3.4.7 Lower Bois d'Arc Creek Reservoir

3.4.7.1 Description

Lower Bois d'Arc Creek Reservoir is a proposed reservoir on Bois d'Arc Creek, a tributary of the Red River. Figure 3.4.7-1 shows the location of the project, which is in Fannin County in North-Central Texas. A reservoir at this site (then called the Bonham Reservoir) was included in the Red River Compact (Red River Compact Commission, 1979). The project has been studied previously for the Red River Authority and the North Texas Municipal Water District (Freese and Nichols, 1984 and 1996) and was recommended as a water supply for the North Texas Municipal Water District in the 2001 and 2006 Region C Water Plans (Freese and Nichols et al., 2001 and 2006a) and the 2002 and 2007 Texas State Water Plan (Texas Water Development Board, 2002 and 2006).

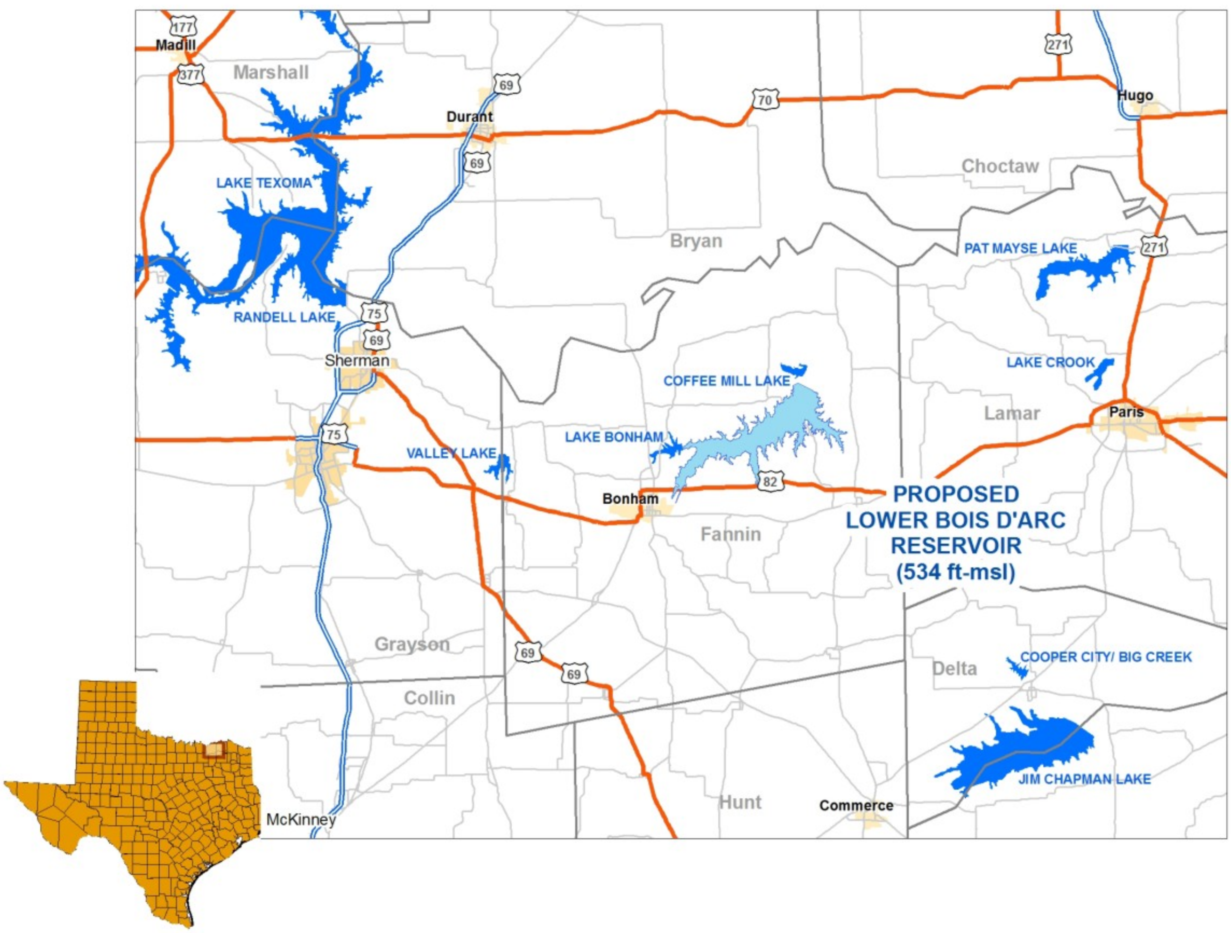

Figure 3.4.7-1. Location Map of Lower Bois d'Arc Creek Reservoir

Lower Bois d'Arc Creek Reservoir is recommended as a unique reservoir site in both the 2001 and 2006 Region C Water Plans. The reservoir is planned to provide water to the North Texas Municipal Water District, which serves water to customers over an eight-county area in north central Texas. The projected needs of the District for additional supply are 113,000 acft/yr in 2010, increasing to over 545,000 acft/yr by 2060 (Freese and Nichols et al, 2006a). The projected needs for additional water supply within 50 miles of the proposed reservoir site by 2060 are 728,028 acft/yr. The nearest major demand center is the Dallas-Fort Worth area, which is located approximately 60 miles southwest of the reservoir site.

3.4.7.2 Reservoir Yield Analysis

The reservoir area capacity data was developed from USGS topographic data and aerial photography that was flown in March 2004. The aerial photography provided 2-foot contour data at the reservoir site up to elevation 540 ft-msl. Table 3.4.7-1 shows the area-capacity-elevation (ACE) data for Lower Bois d'Arc Creek Reservoir. Figures 3.4.7-2 and 3.4.7-3 show the ACE curves and inundation at 10-foot contours.

The firm yields for Lower Bois d'Arc Creek Reservoir were performed using a modified version of the February 8, 2006 Red River WAM (Espey et al. 2002 and TCEQ 2006) Yields were calculated at elevations 530, 534, 536, and 538 ft-msl. The conservation elevation for the proposed reservoir is 534 ft-msl. The yield at this elevation is 126,280 acft/yr.

The hydrology at the Lower Bois d'Arc Creek dam site was calculated outside the WAM and input directly to the model. This adjustment was made because the original WAM underestimates the flows in the Bois d'Arc Creek watershed. From December 1962 to September 1985, the USGS operated the Bois d'Arc Creek near Randolph gage, which measured flows from about 22 percent of the proposed reservoir watershed. There were no known diversions or return flows above this gage, so the flows are representative of natural conditions. A recent study of the proposed reservoir compared these historical flows to naturalized flows in adjacent watersheds (Freese and Nichols, 2006b). This study concluded that naturalized flows in the Sulphur River Basin were probably a better estimator of flows in the Bois d'Arc Creek watershed than incremental flows in the main stem of the Red River, which is the default method used in the TCEQ Red River WAM. The study recommended adding a new primary control

Table 3.4.7-1.
Elevation-Area-Capacity Relationship for Lower Bois d'Arc Creek Reservoir

Elevation (feet)	Area (acre)	Capacity (acft)
464.0	5	4
470.0	19	76
480.0	378	1,197
490.0	2,001	15,109
500.0	4,288	50,684
510.0	6,987	99,108
520.0	10,601	180,995
530.0	14,724	302,570
534.0	16,526	367,609
540.0	19,616	467,767
550.0	23,967	678,337
560.0	29,670	954,617

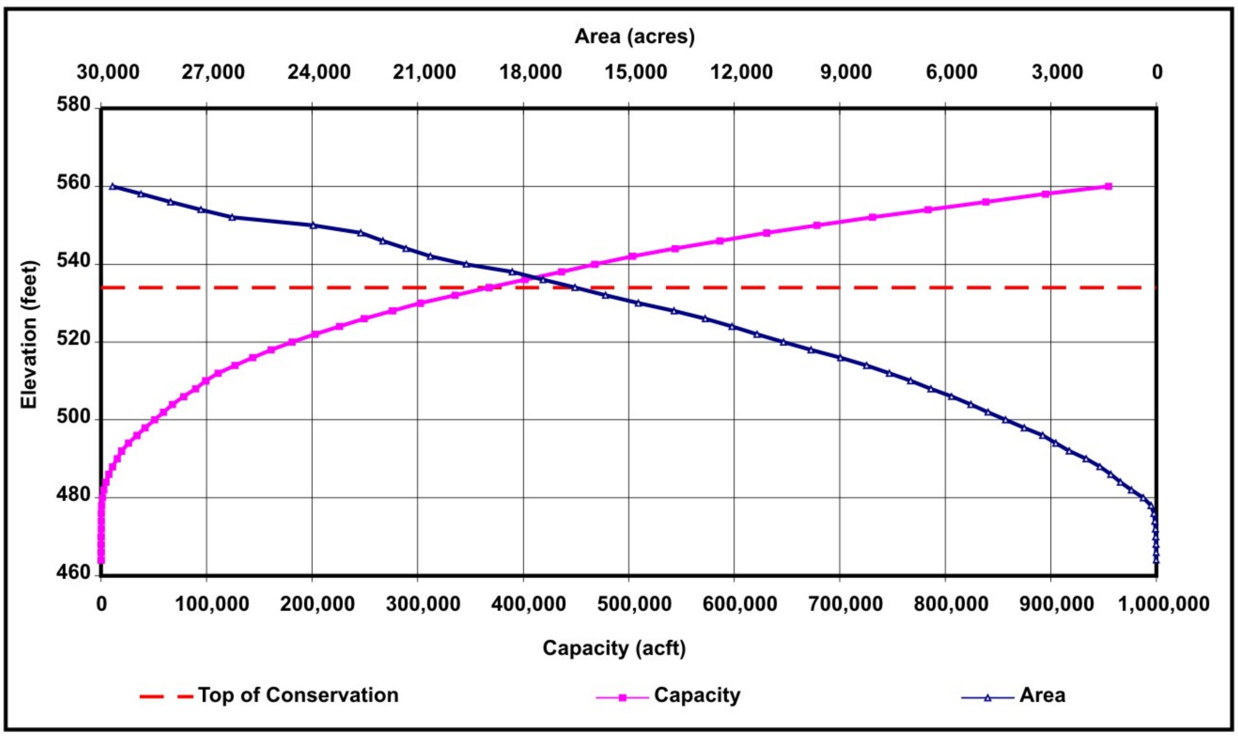

Figure 3.4.7-2. Elevation-Area-Capacity Relationship for Lower Bois d'Arc Creek Reservoir

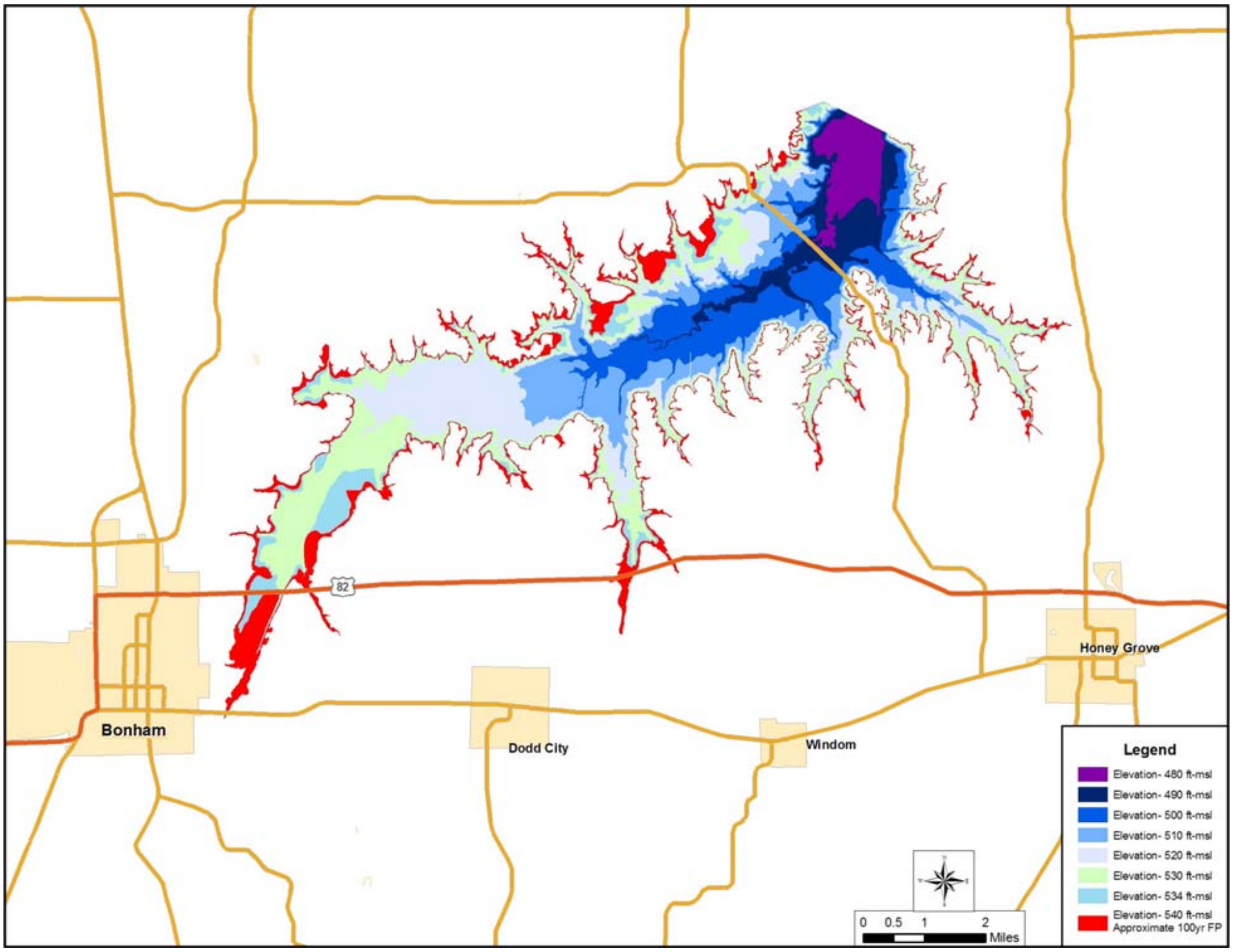

Figure 3.4.7-3. Inundation Map for Lower Bois d'Arc Creek Reservoir

point at the proposed reservoir site using flows based on data from the Randolph gage on Bois d'Arc Creek and naturalized flows in the Sulphur Basin. This method was adopted for the current yield evaluations. More information can be found in the *Report Supporting an Application for a Texas Water Right for Lower Bois d'Arc Creek Reservoir* (Freese and Nichols, 2006b).

For the hydrologic analyses, a new control point was added to the Red River WAM between secondary control points X10200 and X10260. This control point has a drainage area of 327 square miles. A standard firm yield was calculated assuming that water was passed to downstream senior water rights as determined in the WAM Run 3.

The yield studies used the Consensus Criteria for Environmental Flow Needs (CCEFN) bypass criteria developed in the 2006 study of the reservoir. The CCEFN criteria may be found in Table 3.4.7-2. At the recommended conservation elevation, the bypass criteria reduce the yield of the reservoir by 880 acft/yr.

Table 3.4.7-2.
Consensus Criteria for Environmental Flow Needs for Lower Bois d'Arc Creek Reservoir

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Median	acft	1,568	2,515	2,348	1,873	1,779	706	105	12	30	103	467	1,201
	cfs	25.5	44.9	38.2	31.5	28.9	11.9	1.7	0.2	0.5	1.7	7.8	19.5
25th	acft	447	884	827	664	520	100	4	0	0	0	47	144
	cfs	7.3	15.8	13.4	11.2	8.5	1.7	0.1	0.0	0.0	0.0	0.8	2.3
7Q2	acft	0	0	0	0	0	0	0	0	0	0	0	0

Table 3.4.7-3 and Figure 3.4.7-4 show the results of the yield studies. Note that in Figure 3.4.7-4 the yield of the reservoir per acre-foot of increased conservation storage is higher at a conservation elevation of 538 feet. However, the proposed reservoir is immediately downstream of Lake Bonham and the City of Bonham. Increasing the elevation of the reservoir would impact the existing dam for Lake Bonham and increase the potential for flooding in the City of Bonham. The storage trace for the recommended conservation pool elevation and the storage frequency curve are shown in Figure 3.4.7-5. This figure shows that at the proposed conservation elevation of 534 feet, the reservoir would be full about 13 percent of the time and below 50 percent full (183,805 acft) less than 20 percent of the months.

Table 3.4.7-3.
Firm Yield vs. Conservation Storage for Lower Bois d'Arc Creek Reservoir

Conservation Pool Elevation (ft-msl)	Conservation Storage (acft)	Environmental Bypass Criteria	Yield (acft/yr)	Critical Period
530.0	302,570	CCEFN	117,190	7/75 - 8/80
534.0*	367,609	CCEFN	126,280	7/75 - 2/81
		None	127,160	7/75 - 2/81
536.0	401,647	CCEFN	130,820	7/75 - 2/81
538.0	436,333	CCEFN	139,570	7/51 - 2/57

*Proposed conservation storage.

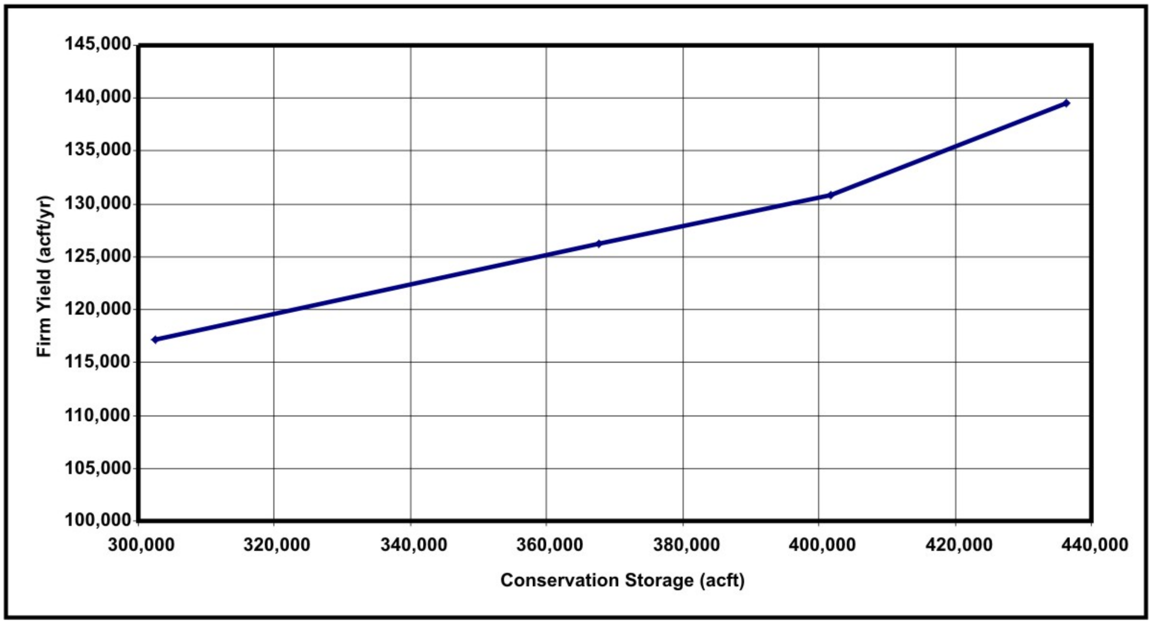

Figure 3.4.7-4. Firm Yield vs. Conservation Storage for Lower Bois d'Arc Creek Reservoir

3.4.7.3 Reservoir Costs

Costs for the Lower Bois d'Arc Creek Reservoir Dam assume a zoned earthen embankment and uncontrolled spillway. The length of the dam is estimated at 10,400 feet with a maximum height of 90 feet. The service spillway would include an approach channel; a 150-foot uncontrolled concrete weir, chute, hydraulic jump stilling basin, and outlet channel.

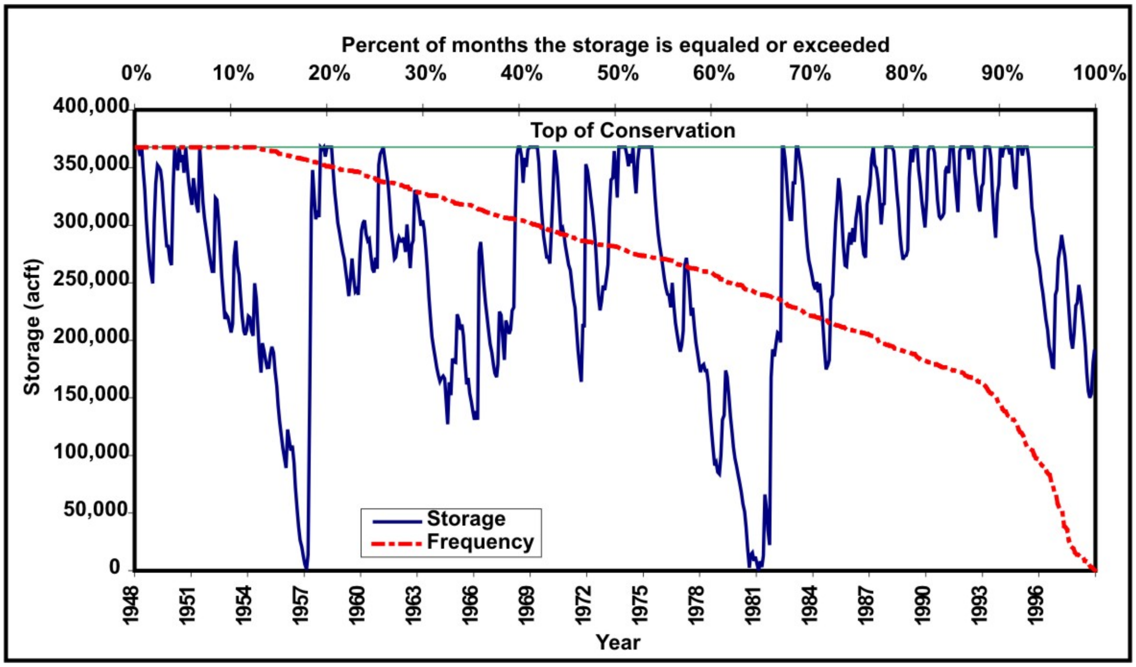

Figure 3.4.7-5. Simulated Storage in Lower Bois d'Arc Creek Reservoir (Conservation Elevation = 534 ft-msl, Diversion = 126,280 acft/yr)

Conflicts identified at the site include a cemetery, electrical lines, several roads (including U.S. Highway 82 and F.M. 1396), a 10-inch gas line and several other structures. A list of the potential conflicts is provided in Table 3.4.7-4. In addition to these conflicts, the cost estimate includes protection of the downstream slope of the Lake Bonham Dam, which will abut the upper reaches of the Lower Bois d'Arc Creek Reservoir. Costs for these conflict resolutions were developed from data provided by TNRIS and from the study report in support of the water right permit application for Lower Bois d'Arc Creek Reservoir (Freese and Nichols, 2006b). The conflict costs represent less than 10 percent of the total construction cost of the reservoir project. Figure 3.4.7-6 shows the conflicts as mapped by TNRIS.

Table 3.4.7-4. List of Potential Conflicts for Lower Bois d'Arc Creek Reservoir

Gas Pipeline	Power Transmission Lines
Roads	Cemetery

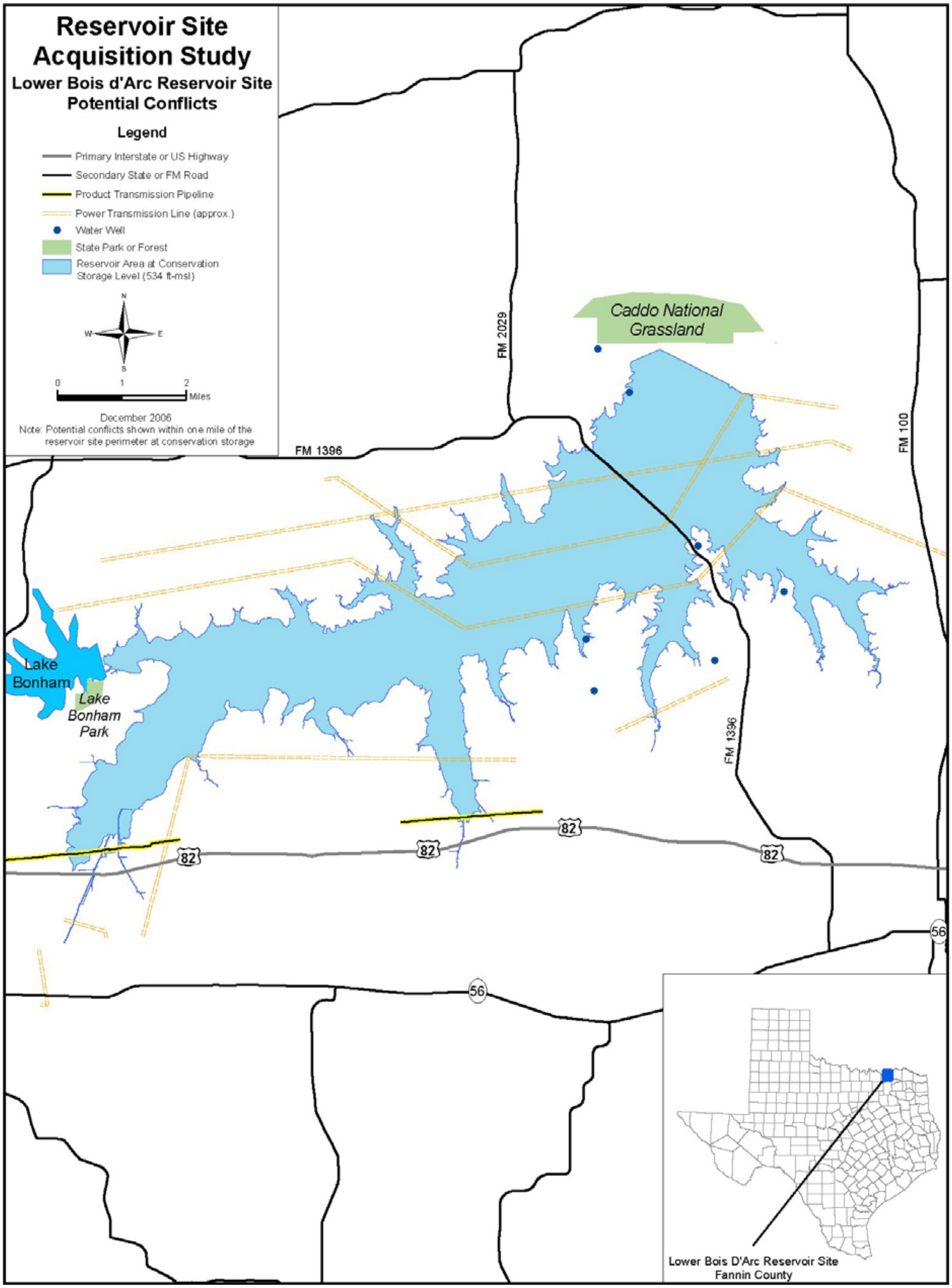

Figure 3.4.7-6. Potential Major Conflicts for Lower Bois d'Arc Creek Reservoir

Table 3.4.7-5 shows the estimated capital costs for the Lower Bois d'Arc Creek Reservoir Project, including construction costs, engineering, permitting and mitigation. Unit costs for the dam and reservoir are based on the unit cost assumptions used in this study. Local costs could vary. Utilizing these unit costs, the total estimated cost of the project is $248 million (2005 prices). Assuming a yield of 126,200 acft/yr, raw water from the project will cost approximately $140 per acre-foot ($0.43 per 1,000 gallons) during the debt service period.

3.4.7.4 Environmental Considerations

Lower Bois d'Arc Creek Reservoir is located on an ecologically significant stream as identified by the Texas Parks and Wildlife Department. The designation is based on biological function, hydrologic function, and the presence of a riparian conservation area. The Region C Water Planning Group did not identify this stream segment as ecologically unique in the 2006 water plan. Portions of the creek that would be impacted by the reservoir were altered (straightened and widened) approximately 80 years ago to reduce localized flooding. The site is located immediately upstream of the Caddo National Grasslands, but would have minimal impacts to these lands. The U.S. Fish and Wildlife Service has identified Priority 4 bottomland hardwoods considered "moderate quality bottomlands with minor waterfowl benefits" (USFWS, 1985) in the vicinity of the project.

Lower Bois d'Arc Creek Reservoir will inundate 16,526 acres of land at conservation storage capacity. Table 3.4.7-6 and Figure 3.4.7-7 summarize existing landcover for the Lower Bois d'Arc Creek Reservoir site as determined by TPWD using methods described in Appendix C. Existing landcover within this reservoir site is dominated by upland deciduous forest (42 percent) with sizeable areas of grassland (28 percent) and agricultural land (17 percent). Bottomland hardwood forest comprises only about 2.2 percent of the reservoir area while marsh, swamp, and open water total about 3.5 percent of the reservoir area.

Table 3.4.7-5.
Cost Estimate — Lower Bois d'Arc Creek Reservoir @ Elevation 534 ft-msl

	Quantity	Unit	Unit Price	Cost
Dam & Reservoir				
Mobilization (5%)	1	LS	$2,976,100	$2,976,000
Clearing and Grubbing	85	AC	$4,000	$340,000
Care of Water During Construction (1%)	1	LS	$589,300	$589,000
Required Excavation	2,339,400	CY	$2.50	$5,849,000
Borrow Excavation	2,030,000	CY	$2.00	$4,060,000
Random Compacted Fill	3,261,000	CY	$2.50	$8,153,000
Core Compacted Fill	711,200	CY	$3.00	$2,134,000
Soil Bentonite Slurry Trench	497,700	SF	$15.00	$7,466,000
Soil Cement	114,900	CY	$65.00	$7,469,000
Flex Base Roadway	29,200	SY	$20.00	$584,000
Sand Filter Drain	293,000	CY	$35.00	$10,255,000
Grassing	41	AC	$4,500	$185,000
Intake Tower for Low-Flow Outlet	527	CY	$750	$395,000
Conduit for Low-Flow Outlet	660	CY	$500	$330,000
Impact Basin for Low-Flow Outlet	160	CY	$500.00	$80,000
Gates and Miscellaneous for Low-Flow Outlet	1	LS	$200,000	$200,000
Electrical System and Instrumentation for Low-Flow Outlet	1	LS	$195,000	$195,000
Spillway Structure and Reinforced Concrete	19,700	CY	$375	$7,388,000
Roller Compacted Concrete	49,900	CY	$60	$2,994,000
Bridge	3,000	SF	$150	$450,000
Barrier and Warning System	1	LS	$50,000	$50,000
Embankment Instrumentation	1	LS	$250,000	$250,000
Timber Guard Posts and Guard Rail	1	LS	$55,000	$55,000
Misc. Internal Drainage	1	LS	$50,000	$50,000
Engineering and Contingencies				$21,874,000
Subtotal for Dam & Reservoir				**$84,371,000**
Conflicts				
Utilities				
10-in Gas Pipeline	3,720	LF	$27	$100,000
138 KV Line	1	LS	N/A	$1,500,000
345 KV line	1	LS	N/A	$3,735,000
Other structures	1	LS	N/A	$3,000,000
Cemeteries	27	EA	$6,000	$162,000
Major Roads (raised)	5,000	LF	$900	$4,500,000
Other roads	7,200	LF	$150	$1,080,000
Lake Bonham (protection)	1	LS	$175,000	$175,000
Engineering and Contingencies at 35%				$4,988,000
Land Acquisition - Conservation Pool plus 10%	22,000	AC	$2,675.00	$58,850,000
Environmental Studies and Mitigation Lands	22,000	AC	$2,675.00	$58,850,000
CONSTRUCTION TOTAL				**$221,311,000**
Interest During Construction (36 months)				**$26,927,000**
TOTAL COST				**$248,238,000**
ANNUAL COSTS				
Debt Service (6% for 40 years)				$16,498,000
Operation & Maintenance				$1,125,000
Total Annual Costs				**$17,623,000**
UNIT COSTS				
Per Acre-Foot				$140
Per 1,000 Gallons				$0.43

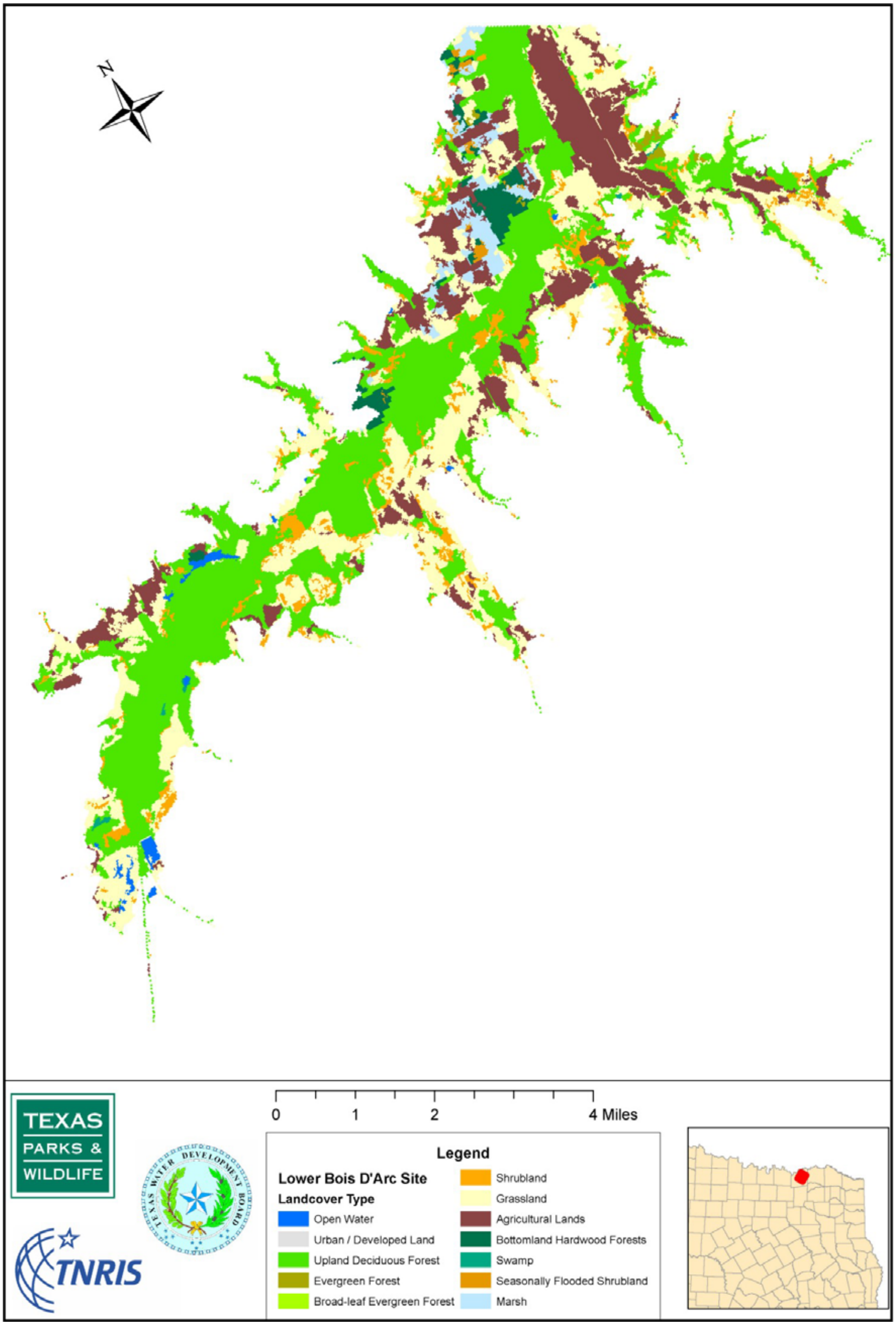

Figure 3.4.7-7. Existing Landcover for Lower Bois d'Arc Creek Reservoir

Table 3.4.7-6.
Acreage and Percent Landcover for Lower Bois d'Arc Creek Reservoir

Landcover Classification	*Acreage*[1]	*Percent*
Bottomland Hardwood Forest	373	2.2%
Marsh	407	2.5%
Seasonally Flooded Shrubland	73	0.4%
Swamp	29	0.2%
Evergreen Forest	61	0.4%
Upland Deciduous Forest	6,936	41.9%
Grassland	4,671	28.2%
Shrubland	1,038	6.3%
Agricultural Land	2,826	17.1%
Open Water	135	0.8%
Total	16,549	100.0%

[1] Acreage based on approximate GIS coverage rather than calculated elevation-area-capacity relationship.

3.4.8 Marvin Nichols Reservoir (Site IA)

3.4.8.1 Description

Marvin Nichols Reservoir (Site IA) would be located on the Sulphur River in Red River and Titus Counties. Figure 3.4.8-1 shows the location of the reservoir at the proposed conservation pool elevation of 328 ft-msl, with a conservation capacity of 1,562,669 acft. The inundated area at the top of conservation pool is 67,392 acres. The reservoir has a total drainage area of 1,889 square miles, of which 479 square miles are above Lake Chapman.

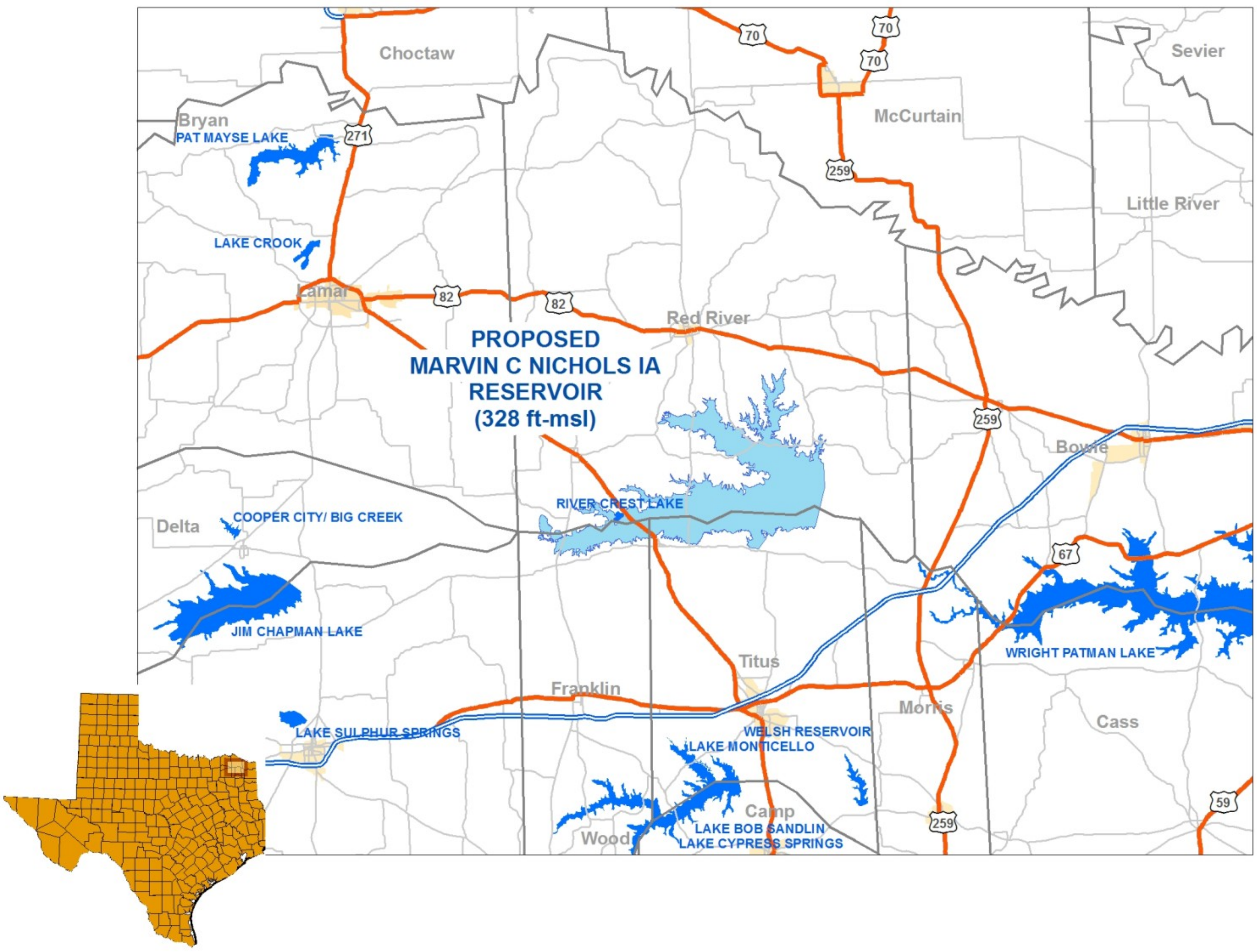

Figure 3.4.8-1. Location Map for Marvin Nichols Reservoir (Site IA)

This reservoir has been previously studied at various dam locations on the Sulphur River since the 1960s. It was first included in a state water plan in 1969 and has been included in each state plan since. More recently, this site was studied by Freese and Nichols in 1990, 1996, 2000, and 2006, and it is a recommended water management strategy for the North Texas Municipal Water District, Tarrant Regional Water District, and the Upper Trinity River Water District in the 2006 Region C Water Plan (Freese and Nichols *et al*., 2006) and the 2007 Texas State Water Plan (TWDB, 2006). It is also an alternate strategy for the City of Dallas.

Marvin Nichols Reservoir is a recommended unique reservoir site in the 2001 and 2006 *Region C Water Plans*. The reservoir would provide water to several major water providers in the greater Dallas-Fort Worth area in the Region C water planning area. The need for additional water supply for the Region C planning area are expected to exceed 1.9 million acft/yr by 2060 (Freese and Nichols *et al*, 2006a). The projected water shortages within 50 miles of the proposed reservoir site by 2060 are 53,141 acft/yr. The nearest major demand center is the Dallas-Fort Worth area, which is located approximately 115 miles southwest of the reservoir site.

3.4.8.2 Reservoir Yield Analysis

The elevation-area-capacity relationship for Marvin Nichols Reservoir is included in Table 3.4.8-1 and Figure 3.4.8-2. The data in Table 3.4.8-2 were developed by Freese and Nichols (2000) by measurement from U.S. Geological Survey topographic quadrangle maps with scale 1:24,000 and 10-foot contour intervals. Figure 3.4.8-3 shows the reservoir inundation at different elevations in a 10-foot interval, including the elevation with the probable maximum flood at 335 feet.

The reservoir will be subject to regulatory bypass to meet environmental needs. For this study, the Consensus Criteria for Environmental Flow Needs (TWDB, 1997) were adopted and are shown in Table 3.4.8-2.

The firm yield of Marvin Nichols Reservoir was calculated with the full authorization scenario (Run 3) of the Water Availability Model of the Sulphur River Basin (dated July 15, 2004) obtained from TCEQ (R.J. Brandes, 1999 and TCEQ, 2006). A control point was added on the North Sulphur River at the dam location.

In the WAM Models, flows at ungaged locations are usually calculated using the drainage area ratio method with known flows at gaged locations. The drainage areas of the Sulphur WAM were calculated by the University of Texas Center of Research in Water Resources (CRWR). These areas are different from values published from U.S. Geological Survey. In some cases, the difference is more than 10 percent.

Table 3.4.8-1.
Elevation-Area-Capacity Relationship for Marvin Nichols Reservoir

Elevation (feet)	*Area (acres)*	*Capacity (acft)*
260.0	0	0
265.0	96	235
270.0	192	954
275.0	3,435	9,944
280.0	6,678	35,207
285.0	10,690	78,612
290.0	14,703	142,084
295.0	20,072	229,008
300.0	25,441	342,780
305.0	30,778	483,319
310.0	36,114	650,543
315.0	43,726	850,130
320.0	51,337	1,087,776
325.0	61,372	1,369,531
328.0	67,392	1,562,669
330.0	71,406	1,701,463

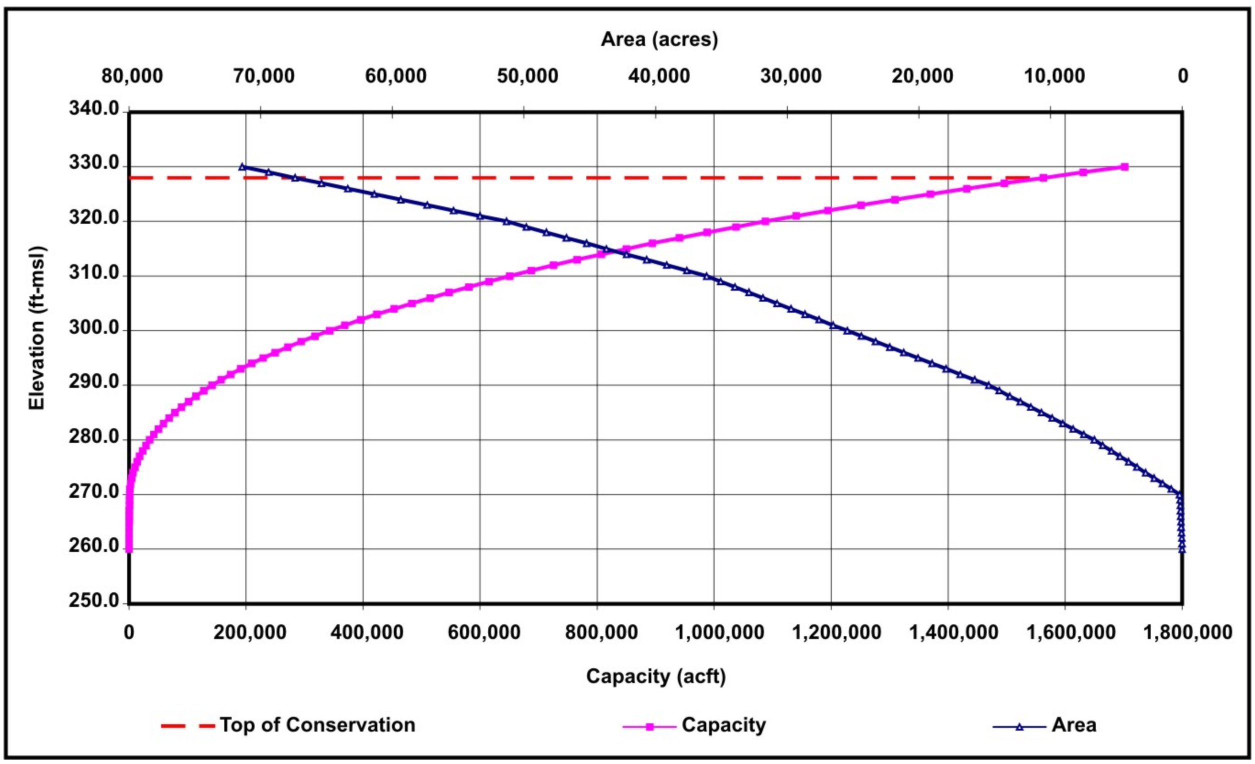

Figure 3.4-8-2. Elevation-Area-Capacity Relationship for Marvin Nichols Reservoir

Table 3.4.8-2.
Consensus Criteria for Environmental Flow Needs for Marvin Nichols Reservoir

	Median		25th Percentile		7Q2	
	acft	cfs	acft	cfs	acft	cfs
Jan	13,845	225.1	3,419	55.6	69	1.1
Feb	21,947	391.6	6,659	118.8	63	1.1
Mar	31,133	506.2	8,975	145.9	69	1.1
Apr	19,656	330.2	6,143	103.2	67	1.1
May	32,113	522.1	6,092	99.0	69	1.1
Jun	11,994	201.5	3,110	52.3	67	1.1
Jul	2,564	41.7	552	9.0	69	1.1
Aug	911	14.8	220	3.6	69	1.1
Sep	1,011	17.0	123	2.1	67	1.1
Oct	1,562	25.4	251	4.1	69	1.1
Nov	5,055	84.9	1,083	18.2	67	1.1
Dec	11,641	189.3	2,201	35.8	69	1.1
Total	153,432		38,827		814	
Average	12,786	212.5	3,236	54.0	68	1.1

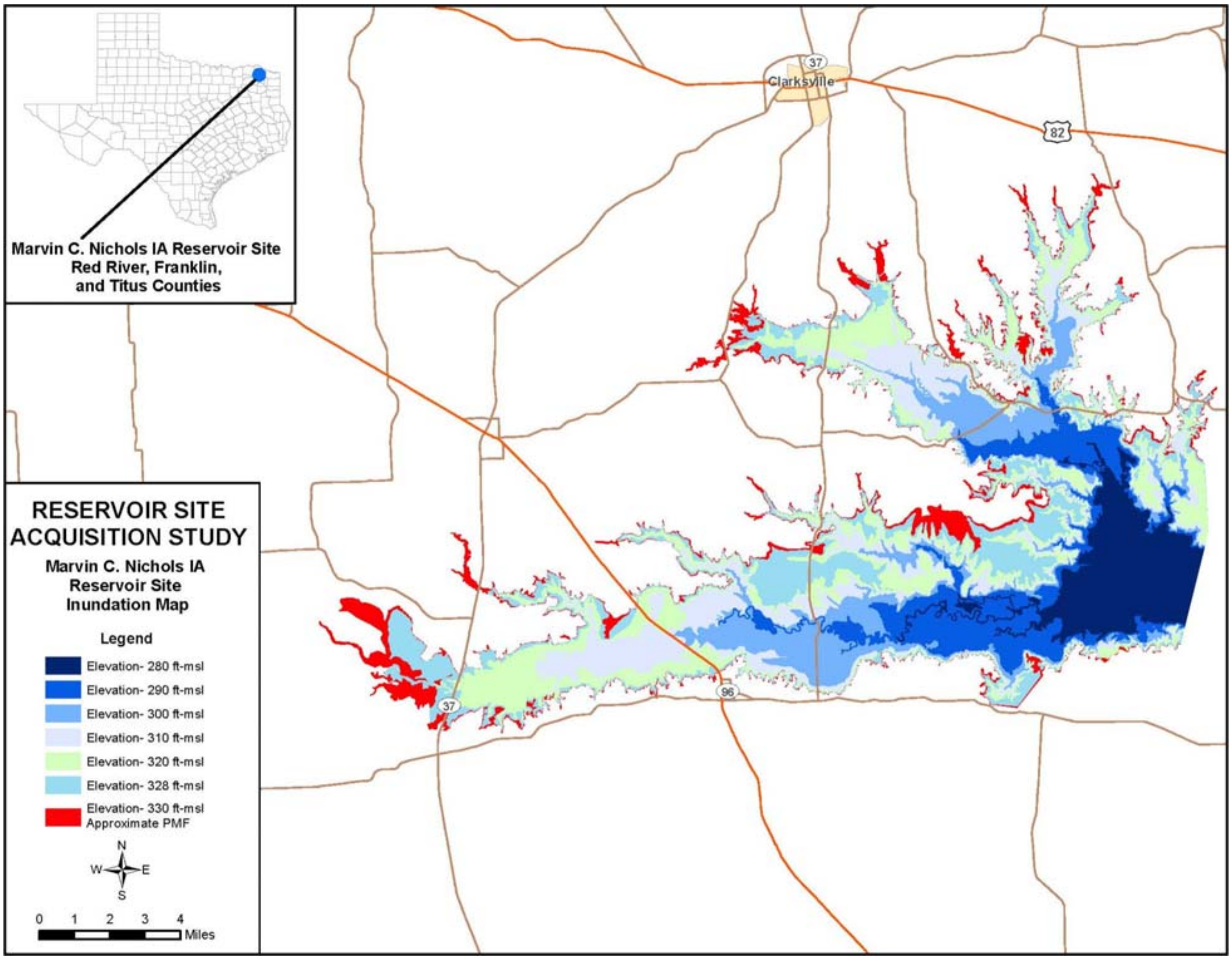

Figure 3.4.8-3. Inundation Map for Marvin Nichols Reservoir

Preliminary yield studies conducted in this study determined that the flows calculated using the Sulphur WAM with the drainage area ratio method are different from previous hydrologic studies because of differences in the drainage areas. The USGS values are widely accepted and are more accurate than the CRWR values as developed for the Sulphur Basin WAM. Therefore, for purposes of estimating the firm yields of the proposed reservoirs in the Sulphur Basin, naturalized flows at the reservoir sites were calculated using the drainage area ratio method with drainage areas obtained from the USGS rather then CRWR. For Marvin Nichols Reservoir, naturalized flows were calculated using the South Sulphur River near Talco (WAM Control Point C10), the White Oak Creek near Talco (WAM Control Point D10), and the Sulphur River near Darden (WAM Control Point E10).

The scope of work of this study does not include a verification or modification of the drainage areas of the Sulphur WAM Model. However, entering the naturalized flow at the reservoir sites is sufficient to produce accurate estimates of firm yield.

Net evaporation rates were calculated from TWDB quadrangle data of precipitation and lake evaporation. Evaporation at the Marvin Nichols Reservoir site was calculated as the average of Quadrangles 412 and 413. Net evaporation rates entered in the Sulphur WAM were adjusted to remove the portion of the precipitation in the reservoir surface area that was already accounted for in the natural inflow.

Yields were calculated for elevations 330, 328, 323, and 318 ft-msl, subject to bypass for Consensus Criteria for Environmental Flow Needs and assuming stand-alone reservoir operations with no minimum reserve content. Results of firm yield at these elevations are included in Table 3.4.8-3 and Figure 3.4.8-4. At the conservation pool level of 328 feet, the firm yield is 602,000 acft/yr. Environmental flow requirements reduce the yield of the reservoir by 12,800 acft/yr.

An evaluation of the impacts of the construction of other reservoir sites in the Sulphur River Basin on the yield of each of the reservoirs was conducted and the findings are included in Appendix A of this report. Based on this evaluation, the yield of Marvin Nichols Reservoir will decrease if one or more of the proposed reservoirs in the Sulphur Basin (Ralph Hall, Parkhouse I, and/or Parkhouse II) are built, assuming that Marvin Nichols has a junior priority to any of these reservoirs. As of November 2006, Ralph Hall Lake is in the permitting process, and likely would be senior to Marvin Nichols. Yield analysis determined that Ralph Hall Lake would reduce the firm yield of Marvin Nichols IA by 17,900 acft/yr, which is 3 percent of the stand-alone yield. If all of the other proposed reservoirs in the Sulphur Basin are built, the yield of Marvin Nichols would be 460,800, which is 141,200 acft/yr less than the stand-alone yield (or a reduction of 23 percent).

Figure 3.4.8-5 presents a simulated storage trace derived using the Sulphur WAM. A frequency curve for storage content is also shown in Figure 3.4.8-5. At the conservation pool elevation of 328 ft-msl, the reservoir would be full about 17 percent of the time and would be below 50 percent of the conservation storage about 10 percent of the months.

Table 3.4.8-3.
Firm Yield vs. Conservation Storage for Marvin Nichols Reservoir

Conservation Pool Elevation (ft-msl)	Conservation Storage (acft)	Environmental Bypass Criteria	Yield (acft/yr)	Critical Period
318.0	988,151	CCEFN	465,300	5/53-1/57
323.0	1,250,808	CCEFN	527,800	5/53-1/57
328.0*	1,562,669	CCEFN	602,000	5/53-1/57
		None	614,800	5/53-1/57
330.0	1,701,463	CCEFN	635,200	5/53-1/57

*Proposed conservation storage.

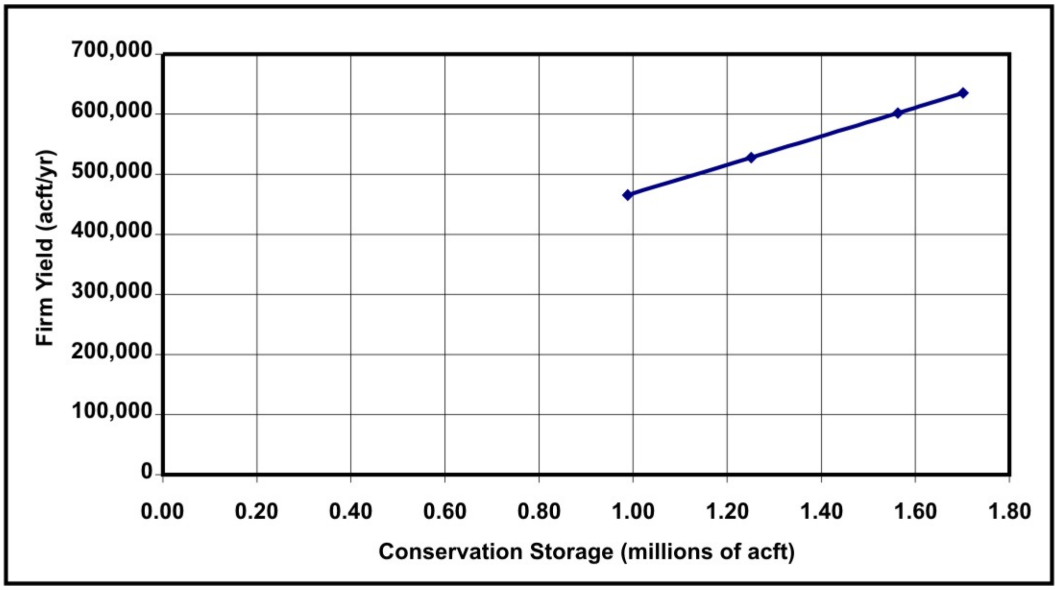

Figure 3.4.8-4. Firm Yield vs. Conservation Storage for Marvin Nichols Reservoir

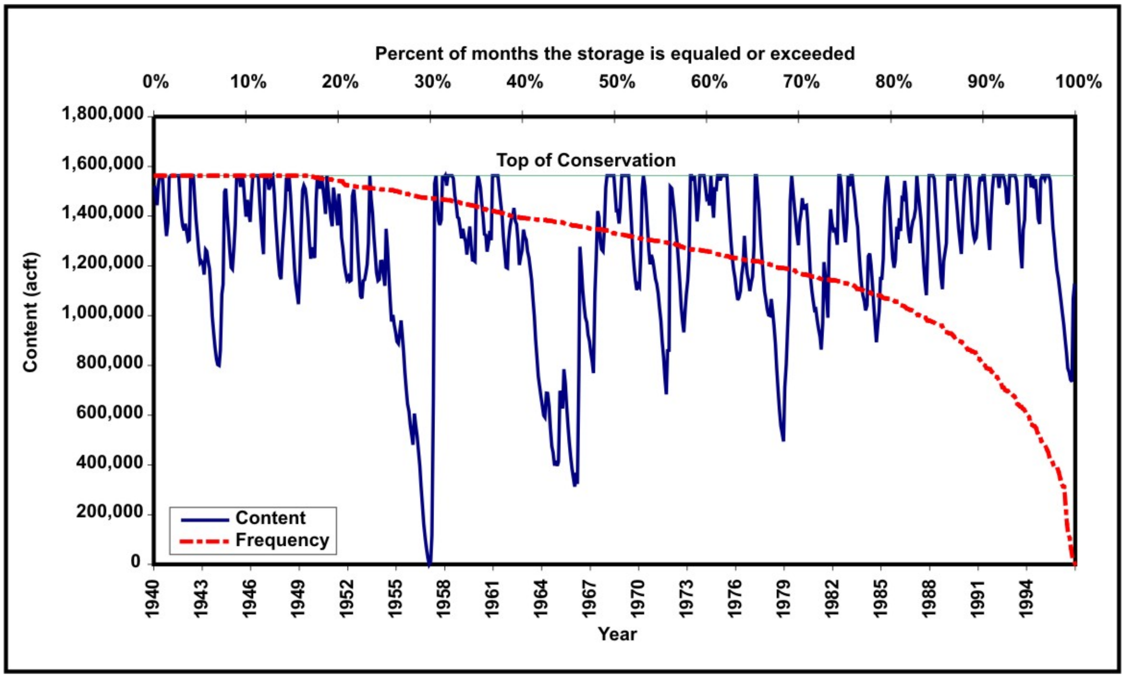

Figure 3.4.8-5. Simulated Storage in Marvin Nichols Reservoir (Conservation Elevation = 328 ft-msl, Diversion = 602,000 acft/yr)

3.4.8.3 Reservoir Cost

The costs for the Marvin Nichols IA Dam are based on data developed for the Sulphur River Basin Reservoir Study (Freese and Nichols, 2000) and used in the 2006 *Region C Water Plan*. The dam and spillway costs assume an earthen embankment with a gated spillway structure. The length of the dam is estimated at approximately 40,400 feet, with a top of dam elevation at 337 ft-msl. The service spillway includes a gated ogee-type weir constructed of concrete, thirteen tainter gates, a stilling basin, and discharge channel.

Figure 3.4.8-6 shows potential conflicts as mapped by TNRIS. The conflicts identified at the site include several cemeteries, electrical lines, roads (including U.S. Highway 271 and State Highway 37), oil and gas pipelines, oil and gas wells and water wells. A list of the potential conflicts is provided in Table 3.4.8-4. Costs and quantities for these conflict resolutions were developed from data provided by TNRIS and from the Region C Water Plan (Freese and Nichols, 2006a). The conflict costs represent approximately 10 percent of the total construction cost of the reservoir project.

Table 3.4.8-4.
List of Potential Conflicts for Marvin Nichols Reservoir

Oil & Gas Pipelines	Power Transmission Lines
Roads	Cemeteries
Oil & Gas Wells	Water Wells

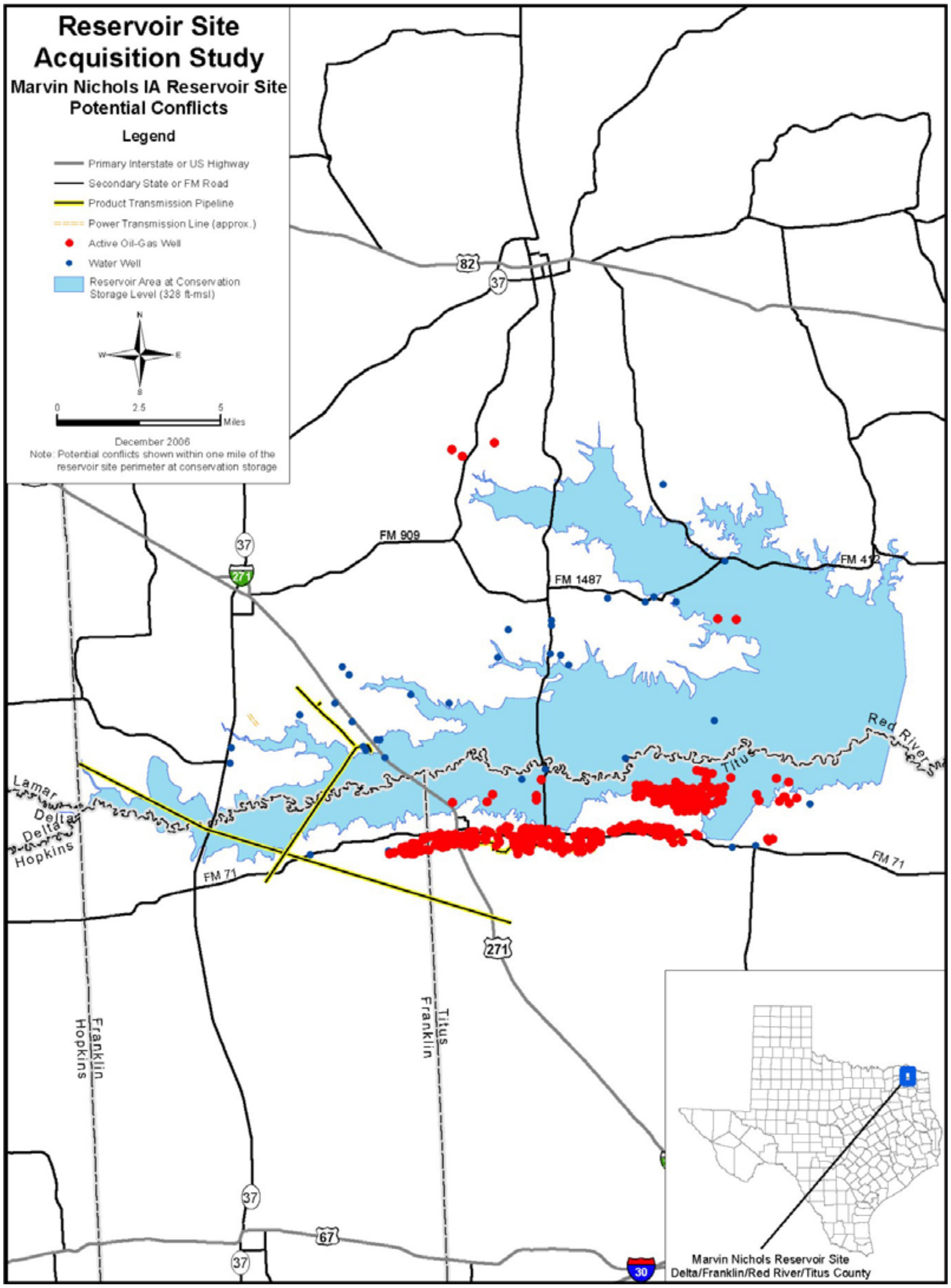

Figure 3.4.8-6. Potential Major Conflicts for Marvin Nichols Reservoir

Table 3.4.8-5 shows the estimated capital costs for the Marvin Nichols Reservoir Project, including construction costs, engineering, permitting and mitigation. Costs for the dam and reservoir are based on the unit cost assumptions used in this study. The total estimated cost of the project is $510 million (2005 prices). Assuming a yield of 602,000 acft/yr, raw water from the project will cost approximately $61 per acft ($0.19 per 1,000 gallons) during the debt service period.

3.4.8.4 Environmental Considerations

The Marvin Nichols IA Reservoir is located approximately 29 river miles upstream of an ecologically significant stream segment as identified by the Texas Parks and Wildlife Department (TPWD, 1999). The reservoir itself is not located on an ecologically significant stream segment. The Sulphur River downstream of the IH-30 bridge in Morris County is considered an ecologically significant stream based on biological function associated with bottomland hardwood forests and the presence of the paddlefish, which is a state-listed threatened species. The Region D Water Planning Group did not identify Sulphur River as ecologically unique in the 2006 regional water plan.

Marvin Nichols Reservoir would inundate approximately 67,300 acres. The U.S. Fish and Wildlife Service has classified some of this acreage as Priority 1 bottomland hardwoods, which are considered "excellent quality bottomlands of high value to key waterfowl species" (USFWS, 1985). Previous studies have also identified surface lignite deposits within the project area. At this time, there are no lignite mining areas.

Table 3.4.8-6 and Figure 3.4.8-7 summarize existing landcover for the Marvin Nichols Reservoir site as determined by TPWD using methods described in Appendix C. Existing landcover within this reservoir site is dominated by largely contiguous bottomland hardwood forest (39 percent) with sizeable areas of upland deciduous forest (20 percent) and grassland (19 percent). Marsh, swamp, and open water total about 13 percent of the reservoir area.

Table 3.4.8-5.
Cost Estimate — Marvin Nichols Reservoir @ Elevation 328 ft-msl
(page 1 of 2)

	Quantity	Unit	Unit Price	Cost
DAM & RESERVOIR				
Mobilization (5%)	1	LS	$8,183,300	$8,183,000
Spillway Construction				
Mass Concrete	87,300	CY	$150	$13,095,000
Reinforced Concrete	26,800	CY	$400	$10,720,000
Soil Cement	3,600	CY	$65.00	$234,000
Spillway Bridge	640	LF	$1,300	$832,000
Gates, Including Anchoring System	14,040	SF	$275	$3,861,000
Gate Hoist and Operating System	13	EA	$250,000	$3,250,000
Stop Gate and Lift Beam	640	LF	$2,000	$1,280,000
Instrumentation	640	LF	$700	$448,000
Excavation	2,894,000	CY	$3	$7,235,000
Structural Fill	121,000	CY	$12	$1,452,000
Subtotal of Spillway Construction				**$42,407,000**
Embankment Construction				
Random Fill	6,049,600	CY	$2.50	$15,124,000
Impervious Core	1,455,000	CY	$3.00	$4,365,000
Borrow	4,731,600	CY	$2.00	$9,463,000
Foundation Drain (Filter Material)	502,500	CY	$35.00	$17,588,000
Soil Cement	337,800	CY	$65.00	$21,957,000
Slurry Trench Cutoff	1,770,000	SF	$15.00	$26,550,000
Asphalt Paving on Embankment Crest	68,350	SY	$20.00	$1,367,000
Containment Levee	79,100	CY	$2.50	$198,000
Subtotal of Embankment Construction				**$96,612,000**
Other Items				
Barrier Warning System	640	LF	$100	$64,000
Electrical System	1	LS	$550,000	$550,000
Power Drop	1	LS	$250,000	$250,000
Spillway Low-Flow System	1	LS	$400,000	$400,000
Stop Gate Monorail System	640	LF	$1,000	$640,000
Grassing	100	AC	$4,500	$450,000
Clearing and Grubbing/ Site Preparation	321	AC	$4,000	$1,284,000
Care of Water (3%)	1	LS	$4,209,100	$4,209,000
Reservoir Land Clearing	16,800	AC	$1,000	$16,800,000
Subtotal of Other Items				**$24,647,000**
Engineering and Contingencies - Dam & Reservoir				$57,283,000
Conflicts				
Roads				
Federal Highway	16,300	LF	$900	$14,670,000
State Highway	6,000	LF	$900	$5,400,000
F.M	33,400	LF	$150	$5,010,000
Oil & Gas Pipelines				
30-inch	27,000	LF	$98	$2,646,000
16-inch	28,000	LF	$42	$1,176,000
8-inch	20,000	LF	$23	$460,000
6-inch	42,000	LF	$20	$840,000
Power Lines	3,600	LF	$450	$1,620,000
Cemetaries				
Wims	25	EA	$6,000	$150,000
Singleton	10	EA	$6,000	$60,000
Evergreen	75	EA	$6,000	$450,000

Table 3.4.8-5.
Cost Estimate — Marvin Nichols Reservoir @ Elevation 328 ft-msl
(page 2 of 2)

	Quantity	*Unit*	*Unit Price*	*Cost*
Wells (each)				
Oil and Gas Wells	94	EA	$25,000	$2,350,000
Water Wells	9	EA	$49,000	$441,000
Engineering and Contingencies - Conflicts				$12,346,000
Land Purchase Costs	77,427	AC	$1,201	$92,990,000
Environmental Studies and Mitigation Lands	77,427	AC	$1,201	$92,990,000
CONSTRUCTION TOTAL				**$454,548,000**
Interest During Construction (36 months)				**$55,305,000**
TOTAL COST				**$509,853,000**
ANNUAL COSTS				
Debt Service (6% for 40 years)				$33,886,000
Operation & Maintenance				$2,946,000
Total Annual Costs				**$36,832,000**
UNIT COSTS				
Per Acre-Foot				$61
Per 1,000 Gallons				$0.19

Table 3.4.8-6.
Acreage and Percent Landcover for Marvin Nichols Reservoir

Landcover Classification	*Acreage[1]*	*Percent*
Bottomland Hardwood Forest	26,309	39.2%
Marsh	6,259	9.3%
Seasonally Flooded Shrubland	1,198	1.8%
Swamp	565	0.8%
Evergreen Forest	27	0.0%
Upland Deciduous Forest	13,667	20.4%
Grassland	13,069	19.5%
Shrubland	1,027	1.5%
Agricultural Land	3,169	4.7%
Urban / Developed Land	8	0.0%
Open Water	1,847	2.8%
Total	67,145	100.0%

[1] Acreage based on approximate GIS coverage rather than calculated elevation-area-capacity relationship.

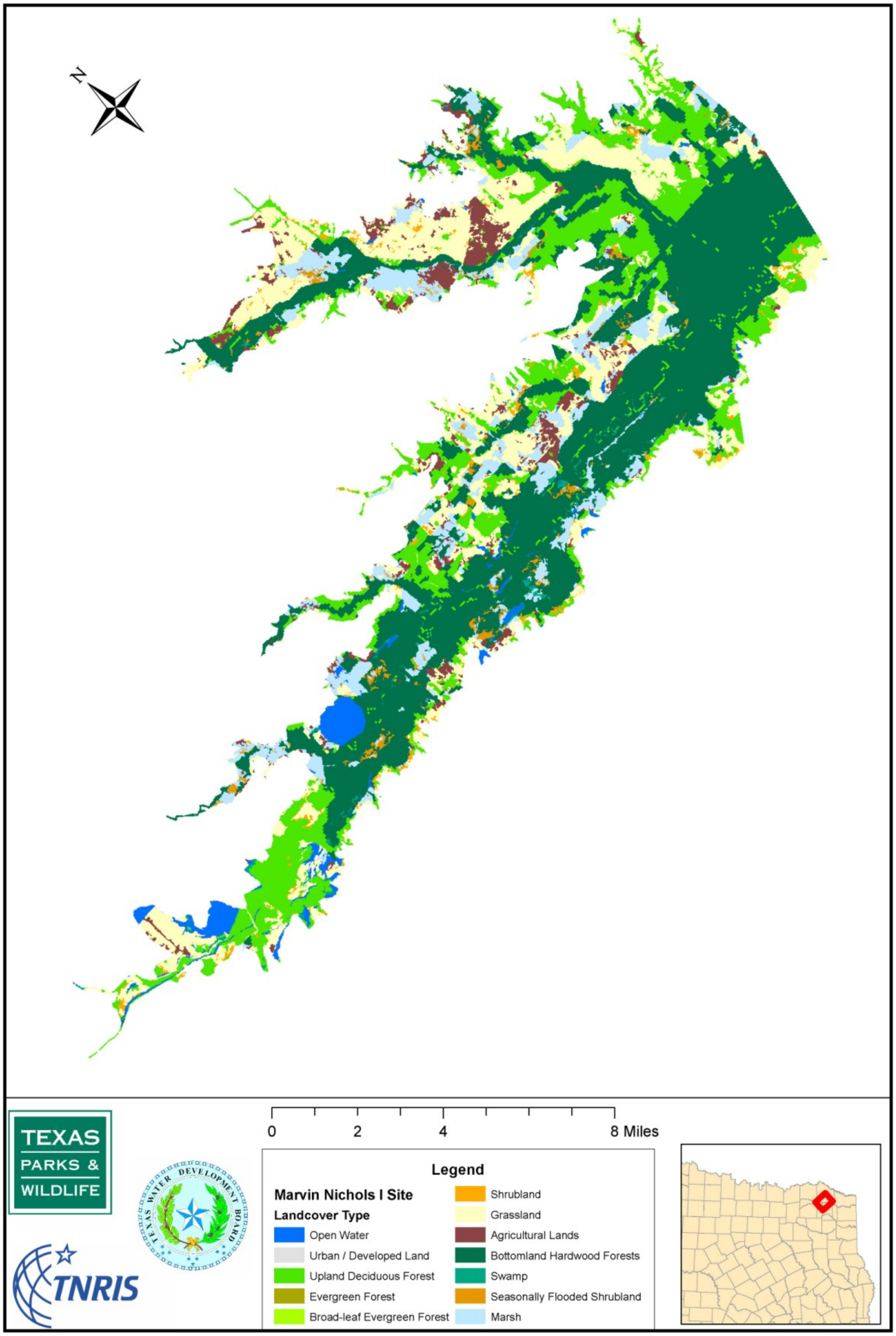

Figure 3.4.8-7. Existing Landcover for Marvin Nichols Reservoir

(This page intentionally left blank.)

3.4.9 Nueces Off-Channel Reservoir

3.4.9.1 Project Description

The Nueces Off-Channel Reservoir is recommended in the 2006 Coastal Bend Regional Water Plan (HDR, 2006) as a strategy to increase the firm yield of the Choke Canyon Reservoir/Lake Corpus Christi (CCR/LCC) System and potentially provide ecosystem restoration benefits. Choke Canyon Reservoir has a storage capacity of approximately 695,000 acft and a contributing drainage of approximately 5,500 square miles. Lake Corpus Christi has a storage capacity of approximately 257,000 acft and a contributing drainage of approximately 16,500 square miles. This configuration creates a situation where the smallest reservoir has the largest potential for capturing storm flows because of the larger contributing drainage area. The yield of the CCR/LCC System is affected by the limited storage capacity of Lake Corpus Christi and its limited ability to impound major storm events that travel down the Nueces River. Since Lake Corpus Christi has the smaller capacity, many times it fills and spills flow to Nueces Bay when there is available capacity in Choke Canyon Reservoir. Water pumped from Lake Corpus Christi into the Nueces Off-Channel Reservoir will result in more water in storage and enhance the system yield.

The Nueces Off-Channel Reservoir site is shown in Figure 3.4.9-1. The reservoir is located near the upper western section of Lake Corpus Christi. The Nueces Off-Channel Reservoir will require an intake and pump station at Lake Corpus Christi to pump available water from Lake Corpus Christi.

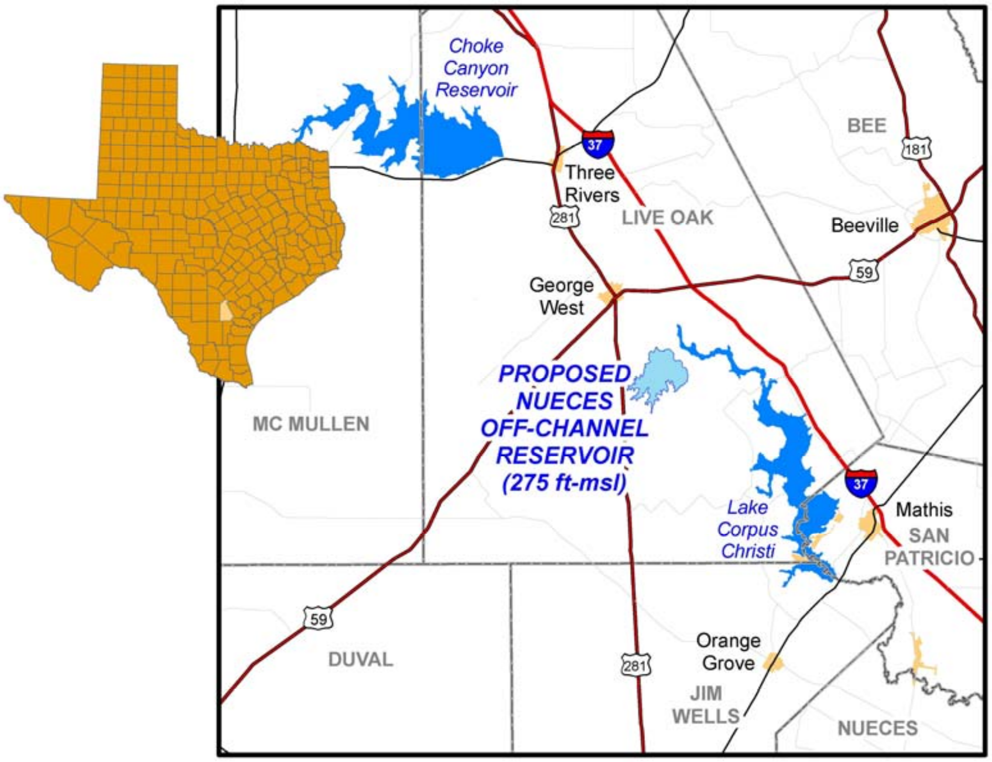

Figure 3.4.9-1. Location Map of Nueces Off-Channel Reservoir

Projected municipal, industrial (including manufacturing), and steam-electric needs for additional water supply prior to year 2060 total 159,640 acft/yr for counties within a 50-mile radius of the Nueces Off-Channel Reservoir site. The 50-mile radius encompasses all or parts of Atascosa, Bee, Duval, Goliad, Jim Wells, Karnes, Kleberg, La Salle, Live Oak, McMullen, Nueces, Refugio, San Patricio, Webb, and Wilson Counties. The nearest major population and water demand center to the Nueces Off-Channel Reservoir site is Corpus Christi (56 miles).

3.4.9.2 Reservoir Yield Analyses

The elevation-area-capacity relationship for Nueces Off-Channel Reservoir is presented in Figure 3.4.9-2 and Table 3.4.9-1 and was developed from 10-ft contour, digital hypsography data from the Texas Natural Resources Information System (TNRIS). These data are derived from the 1:24,000-Scale (7.5-minute) quadrangle maps developed by the USGS. The total area inundated at each 10-ft elevation contour is shown in Figure 3.4.9-3. At the conservation storage pool elevation of 275.3 ft-msl, Nueces Off-Channel Reservoir would inundate 5,294 acres and have a capacity of 250,000 acft.

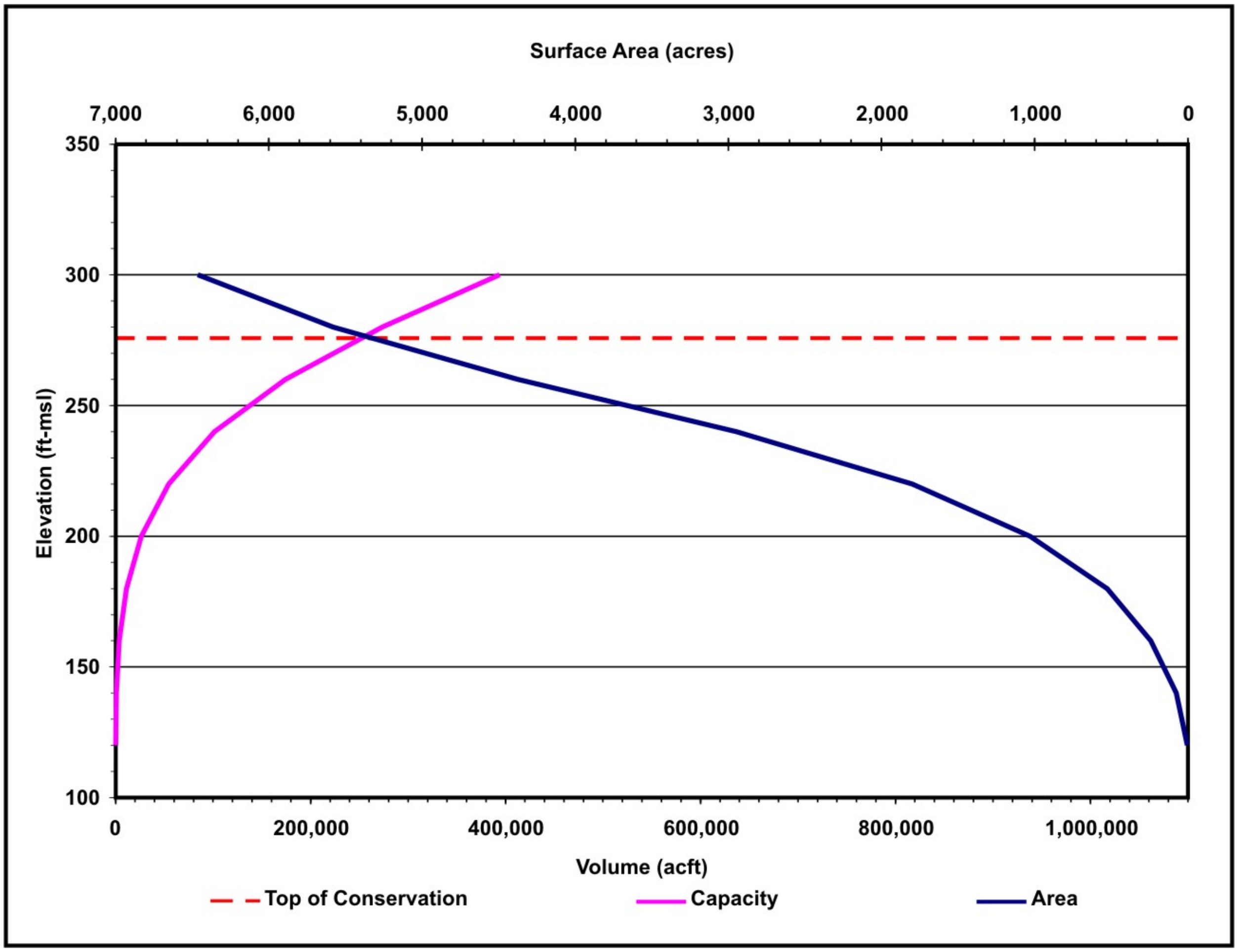

Figure 3.4.9-2. Elevation-Area-Capacity Relationship for Nueces Off-Channel Reservoir

Table 3.4.9-1.
Elevation-Area-Capacity Relationship for Nueces Off-Channel Reservoir

Elevation (feet)	*Area (acres)*	*Capacity (acft)*
120	4	0
140	76	645
160	243	3,678
180	528	11,209
200	1,029	26,503
220	1,800	54,437
240	2,946	101,432
260	4,374	174,169
275.3	5,294	250,000
280	5,579	273,455
300	6,465	393,787

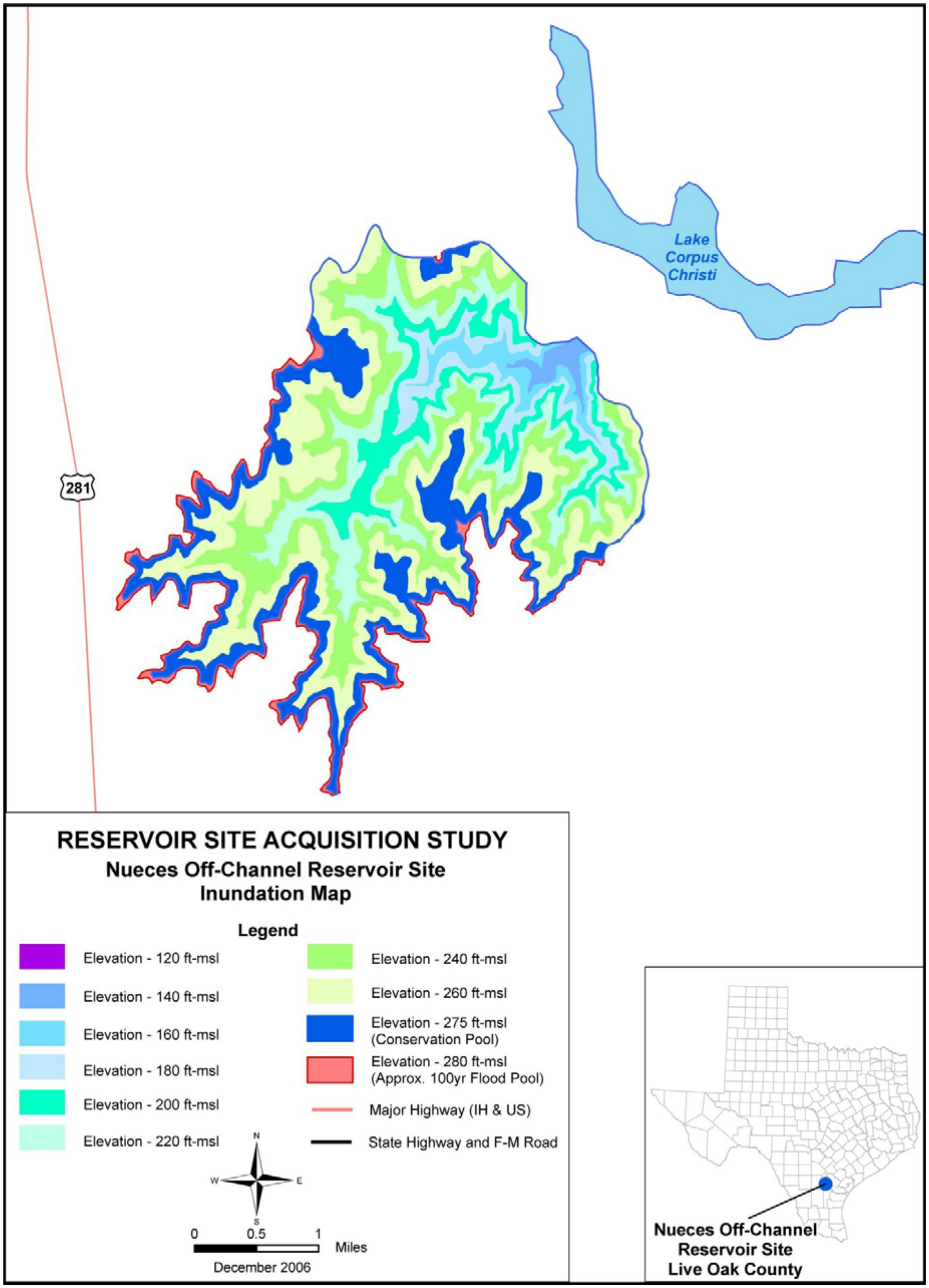

Figure 3.4.9-3. Inundation Map for Nueces Off-Channel Reservoir

Firm yield simulations were made for the historical period from 1934 to 2003 using the City of Corpus Christi's Phase IV Operations Plan (Naismith Engineering, 1999), the 2001 TCEQ Agreed Order (TCEQ, April 2001), and 2010 reservoir sedimentation conditions. It is assumed that Consensus Criteria for Environmental Flow Needs are not applicable because diversions are made from Lake Corpus Christi and the entire system is operated under the current Agreed Order. These simulations were performed using an updated version of the City of Corpus Christi's Lower Nueces River Basin and Estuary (NUBAY) Model (HDR, January 2006) that includes the capability to simulate the Nueces Off-Channel Reservoir. Operating guidelines for the reservoirs and the pump station and pipeline are detailed below.

Operational guidelines for the reservoir, pump station, and pipeline operations for the Nueces Off-Channel Reservoir were developed to identify the optimum set of Lake Corpus Christi elevation triggers, pipeline capacity, and Nueces Off-Channel Reservoir storage capacity. After several combinations were evaluated, the Nueces Off-Channel Reservoir, Choke Canyon Reservoir, and Lake Corpus Christi were operated in the following manner:

1. Water would be pumped from Lake Corpus Christi to fill the Nueces Off-Channel Reservoir, up to the capacity of the pump station and pipeline, any time the elevation in Lake Corpus Christi was 93 ft-msl or greater and storage was available in the Nueces Off-Channel Reservoir. The conservation pool elevation of Lake Corpus Christi is 94 ft-msl.
2. The Nueces Off-Channel Reservoir would release to Lake Corpus Christi any time the elevation in Lake Corpus Christi was less than or equal to 80 ft-msl.
3. Releases from Choke Canyon Reservoir were triggered when Lake Corpus Christi elevation level was less than or equal to 74 ft-msl.

Nueces Off-Channel Reservoir was most recently studied by Region N in the 2006 Regional Water Plan. In the Region N plan, Nueces Off-Channel was evaluated at four conservation storage capacities — 100,000 acft, 200,000 acft, 300,000 acft, and 400,000 acft. It was determined that the optimal size for the Nueces Off-Channel Reservoir is most likely somewhere between 200,000 acft and 300,000 acft.

Four potential conservation storage capacities are modeled herein for Nueces Off-Channel Reservoir. These conservation storage capacities are 150,000 acft, 200,000 acft, 250,000 acft, and 300,000 acft. Firm yield estimates for Nueces Off-Channel Reservoir for all four conservation capacities are shown in Table 3.4.9-2. Current planning initiatives envision a conservation capacity of 250,000 for Nueces Off-Channel Reservoir, thereby yielding an additional water supply of 39,935 acft/yr above the Lake Corpus Christi / Choke Canyon Reservoir System yield of 231,925 acft/yr. Figure 3.4.9-4 shows the relationship between firm yield and conservation capacity for Nueces Off-Channel Reservoir / Lake Corpus Christi / Choke Canyon Reservoir System. For the purposes of this study, diversion pump station and pipeline capacities were assumed to be 1,000 cfs for all four conservation capacities.

Table 3.4.9-2.
Firm Yield vs. Conservation Storage for Nueces Off-Channel Reservoir

Conservation Pool Elevation (ft-msl)	Conservation Storage (acft)	2010 Firm Yield[1] (acft/yr)	2010 Yield Increase (acft/yr)
253.4	150,000	257,335	25,410
265.2	200,000	264,765	32,840
275.3*	250,000	271,860	39,935
284.4	300,000	272,013	40,088

*Proposed conservation storage.
[1]Base System Yield without Nueces Off-Channel Reservoir is 231,925 acft/yr

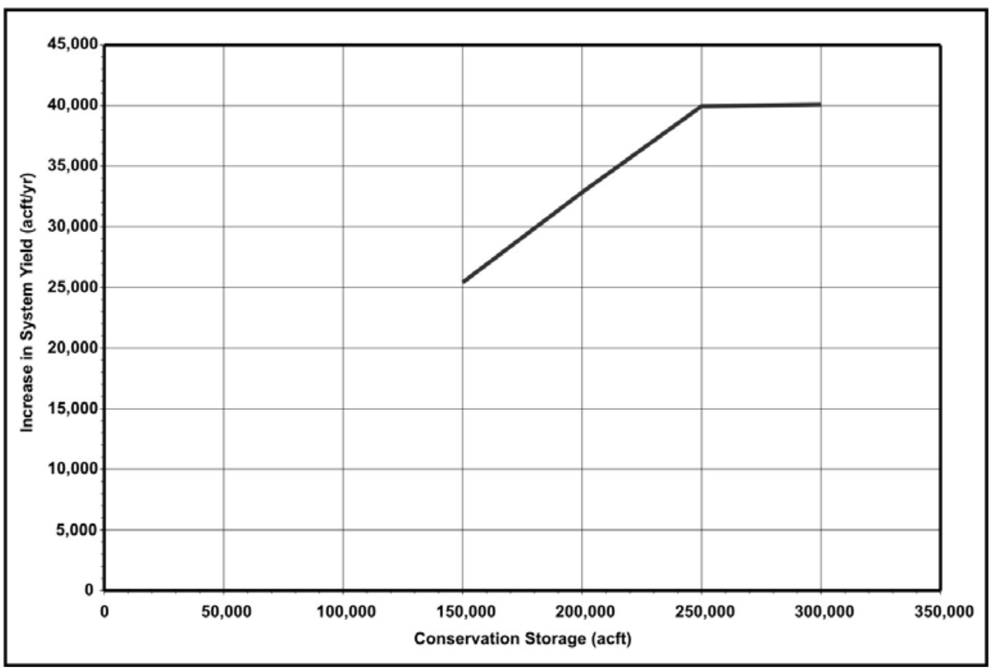

Figure 3.4.9-4. Firm Yield vs. Conservation Storage for Nueces Off-Channel Reservoir

Figure 3.4.9-5 illustrates storage fluctuations through time for Nueces Off-Channel Reservoir and Figure 3.4.9-6 shows the combined system storage in Lake Corpus Christi, Choke Canyon Reservoir, and Nueces Off-Channel Reservoir. The storage frequency curve in Figure 3.4.9-5 indicates that the reservoir would be full less than 10 percent of the time, more than half full about 45 percent of the time, and empty about 24 percent of the time. As shown in Figure 3.4.9-6, however, the system of reservoirs would be above 50 percent of storage capacity about 72 percent of the time.

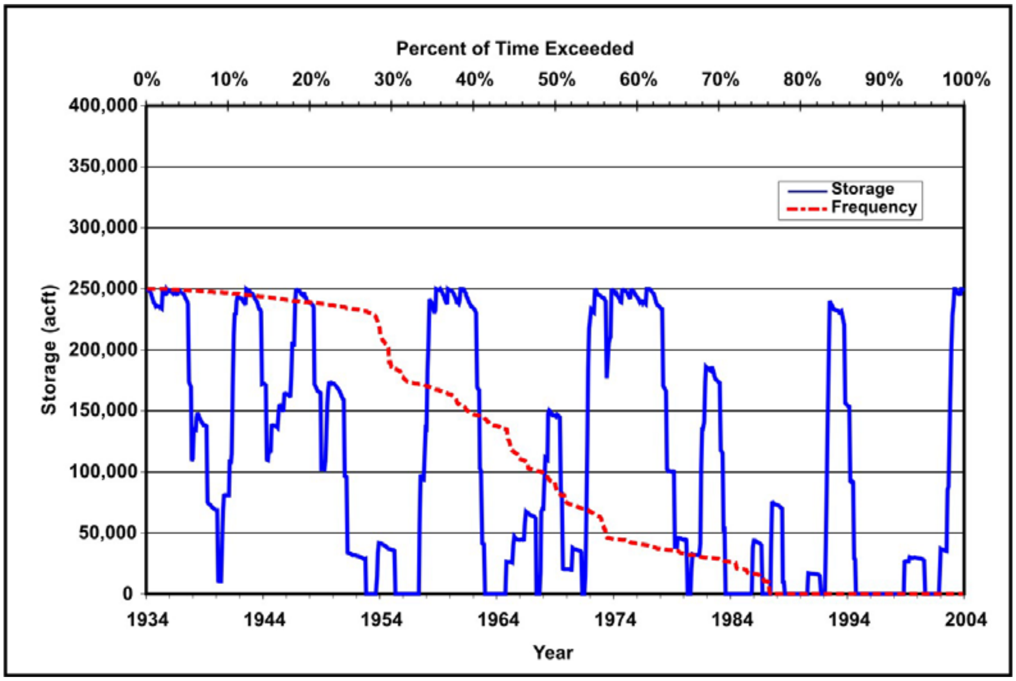

Figure 3.4.9-5. Simulated Storage in Nueces Off-Channel Reservoir (Conservation Elevation = 275.3 ft-msl, Incremental Yield = 39,935 acft/yr)

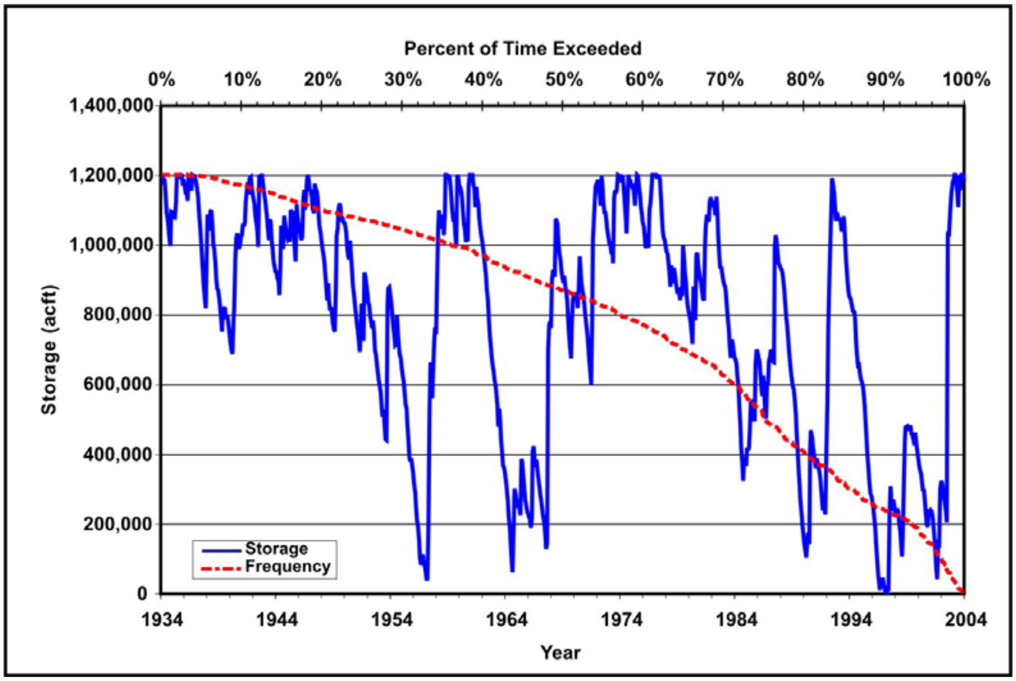

Figure 3.4.9-6. Simulated System Storage for Lake Corpus Christi, Choke Canyon Reservoir, and Nueces Off-Channel Reservoir (System Diversion = 271,860 acft/yr)

3.4.9.3 Reservoir Project Cost Estimates

The Nueces Off-Channel Reservoir is estimated to have a maximum earthen dam height of 135 feet. The diversion works from Lake Corpus Christi to the Nueces Off-Channel Reservoir includes a 646 MGD intake and pump station, a 2.8 mile, 120-inch pipeline, and a stilling basin. Figure 3.4.9-7 shows the major conflicts within the conservation pool of Nueces Off-Channel Reservoir. Potential conflicts include oil and gas wells, water wells, product transmission pipelines, and a power transmission line. Resolution of facility conflicts represents approximately 5 percent of the total construction cost.

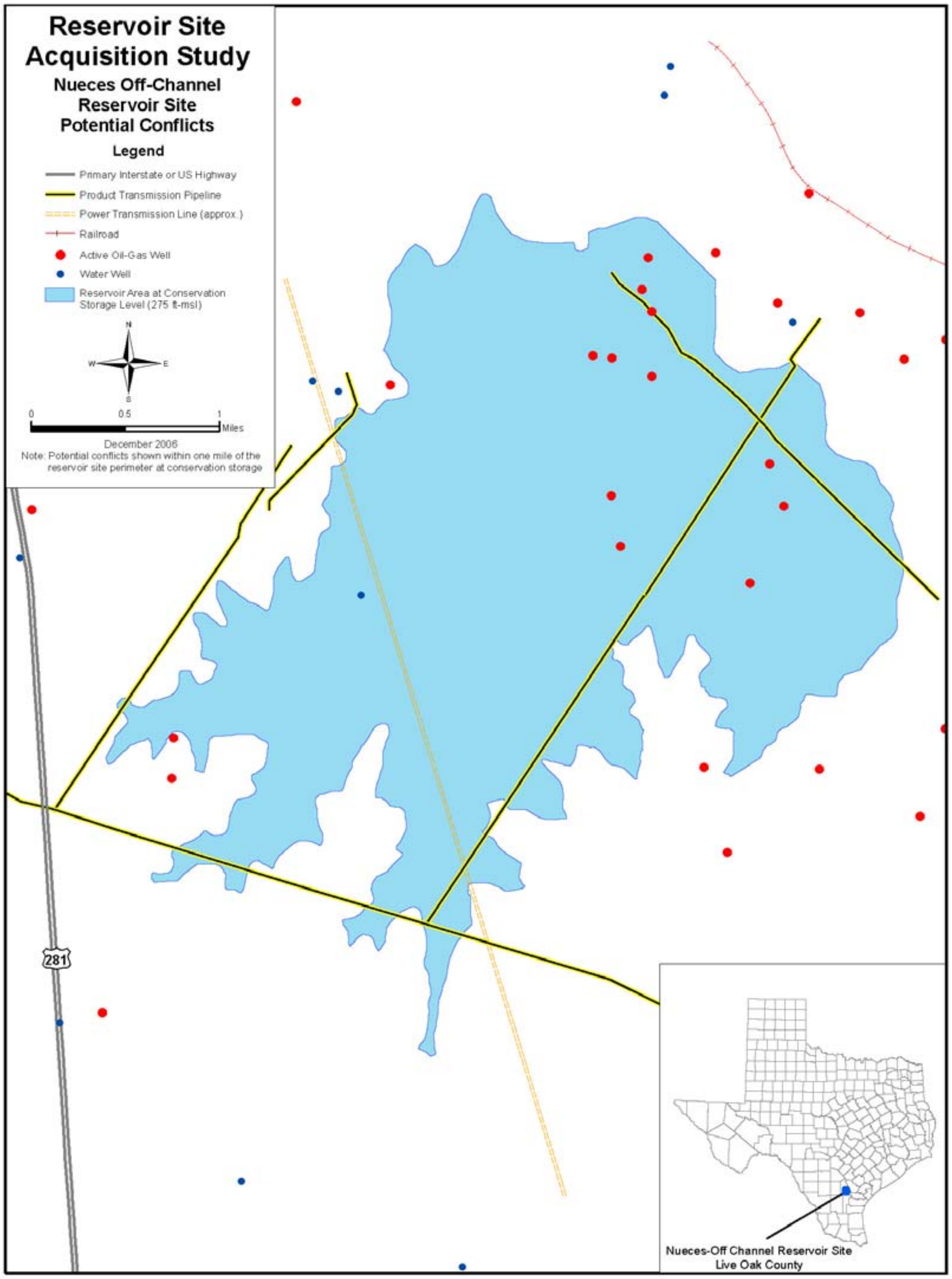

Figure 3.4.9-7. Potential Major Conflicts for Nueces Off-Channel Reservoir

A summary cost estimate for Nueces Off-Channel Reservoir at elevation 275 ft-msl (250,000 acft) is shown in Table 3.4.9-3. Quantities and relocation costs are detailed information from the 2006 Region N Water Plan. Dam and reservoir costs total about $97 million, while relocations total another $9.8 million. Land, which includes mitigation lands, totals about $11.7 million. The diversion intake, pump station, and pipeline from Lake Corpus Christi to the

Nueces Off-Channel Reservoir adds another $70 million. Annual costs for Nueces Off-Channel Reservoir are approximately $17 million during the 40-year debt service period, giving the project a unit cost of raw water at the reservoir of $425/acft ($1.31 per 1000 gallons).

Table 3.4.9-3.
Cost Estimate — Nueces Off-Channel Reservoir @ 275.3 ft-msl

	Quantity	*Unit*	*Unit Price*	*Cost*
Dam & Reservoir				
Dam Embankment	14,363,228	CY	$5.00	$71,816,140
Engineering Contingencies (35%)				$25,135,649
Subtotal Dam & Reservoir				**$96,951,789**
Pump & Pipeline				
Pump Station & Intake (25,820 HP; 646 MGD)	1	LS	$35,233,653	$35,233,653
Pipeline (120-inch)	14,770	LF	$870	$12,849,900
Stilling Basin (1000 cfs)	1	LS	$3,751,000	$3,751,000
Engineering Contingencies (35%)				$18,142,093
Subtotal Pump & Pipeline				**$69,976,646**
Conflicts				
H20 Wells	2	EA	$25,000	$50,000
Oil & Gas Wells	15	EA	$50,000	$750,000
Oil & Gas Pipeline	55,144	LF	$42	$2,316,055
Power Transmission Line	16,111	LF	$450	$7,249,989
Engineering Contingencies (35%)				$2,537,496
Subtotal Conflicts				**$9,787,485**
Land				
Land Acquisition	5,294	AC	$1,111	$5,881,634
Environmental Studies and Mitigation Lands	5,294	AC	$1,111	$5,881,634
Subtotal Land				**$11,763,268**
CONSTRUCTION TOTAL				**$188,479,188**
Interest During Construction (36 months)				**$22,617,503**
TOTAL COSTS				**$211,096,690**
ANNUAL COSTS				
Debt Service (6% for 40 Years)				$14,029,486
Operations & Maintenance				$2,501,127
Pumping Energy				$459,792
Total Annual Costs				**$16,990,405**
Firm Yield (acft/yr)				**39,935**
Unit Costs of Water ($/acft/yr)				**$425**

3.4.9.4 Environmental Considerations

The Nueces Off-Channel Reservoir site is located adjacent to TCEQ-classified stream segment 2103. Although Texas Parks and Wildlife Department (TPWD) considers the upstream and downstream segments of the Nueces River ecologically significant (TPWD, 1999), it does not include Lake Corpus Christi, from which diversions to the Nueces Off-Channel Reservoir would be made, in this classification.

The Nueces Off-Channel Reservoir will inundate 5,294 acres of land at conservation storage capacity. Table 3.4.9-4 and Figure 3.4.9-8 summarize existing landcover for the Nueces Off-Channel Reservoir site as determined by TPWD using methods described in Appendix C. Existing landcover within this reservoir site is dominated by grassland (49 percent) and shrubland (43 percent).

Table 3.4.9-4.
Acreage and Percent Landcover for Nueces Off-Channel Reservoir

Landcover Classification	*Acreage[1]*	*Percent*
Grassland	2,637	49.4%
Shrubland	2,280	42.7%
Broad Leaf Evergreen Forest	394	7.4%
Urban / Developed Land	25	0.5%
Total	**5,336**	**100.0%**

[1] Acreage based on approximate GIS coverage rather than calculated elevation-area-capacity relationship.

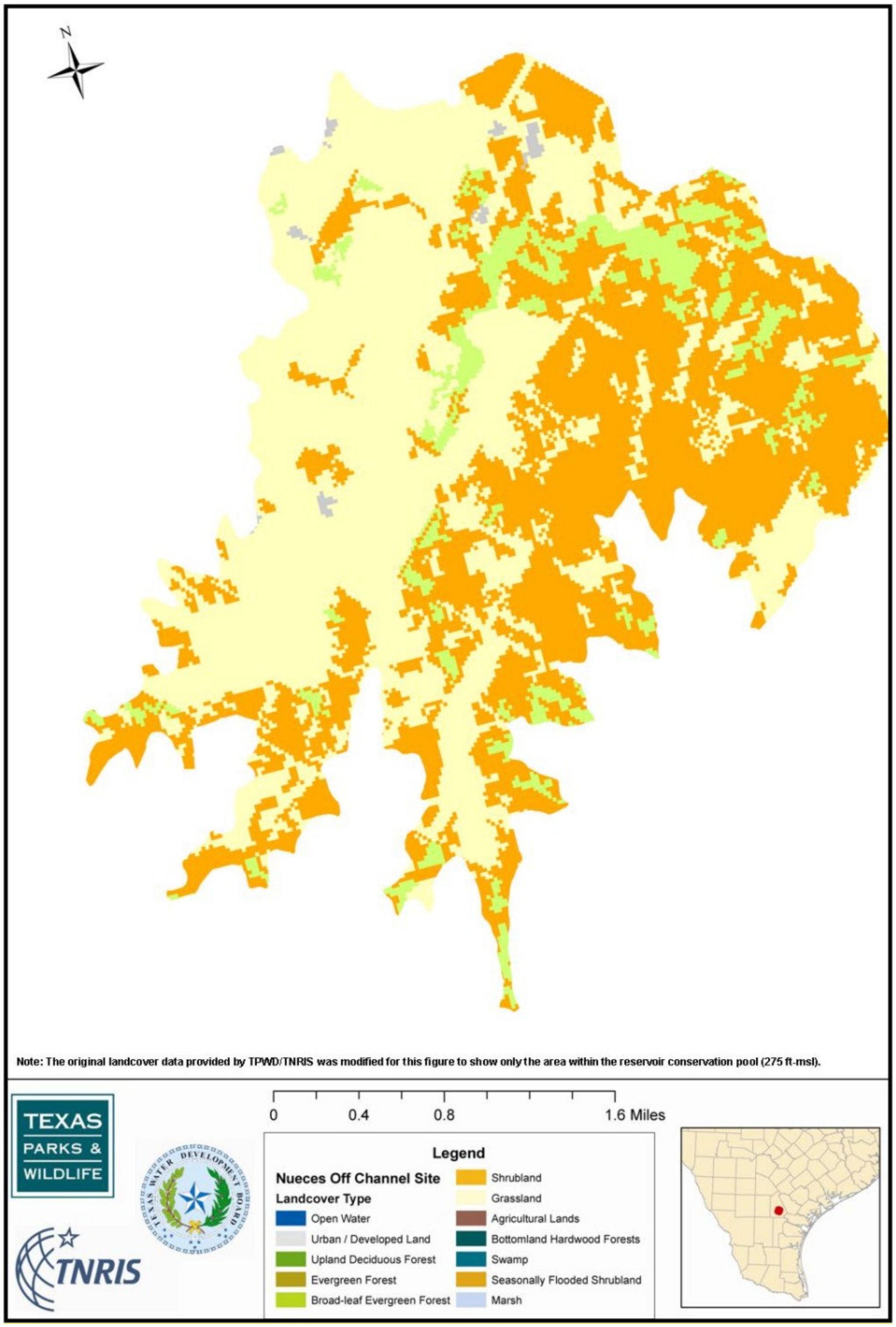

Figure 3.4.9-8. Existing Landcover for Nueces Off-Channel Reservoir

3.4.10 Palmetto Bend Reservoir — Stage II

3.4.10.1 Project Description

The Texas Water Development Board (TWDB) and the Lavaca-Navidad River Authority (LNRA) hold Certificate of Adjudication No. 16-2095B, for the completion of Palmetto Bend Stage II Dam and Reservoir (Stage II of Lake Texana) on the Lavaca River. Stage I, now known as Lake Texana, was completed in 1981 and is located on the Navidad River. Stage I is operated by LNRA for water supply purposes and has a firm yield of 79,000 acft/yr.

Originally, the U.S. Bureau of Reclamation proposed that Stage II would be located on the Lavaca River and share a common pool with Stage I (Lake Texana). However, previous studies have shown that Stage II could be constructed more economically if operated separately from Lake Texana and located further upstream at an alternative site on the Lavaca River (HDR, May 1991). As proposed, at the original site, the Certificate of Adjudication states (TNRCC, 1994):

> "Upon completion of the Stage 2 dam and reservoir on the Lavaca River, owner Texas Water Development Board is authorized to use an additional amount of 18,122 acft/yr, for a total of 48,122 acft/yr, of which up to 7,150 acft/yr shall be for municipal purposes, up to 22,850 acft/yr shall be for industrial purposes, and at least 18,122 acft/yr shall be for the maintenance of the Lavaca-Matagorda Bay and Estuary System. The entire Stage 2 appropriation remains subject to release of water for the maintenance of the bay and estuary system until a release schedule is developed pursuant to the provisions of Section 4.B of this certificate of adjudication."

For the purposes of this study, Stage II is assumed to be constructed at the alternative site located approximately 1.4 miles upstream of the original site (Figure 3.4.10-1). Since this site results in a different yield than stated in the certificate, the conditions in the certificate will need to be revised to account for the change in yield of Stage II. The revisions to the certificate should also reflect the impacts that joint operations of Lake Texana and Palmetto Bend Stage II could have on the releases necessary to maintain the bay and estuary system downstream of the projects.

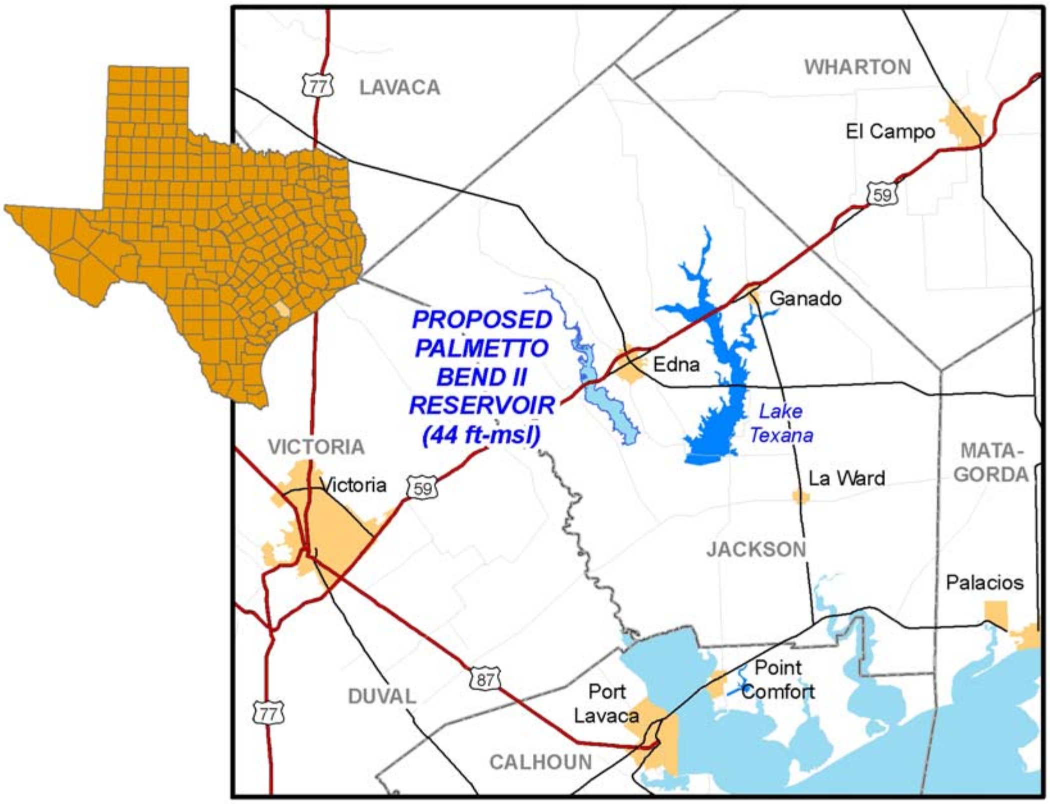

Figure 3.4.10-1. Location Map of Palmetto Bend Reservoir — Stage II

The LNRA has expressed a renewed interest in the potential development of Stage II. In the 2001 Coastal Bend Regional Water Plan (HDR, 2006), water supply from the development of Stage II was evaluated as part of an interregional water supply by both the Coastal Bend Regional Water Planning Group (Region N) and the South Central Texas Regional Water Planning Group (Region L). Previously, the South Central Texas Region Water Planning Group considered two Stage II water delivery options: to coastal irrigation areas near the Colorado River at Bay City and to the Guadalupe River near the Saltwater Barrier. However, the South Central Texas Regional Water Planning Group did not recommend these options in either the 2001 or 2006 regional water plans. Stage II is a recommended water management strategy in the 2006 Coastal Bend Regional Water Plan.

Projected municipal, industrial (including manufacturing), and steam-electric needs for additional water supply prior to year 2060 total 79,857 acft/yr for counties within a 50-mile radius of the Palmetto Bend Reservoir – Stage II site. The 50-mile radius encompasses all or parts of Aransas, Calhoun, Colorado, Dewitt, Goliad, Jackson, Lavaca, Matagorda, Refugio, Victoria, and Wharton Counties. The nearest major population and water demand centers to the Palmetto Bend Reservoir – Stage II site are Corpus Christi (93 miles) and Houston (100 miles).

3.4.10.2 Reservoir Yield Analyses

The elevation-area-capacity relationship for Palmetto Bend Reservoir – Stage II is presented in Figure 3.4.10-2 and Table 3.4.10-1 and was developed from 10-ft contour, digital hypsography data from the Texas Natural Resources Information System (TNRIS). These data are derived from the 1:24,000-Scale (7.5-minute) quadrangle maps developed by the USGS. The total area inundated at each 10-ft elevation contour is shown in Figure 3.4.10-3. Surface areas and capacities associated with 44 ft-msl are computed by linear interpolation between values for 40 ft-msl and 45 ft-msl and are subject to future refinement based on more detailed topographic information. At the conservation storage pool elevation of 44 ft-msl, Palmetto Bend Reservoir – Stage II would inundate 4,564 acres and have a capacity of 52,046 acft.

Table 3.4.10-1.
Elevation-Area-Capacity Relationship for
Palmetto Bend Reservoir – Stage II

Elevation (feet)	Area (acres)	Capacity (acft)
4	0	0
5	16	5
10	49	161
15	92	507
20	159	1,127
25	609	2,927
30	1,649	8,360
35	2,725	19,182
40	3,688	35,152
44	4,564	52,046
45	4,783	56,269
50	5,868	82,851

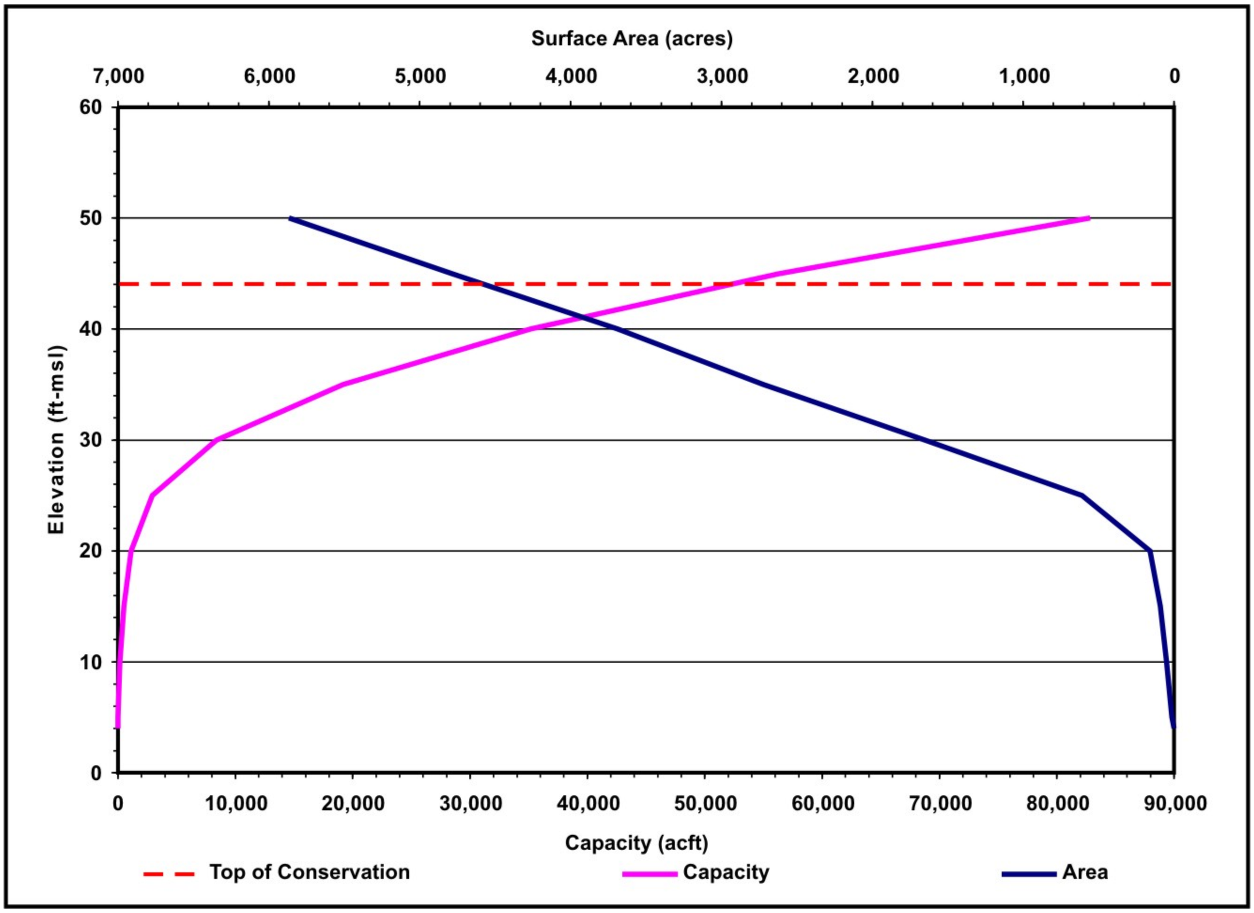

Figure 3.4.10-2. Elevation-Area-Capacity Relationship for Palmetto Bend Reservoir – Stage II

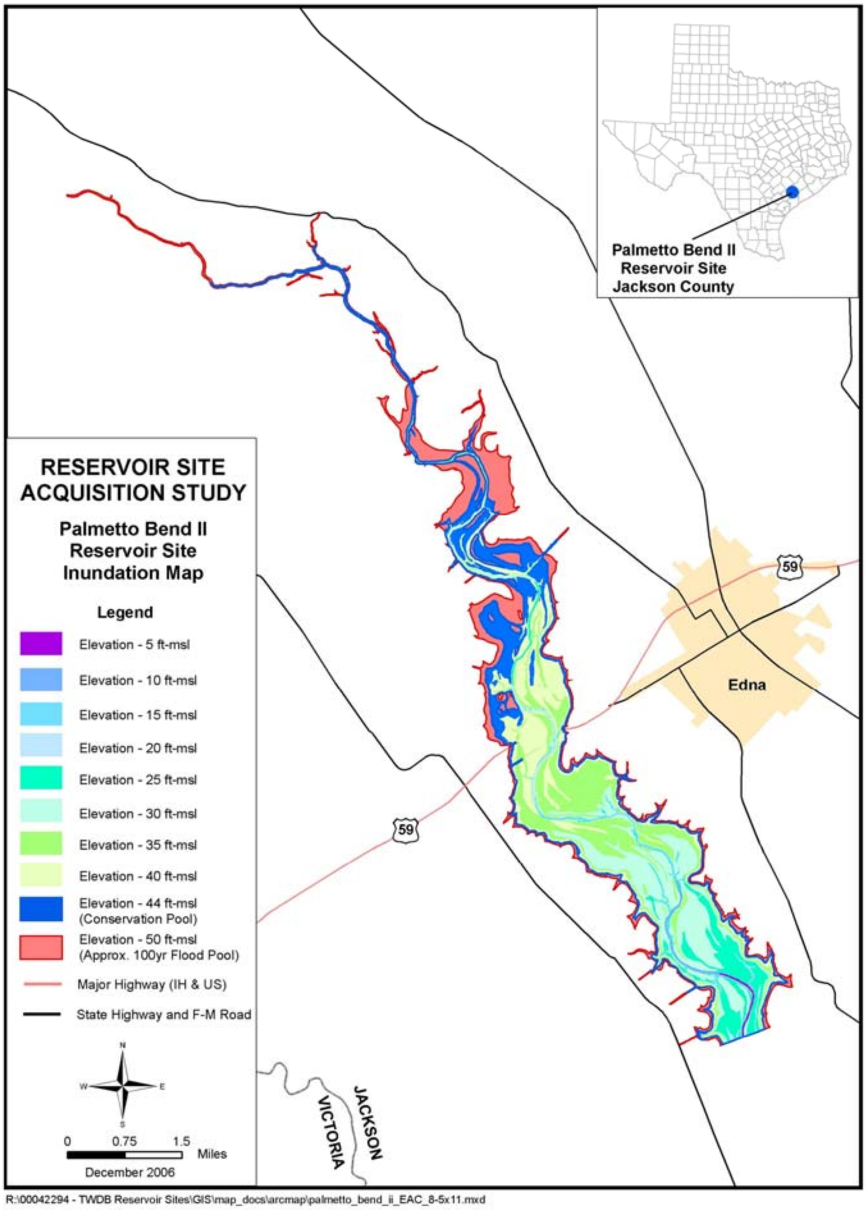

Figure 3.4.10-3. Inundation Map for Palmetto Bend Reservoir – Stage II

The Consensus Criteria for Environmental Flow Needs (CCEFN) (TWDB, August 1997), a three-staged criteria that uses percentage of reservoir capacity as triggers for determining the pass-through requirement, is used for modeling of Palmetto Bend Reservoir – Stage II. Pass-through flows are the monthly naturalized median flow when reservoir storage is greater than 80 percent of capacity, the monthly naturalized 25th percentile flow when the reservoir is between 50 and 80 percent of capacity, and the published 7Q2 when reservoir capacity is less than 50 percent of conservation capacity. The CCEFN values used include the median and quartile flows in Table 3.4.10-2 and the 7Q2 value of 21.6 cfs published in the Texas Surface Water Quality Standards (Texas Administrative Code).

Table 3.4.10-2.
Consensus Criteria for Environmental Flow Needs for
Palmetto Bend Reservoir – Stage II

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Median (cfs)	63.0	92.8	76.9	78.9	92.2	85.6	47.5	37.3	41.2	39.2	48.3	55.1
Median (acft)	3,874	5,154	4,728	4,695	5,669	5,094	2,921	2,294	2,452	2,410	2,874	3,388
Quartile (cfs)	26.1	39.0	37.6	36.8	35.4	36.7	22.7	21.6	21.6	21.6	21.6	24.3
Quartile (acft)	1,605	2,166	2,312	2,190	2,177	2,186	1,396	1,328	1,285	1,328	1,285	1,494
7Q2 (cfs)	21.6	21.6	21.6	21.6	21.6	21.6	21.6	21.6	21.6	21.6	21.6	21.6
7Q2 (acft)	1,328	1,200	1,328	1,285	1,328	1,285	1,328	1,328	1,285	1,328	1,285	1,328

The firm yield of Palmetto Bend Reservoir – Stage II is estimated by using the TCEQ Lavaca River Basin Water Availability Model (Lavaca WAM) (USBR, 2001) data sets and the Water Rights Analysis Package (WRAP) (TCEQ, 2004). The Lavaca WAM simulates a repeat of the natural streamflows over the 57-year period of 1940 through 1996 accounting for the appropriated water rights of the Lavaca River Basin with respect to location, priority date, diversion amount, diversion pattern, storage, and special conditions including instream flow requirements.

Four potential conservation storage capacities are modeled for Palmetto Bend Reservoir – Stage II. These conservation storage capacities are associated with 50 ft-msl, 44 ft-msl, 40 ft-msl, and 35 ft-msl conservation pool elevations. Table 3.4.10-3 includes the conservation storage capacities associated with these four conservation elevations.

Palmetto Bend Reservoir – Stage II is simulated with the priority date as provided by TCEQ in Certificate of Adjudication No. 16-2095B. Firm yield estimates for Palmetto Bend Reservoir – Stage II for all four conservation elevations are shown in Table 3.4.5-3. Current planning envisions a conservation elevation of 44 ft-msl for Palmetto Bend Reservoir – Stage II, thereby yielding a water supply of 22,964 acft/yr. Figure 3.4.10-4 shows the relationship between firm yield and conservation capacity for Palmetto Bend Reservoir – Stage II.

Table 3.4.10-3.
Firm Yield vs. Conservation Storage for Palmetto Bend Reservoir – Stage II

Conservation Pool Elevation (ft-msl)	Conservation Storage (acft)	Environmental Bypass Criteria	Yield (acft/yr)
35.0	19,182	CCEFN	8,878
40.0	35,152	CCEFN	16,819
44.0*	52,046	CCEFN	22,964
		None	30,606
50.0	82,851	CCEFN	31,161

*Proposed conservation storage.

Palmetto Bend Reservoir – Stage II was most recently evaluated by Regions L and N in the 2001 Regional Water Plans. The firm yield of Palmetto Bend Reservoir – Stage II was reported as 28,000 acft/yr at conservation elevation 44 ft-msl. The firm yield estimate in the current study differs from the 2001 Regional Water Plans because SIMDLY (a daily reservoir simulation model), rather than the WRAP model was used in regional planning. In addition, the refined elevation-area-capacity relationship in the current study has reduced the conservation capacity at elevation 44 ft-msl from 57,676 acft to 52,046 acft.

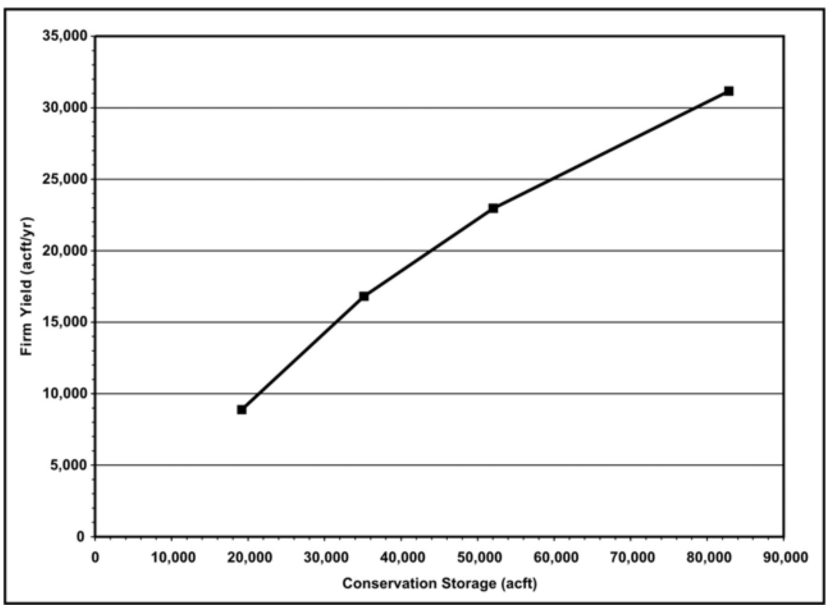

Figure 3.4.10-4. Firm Yield vs. Conservation Storage for Palmetto Bend Reservoir – Stage II

Figure 3.4.10-5 illustrates storage fluctuations through time for Palmetto Bend Reservoir – Stage II subject to firm yield diversions and CCEFN. The reservoir storage frequency curve in Figure 3.4.10-5 indicates that the reservoir would be full about 38 percent of the time and more than half full about 90 percent of the time.

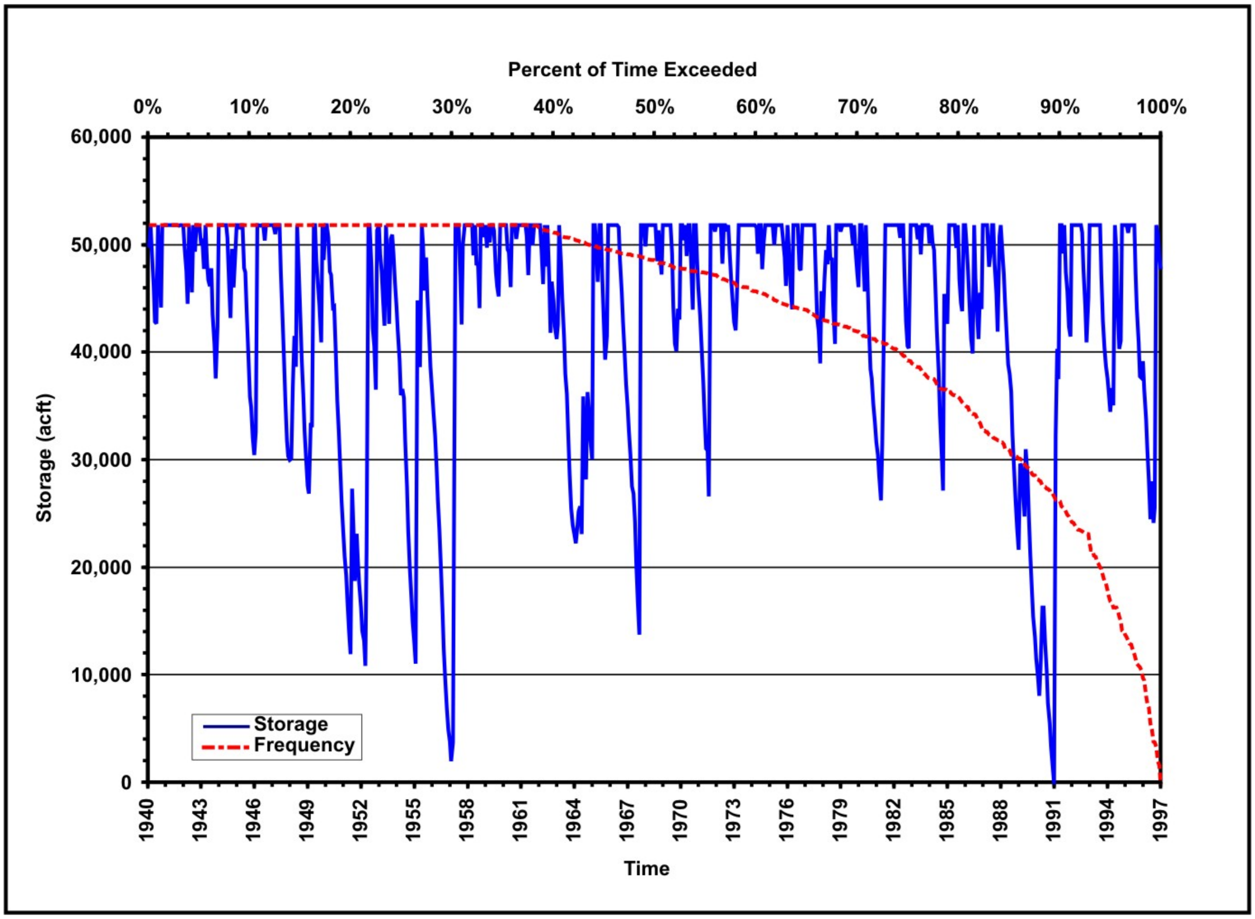

Figure 3.4.10-5. Simulated Storage in Palmetto Bend Reservoir – Stage II (Conservation Elevation = 44 ft-msl, Diversion = 22,964 acft/yr)

3.4.10.3 Reservoir Project Cost Estimates

Costs for Palmetto Bend Reservoir – Stage II assume a zoned earthen embankment and uncontrolled spillway. The dam is estimated to be approximately 6,000 feet in length and have a maximum height of approximately 50 feet. Figure 3.4.10-6 shows the major conflicts within the conservation pool of Palmetto Bend Reservoir – Stage II. Potential conflicts include water wells, oil & gas wells, product transmission pipelines, power transmission lines, a railway, and U.S. Highway 59. Resolution of facility conflicts represents approximately 29 percent of the total construction cost.

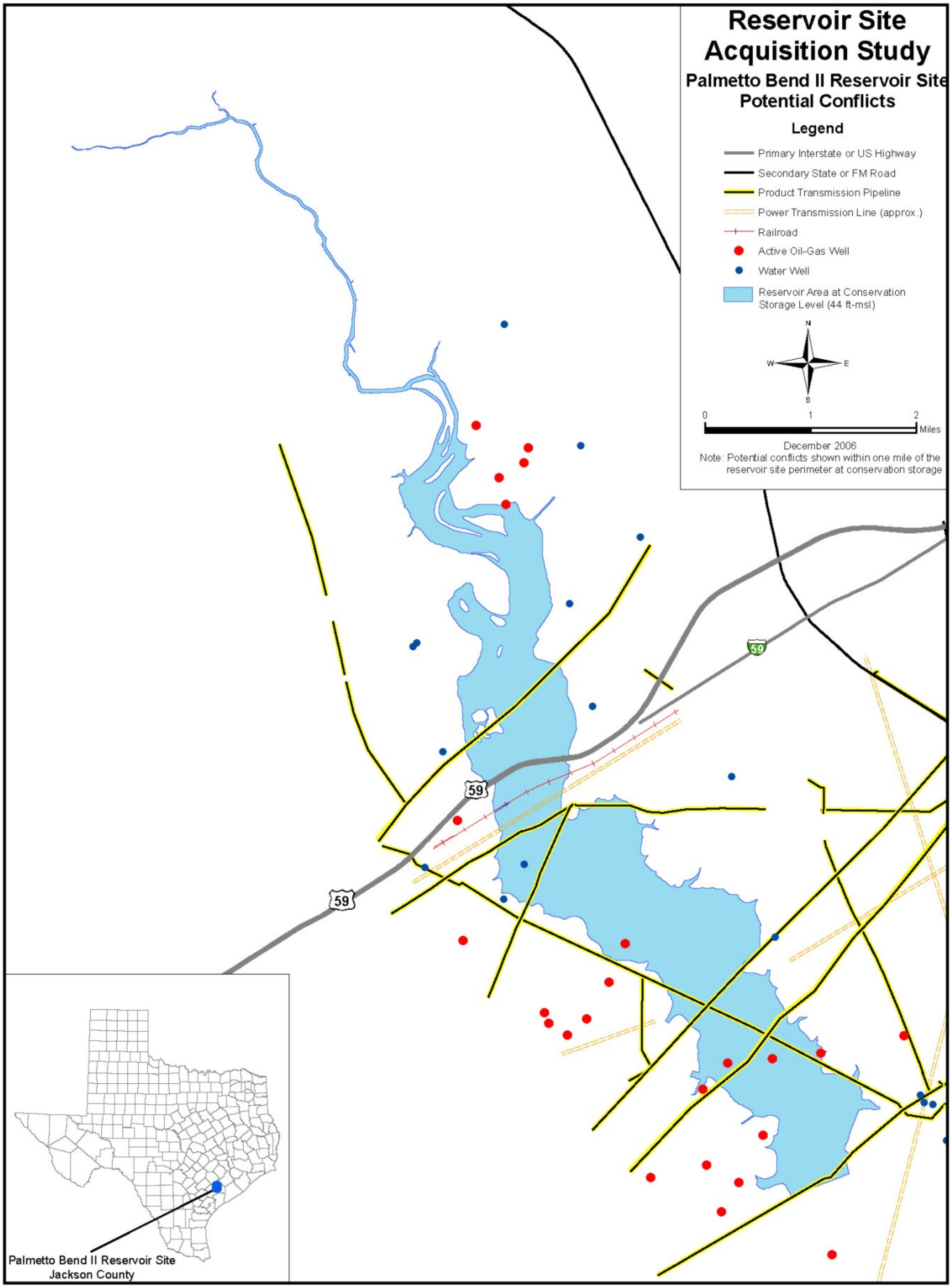

Figure 3.4.10-6. Potential Major Conflicts for Palmetto Bend Reservoir – Stage II

A summary cost estimate for Palmetto Bend Reservoir – Stage II at elevation 44 ft-msl is shown in Table 3.4.10-4. Dam and reservoir costs total about $83.8 million, while relocations total another $41.3 million. Land, which includes mitigation lands, totals about $17 million. Annual costs for Palmetto Bend Reservoir – Stage II are approximately $11.8 million during the 40-year debt service period, giving the project a unit cost of raw water at the reservoir of $515/acftr ($1.58 per 1000 gallons).

Table 3.4.10-4.
Cost Estimate — Palmetto Bend Reservoir – Stage II @ Elevation 44 ft-msl
(page 1 of 2)

	Quantity	*Unit*	*Unit Price*	*Cost*
Dam & Reservoir				
Mobilization (5%)	1	LS		$2,797,713
Clearing and Grubbing		LS		$1,659,435
Care of Water During Construction (3%)	1	LS		$1,678,628
Dam		LS		$2,887,690
Spillway		LS		$41,022,059
Excess Excavation Disposal Berms & Drainage Channels		LS		$6,599,656
Upstream Slope Protection		LS		$1,436,364
Underdrain System		LS		$737,225
Channel Slope Protection		LS		$1,566,942
Dam Road		LS		$711,381
Revegetation		LS		$992,941
Engineering Contingencies (35%)				$21,731,512
Subtotal Dam & Reservoir				**$83,821,546**
Conflicts				
H20 Drill	2	EA	$25,000	$50,000
H20 Wells	5	EA	$25,000	$125,000
Oil & Gas Wells	4	EA	$25,000	$100,000
Oil & Gas Pipeline	48,619	LF	$98	$4,764,639
Power Transmission Line	25,580	LF	$450	$11,511,157
Rail	4,246	LF	$750	$3,184,675
Major Roads	12,094	LF	$900	$10,884,532
Engineering Contingencies (35%)				$10,717,001
Subtotal Conflicts				**$41,337,004**

Table 3.4.10-4.
Cost Estimate — Palmetto Bend Reservoir – Stage II @ Elevation 44 ft-msl
(page 2 of 2)

Land				
Land Acquisition	5,217	AC	$1,627	$8,488,059
Environmental Studies and Mitigation Lands	5,217	AC	$1,627	$8,488,059
Subtotal Land				**$16,967,118**
CONSTRUCTION TOTAL				**$142,134,667**
Interest During Construction (36 months)				**$17,056,160**
TOTAL COSTS				**$159,190,827**
ANNUAL COSTS				
Debt Service (6% for 40 Years)				$10,579,822
Operations & Maintenance				$1,257,323
Total Annual Costs				**$11,837,146**
Firm Yield (acft/yr)				**22,964**
Unit Costs of Water ($/acft/yr)				**$515**

3.4.10.4 Environmental Considerations

Palmetto Bend Reservoir – Stage II will inundate a portion of TCEQ-classified stream segment 1601 on the Lavaca River. Texas Parks and Wildlife Department (TPWD, 1999) listed the segment of the Lavaca River immediately downstream of the reservoir as ecologically significant. Palmetto Bend Reservoir – Stage II could have effects relevant to two TPWD criteria as follows:

- Biological Function — Extensive freshwater wetland habitat displays significant overall habitat value.
- Threatened or Endangered Species/Unique Communities — the diamondback terrapin is a species of concern.

Palmetto Bend Reservoir – Stage II will inundate 4,564 acres of land at conservation storage capacity. Table 3.4.10-5 and Figure 3.4.10-7 summarize existing landcover for the Palmetto Bend Reservoir – Stage II Reservoir site as determined by TPWD using methods described in Appendix C. Existing landcover within this reservoir site is dominated by grassland (42 percent) with broad-leaf evergreen forest (34 percent) and upland deciduous forest (11 percent) concentrated along the Lavaca River.

Table 3.4.10-5.
Acreage and Percent Landcover for Palmetto Bend Reservoir – Stage II

Landcover Classification	***Acreage[1]***	***Percent***
Grassland	2,020	42.2%
Broad Leaf Evergreen Forest	1,630	34.0%
Agricultural Land	234	4.9%
Upland Deciduous Forest	515	10.8%
Shrubland	365	7.6%
Open Water	22	0.5%
Total	**4,786**	**100.0%**

[1] Acreage based on approximate GIS coverage rather than calculated elevation-area-capacity relationship.

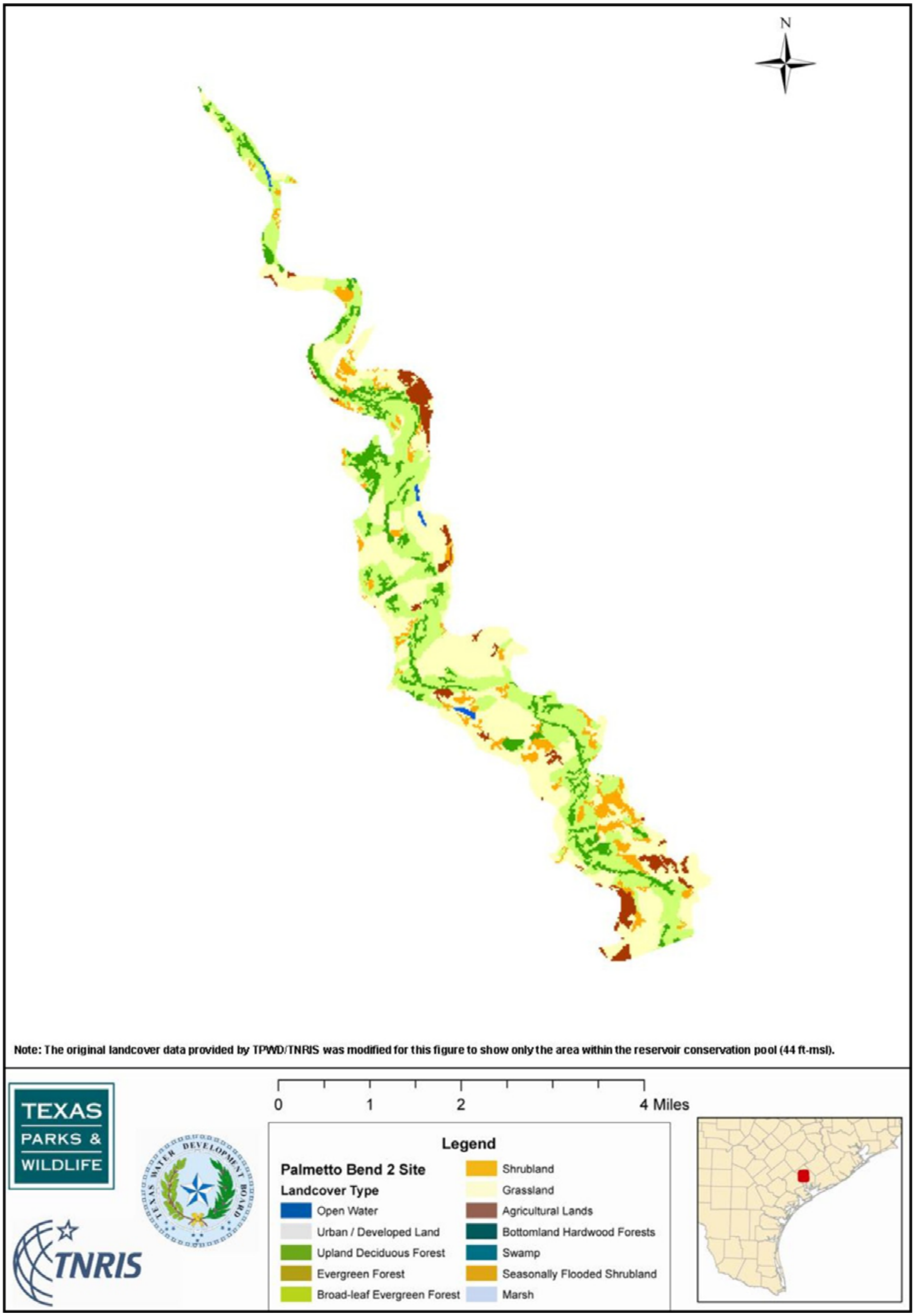

Figure 3.4.10 -7. Existing Landcover for Palmetto Bend Reservoir – Stage II

(This page intentionally left blank.)

3.4.11 George Parkhouse I Lake

3.4.11.1 Description

George Parkhouse I Lake would be located on the South Sulphur River in Delta and Hopkins Counties, about 18 miles northeast of the City of Sulphur Springs. Figure 3.4.11-1 shows the location of the reservoir. The proposed conservation pool is at elevation 401 ft-msl, with a conservation capacity of 651,712 acft. The inundated area at the top of conservation pool is 28,855 acres. The reservoir has a total drainage area of 654 square miles, of which 479 are above Lake Chapman.

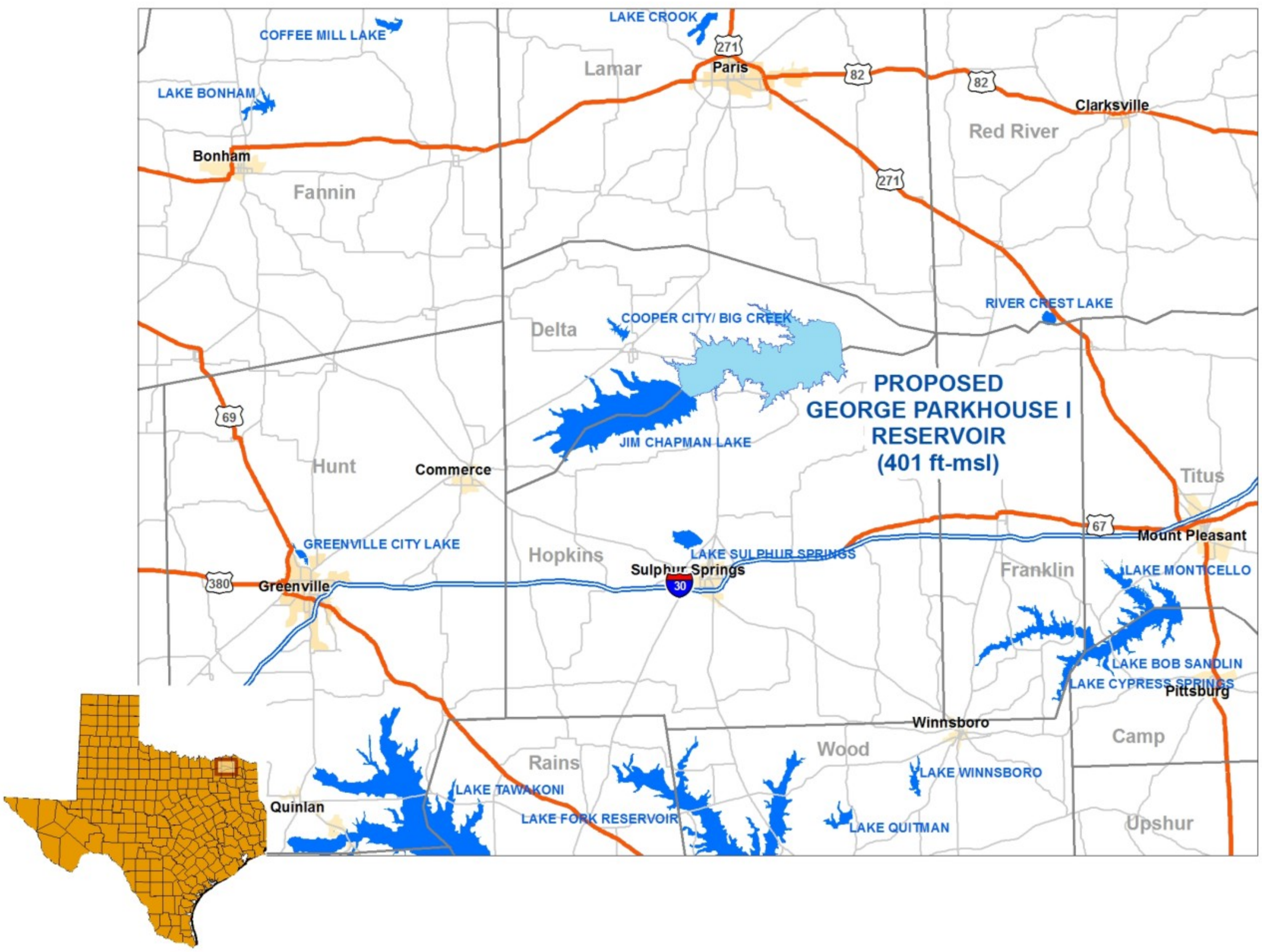

Figure 3.4.11-1. Location Map of George Parkhouse I Lake

This reservoir has been previously studied by Freese and Nichols (1990, 1996, and 2000) and it is an alternate water management strategy for North Texas Municipal Water District and the Upper Trinity River Water District in the 2006 *Region C Water Plan* (Freese and Nichols *et al*., 2006a).

The George Parkhouse I Lake site is not a recommended unique reservoir site in the 2006 regional water plans, but it is one of several potential reservoir sites in the Sulphur River Basin. The projected needs for additional water supply within 50 miles of the proposed reservoir site are 561,591 acft/yr. Much of this need is associated with Region C, located west of the proposed reservoir site. The nearest major demand center is the Dallas-Fort Worth metroplex, which is located approximately 93 miles southwest of the reservoir site.

3.4.11.2 Reservoir Yield Analysis

The elevation-area-capacity relationship is included in Table 3.4.11-1 and shown in Figure 3.4.11-2. The data in Table 3.4.11-1 were developed by Freese and Nichols (2000) by measurement from U.S. Geological Survey topographic quadrangle maps with scale 1:24,000 and 10-foot contours. Figure 3.4.11-3 shows the inundation map at different elevations in a 10-foot interval. The elevation of the 100-year flood and the maximum probable flood depend on how the storm is routed through Lake Chapman. Lake Chapman flood control operations may change if George Parkhouse I Lake is built. The analysis required to determine the elevation of the 100-year flood and probable maximum flood requires detailed hydrologic modeling that are not part of the scope of this study. Therefore, the inundated areas during the representative flood events are not included for this reservoir.

Table 3.4.11-1.
Elevation-Area-Capacity Relationship for George Parkhouse I Lake

Elevation (feet)	Area (acres)	Capacity (acft)
335.0	0	0
340.0	28	74
345.0	242	745
350.0	456	2,489
355.0	2,513	9,884
360.0	4,571	27,584
365.0	6,567	55,423
370.0	8,563	93,245
375.0	11,158	142,543
380.0	13,752	204,814
385.0	17,270	282,363
390.0	20,787	377,499
395.0	24,563	490,868
400.0	28,338	623,116
401.0	28,855	651,712
405.0	30,922	771,264
410.0	33,506	932,332

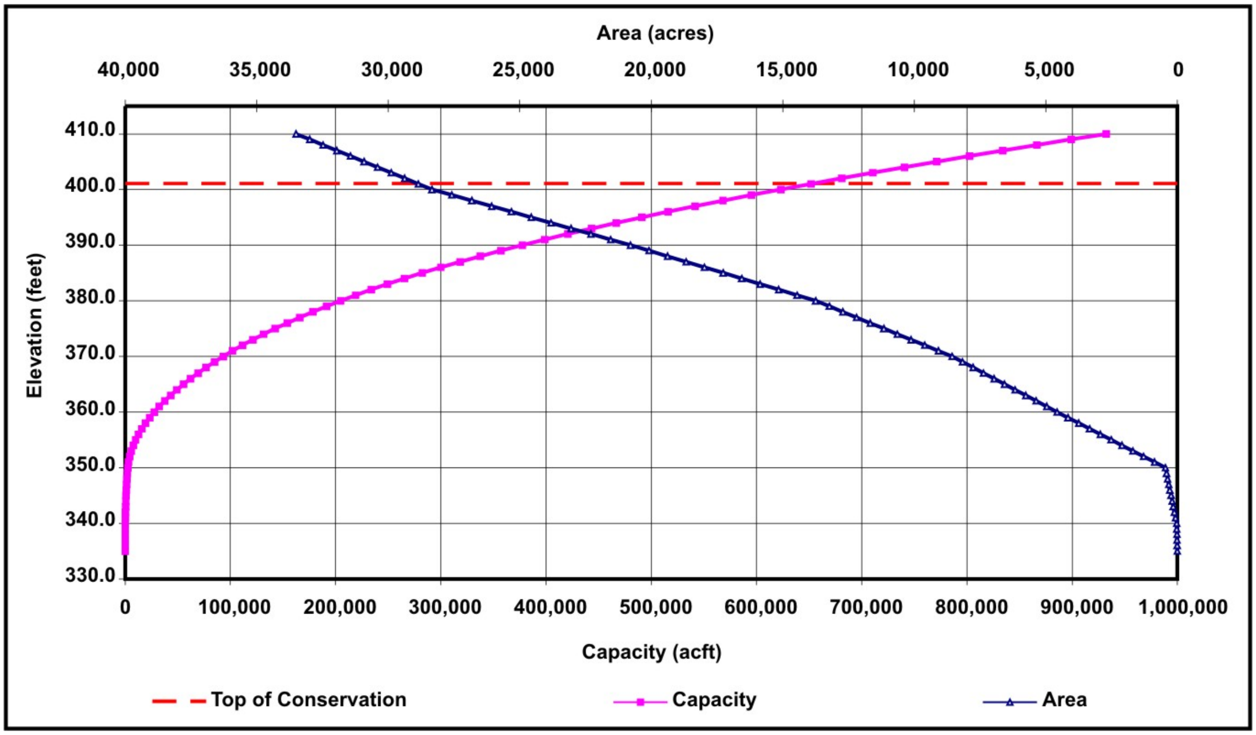

Figure 3.4.11-2. Elevation-Area-Capacity Relationship for George Parkhouse I Lake

The reservoir will be subject to bypass of inflow for environmental needs. Table 3.4.11-2 includes the environmental flows needs calculated using the Consensus Criteria for Environmental Flow Needs (TWDB, 1997). The analyses assume that the reservoir will have to pass the lesser of the inflow and the values of Table 3.4.11-2.

Table 3.4.11-2.
Consensus Criteria for Environmental Flow Needs for George Parkhouse I Lake

	Median		*25th Percentile*		*7Q2*	
	acft	***cfs***	***acft***	***cfs***	***acft***	***cfs***
Jan	1,919	31.2	318	5.2	0	0.0
Feb	3,596	64.2	794	14.2	0	0.0
Mar	3,748	60.9	800	13.0	0	0.0
Apr	2,697	45.3	638	10.7	0	0.0
May	4,687	76.2	741	12.0	0	0.0
Jun	1,854	31.1	294	4.9	0	0.0
Jul	233	3.8	22	0.4	0	0.0
Aug	47	0.8	0	0.0	0	0.0
Sep	72	1.2	0	0.0	0	0.0
Oct	180	2.9	9	0.2	0	0.0
Nov	696	11.7	88	1.5	0	0.0
Dec	1,916	31.1	177	2.9	0	0.0
Total	21,644		3,879		0	
Average	1,804	30.0	323	5.4	0	0.0

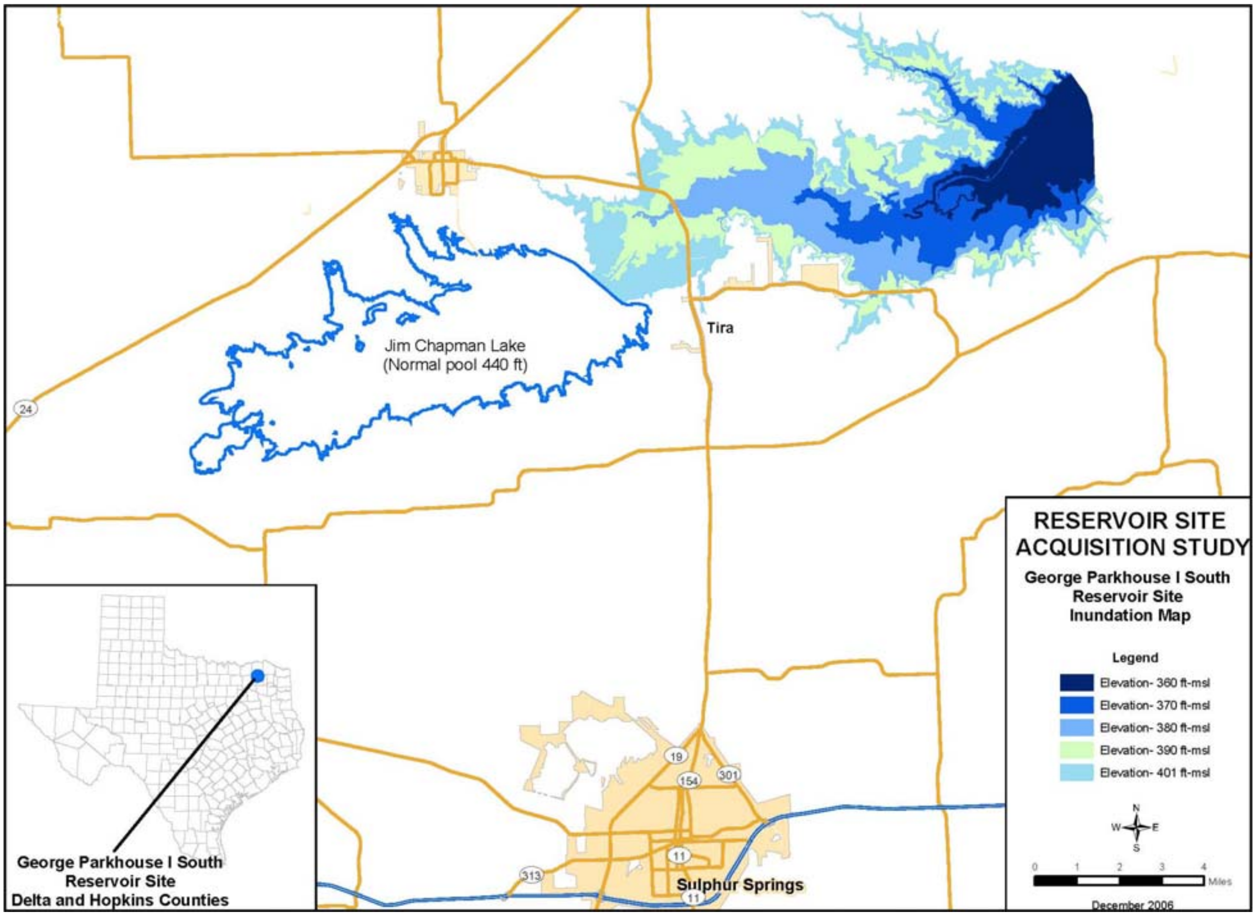

Figure 3.4.11-3. Inundation Map for George Parkhouse I Lake

The firm yield of Parkhouse I Lake was calculated with the full authorization scenario (Run 3) of the Water Availability Model of the Sulphur River Basin (dated July 15, 2004) obtained from TCEQ (Brandes, 1999 and TCEQ, 2006). A control point was added on the South Sulphur River at the dam location.

The naturalized flows at the reservoir sites were calculated using the drainage area ratio method with the existing series naturalized flows at gaged locations and drainage areas obtained from the USGS, as was done for Marvin Nichols (See Section 3.4.8).

Net evaporation rates were calculated from TWDB quadrangle data of precipitation and gross lake evaporation. Evaporation at the reservoir site was based on data from Quadrangle 412. Net evaporation rates entered in the Sulphur WAM were adjusted to remove the portion of the precipitation on the reservoir surface area that has been accounted for in the natural inflow.

Yields were calculated for elevations 410, 401, 396, and 390 feet, subject to bypass for environmental flow needs and assuming stand-alone reservoir operations with no minimum reserve content. Results of firm yield analyses at these elevations are included in Table 3.4.11-3 and Figure 3.4.11-4. A conservation pool elevation of 401 ft-msl was selected for this study to minimize the potential conflicts with Jim Chapman Lake and impacts to the communities of Charleston and Vasco. At higher conservation pool elevation (410 feet), additional protection of the dam and possible modifications to the spillway operation at Lake Chapman would be needed. Also the spillway size for the Parkhouse I Lake would need to be increased to keep the probable maximum flood from impacting neighboring communities. At the conservation pool level of 401 feet, the firm yield is 122,000 acft/yr. Environmental flow requirements reduce the yield of the reservoir by 2,400 acft/yr.

The yield of Parkhouse I Lake will decrease if one or more of the proposed reservoirs in the Sulphur Basin (Ralph Hall, Parkhouse II, and/or Marvin Nichols) are built and Parkhouse I Lake has a junior priority to any of these reservoirs. The scenario that produces the lowest yield assumes that Parkhouse I Lake is built after all of the other proposed reservoirs in the Sulphur Basin. Under this scenario, the yield of Parkhouse I Lake would be 48,400 acft/yr, or 73,600 acft/yr less than assuming the reservoir is senior to any other proposed reservoir. Appendix A is a memorandum describing the sensitivity of firm yield to the development of other reservoirs.

Table 3.4.11-3.
Firm Yield vs. Conservation Storage for George Parkhouse I Lake

Conservation Pool Elevation (ft-msl)	***Conservation Storage (acft)***	***Environmental Bypass Criteria***	***Yield (acft/yr)***	***Critical Period***
390.0	377,409	CCEFN	86,600	6/51 - 1/57
396.0	515,807	CCEFN	104,700	9/50 -2/57
401.0*	651,712	CCEFN	122,000	9/50 - 2/57
		None	124,400	
410.0	932,332	CCEFN	157,300	6/50-3/66
*Proposed conservation storage.				

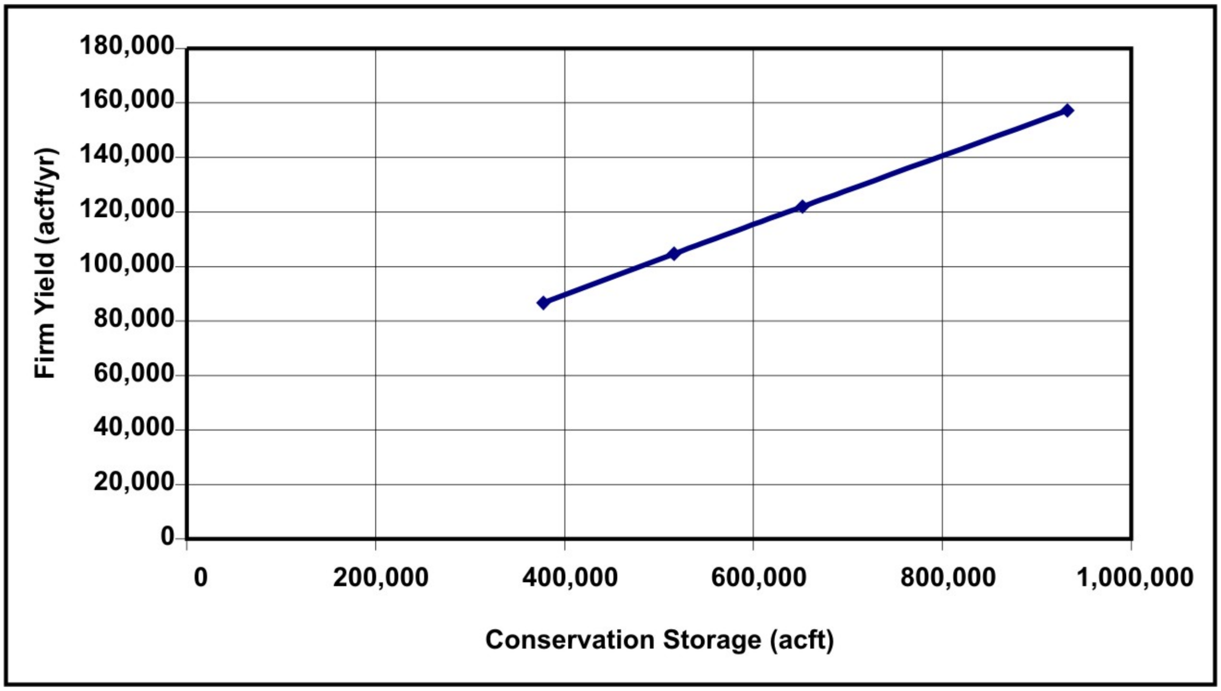

Figure 3.4.11-4. Firm Yield vs. Conservation Storage for George Parkhouse I Lake

Previous evaluations of the yield of the George Parkhouse I reservoir site have been conducted by Freese and Nichols in 1990, 1996, 2000, and 2006. The 2000 study shows that the firm yield (without restrictions due to environmental flows) is 164,500 acft/yr. The 2006 Region C Water Plan (Freese and Nichols *et al*., 2006) shows that yield of Parkhouse I is 135,600 acft/yr. Both of these studies assume a conservation pool elevation of 410 ft-msl for yield. Other differences in the yields are due to assumptions for drainage areas. The Sulphur WAM uses maps developed by CRWR to calculate drainage areas. CRWR drainage areas were used for consistency with the other areas of the Sulphur WAM, and were used in the yield determination for Region C Water Plan. The 2000 study and this study used drainage areas calculated with USGS data, which results in greater inflow to the reservoir.

Figure 3.4.11-5 presents a simulated storage trace and a frequency curve for storage content assuming annual diversions of 122,000 acft. At the conservation pool of 401 feet, and with full diversion, the reservoir would be full about 11 percent of the time and would be below 50 percent of the conservation storage about 13 percent of the months.

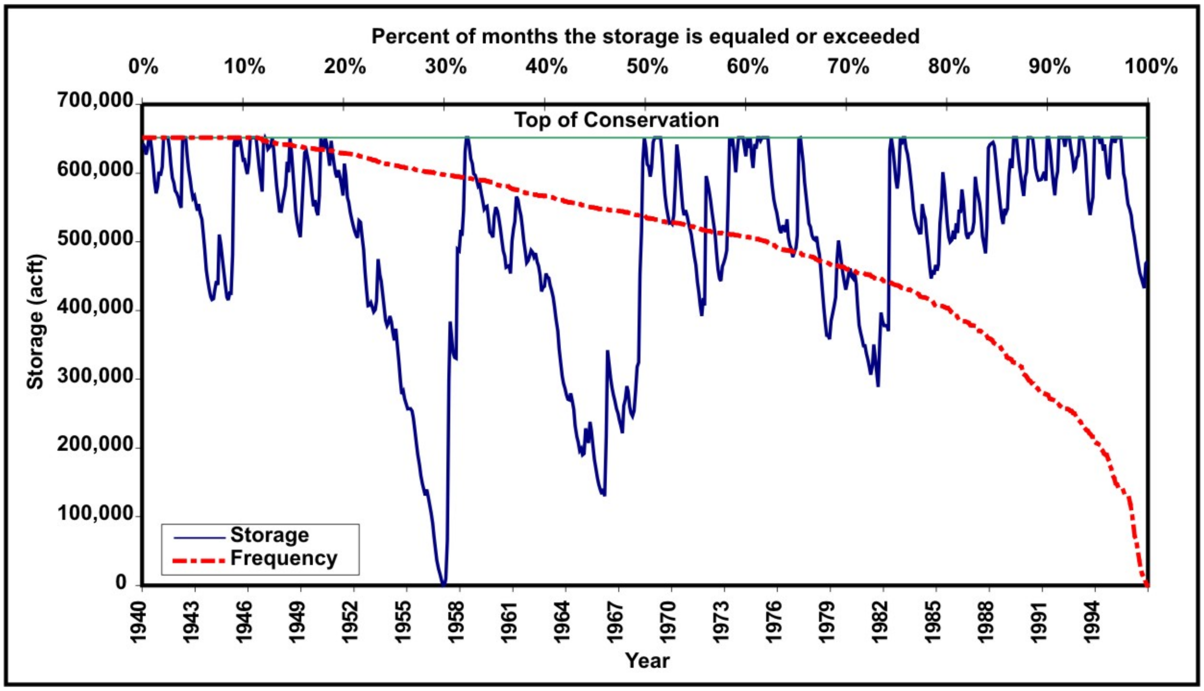

Figure 3.4.11-5. Simulated Storage in George Parkhouse I Lake (Conservation Elevation = 401 ft-msl, Diversion = 122,000 acft/yr)

3.4.11.3 Reservoir Cost

The quantities used for the costs for the George Parkhouse I Dam are based on data developed from previous studies (Freese and Nichols, 1990 and 2006a). The dam and spillway costs assume a zoned earthen embankment with a gated spillway structure. The length of the dam is estimated at 22,000 feet with a maximum elevation at 420 ft-msl. The service spillway includes a gated ogee-type weir constructed of concrete, eight tainter gates, a stilling basin and discharge channel. An 800-foot wide emergency spillway is also included in the preliminary design assumptions.

The structural conflicts identified at the site include electrical lines, several roads (including State Highways 154 and 19), and product transmission pipelines. A list of the potential conflicts is provided in Table 3.4.11-4. Quantities for these conflict resolutions are based on data obtained from the Railroad Commission and TNRIS. Figure 3.4.11-6 shows the conflicts as mapped by TNRIS. In addition to these conflicts, there are several environmental conflicts. The reservoir pool includes a 200-acre tract that is in the wetland reserve program and 1,200 acres of the Jim Chapman Lake Wildlife Management Area.

Table 3.4.11-4.
List of Potential Conflicts for George Parkhouse I Lake

Gas Pipelines	Power Transmission Lines
Roads	Parks

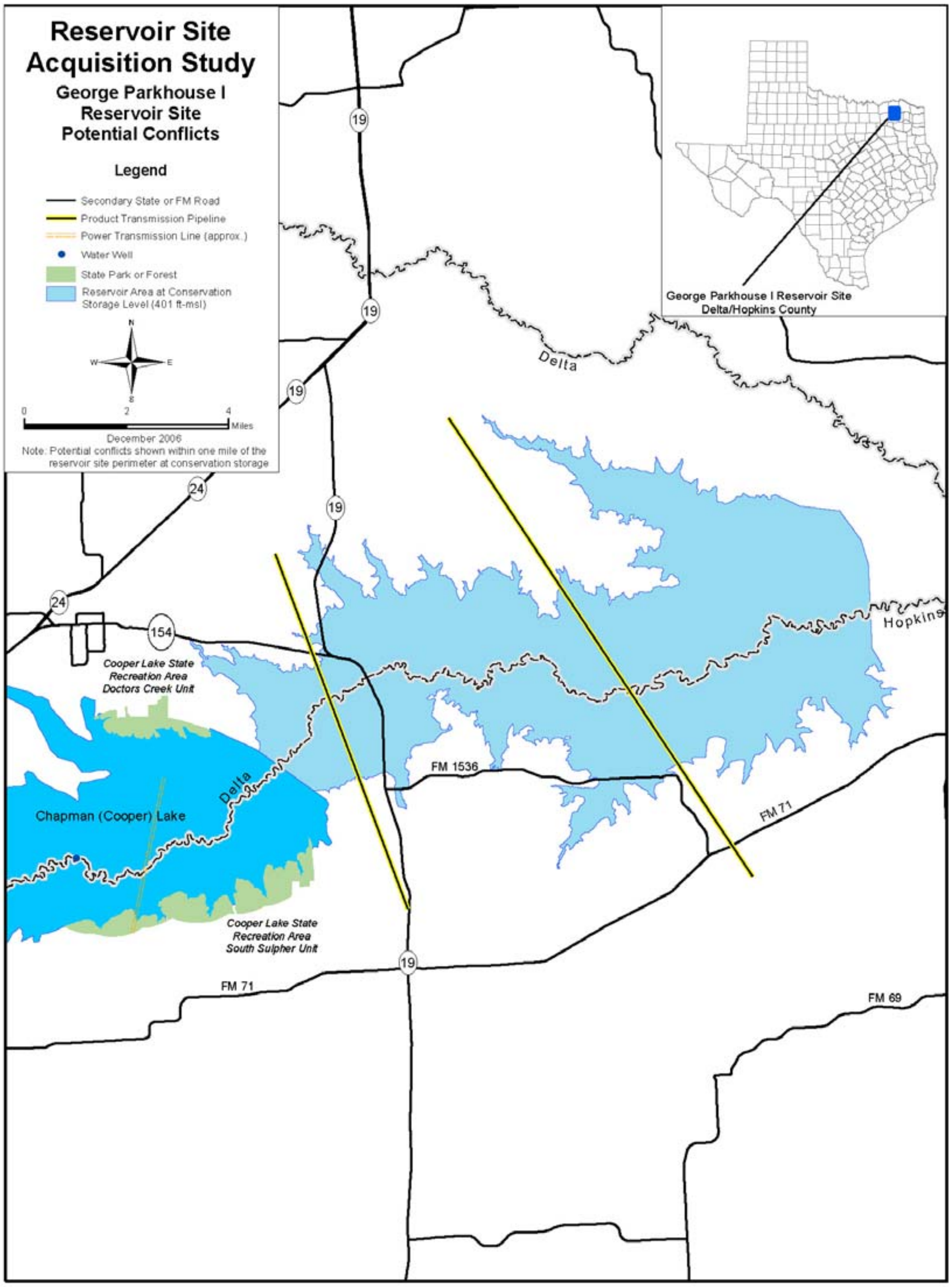

Figure 3.4.11-6. Potential Major Conflicts for George Parkhouse I Lake

Table 3.4.11-5 shows the estimated capital costs for the George Parkhouse I Lake Project, including construction costs, engineering, permitting and mitigation. Costs for the dam and reservoir are based on the unit cost assumptions used in this study. The total estimated cost of the project is $291 million (2005 prices). Assuming a yield of 122,000 acft/yr, raw water from the project will cost approximately $174 per acre-foot ($0.53 per 1,000 gallons) during the debt service period.

3.4.11.4 Environmental Considerations

The George Parkhouse I Lake is not located on an identified ecologically significant stream segment. The Region D Water Planning Group did not identify the Sulphur River as ecologically unique in the 2006 water plan. The reservoir site is located some distance upstream of a Priority 1 bottomland hardwood preservation site identified as Sulphur River Bottoms West (USFWS, 1985).

George Parkhouse I Lake would inundate approximately 29,000 acres at conservation storage capacity. Table 3.4.11-6 and Figure 3.4.11-7 summarize existing landcover for the George Parkhouse I Lake site as determined by TPWD using methods described in Appendix C. Existing landcover within this reservoir site is dominated by contiguous bottomland hardwood forest (37 percent) with sizeable areas of grassland (16 percent), marsh (16 percent), and agricultural land (16 percent).

Table 3.4.11.5.
Cost Estimate — George Parkhouse I Lake @ Elevation 401 ft-msl
(page 1 of 2)

	Quantity	*Unit*	*Unit Price*	*Cost*
Dam & Reservoir				
Excavation				
Approach Channel	140,200	CY	$2.50	$351,000
Discharge Channel	123,000	CY	$2.50	$308,000
Spillway	289,300	CY	$2.50	$723,000
Emergency Spillway	434,300	CY	$2.50	$1,086,000
Fill				
Random Compacted Fill	7,169,400	CY	$2.50	$17,924,000
Impervious Fill	1,567,800	CY	$3.00	$4,703,000
Filter	668,200	CY	$35	$23,387,000
Bridge	190	LF	$1,300	$247,000
Roadway	63,067	SY	$20	$1,261,000
Slurry Trench	800,000	SF	$15	$12,000,000
Soil Cement	394,130	CY	$65	$25,618,000
Elevator	1	LS	$100,000	$100,000
Barrier Warning System	456	LF	$100	$46,000
Gates				
Gate & Anchor	2,240	SF	$275	$616,000
Stop Gate & Lift	160	LF	$2,000	$320,000
Hoist	8	Ea	$250,000	$2,000,000
Electrical	1	LS	$550,000	$550,000
Power Drop	1	LS	$250,000	$250,000
Spillway Low-Flow System	1	LS	$400,000	$400,000
Stop Gate Monorail System	390	LF	$1,000	$390,000
Embankment Internal Drainage	39,300	LF	$60	$2,358,000
Guardrail	780	LF	$30	$23,000
Grassing	28	Ac	$4,500	$126,000
Concrete (mass)	52,000	CY	$150	$7,800,000
Concrete (walls)	5,600	CY	$475	$2,660,000
Mobilization (5% of subtotal)				$5,262,000
Care of water (3% of subtotal)				$3,157,000
Clearing and Grubbing	200	AC	$4,000	$800,000
Land Clearing	950	AC	$1,000	$950,000
Engineering and Contingencies (35%)				$40,396,000
Subtotal for Dam & Reservoir				**$155,812,000**
Conflicts				
Highways				
State Highways (S.H. 154 and S.H. 19)	35,100	LF	$900	$31,590,000
F.M.	18,500	LF	$150	$2,775,000
Gas pipelines				
30-inch	95,000	LF	$98	$9,310,000
10.75-in	81,300	LF	$30	$2,439,000
Power Transmission lines	5,330	LF	$450	$2,399,000
Engineering and Contingencies (35%)				$16,980,000
Subtotal of Conflicts				**$65,493,000**

Table 3.4.11.5.
Cost Estimate — George Parkhouse I Lake @ Elevation 401 ft-msl
(page 2 of 2)

Dam & Reservoir	Quantity	Unit	Unit Price	Cost
Land Acquisition	31,741	AC	$1,201	$38,121,000
Environmental Studies and Mitigation Lands	31,741	AC	$1,201	$38,121,000
Total Reservoir Construction Cost				**$259,426,000**
Interest During Construction (36 months)				**$31,564,000**
TOTAL COST				**$290,990,000**
ANNUAL COSTS				
Debt Service (6% for 40 years)				$19,340,000
Operation & Maintenance				$1,894,000
Total Annual Costs				**$21,234,000**
UNIT COSTS				
Per Acre-Foot				$174
Per 1,000 Gallons				$0.53

Table 3.4.11-6.
Acreage and Percent Landcover for George Parkhouse I Lake

Landcover Classification	Acreage[1]	Percent
Bottomland Hardwood Forest	10,379	36.8%
Marsh	4,566	16.2%
Seasonally Flooded Shrubland	584	2.1%
Swamp	83	0.3%
Upland Deciduous Forest	2,428	8.6%
Grassland	4,611	16.4%
Shrubland	211	0.7%
Agricultural Land	4,470	15.9%
Urban / Developed Land	5	0.0%
Open Water	848	3.0%
Total	28,185	100.0%

[1] Acreage based on approximate GIS coverage rather than calculated elevation-area-capacity relationship.

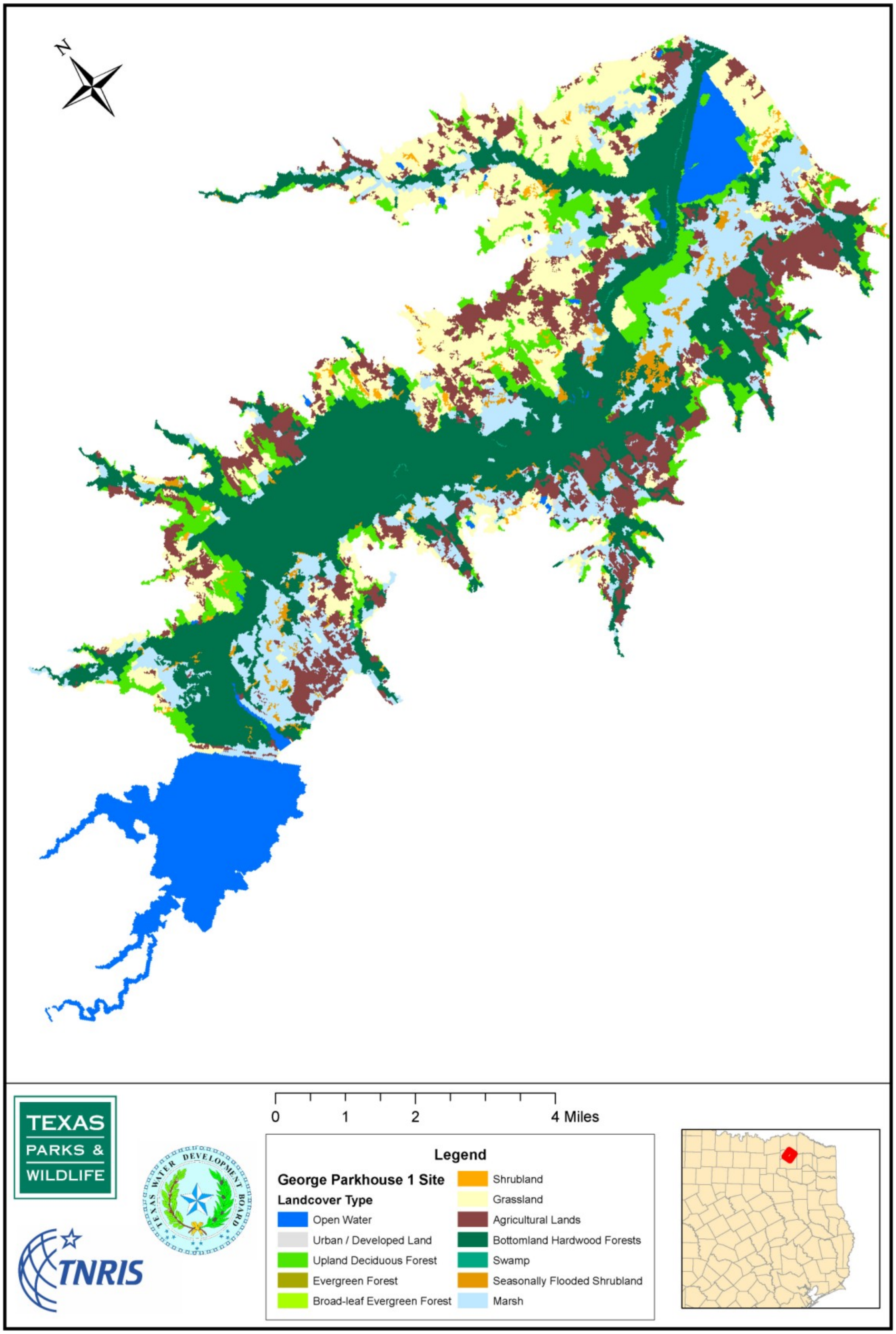

Figure 3.4.11-7. Existing Landcover for George Parkhouse I Lake

(This page intentionally left blank.)