS process because a permit cannot be issued by the USACE if such issuance would be contrary to the public interest and would not comply with the Section 404(b)(1) guidelines. Also, the inclusion of the No-Action Alternative in this analysis is required under the provisions of NEPA (40 CFR 1502.14(d)), and it serves as a basis for comparison of the environmental impacts among alternatives.

The No-Action Alternative does not mean that there would be no impacts. The No-Action Alternative would mean that existing water resources would continue to be used, and expanded if possible. This would particularly apply to groundwater, as existing surface water supplies have little additional water available for future use. However, as discussed below, additional groundwater resources to meet projected needs are not widely available in the region. Expanded groundwater extraction could result in excessive aquifer drawdown. With the No-Action Alternative, some projected demand shortages in the Five-County Area would remain unsatisfied.

1.5.2 Alternatives Available to ANRA

In the early 1990s, ANRA initially conducted a comprehensive water planning study to identify potential water supply alternatives for the region (LAN, 1991a). All existing water supply reservoirs in the Sabine, Trinity, and Neches River Basins were evaluated for suitability to meet the projected water demands of the Five-County Area. In the Sabine and Trinity Basins, only Toledo Bend Reservoir had uncommitted water available. An alternative comprising a pipeline from Toledo Bend Reservoir to serve the Five-County Area is included in this EIS. In the Neches Basin, Lakes Sam Rayburn/B.A. Steinhagen and Palestine were the only lakes with significant supplies of uncommitted water. Expanded use of groundwater was also considered as a means to meet future demands. Various potential new reservoirs in addition to Lake Columbia were also evaluated in the LAN study. Of those, only Little Cypress Reservoir was considered; however, Little Cypress now is no longer being pursued.

The 2006 Region I Plan considered water conservation, wastewater reuse, expanded use of existing supplies including groundwater, and potential new reservoirs as water supply strategies for meeting future demands in the planning region. Lake Columbia was recommended as one of the water supply strategies (SPI, 2006). A number of alternative dam locations for Lake Columbia were also considered and are discussed below.

Toledo Bend Reservoir Pipeline

This alternative would involve construction of a large-diameter pressure pipeline approximately 86 miles in length extending from the upper part of Toledo Bend Reservoir on the Sabine River generally westward to a terminal reservoir located near the proposed Lake Columbia site in the Neches Basin. EPA (2003) performed an analysis of this alternative and determined that the pipeline would need to be 66 inches in diameter initially at Toledo Bend Reservoir and that it could decrease in size in the downstream direction to the terminal reservoir in the Neches Basin. The applicant provided additional information to the USACE indicating a 72-inch diameter pipeline would be required along the entire route, stating, “Moving from larger to smaller pipelines is not standard practice and would have impacts to the life cycle costs of the transmission system” (FNI, 2007b). The EPA analysis is contained in Appendix A of the EIS. Freese & Nichols’ analysis of this alternative is contained in Appendix B of the EIS. An intake structure and pump station would be required at Toledo Bend, and two booster pump stations would be necessary to convey water along the route (EPA, 2003). A terminal reservoir covering up to several hundred acres would be required at the receiving end of the pipeline (FNI, 2007b). The exact size and location of the intake, pumping stations, and the terminal reservoir have not been determined. The pipeline and associated facilities would be capable of delivering 85,507 acre-feet of Toledo Bend water per year to the Five-County Area. This delivery would be considered an inter-basin transfer of water (from the Sabine Basin to the Neches Basin) and would require special authorization from TCEQ and amendment of the water right permit. The cost of water from the Toledo Bend Pipeline alternative is estimated to be more than three times that of Lake Columbia; therefore, the use of Toledo Bend Reservoir as a source of supply for the Five-County Area is not considered practicable

The anticipated pipeline route would likely be located parallel to existing highways in most areas, although routes through several cities (Center, Timpson, Mount Enterprise, and Reklaw) are not described (EPA, 2003). The intake structure/pump station and approximately the first 13 miles of the pipeline route would be located in the Sabine National Forest. In addition, the EPA analysis considered clearing and land acquisition in right-of-way widths ranging from about 4 to 24 feet. For a line of this size, the right-of-way requirements are likely to be up to 100 feet in width for construction and 50 feet permanently (Stover, 2007). This could potentially result in the disturbance of over 1,000 acres for construction, with a permanent right-of-way of about 500 acres required over the entire pipeline route.

The pipeline would likely impact some sensitive areas including the 13 miles through the Sabine National Forest and numerous waters of the US. There would be numerous stream crossings, including major crossings at the Angelina River, Attoyac Bayou, and Stryker Creek and associated adjacent wetlands. Approximately one mile of the pipeline would traverse a U.S. Fish & Wildlife Service (USFWS) Priority One bottomland hardwood preservation area at the confluence of the Angelina River and Stryker Creek at the U.S. Highway 84 crossing (USFWS, 1985). This would impact approximately 12 acres of the Priority One area, considering a 100-foot construction right-of-way.

Under the Toledo Bend Pipeline alternative, streams, vegetation, wildlife, and aquatic communities along the 86-mile pipeline route, at the intake structure and pump station on Toledo Bend Reservoir, and in the vicinity of the terminal reservoir at the delivery point in the Neches Basin would potentially experience varying degrees of adverse impacts.

1.5.3 Alternatives Eliminated from Detailed Analysis

As part of the permit evaluation process, the applicant provided other alternatives considered but eliminated from further detail. The USACE has determined that elimination of these alternatives from further detail is reasonable. A summary of alternatives considered in the EIS process but eliminated from detailed analysis is presented below.

Expanded Use of Groundwater

Current TWDB studies indicate that although there is some additional groundwater available in certain locations within the Five-County Area, there is insufficient groundwater of suitable quality available to meet all projected water demand shortages. In some places, groundwater is already being over drafted. There are significant water needs for municipal uses and steam electric generation in the Five-County Area that cannot be met with groundwater.

Sam Rayburn Reservoir Flood Storage Reallocation

The available water supply from Sam Rayburn Reservoir, operated as a system in conjunction with B.A. Steinhagen Reservoir downstream, is already fully needed to meet the estimated future demands of the Lower Neches Valley Authority, the owner of the water rights for the reservoirs (SPI, 2006). However, the reallocation of flood control storage in the reservoir to conservation storage has been considered as a potential means for developing an additional water supply from Sam Rayburn Reservoir. This would require raising the normal lake level about a foot above the top of the existing conservation pool into the flood pool. A rise in lake level of this amount would result in more frequent inundation of the existing shoreline, including environmental features, structural facilities, and cultural resources and would likely require mitigation, replacement, relocation, and/or real estate acquisition. This modification would also result in disruptions to the use of existing shoreline facilities. As many as five marinas have operated on the reservoir; currently there are three active marinas (USACE, 2009). Additionally, adverse impacts would likely occur in conjunction with the inundation of high quality forested wetlands located in the upper end of the reservoir. There would also be potentially significant cultural resources impacts. As stated by the EPA (2003), “Most importantly, the quality of the habitat that would be inundated is higher than the quality of the habitat that would be destroyed through the creation of Lake Columbia.”

The most significant adverse impact associated with the reallocation of flood storage in Sam Rayburn Reservoir may be increased flood damage downstream along the Angelina and Neches Rivers. Flood control is the primary federal purpose for this reservoir.

Conveying water from Sam Rayburn to the Five-County Area also would require a 76-mile pipeline with associated intake and pumping facilities and a terminal reservoir. With the cost of water from the Toledo Bend Pipeline alternative being more than twice that of the proposed Lake Columbia, it is likely that delivering water to the Five-County Area from Sam Rayburn Reservoir would also be considerably more expensive. Finally, the reallocation of storage in the flood pool would require approval of the Corps of Engineers, a corresponding Act of Congress, and acquisition of a new state water right permit or amendment of the existing permit for the reservoir. For this multitude of reasons, the use of Sam Rayburn Reservoir as a potential supply for water in the Five-County Area is not considered to be a practicable alternative.

B.A. Steinhagen Reservoir

B.A. Steinhagen Reservoir is downstream of Sam Rayburn Reservoir and is operated in conjunction with Sam Rayburn as a water supply system for users in the lower Neches Basin. Much of the inflow to Steinhagen Reservoir originates as hydropower releases from Rayburn. Because of complicated water rights issues, the only uncommitted water available from B.A. Steinhagen would be that water released from Sam Rayburn, and it would require acquisition of a new state water right permit. It is estimated that approximately 130,000 acre-feet per year could be available through this alternative (SPI, 2006). However, to convey water from B.A. Steinhagen Reservoir to the Five-County Area would require a pipeline 134 miles long (compared to 86 miles for the Toledo Bend alternative), an intake structure and pump station on Steinhagen, five booster pump stations along the pipeline (LAN, 1991a) (compared to two booster pumps for the Toledo Bend alternative), and a terminal reservoir, similar to the Toledo Bend Pipeline alternative. Since the Toledo Bend Pipeline was the most costly alternative investigated, at more than three times the estimated cost of water from Lake Columbia, the use of B.A. Steinhagen Reservoir as a source of supply for the Five-County Area is expected to significantly exceed that cost and is not considered practicable.

Lake Palestine

Lake Palestine has a yield of approximately 238,000 acre-feet per year of which only about 5000 acre-feet/year is uncommitted (EPA, 2003). The major rights to water that are committed from Lake Palestine belong to the cities of Dallas, Tyler, and Palestine. While some of the committed water is currently unused, this unused water is not necessarily available for use in the Five-County Area since this would require a willing seller. The City of Dallas is the only entity with significant unused water from the reservoir, but Dallas intends to fully use its share of Lake Palestine water and is currently investigating the construction of a pipeline from the reservoir to the Dallas-Fort Worth metroplex. This is also the pipeline that Dallas would potentially use to convey water from Lake Columbia and other sources if such supplies were to be available. It is highly unlikely that Dallas would be willing to sell any of its Lake Palestine water and may even claim the remaining uncommitted water from the reservoir. Consequently, Lake Palestine is not considered to be a viable alternative for supplying water to the Five-County Area.

Alternative Dam Locations

During the water supply planning studies originally performed for ANRA (LAN, 1991a and b), alternative dam sites for the proposed Lake Columbia were also evaluated. Dam sites further upstream could potentially be impacted by a fault within the Mount Enterprise fault zone, or would have backed water up to the Tyler Lakes, and were therefore considered undesirable. Dam sites downstream could also be impacted by a similar fault. Downstream of Keys Creek, which is approximately one mile below the proposed dam site, potential water quality problems could occur in the associated reservoir because Keys Creek receives the effluent from the Jacksonville wastewater treatment plants. For these reasons, it was decided to place the Lake Columbia dam upstream of Keys Creek and between the Mount Enterprise faults (Boyd, 2009). The alternative dam locations were determined not to be practicable due to technical and logistical considerations.

1.6 General Description of Dredged or Fill Material

1.6.1 General Characteristics of Material

Native soils within the permit area have been presented in Section 4.3 and Table 4.3-2 of the Lake Columbia EIS. The Five-County Area is composed of coastal plain sediments that formed the parent material for the present soil associations. The major soils that exist in the region are listed in Table 4.3-1 of the EIS. Most soils in the area are characterized as loamy and sandy soils. Surface soils at the proposed Lake Columbia site are generally alluvial deposits as described in Section 4.2.1.2 of the EIS.

The Cherokee and Smith County soil surveys show numerous types of surface soils within the proposed dam and reservoir area. Generally, the soils are classified as terrace and floodplain soils consisting primarily of clay loam, but also fine sandy loam, and loamy fine sand (LAN, 1991a; USDA, 1959; NRCS, 2007). General uses of these soils are mostly wetlands, pasture, forest, and scrub/shrub.

1.6.2 Quantity of Material

The proposed dam, spillway, and construction areas would involve the discharge of approximately 672,000 cubic yards of fill material into approximately 220 acres of waters of the US. The actual footprint of the dam and spillway structure would be 164 acres. The total estimated amount of above-grade fill required for the dam is estimated to be 3.6 million cubic yards. The top of the dam would be at elevation 336 feet, or approximately 70 feet above the bottom of Mud Creek. The dam would be 6800 feet long.

1.6.3 Source of Material

Suitable borrow material would be obtained primarily from within the reservoir pool area. Exact locations of borrow pits are unknown, but construction materials are planned to be obtained entirely from the reservoir pool area, and these areas would ultimately be inundated by the reservoir.

1.7 Description of Proposed Discharge Site

The proposed Lake Columbia Discharge Site is located within the Interior Gulf Coastal Plain in the piney woods of East Texas. The inland portion of this region is characterized by gently rolling and sometimes hilly features that level off into virtually flat terrain towards the coastline. Lake Columbia lies within the hillier interior portion about 85 miles north-northwest of the Kisatchie Escarpment. This escarpment acts as a natural transition between the inland hills and the flatter coastland. Within East Texas, streams meandering toward the southeast have cut wide, shallow valleys. Floodplains occur 100 to 150 feet below the surrounding uplands and may be from one to ten miles wide.

Lake Columbia would be located on Mud Creek which lies in a broad, flat valley/floodplain flanked by rolling hills. The Mud Creek floodplain is typically about 1-1.5 miles wide. At the proposed dam site, the Mud Creek bottom elevation is approximately 270 feet (all elevations NGVD). To the east, hills rise steeply to elevations in the range of 400-450 feet. To the west, the terrain is more gently sloping, eventually rising to about 350-450 feet.

The bedrock formation exposed at the abutments of the proposed Lake Columbia dam site is the Queen City Sand of Eocene age, while the deposits in Mud Creek are alluvium. Soil borings conducted at the proposed discharge site indicated 18 to 28 feet of alluvium underlain by clays and sands of the Queen City formation. Large quantities of clay and random fill for construction of the dam are available in the reservoir area within about two miles of the dam (FNI, 2003a). The following descriptions are taken from the Geologic Atlas of Texas Palestine Sheet (Bureau of Economic Geology, 1968).

The alluvial deposits present in Mud Creek are described as:

> "*Clay, silt, and sand, organic matter abundant locally, includes point bar, natural levee, stream channel, backswamp, indistinct terrace, and perhaps some Deweyville deposits, as well as a few small inliers of Tertiary formations*."

The apparent terrace deposits in the alluvium at the discharge site are thought to be clays of the Queen City Sand at an elevation intermediate between the floodplains and the uplands.

Faults roughly paralleling the dam alignment are located approximately three quarters of a mile downstream and two miles upstream of the discharge site and are part of the Mount Enterprise Fault System. The downstream fault reportedly dips to the northwest and is downthrown to the northwest, whereas the upstream fault is downthrown to the southeast forming a graben, defined as a downthrown block of land bordered by parallel faults. The faults in this area are considered inactive (LAN, 1991a; FNI, 2003a; Jackson, 1982).

Salt domes occur in Jackson County, and a salt pillow is mapped immediately southeast of the dam site, but none were found within the immediate discharge site.

The dam for proposed Lake Columbia would be located on Mud Creek within Cherokee County, approximately five miles from the town of Jacksonville and approximately 16 stream miles upstream from the Angelina River. The USGS topographic map of this area shows two channels for Mud Creek at the proposed discharge site with marshy areas between the channels and near the edges of the valley. The area was heavily wooded in the past, however in recent years (since 1994), satellite images show that the discharge site has been logged and cleared and the channels straightened.

Mud Creek is classified as a fifth-order stream below its confluence with Prairie Creek in Smith County (just below the Tyler Lakes) and remains a fifth-order stream from there downstream to its confluence with the Angelina River. Mud Creek is a perennial stream from its confluence with the Angelina River to a point immediately upstream of its confluence with Prairie Creek in Smith County (TNRCC, 2000). Mud Creek experiences periodic low-flow conditions similar to other East Texas streams, and therefore water quality is as much a function of the quantity of flows coming in from contributing streams as the incoming quality of water. Further upstream from the tributaries are Lake Tyler and Lake Tyler East.

There is one streamflow gauging station on Mud Creek, USGS No. 08034500 (Mud Creek near Jacksonville), that has a period of record from 1939 to 1979 and 2001 to present. The drainage area of Mud Creek and its tributaries above this gage covers 376 square miles. The average mean daily flow for 1940 through 1979 is 258 cubic feet per second (cfs), and the median is 74 cfs. The minimum mean daily flow is 0 cfs and the maximum is 22,700 cfs.

Water quality in Mud Creek is considered to be generally good, with acceptable DO, and low levels of dissolved solids, nutrients, and metals, excluding iron and manganese, which are commonly elevated in East Texas streams. None of the parameters measured exceeded acceptable concentrations for surface water quality (LAN, 1991b). These data are consistent from 1990 to 2008, as they show the improvement in water quality since the mid 1970s, which is largely attributable to improvements in wastewater treatment plants.

2.0 FACTUAL DETERMINATIONS

2.1 PHYSICAL SUBSTRATE DETERMINATIONS

2.1.1 Substrate Elevation and Slope

This section relates to substrate elevation/slope within the area of fill placement. Existing wetlands and waters of the US would be inundated in the reservoir pool by water depths of less than 1 foot to greater than 40 feet. New wetlands would be expected to develop around portions of the perimeter of the reservoir at elevations generally above natural wetlands and waters of the US. The new wetlands would develop along protected shoreline areas with gentle slopes.

At the proposed dam site, the Mud Creek bottom elevation is approximately 270 feet (all elevations NGVD). To the east, hills rise steeply to elevations in the range of 400 to 450 feet. To the west, the terrain is more gently sloping, eventually rising to about 350 to 450 feet. The highest elevation in the proposed project area is Gill Mountain, 594 feet, which is approximately 2.5 miles northeast of the dam site. The top of the dam would be at an elevation of 336 feet, or approximately 70 feet above the bottom of Mud Creek.

2.1.2 Sediment Type

Describe current sediment/substrate Sediment types would gradually change within the reservoir pool due to accumulations of silts and organic materials on the floor of the reservoir.

2.1.3 Dredged/Fill Material Movement

The only significant movement of dredged or fill materials would be the mechanical transport of borrow materials for dam construction. Suitable clay materials are believed to exist within the reservoir footprint within 2 miles of the dam site. Those materials would be excavated and transported to the dam site for construction of the dam. The total estimated amount of above-grade fill required for the dam is estimated to be 3.6 million cubic yards.

2.1.4 Physical Effects on Benthos

Describe the effects associated with dam construction. The aquatic habitat available for invertebrates would be changed in the proposed reservoir pool from a primarily lotic (flowing water) to lentic (still water) habitat. In general, invertebrates that inhabit streams are adapted to make use of the available current as a source of food and dissolved oxygen while securing themselves to the substrate or other surface to avoid being swept away. Those that inhabit riffle zones normally require highly oxygenated water. Organisms that inhabit reservoirs do not usually require highly oxygenated waters. Some are surface dwellers such as whirligig beetles (Gyrinidae). Most, however, are limited to the limnetic zone and emergent plants found there.

Another expected change may be the available substrate. While the lotic depositional areas in a stream generally contain relatively high amounts of detritus and silt, under normal flows they are continually “flushed” by the current. This would not occur in an impoundment and would be limiting for some mussel species. Heavy mussels tend to sink in deep, soft silt. Additionally, most mussel species cannot tolerate overlying silt for more than a short period (Howells, Neck, and Murray, 1996). However, some unionid species, such as the little spectaclecase are known to occur in reservoirs.

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The proposed project would likely result in the establishment of a productive invertebrate community. However, it is anticipated the composition would be less diverse than in a flowing system because dynamic hydrologic conditions and microhabitats are typically lacking. The macroinvertebrate communities downstream of the impoundment should not change greatly, if adequate channel flows are maintained. The aquatic habitat available for invertebrates would be changed in the proposed reservoir pool from a primarily lotic (flowing water) to lentic (still water) habitat. In general, invertebrates that inhabit streams are adapted to make use of the available current as a source of food and dissolved oxygen while securing themselves to the substrate or other surface to avoid being swept away. Those that inhabit riffle zones normally require highly oxygenated water. Organisms that inhabit reservoirs do not usually require highly oxygenated water. Some are surface dwellers such as whirligig beetles (Gyrinidae). Most, however, are limited to the limnetic zone and emergent plants found there.

2.1.5 Other Effects

None anticipated.

2.1.6 Actions Taken to Minimize Impacts

During construction, a construction storm water discharge permit must be obtained and a Storm Water Pollution Prevention Plan prepared and implemented. This plan would require the establishment of best management practices to reduce the impact of soil disturbance and sediment delivery to surface waters that could impact the aquatic environment.

2.2 WATER CIRCULATION AND FLUCTUATION DETERMINATION

2.2.1 Water

Water Chemistry

The low-flow releases from the proposed Lake Columbia dam should provide generally improved water quality in Mud Creek below the dam during base flow conditions. Increased base flows help maintain dissolved oxygen levels, moderate temperatures, and reduce the severity of critical low flows with regard to impacts on aquatic organisms. Maintaining base flows is critical to sustaining a viable and productive aquatic ecosystem. Low base flows generally represent critical conditions for water quality and aquatic organisms.

Water temperatures in Mud Creek downstream of the proposed Lake Columbia may change because of the different temperature of the water released from the reservoir for downstream users. Water temperatures in reservoirs are known to vary spatially and vertically as they are influenced by atmospheric heating and cooling over long periods of time. Consequently, water released from the reservoir would directly affect water temperatures in Mud Creek below the dam, and temperatures may increase or decrease depending on the time of year and from what depth the water is released. Lake Columbia would have a selective withdrawal tower, and water could be released from near the surface, at mid-depth, or near the bottom, depending on lake level. A bottom release would result in relatively colder-than-normal water during the months of May to September. A surface release in those months could result in slightly warmer water downstream. With a maximum depth of about 50 feet, it is likely that Lake Columbia would be stratified during part of the year, and a thermocline (zone where temperature rapidly decreases with depth) could develop during the period from late spring until September, although it would likely only be in the deepest parts of the lake in late summer.

Existing water quality in Mud Creek is generally good, and good water quality would be expected in the proposed lake. However, when a reservoir is first filled, vegetation and organic material in the soil decompose and a release of nutrients and depletion of dissolved oxygen (DO) can occur. This is not a long-term problem because once that material has decomposed, it exerts a lower demand on DO, and the release of nutrients is greatly reduced. The release of nutrients might result in some algal blooms after the reservoir fills, but this would likely decrease after one or two years, depending on inflows. And because the reservoir would not be particularly deep, approximately 50 feet maximum, mixing and re-aeration would occur through most of the water column, leaving only a small area of the impoundment in which depleted DO would occur at depth.

Temperature stratification within the reservoir would likely occur during most of the summer, as discussed above. With most lakes in Texas, there can be depressed or anoxic DO levels in the zone below the thermocline, known as the hypolimnion. Mixing and re-aeration do not occur in a strongly stratified lake in the hypolimnion. This creates a reducing environment, which can cause the release of odorous sulfides, nutrients (ammonia and phosphorus), and metals from the bottom sediments. In an effort to mitigate these potential conditions in Lake Columbia, a selective withdrawal tower would be constructed within the reservoir to allow releases for downstream users to be made from different depths within the reservoir. With a bottom release, the combination of low-DO water and the presence of these materials can have adverse water quality impacts downstream. With a release from the epilimnion (the zone above the thermocline), as proposed for Lake Columbia, these impacts would largely be avoided. Furthermore, since the maximum depth is only about 50 feet, the thermocline would be expected to reach near the bottom of the lake by late summer, which would reduce the duration of any such effects.

Studies have shown that the small increase in water temperature that occurs from releases of water from the epilimnion of impoundments is not detrimental to warm water stream fisheries in the southern US (Robinette, 1978). The study also indicates that water quality was not adversely affected when withdrawal of water was from the epilimnion, and that there may be some increase in biologic productivity because of the higher DO content of the released water. Other studies (USDA, 1979) have shown that benthic populations are much higher and species diversity was improved in streams downstream of impoundments. It was suggested that the moderation of flood flows and prolonged release may be responsible.

Clarity and Color

Turbidity is naturally high in many streams in East Texas, including Mud Creek. The release of clear water from the proposed lake would result in unnaturally clear water for some distance below the dam. Phillips (2001) investigated several sites in Lake Nacogdoches and Bayou Loco, a tributary of the Angelina River. This study area was in Nacogdoches County, which is in the same climatic and physiographic regions as Mud Creek and the proposed Lake Columbia. Because of the proximity and similarities between the sites, it is reasonable to expect similar results with regard to Lake Columbia and its impact on Mud Creek. For the Lake Nacogdoches/Bayou Loco study, sites were instrumented with nephelometer devices to measure turbidity. Although turbidity is influenced by biological factors as well as inorganic suspended solids and sediment loads, the close proximity of the sites to Mud Creek allows the assumption that variation in turbidity is a result of suspended solids. Results from the study show that at a site approximately 10 miles downstream from Lake Nacogdoches, turbidity levels were generally similar to those on Bayou Loco upstream of the lake. Based on these data, it is considered unlikely that the proposed Lake Columbia would cause appreciable impacts to downstream turbidity in Mud Creek for more than a few miles downstream. Dams and reservoirs are sediment traps, so it is likely that the turbidity of the proposed reservoir itself would be less than current instream turbidity.

Odor and Dissolved Gas Levels

The release of odorous sulfides, nutrients (ammonia and phosphorus), and metals from the bottom sediments is possible in a strongly stratified lake where mixing and re-aeration do not occur in the lakes hypolimnion. In an effort to mitigate these potential conditions in Lake Columbia, a selective withdrawal tower would be constructed within the reservoir to allow releases for downstream users to be made from different depths within the reservoir. With a bottom release, the combination of low-DO water and the presence of these materials can have adverse water quality impacts downstream. With a release from the epilimnion (the zone above the thermocline), as proposed for Lake Columbia, these impacts would largely be avoided. Furthermore, since the maximum depth is only about 50 feet, the thermocline would be expected to reach near the bottom of the lake by late summer, which would reduce the duration of any such effects.

Taste

The proposed reservoir project would have no appreciable effects on taste.

Nutrients

Lake Columbia would act as a trap for suspended nutrients carried by Mud Creek and its tributaries upstream of the dam. Some of these nutrients would be consumed by aquatic macrophytes and algae in the water column.

Eutrophication

Lake Columbia would also act as a trap for suspended sediment carried by Mud Creek and its tributaries upstream of the dam. This combined with accumulations of organic materials and nutrients washed into the reservoir from the surrounding watershed would contribute to eutrophication over time.

2.2.2 Current Patterns and Circulation

Current Patterns and Flow

There are numerous hydrologic effects caused by dams and reservoirs; however, the magnitude of these effects depends greatly on the type of stream, the surrounding environment, the type and size of dam and reservoir, and how they are operated. Some of the common effects are reflected by changes in downstream hydrology, morphology, and water quality. Upstream effects result from the conversion of the flowing stream within the body of the reservoir to a lake.

The Lake Columbia dam is not designed for flood control. Therefore, all inflows into Lake Columbia when the water surface elevation of the reservoir is at or above the conservation pool level of 315 feet NGVD would automatically spill downstream through the service and/or emergency spillways.

Stratification

Temperature stratification within the reservoir would likely occur during most of the summer, as discussed above. With most lakes in Texas, there can be depressed or anoxic DO levels in the zone below the thermocline, known as the hypolimnion. Mixing and re-aeration do not occur in a strongly stratified lake in the hypolimnion. This creates a reducing environment, which can cause the release of odorous sulfides, nutrients (ammonia and phosphorus), and metals from the bottom sediments. In an effort to mitigate these potential conditions in Lake Columbia, a selective withdrawal tower would be constructed within the reservoir to allow releases for downstream users to be made from different depths within the reservoir. With a bottom release, the combination of low-DO water and the presence of these materials can have adverse water quality impacts downstream. With a release from the epilimnion (the zone above the thermocline), as proposed for Lake Columbia, these impacts would largely be avoided. Furthermore, since the maximum depth is only about 50 feet, the thermocline would be expected to reach near the bottom of the lake by late summer, which would reduce the duration of any such effects.

Hydrologic Regime

Changes in the overall flow regime downstream of the dam have been predicted by Freese and Nichols based on the results of daily reservoir operation simulations using 1940-1996 historical data from the TCEQ Neches Basin Water Availability Model (WAM). These simulations assumed full withdrawal for water supply, continued upstream return flows of 9.99 mgd, no channel losses, and no releases made for downstream senior water rights. The median daily lake elevation for this scenario was 312.5 feet, or 2.5 feet below the top of the conservation pool. (FNI, 2005)

As expected, when compared to existing conditions without Lake Columbia in operation, flows in Mud Creek would be reduced with the proposed reservoir in place, not considering water supply releases and downstream return flows. Zero flow in Mud Creek would be expected approximately 80% of the time immediately below the dam, about 10% of the time below Keys Creek, and about 5% of the time at State Highway 110.

A median (50 percentile) base flow of about 25 cfs would be expected at the dam. The median flow would increase to approximately 39 cfs at Keys Creek with the additional inflows from the incremental drainage area and the 4.3 cfs of return flows from Jacksonville and correspondingly to about 51 cfs at State Highway 110. Existing median flows without Lake Columbia in place are approximately 80 cfs at the dam, 90 cfs at Keys Creek, and 102 cfs at State Highway 110. With

Lake Columbia in operation and delivering water to the downstream participants, low base flows would be increased over existing conditions, and there would essentially be no periods of zero flow in Mud Creek below the dam. There would be some changes in geomorphology related to the reduced flows and clear-water releases from the proposed lake.

2.2.3 Normal Water Level Fluctuations

The impoundment of stream flows within the reservoir and the capacity of the service and/or emergency spillways would cause the magnitude of peak flood flows to be reduced downstream, while the duration of flood events would likely be extended. Diversions from the reservoir also would affect flood flows. Because of the existing topography and stream geomorphology (shallow, braided channel and wide, flat, alluvial floodplain with abrupt side slopes) that characterize the downstream channel, there would continue to be some level of overbanking with the reservoir in operation, which is necessary to maintain connectivity of channels and wetlands within the floodplain. This would help to minimize the reduction in downstream floodplain width and area that would otherwise occur because of the effects of the dam and reservoir (FNI, 2005).

There would also be an 8% to 16% reduction in the floodplain area downstream of the dam for both frequent and less-frequent flood events. These reduced floodplain areas generally are confined to edges of the existing floodplain where the flat alluvial area intersects the abrupt side slopes that form the alluvial valley (FNI, 2005).

2.2.4 Salinity Gradients

Not applicable.

2.2.5 Actions That Would be Taken to Minimize Impacts

Prior to construction of the Lake Columbia dam and associated facilities, a construction storm water discharge permit must be obtained from the TCEQ, and a Storm Water Pollution Prevention Plan must be prepared and implemented during construction activities. This plan would require the establishment of best management practices to reduce the impact of soil disturbance and sediment delivery to surface waters.

In an effort to minimize overall project and associated development effects, ANRA has established Water Quality Regulations for Lake Columbia under its authority pursuant to Texas Senate Bill 1362 (2003) that are focused on protection of water quality as itemized below. As an additional measure to minimize adverse effects associated with lake related development, ANRA plans to purchase land around the proposed Lake Columbia up to an elevation of 318 feet NGVD. This purchase would be done in order to institute permitted use controls on its fee title land and would reduce potential adverse effects to 1,150 acres of land contiguous to the Permit Area. This measure would result in the establishment and enforcement of restrictions on 3,350 acres designed to minimize the potential for adverse effects associated with anticipated development. The average width of the area to be regulated is approximately 200 feet.

ANRA's Lake Columbia Water Quality Regulations are provided in Appendix D of the EIS. Key elements of the Water Quality Regulations are:

- No construction of pipelines and utility lines within Lake Columbia.
- Construction of or enlargement of existing Hazardous or Municipal Solid Waste facilities is prohibited within the Lake Columbia watershed, with exceptions for existing cities.
- Unapproved petroleum storage tanks with a capacity greater than 100 gallons are prohibited in the No Discharge Zone (2,000 feet from the lake).
- Forestry Best Management Practices (BMPs) are mandatory for all forestry activities in the No Discharge Zone. Forestry BMPs have been defined by the Texas Forest Service and are followed by the Texas forestry industry on a volunteer basis (TFS, 2004). BMPs refer to conservation practices that can be used to protect water quality from nonpoint source pollution during forestry (silvicultural) operations (TFS, 2009).
- Limits and controls are placed on on-site sewage facilities in the No Discharge Zone.
- Property owners are required to take action to prevent erosion from occurring on their property in the No Discharge Zone.
- Any construction between elevations 315 and 330 (Construction Regulated Zone) is restricted and must be approved by ANRA.
- Any shoreline property that is to be subdivided must contain a Shoreline Habitat Plan that states how the shoreline habitat will be maintain, restored and protected, with the means and methods of stabilizing the shoreline to prevent erosion identified. At least 60% of all shoreline within 50 feet of the elevation 315 level must be maintained in a natural condition.
- All development within the No Discharge Zone equal to or greater than one acre must comply with TCEQ TPDES General Permit No. TXR150000. All other development must control runoff and sedimentation.

ANRA would also implement an operational plan developed to ensure that releases would be made from the epilimnion (zone above the thermocline) at times when Lake Columbia is thermally stratified. Under this plan, impacts on downstream temperature and water quality as discussed above would be reduced and minimized. The releases should have no notable impact on water quality in the lake itself.

2.3 SUSPENDED PARTICULATE/TURBIDITY DETERMINATIONS

2.3.1 Expected Changes in Suspended Particulates and Turbidity Levels in the Vicinity of the Reservoir

Turbidity is naturally high in many streams in East Texas, including Mud Creek. The release of clear water from the proposed lake would result in unnaturally clear water for some distance below the dam. Phillips (2001) investigated several sites in Lake Nacogdoches and Bayou Loco, a tributary of the Angelina River. This study area was in Nacogdoches County, which is in the same climatic and physiographic regions as Mud Creek and the proposed Lake Columbia. Because of the proximity and similarities between the sites, it is reasonable to expect similar results with regard to Lake Columbia and its impact on Mud Creek. For the Lake Nacogdoches/Bayou Loco study, sites were instrumented with nephelometer devices to measure turbidity. Although turbidity is influenced by biological factors as well as inorganic suspended solids and sediment loads, the close proximity of the sites to Mud Creek allows the assumption that variation in turbidity is a result of suspended solids. Results from the study show that at a site approximately 10 miles downstream from Lake Nacogdoches, turbidity levels were generally similar to those on Bayou Loco upstream of the lake. Based on these data, it is considered unlikely that the proposed Lake Columbia would cause appreciable impacts to downstream turbidity in Mud Creek for more than a few miles downstream. Dams and reservoirs are sediment traps, so it is likely that the turbidity of the proposed reservoir itself would be less than current instream turbidity.

2.3.2 Effects on Chemical and Physical Properties of the Water Column

Light Penetration

As discussed under turbidity, it is likely that the reservoir will be less turbid and have greater water clarity that the natural stream, thus allowing greater light penetration.

Dissolved Oxygen

The low-flow releases from the proposed Lake Columbia dam as described in Section 4.5.2.2 of the EIS should provide generally improved water quality conditions below the dam during base flow conditions with higher dissolved oxygen and lower turbidity.

Toxic Metals and Organics

No toxic metals or organics are expected.

Pathogens

Treated wastewater discharges occur upstream and downstream of the proposed reservoir. The possibility for the occurrence of pathogens in the water column exists, but is generally expected to be minimal.

Aesthetics

During construction, the viewshed would be impacted by clearing for portions of the reservoir pool area, construction of the dam itself, and excavation from the borrow area. Since the area is sparsely populated, the main impact locations would be from highway bridges, such as U.S. 79; however, the dam site is 3 miles downstream from the bridge and the visual impact would be limited.

The largely forested floodplain would become a vast area of open water. The relative aesthetics of forest versus open water are subjective. The dam would be a permanent structure, although as above, access to view the dam itself would be somewhat limited.

2.3.3 Effects on Biota

Primary Production, Photosynthesis

Terrestrial primary production and photosynthesis of the densely vegetated landscape within the reservoir pool would be lost following inundation. However, photosynthesis by algae in the water column and macrophytes along the shore would contribute to primary productivity within the reservoir.

Suspension/Filter Feeders

The lotic depositional areas in a stream generally contain relatively high amounts of detritus and silt, under normal flows they are continually "flushed" by the current. This would not occur in an impoundment and would be limiting for some mussel species. Heavy mussels tend to sink in deep, soft silt. Additionally, most mussel species cannot tolerate overlying silt for more than a short period (Howells, Neck, and Murray, 1996). However, some unionid species, such as the little spectaclecase are known to occur in reservoirs.

Sight Feeders

Sight feeders would largely include fish species. Some stream fishes such as lamprey, pirate perch, and silversides that occur in reasonably small numbers and are often represented by a single species could be lost completely. The catfish and sucker families would likely lose some member species while others would remain. While no suckers are likely to be common, catfish species, particularly the channel catfish (*Ictalurus punctatus*) and the flathead (*Pylodictis olivaris*), would likely flourish, while the two madtom species that are stream adapted would decline. Topminnows, minnows, and darter species would likely be the most affected groups by the impoundment of stream habitat. These families are currently represented by numerous species in Mud Creek and would likely lose from 50% to 75% of their species due to impoundment.

The Texas Parks and Wildlife Department (TPWD) would develop and manage the fishery resources in the proposed Lake Columbia. Species and numbers of each stocked statewide that could be utilized in the proposed reservoir included the largemouth bass (*M. salmoides salmoides*), 162,310; the Florida largemouth bass (*M. salmoides floridanus*), 5,780,482; channel catfish, 873,490; bluegill (*L. macrochirus*), 417,585; white crappie (*Pomoxis annularis*), 856; threadfin shad (*D. petenense*) 900; and blue catfish (*I. furcatus*) 143,727. White bass (*Morone chrysops*) and gizzard shad (*D. cepedianum*) are other species that might be included.

2.3.4 Actions Taken to Minimize Impacts

ANRA has proposed to compensate for the impacts to the 5,746.5 acres of waters of the U.S. and other wildlife habitat within the Permit Area as detailed in its Compensatory Mitigation Plan (FNI, 2009b - see Appendix C of the EIS). The goal of the plan is to replace and/or restore aquatic functions and services in waters of the U.S. that are expected to be lost because of the development of the proposed Lake Columbia. ANRA proposes to provide mitigation through a combination of on-site compensatory mitigation (within the proposed reservoir footprint), near-site minimization of adverse impacts (land immediately surrounding the proposed reservoir and land within the upstream watershed and 100-year floodplain of Mud Creek downstream of the dam), and additional off-site compensatory mitigation. The on-site and near-site portions primarily involve minimization of impacts and habitat regulation through implementation of ANRA's adopted Water Quality Regulations (see Appendix D of the EIS), acquisition of land and easements, regulating the amount of reservoir footprint and shoreline that can be cleared and modified, and establishment of approximately 1,195 acres of fringe wetlands. The off-site portion involves replacing impacted waters of the U.S. with functionally equivalent land within the Neches Basin, primarily in the area of Big Thicket National Preserve, and with the purchase of mitigation bank credits, if necessary.

Measures to minimize overall adverse effects on surrounding lands include:

- Limiting timber harvesting and clearing to wetland enhancements.
- Eliminating livestock grazing.
- Limitations on public access and consumptive uses.
- Restoration of degraded forested wetlands.

- Preservation of intermittent streams and riparian buffers.
- Preservation of perennial streams and riparian buffers.

ANRA has received a financial commitment from the Texas Water Development Board (TWDB), which will loan funds for the purchase of land. ANRA's plan states that it would acquire suitable land that would directly compensate for the HGM-calculated loss of FCUs. The applicant believes the proposed mitigation plan would satisfy the goal of no overall net loss of wetland functions and would provide a significant benefit to public interests by assisting in the preservation of a national and internationally recognized ecosystem in the Neches Basin (FNI, 2003a; FNI, 2009b).

During construction, a construction storm water discharge permit must be obtained and a Storm Water Pollution Prevention Plan prepared and implemented. This plan would require the establishment of best management practices to reduce the impact of soil disturbance and sediment delivery to surface waters that could impact aquatic biology.

ANRA has adopted Water Quality Regulations for the proposed Lake Columbia. These regulations identify and define various water quality zones with prohibited activities and requirements on certain regulated activities to minimize impacts on water quality and aquatic habitat. ANRA's Lake Columbia Water Quality Regulations are attached in Appendix D of the EIS.

As discussed in Section 4.5 of the EIS, ANRA has stated that releases would be made from the epilimnion (zone above the thermocline) at times when Lake Columbia is thermally stratified. Under this policy, impacts on downstream temperature, water quality, and aquatic habitat would be reduced.

2.4 CONTAMINANT DETERMINATIONS

The material proposed for fill into waters of the US would not introduce, relocate, or increase contaminants in the material itself or in the aquatic environment at the proposed disposal site.

2.5 AQUATIC ECOSYSTEM AND ORGANISM DETERMINATIONS

2.5.1 Effects on Plankton

In general, the diversity and biomass of plankton in the water column would be expected to increase with the reservoir over the natural stream condition due to the greater volume of water and surface area, and generally greater water clarity.

2.5.2 Effects on Benthos

The aquatic habitat available for invertebrates would be changed in the proposed reservoir pool from a primarily lotic (flowing water) to lentic (still water) habitat. In general, invertebrates that inhabit streams are adapted to make use of the available current as a source of food and dissolved oxygen while securing themselves to the substrate or other surface to avoid being swept away. Those that inhabit riffle zones normally require highly oxygenated water. Organisms that inhabit reservoirs do not usually require highly oxygenated waters. Some are surface dwellers such as whirligig beetles (Gyrinidae). Most, however, are limited to the limnetic zone and emergent plants found there.

Another expected change may be the available substrate. While the lotic depositional areas in a stream generally contain relatively high amounts of detritus and silt, under normal flows they are continually "flushed" by the current. This would not occur in an impoundment and would be limiting for some mussel species. Heavy mussels tend to sink in deep, soft silt. Additionally, most mussel species cannot tolerate overlying silt for more than a short period (Howells, Neck, and Murray, 1996). However, some unionid species, such as the little spectaclecase are known to occur in reservoirs.

The reservoir habitat created can support a productive invertebrate community, although the composition tends to be less diverse than in a flowing system because dynamic hydrologic conditions and microhabitats are typically lacking. The macroinvertebrate communities downstream of the impoundment should not change greatly, if adequate channel flows are maintained.

2.5.3 Effects on Nekton

The inundation of Mud Creek would alter the biological community substantially over what exists at present. Stream species would largely be replaced by species that do well in, or at a minimum tolerate, reservoir habitat.

Eighty four fish species' ranges include the proposed reservoir area. The streams, ponds, and small lakes of the Mud Creek floodplain are likely to contain 69 of the possible 84 species. The other 15 species whose range is included in the reservoir footprint have been considered unlikely to occur due to habitat requirements that are not met by Mud Creek.

Overall, of the 69 species, 39 would likely remain while 30 species would likely be eliminated. Some stream fishes such as lamprey, pirate perch, and silversides that occur in reasonably small numbers and are often represented by a single species could be lost completely. The catfish and sucker families would likely lose some member species while others would remain. While no suckers are likely to be common, catfish species, particularly the channel catfish and the flathead (*Pylodictis olivaris*), would likely flourish, while the two madtom species that are stream adapted would decline. Topminnows, minnows, and darter species would likely be the most affected groups by the impoundment of stream habitat. These families are currently represented by numerous species in Mud Creek and would likely lose from 50% to 75% of their species due to impoundment. Those species predicted to remain are generally more tolerant of pond or lake conditions than those that would likely drop out. Minnows, mosquitofish (*Gambusia affinis*), topminnows, and sunfish species were the most abundant species in the TNRCC 1996 and 1999 studies of Mud Creek and associated tributaries.

Whereas the more diverse stream fishery consists of 69 species representing 17 families, the proposed reservoir is expected to contain approximately 30 species representing 14 families of fishes. Therefore, an expected reduction in species of 56.5% (34 species) would be anticipated. Of the 30 species likely to inhabit the reservoir, eight could be abundant, 20 would be common, six would be uncommon, and five would be restricted to shallow, vegetated portions of the proposed reservoir where they could be locally common. The abundant species would likely include the largemouth bass (*Micropterus salmoides*), channel catfish, green sunfish (*L. cyanellis*), bluegill, redear sunfish (*L. microlophus*), mosquitofish (*Gambusia affinis*), gizzard shad (*Dorosoma cepedianum*), and threadfin shad (*D. petenense*). Thirteen of the 30 species likely to occur in the reservoir are sunfish species, five are catfish species, and only six are minnow species. Whereas habitat diversity characterizes Mud Creek in the area of the reservoir, the aquatic habitat of the proposed reservoir would be less diverse and less dynamic as is typical of a lake with a controlled spillway. The majority of the fishes would occur in areas of greatest cover and forage. These areas would likely be within the first 5 to 10 feet of depth along the shoreline, which likely represents approximately 3040 acres (approximately 30%) of the 10,133-acre reservoir.

In areas of the reservoir where vegetation would not be cleared, the structure would provide additional cover for species such as bass and sunfish. Channel catfish and flathead catfish would occupy old stream channels, drop-offs, and bars. Due to the lack of topographic relief within the existing floodplain, the proposed lake bed would be relatively flat. Because the reservoir would have a relatively shallow average depth, some cover may be provided by aquatic plants or stumpage in water 15 to 18 feet deep.

The Texas Parks and Wildlife Department (TPWD) would develop and manage the fishery resources in the proposed Lake Columbia. The Inland Fisheries Division of TPWD is responsible for managing the fishery resources in approximately 800 public impoundments and about 191,000 miles of rivers and streams together, totaling 1.7 million acres. The proposed Project is located within TPWD Region III, specifically III C (TPWD, 2007). Some of the impoundments in Region III managed by TPWD include Lake Fork, Lake Athens, Lake Bob Sandlin, Gilmer Reservoir, Gladewater City Lake, Lake Jacksonville, Lake O' the Pines, Martin Creek Reservoir, Lake Murvaul, Lake Nacogdoches, Lake Palestine, Lake Quitman, Sam

Rayburn Reservoir, Lake Tawakoni, and Toledo Bend Reservoir. These impoundments range from approximately 1000 acres to over 100,000 acres. Reservoirs such as these are surveyed by TPWD every three to five years under the Statewide Freshwater Fisheries Monitoring and Management Program.

The TPWD establishes a fisheries management plan for each impoundment. For new impoundments such as the proposed project, this would likely include the stocking of fish species TPWD deems appropriate for the particular impoundment.

During 2006 the species and numbers of each stocked statewide that could be utilized in the proposed reservoir included the largemouth bass (*M. salmoides salmoides*), 162,310; the Florida largemouth bass (*M. salmoides floridanus*), 5,780,482; channel catfish, 873,490; bluegill, 417,585; white crappie (*Pomoxis annularis*), 856; threadfin shad (*D. petenense*) 900; and blue catfish (*I. furcatus*) 143,727. White bass (*Morone chrysops*) and gizzard shad (*D. cepedianum*) are other species that might be included. The above species are all listed as managed species in the East Texas reservoirs named above. Selection of specific species for stocking, in addition to stocking timeframe, would be dependent on management recommendations made annually by the TPWD scientists. In addition, the Lake Survey reports available for these impoundments for 2006 mention fisheries for black crappie (*P. nigromaculutus*), flathead catfish (*P. olivaris*), red ear sunfish (*L. microlophus*), redbreast sunfish (*L. auritus*), and palmetto bass (white bass [*M. chrysops*] X striped bass [*M. saxatilis*).

2.5.4 Effects on Aquatic Food Web

Species compositions of all trophic levels in the aquatic food web are likely to change at some level. Aquatic habitats would be changed in the proposed reservoir pool from a primarily lotic (flowing water) to lentic (still water) system. While changes would occur, the system would remain productive, but with less diversity.

2.5.5 Effects on Special Aquatic Sites

Sanctuaries and Refuges

The proposed project would have no effect on either sanctuaries or refuges.

Wetlands

Wetlands are landforms that provide habitat, food, and breeding grounds for birds, animals, and fish. They also help control floodwaters and serve important filtering functions. Within the permit area, approximately 5,351 acres of jurisdictional wetlands would be directly affected. Of the jurisdictional wetlands, 3,689 acres are bottomland forested wetlands, 1,518 acres are herbaceous wetlands, 144 acres are scrub-scrub wetlands, and 0.5 acres are hillside bog wetlands. Most of these wetlands would be converted to open water habitat. However, some wetlands would re-establish themselves along the reservoir's edge. ANRA has proposed to compensate for the impacts to the 5,746.5 acres of waters of the U.S. and other wildlife habitat within the Permit Area as detailed in its Compensatory Mitigation Plan (FNI, 2009b). The applicant believes the proposed mitigation plan would satisfy the goal of no overall net loss of wetland functions and would provide a significant benefit to public interests by assisting in the preservation of a national and internationally recognized ecosystem in the Neches Basin (FNI, 2003a; FNI, 2009b). This plan has been endorsed by the Big Thicket Association, The Conservation Fund, and The Nature Conservancy (BTA, 2007b). The Big Thicket Association has a strategic plan that identifies available high quality wetlands that meet or exceed the quality of lands that would be impacted by Lake Columbia, including bottomland tracts in the lower, middle, and upper Neches as some of the highest priority tracts (BTA, 2006, 2007a).

Riffle and Pool Complexes

Mud Creek contains a variety of habitats within its stream systems. These habitats include runs, riffles, and pools. Runs primarily include areas where flow is more noticeable compared to quiet bodies of water. Riffles are shallow, swift, sections of streams. Pools include long, slow-moving bodies of water or stagnated sections of water. Aquatic habitats would be changed in the proposed reservoir pool from a primarily lotic (flowing water) to lentic (still water) system.

2.5.6 Threatened and Endangered Species

Adverse effects to federally listed T/E species are not expected to occur as a result of construction of the proposed new reservoir. No federally or state listed T/E species have been encountered during permit area-specific investigations performed to date (LAN, 1991b, Hicks, 1994 and FNI, 2003).

2.5.7 Other Wildlife

Construction of the proposed dam and reservoir would eliminate approximately 10,655 acres of terrestrial habitat with the effect of displacing many terrestrial species of wildlife to similar habitats located beyond the permit area. Moreover, at normal water level, the construction of the proposed reservoir would also adversely affect approximately 14 miles of existing aquatic habitats along Mud Creek and its tributaries through inundation; thereby, converting existing stream habitat to reservoir (open water) habitat.

Species assemblages of terrestrial wildlife in habitats outside of the permit area may be adversely affected as a result of exceeding the current, pre-project carrying capacity of a given habitat, causing potential population shifts into marginal habitats. However, in the long-term, it is expected that these assemblages would again reach their natural equilibrium. An exception to this prediction would be the feral hog population, which is uncontrolled by natural means and is ever expanding. The displacement of feral hogs occurring within the permit area to outlying areas could possibly result in a long-term adverse effect on existing wildlife habitat (and agricultural interests) in the immediate region of the proposed Project.

Wildlife habitat (and related vegetational communities) outside of the permit area would likely experience indirect adverse effects from the presence of the proposed new reservoir. As stated above, species assemblages of terrestrial wildlife in habitats outside of the permit area may be adversely affected as a result of exceeding the current, pre-project carrying capacity of a given habitat, particularly with respect to feral hogs.

Based on development patterns observed at other East Texas reservoirs, the new reservoir would also attract various levels of residential and commercial development and recreational areas such as parks along its shoreline and/or immediate proximity. Local benefits of non-consumptive uses (e.g., photographing wildlife, birding, etc.) are expected to greatly increase along with increased public access to the permit area brought about by the existence of the proposed reservoir.

2.5.8 Actions to Minimize Impacts

ANRA has proposed to compensate for the impacts to the 5,746.5 acres of waters of the U.S. and other wildlife habitat within the Permit Area as detailed in its Compensatory Mitigation Plan (FNI, 2009b - see Appendix C of the EIS). The goal of the plan is to replace and/or restore aquatic functions and services in waters of the U.S. that are expected to be lost because of the development of the proposed Lake Columbia. ANRA proposes to provide mitigation through a combination of on-site compensatory mitigation (within the proposed reservoir footprint), near-site minimization of adverse impacts (land immediately surrounding the proposed reservoir and land within the upstream watershed and 100-year floodplain of Mud Creek downstream of the dam), and additional off-site compensatory mitigation. The on-site and near-site portions primarily involve minimization of impacts and habitat regulation through implementation of ANRA's adopted Water Quality Regulations (see Appendix D of the EIS), acquisition of land and easements, regulating the amount of reservoir footprint and shoreline that can be cleared and modified, and establishment of approximately 1,195 acres of fringe wetlands. The off-site portion involves replacing impacted waters of the U.S. with functionally equivalent land within the Neches Basin, primarily in the area of Big Thicket National Preserve, and with the purchase of mitigation bank credits, if necessary.

Measures to minimize overall adverse effects on surrounding lands include:

- Limiting timber harvesting and clearing to wetland enhancements.
- Eliminating livestock grazing.
- Limitations on public access and consumptive uses.
- Restoration of degraded forested wetlands.

- Preservation of intermittent streams and riparian buffers.
- Preservation of perennial streams and riparian buffers.

ANRA has received a financial commitment from the Texas Water Development Board (TWDB), which will loan funds for the purchase of land. ANRA's plan states that it would acquire suitable land that would directly compensate for the HGM-calculated loss of FCUs. The applicant believes the proposed mitigation plan would satisfy the goal of no overall net loss of wetland functions and would provide a significant benefit to public interests by assisting in the preservation of a national and internationally recognized ecosystem in the Neches Basin (FNI, 2003a; FNI, 2009b).

2.6 PROPOSED DISPOSAL SITE DETERMINATIONS

2.6.1 Mixing Zone Determination

Impacts would occur to those wetlands and other waters of the US that would be displaced by the proposed dam. A complete loss of functions for those aquatic resources would be experienced.

2.6.2 Determination of Compliance with Applicable Water Quality Standards

The project would not result in a violation of current applicable water quality standards for the State of Texas.

2.6.3 Potential Effects on Human Use Characteristics

Municipal and Private Water Supply

The project would not adversely affect any municipal or private water supplies. The project would add future yield to meet anticipated demand for water supplies in the Five-County Area.

Recreational and Commercial Fisheries

There are currently limited opportunities for recreational fisheries, as the current project area consists of privately owned land, recreational fishing would be limited to private landowners and their guests along Mud Creek. The proposed Lake Columbia would establish extensive areas of fish habitat and would likely develop into a quality resource for recreational fishing.

Water-Related Recreation

Land identified for the proposed Lake Columbia is currently privately owned small to medium sized streams, ponds, and wetlands with limited water-related recreational opportunities.. The majority of water-related recreational opportunities would be limited to private use of Mud Creek for hiking, fishing, and kayaking under favorable flow conditions. However, the proposed reservoir would provide opportunities for water sports, including boating, fishing, swimming, camping, hiking, bird watching, and other outdoor activities that would become available to the public. Estimated data relative to lake visitation are shown in Table 4.10-23 of the EIS.

Aesthetics

During construction, the viewshed would be impacted by clearing for portions of the reservoir pool area, construction of the dam itself, and excavation from the borrow area. Since the area is sparsely populated, the main impact locations would be from highway bridges, such as US 79; however, the dam site is 3 miles downstream from the bridge and the visual impact would be limited.

After construction, the largely forested floodplain would become a vast area of open water. The relative aesthetics of forest versus open water are subjective. The dam would be a permanent structure, although as above, access to view the dam itself would be somewhat limited.

Parks, National and Historical Monuments, National Seashores, Wilderness Areas, Research Sites, and Similar Preserves

The proposed project would have no effect on national and historical monuments, national seashores, wilderness areas, research sites, or similar preserves.

2.7 DETERMINATION OF CUMULATIVE EFFECTS ON THE AQUATIC ECOSYSTEM

The affected environment for aquatic biology is primarily focused on the Permit Area. Several types of studies have been conducted in this area, and they are briefly summarized herein in terms of aquatic habitat, fish and benthos, and macroinvertebrates. Relative to habitat, the Permit Area contains 70 linear miles (255 acres) of perennial stream, 39 linear miles (47 acres) of intermittent streams, 3 linear miles (30 acres) of channelized Mud Creek, and 63 acres of open water (ponds and oxbows). These data apply within an upstream distance of about 14 miles from the proposed dam site; thus, it can be noted that Mud Creek is highly meandering in the Permit Area.

Several Use-Attainability Analysis (UAA) studies have been conducted to determine various habitat data and water quality conditions. Such studies by the TCEQ and its precursor agency, the TNRCC, are conducted on water bodies for which aquatic life uses and DO criteria have been or will be established. To date, UAA studies have been conducted on Mud Creek and several tributaries. The following habitat data and rankings were found in Mud Creek at the U.S. Highway 79 crossing: aquatic life use rank – high, habitat quality rank – intermediate, substrate – silt, flow at sampling – 20.9 cfs, DO – 5.6 mg/L, average water depth – 2.5 feet, maximum water depth – 3.3 feet, average stream width – 36 feet, and length of creek sampled – 1,108 feet. In general, this location indicated good conditions for aquatic life and seasonable water quality. At this location Mud Creek is a perennial stream with an estimated 7-day, 2-year low flow (7Q2) of 5.1 cfs (over the time period from 1960 to 1979).

Several historical studies of fish species in the Permit Area have also been conducted. It has been determined that at least 84 species of fish have habitat ranges that include the Permit Area. Four studies conducted from 1988 to 1999 actually collected 46 fish species. In UAA studies of Mud Creek at US 79 in 1996 and 1999, 139 fish comprising 24 species were collected. Downstream on Mud Creek at State Highway 110, 317 fish representing 21 species were found. These data indicate good fish diversity both within and downstream of the Permit Area. These fish communities compare favorably with the findings from other UAA studies in the Neches River Basin.

In 1987, aquatic invertebrate studies were also conducted in two tributaries of Mud Creek, and the results are applicable to Mud Creek itself. Specifically, the findings indicated that Mud Creek could be expected to include a variety of crustaceans, mollusks, segmented worms, and insects.

There are no known commercially important fish species in the Permit Area; however, recreationally important game fish include channel catfish, largemouth bass, and sunfish. Finally, a list of 32 invasive fish species from the TPWD was considered for relevance to the Permit Area. Following consideration of their habitat requirements, it was determined that the probability of their introduction to Lake Columbia was very low, as was their likelihood of survival.

The construction phase of the Proposed Action would lead to the inundation of the Permit Area. Within this area are 5,746.5 acres of waters of the US, including 5351.5 acres of wetlands. Operation of the Proposed Action would involve a 10,133-acre lake on Mud Creek rather than the meandering stream prior to construction. The resultant aquatic biological community would be changed from a flowing system to an impounded one. A review of surveys of pre-impoundment fish species, and further consideration of species which are associated with reservoirs have resulted in a potential list of 69 possible species in the lake. Of these 69 species, further evaluation indicated that 39 would likely remain in Lake Columbia. Some changes in fish species assemblages are also anticipated. For example, the stream fishery had 69 species representing 17 families, while the lake fishery is projected to include 30 species representing 14 families.

Invertebrates in the Permit Area would also be impacted by both construction and operation. The basic effects would be associated with the aquatic habitat changing from a flowing system to an impounded system. Invertebrate communities can adapt to such changes; however, the reservoir community is expected to be less diverse because dynamic flow conditions are dampened.

Several continuing actions are anticipated to affect aquatic biology within the proposed lake. Such effects could result from direct changes to surface water quality which in turn affect aquatic habitat, fish, benthos, and macroinvertebrates. These contributing actions that affect both surface water quality and aquatic biology include wastewater treatment plant discharges, agricultural lands, and timber production via logging operations. These three actions are located in both the upper and downstream Mud Creek watersheds. Agricultural lands and timber production are listed as causing moderate relative contributions to effects on surface-water quality and aquatic biology. Wastewater treatment plant discharges have low relative contributions.

Future actions could also contribute to surface water quality impacts and to effects on aquatic biology. Three future actions, in addition to the three continuing actions above, could also contribute to cumulative effects. The future actions include development and use of public access areas and marinas along the Lake Columbia shoreline, recreational usage of the proposed Lake Columbia and its environs, and shoreline developments around the proposed Lake Columbia. Recreational usage of the Lake and its environs would be expected to have moderate relative contributions to cumulative effects on aquatic biology in the Permit Area and Shoreline Development Area. The other two future actions would be expected to have low relative contributions.

Three future actions also would be expected to yield beneficial effects on surface water quality and/or aquatic biology. The first one entails ANRA regulation of recreational and commercial activities on and surrounding the proposed Lake Columbia. This action, which involves land use controls, is part of the program associated with Lake Columbia Water Quality Regulations (Appendix D of the EIS). The second future action involves a fisheries management plan to be prepared by the TPWD. This plan includes fish stocking, periodic monitoring, and various efforts to promote diverse and sustainable fish populations in Lake Columbia. The third action involves ANRA’s Compensatory Mitigation Plan (Appendix C of the EIS). This plan includes mitigation and improvement elements that are related to aquatic biology.

Operation of the Lake Columbia project would also be expected to alter the aquatic biological conditions in the downstream portion of the Mud Creek Watershed. Alterations in the volume, frequency, duration, and timing of downstream flows would occur. Further, the size of the downstream floodplain area would be reduced. It is anticipated that these changed conditions would also influence downstream aquatic habitats, fish and benthos, and invertebrates. However, there are many uncertainties in such effects.

Finally, quantitative information on cumulative effects on aquatic biology in the Permit Area and the downstream Mud Creek watershed is not available and not predictable. Such information is needed for both the levels of effects and their significance determinations, as well as for establishing the relative contributions of other continuing and future actions and the Proposed

Action. Accordingly, ANRA would develop a focused monitoring program to establish these levels and contributions. This program should coincide with earlier monitoring programs for soil erosion and land usage in the Permit Area, Shoreline Development Area, and upper Mud Creek watershed; and for surface-water hydrology and quality in the Permit Area and the downstream Mud Creek watershed.

2.8 DETERMINATION OF SECONDARY EFFECTS ON THE AQUATIC ECOSYSTEM

2.8.1 Downstream Floodplain Effects

Secondary effects would occur downstream of the proposed reservoir. The most recent review of the effects of the proposed reservoir on flow was the Freese and Nichols, Inc. 2005 study that addressed the potential downstream area of effect in the Mud Creek floodplain based upon expected reservoir operation conditions (FNI, 2005). Their study area included the entire existing 100-year floodplain from the proposed dam site to the confluence of Mud Creek with the Angelina River (see Figure 1.1-1 in the EIS). The study included computer simulations of proposed reservoir operation and hydraulic and hydrologic modeling to compare with and without reservoir scenarios. Based on USACE evaluation of this study, the conclusions appear to be reasonable and relevant to predicting impacts. The study was intended to define the geographic boundaries of the two scenarios to determine areas of potential impact. The study provides an extensive set of conclusions. The conclusions regarding the volume and extent of floodplain flooding are recounted below:

1. "The area of potentially affected floodplain is relatively small (17% or less of the existing, downstream floodplain area) for both frequent (i.e., 2-year and 5-year) and less-frequent (i.e., 10-, 25-, and 100-year) flood events based on the results of simulated reservoir operation scenarios assuming full withdrawal for water supply."

2. "The Mud Creek floodplain is broad and flat with abrupt side slopes in many places along its margin. This topography tends to minimize the reduction in downstream floodplain width and area that might occur due to the Lake Columbia dam."

3. "The passive nature of the operation of Lake Columbia dam, with its uncontrolled service and emergency spillways, would allow normal inflows to pass through the reservoir when its water surface elevation is at or above the normal pool level of 315 feet msl."

4. "The Loco Bayou site downstream of Lake Nacogdoches studied by Phillips (2001) is approximately 30 miles southeast of the Lake Columbia study area. The proposed Lake Columbia is similar to Lake Nacogdoches in that both are water supply reservoirs, they have uncontrolled service spillways, they occur in the same climatic and physiographic regions; and both are situated on alluvial tributaries of the Angelina River. Because of

their proximity and similarities, it is expected that the observable downstream impacts of Lake Columbia on Mud Creek channel or floodplain morphology would be limited to a relatively short distance."

5. "The predicted incremental reductions in width of the floodplain for the various flood profiles modeled are not expected to result in a detectable change in forest species composition in the foreseeable future. The change likely would be imperceptible over decades and likely would not affect any forest stands beyond the 100-year floodplain. If there is an effect, it would probably occur as a long-term shift to the next drier species assemblage at the edge of the floodplain."

6. "Because no measurable effect on forest species composition is expected within the limits of the 100-year floodplain due to the Lake Columbia dam, no adverse impacts are expected on the U.S. Fish and Wildlife Service (1985) proposed Priority One Bottomland Hardwood site on Mud Creek downstream from the dam."

7. "Hydraulic modeling results indicated that the downstream floodplain area for any given flood event is not overly sensitive to the starting water surface elevation in Lake Columbia."

8. "Using the hydric soils within the 100-year floodplain as an indicator of the extent of wetlands, a maximum of 72% of the area (7,187 acres) may be wetlands. … The non-hydric soils, which would indicate non-wetland areas, cover the remaining 28% (2,807 acres) of the floodplain. The non-hydric areas … are more prevalent along the right side of the floodplain (facing downstream), which is consistent with the wider floodplain difference between existing and future floodplains on the right side...."

9. "Assuming that wetlands correlate to the hydric soils within the Mud Creek floodplain, wetlands could occur as far out as the edge of the 100-year floodplain along much of the downstream study area. Local conditions such as precipitation or drainage from upland slopes controls wetland hydrology in the Mud Creek floodplain rather than flooding, because such infrequent flooding would not be adequate to sustain wetlands. Therefore, the Lake Columbia dam likely would have negligible impact on wetland hydrology in the downstream corridor."

The above general conclusions Nos. 5 and 6 reached by FNI (2005) regarding minimal expected changes or adverse effects to downstream bottomland hardwood forests are reasonable since vegetative communities, particularly wetlands, that exist near the outer edges of floodplains are not dependent on the infrequent overbanking hydrology associated with the stream. The frequency of occurrence and duration of overbanking events in the outer edges of the floodplain

(2- to 100-year event elevations) are not in themselves sufficient to support hydric plant communities that generally require inundation or saturation at frequencies less than one year. Other hydrologic support mechanisms, such as shallow groundwater, runoff from adjacent higher areas, ponding because of flat or depressed topography, and direct precipitation (the area receives approximately 45 inches of rain per year) become increasingly of greater importance to maintain hydric plant communities with higher topographic position in the floodplain where advective (stream) hydrology has less influence. This is in contrast to the more immediate effects expected in water-scarce semi-arid or sub-arctic regions where flood hydrology is typically more important (Nilsson and Berggren, 2000). While overbanking floods can provide new sediment enrichment, nutrients, and seed dispersal that help maintain the vigor and species composition of hydric plant communities, even those benefits are of diminishing importance in the higher elevations of the floodplain.

With regard to the USFWS (1985) proposed Mud Creek priority 1 bottomland hardwood site (Conclusion No. 6), a large portion of that site extends beyond the 100-year floodplain of Mud Creek, which should preclude any measurable impacts caused by Lake Columbia in those portions of the site, and indicates hydrologic support from other sources, as discussed above. It is also located approximately 15 river miles downstream of the proposed dam just above the confluence of Mud Creek and the Angelina River where floodplain impacts would be reduced. The USFWS identified the dominant forest species as overcup oak (*Quercus lyrata*) (obligate wetland species), willow oak (facultative wetland species), green ash (facultative wetland minus), and hackberry [sugarberry] (facultative species). According to the USFWS (1988) definition of wetland plant indicator categories, *obligate wetland* species are expected to occur more than 99% of the time under natural conditions in wetlands; *facultative wetland* species are expected to occur in wetlands between 67% and 99% of the time; and *facultative* species are expected to occur in wetlands between 34% and 66% of the time. In addition, the USFWS (1988) further clarifies that "many obligate wetland species occur in permanently or semi-permanently flooded wetlands, but a number of obligates also occur and some are restricted to wetlands which are only temporarily or seasonally flooded." This would be consistent with this site. Thus, none of these bottomland hardwood species are expected to occur or survive only in wetlands. Impacts on the established forest species at the fringe of the floodplain are not expected.

Baseline and with-project hydrologic information for the area below the proposed reservoir are presented in Section 4.5 of the EIS. As identified in that section, data from the USGS gauging station at US 79 near Jacksonville indicate that the median flow in Mud Creek for the period of record was 74 cfs with a minimum mean daily flow of 0 cfs and a maximum of 22,700 cfs. Flow duration curves are presented at the US 79 gage and at three locations downstream of the dam site.

ANRA has indicated that four reservoir participants (Nacogdoches, Caro WSC, Temple-Inland, and Alto) would receive their water through downstream releases. Their share constitutes 21% of the reservoir yield, 17,956.5 acre-feet/year or 24.8 cfs on a continuous basis, and the Jacksonville WWTP currently permitted discharge is equal 4.3 cfs. ANRA has a contract with the City of Jacksonville to assure that the City's return flows will continue to be discharged in the future and not be retained for reuse. Therefore, the total of the permitted WWTP discharge and the releases to downstream users is 29.1 cfs. Additional inflows would also come from Coon and Keys Creeks, which enter Mud Creek near the proposed dam site, as well as other downstream tributaries.

Examination of data for a Mud Creek cross-section near US 79 indicates that overbanking occurs in this area at a flow of about 140 to 150 cfs. Under baseline flow conditions, flows of 140 to 150 cfs or greater would occur about 37% of the time, whereas with the reservoir this frequency would be about 17% in the immediate reach downstream of the dam, increasing to about 23% farther downstream. Therefore, based upon both studies, the floodplain area below the reservoir would continue to flood about half as frequently as without the dam, but would still continue to flood about 84% of the area formerly flooded. Furthermore, much of this floodplain area (approximately 1222 acres) that would experience reduced flooding is upland area rather than wetlands (FNI, 2005). FNI (2005) does not elaborate on what actual percentage of the area are wetlands.

2.8.2 Instream Flow Effects

In the Lake Eastex (Columbia) Planning Studies, Freese and Nichols, Inc. projected the effect on reservoir yield of upstream return flows and three levels of inflow bypasses (FNI, 2003a). Table 2.1 provides the results of these analyses for the 12 scenarios studied. In this table, return flows (in MGD – million gallons/day) represent potential discharges from wastewater plants located upstream of the proposed reservoir. The yields presented for each of the three return flow scenarios are for four potential bypass scenarios (Table 2.1): no intentional inflow bypass (No Bypass); and intentional inflow bypasses equal to 5 cfs; 10 cfs; and those corresponding to what is referred to as the Consensus Planning Criteria (CPC), as used by the TWDB for purposes of regional water supply planning. No flow values are assigned to the CPC bypass because they vary depending upon current hydrologic conditions as depicted by reservoir storage.

As expected, the worst-case scenario with regard to yield would be the zero return flow case. The FNI (2003a) conclusion was that bypassing inflows up to 5cfs or 10 cfs would augment local runoff, groundwater, and return flow contributions to the stream below the proposed reservoir while not substantially reducing the Project yield. However, the CPC bypass resulted in larger yield reductions.

Table 2.1: Reservoir Yield Under Various Upstream Return Flow and Bypass Scenarios

Return Flow (MGD)	Reservoir Yield (ac-ft/yr)			
	No Bypass	**up to 5 cfs**	**up to 10 cfs**	**Consensus**
9.99	91,040	87,360	83,690	76,270
4.66	85,090	81,415	78,600	71,285
0.00	79,880	77,600	75,420	67,600

Source: FNI, 2005

The CPC criteria were developed through collaboration among TWDB, TPWD, TCEQ and other scientists as a potential means for maintaining sufficient streamflows to support instream environmental uses. As discussed in the Texas Water Plan (TWDB, 2007a), the CPC criteria include median, first quartile, and 7-day, 2-year low (7Q2) flow values as bypass flow rates, depending on the reservoir storage level at the time of bypass. Application of these planning criteria resulted in bypass flow rates for the proposed reservoir that generally exceeded 10 cfs and reduced the reservoir yield substantially (see Table 2.1). For instance, the reservoir yield with no return flows or bypasses equals 79,880 acre-feet/year, which is 12,280 acre-feet/year more than the 67,600 acre-feet/year of yield for conditions with no return flows and the CPC bypass criteria in effect.

Based on this evaluation, it appears the reduction in yield at 10 cfs of inflow bypass is approximately 36% less than the yield corresponding to the CPC bypass. ANRA's current plan for reservoir operation presented above would be a continuous release of 24.8 cfs (17,956.5 acre-feet/year) to meet the demands of four reservoir participants downstream, assuming the participants were using their full amounts at a constant rate (TRC Brandes, 2007b). ANRA's operation plan would therefore release 5676 acre-feet/year more water than required by the CPC criteria. Since withdrawals of water released from Lake Columbia would occur for over 40 river miles downstream of the proposed dam, instream aquatic habitat along this reach would benefit from the consistent 24.8-cfs release.

The channel and floodplains at the USGS gage (US 79) are reasonably representative of the stream below the dam site based upon USGS maps and the survey data provided of the stream cross-section (TRC Brandes, 2007). At a flow of 29 cfs, the stream at US 79 is roughly 26 feet wide and 4.25 feet deep (the cross-section was actually surveyed at a gage reading of 33 cfs). The width and depth at 29 to 33 cfs is highly consistent with that described in the use attainability analysis (UAA) studies reviewed in Section 4.8.3.1 of the EIS. This width and depth of water is sufficient to support the fisheries and benthos populations described in the UAAs (TNRCC, 1996 and 1999). Another cross-section near State Highway 110 several miles downstream produced results consistent with this cross-section.

The releases and Jacksonville return flow levels occur 100% of the time. About 20 to 23% of the time the releases and return flows would provide higher flows than would naturally occur in the stream and prevent the flow from falling below 29 cfs down to zero as recorded historically. Eighty percent of the time Mud Creek historically would have had higher flows than with the reservoir present. About 40% of the time those flows would be in the range of 30 to 140 cfs and would result in more instream habitat. The major impact of the proposed reservoir on downstream flows is the reduction of flows capable of overbanking the stream. Flows at 140 cfs or greater create the diverse habitats found throughout the floodplain area of Mud Creek. Such flows, which historically occurred 37% of the time, would occur at a reduced rate ranging from 17% to 23% of the time. This reduction has a greater effect on the total amount of aquatic habitat downstream because of the overbanking and flood filling the slough, ponds, and oxbow areas of the floodplain.

Within the stream itself, the ANRA operating plan coupled with 4.3 cfs of return flows from the Jacksonville WWTP and additional local inflow from streams below the dam and spills from the reservoir would prevent the stream from going completely dry. While not fully offsetting the impact of the lower frequency of overbanking flows, the operating scenario would provide sustained flows during low flow periods and to some extent offset negative effects associated with lowered average streamflows. There should be sufficient aquatic habitat to provide protection for the fish and benthos populations within the stream channel areas; however, much of the adjacent flooded area habitat would be reduced perhaps significantly during dry years. In average flow years, spills from the reservoir would likely support the bulk of habitat adjacent to the stream channel.

3.0 PRELIMINARY DETERMINATION OF COMPLIANCE OR NON-COMPLIANCE WITH THE RESTRICTIONS OF DISCHARGE

The following paragraphs summarize the comparison of anticipated impacts from the proposed Lake Columbia project, as mitigated by ANRA's Compensatory Mitigation Plan (Appendix C of the EIS), with the specific regulatory criteria on restriction of discharge as listed in 40 CFR 230.10 and excerpted below.

No adaptations to the Section 404(B)(1) guidelines were made relative to this evaluation.

A. "Except as provided under Section 404(B)(2), no discharge of dredged or fill material shall be permitted if there is a practicable alternative to the proposed discharge which would have less adverse impact on the aquatic ecosystem, so long as the alternative does not have other significant adverse environmental consequences."

The proposed project is to provide a long-term economically viable source of water for the Five-County Area. A number of alternatives were evaluated, including the No-Action alternative. The various alternatives were found not to be practicable due to excessive cost and logistical issues. The No-Action Alternative is not practicable because it did not satisfy the purpose of the proposed project.

There are no practicable alternatives that would have less adverse impacts on the aquatic ecosystem.

B. *"No discharge of dredged or fill material shall be permitted if it:*

(1) Causes or contributes, after consideration of disposal site dilution and dispersion, to violations of any applicable State water quality standard."

The proposed disposal of fill material at the Lake Columbia project site would not violate any State water quality standards.

(2) Violates any applicable toxic effluent standard or prohibition under Section 307 of the CWA."

The proposed project would not violate the toxic effluent standards under Section 307 of the CWA.

(3) Jeopardizes the continued existence of species listed as endangered or threatened under the Endangered Species Act of 1973, as amended, or results in the likelihood of destruction or adverse modification of a habitat which is determined by the Secretary of the Interior or Commerce, as appropriate, to be a critical habitat under the Endangered Species Act of 1973, as amended."

The proposed project would not jeopardize endangered or threatened species or their critical habitat.

(4) "Violates any requirement imposed by the Secretary of Commerce to protect any marine sanctuary designated under Title III of the Marine Protection, Research, and Sanctuaries Act of 1972."

The proposed project will not impact any marine sanctuary.

C. *"Except as provided under Section 404(B)(2), no discharge of dredged or fill material shall be permitted which will cause or contribute to significant degradation of the waters of the United States."*

With the inclusion of mitigation measures proposed by ANRA as part of the proposed action, as presented as Appendix C of the EIS, the proposed action would not cause or contribute to significant degradation of the waters of the US. The proposed project would not discharge pollutants resulting in significant adverse effects on" (1) human health or welfare; (2) life stages of aquatic life and other wildlife dependent on aquatic ecosystems; (3) aquatic ecosystem diversity, productivity, and stability; and (4) recreational, aesthetic, and economic values.

D. *"Except as provided under Section 404(B)(2), no discharge of dredged or fill material shall be permitted unless appropriate and practicable steps have been taken which will minimize potential adverse impacts of the discharge on the aquatic ecosystem."*

Steps to minimize adverse impacts of the project on the aquatic ecosystem include Best Management Practices during construction, downstream releases of water, and the mitigation of unavoidable impacts as discussed in ANRA's proposed Compensatory Mitigation Plan in Appendix C of the EIS.

Conclusion

The discharge complies with the USACE guidelines, with the inclusion of ANRA's proposed mitigation measures and the appropriate and practicable conditions listed below to minimize pollution or adverse effects to the affected ecosystem.

3.1 ALL WETLAND LOSSES WOULD BE MITIGATED

ANRA has proposed to compensate for the impacts to the 5,746.5 acres of waters of the U.S. and other wildlife habitat within the Permit Area as detailed in its Compensatory Mitigation Plan (FNI, 2009b - see Appendix C of the EIS). The goal of the plan is to replace and/or restore aquatic functions and services in waters of the U.S. that are expected to be lost because of the development of the proposed Lake Columbia. ANRA proposes to provide mitigation through a combination of on-site compensatory mitigation (within the proposed reservoir footprint), near-site minimization of adverse impacts (land immediately surrounding the proposed reservoir and land within the upstream watershed and 100-year floodplain of Mud Creek downstream of the dam), and additional off-site compensatory mitigation. The on-site and near-site portions primarily involve minimization of impacts and habitat regulation through implementation of ANRA's adopted Water Quality Regulations (see Appendix D of the EIS), acquisition of land and easements, regulating the amount of reservoir footprint and shoreline that can be cleared and modified, and establishment of approximately 1,195 acres of fringe wetlands. The off-site portion involves replacing impacted waters of the U.S. with functionally equivalent land within the Neches Basin, primarily in the area of Big Thicket National Preserve, and with the purchase of mitigation bank credits, if necessary.

Measures to minimize overall adverse effects on surrounding lands include:

- Limiting timber harvesting and clearing to wetland enhancements.
- Eliminating livestock grazing.
- Limitations on public access and consumptive uses.
- Restoration of degraded forested wetlands.
- Preservation of intermittent streams and riparian buffers.
- Preservation of perennial streams and riparian buffers.

A Hydrogeomorphic Model (HGM) analysis has been performed for this EIS. An HGM analysis determines losses to the major wetland functions of the impacted waters and attempts to quantify such losses in terms of what is referred to as Functional Capacity Units (FCUs). This HGM process is described in detail in Section 4.5.2.2 of the EIS, and the resulting loss in FCUs because of the construction and operation of Lake Columbia are presented and quantified.

ANRA has received a financial commitment from the Texas Water Development Board (TWDB), which will loan funds for the purchase of land. ANRA's plan states that it would acquire suitable land that would directly compensate for the HGM-calculated loss of FCUs. The applicant believes the proposed mitigation plan would satisfy the goal of no overall net loss of wetland functions and would provide a significant benefit to public interests by assisting in the preservation of a national and internationally recognized ecosystem in the Neches Basin (FNI, 2003a; FNI, 2009b). This plan has been endorsed by the Big Thicket Association, The Conservation Fund, and The Nature Conservancy (BTA, 2007b). The Big Thicket Association has a strategic plan that identifies available high quality wetlands that meet or exceed the quality of lands that would be impacted by Lake Columbia, including bottomland tracts in the lower, middle, and upper Neches as some of the highest priority tracts (BTA, 2006, 2007a).

3.2 BEST MANAGEMENT PRACTICES

Best Management Practices would be implemented to limit erosion and reduce sediment transport as a result of storm water runoff from proposed project activities and disturbance areas.