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ENVIRONMENTAL ASSESSMENT REPORT

for the

LAKE BOSQUE PROJECT

BOSQUE COUNTY, TEXAS

Prepared for

The Brazos River Authority

Prepared by

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1.0 The Proposed Project

The following document is an Environmental Assessment Report that summarizes regional and site specific environmental data and examines the consequences of the construction and operation of the Lake Bosque Project by the Brazos River Authority (BRA). This report is based primarily on nine documents prepared specifically to address in detail the important aspects of the Lake Bosque Project. The documents listed below should be consulted when a more extended discussion, data presentation, or guide to the literature used to support assertions or opinions is desired:

* Baseline Ecology Report: the Lake Bosque Project, Technical Consulting Associates (now Paul Price Associates, Inc.), 1985;
* Baseline Ecology Report Supplement I: North Bosque River Regional Survey, Paul Price Associates, Inc., 1987;
* Baseline Ecology Report Supplement II: Important Species, Paul Price Associates, Inc., 1987;
* Socioeconomic Baseline Report for the Lake Bosque Project, Paul Price Associates, Inc., 1987;
* Water Supply Alternatives for Bosque County, HDR Infrastructure, Inc., 1982;
* Analysis of Project Alternatives for Proposed Lake Bosque Project, HDR Infrastructure, Inc., 1987;
* Reservoir Operation Studies for Proposed Lake Bosque Project and Lake Waco Enlargement, HDR Infrastructure, Inc., 1987;
* Geotechnical Investigation, Bosque Reservoir Site, Bosque County, Texas, NFS Services, Inc., 1983;
* An Archaeological and Historical Survey of the Proposed Lake Bosque Reservoir Site, Bosque County, Texas, Lone Star Archaeological Services, Georgetown, Texas, 1987.

In addition, numerous publications, government agency reports and personal communications with qualified individuals are cited in support of the information and analyses presented here.

1.1 Scope of Project

The proposed project consists of the construction and operation of Lake Bosque, a municipal water supply reservoir at river mile 58.3 on the North Bosque River about four miles north of Meridian, in Bosque County, Texas (Figure 1-1). The new reservoir will be operated as a system with Lake Waco to maximize benefits in the Bosque River Basin. The conservation pool will cover 4564 acres at an elevation of 830 feet above mean sea level (MSL) and have an initial storage capacity of 102,909 acre-feet. As a result of dam construction and operation the existing 100 year floodplain in the reservoir reach will be raised to an approximate elevation of 841.3 feet MSL. The project will also include closure of four county road segments (tentatively), realignment of short portions of FM 927 and FM 144, and the rerouting of several electric transmission line segments each less than one mile in length (Figure 1-2).

The capability to add a raw water diversion point will be included as part of the controlled outlet structure of the dam. This feature is intended for use by the Bosque County participants when they elect to take their 2.98 mgd share of the reservoir yield, projected to occur between 1990 and 2005. Since McLennan County users will receive Lake Bosque water via Lake Waco and the City of Waco's water treatment and distribution system, no new raw water delivery facilities will be neccessary for them.

The dam is to be an earthfill embankment with an impermeable core, approximately 14,000 feet in length with a crest

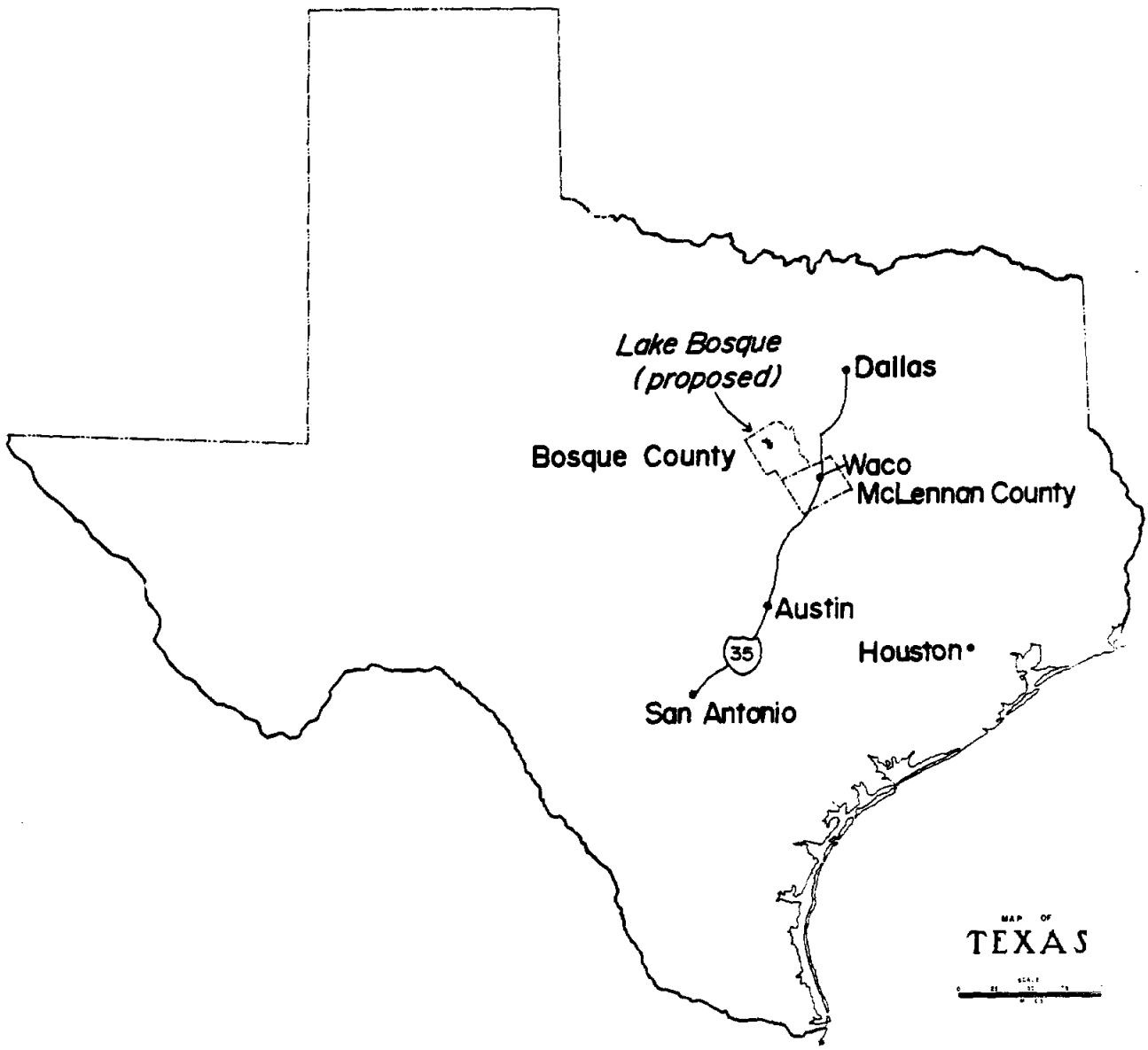

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Figure 1-1
Proposed Lake Bosque
Resevoir Site

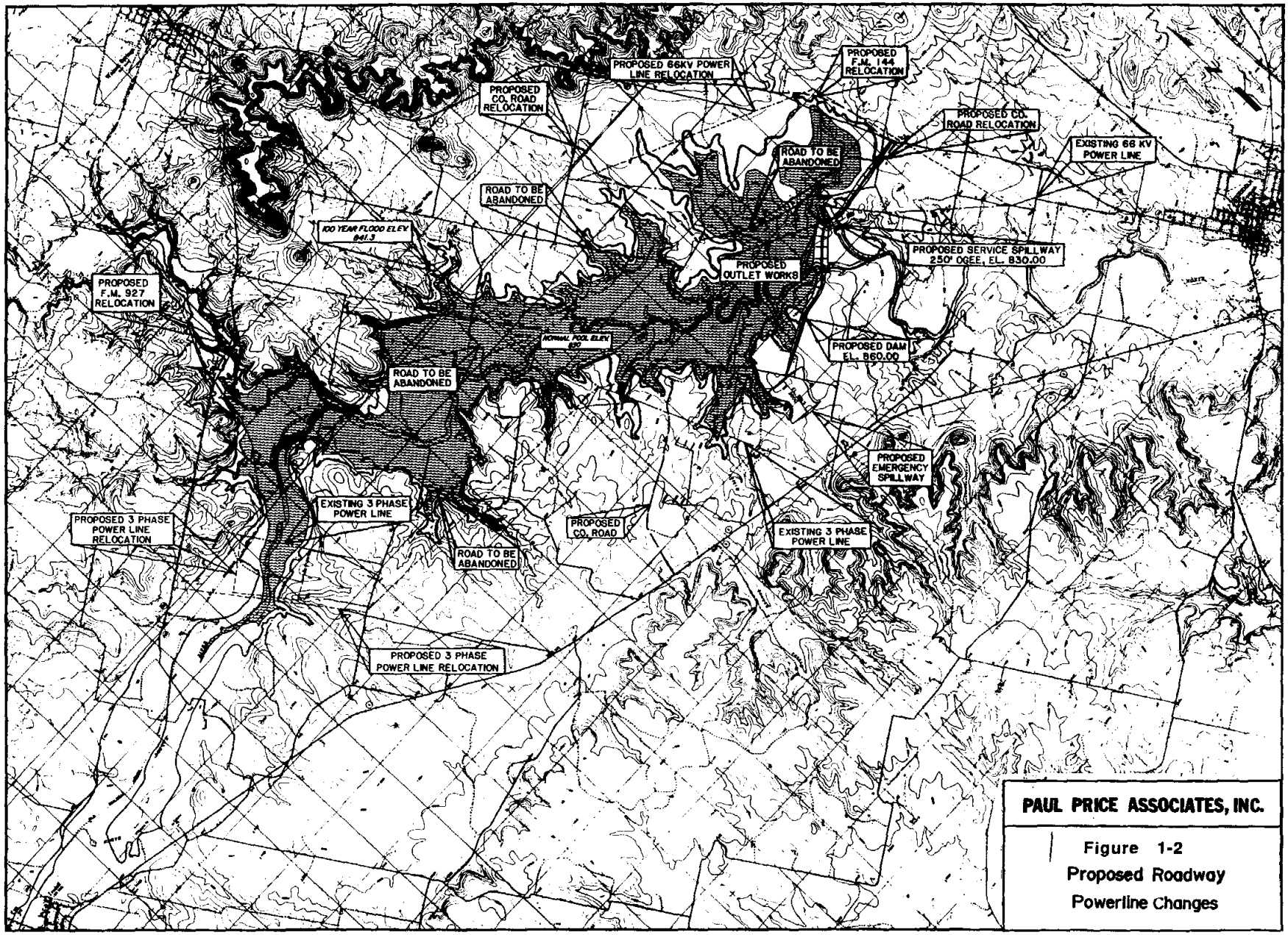

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Figure 1-2
Proposed Roadway
Powerline Changes

elevation at 860 feet MSL. The primary spillway will be an uncontrolled concrete structure 250 feet wide with a crest at 830 feet MSL, the top of the conservation pool. The 2000 foot wide emergency spillway will be set at the 100 year flood elevation, 841.3 feet MSL, to allow passage of the Probable Maximum Flood without overtopping the embankment. Controlled release will be accomplished by use of a structure capable of selective, multilevel withdrawl and an outlet discharging into a stilling basin at the base of the primary spillway. The outlet will be constructed with a fixture to allow its eventual use as a raw water diversion point.

1.1.1 Construction Activities

Construction of the dam, spillways and associated structures is expected to take two years, with an additional one to six years required for the reservoir to fill. There is a 50% probablilty that it will fill within two years. Most of the materials to be used for dam construction are available on site from the spillway excavation and borrow areas. The borrow areas (about 230 acres) will be contained within the conservation pool area of the reservoir site. Clearing will be limited to that neccessary for construction activities and, if neccessary, to provide safe lanes for any boat launching facilities that may be constructed.

The proposed dam and spillways will cover 192 acres and the resulting conservation pool will inundate 4564 acres. An additional 1387 acres above the conservation elevation will be included in a new 100 year floodplain subject to periodic inundation.

1.1.2 Proposed Operation

It is anticipated that Lake Bosque and Lake Waco will be operated as a system. Water will be directly diverted from Lake Bosque for use in Bosque County, while releases of water from Lake Bosque to the North Bosque River will be made for delivery through Lake Waco for use in McLennan County. System operation can be structured to significantly increase the total water yield from lakes Bosque and Waco. Under maximum demand conditions, the greatest system yield will be obtained by maximizing storage in Lake Bosque and making releases only as neccessary to maintain the minimum useable pool in Lake Waco. However, until future water supply needs approach system yield, it will not be neccessary to make releases in accordance with this operating procedure, and it is planned that the system will be operated to stabilize the level of Lake Waco for enhanced recreation with releases from Lake Bosque.

The maximum yield of the two reservoir system will be 97,770 acre-feet per year (87.29 mgd), 17,900 acre-feet per year (15.98 mgd) of which will be attributable to Lake Bosque. Of the 15.98 mgd, 2.98 mgd will be used in Bosque County while the remaining 13.00 mgd will be delivered to Lake Waco for use in McLennan County.

1.2 Purpose and Need for the Project

The Lake Bosque Project is being proposed to enhance the quantity and quality of available water supplies in Bosque and McLennan Counties, particularly for those project participants which rely on ground water for present supplies and future growth. Except for Lake Waco which supplies the City of Waco, present water supplies for Bosque and McLennan Counties consist primarily of ground water from the Travis Peak formation of the Trinity Group. This aquifer is being

mined at present rates of withdrawl and the region has been designated a Critical Ground Water Management Area by the Texas Water Commission. These are areas the Texas Water Commission believes are experiencing, or will experience within the next 20 years, serious problems with groundwater supply.

Studies were initiated in 1981 to examine the available alternatives and recommend solutions to the widely recognized coming water shortage in the region. Construction and operation of Lake Bosque will provide higher quality water to project participants, mitigate overpumping of ground water resources and assure the availability of a dependable water supply through the period 1990-2040 and beyond.

The reservoir's firm yield of 15.98 million gallons per day (mgd) is fully contracted for by the participating municipalities of Bosque and McLennan Counties (Meridian, Clifton, Bellmead, Hewett, Lacy-Lakeview, McLennan Co. WCID No. 2, Waco and Woodway) and financing is to be by sale of revenue bonds. Future water requirements are projected to begin exceeding the water supplies of some project participants by the year 2000, and is anticipated to continue increasing through the life of the project at an average rate of approximately 1.7% per year. Projections of future demand are discussed in the Baseline Socioeconomic Report (Paul Price Associates Inc., 1987), and in Section 3.8.3.5 of this document.

2.0 Water Supply Alternatives

HDR Infrastructure Inc. (1982; 1987) reviewed potential water supply alternatives and recommended Lake Bosque as the supply project that will best serve the needs of all eight project participants. Alternatives considered included: 1) additional groundwater development, 2) conservation, 3) new reservoir construction on the North Bosque (four sites) and Leon (one site) Rivers, 4) waste water reuse and 5) two methods of using uncommitted Brazos River water. All but two of the alternatives considered were judged to be technically feasible and environmentally sound to the extent that no unique or irretrievable resource losses would result from implementation. Therefore, unit cost for development, treatment and transmission of treated water was the main basis for comparison and selection of the preferred alternative.

2.1 Water Supply Alternatives considered

Four alternatives other than development of new surface water supply sources were examined and are summarized below in Section 2.1.1, Non Structural Alternatives. Structural Alternatives included examination of four reservoir sites on the North Bosque, one site on the Leon River, and development of diversion and off channel storage facilities on the Brazos River.

2.1.1 Non Structural Alternatives

2.1.1.1 Groundwater Use and Conservation

More extensive use of groundwater supplies and/or implementation of water conservation measures were evaluated and it was found that neither of these two procedures provided a sufficient and reliable supply to meet the demand

of the project participants. Groundwater supplies are already being overdrafted and even in concert with reasonably achievable conservation levels cannot be expected to meet their projected demands.

2.1.1.2 Wastewater Reuse

The Brazos River Authority's Regional Wastewater Treatment Plant at Waco is currently discharging approximately 21 mgd. Therefore, increasing the firm yield of Lake Waco by pumped diversion of adequately treated wastewater effluent can develop the needed additional water supply. Although wastewater reuse has not yet been widely implemented, it appears technically feasible and may become a realistic water supply alternative in the future. Potential problems to be addressed include public concerns and perceptions, additional nutrient delivery to an already eutrophic reservoir, and transmission of water to the Bosque County users which are located as much as 60 miles from the Lake Waco diversion structure.

2.1.1.3 Lake Whitney Alternative

Lake Whitney is an existing Corps of Engineers multi-purpose project upstream of the City of Waco on the Brazos River astride the eastern boundary of Bosque County. A portion of the existing conservation storage has been purchased from the federal government by the Brazos River Authority and is presently contractually committed to entities other than the Lake Bosque project participants. The purchase of the remaining conservation storage space, with an appropriate water rights permit, could be used to develop a firm yield water supply for the two water systems serving the Bosque and McLennan County participants. The concurence of the U.S. Congress would be required to purchase the remaining storage space.

The McLennan County entities would receive their supply by releasing water down the Brazos River to an existing channel reservoir within the City of Waco. Released water would be diverted from the channel reservoir for treatment that would have to include demineralization and wholesale distribution. The demineralization step is necessary because dissolved solids concentrations in the Brazos River often exceeds the Secondary Constituent levels set for drinking water by the Texas Department of Health. The Bosque County entities would construct a raw water intake structure in Lake Whitney and divert their supply by pipeline to a similar demineralization and conventional treatment facility for wholesale distribution.

2.1.2 Structural Alternatives

2.1.2.1 North Bosque River Reservoir Sites

A previous study by HDR showed that a reservoir on the North Bosque River was the most economical water supply project for Bosque County (HDR Infrastructure, 1982). A review of USGS maps identified four sites on the North Bosque River as having the topographic characteristics that will allow development of reasonable storage capacity without incurring extensive relocation costs (HDR Infrastructure, 1987). All four North Bosque River alternative sites are located in Bosque County. Practical conservation storage volumes at these sites ranged from 29,200 acre-feet to 102,909 acre-feet. Estimated areal yields after 50 years of sediment accumulation ranged from 17,500 (15.6 mgd) to 35,000 (31.25 mgd) acre-feet per year.

Since all four potential reservoir sites are located in areas that are very similar in terms of soils, topography, vegetation and aquatic habitats, the primary predictors of

environmental impact are conservation pool areas and position in the basin. Site 1 (3,083 surface acres) was located about six miles upstream of the proposed Lake Bosque, which is Site 2 and will cover 4564 acres. Site 3 (2,018 acres) was located just upstream of Clifton while Site 4 (4,938 acres) was about two miles upstream of Valley Mills. These four sites can be ranked in ascending order of probable fish and wildlife habitat impact as follows: Site 3 < Site 1 < Site 2 = Site 4.

2.1.2.2 Leon River Reservoir Site

The Leon River site selected for study is located approximately 4 river miles upstream of the town of Gatesville in Coryell County, Texas. The selection of this site is based on its ability to support a new reservoir, as well as its close proximity to the participating entities requiring water. The Gatesville location represents the most downstream site before inundation of either federal lands or population centers becomes significant.

The proposed Gatesville Reservoir would have an optimum conservation pool elevation of 864 feet MSL. At this elevation, the initial conservation storage pool would be about 500,000 acre-feet and surface area would be 14,400 acres. Since the site is environmentally very similar to the Bosque River sites, impacts here are also expected to be roughly proportional to inundated area. Construction of this reservoir would result in greater impacts than at any of the sites on the North Bosque. Delivery of water to both Bosque and McLennan Counties would also involve extensive pipeline construction.

2.1.2.3 Diversion and Off-Channel Storage, Brazos River

This alternative involves diversion of unappropriated Brazos River flows, when available, into an off-channel storage reservoir constructed in the floodplain adjacent to the Brazos River. The stored water would have to undergo conventional treatment and demineralization before distribution to the project participants. Delivery of the Bosque County demand of 2.98 mgd would require substantial pipeline construction from Waco to those participants.

2.2 Selection of the Proposed Project

Unit treated water costs were developed for each alternative and served as the basis for comparing the economic feasibility of each alternative, including treatment and delivery to the existing systems of the project participants. In alternatives requiring demineralization (Lake Whitney, Brazos River Diversion), the process requires conventional water treatment prior to the demineralization step. Part of the treated water must be discharged to carry off the removed minerals. Costs associated with treatment, storage, pumping, and transmission of this additional quantity of water were included in unit treated water cost estimates. Other costs, including avoidance or mitigation of environmental, social, or cultural impacts were considered to be reasonably similar for all five reservoir sites. The alternatives not involving construction of a new reservoir were all assumed to have lower costs in that category.

The proposed Lake Bosque site offers the lowest cost per unit of yield and is the most economical alternative. Its location is advantageous since all project participants are located downstream from the reservoir and water can be supplied with least capital investment and operating cost for diversion, treatment and transmission facilities. The site impounds water without exposure to unreasonable

evaporation and seepage losses, and the construction requirements are not unusual.

3.0 The Affected Environment

The human and natural environments potentially affected by the proposed Lake Bosque are centered in portions of Bosque and McLennan Counties in central Texas. Of particular importance is the lower half of the North Bosque River basin which encompasses the reservoir site, the Bosque County project participants and the downstream river reach potentially affected by the presence of the dam.

The Bosque River is a major tributary of the Brazos River, which it joins at Waco, Texas. The Bosque is dammed a few miles upstream of its confluence, forming Lake Waco. Above this impoundment, the North, Middle and South Bosque Rivers drain a 1670 square mile basin extending about 90 miles to the northwest. The North Bosque River has the most extensive sub-basin of the three, draining an area of about 1290 square miles in portions of McLennan, Bosque, Coryell, Hamilton, Somervell, and Erath counties (Figure 3-1).

3.1 Climate and Air Quality

3.1.1 Climate

The basin of the North Bosque River is located near the dry margin of the subtropical humid belt 250 miles northwest of the Gulf of Mexico which exerts considerable influence on the climate of the region. Summers are typically hot and humid with prevailing southeasterly winds carrying Gulf moisture. The winters tend to be mild and to exhibit lower humidities characteristic of the prevalent northern and western air masses of that season. Rainfall tends to decrease from the eastern to the western extremities of the basin (Proctor, 1969; TDWR 1982; NFIC, 1987).

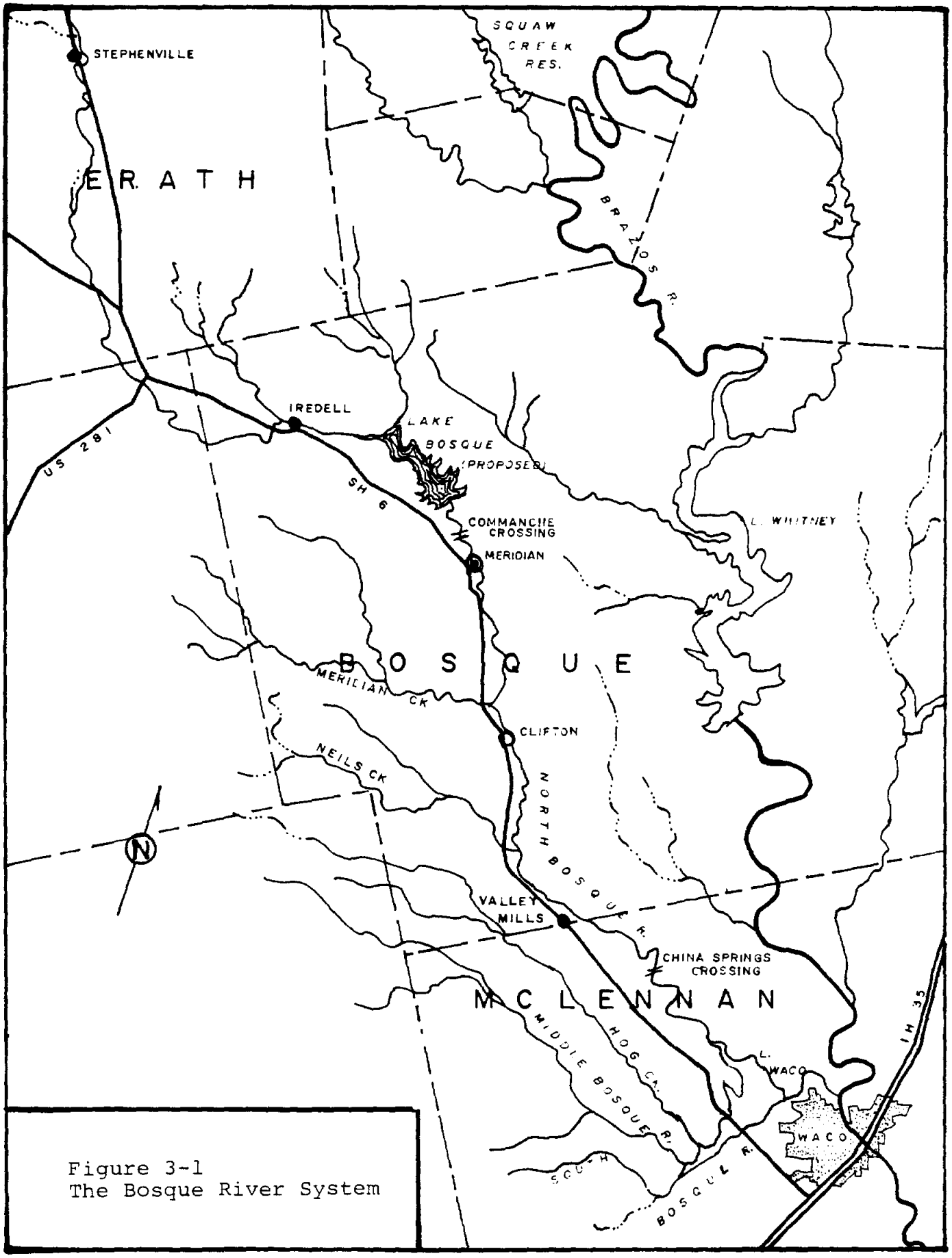


Figure 3-1
The Bosque River System

The climate of Bosque County is dominated by continental characteristics; large daily and annual temperature ranges and wide year to year fluctuations in seasonal rainfall patterns are the rule. Monthly average temperatures at Whitney Dam, 21 miles southeast of the project site, range from about 45 F in January to 85 F in July and August. The growing season averages 245 days, with average first and last frost dates of 21 November and 23 March, respectively.

Precipitation averages 30-35 inches per year in Bosque County (31.6 inches at Whitney Dam) and evapotranspiration averages 30-32 inches. Although rainfall exhibits a relatively even distribution throughout the year, weather extremes can be quite pronounced, particularly with respect to large spring thunderstorms and summer hurricane outliers that may be intensified by the orographic effect of the Balcones Escarpment. Months with highest average rainfall are April, May, June, September and October, but the range is only from an average of 1.75 inches in August to 4.59 inches in May. Annual snowfall averages less than 1 inch, and is generally confined to the months of January and February.

Local climate is variably affected by orientation and topography. Differential insolation on opposite valley walls can result in several degrees difference in both average surface temperatures and in diurnal range, with commensurate differences in consequent characteristics such as soil moisture, erosion rates and vegetative cover. In the vicinity of the proposed reservoir, topography can be very important in determining local climate where steeper slopes may be quite arid and seepage onto flat limestone ledge outcrops may create mesic microclimates in otherwise upland areas.

3.1.2 Air Quality

The Texas Air Control Board (TACB) classifies McLennan County as an attainment area for all pollutants of concern. Monitoring has shown levels of airborne pollutants to be less than the criteria of the national primary, national secondary and state of Texas air quality standards for ozone, carbon monoxide, sulfur dioxide, nitrogen oxides, lead and particulates. A similar determination has been made for Bosque County except that ozone monitoring has not been conducted. Because Bosque County is a rural area with no large sources of emissions, the TACB does not anticipate excess ozone levels to be present there.

3.2 Noise

The proposed project is located in a sparsely populated rural area without significant manufacturing or currently operating mining facilities. The only noise sources in the vicinity of the project are seasonally operated farming machinery, trucks and automobiles. The most significant of these sources appear to be traffic on State Highway 6, FM 144, and FM 927 which surround the proposed reservoir site on the west, east and north sides. Segments of Highways 6 and 144 lie within one mile of proposed construction areas.

3.3 Geology and Soils

3.3.1 Stratigraphy and Lithology

The North Bosque watershed is located on the structurally stable Texas craton (Proctor, 1969) in a zone of very low seismic activity. It is underlaid by Cretaceous aged marine sediments of the Washita, Fredricksburg, and Trinity groups, and Pennsylvanian rocks of the Atoka series. Figure 3-2 illustrates the distribution of exposed geologic

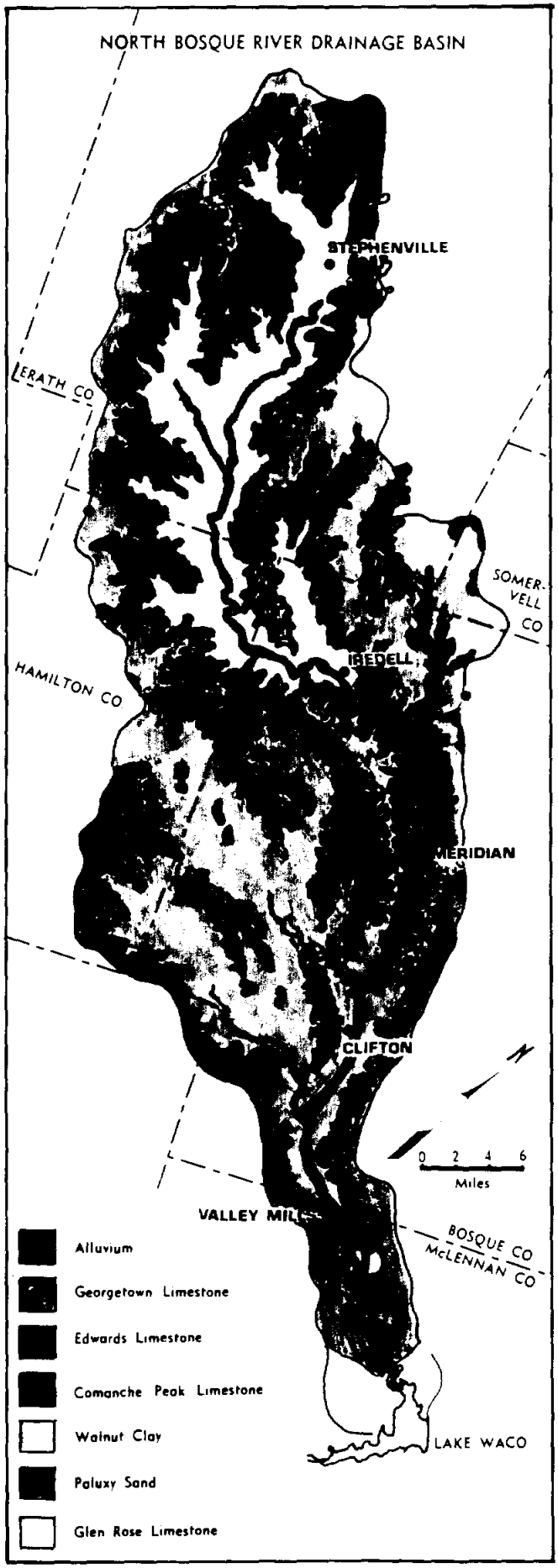


Figure 3-2
Geological Map
of the North Bosque
Watershed (from
Proctor, 1969)

formations in the North Bosque River Basin. Except for recent alluvium filling the valley floors along major stream channels, all the outcrops in the basin are Lower Cretaceous aged marine limestones, shales and sandstones. The exposed strata strike north northeast and dip southeastward at 12 to 27 feet per mile. This structure strongly influences local gradient in the North Bosque River and affects the type and distribution of aquatic habitats (see Section 3.5.1, Aquatic Habitats and Biota).

Most of the reservoir site covers recent valley alluvium that is underlaid by the Paluxy formation. This formation consists of dense, light gray, fine sand interbedded with occasional strata of soft, gray shale and weakly cemented sandstone. Small areas within the upland portion of the reservoir site are occupied by outcrops of the Paluxy and Walnut formations. The Walnut consists of moderately hard tan to light gray limestone alternating with clay and shale and containing massive shell beds. The Glen Rose formation, consisting of hard, light gray limestone strata alternating with shale and marly limestone beds is exposed in the stream bed of the North Bosque at the extreme upper limit of inundation. Above Iredell, the upper half of the Bosque basin is underlaid primarily by the Glen Rose and Paluxy formations.

3.3.2 Physiography

The lowermost reach of the North Bosque River, below Valley Mills, is located in the Washita Prairie physiographic region. This is a rolling prairie developed on the Georgetown Limestone exhibiting little relief and a vegetational cover primarily of grasslands with scattered stands of oak. Although the soils of the Washita Prairie are considered reasonably fertile, they are used almost

exclusively for grazing except along the North Bosque River where alluvial soils are used for crop and hayland.

From the vicinity of Valley Mills to Iredell and including the proposed Lake Bosque site, the North Bosque River flows through the Lampasas Cut Plain Physiographic Region, the highly dissected northern extension of the Edwards Plateau. It is characterized by broad, level to rolling valleys separated by steep sided, flat topped divides that are the remnant (cut) plain. Local relief is much greater than in the Washita Prairie, with elevation differences of 150 to 200 feet between valley floors and divides common. The distinct topography is largely the result of the physical resistance to weathering and hydraulic properties of the Edwards Limestone formation which forms a resistant cap on the tops of the divides. The less resistant Commanche Peak Limestone and Walnut Clay formations, which form (respectively) the steep, upper slopes below the Edwards cap and the lower slopes and valley floors, are eroded much more rapidly than the Edwards producing the characteristic mesa dominated landscape. The Edwards limestone here is a perennial aquifer, exhibiting a "spring line" of seeps and springs at its base that increases erosional activity on the underlying Commanche Peak and Trinity formations and contributes to area streamflow.

Above Iredell (and the proposed reservoir site) the remainder of the North Bosque basin lies in the Paluxy Cross Timbers and Glen Rose Prairie physiographic regions. These are regions of little relief and are underlaid by the Paluxy Sands and Glen Rose formations, respectively.

3.3.3 Soils

In the Lampasas Cut Plain, only soils developed on the Walnut formation, Paluxy Sands and Recent alluvium are

utilized for agricultural activities other than grazing. Upland soils within the reservoir site range from very shallow to moderately deep, sloping clayey sands of the Denton-Purves and Tarrant-Denton units (SCS, 1980). These soils are developed on the limestones of the Walnut formation and account for about 22 and 8 percent, respectively, of Bosque county soils. More intensively farmed, the Krum-Sunev and Frio-Bosque soils of the bottomlands are easily cultivated since even adjacent to the river channel they are only occasionally flooded. These soils are calcareous clay- and silty-clay loams that are developed on recent alluvium and are the characteristic riparian soils of the North Bosque River. They exhibit high crop potentials and account for about 12 and 3 percent, respectively, of Bosque County soils.

The Soil Conservation Service classifies 205,458 acres (32%) of the 641,920 acres of Bosque County as prime farming soils, based on soil depth, moisture, slope, stoniness, erodibility, and presence of soil problems. Prime farmland soils occupy about two thirds of the proposed reservoir site, considering both the dam and conservation pool.

3.3.4 Paleontology

The Walnut Clay formation exhibits widespread occurances of marine fossils, primarily in the form of oyster reefs dominated by the Lamellibranch genus *Gryphaea*. These fossil reefs can be large structures that outcrop on the surface throughout the Lampasas Cut Plain as low, rounded hills or benches. The Glen Rose formation, which begins to outcrop in the river channel in the vicinity of Iredell, above all but the extreme upper reach of the reservoir, is known in particular for the dinosaur tracks that have been found at numerous outcrop locations from Glen Rose to Uvalde.

3.3.5 Economic Geology

Geological resources in the vicinity of the proposed reservoir appear limited to sand and gravel deposits that are widely distributed along the North Bosque River, and limestones suitable for construction purposes that are present in numerous areas in Bosque and McLennan Counties. Resource extractive industries (e.g., mining, oil and gas) do not constitute a significant portion of the economy of Bosque County at the present time. No operating oil or gas wells or mining facilities are located within the proposed reservoir site.

3.4 Water Resources

3.4.1 Ground Water

Groundwater resources in Bosque and McLennan Counties include aquifers of the Trinity Group, Edwards formation, Brazos valley alluvium, and Woodbine formation (TDWR, 1982). The Travis Peak formation of the Trinity group provides by far the largest fraction of groundwater supplies in these counties. The Hensel and Hosston members of the Travis Peak formation provide over 95% of the municipal and industrial water supply in Bosque County. In McLennan County all the project participants except the City of Waco use these aquifers for their primary water supply, as do nearly all other entities in the county.

The Hensel and Hosston members of the Trinity Group have freshwater sand thicknesses ranging from 50 to 120 feet. Aquifer depths range from several hundred feet in western Bosque County to nearly 2000 feet in eastern McLennan County. Pumping capacity of wells developed in these formations range up to 300 gallons per minute. Originally artesian, development of the resource has resulted in

declining water levels throughout the study area. At present rates of withdrawal, the aquifer is being mined, and has been included in a Critical Groundwater Management Area by the Texas Water Commission. These have been defined as areas that are experiencing, or will experience within the next 20 years, serious problems with groundwater supply.

The recharge zone of the Trinity aquifer outcrops in a north-south bearing band that touches the western edge of Bosque County and extends westward to cover most of Erath, Hamilton and Comanche Counties. This aquifer does not compact when drawn down and the outcrop is located in an area having sufficient rainfall that recharge can occur within a reasonable period if overdrafting is halted. Information on sustainable withdrawal rates is not currently available for this area.

While the Edwards formation in Bosque county supports a number of perennial springs and seeps, it does not make any substantial contribution to municipal or industrial water supplies. The Paluxy Sand, which outcrops in the vicinity of the proposed Lake Bosque, is another minor aquifer providing small to moderate supplies of freshwater (10-20 gallons per minute) for agricultural purposes in Bosque County. This aquifer has a high mineral content and relatively low permeability that restricts its potential for water supply development. At the reservoir site the valley of the North Bosque River is a discharge area for the Paluxy formation. A low gradient groundwater flow from west to east is present in this aquifer at the proposed dam site. (NFS Services, Inc., 1983).

In Mclennan County, the Woodbine occurs only in a small area in the northern part of the county, while the Brazos

Alluvium constitutes a relatively limited ground water resource within the confines of the Brazos River valley.

3.4.2 Surface Water

Surface water resources in the study area are limited to the Brazos and Bosque Rivers, their tributaries and impoundments, and the many smaller impoundments constructed for agricultural purposes. Several reservoirs have been constructed on the Brazos River, including Lake Whitney which is on the northeastern county line about 15 miles east of the proposed Lake Bosque site. Brazos River reservoirs have seen only limited use as municipal water supply sources because the dissolved solids concentration of Brazos River water commonly exceeds state and federal drinking water standards. Much of this material originates from brine springs located on the Salt Fork of the Brazos River. The federal government has considered addressing this problem by building a system of large reservoirs in the Salt Fork basin to contain and evaporate the salt spring discharges. However, salinity reduction in the Brazos River and its impoundments by these federal salt control projects appears unlikely because of construction costs and potential environmental effects.

Lake Waco, on the Bosque River, is the water supply for the City of Waco. The existing conservation storage volume of this reservoir is contractually committed to the City of Waco so water from this source is unavailable to the other communities of McLennan and Bosque Counties. Lake Waco as presently permitted can supply 58,200 acre feet (51.96 mgd) per year. An enlargement has been proposed by the City of Waco (possibly occurring by year 2000) to increase Lake Waco's yield by 20,100 acre feet (17.9 mgd) under 2040 sediment conditions.

3.4.2.1 Hydrology and Water Quality

The stream gages nearest the location of the proposed Lake Bosque are U.S. Geological Survey (USGS) stations at Hico, about 28 miles upstream, and at Clifton, about 20 miles downstream of the dam site. Drainage area at the proposed dam is 707.6 square miles, which encompasses 73% of the area above the Clifton gage. Average discharge of the North Bosque River at Clifton is approximately 187 cubic feet per second (cfs) when calculated over the entire 1923-1985 period of record (USGS, 1987). At the Clifton gage the median annual discharge, that flow at which one half the daily average flows are greater and one half are less is 20 cfs, 10.7% of the average. The large difference between the average and median discharges reflects the statistical effect of occasional large flood flows and indicates the great variation in discharge experienced at a given location. Median discharge calculated on a monthly basis shows a spring (March-June) maximum in which median monthly discharges are roughly 2 to 4 times the annual median. The July-October low flow period exhibits medians of one half to one forth the annual value while the remaining months tend to approximate it (Figure 3-3).

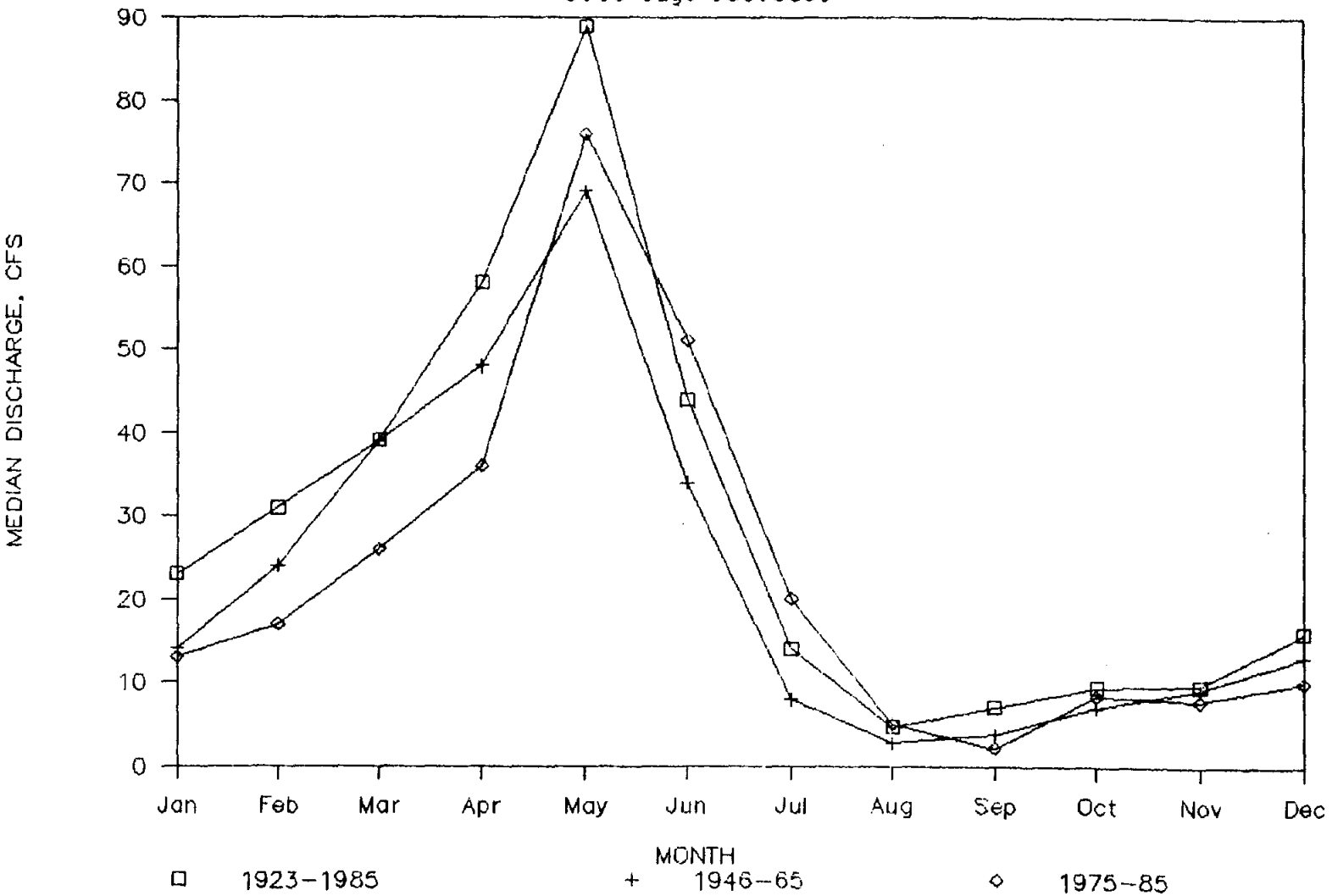
Yield and reservoir operation studies (HDR Infrastructure, Inc., 1987a) were performed using the period of record 1946-1965 in order to include the critical drought period. This procedure is used in order to ascertain the reliable, or firm, yield of the system, on which the water users can depend. Median annual discharge during this latter period is about 14 cfs, or 30% less than that for the entire Clifton period of record.

In order to evaluate the effect of possible trends in the rainfall-runoff relationship on discharge characteristics at the proposed dam site and at the Clifton gage, additional

Figure 3-3

Median Flow by Month at Clifton, Texas

USGS Gage 08095000



analyses were performed. Because of watershed changes, particularly the construction of flood retarding and sediment retention structures in the East and upper North Bosque basins during the period 1955-1975, records indicate that the rainfall-runoff ratio has declined, resulting in a real decrease in discharge. The period since completion of the SCS structures (1975-1985) has annual and median monthly flows at Clifton that are similar to those calculated for the 1946-1965 period. Median annual discharge for 1975-1985 is about 15 cfs at the Clifton gage. Plots of the median monthly discharges calculated for all three periods of record are included in Figure 3-3.

To allow discharges at the proposed dam site to be accurately estimated using available gage records, synoptic discharge measurements at Hico, Clifton and at Comanche Crossing (between Meridian and the dam site) were used to delineate the relation between discharge at the three locations. Figure 3-4 shows monthly median discharges at the proposed dam site calculated over the 1975-1985 period of record, and Table 3-1 presents the range of flow frequencies from which the figure was derived. The 1975-1985 period was chosen to determine discharge at the dam site to reflect the present and most probable future flow regime.

Water quality information is available for the North Bosque River in the Texas Parks and Wildlife Department fishery survey reports for Lake Waco (TPWD, 1974; 1975; 1976), from Statewide Monitoring Network stations maintained by the Texas Water Commission (TWC, 1987), from an intensive survey report (TDWR, 1980) and from data collected during the baseline studies (TCA, 1985; Paul Price Associates Inc., 1987a).

Figure 3-4

Median Flow by Month at Bosque Dam Site

Period of Record: 1975-85

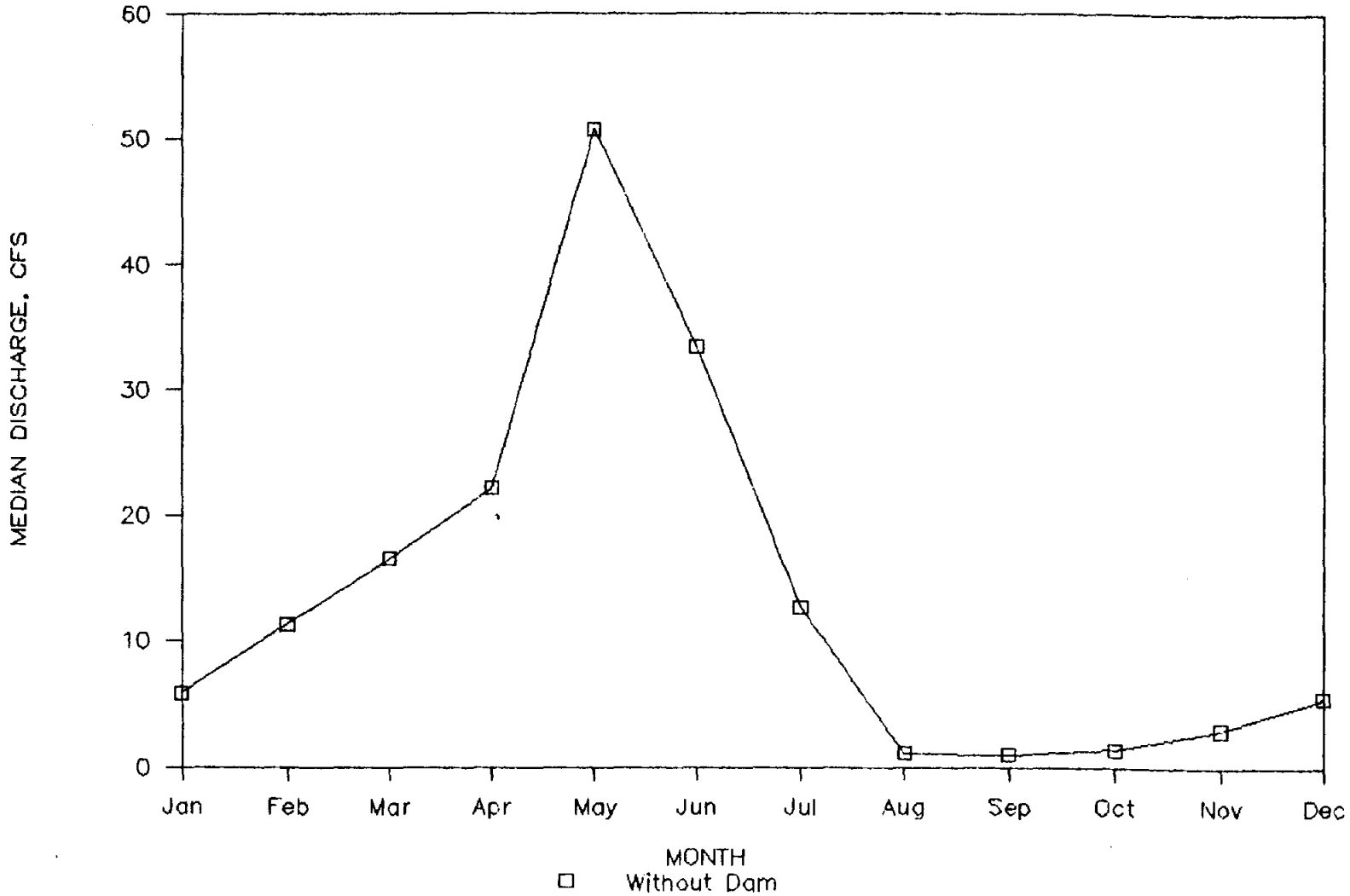


Table 3-1 Monthly Flow Frequency Distribution at the proposed Dam Site

Percent of Days with Less Than Tabulated Flows	January	February	March	April	May	June	July	August	September	October	November	December
98%	132.00	485.00	776.00	1426.00	1749.00	653.00	231.00	54.20	73.00	187.00	42.60	82.20
95%	69.80	218.00	338.00	565.00	1071.00	391.00	101.00	25.80	23.10	82.10	24.00	49.30
90%	53.00	138.00	148.00	308.00	581.00	203.00	47.00	19.60	4.53	27.20	16.40	27.90
80%	32.80	41.50	81.80	131.00	275.00	106.00	28.20	11.10	2.76	4.53	9.59	11.30
70%	16.60	19.60	46.20	69.80	153.00	69.20	22.70	4.34	2.37	2.56	5.52	8.62
50%	5.91	11.40	17.70	22.20	50.70	33.50	5.91	1.10	0.97	1.36	2.96	5.52
30%	4.14	5.72	10.50	5.32	12.90	9.90	0.39	0.00	0.00	0.49	1.79	2.76
20%	3.75	4.73	5.12	3.75	5.52	4.14	0.00	0.00	0.00	0.00	0.95	1.95
10%	3.15	3.15	2.76	2.56	2.96	1.38	0.00	0.00	0.00	0.00	0.00	0.87
5%	2.96	2.76	1.81	1.95	0.14	0.34	0.00	0.00	0.00	0.00	0.00	0.14

Note: Tabulated values are average daily flows in cubic feet per second.
Source: HDR Infrastructure, 1987

Designated uses for Segment 1226 are Contact Recreation and High Quality Aquatic Life (Texas Water Code, 26.023.333.21.A). This Segment is not designated for Public Water Supply use, but Segment 1225, Lake Waco, is so designated and is used for that purpose.

Numerical criteria for Segment 1226 are:

Chloride	75	milligrams per liter (mg/l)
Sulfate	60	mg/l
TDS	540	mg/l
D.O.	5.0	mg/l
pH	6.5-9.0	units
Fecal Coliform	200/100	ml
Temperature	91	F

North Bosque River water is typically of slightly alkaline pH (7.0-9.0), moderate conductivity (300-600 micromhos per centimeter, umho/cm) and moderate to high alkalinity and hardness (100-300 mg/l). Bicarbonate is the dominant anion, chloride and sulfate concentrations are usually moderate, generally in the ranges 15-30 mg/l, and 20-50 mg/l, respectively.

Nutrient levels tend to be moderate to high. For example, about half of all total phosphorus samples collected between Meridian and Clifton since 1983 have exceeded 0.05 mg/l. During the 1980 through 1983 period most values from that location fell in the range 0.02-0.05 mg/l. Inorganic nitrogen levels also tend to be moderate to occasionally high, but ammonia is generally not present at problem levels. Chlorophyll *a* measurements from North Bosque stations do not indicate excessive amounts of suspended algae in response to these nutrients. However, all solid surfaces in shallow water typically exhibit massive growths of filamentous green algae, which apparantly constitutes a mainstay of the river food webs.

While dissolved oxygen (DO) levels are only rarely observed to fall below 5.0 mg/l, diurnal ranges are often quite large, presumably reflecting the metabolism of the large algal biomass. Data collected in April 1978 showed a zone from Stephenville to Hico affected by wastewater discharge (TDWR, 1980). This impact was not evident in diurnal DO measurements made in October 1983 (TWC, 1987). Unlike the North Bosque River, Lake Waco periodically exhibits serious DO depletion in the hypolimnion. The City of Waco operates a system of compressed air bubblers in the North Bosque arm of the lake to suppress stratification and assist in reaeration to help minimize water treatment costs.

3.4.2.2 Wetlands and Floodplains

Wetlands in the proposed reservoir site are mapped and discussed in the Baseline Ecology Survey (TCA, 1985). These consist, for the most part, of the channel of the North Bosque, its tributaries and artificial stock watering ponds. There are also a few small seep areas that are sufficiently persistant to allow development of wetland vegetation. This situation appears typical of the remainder of the North Bosque Valley all the way to Lake Waco.

Generalized flood potential and floodplain studies that include the North Bosque River have been conducted by the U.S. Army Corps of Engineers but the only FEMA floodplain study available is for Valley Mills. HDR Infrastructure, Inc. has estimated the present 100, 50 and 10 year floods to have peaks of 94,500, 80,360 and 47,660 cfs, respectively, at the proposed dam site. In the reach below the dam site to Meridian, the 100 year flood inundates an average of about 145 acres per stream mile, giving an average stream width at maximum stage of approximately 1200 feet.

3.5 Aquatic Biology

3.5.1 Aquatic Habitats and Biota

Aquatic habitats are defined by the same factors that shape terrestrial ones; the interaction of regional climate, geology and soils together with the biological responses of resident species and human activities. As a result of regional geology and climate, the North Bosque River exhibits the same channel morphology from the proposed reservoir headwaters below Iredell all the way to Lake Waco, a distance of about 60 river miles. These same factors have also influenced human settlement patterns and land uses, resulting in relatively uniform cultural impacts throughout this reach.

3.5.1.1 Channel Characteristics

The North Bosque River channel is typically 75 to 150 feet wide, incised into an alluvial floodplain in which it is free to meander. The channel is bordered with steep to vertical banks up to about 30 feet in height. Unless vertical, the banks support a narrow strip of brush or woodland. Except for these wooded strips, which rarely exceed 50 feet in width, land adjacent to the river is almost exclusively cultivated (SCS, 1980).

The river exhibits a characteristic **pool-riffle sequence** throughout the survey reach that consists of elongated pools, commonly 200 to 1000 yards, or more, in length, often occupying the full width of the bed, that terminate in short boulder/cobble/gravel riffles. At intervals, the common pool/ short riffle sequence gives way to reaches in which bed elevation appears to drop sharply in a series of short pools, boulder/cobble riffles and deeper runs over gravel/cobble substrates. The wetted area in these reaches

typically does not occupy the entire channel bottom, but is a narrower channel meandering among an extended series of gravel bars.

The gradient of the North Bosque River ranges from a maximum of 27 feet per mile to a minimum of less than 5 feet per mile. The reach from the reservoir headwaters to Commanche Crossing (Figure 3-1) and most of the way to Lake Waco exhibits an average gradient of about 5.5 feet per mile. Between the proposed dam site and Lake Waco, high gradient reaches occur between Meridian and Clifton (14 feet per mile) and below China Springs Crossing (27 feet per mile) . The higher gradient portion of the Meridian-Clifton reach is about 6 miles in length, while the highest gradient reach, just above Lake Waco is only 3-4 miles long. The average gradient for the entire length of the North Bosque River is 9.9 feet per mile. Changes in gradient are controlled by the lithology and structure (dip) of the formations traversed by the river channel. This relation is illustrated in Figure 3-5.

The East Bosque River is a smaller, intermittent stream with a narrow, but well developed channel which in many places is heavily shaded by surrounding vegetation. Substrates are typically gravel (often *Gryphaea* fossils) with occasional outcropping slabs and loose boulders in the reach to be inundated. This stream usually exhibits clearer water than the North Bosque, a greater variety of rooted vegetation and substantially greater accumulations of terrestrial plant debris from riparian vegetation. The food webs of the East Bosque River, in common with most lower order streams, are probably based primarily on the consumption of detritus.

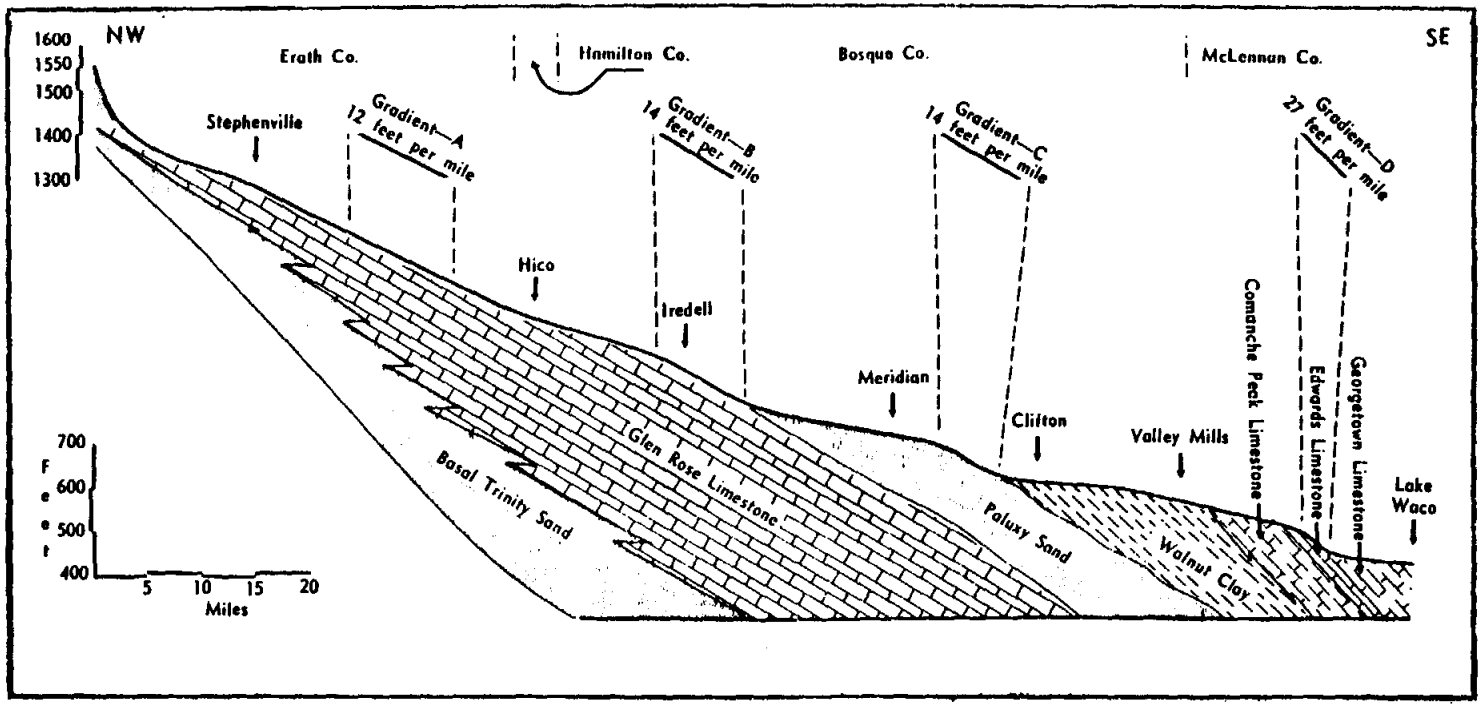


Figure 3-5
The Influence of Underlying Geological Structure on the Longitudinal Gradient of the North Bosque River (from Proctor, 1969)

3.5.1.2 Pool Habitats

Pool habitats with muddy sand and gravel substrates dominate the river environment both within the reservoir site and in the reach downstream to Lake Waco. The extreme upper portion of Lake Bosque (Station 5, TCA, 1985) will inundate a portion of the streambed floored with slabs of Glen Rose limestone overlaid by sheets and bars of gravel and finer sediments. Habitats here are comprised almost entirely of shallow, rock bottomed pools.

Rooted aquatic vegetation is largely absent from the pools, as they tend to have steeply sloping littoral margins that, together with the characteristically turbid water, periodic scouring during high flows and marginal shading from riparian vegetation, limits the development of these species. Pool depths, even at zero flow when intervening segments are dry, appear to commonly exceed six feet. Pools tend to become gradually shallower in an upstream direction, with the uppermost segment often consisting of a very flat stream bed completely inundated by a few inches of water even at relatively low flow. Silty sands and gravel dominate the physical habitat in the river. Rocky areas, stands of aquatic vegetation, accumulations of plant debris and masses of tree roots exposed in cut banks all occur occassionally and contribute to habitat diversity but cannot be considered common.

Given this general lack of cover in the North Bosque River, it is probable that shallow areas in the main stem and in the tributaries are important as spawning areas and as refuges for forage species and the juveniles of larger forms.

Pools are also the dominant habitat component in the East Bosque River. Small, relatively clear pools formed where

the extensive gravel substrate has been scoured out at the base of a bluff or channel bend are typical of this stream. These pools often contain substantial stands of aquatic vegetation and accumulations of plant debris. During extended dry periods only a small proportion (10% or less) of the stream bed of the East Bosque River contains surface water.

3.5.1.3 Riffle Habitats

Pools terminate in riffles that are usually quite short (less than 50 yards) regardless of their composition. Ledge outcrops occur occasionally, but riffles with gravel/cobble/boulder substrates are most common.

The riffle at Comanche Crossing (Station 1 in the Baseline Ecology Survey and the location of IFIM studies by the U.S. Fish and Wildlife Service) is reasonably typical of the North Bosque River. This riffle drops nearly two feet in bed elevation in 50 yards. If we assume all changes in stream bed elevation occur in riffles, and that all riffles have the same gradient, we will expect about 150 yards/mile (8.5% of channel length) of riffle habitat in the low gradient (5.5 feet per mile) reaches that account for 83% of the channel from the reservoir headwaters to Lake Waco.

Compared to lower gradient reaches, pools in the Meridian-Clifton high gradient segment were shorter, generally less than 200 yards in length, but riffles were also shorter, ranging from single falls over ledges through cobble/gravel runs up to 30 yards in length. Riffles accounted for about 20% of channel length in the reach examined.

Riffle habitat is very restricted in the reach of the East Bosque River to be inundated by construction of Lake Bosque. Like the uppermost North Bosque River reach of the proposed

reservoir, substrates are either gravel bars or limestone slabs and the riffle habitats typical of most of the North Bosque River tend to be absent.

3.5.1.4 Aquatic Biota

For the reasons noted above, aquatic macrophytes are restricted in distribution in the North Bosque River. The only species observed in significant amounts there has been American water willow (*Justicia americana*), although bladderwort (*Utricularia* sp.) and South American elodea (*Elodea densa*) were present in the East Bosque. River productivity appears to be based primarily on algal growth. The large pools that dominate the river environment support planktonic algae, while solid surfaces in shallow areas usually exhibit substantial stands of filamentous green algae, predominantly *Cladophora* sp., but *Hydrodictyon* sp. has also been observed and others are undoubtedly present. Both are common in nutrient rich waters in Central Texas. The paucity of terrestrial plant debris in the river is further indication of the autotrophic character of this stream.

Invertebrate assemblages reflect the substrates, the flow regiemes and the food supplies available at the times of collection. Pool habitats tend to exhibit a diverse and abundant assemblage of organisms that live within and sprawl upon sandy and silty sediments. This community is dominated by chironomids, oligochaetes and the asiatic clam, *Corbicula fluviatilis*. Other groups tend to be more restricted in diversity and abundance by the low substrate diversity characteristic of this river, but includes typically lentic taxa of Crustacea, Ephemeroptera, Odonata, Coleoptera, Gastropoda and others, rather than species of definitely riverine association.

Riffle areas are heavily dominated by filter feeders, including the caddisfly *Cheumatopsyche* sp. and blackflies (Simulidae), and by Mayflies that cling to stones and graze on epilithic algae (*e.g.*, *Heptagenia* sp., *Stenonmema* sp.). The large megalopteran predators (e.g., *Corydalus* spp.) are conspicuous by their absence from these habitats. The kinds and numbers of riffle invertebrates common in the proposed reservoir site appear to dominate downstream riffle habitats as well, at least to China Springs Crossing.

The general lack of substantial stands of rooted vegetation or accumulations of organic detritus (e.g., leaf pack, etc.), the extensive development of attached algae on submerged surfaces and the planktonic algae of the large, unshaded pools is reflected in the preponderance of surface inhabiting collectors and scrapers and the rarity of shredders in the invertebrate assemblage. This community structure indicates that the food webs in the North Bosque River are primarily based on direct consumption of instream (autochthonus) production rather than being detrital based, as is generally the case in smaller streams such as the East Bosque River.

Table 3-2 lists fish species collected in the Bosque River during the ecological baseline survey (1984-1985) and by Texas Parks and Wildlife Department in 1953 and fish reported from Lake Waco (TCA, 1985; TPWD, 1954; 1974; 1975; 1976). The assemblage is not atypical for the Texan Biotic Provence, which is an ecotonal region between the eastern woodland and western grassland faunas. Most of the species collected are widely distributed, but one, the chub shiner (*Notropis potteri*), is restricted to the Texan Biotic Provence. Others, including the blackstripe topminnow (*Zygonectes notatus*), blacktail shiner (*Notropis venustus*) and spotted bass (*Micropterus punctulatus*) are primarily eastern and coastal plain species.

Table 3-2 Fish Species Occuring in the North Bosque River and Lake Waco

Common Name	Scientific Name	Collected Oct. 1984 or May 1985	Reported 1953 by TPWD**	Reported from Lake Waco *
Spotted Gar	*Lepisosteus oculatus*			+
Longnose Gar	*L. osseus*	+		+
Threadfirm Shad (v)	*Dorosoma petenense*			+
Gizzard Shad	*D. cepedianum*	+	+	+
Carp	*Cyprinus carpio*	+		+
Golden Shiner	*Notemigonus crysoleucas*	+		+
Pugnose Minnow	*Opsopoeodus emiliae*	+		
Suckermouth Minnow	*Phenacobius mirabilis*	+		
Chub Shiner	*Notropis potteri*		+	
Blacktail Shiner	*N. venustus*	+	+	+
Red Shiner	*N. lutrensis*	+	+	+
Ghost Shiner	*N. buchanani*	+		
Blackspot Shiner	*N. atrocaudalis*			+
Bullhead Minnow	*Pimephales vigilax*			+
Fathead Minnow	*P. promelas*	+		
Stoneroller	*Campstoma anomalum*			+
Small Mouth Buffalo	*Ictiobus bubalus*			+
River Carpsucker	*Carpiodes carpio*	+	+	+
Gray Redhorse	*Moxostoma congestum*			+
Creek Chubsucker	*Erimyzon oblongus*		+	

Table 3-2 Fish Species Occuring in the North Bosque River and Lake Waco

Common Name	Scientific Name	Collected Oct. 1984 or May 1985	Reported 1953 by TPWD**	Reported from Lake Waco *
Channel Catfish (V)	*Ictalurus punctatus*	+	+	+
Black Bullhead	*Ictalurus melas*			+
Yellow Bullhead	*I. natalis*			+
Flathead Catfish	*Pylodictis olivaris*			+
Freckled Madtom	*Noturus nocturnus*			+
Blackstripe Top-minnow	*Fundulus notatus*	+	+	+
Black spotted Top-minnow	*Fundulus olivaceus*			+
Mosquitofish	*Gambusia affinis*	+	+	+
Mississippi Silverside	*Menedia andens*			+
Brook Silverside	*Labidesthes sicculus*			+
Spotted Bass	*Micropterus punctulatus*	+	+	+
Largemouth Bass (V)	*M. salmoides*	+	+	+
Warmouth	*Lepomis gulosus*	+		+
Green Sunfish	*L. cyanellus*	+	+	+
Redear Sunfish	*L. microlophus*			+
Bluegill	*L. Macrochirus*	+	+	+
Orange Spotted Sunfish	*L. humilis*			+
Longear Sunfish	*L. megalotis*	+	+	+
White Crappie	*Pomoxis annularis*	+		+
Black Crappie	*Pomoxis nigromaculatus*			+
Striped Bass (V)	*Roccus saxatilis*			+

Table 3-2 Fish Species Occuring in the North Bosque River and Lake Waco

Common Name	Scientific Name	Collected Oct. 1984 or May 1985	Reported 1953 by TPWD**	Reported from Lake Waco *
White Bass	*Roccus chrysops*			+
Walleye (V)	*Stizostedion vitreum*			+
Logperch	*P. caprodes*	+		+
Freshwater Drum	*Aplodinotus grunniens*			+

Notes: * Texas Parks and Wildlife Department, 1974,1976.
** Texas Parks and Wildlife Department, 1954. (V) = stocked by TPWD into Lake Waco.

The species known to inhabit the North Bosque River tend to be characteristic of pool or backwater habitats and most are capable of survival and reproduction in a reservoir. For example, the only darter collected from the reservoir site has been the logperch (*Percina caprodes*). This fish was more widely distributed and abundant in samples collected during a zero flow period (fall 1984) than in the following spring when riffles were present. The species is also reported to be present in Lake Waco.

Of the forage fish, the most abundant species were mosquitofish (*Gambusia affinis*) and blackstripe topminnow, but the cyprinids (minnows) constituted the most diverse group of small fishes collected in the reservoir site. So called rough fish, primarily longnose gar (*Lepisosteous osseus*), river carpsucker (*Carpiodes carpio*) and gizzard shad (*Dorosoma cepedianum*), were common in collections from the proposed reservoir site. Gamefish tended to be present in lower numbers, and were represented by channel catfish (*Ictalurus punctatus*) and several centrarchid species including spotted bass (*Micropterus punctulatus*), crappie (*Pomoxis annularis*), warmouth (*Lepomis gulosus*), bluegill (*L. macrochirus*), and longear sunfish (*L. megalotis*). Most of these species are also present in Lake Waco, although in different proportions, and the Lake appears to have a somewhat more diverse assemblage than the river.

All groups, but particularly large multivoltine forms, are affected by the periodic low flow periods that reduce the river to a series of isolated pools. During these periods primary production can decrease dramatically due to the lack of nutrient input and inadequate recycling, while the paucity of cover may expose invertebrates, small fish species, and juveniles, to catastrophic levels of predation. Periods of zero summer flow at the proposed dam site

presently recur at an average rate of once in three years (Table 3-1).

3.5.2 Important Species

Important species are defined as those which (a) are commercially or recreationally valuable, (b) are threatened or endangered, (c) affect the well-being of some important species within criteria (a) or (b); or, (d) are critical to the structure and function of the ecological system.

3.5.2.1 Commercially or Recreationally Important Species

Local fishermen and Texas Parks and Wildlife Department personnel report that channel and yellow catfish (*Ictalurus natalis*) constitute the most important recreational resource in the North Bosque River. Bass and crappie are also sought, often incidentally to catfishing, and rough fish such as buffalo, carp and gar, are sometimes fished for. These species are all reported by Texas Parks and Wildlife Department to be present in Lake Waco, although the assemblage reported from that lake appears to be substantially more diverse than is present in the North Bosque River.

While Lake Waco supports a substantial fishery for white bass (*Roccus chrysops*), this species is not believed to run upstream even as far as China Springs Crossing, and no other important, strongly migratory fish is known from the Bosque River.

3.5.2.2 Threatened and Endangered Species

With one exception, no threatened or endangered aquatic species, listed either by the Texas Parks and Wildlife Department or by U.S. Fish and Wildlife Service, is known to

occur or is considered likely to occur in Bosque County. Harter's water snake (*Nerodia harteri*) is listed as endangered by the TPWD, and is considered "confirmed" in Bosque County. The upper Brazos River drainage subspecies (*N. h. harteri*) is not currently believed to be in danger of extinction by USFWS, and intensive surveys in its range indicate that it is highly unlikely to be found in the Bosque River system (Maxwell, 1982; Scott and Fitzgerald, 1985).

3.5.2.3 Other Important Species

No single species is known to be critical to the survival of any important species, or to the functioning of the community as a whole. The most abundant species, or groups of species, present in the river are considered important in that they define the character of the biological community. A variety of algal producers and both invertebrate and vertebrate consumers constitute a complex food web based largely on in situ photosynthesis. But no particular species, either among the algal producers or among the consumer links, appears likely to be critical to this trophic structure as none of the consumers is known to be strictly dependant on one or a few species for its nutrition.

The stands of water willow present in the channel may be important in providing habitat for some invertebrate taxa that might otherwise be excluded and they probably serve as cover for forage fish and juveniles of larger species. However, the extent of the habitat created by this species is not great, and it is unlikely, given the taxa collected in the North Bosque River, that it can be considered critical to the functioning of the aquatic community or to a particular important species.

3.6
Vegetation

The Lake Bosque site lies in the southeast region of the Cross Timbers and Prairies Vegetational Area (Gould, 1975). Although the climax vegetation type of the Cross Timbers is typically upland woodland dominated by post oak (*Quercus stellata*) and blackjack oak (*Q. marilandica*) little of this is present in the vicinity of the reservoir site. Due to the proximity of the project area to other vegetational areas (i.e., Blackland Prairies to the east, Rolling Plains to the west, and Edwards Plateau to the south), the native vegetation of the project area contains species characteristic of these adjacent areas. Project area upland woodlands, for example, are dominated by many species characteristic of the Edwards Plateau.

Over 200 plant species were identified in the project area during the original baseline studies. These species were grouped into eight major plant communities consisting of upland and bottomland woodlands, native grasslands, improved pastures, stream beds, aquatic habitats, wetlands, and croplands. A vegetation map of the Lake Bosque project area is presented in the Baseline Ecology Report (TCA 1985). Table 3-3, reproduced from TCA, 1985, lists the acreages of each community type affected by the proposed project.

3.6.1 Plant Communities And Characteristic Species

3.6.1.1 Upland Woodland

Upland woodlands, which encompass only 182.5 acres within the 4756 acre reservoir site (the area occupied by the conservation pool, dam and spillway), occur primarily as narrow bands along ridge tops at the periphery of the project area. These woodlands are dominated by ash juniper

Table 3-3 Areas (acres) and Percentages of Vegetation Map Units, Bosque Lake Project Area, May 1985

	Normal Pool (1)	100 year Flood Pool (2)	Dam & Spillways (3)	Total	Percentage of Total
U Upland Woodland	106.29	92.74	3.44	202.47	3.30%
Uj Upland, Juniper dominated	72.78	4.82	0.00	77.60	1.26%
Up Upland, Post Oak dominated	0.00	0.00	0.00	0.00	0.00%
N Native Pasture	1,466.71	765.84	44.08	2,276.63	37.06%
Nm Native Pasture > 50% Mesquite cover	14.46	2.30	0	16.76	0.27%
I Improved Pasture	927.00	239.44	80.35	1,246.79	20.30%
C Cropland	1,000.00	130.16	49.36	1,179.52	19.20%
Cp Pecan Orchard	6.89	0.00	0.00	6.89	0.11%
B Bottomland Woodland	780.53	105.83	12.40	898.76	14.63%
W Wetland	12.86	13.55	0.00	26.41	0.43%
A Aquatic (ponds)	18.13	12.41	0.00	30.54	0.50%
S Streambed	158.86	20.20	1.83	180.89	2.94%
TOTALS	4,564.51	1,387.29	191.46	6,143.26	1.00

Note: (1) Acres inundated at normal operating pool, 830 ft. MSL.
(2) Area of intermittant inundation, between elevations 830 and 841.3 MSL.
(3) Area covered by dam and spillways.
Source: Technical Consulting Associates, 1985

(*Juniperus ashei*), plateau live oak (*Quercus fusiformis*), Texas red oak (*Q. texana*), and cedar elm (*Ulmus crassifolia*). Texas ash (*Fraxinus texensis*), post oak, coma (*Bumelia lanuginosa*), and netleaf hackberry (*Celtis reticulata*) are also common overstory species.

3.6.1.2 Bottomland Forest

The bottomland forests of the project area represent the western most outliers of the extensive bottomland forests of the eastern United States. Within the reservoir site this community occupies 792.9 acres of broad, first and second bottomland terraces along the North Bosque River, narrow riparian areas along secondary drainages, and mesic slopes immediately adjacent to the river. Although this habitat type is referred to as "bottomland forest" (and "decidous forested wetland" by the U.S. Fish and Wildlife Service), it does not generally fit the U.S. Army Corps of Engineers definition of a wetland and is not dependant on annual inundation by the North Bosque River for maintenence. The Bosque County Soil Survey (SCS, 1980) shows the forests adjacent to the Bosque River channel are developed on occasionally flooded (2-5 years) Bosque Loam and Frio Silty Clay Loam soils. Those on mesic slopes along tributary channels and in other areas away from the main river channel have developed on a variety of soils.

Due to the distribution of this community, substantial variation in floral composition of the overstory, understory, shrub, and ground cover layers amongst the stands sampled were evident. Cedar elm was the single most dominant species present, while bur oak (*Quercus macrocarpa*), pecan (*Carya illinoiensis*), and Texas sugarberry (*Celtis laevigata*) were the most common co-dominants on the bottomland terraces. Boxelder (*Acer negundo*) was most important on the mesic slopes along the

river in association with pecan, Texas sugarberry, cedar elm, and American elm (*Ulmus americana*).

3.6.1.3 Native Grassland

Native grasslands account for 1525.2 acres of the reservoir site. A small portion (14.5 acres) has greater than fifty percent honey mesquite (*Prosopis glandulosa*) cover. The majority of this community consists of overgrazed upland pastures, but also includes well-managed or lightly grazed pastures, roadsides, and a few small remnants of native prairies. The dominants of the original tallgrass prairie have decreased in importance over most of the site, primarily due to overgrazing, fire control, and mowing (roadsides). Such decreasers include little bluestem (*Schizachyrium scoparium*), big bluestem (*Andropogon gerardi*), and Indian grass (*Sorghastrum nutans*). Texas wintergrass (*Stipa leucotricha*) is most common in overgrazed pastures, usually in association with Texas grama (*Bouteloua rigidiseta*), silver beardgrass (*Bothriochloa saccharoides*), buffalo grass (*Buchloe dactyloides*), and side-oats grama (*Bouteloua curtipendula*). As a result of mowing pressure, roadsides are dominated by increasers such as King Ranch bluestem (*Bothriochloa ischaemum* var. *songaricus*), silver beardgrass, jointed goat-grass (*Triticum cylindricum*), three-awn (*Aristida* spp.), and Texas wintergrass.

Well-managed native pastures occur at scattered locations in the project area, but are most prominent in the northeast portion. Native grasses are prevalent in many of these pastures because of active reseeding efforts. Climax grasses present include little bluestem, side-oats grama, Indian grass, muhly (*Muhlenbergia* spp.) and dropseed (*Sporobolus* spp.).

3.6.1.4 Improved Pasture

Improved pastures cover 1007.4 acres of the reservoir site. These were formerly native grasslands which have given way, through planting efforts, to exotic grasses such as King Ranch bluestem, kleingrass (*Paspalum coloratum*), and both common and coastal bermudagrass (*Cynodon dactylon*). Increasers which may also be found on improved grasslands include Texas wintergrass, windmill fingergrass (*Chloris verticillata*), silver beardgrass, and broomweed (*Xanthocephalum dracunculoides*). In addition, numerous dicot herbs of importance to this community may be found at different times of the year.

3.6.1.5 Stream Beds

This 160.7 acre plant community is limited to the stream beds and immediately adjacent, nonforested banks along the North and East Bosque rivers. Most of the stream bed consists of linear pools and exposed bars of rock and gravel which are scoured and rearranged during flood events. Aquatic vegetation is almost entirely limited to stands of American water willow (*Justicia americana*) and mats of filamentous green algae including *Cladophora* sp. and *Hydrodictyon* sp., except during extended dry periods when species characteristic of marginal lentic habitats (see Aquatic Habitats, below) invade the channel.

Where terrestrial vegetation has become established, the stream banks may become densely vegetated with species such as sumac (*Rhus* spp.), eastern prickly pear (*Opuntia compressa*), Mexican devil-weed (*Aster spinosus*), mist-flower (*Eupatorium coelestinum*), little bluestem, buffalo-gourd (*Cucurbita foetidissima*), side-oats grama, Johnson grass (*Sorghum halepense*), and cat-brier (*Smilax bona-nox*). More elevated, protected areas may have Arizona walnut (*Juglans*

major), buttonbush (*Cephalanthus occidentialis*), bastard indigo (*Amorpha fruticosa*), Roosevelt weed (*Baccharis neglecta*), and rough-leaf dogwood (*Cornus drummondii*). Numerous herbs and vines specific to this community include cardinal flower (*Lobelia cardinalis*), hierba del marrano (*Aster subulatus* var. *ligulatus*), horse-weed (*Conyza canadensis*), late eupatorium (*Eupatorium serotinum*), hairy grama (*Bouteloua hirsuta*), morning glory (*Ipomoea trichocarpa*), noseburn (*Tragia brevispica*), and others. Substantial development of terrestrial vegetation is presently uncommon within the channel. However, stands of cocklebur (*Xanthium strumarium*), Johnsongrass, buttonbush, and other weedy species develop on the gravel bars during extended low flow periods.

3.6.1.6 Aquatic Habitats

The aquatic habitats of the reservoir site account for about 18.1 acres, which only includes scattered farm and stock ponds. Emergent species which dominate the periphery of these ponds include buttonbush, pink smartweed (*Persicaria bicornis*), Texas frog fruit (*Phyla incisa*), spikerush (*Eleocharis* spp.), sedges (*Carex* spp.), common bermudagrass, American water willow, wild petunia (*Ruellia nudiflora*), black willow (*Salix nigra*), and Roosevelt weed.

3.6.1.7 Wetlands

Wetlands occupy 12.9 acres of the reservoir site. The majority of the wetland habitats are areas immediately along the edges of streams and ponds, old river meander depressions in the floodplain, and beaver impoundments. In these areas, emergent marsh vegetation occurs as small, scattered patches. With the exception of black willow and Roosevelt weed, dominant species in this community include those listed for aquatic habitats.

3.6.1.8 Cropland

Croplands account for 1056.2 acres, plus 6.9 acres of pecan groves. Row crops of sorghum (*Sorghum bicolor*), wheat (*Tritiicum aestivum*), and oats (*Avena fatua*) occupy the majority of this largely bottomland acreage. Oats are widely planted, especially in the bottomland pastures, during the fall. Common ruderal species which invade cultivated and fallow fields include Johnsongrass, cat-brier, cocklebur, bull nettle (*Cnidoscolus texanus*), ragweed (*Ambrosia* spp.), common sunflower (*Helianthus annuus*), and broomweed.

3.6.2 Important Plant Species and Communities

Important species are defined above, in Section 3.4.2. Important communities are considered to be those that have unusual ecological value.

3.6.2.1 Recreationally and Commercially Valuable Species

Commercially important tree species in the project area include **ash juniper and hardwoods** (cedar elm, green ash, pecan, Shumard red oak, plateau live oak, and others) which may be used for fence posts or firewood. In addition, pecans may be sold for profit or used for personal consumption. The regional diversity in soils and range sites leads to wide variations in the density and relative importance of tree species.

Both native and improved forage grasses and row crops are of commercial importance both as on site livestock feed and as **cash crops.** Common and coastal bermuda grass, King Ranch bluestem, and Kleingrass are most important in the area's extensive improved pastures. Common and coastal bermuda

grass and Johnsongrass are important cultivated species in the hayfields, and the row crops of greatest commercial importance oat, sorghum, and wheat.

Numerous plant species on the site are ecologically important as browse and forage materials for important wildlife species. Examples include various grape species (*Vitis* spp.), cat-brier, common elder-berry (*Sambucus canadensis*), numerous oak species, possum-haw (*Ilex decidua*), yaupon (*Ilex vomitoria*), rough-leaf dogwood, common buttonbush, American beautyberry (*Callicarpa americana*), pecan, black hickory (*Carya texana*), black willow, cedar elm, Texas sugarberry, southern dewberry (*Rubus trivialis*), poison ivy (*Rhus toxicodendron*), Texas persimmon (*Diospyros texana*), red ash (*Fraxinus pennsylvanica*), and various sedges and grasses. Oak mast is of particular importance to deer.

3.6.2.2 Endangered and Threatened Plant Species

No threatened or endangered plant species, either listed by the U. S. Fish and Wildlife Service or the Texas Parks and Wildlife Department or Texas Organization for Endangered Species (TOES) are known from these counties.

3.6.2.3 Important Communities

Bottomland forest and riparian habitats are of particular ecological importance in the project area, as well as in the general region. These habitats, while relatively small in areal extent, are responsible for much of the diversity in plant and wildlife in the project area. Many important species are limited to or prefer these types of habitats. Because of the trend of reduction in bottomland forest throughout Texas, primarily as a result of agricultural

activities, this lowland habitat type is of particular concern.

3.7 Wildlife

The Lake Bosque project area occurs on the western edge of the Texan Biotic Province near the northeastern edge of the Balconian Biotic Province as delineated By Blair (1950). The Texan Province extends south as a broad strip to the Gulf Coast between Calhoun and Brazoria counties, and it extends north through central Oklahoma to the Kansas border. The region is considered to be an ecotone between the eastern forests and western grassland. This ecotonal nature of the region is further indicated by its placement in the Cross Timbers and Prairies Vegetational Area.

Results of the site-specific surveys revealed a diverse fauna in the Lake Bosque project area, with faunal elements exhibiting a variety of biotic affinities. Fourteen species of mammals, 61 species of birds and 27 species of reptiles and amphibians were detected during the fall reconnaissance and spring baseline surveys (1984-85). Common and other characteristic species are discussed in the following paragraphs.

Although the majority of the project area wildlife habitats and species were typical of the Texan Province, the wildlife species assemblage in the project area was distinctly marked by Balconian Province characteristics. The Cretaceous-age limestone uplands in the project area provided habitat for some Edwards Plateau forms that are not typical of, or at least are not as common in the rest of the Texan Province. For example, the white-ankled mouse (*Peromyscus pectoralis*), a typical Balconian Province species was common in the woodlands. Some other observed species that are more typical of the Balconian than the

Texan Province included the Texas greater earless lizard (*Cophosaurus texana*), Texas spotted whiptail (*Cnemidophorus gularis*), ladder-backed woodpecker (*Picoides scalaris*), and rufous-crowned sparrow (*Aimophila ruficeps*).

Like most areas in the region, clearing of bottomland forest for agriculture has resulted in its conversion to open habitats of improved pasture and cropland.

3.7.1 Wildlife Communities and Species

3.7.1.1 Bottomland/Riparian Woodland

Typical bottomland/riparian woodland associated wildlife species were present in the project area, but their preferred habitat was limited to relatively small interspersions of woodland, mostly in the form of narrow riparian strips.

Transect counts of birds in one of these bottomland/riparian strips indicated that the most common breeding species included the northern cardinal (*Cardinalis cardinalis*), Carolina chickadee (*Parus carolinensis*), tufted titmouse (*P. bicolor*), Louisiana waterthrush (*Seirus motacilla*), and Carolina wren (*Thryothorus ludovicianus*).

The white-ankled mouse was the only common small mammal captured in the bottomland habitat sampled by live-trapping. The white-tailed deer (*Odocoileus virginianus*), northern raccoon (*Procyon lotor*), and fox squirrel (*Sciurus niger*) were also commonly observed in this habitat. The gray treefrog (*Hyla versicolor* or *H. chrysoscelis*) was a common amphibian in the bottomlands.

Other less common, but equally characteristic species of the bottomland included the nine-banded armadillo (*Dasypus*

novemcinctus), Virginia opossum (*Didelphis virginiana*), red-bellied woodpecker (*Melanerpes carolinus*), downy woodpecker (*Picoides pubescens*), eastern wood pewee (*Cotopus virens*), yellow-billed cuckoo (*Coccyzus americanus*), red-eyed vireo (*Vireo olivaceus*), wild turkey (*Meleagris gallopavo*), and Texas rat snake (*Elaphe obsoleta*).

3.7.1.2 Upland Woodlands

Wildlife habitats of the upland woodlands in the project area have also been affected by clearing, primarily for conversion to native rangeland. As with the bottomlands, there are no large contiguous acreages of upland woodland, and strips of woodland on ridges at the periphery of the reservoir site are the most typical woodland situations. In some places these strips border the narrow riparian habitats of the intermittent drainages. In these locations, wildlife usage of the two habitat types overlaps to a considerable extent.

Based on transect counts, the most common breeding season birds in the upland woodland habitat type included the Carolina chickadee, brown-headed cowbird (*Molothrus ater*), northern cardinal, tufted titmouse, painted bunting (*Passerina ciris*), and lark sparrow (*Chondestes grammacus*). Mourning dove (*Zenaida macroura*) nest in the woody vegetation of the uplands as evidenced by a nest with two eggs found along the sampling transect. The red-tailed hawk (*Buteo jamaicencis*) was the common summer raptor in this habitat, but this wide-ranging species uses a variety of terrestrial habitats.

As in the bottomland woodland, the only commonly captured small mammal was the white-ankled mouse. Eastern cottontails (*Sylvilagus floridianus*) were commonly seen at

the woodland/grassland edges and in openings of the upland woodlands.

The rocky slopes in the uplands harbored a number of reptilian species including the Texas greater earless lizard, Texas spotted whiptail, great plains ground snake (*Sonora episcopa*), and Texas lined snake (*Tropidoclonion lineatum*). The Texas spiny lizard (*Sceloporus olivaceus*), southern fence lizard (*S. undulatus*), Texas rat snake and gulf coast toad (*Bufo valliceps*) were also common species.

3.7.1.3 Open Habitat

Terrestrial wildlife habitats in the project area were predominantly open pastureland, rangeland, and croplands (3588.9 acres or 75.5% of the reservoir site).

Dominant breeding season birds detected in the native grassland transect included the eastern meadowlark (*Sturnella magna*), scissor-tailed flycatcher (*Tyrannus forficatus*), brown-headed cowbird, grasshopper sparrow (*Ammordramus sayannarum*), northern mockingbird (*Mimus polyglottus*), northern bobwhite (*Colinus virginianus*), and dickcissel (*Spiza americana*). Other characteristic birds of the open habitats included the western kingbird (*Tyrannus verticalis*), eastern kingbird (*T. tyrannus*), killdeer (*Charadrius vociferus*), common nighthawk (*Chordeilus minor*), Cassin's sparrow (*Aimophila cassinii*), mourning dove, and loggerhead shrike (*Lanius ludovicianus*). The red-tailed hawk was the only common summer raptor of the open habitats; however, the American kestrel (*Falco sparverius*) became conspicuous in the fall. The turkey vulture was an abundant resident, and a nest with young of this species was photographed in the attic of an abandoned house in a grassland area.

The white-footed mouse (*Peromyscus leucopus*) and plains harvest mouse (*Reithrodontomys montanus*) were the small mammals captured in grasslands. Both the black-tailed jackrabbit (*Lepus californicus*) and the eastern cottontail were common, with the jackrabbits occurring most often at the more heavily grazed sites. At night, white-tailed deer can be seen in the open habitats.

Several species of reptiles and amphibians were found in the open habitats of the Lake Bosque project area, including the gulf coast toad, ornate box turtle (*Terrapene ornata*), prairie racerunner (*Cnemidophorus sexlineatus*), prairie kingsnake (*Lampropeltis calligaster*), western coachwhip (*Masticophis flagellum*), and bullsnake (*Pituophis melanoleucus*).

3.7.1.4 Aquatic and Other Wetlands

Aquatic and other wetland habitats of the project area were mostly associated with the North Bosque River, its tributaries, and farm ponds. These areas provide water sources for wildlife species in surrounding habitats, as well as habitat for a number of directly wetland dependent species.

Amphibians and reptiles typical of these areas included Blanchard's cricket frog (*Acris crepitans*), gray treefrog, spotted chorus frog (*Pseudacris clarki*), Strecker's chorus frog (*P. streckeri*), upland chorus frog (*P. triseriata*), bullfrog (*Rana catesbiana*), southern leopard frog (*R. utricularia*), Texas slider (*Chrysemys concinna*), red-eared slider (*C. scripta*), spiny softshell (*Trionyx spiniferus*), blotched water snake (*Nerodia erythrogaster*), and red-striped ribbon snake (*Thamnophis proximus*).

Birds that were typically associated with wetlands included the little blue heron (*Egretta caerulea*), green-backed heron (*Butorides striatus*), belted kingfisher (*Ceryle alcyon*), Louisiana waterthrush, and red-winged blackbird (*Agelaius phoeniceus*). Many other wildlife species, including mammals, use wetlands extensively, even though their primary habitat type may be of another category. Some mammals, such as the beaver (*Castor canadensis*) and northern raccoon make major use of such areas as foraging habitat.

3.7.2 Important Wildlife Species and Habitats

Important species are defined above, in section 3.4.2. Important habitats are considered to be those that have unusual ecological value.

3.7.2.1 Recreationally or Commercially Important Species

Several species of game mammals and birds have geographic ranges that encompass Bosque County. The fact that such species are hunted and/or trapped indicates that they are an economic and recreational resource to the area. A more detailed discussion of the biology and status of each of these species is presented in "Baseline Ecology Report Supplement II: Important Species" (Paul Price Associates, Inc. 1987b).

As defined by the Texas Parks and Wildlife Department for reporting purposes, the Cross Timbers and Prairies Ecological Region (Cross Timbers), which encompasses the project area, ranks fourth among the ten ecological regions in Texas with respect to mourning dove spring population size. Mourning dove population counts in the project area in May, 1985 indicated levels typical for the region.

The Cross Timbers ranks second out of eight ecological areas in Texas which support populations of bobwhite quail. The results of the May, 1985 survey of the project area showed bobwhite populations to be typical of the region.

In 1985 the Texas Parks and Wildlife Department reported a post hunting season wild turkey population in Bosque County that ranked 15th of the 25 counties in the Cross Timbers, only 21.8% of the high county (Brown) count.

Many species of waterfowl winter in or migrate through the Cross Timbers. Although goose populations are minimal, approximately 19.9% of the total 1984-85 Texas duck harvest was within the north central reporting zone which includes the project area. The most commonly harvested species there are the wood duck (*Aix sponsa*), mallard (*Anas platyrhynchos*), gadwall, and green-winged teal (*A. crecca*). The project area provides little habitat for these species, since the only wetlands are farm ponds and portions of the North Bosque River.

The Cross Timbers supported approximately 7.8% (287,308) of the state's white-tailed deer population in 1985, ranking fifth among ten ecological regions. Many general observations of deer in the project area were in the bottomland woodlands but the species was widespread at various upland sites as well.

The Cross Timbers was first of all ecological regions in Texas in eastern cottontail rabbit and third in blacktail jackrabbit population sizes. Good habitat for both species existed in the Lake Bosque project area at the time of the baseline studies.

In addition to the game species discussed above, the range of several furbearers includes Bosque County, including

northern raccoon, skunks (species combined), Virginia opossum, ringtail (*Bassariscus astutus*), gray fox (*Urocyon cinereargenteus*), coyote (*Canis latrans*), red fox (*Vulpes vulpes*), and bobcat. Habitat for all of these species is present in the project area, and most were observed during the surveys, together with signs of beaver.

3.7.2.2 Endangered and Threatened Wildlife Species

Twelve species of endangered, threatened or protected nongame wildlife species (USFWS 1986; TPWD 1987) have been reported from Bosque County or are assumed to have some probability of occurrence. The biology of these species and their status as determined by each organization are discussed in detail in "Baseline Ecology Report Supplement II: Important Species" (Paul Price Associates Inc. 1987b). While the geographic range of these species encompasses the project area, the actual likelihood that they occur on the site or that suitable habitat is even present, varies depending on the biological requirements of each individual species. The following paragraphs give a brief statement of the expected status of each species in the project area.

Five federally listed endangered or threatened species potentially occur in Bosque County. These are the bald eagle (*Haliaeetus leucocephalus*), arctic peregrine falcon (*Falco peregrinus tundrius*), whooping crane (*Grus americana*), (interior) least tern (*Sterna albifrons athalassos*), and the black-capped vireo (*Vireo atricapilla*) which is currently proposed by USFWS for listing as endangered, and is, as such, protected.

The USFWS lists Bosque County and bordering McLennan County as having wintering areas for the bald eagle, presumably around reservoirs. It is therefore possible that bald eagles can occasionally pass through the project area and

might find some feeding habitat along the Bosque River during periods when the river has low turbidity. However, no sightings have been reported for nearby Meridian State Park which has a small lake and surrounding woodlands that could be potential habitat. It is highly improbable that the bald eagle would nest in the project area even if suitable habitat were present.

Peregrine falcons, including the arctic subspecies, occur only as migrants in North Texas. Although no records are reported for Bosque County (including Meridian State Park), there is at least one sight record for McLennan County which borders Bosque County to the southeast. The project area does contain some areas of habitat that could be occupied briefly by migrating peregrine falcons.

Portions of North Texas, including Bosque County, lie within the migratory corridor that whooping cranes follow enroute to and from their nesting grounds in Wood Buffalo National Park, Canada. However, in Texas, there are no known regular migration stopover points such as are found in certain areas in Nebraska; in fact, there are only a few scattered confirmed ground sightings of whooping cranes anywhere in Texas other than on the wintering grounds on the coast. None of these are for Bosque County, and the likelihood of the whooping crane using the project area habitats is slim.

A summer specimen record of the interior least tern from Palo Pinto County and unconfirmed summer and breeding records for McLennan County have been reported. No sight or specimen records are reported for Bosque County or other bordering counties. Inasmuch as there appears to be little, if any, preferred habitat for the least tern in the project area, it is unlikely that the species will occur there, except perhaps as an extremely rare migrant.

The black-capped vireo is an inhabitant of well-drained, bushy or thicket covered hills typical of many parts of the Edwards Plateau. Specimen and/or sight records for three counties bordering Bosque County are known. The species has been reported for Meridian State Park, but despite having what appeared to be potential habitat, the project area did not harbor the species during 1984 and 1985 surveys.

Seven species in addition to the first five discussed above are listed as either endangered or protected nongame species (equivalent to threatened) by the TPWD. The following paragraphs present a brief statement of the expected status of each species, except the Brazos water snake (discussed above in Section 3.5.2.2), in the project area.

The white-faced ibis (*Plegadis chihi*) and the wood stork (*Mycteria americana*) are threatened avian species that do not breed in or near Bosque County. In the United States the latter nests only in Florida. Both species often exhibit a postnesting wandering period during which they may occur very irregularly at inland locations. Based on past records of occurrence in North Texas, their presumed ranges include Bosque County. The wood stork is considered "probable" and the white-face ibis is "confirmed" for the county by TPWD.

The American swallow-tailed kite (*Elanoides forficatus*) is currently considered threatened by TPWD, and is under review by USFWS as a "Category 2" species (further biological research needed to evaluate its status). The species is associated with wetland woodlands and associated native prairie type habitats and is not expected to nest in Bosque County, nor are there any sight or specimen records for Bosque County. Based on the presumed potential migration range, TPWD lists the kite as "possible" for Bosque County.

The golden-cheeked warbler (*Dendroica chrysoparia*) is a state listed threatened species that is endemic to central Texas where it nests in very old juniper (*Juniperus* spp.) woodlands. This warbler species is also under review as a "Category 2" species by USFWS. With regard to Bosque County, a population in Meridian State Park was reported and it is probable that suitable habitat occurs in other mature upland cedar brake areas in Bosque County. Surveys of the project area, including the 73 acres of juniper woodland in the reservoir site, did not reveal nesting habitat for the golden-cheeked warbler. TPWD lists the bird as being "confirmed" for Bosque County due to its known occurrence in Meridian State Park.

The Texas horned lizard (*Phrynosoma cornutum*) has been recorded from Bosque County and is listed as "confirmed" for the county by TPWD. Individuals of this species have been observed in the northeastern portion of the project area on the arid upland terraces overlooking the alluvial valley floor. These sites are located at or above the conservation pool elevation (830 feet MSL), but individuals of this species may occur within the reservoir site, although none were collected with the 19 species of reptiles identified during the 1984-85 baseline ecology survey.

The Timber Rattlesnake (*Crotalus horridus*) is listed by TPWD as "confirmed" for Bosque County. A southeastern species typically inhabiting heavy cover, it has been reported from riparian environments on the Trinity and Brazos Rivers as far west as Bosque and McLennan Counties. None were observed on the reservoir site during either the Ecology or the Cultural Resources surveys.

3.7.2.3 Important Habitats

Bottomland forest and riparian habitats are of particular ecological importance in the project area, as well as in the general region. These habitats, while relatively small in areal extent, are responsible for much of the diversity in plants and wildlife in the project area. Many important species, as previously discussed, are limited to or prefer these types of habitats. Because of clearing of bottomland forest for agricultural purposes throughout the region, this lowland habitat type is of particular concern.

3.8 Socioeconomics and Land Use

The following sections are based primarily on a comprehensive study of Bosque and McLennan counties reported in detail in "Baseline Socioeconomic Report for the Lake Bosque Project, Bosque County, Texas" (Paul Price Associates Inc., 1987).

3.8.1 Population

Population characteristics were examined in Bosque and McLennan Counties which include the proposed reservoir site and the communities participating in the project.

Bosque and McClennan Counties experienced relatively slow growth during the 1960s, The 1970s brought unprecedented growth to Texas as well as to Bosque County, and on a somewhat lesser scale, to McClennan County. Bosque County's 1980 population of 13,401 represents a 22% increase over 1970. McLennan County's 1980 population of 170,755 increased by 16% during the same decade. Table 3-4 displays 1970 and 1980 population figures and growth rates for the two counties and eight project participants.

Table 3-4 Population Growth in the Study Area 1970 and 1980

Jurisdiction	1970 Population	1980 Population	% Change 1970-1980
Bosque County	10,966	13,401	22.2%
Meridian	1,162	1,330	14.5%
Clifton	2,578	3,063	18.8%
McLennan County	147,553	170,755	15.7%
Bellmead	7,698	7,569	-1.7%
Hewitt	569	5,247	822.1%
Lacy-Lakeview	2,558	2,752	7.6%
McLennan Co. WCID #2 (Elm Mott)	NA	1,300	----
Waco	95,326	101,261	6.2%
Woodway	4,819	7,091	47.1%

Source:
U. S. Bureau of the Census. General Population Characteristics, 1970-1980.
Note: NA = not available

3.8.1.1 Age Distribution

The age distribution of the study area's 1980 population was characterized by a higher proportion of elderly than the state average. In McLennan County, the proportion of elderly age 75 years and older was only slightly higher than the states' average. However, in Bosque County, the proportion of people 75 years and older was almost three times as high as the state average, and the proportion of those aged 70-75 was twice as high as the state average. The Texas Department of Health expects this trend to continue through 2000.

3.8.1.2 Population Projections

Five population projection models were examined in detail and evaluated on the basis of the assumptions and methodologies employed. The Texas Water Development Board (TWDB) Low Series Population Projections were jugded to provide the most probable scenario for future population growth. However, in planning for critical infrastructure and community resources, particularly where long lead times for development are involved, use of a "most probable" projection may result in significant deficits in needed facilities and resources. Therefore, we believe that for critical planning purposes the low series projections represent the minimum future population sizes to be accomodated. The upper limit of reasonably probable future population growth was assumed to be represented by the TWDB High Series Population Projections.

TWDB low series population projections for the study area show Bosque County's population increasing to 24,045 by 2040, a 79% increase from 1980. The high series population projection shows the population increasing by 128% to 30,505 in 2040. The range of projections for the 2040 population

in McLennan County is 239,559 (a 40% increase over 1980) for the low series, to 287,645 (68% increase) for the high series. Population projections for the study area continue the historical trend of communities in the City of Waco's ETJ growing at a much faster rate than the City of Waco. Table 3-5 displays the TWDB Low and High population projections for McLennan and Bosque Counties and the participating municipalities.

3.8.2 Local Economy

Since the 1960's, the major employment sectors by Standard Industrial Classification (SIC) Code in McLennan County have been Manufacturing, Trade, Service and Government. The total labor force for 1986 was 71,446, an increase of 11% over 1980. The fastest growing industries since 1980 have been Agriculture and Finance, Insurance, Real Estate (FIRE) and Service. Manufacturing and Mining employment declined slightly.

During the 1960's and 1970's, major employment sectors in Bosque County were Agriculture, Trade and Service. Since the 1960s, the proportion of the labor force employed in Agriculture and Service Industries has steadily declined while the number of workers employed in Manufacturing, Construction and the category of Other industries has increased. In 1980, the three largest employment sectors were Manufacturing, Trade, and Government. The Texas Employment Commission (TEC) estimates a total work force of 3,040 in 1980 and 3,168 in 1986, an increase of 4%. Because TEC employment statistics do not include the self-employed and unpaid family workers in their estimated labor force figures it is likely that these estimates are lower than the actual work force in Bosque County. United States Bureau of the Census estimated the total 1980 work force at

Table 3-5 Study Area Population Projections

Jurisdiction	1980 Population	1990 Projection	2000 Projection	2010 Projection	2020 Projection	2030 Projection	2040 Projection	% Change 1980-2040
BOSQUE COUNTY								
TWDB High Case	13,401	15,633	19,790	22,015	24,489	27,332	30,505	128%
TWDB Low Case	13,401	15,175	16,653	18,275	20,032	21,947	24,045	79%
Clifton								
High Case	3,063	3,737	4,793	5,332	5,932	6,620	7,388	141%
Low Case	3,063	3,738	4,244	4,750	5,316	5,971	6,707	119%
Meridian								
High Case	1,330	1,662	2,142	2,383	2,650	2,958	3,303	148%
Low Case	1,330	1,613	1,802	1,978	2,168	2,376	2,604	96%
MCLENNAN COUNTY								
TWDB High Case	170,755	200,412	208,117	219,587	240,264	262,889	287,645	68%
TWDB Low Case	170,755	190,790	194,846	198,243	206,793	222,574	239,559	40%
Bellmead								
High Case	7,569	10,766	11,708	12,353	13,517	14,790	16,183	114%
Low Case	7,569	10,249	10,961	11,152	11,634	12,522	13,478	78%
Hewitt								
High Case	5,247	6,158	6,395	6,747	7,383	8,078	8,838	68%
Low Case	5,247	5,862	5,987	6,091	6,355	6,839	7,359	40%
Lacy-Lakeview								
High Case	2,752	3,443	3,626	3,826	4,187	4,581	5,012	82%
Low Case	2,752	3,277	3,394	3,454	3,604	3,878	4,173	52%
McLennab County WCID #2 (Elm Mott)* **								
High Case	1,300	1,275	1,286	1,357	1,484	1,624	1,777	37%
Low Case	1,300	1,213	1,203	1,224	1,277	1,375	1,481	14%
Waco								
High Case	101,261	114,555	115,909	122,297	133,813	146,413	160,199	58%
Low Case	101,261	109,056	108,518	110,408	115,171	123,961	133,422	32%
Woodway								
High Case	7,091	12,170	14,368	15,160	16,587	18,149	19,858	180%
Low Case	7,091	11,586	13,452	13,686	14,277	15,366	16,539	133%

Source: County1980-2030 projections are revisions by the Texas Water Development Board as of 2/1987.
2040 projections were extended by Paul Price Associates.
NOTE: *** Elm Mott (McLennan County WCID #2) projections are by Paul Price Associates, Inc.
Municipal estimates were derived by disagregating the the TWDB county population figures.

5,378. Their estimates include self employed and family workers.

3.8.2.1 Income Analysis

To compare local family income with state family income, all family households in Texas were separated into five equal groups (quintiles) by annual income level for 1970 and 1980. In comparison to the state average, both counties are characterized by a high proportion of low income families and a low proportion of medium to high income families. In McLennan County those proportions were only 4-6% higher or lower than the state average, but in Bosque County the difference was much greater. In 1980, 28% of all families were in the lowest income bracket, compared to the state average of 20%. Fifty-six percent of all Bosque County families were in the two lowest income brackets, compared to the state average of 40%. Only 14% of the county's families were in the top two income brackets, compared to the state average of 40%. The proportion of families qualifying for middle to upper income brackets, while still considerably lower than the state average, increased over the decade.

3.8.3 Community Facilities and Services

3.8.3.1 Education

There are 26 independent School Districts (ISDs) in the study area, 18 in McLennan County and eight in Bosque County. Of the total 1985-86 student enrollment of 37,791, 93% attended McLennan County schools and 7% attended Bosque County schools. The ratio in McLennan County averaged 18.2 students per teacher while in Bosque County the average was 15.7. Average expenditure per student in McLennan County was $2,790; in Bosque County, average expenditure per student was $3,125.

3.8.3.2 Public Safety

None of the participating municipalities satisfy the public safety standards of 2.1 police officers per 1,000 population. The police officer to population ratio ranges from a low of .75 for Meridian to a high of 1.97 for Woodway. The community of Elm Mott does not employ a police officer.

Fire protection in the study area is provided by volunteer and full-time paid firemen. Only Bellmead and the City of Waco employ full-time firemen; however, the ratio of firemen to 1,000 population for both communities is below the accepted safety standard of two full-time firemen per 1,000 population. The remaining project communities rely on volunteer firemen for fire protection.

3.8.3.3 Health Service and Facilities

The study area contains eight hospitals and 1,995 beds, of which 95% are located in McLennan County. Both McLennan and Bosque County's ratios of 10.37 and 6.8 beds per 1,000 population is higher than the recommended minimum of five beds per 1,000 population. Of the 318 physicians in the two counties, 95% practice in McLennan County. The public health standard ratio of 0.7 physicians per 1,000 population is exceeded in both counties.

3.8.3.4 Existing Water and Wastewater Treatment Facilities

Each of the project participants maintains a water system and provides wastewater treatment services. Except the City of Waco, all the participants rely on Trinity ground water for water supplies. These communities do not have developed facilities for treating surface water.

3.8.3.5 Future Water Requirements

Water demand projections were prepared through 2040 for communities currently participating in the Lake Bosque project, as well as for probable customer entities, rural county areas and manufacturing in the two county study area (Paul Price Associates Inc., 1987). Initial water demand projections incorporated Texas Water Development Board (TWDB) low series population projections and high series per capita water demand projections. The high demand per capita estimates were employed because these levels are already being exceeded in McLennan County, and because they include drought period demands which must be planned for to protect public health, welfare and safety. Per capita water demand includes the adjustments for future conservation projected by TWDB.

To prevent a situation of unmet demand requiring additional capital investment, and possibly more serious consequences, water demand projections should allow for the highest reasonable population growth and per capita water demand. Reservoir firm yield supplies should accommodate an upper limit as well as satisfying the minimum projected demand. For the Lake Bosque Project, this range begins with the initial water demand projection mentioned above and is capped by a projection using the TWDB's High Series population projection, high per capita demand and high manufacturing demand.

Municipal per capita demand ratios for project participants, potential customer cities, the City of Waco and other (rural) portions of McLennan County and Bosque County are shown in Table 3-6. Generally, per capita consumption rates

Table 3-6 Per Capita Water Demand Projections

Demand Categories	1980	1990	2000	2010	2020	2030	2040
Municipal Per Capita Demand (GPD)							
Project Participants (excludes City of Waco)	162	184	187	187	187	187	187
Potential Customers	159	189	190	190	190	190	190
City of Waco	261	280	285	285	285	285	285
All Municipalites	235	252	254	254	254	254	254
Other Per Capita Demand (GPD)							
McLennan Co.	125	180	186	185	183	181	180
Bosque Co.	108	161	166	166	166	166	166

Source:
Texas Water Development Board, High Series Water Demand Projections.

peak in year 2000 and are assumed by the TWDB to remain stable thereafter due to conservation measures. Potential project customers are defined as communities currently relying on ground water but identified by the TWDB as relying on Lake Waco water as a future supply source.

The projected 2040 water demand range for each user category is shown in Table 3-7. Municipal water use in 1980 by project participants (excluding the City of Waco) was 4.60 mgd and is projected to increase through 2040 to a range of 9.85 to 11.71 million gallons per day (mgd), a 114% to 154% increase. The City of Waco is the largest water consumer in the area, with 1980 water use at 26.44 mgd and projected 2040 low and high water demands of 38.02 to 45.66 mgd. Water use in 1980 by potential customers amounted to 1.07 mgd and is projected to increase by 99% to 138% (see Table 3-7).

The category of Other demand includes demand from rural county areas and demand from communities with populations smaller than 1,000. In 1980, Other demand was 3.81 mgd for the two county study area; 2040 demand was projected to be between 7.14 and 8.73 mgd, an increase of 87% to 129% (see Table 3-7). Total municipal demand, including project participants, the City of Waco, potential customers, and Other demand in 1980, was 35.92 mgd. Projected low and high 2040 demand ranges from 57.14 to 68.65 mgd, increases of 59% and 91%, respectively.

Manufacturing demand in the two county study area during 1980 was 3.63 mgd. The TWDB provides two demand projections

Table 3-7 Reported 1980 Water Use and Projected Low and High Range 2040 Water Demand

User Category	Reported 1980 Water Use		Low Range 2040 Demand Projection		High Range 2040 Demand Projection	
	mgd	Acre-feet	mgd	Acre-feet	mgd	Acre-feet
Municipal Demand						
Project Participants (excludes City of Waco)	4.60	5,153	9.85	11,033	11.71	13,117
Potential Customers	1.07	1,199	2.13	2,386	2.55	2,865
Total Municipal Demand	5.67	6,352	11.98	13,419	14.26	15,973
City of Waco	26.44	29,617	38.02	42,588	45.66	51,146
Total Municipal Demand including the City of Waco	32.11	35,968	50.00	56,008	59.92	67,119
Other Demand (rural)						
McLennan County	2.97	3,323	4.84	5,422	5.81	6,505
Bosque County	0.84	941	2.30	2,576	2.92	3,271
Total	3.81	4,264	7.14	7,998	8.73	9,776
Total Municipal and Other Demand	35.92	40,232	57.14	64,006	68.65	76,895
Manufacturing Demand						
McLennan County	3.55	3,977	19.76	22,134	23.42	26,234
Bosque County	0.08	90	0.28	314	0.32	358
Total	3.63	4,066	20.04	22,448	23.74	26,592
Total Muncipal, Other and Manufacturing Demand						
Including the City of Waco	39.55	44,298	77.18	86,454	92.39	103,488
Excluding the City of Waco	13.11	14,681	39.16	43,866	46.73	52,342

Source: Paul Price Associates, Inc. Socioeconomic Baseline Report for the Lake Bosque Project, 1987. Texas Water Development Board.
Note: Demand for Elm Mott was originally included in the category of Other Demand. In this table Elm Mott is not included in the Other Demand category because its demand is already included in the project participant category.

(high and low series) to use for planning purposes and both are shown in Table 3-7. We believe the low series manufacturing demand projection represents the most probable scenario under present conditions, but an aggressive regional economic development program coupled with an assured water supply could result in accelerated manufacturing demand. Projected low and high 2040 demand ranged from 20.04 to 23.74 mgd, increases of 452% and 554%, respectively.

3.8.3.6 Transportation

The proposed Lake Bosque lies in northwest Bosque County within the tract of land bordered by Highway 6, FM 144 and FM 927. Gravel surfaced county roads provide access from the site to major roadways. Traffic volume, in 1985 along State Highway 6 near the project site averaged 1,350 vehicles per day. Along FM 144 the average was 890 vehicles per day, while FM 927 carried an average of 420 vehicles per day. Traffic volume, in 1984, on area county roads ranged from 35 to 100 vehicles per day. There are no major road improvements planned for Bosque County by the State Department of Highways and Public Transportation.

Air strips are available in Clifton and Waco, 24 and 50 miles, respectively, from the proposed site. Complete air services and commercial flights are available only in Waco.

Commercial rail service is available in Clifton. Amtrak passenger rail service is available in the Dallas Fort Worth area approximately 70-100 miles from the proposed Lake Bosque.

3.8.3.7 Housing

Vacancy rates for owner occupied housing units in Bosque and McLennan Counties indicate a shortage of available housing. Rental vacancy rates point to a slightly larger but still limited supply of available rental units. In McLennan County, there were about 61,554 occupied housing units with 2.65 persons per housing unit in 1980. Median value of owner-occupied homes was $29,100. In Bosque County there were approximately 5,513 occupied housing units with 2.36 persons per occupied unit in 1980. Median value of owner-occupied homes was $23,000. There are 11 homes currently located within the the 100 year flood elevation (841.3 MSL) at the proposed Lake Bosque site.

3.8.4 Public Finance

Total bi-county governmental revenue for fiscal year ended September 1985 was $24,081,188. McLennan County revenues of $22,051,851 accounted for 92% of total revenues and Bosque County revenues of $2,029,337 accounted for 8%. Property taxes contributed 42% and 30%, respectively, of total county revenues. Intergovernmental transfers, a significant source of revenue for McLennan County, contributed 16% of total revenue, but accounted for only 4% of total revenues in Bosque County. Licenses and Permits accounted for 24% of revenues in Bosque County, and were a major revenue source. Principal county expenditures in Bosque County were for Public Safety. In McLennan County, principal county expenditures were for General Government Services. Per capita expenditure in McLennan County was $121; in Bosque County per capita expenditure was $110. McLennan County had excess revenues of $1,023,527 (5.5% of total revenues). Bosque County had excess revenues of $323,961 (18% of total revenues).

The financial position of Bosque and McLennan Counties is good. Both have strong credit ratings and, if needed, have ample tax margins allowing major increases in property tax revenues. The project participants are also in good financial condition, with relatively low property tax rates, ample tax margins and low per capita debt ratios.

In McLennan County, assessed 1985 property valuations of $3.4 billion represent an increase of 6.84% from the preceding year. The County can raise $20.3 million in additional tax revenue before reaching the legal property tax limit. Assessed 1985 property valuations in Bosque County stood at $385.6 million. The County can raise $2.4 million in additional tax revenue before reaching the legal property tax limit.

Measures for calculating bond and credit rating strength reveal that both counties are secure, as per capita debt is low, as well as the ratio of debt to assessed value. In addition, McLennan County was assigned an A-1 rating by Moody's investors in 1985, further indicating the financial strength of the County.

Property tax rates for each of the seven project participating municipalities are much lower than the legal limit of $2.50 per $100 valuation. Present property tax rates range from $0.22 per $100 (Clifton) to $0.56 per $100 (Waco).

Based on three different methods of analyzing municipal credit soundness, all participants, except Hewitt, Waco and Lacy-Lakeview, satisfied each criteria. Hewitt and Waco had a slightly higher than desirable debt service to revenue ratio and Hewitt and Lacy-Lakeview had a slightly higher than recommended net debt per capita.

picnic tables, soccer fields, softball fields, swimming areas, walking and hiking trails.

An aesthetic survey of the proposed Lake Bosque site was conducted in February of 1987. Five viewsheds were photographed and evaluated for aesthetic values including topographical features, coloration, vegetational diversity and vividness, unique geological formations, man-made structures and uniqueness of view with respect to the region. The survey emphasized views presently available to the public from area roads.

The surveyed area is located in a transitional zone and includes rolling pastures and farmland with interspersed woodlands and grasslands. The Bosque River valley is characterized by river-bottom land of 800 feet mean sea elevation (MSL), is dotted with 900-1,050 foot high hills and encompassed by an 800-1,000 foot high ridge. Panoramic views of the valley and the proposed lake site are available almost anywhere at elevations above 850 feet. Natural vegetation and animal life includes grasses, trees, flowers and animals typical of Central Texas.

From each vantage viewshed, visual landscape elements of the proposed Lake Bosque site include pastureland, cropland, some wooded areas, farm machinery, an occasional farm house, livestock, natural vegetation (scrub oak, brush, cactus, etc.), and barbed wire fences. See Paul Price Associates Inc., 1987, for photographs.

3.8.6 Land Use

Land uses identified in the evaluation of the proposed Lake Bosque site include cropland, pastureland, woodland, residential, wetland and stockponds. Of the total 641,337

acreas in Bosque County, 595,172 acres (92.8%) consist of cropland, pastureland, hayland and rangeland.

The most significant changes in land use in Bosque County since 1958 have been a 127% increase in pasture and hayland, a 33% decrease in cropland and an 18% increase in land designated as Other land (includes water, urban, roads, railroads, and recreation land uses).

Since 1970, the majority of Bosque County's total market cash receipts were from livestock and livestock products. When compared to market cash receipts for the other 25 counties in the Blackland Agriculture District, the County was above average overall for livestock and livestock products market cash receipts, and slightly below average for crop cash receipts and total crops and livestock cash receipts.

3.9 Cultural Resources

3.9.1 Regional Setting

Bosque County lies near the northern margin of the Central Texas Archaeological Region in which the terms Paleoindian, Archaic, Neoarchaic and Historic have been used to describe major periods of cultural history (Howard, 1983). Prehistoric cultural associations and chronologies are based primarily on projectile point assemblages supplemented with radiocarbon dates.

Paleoindian people are believed to have been migratory with a hunting economy, but most of our knowledge of them has come from excavations remote from Central Texas. Radiocarbon studies from a relatively few sites in Central Texas date Paleoindian occupation of the region as being

prior to about 8500 years before the present (B.P.). These early sites tend to be difficult to recognize, perhaps because of an overreliance by American archaeologists on the use of chronologies linked to the presence of projectile points. Accordingly, there are probably sites in the vicinity of Lake Bosque which are older than the one located during this survey. However, this Paleoindian site is an indicator, along with other work in Central Texas, that human occupation of the North Bosque River Valley has continued (perhaps intermittently) for the last 14,000 to 15,000 years. Previous surveys have located Paleoindian sites in the vicinity of Lake Waco, Lake Whitney, Squaw Creek Reservoir and several locations on the Brazos River. Several sites on the Brazos River are of such depth and density of projectile points as to indicate either sedentary occupation or numerous short-term occupations over a very long period.

Archaic peoples, distinguished on the basis of tool forms, are believed to have also been primarily migratory with a hunting and gathering economy. The Archaic, occuring roughly between 8500 and 1250 B.P., has been extensively studied in Central Texas where early, middle and late periods are distinguished on the basis of apparantly differing subsistence strategies. While early Archaic sites are relatively rare, middle Archaic (beginning about 5,000 B.P.) sites are more common and those of the late Archaic (3,000 B.P.) are fairly abundant. As population densities presumably increased throughout the Archaic, evidence indicates that both the variety of food sources and the technological developments neccessary to exploit them increased. Several Archaic sites are known from the North Bosque River including one at Comanche Crossing, between the proposed reservoir site and Meridian.

During the Neoarchaic period (1250 to 250 B.P.) the subsistance economy did not appear to differ substantially from that of the Archaic. These people engaged in hunting, gathering, fishing and some agriculture. River terrace and shelter sites in Central Texas, and in the vicinity of the proposed project, often contain indications of a riverine subsistence orientation. Some of these sites contain Caddoan artifacts, or exotic materials such as obsidian that do not occur naturally in Texas, implyimg considerable movement or contacts with other, remote cultural groups.

The Historic period dates from the advent of Europeans into the Central Texas area during the early eighteenth century. Aboriginal tribes resident in the area at the begining of the nineteenth century include Tawakoni, Tonkawa and Hainai. The town of Waco was surveyed in 1849, settlement of the Bosque County area by whites became significant during the 1850's, and Meridian was established in 1854. The earliest settlers from Norway, the descendants of whom still maintain a distinct community in Bosque County, also established themselves during that year.

Conflicts with the aboriginal inhabitants continued throughout the mid-century and was particularly intense during and after the War Between the States. The "Indians of the Brazos" were transferred to the Wichita Agency in Oklahoma in 1869 but the threat of hostilities did not cease completely until the Comanche were finally expelled from Central Texas in the mid 1870's.

The railroad was important in helping establish local communities, including Walnut Springs and Morgan, and linking them with existing towns like Iredell. A section of roadbed and artifacts believed to belong to the Texas Central Railroad and dating from the last quarter of the nineteenth century is present on the reservoir site. The

decline and eventual abandonment of the railroad in the 1940's adversely affected the local economy, as did the decrease in economic importance of farming in Bosque County. During the twentieth century, and continuing to the present, ranching has become a more important part of the county economy as farm yields and profits have declined. At present, less than a dozen families are now living in or adjacent to the reservoir site, probably the smallest number of people since Paleoindian times.

3.9.2 Lake Bosque Site Survey

Prior to the archaeological survey performed in response to the permitting requirements of the proposed Lake Bosque project, no sites, either prehistoric or historic, had been recorded from the vicinity of the project area in the Texas Archaeological Research Laboratory files (Howard, 1983). A total of 145 sites were located and recorded during the Archaeological and Historical Survey (Lone Star Archaeological Services, 1987). Of these, 77 were prehistoric, 49 were historic and the remainder contained material from both periods. The sites recorded in the project area reflect human use from the Paleoindian period to the present century, including the Great Depression of the 1930's. In addition to a 100% pedestrian survey and probing, selected sites were subjected to additional testing appropriate to the location and resource, including large-scale excavation using power equipment. The latter technique was useful primarily in locating, defining and evaluating buried terrace deposits.

In the Archaeological and Historical Survey (Lone Star Archaeological Services, 1987), each recorded site is mapped, fully described, and evaluated in terms of its potential value for additional study and with respect to its eligibility for inclusion either in the National Register of

Historic Places or as a State Archaeological Landmark. Table 3-8 summarizes the primary characteristics of these sites. Of the 63 sites located that are eligible for nomination to the National Register of Historic Places, 34 were prehistoric, 20 were occupied during historic times and the remaining nine exhibited multiple periods of occupation. The 36 sites consisting of those National Register sites to be encompassed by the conservation pool of Lake Bosque will be State Archaeological Landmarks by the Provisions of the Antiquities Code of Texas (Title 9, Section 191.092).

Table 3-8

Effects-On-Sites Characterization for lake Bosque Project 76 affected

Site Number	Elevation Feet m.s.l.	Period of Occupation	STATUS SAL	STATUS NRE	EFFECTS OF NO ACTION Impact	Agent	Occurs	Result	EFFECTS OF CONSTRUCTION Impact	Agent	Result	EFFECTS OF OPERATION Impact	Agent	Occurs	Result
41BQ219	846-851	prehistoric	-	-	turned	tillage	seasonal	damage	none	-	-	unknown	-	-	-
41BQ220	840-852	prehistoric	-	-	turned	tillage	seasonal	damage	none	-	-	inundation	lake	flood	-
41BQ221	828-832	historic	-	-	disturbed	road	unknown	damage	dam	dam	loss	none	-	-	-
41BQ222	836-848	historic	-	-	disturbed	house	unknown	damage	none	-	-	inundation	lake	flood	-
41BQ223	820-830	prehistoric	-	-	disturbed	dozer	unknown	loss	none	-	-	inundation	lake	pool	-
41BQ224	860-862	historic	-	-	none	-	-	-	none	-	-	none	-	-	-
41BQ225	828-840	prehistoric	-	-	erosion	road	seasonal	damage	none	-	-	inundation	lake	pool	-
41BQ226	834-842	historic	-	-	construction	pens	once	loss	none	-	-	inundation	lake	flood	-
41BQ227	820-850	prehistoric	-	-	eroded	wash	on-going	loss	none	-	-	inundation	lake	pool	-
41BQ228	860+	historic	-	⊠	erosion	wash	on-going	damage	none	-	-	none	-	-	-
41BQ229	900-920	historic	-	⊠	none	-	-	-	none	-	-	none	-	-	-
41BQ230	845-848	prehistoric	-	-	eroded	wash	on-going	loss	none	-	-	none	-	-	-
41BQ231	860+	historic	-	⊠	none	-	-	-	none	-	-	none	-	-	-
41BQ232	860-870	prehistoric	-	-	erosion	road	on-going	loss	none	-	-	none	-	-	-
41BQ233	850-860	prehistoric	-	-	erosion	wash	on-going	damage	none	-	-	none	-	-	-
41BQ234	834-838	historic	-	-	cleared	highway	once	loss	none	-	-	none	-	-	-
41BQ235	820-842	prehistoric	⊠	⊠	erosion	wash	on-going	damage	none	-	-	inundation	lake	pool	loss
41BQ236	822-832	historic	⊠	⊠	erosion	wash	on-going	damage	none	-	-	inundation	lake	pool	loss

Table 3-8

Effects-On-Sites Characterization for lake Bosque Project

Site Number	Elevation Feet m.s.l.	Period of Occupation	STATUS SAL	STATUS NRE	EFFECTS OF NO ACTION Impact	Agent	Occurs	Result	EFFECTS OF CONSTRUCTION Impact	Agent	Result	EFFECTS OF OPERATION Impact	Agent	Occurs	Result
41BQ201	856-862	prehistoric	-	-	eroded	wash	on-going	loss	none	-	-	none	-	-	-
41BQ202	860-870	prehistoric	-	-	eroded	wash	on-going	loss	none	-	-	none	-	-	-
41BQ203	840-845	prehistoric	-	-	eroded	wash	on-going	loss	none	-	-	inundation	lake	flood	-
41BQ204	821-830	multiple	⊠	⊠	none	-	-	-	none	-	-	inundation	lake	pool	loss
41BQ205	835-845	historic	-	⊠	none	-	-	-	none	-	-	inundation	lake	flood	loss
41BQ206	838-850	prehistoric	-	⊠	erosion	wash	on-going	damage	none	-	-	inundation	lake	flood	loss
41BQ207	835-842	historic	-	⊠	none	-	-	-	none	-	-	inundation	lake	flood	loss
41BQ208	842-849	prehistoric	-	⊠	turned	tillage	seasonal	damage	none	-	-	unknown	-	-	-
41BQ209	841-846	prehistoric	-	⊠	turned	tillage	seasonal	damage	none	-	-	unknown	-	-	-
41BQ210	843-845	prehistoric	-	⊠	turned	tillage	seasonal	damage	none	-	-	unknown	-	-	-
41BQ211	832-836	prehistoric	-	⊠	turned	tillage	seasonal	damage	none	-	-	inundation	lake	flood	loss
41BQ212	830-835	prehistoric	-	-	turned	tillage	seasonal	loss	none	-	-	inundation	lake	flood	-
41BQ213	842-846	prehistoric	-	⊠	turned	tillage	seasonal	damage	none	-	-	unknown	-	-	-
41BQ214	846-849	prehistoric	-	-	eroded	wash	on-going	loss	none	-	-	unknown	-	-	-
41BQ215	848-858	prehistoric	-	⊠	turned	tillage	seasonal	damage	none	-	-	unknown	-	-	-
41BQ216	839-845	prehistoric	-	⊠	turned	tillage	seasonal	damage	none	-	-	inundation	lake	flood	loss
41BQ217	830-840	prehistoric	-	-	redeposit	wash	on-going	loss	none	-	-	none	-	-	-
41BQ218	846-854	prehistoric	-	⊠	turned	tillage	seasonal	damage	none	-	-	unknown	-	-	-

Table 3-8

Effects-On-Sites Characterization for lake Bosque Project

Site Number	Elevation Feet m.s.l.	Period of Occupation	STATUS SAL	STATUS NRE	EFFECTS OF NO ACTION Impact	Agent	Occurs	Result	EFFECTS OF CONSTRUCTION Impact	Agent	Result	EFFECTS OF OPERATION Impact	Agent	Occurs	Result
41BQ183	840-845	prehistoric	-	-	eroded	wash	on-going	loss	none	-	-	none	-	-	-
41BQ184	850-853	prehistoric	-	-	eroded	wash	on-going	loss	none	-	-	none	-	-	-
41BQ185	800-802	historic	☐	☐	none	-	-	-	removal	clearing	loss	none	-	-	
41BQ186	829-834	historic	☒	☒	displaced	machine	unknown	damage	none	-	-	inundation	lake	pool	loss
41BQ187	840-844	prehistoric	-	☒	erosion	wash	on-going	damage	none	-	-	none	-	-	-
41BQ188	802-806	historic	-	-	none	-	-	-	none	-	-	inundation	lake	pool	loss
41BQ189	825-828	prehistoric	☒	☒	erosion	wash	on-going	damage	none	-	-	inundation	lake	pool	loss
41BQ190	828-830	historic	☒	☒	none	-	-	-	none	-	-	inundation	lake	pool	loss
41BQ191	839-842	prehistoric	-	☒	erosion	wash	on-going	damage	none	-	-	inundation	lake	flood	loss
41BQ192	830-832	prehistoric	-	-	cleared	machine	unknown	loss	none	-	-	inundation	lake	flood	-
41BQ193	826-829	historic	-	-	cleared	machine	unknown	loss	none	-	-	inundation	lake	pool	-
41BQ194	825-828	prehistoric	-	-	eroded	road	unknown	loss	none	-	-	inundation	lake	pool	-
41BQ195	810-818	prehistoric	☒	☒	erosion	wash	on-going	damage	none	-	-	inundation	lake	pool	loss
41BQ196	822-829	multiple	☒	☒	erosion	wash	on-going	damage	none	-	-	inundation	lake	pool	loss
41BQ197	900-905	prehistoric	-	-	eroded	wash	on-going	loss	none	-	-	none	-	-	-
41BQ198	853-857	multiple	-	☒	none	-	-	-	none	-	-	none	-	-	-
41BQ199	846-850	historic	-	☒	none	-	-	-	none	-	-	unknown	-	-	-
41BQ200	860	multiple	-	☒	none	-	-	-	none	-	-	none	-	-	-

Table 3-8

Effects-On-Sites Characterization for lake Bosque Project

Site Number	Elevation Feet m.s.l.	Period of Occupation	STATUS SAL	STATUS NRE	EFFECTS OF NO ACTION Impact	Agent	Occurs	Result	EFFECTS OF CONSTRUCTION Impact	Agent	Result	EFFECTS OF OPERATION Impact	Agent	Occurs	Result
41BQ165	835-838	historic	-	-	none	-	-	-	dam	dam	loss	none	-	-	-
41BQ166	842-845	multiple	-	-	eroded	wash	on-going	loss	none	-	-	none	-	-	-
41BQ167	832-835	prehistoric	-	⊠	erosion	wash	on-going	damage	none	-	-	inundation	lake	flood	loss
41BQ168	774-788	prehistoric	⊠	⊠	erosion	wash	on-going	damage	none	-	-	inundaton	lake	pool	loss
41BQ169	763-766	prehistoric	⊠	⊠	turned	tillage	seasonal	damage	none	-	-	inundation	lake	pool	loss
41BQ170	800-820	prehistoric	-	-	scraped	dozer	once	loss	none	-	-	inundation	lake	pool	-
41BQ171	830-840	historic	-	-	scraped	dozer	once	loss	none	-	-	inundation	lake	flood	-
41BQ172	830-835	prehistoric	-	-	scraped	dozer	once	loss	none	-	-	inundation	lake	flood	-
41BQ173	788-790	prehistoric	⊠	⊠	turned	tillage	seasonal	damage	none	-	-	inundation	lake	pool	loss
41BQ174	835-841	prehistoric	-	-	erosion	wash	on-going	damage	none	-	-	inundation	lake	flood	damage
41BQ175	812-814	geological	-	-	-	-	-	-	-	-	-	-	-	-	-
41BQ176	859-861	multiple	-	-	eroded	wash	on-going	loss	none	-	-	none	-	-	-
41BQ177	860-870	prehistoric	-	-	eroded	wash	on-going	loss	none	-	-	none	-	-	-
41BQ178	840-843	prehistoric	-	-	eroded	wash	on-going	loss	none	-	-	none	-	-	-
41BQ179	845	multiple	-	-	cleared	machine	once	loss	none	-	-	none	-	-	-
41BQ180	813-823	prehistoric	-	-	eroded	wash	on-going	loss	none	-	-	none	-	-	-
41BQ181	820-826	prehistoric	-	-	eroded	wash	on-going	loss	none	-	-	none	-	-	-
41BQ182	833-836	historic	-	-	displaced	machine	once	loss	none	-	-	none	-	-	-

Table 3-8

Effects-On-Sites Characterization for lake Bosque Project

Site Number	Elevation Feet m.s.l.	Period of Occupation	STATUS SAL	STATUS NRE	EFFECTS OF NO ACTION Impact	Agent	Occurs	Result	EFFECTS OF CONSTRUCTION Impact	Agent	Result	EFFECTS OF OPERATION Impact	Agent	Occurs	Result
41BQ147	820-830	prehistoric	⊠	⊠	erosion	wash	seasonal	damage	none	-	-	inundation	lake	pool	loss
41BQ148	800-820	prehistoric	⊠	⊠	erosion	wash	seasonal	damage	none	-	-	inundation	lake	pool	loss
41BQ149	810-823	multiple	⊠	⊠	turned	tillage	seasonal	damage	none	-	-	inundation	lake	pool	loss
41BQ150	848-850	prehistoric	-	-	eroded	wash	seasonal	loss	none	-	-	none	-	-	-
41BQ151	840-851	prehistoric	-	⊠	clearing	highline	once	damage	dam	spillway	loss	none	-	-	-
41BQ152	815-828	historic	⊠	⊠	erosion	wash	seasonal	damage	dam	dam	loss	none	-	-	-
41BQ153	785-805	historic	⊠	⊠	filling	wash	seasonal	positive	spillway	haul road	loss	none	-	-	-
41BQ154	800-838	prehistoric	-	-	erosion	wash	seasonal	damage	spillway	haul road	loss	none	-	-	-
41BQ155	790-830	prehistoric	-	-	clearing	highline	once	damage	none	-	-	none	-	-	-
41BQ156	775-780	historic	-	-	none	-	-	-	none	-	-	inundation	lake	pool	loss
41BQ157	820-825	historic	-	-	altered	building	on-going	loss	none	-	-	inundation	lake	pool	none
41BQ158	774-779	prehistoric	⊠	⊠	sloughing	river	on-going	damage	none	-	-	inundation	lake	pool	loss
41BQ159	833-843	historic	-	⊠	none	-	-	-	none	-	-	inundation	lake	flood	damage
41BQ160	810-811	prehistoric	⊠	⊠	erosion	wash	on-going	damage	none	-	-	inundation	lake	pool	loss
41BQ161	812-824	prehistoric	-	-	eroded	wash	on-going	loss	none	-	-	inundation	lake	pool	none
41BQ162	800-810	historic	⊠	⊠	none	-	-	-	dam	dam	loss	none	-	-	-
41BQ163	815-817	prehistoric	-	-	eroded	wash	on-going	loss	dam	dam	-	none	-	-	-
41BQ164	869	historic	-	-	none	-	-	-	none	-	-	none	-	-	-

Table 3-8

Effects-On-Sites Characterization for lake Bosque Project

Site Number	Elevation Feet m.s.l.	Period of Occupation	STATUS SAL	STATUS NRE	EFFECTS OF NO ACTION Impact	Agent	Occurs	Result	EFFECTS OF CONSTRUCTION Impact	Agent	Result	EFFECTS OF OPERATION Impact	Agent	Occurs	Result
41BQ129	820-828	historic	-	-	cleared	owner	unknown	loss	none	-	-	inundation	lake	normal	loss
41BQ130	845-846	historic	-	⊠	clearing	owner	unknown	damage	none	-	-	none	-	-	-
41BQ131	826-836	historic	-	-	cleared	owner	unknown	loss	none	-	-	inundation	lake	pool	none
41BQ132	870	historic	-	-	cleared	owner	unknown	loss	none	-	-	none	-	-	-
41BQ133	856-860	historic	-	-	cleared	owner	once	loss	none	-	-	none	-	-	
41BQ134	850-854	historic	-	-	erosion	wash	seasonal	damage	none	-	-	none	-	-	-
41BQ135	858-870	prehistoric	-	-	erosion	wash	seasonal	damage	none	-	-	none	-	-	-
41BQ136	830-850	historic	-	-	cleared	dozer	once	loss	none	-	-	none	-	-	-
41BQ137	810-822	prehistoric	⊠	⊠	erosion	wash	seasonal	damage	none	-	-	inundation	lake	pool	loss
41BQ138	808-812	multiple	⊠	⊠	cleared	owner	once	disturbed	none	-	-	inundation	lake	pool	loss
41BQ139	796-820	prehistoric	⊠	⊠	erosion	wash	seasonal	damage	none	-	-	inundation	lake	pool	loss
41BQ140	802-804	historic	-	-	razed	owner	once	loss	none	-	-	inundation	lake	pool	-
41BQ141	780-793	historic	-	-	disturbed	dozer	unknown	loss	none	-	-	inundation	lake	pool	-
41BQ142	810-820	prehistoric	-	-	eroded	wash	seasonal	loss	none	-	-	inundation	lake	pool	-
41BQ143	800-810	prehistoric	⊠	⊠	erosion	rill	seasonal	damage	none	-	-	inundation	lake	pool	loss
41BQ144	805	historic	-	-	erosion	drain	seasonal	damage	none	-	-	inundation	lake	pool	loss
41BQ145	856-862	prehistoric	-	⊠	erosion	wash	seasonal	damage	none	-	-	indirect	-	-	-
41BQ146	860-870	prehistoric	-	-	erosion	wash	seasonal	damage	none	-	-	indirect	-	-	-

Table 3-8

Effects-On-Sites Characterization for lake Bosque Project

Site Number	Elevation Feet m.s.l.	Period of Occupation	STATUS SAL	STATUS NRE	EFFECTS OF NO ACTION Impact	Agent	Occurs	Result	EFFECTS OF CONSTRUCTION Impact	Agent	Result	EFFECTS OF OPERATION Impact	Agent	Occurs	Result
41BQ111	805-808	prehistoric	⊠	⊠	turned	tillage	annual	damage	none	-	-	inundation	lake	pool	loss
41BQ112	828-830	historic	⊠	⊠	altered	building	on-going	damage	removal	clearing	damage	inundation	lake	pool	loss
41BQ113	845-860	prehistoric	-	-	eroded	wash	seasonal	damage	none	-	-	none	-	-	-
41BQ114	820-850	historic	-	-	eroded	slope	on-going	damage	none	-	-	none	-	-	-
41BQ115	842-848	prehistoric	-	-	eroded	wash	on-going	-	none	-	-	none	-	-	-
41BQ116	815-820	prehistoric	-	-	none	-	-	-	none	-	-	none	-	-	-
41BQ117	840-855	multiple	-	-	erosion	cattle	seasonal	damage	none	-	-	inundation	lake	flood	loss
41BQ118	840-850	multiple	-	-	erosion	cattle	seasonal	damage	none	-	-	inundation	lake	flood	loss
41BQ119	860-868	prehistoric	-	-	scraped	dozer	once	loss	none	-	-	none	-	-	-
41BQ120	853-856	multiple	-	-	altered	building	once	loss	none	-	-	none	-	-	-
41BQ121	838-850	prehistoric	-	-	cleared	dozer	once	damage	none	-	-	inundation	lake	flood	loss
41BQ122	820-828	multiple	⊠	⊠	buried	alluvial	flooding	preserved	none	-	-	inundation	lake	normal	loss
41BQ123	842-845	historic	-	⊠	none	-	-	-	F.M. 927	relocation	unknown	none	-	-	-
41BQ124	818-822	prehistoric	⊠	⊠	turned	tillage	seasonal	damage	none	-	-	inundation	lake	normal	loss
41BQ125	818-819	prehistoric	⊠	⊠	turned	tillage	seasonal	damage	none	-	-	inundation	lake	normal	loss
41BQ126	818-820	prehistoric	-	-	turned	tillage	seasonal	loss	none	-	-	inundation	lake	normal	none
41BQ127	819-824	historic	-	-	razed	owner	unknown	loss	none	-	-	inundation	lake	normal	none
41BQ128	810-816	historic	-	-	none	-	-	-	none	-	-	inundation	lake	normal	loss

Table 3-8

Effects-On-Sites Characterization for lake Bosque Project

Site Number	Elevation Feet m.s.l.	Period of Occupation	STATUS SAL	STATUS NRE	EFFECTS OF NO ACTION Impact	Agent	Occurs	Result	EFFECTS OF CONSTRUCTION Impact	Agent	Result	EFFECTS OF OPERATION Impact	Agent	Occurs	Result
41BQ93	840-842	prehistoric	-	-	erosion	cattle	seasonal	damage	none	-	-	erosion	waves	once	damage
41BQ94	832-835	multiple	-	-	scouring	creek	seasonal	damage	none	-	-	erosion	waves	-	-
41BQ95	850-860	prehistoric	-	⊠	erosion	cattle	seasonal	damage	none	-	-	looting			
41BQ96	833-835	historic	-	-	mixing	vehicles	on-going	damage	mixing	dam	loss	none	-	-	-
41BQ97	820-842	prehistoric	-	-	erosion	cattle	seasonal	damage	mixing	clearing	loss	none	-	-	
41BQ98	812-820	historic	-	-	scouring	creek	seasonal	damage	none	-	-	siltation	lake	seasonal	-
41BQ99	802-806	historic	-	-	mixing	human	on-going	damage	none	-	-	siltation	lake	seasonal	damage
41BQ100	809-812	prehistoric	-	-	erosion	cattle	seasonal	neutral	none	-	-	none	-	-	-
41BQ101	820-830	historic	⊠	⊠	filling	wash	seasonal	positive	none	-	-	erosion	lake	seasonal	damage
41BQ102	828-840	historic	⊠	⊠	filling	wash	seasonal	positive	none	-	-	erosion	lake	seasonal	damage
41BQ103	832-836	historic	-	-	none	-	-	-	mixing	clearing	loss	none	-	-	-
41BQ104	820-870	historic	-	-	erosion	wash	seasonal	damage	-	-	-	none	-	-	-
41BQ105	834-839	prehistoric	-	-	turned	tillage	seasonal	damage	none	-	-	erosion	flood	seasonal	loss
41BQ106	805-806	historic	□	□	none	-	-	-	removal	clearing	loss	none	-	-	-
41BQ107	820-824	multiple	⊠	⊠	erosion	wash	seasonal	damage	none	-	-	erosion	lake	on-going	loss
41BQ108	805	historic	-	-	none	-	-	-	removal	clearing	loss	none	-	-	-
41BQ109	837-840	prehistoric	-	⊠	erosion	wash	seasonal	damage	none	-	-	erosion	flood	seasonal	loss
41BQ110	820-825	multiple	⊠	⊠	erosion	cattle	on-going	damage	none	-	-	erosion	lake	on-going	loss

Table 3-8

Effects-On-Sites Characterization for lake Bosque Project

Site Number	Elevation Feet m.s.l.	Period of Occupation	STATUS SAL	STATUS NRE	EFFECTS OF NO ACTION Impact	Agent	Occurs	Result	EFFECTS OF CONSTRUCTION Impact	Agent	Result	EFFECTS OF OPERATION Impact	Agent	Occurs	Result
41BQ237	778-780	prehistoric	⊠	⊠	sloughing	creek	on-going	damage	none	-	-	inundation	lake	pool	loss
41BQ238	789-791	prehistoric	⊠	⊠	none	-	-	-	none	-	-	inundation	lake	pool	unknown

4.0 Environmental Effects of the Proposed Project

4.1 Climatology and Air Quality

4.1.1 Effects of no action

In the absence of the proposed project regional climate and air quality will continue to be influenced by the factors outlined in Section 3.1. Air quality is not anticipated to undergo substantial change as a result of local influences for the forseeable future.

4.1.2 Construction Effects

Construction of the proposed Lake Bosque is not anticipated to have any substantial effect on regional climate. However, localized effects, including some amelioration of diurnal temperature ranges and the creation of more mesic microclimates can be expected to occur in the immediate vicinity of the reservoir.

Some local and temporary increases in airborne particulates (dust) may result from disturbance of the vegetative cover in construction sites, borrow areas, and haul roads. Significant increases in areas other than the immediate vicinity of the work areas appears unlikely. Particulates are not presently a problem in Bosque County even though extensive soil disturbance now occurs as a result of agricultural practices. More than one thousand acres of seasonally plowed cropland and a considerable extent of unpaved road is present in the reservoir site.

With respect to near field effects, less than 10 residences are located within one mile of the proposed dam site and borrow area, and the nearest community, Meridian, is about four miles away. Two residences are located within the main

embankment and borrow areas and may be vacated before construction begins. The other residences are in locations not expected to experience significantly increased dust levels. Construction machinery exhaust is not a large enough source to significantly affect air quality in the area.

4.1.3 Operation Effects

Reservoir operation is not expected to have any significant effect on climate or air quality, either locally or regionally.

4.2 Noise

4.2.1 Effects of No Action

In the absence of the proposed Lake Bosque, local and regional noise sources and levels will continued to be affected by ongoing economic and technological forces.

4.2.2 Construction Effects

Some localized increases in noise levels will accompany construction activities in the vicinity of the proposed dam. However, there is a paucity of receptors in the area, and less than seven residences within one mile of the dam and borrow areas will be occupied during the construction period. Wildlife in the immediate vicinity of work areas might experience some noise related disturbance, but most species accommodate rather rapidly to mechanical noise that is not accompanied by other threat stimuli.

4.2.3 Operation Effects

Operation of the proposed reservoir is not expected to have any direct effect on local or regional noise levels. Increase in residential land use and recreational activities in the vicinity of the reservoir can result in some local increases in noise, including that resulting from higher traffic volumes on surrounding roads and operation of power boats (see Section 4.5, Socioeconomics and Land Use).

4.3 Geology and Soils

4.3.1 Effects of No Action

Geological resources and soils in Bosque and McLennan Counties will continue to be affected by ongoing population, economic and technological forces in the absence of the proposed reservoir.

4.3.2 Construction Effects

Construction of the proposed Lake Bosque is not anticipated to have any significant effects on the geological resources of the region. Within the reservoir site, various soil and rock materials will be utilized in dam construction. Sand and gravel deposits to be inundated by Lake Bosque do not appear to have much potential for economic recovery and off site sale.

Area palaeontological resources are centered in the Walnut and Glen Rose formations. Outcrops of these formations will be affected only slightly on the reservoir margins and in the river channel at the extreme upstream limit of inundation.

Roughly 3,000 acres of prime farming soils will be affected by dam construction and by inundation as a result of the construction of Lake Bosque. This is about 1.5% of the prime soils in Bosque County and is not anticipated to constitute a significant effect on a limited resource.

4.3.3 Operation Effects

Operation of the proposed Lake Bosque is not expected to have any substantial effect on either the geological or soil resources of Bosque and McLennan Counties. Effects upstream of the dam have been addressed in the preceeding sections, while downstream effects are expected to be negligible. Although Lake Bosque will not have a designated flood control function, flood peaks will be substantially attenuated by the presence of the dam and reservoir. As a result, the 100 year floodplain in the 6.3 mile reach from the proposed dam site to Meridian will be narrowed by about 58% from the present average width at maximum stage of 1200 feet to about 500 feet with the dam in place. Mean area inundated during the 100 year flood will be decreased from 145 acres per mile to 60 acres per mile. Neither direct effects nor resultant land use changes are expected to exert significant adverse effects on soils or geologic resources.

4.4 Water Resources

4.4.1 Effects of No Action

Unless another comparable alternative was selected, failure to construct Lake Bosque will result in continued overdrafting of groundwater resources. Declining water levels will result in increased pumping costs in the short term, a continuing decrease in groundwater quality and contribute to the continuing decline in water availability.

Existing surface water resources will have to be more intensively utilized, possibly to the detriment of other uses. Development of alternative surface water sources will impose financial burdens on project participants substantially greater than that required for the Lake Bosque alternative.

North Bosque River discharge may remain relatively unchanged in the absence of Lake Bosque. However, other projects may be constructed that will affect river flow. For example, additional flood and sediment retention structures might be built in the basin, or water from a project in the Paluxy River Basin may be discharged into the North Bosque from the City of Stephenville's wastewater treatment facilities.

Municipal wastewater discharges and agricultural runoff will continue to contribute sediment, oxygen demanding material, nutrients and toxic compounds to the river, and biotic responses to nutrient loading will continue to be evident. It is to be hoped that improved wastewater treatment and changes in agricultural practices, such as reduced dependence on pesticides or better soil retention of fertilizers, will result in improvements in water quality. However, population increases, or other changes in agricultural land uses and practices might result in adverse changes in surface water quality.

Based on recent past and present trends, it is likely that wastewater effluent quality will improve but that quantities will increase. Because of technological change and economic forces, future agricultural activity is not very predictable. However, it appears probable that the use of more specifially targeted pest and weed control practices will increase, resulting in fewer adverse environmental impacts, while the present pesticide burden in river sediments will continue to decline slowly through deep

burial, degradation, and transport downriver to Lake Waco. On balance, it is unlikely that any great improvement in water quality can be expected in the North Bosque River or Lake Waco, considering present trends.

4.4.2 Construction Effects

Construction of the proposed Lake Bosque dam and reservoir will result in a decrease in pumping from presently used ground water resources. This can result in the eventual recharge of the important Trinity Group aquifers which will decrease pumping costs, improve quality and allow time for development of mechanisms to regulate withdrawl to long term sustainable levels.

Although some enhanced recharge of the Paluxy Sands was originally expected, geotechnical investigations indicated very low transmissivity in this formation, and consequently only small seepage losses from the reservoir. The reservoir site does not coincide with the recharge area of any important aquifer, so neither enhanced recharge nor potential contamination of a source can be expected to result from project construction.

As a result of the presence of Lake Bosque and planned conservation programs, regional surface waters can be managed to allow beneficial uses in addition to municipal water supply to be simultaneously realized.

Water quality in the proposed reservoir is expected to be similar to that now seen in Lake Waco since water chemistry is essentially the same throughout the lower North Bosque River. Based on experience at Lake Waco the proposed reservoir will likely be somewhat enriched and may exhibit DO depletion in the hypolimnion during stratification. Most reservoirs in the region have oxygen depleted bottom water

during the summer and it is not considered a major problem. No substantial water quality problems are anticipated for Lake Bosque, standards for TWC Segment 1226 are not expected to be violated and no water quality conditions are indicated either by available data or by experience in Lake Waco that will prevent the use of Lake Bosque for public water supply or recreation.

4.4.3 Operation Effects

Operation of Lake Bosque is not expected to have any substantial effect on ground water resources beyond those items discussed above. Lake operation will decrease streamflow downstream of the dam. Table 4-1 presents flow frequencies at the proposed dam site derived from simulated reservoir operations under maximum demand (2040) conditions, using the 1946-1965 period of record. This table reflects maintenance maintenence of a minimum release of 0.5 cfs and release of up to a total of 2.0 cfs during April-August periods when inflows are available (see Section 5.0 Mitigation Plans). Comparison of Tables 3-1 and 4-1 shows that the lower flows, those equal to or less than the median for any given month are substantially reduced during the winter and spring but are augmented during the summer and fall months.

Under less than maximum demand conditions, Lake Bosque can be operated to maintain Lake Waco at a relatively stable elevation to enhance recreational benefits there. In that case more frequent releases will result in annual flows intermediate between the extremes exhibited in Tables 3-1 and 4-1, although the seasonal pattern of flows may be altered.

In order to assess the downstream extent of potential hydrologic changes, the reduction in stream discharge at Clifton due to the presence of the dam and reservoir was

Table 4-1 Monthly Flow Frequency Distribution at the proposed Dam Site, Lake Bosque operation under Maximum (2040) Conditions

Percent of Days with Less Than Tabulated Flows	January	February	March	April	May	June	July	August	September	October	November	December
50%	0.50	0.50	0.50	2.00	2.00	2.00	2.00	0.50	0.50	0.50	0.50	0.50
30%	0.50	0.50	0.50	2.00	2.00	2.00	2.00	0.50	0.50	0.50	0.50	0.50
20%	0.50	0.50	0.50	2.00	2.00	2.00	0.50	0.50	0.50	0.50	0.50	0.50
10%	0.50	0.50	0.50	2.00	2.00	2.00	0.50	0.50	0.50	0.50	0.50	0.50
5%	0.50	0.50	0.50	0.50	2.00	0.50	0.50	0.50	0.50	0.50	0.50	0.50

Note: Tabulated values are average daily flows in cubic feet per second.
Source: HDR Infrastructure, 1987

examined for the lower flow ranges. The large base flows available from the perennial tributaries (e.g., Meridian Creek) whose drainage basins include significant areas of Edwards Limestone, and the broad, deep valley alluvium and Paluxy Sands that begin to be present below Iredell are important contributors to flow in the North Bosque River below the proposed dam site.

Table 4-2 shows the percent change in tabulated values for the low flow percentiles at the Clifton gage resulting from the flow reduction due to the proposed project (cell by cell subtraction of the contents of Table 3-1 from Table 4-1, divided by the corresponding cell contents of the Clifton gage flow frequency table without the project). Table 4-2 shows that lower flows at Clifton will usually be reduced by substantially less than 50% and will often, particularly during the summer and fall, be increased. With regard to somewhat higher flows, analysis of reservoir inflow-outflow relationships were utilized to estimate the probable return interval for flows in the 1,000-2,000 cfs range at the proposed dam site. These flows are expected to recur at intervals of one to two years under 2040 operating conditions.

Drainage area runoff relationships were used to estimate the magnitudes of the two- and five-year flood peaks originating solely from storm runoff below the proposed dam site. These results are presented in Table 4-3.

Table 4-2 Percent Decrease, or Increase (+), in flows of Constant Frequency at Clifton, Texas due to the Operation of Lake Bosque under Maximum Demand (2040) Conditions

Flow Percentiles	January	February	March	April	May	June	July	August	September	October	November	December
0.50	41.50%	64.10%	61.90%	56.10%	64.10%	61.80%	19.50%	12.00%	22.70%	10.70%	32.00%	50.00%
0.30	36.00%	43.30%	62.70%	18.30%	54.50%	54.30%	(+85.10%)	(+52.10%)	(+82.00%)	0.00%	43.30%	32.80%
0.20	36.00%	42.00%	38.30%	15.00%	25.00%	24.40%	(+52.10%)	(+66.70%)	(+200.00%)	(+45.00%)	25.00%	32.60%
0.10	72.20%	29.50%	27.70%	18.10%	28.60%	(+30.00%)	(+250.00%)	(+416.70%)	(+833.30%)	(+72.00%)	(+55.60%)	26.70%
0.05	89.30%	33.30%	19.90%	63.60%	169.10%	(+43.20%)	(+333.30%)	*	*	(+208.30%)	(+80.60%)	(+47.00%)

Note: Percent change = (flow at dam with Project - flow at dam without Project) ÷ (flow at Clifton without Project)
*= Zero flows augmented by the 0.5 cfs release from Lake Bosque.
Source: HDR Infrastructure, 1987

Table 4-3

Two and Five Year Flood Flows Originating in Drainage Areas below the Proposed Lake Bosque Dam

Stream miles below dam:	5	12	18*
2 year flood (cfs)	1,000	2,300	7,000
5 year flood (cfs)	2,000	4,300	15,000

*Meridian Creek

Considering highest flow regimes, although the proposed dam and reservoir will not have flood control as a specific purpose, its presence will result in the attenuation of flood peaks. Discharge of storm water will take place over a longer period of time and maximum flows reached will be less compared to the present conditions. For example, the 100 year flood peak will be reduced about 59%, from 94,500 to 39,100 cfs. Lesser floods will be attenuated to a proportionately greater degree; the 50 and 10 year flood peaks will be reduced by 62 and 68%, respectively, over present conditions. Maximum water surface elevations downstream of the reservoir will be reduced along with peak flows. Flooding in the reach between the proposed dam site and Meridian by the 100 year flood will be reduced by about 58%, from an average of 145 acres per mile to 60 acres per mile. This corresponds to a reduction of average inundated surface width from 1200 feet to 500 feet at the 100 year flood peak.

Potential effects on water quality in the tailwater reach include reductions in suspended solids, nutrients and coliform bacteria, discharge of oxygen depleted water with elevated hydrogen sulfide levels and alteration of water temperature patterns. By providing additional assimilatory capacity for the load of nutrients and other materials transported down the North Bosque River, the proposed reservoir is anticipated to result in improved water quality

in the downstream portion of the river and in Lake Waco. Storage in Lake Bosque will result in enhanced oxidation of organic material, uptake of nutrients and sedimentation of algae, bacteria and non living material. The adverse effects, those involving low D.O. and temperature change, can be avoided with established operational techniques while retaining the beneficial effects.

4.5 Ecology

The following sections contain discussions of the potential effects of reservoir construction and operation on the biotic communities of the proposed Lake Bosque Site and downstream areas. Although the U.S. Fish and Wildlife Service has conducted Instream Flow (IFIM) studies on this reach of the North Bosque River, that has not been made avaliable at this time. Therefore, the discussion in Section 4.5.1, Aquatic Biology, and the mitigation plan proposed for aquatic environments in Section 5.1 does not make use of the formal IFIM methodology.

Terrestrial habitat values were also examined by the U.S. Fish and Wildlife Service using the Habitat Evaluation Procedure (HEP). These results are discussed in Section 4.5.2, Vegetation, and were used in formulating the mitigation plan proposed for terrestrial vegetation and wildlife in Section 5.2.

4.5.1 Aquatic Biology

4.5.1.1 Effects of No Action

In the absence of the proposed Lake Bosque, the North Bosque River will continue to be affected by the natural and cultural conditions prevailing in the basin. The river will still be subject to the regional climatic patterns and basin characteristics that produce its typical discharge levels,

water quality and habitats. Biotic communities will continue to reflect the prevalence of pool habitats and sandy gravel/cobble substrates, the dependence of aquatic food webs on in situ production by algal species, the intense colonization of solid surfaces by these same algal species and the wide range and low predictability of river discharges.

Improvements in water quality will have to be substantial to result in appreciable changes to the biological community. Reduction of epilithic algal growth might result in some change in macroinvertebrate relative abundance, but other habitat factors, including the dominant character of the food webs, lack of structural diversity and periodic low flow episodes will continue to strongly influence the fish community.

4.5.1.2 Construction Effects

Construction of the proposed Lake Bosque will convert about 160 acres of stream bed to permanently inundated, deep water habitat, and about 4400 acres of dry land to aquatic habitats experiencing varying frequencies of inundation and depths. While some groups, including the filter feeding invertebrates and forage fish, may experience changes in species composition, most of the remainder of the community is capable of survival and reproduction in a reservoir habitat. None of the species reportedly fished for in the North Bosque River, nor the fish assemblage reported in TCA, 1985, will experience substantial adverse impacts as a result of construction of Lake Bosque. Table 3-2 lists fish species collected in the North Bosque River and notes those also reported from Lake Waco. Because of its size and potential habitat diversity it is expected that the 4564 acre conservation pool will support a significantly larger biomass, and probably a more diverse community than now

occurs in the 160 acres of stream bed to be inundated, or even the approximately 350 acres of stream bed in the reach from the proposed reservoir to Clifton.

Water quality in the proposed reservoir is not expected to exert any substantial adverse influence on the resident biological community. Low D.O. levels in reservoir bottom waters during stratification may make that volume seasonally unavailable to fish and other aerobic organisms. This condition is very common in Texas reservoirs and although it might be supposed that it will result in reduced carrying capacity, it is in fact generally reflective of a more productive system, which supports higher growth rates and biomasses than more oligotrophic waters. Available water quality data and experience in Lake Waco indicates a lack of any other water quality problems that will adversely affect the biotic community of the reservoir.

4.5.1.3 Operation Effects

Effects on aquatic populations resulting from Lake Bosque operation can occur through three major routes. These are (1) the consequences of fluctuations in water surface elevation in the reservoir, (2) changes in the amount and timing of flows in the tailwater and (3) alteration of downstream water quality as a result of discharge of impounded water.

Fluctuations in reservoir elevation can have direct adverse effects on the reproductive success of fish species that spawn in shallow water, particularly those such as the centrarchids (sunfish) that construct nests. However, fluctuating reservoir surface elevation are not always problems. Precise effects are highly site specific and depend on a large number of factors including the nature of the drawdowns (seasonality, frequency, amount, rapidity),

reservoir bathymetry, water quality and substrate distribution, and biotic community characteristics. The frequency and duration of water surface elevation changes will also affect development of littoral vegetation and, consequently, influence aquatic habitats. Too frequent fluctuation will result in suppression of vegetational development in the band between high and low water, while a constant level can lead to undesirably dense and extensive stands of aquatic macrophytes. The former situation is undesirable because it results in reduced aquatic habitat diversity, while the latter condition is a nuisance to human use.

Reservoir simulation studies for maximum demand (2040) conditions showed water surface elevations below 826 MSL occurred only infrequently (during the critical drought period). Considering April-July spawning periods, water surface elevations were stable within 2 feet in 15 of 20 years simulated, and changes of more than 3 feet occured only twice. Under 2040 conditions this route of impact is unlikely to be significant.

More frequent releases to Lake Waco during less than maximum demand conditions will result in somewhat more frequent and extensive drawdowns. However, extensive spring drawdowns are not expected under this operating condition either, because of the large water availability at that season. Consequently, we do not expect significant adverse impacts to biotic communities during less than maximum demand operation.

Changes in tailwater discharge patterns (see Section 4.4.3) will result in a reduction in the total inundated channel area, with most of this loss occuring in riffles, runs and shallow water habitats at the upper ends of pools. Substantial effects to the lotic environment will not extend

below Clifton because of inflow from tributaries and aquifer outcrops. Downstream effects due to low flows will be most pronounced under maximum demand conditions. While Lake Bosque is operated to stabilize Lake Waco, large releases (about 1,000 cfs) will be made periodically in response to requests from the City of Waco. To ameliorate the potential effects of sudden changes in flow, particularly stranding during cessation of the release, a stepped discharge protocol will be employed (see Section 5.1).

Riffles occupy about 10% of the channel length (and a smaller proportion of channel area) between the dam site and Clifton. Aerial photography flown in September, 1984, after several months of zero discharge shows about half the stream bed occupied by permanent pools in the lower half of the reservoir reach and downstream to Meridian. Observations at Comanche Crossing (Station 1 in the Ecology Baseline Survey), between the proposed dam site and Meridian, indicate that substantial inundation of shallow channel reaches occurs when pools are filled. Flows of 2 cfs, or less, will inundate significantly more of these shallow areas, covering about 70-80% of the area wetted at median discharge.

In a pool dominated system such as this, inhabited by species that typically do not require flowing water for survival, it does not appear that reduced riffle habitat will be a substantial adverse effect. Obligate riffle species are largely absent from the North Bosque River, probably because of a combination of stress from low flow episodes and water quality conditions. While riffles have been identified as a source of prey items for fish, food limitation seems an unlikely circumstance for a river showing as much evidence of enrichment as this one.

It is most likely that long term carrying capacity for fish populations in the present North Bosque system is determined by the periodic occurence of low flow episodes. During very low flow summer conditions juveniles and all stages of forage fish can be exposed to intense predation if they are confined to the permanent pools where there is little cover and the water becomes clear as suspended materials settle out and nutrients are depleted and not replenished by inflows. Constant maintenence of some some shallow water non-riffle habitat, particularly during the summer, is probably far more important for resident fish populations than is the provision of flows high enough to inundate substantial riffle areas.

The attenuation of flood peaks resulting from the presence of the dam and reservoir has potential adverse consequences in that periodic flood flows are necessary to remove sands and silts deposited by minor runoff events, or sloughed from the banks, and to prevent invasion of the channel by terrestrial vegetation. Flows sufficient to scour the channel appear to be those in excess of 1,000 cfs which presently recurr more often than once per year. This flow will result in average current velocities of 3-5 feet per second and general mobilization of particles of one to three inches in size into the bed load. Flows of this magnitude are expected to occur at an interval of once in one to two years at the dam site under maximum demand conditions. Flows originating below the impounded part of the basin will substantially augment this scour regime.

Under less than maximum demand conditions, total annual flows will be similar to the present condition but low flow episodes will be periodically interuppted by large (ca. 1,000 cfs) releases to Lake Waco. No adverse impacts from lack of scouring events is expected to result from the proposed project.

Water quality changes as a result of impoundment include those that can be beneficial to downstream environments (reduction of suspended solids, nutrients and fecal coliforms), and those that tend to have adverse effects (release of hypolimnitic water depleted in dissolved oxygen and changes in seasonal temperature regimes). Discharge of relatively clear, low nutrient water will tend to reduce filamentous algal growth and substrate siltation in the tailwater reach possibly extending downstream as far as Clifton. This would tend to have the beneficial effect of altering shallow habitat areas to be more like those characteristic of the tributary streams, such as the East Bosque, and providing somne additional habitat diversity.

Discharge of water low in dissolved oxygen and, even more importantly, disruption of seasonal temperature patterns are widely recognized as having potentially adverse effects on macroinvertebrate and warm water fish assemblages. Avoidance of such impacts can be accomplished with appropriate operational protocols utilizing a multilevel withdrawl and outlet structure (Section 5.1).

4.5.1.4 Effects on Important Species and Habitats

No aquatic species, listed as endangered or threatened by either the State of Texas or the U.S. Fish and Wildlife Service, is known or is likely to occur in either the Lake Bosque site or in the downstream reach. No other important species (Section 3.5.2) are known that will suffer substantial adverse impact as a result of construction and operation of the Lake Bosque Project.

Habitats in the North Bosque River appear to be similar and widely distributed throughout the reach studied. Adverse impacts to unique habitats or communities is considered

unlikely to occur as a result of reservoir construction or operation.

4.5.2 Vegetation

4.5.2.1 Effects of No Action

The no action alternative will eliminate both adverse and beneficial effects of construction and operation related to the proposed Lake Bosque project. The future status of the terrestrial flora of the project site will continue to be strongly affected by regional agricultural economics and management practices. Changes in these practices are not presently predictable. For example, during the interval 1958-1987 pasture and haylands increased from 396 to 50,855 acres in Bosque County, primarily at the expense of cropland. At the same time the "Otherland" use category (including public, recreation, wildlife, water, urban, and transportation route lands) increased from 30,450 to 46,165 acres.

Maintenance of current agricultural practices in the vicinity of the proposed reservoir site will probably result in the continued loss of species and habitat diversity through additional clearing of brush and woodland, planting and management for hybrid pasture grasses, and overgrazing in areas dominated by native vegetation. Substantial loss in habitat value can occur in the bottomland woodland map unit (TCA, 1985) as a result of continued conversion to cropland and improved pasture. Woodland areas amounting to at least half the 799.8 acres contained within the proposed conservation pool are probably at risk. These areas are scattered throughout the reservoir site along the North Bosque and its tributaries where the woodlands are more than just narrow, riparian strips.

The U.S. Fish and Wildlife Service has estimated the value of habitats in the project area using their Habitat Evaluation Procedure (HEP). The following is a simplified outline of the procedure, for a complete explanation of the HEP, see USFWS, 1980.

1) Select important, representative species for which habitat suitabilitiy models are available;

2) collect site-specific data on each habitat type of concern;

3) use field data and species model to estimate the average value of each habitat type for that particular species: the result is a number, the Habitat Suitability Index (HSI), having a range between 0.0 and 1.0;

4) determine the acreage of each habitat type;

5) calculate Habitat Units (HU) for each selected species as the product of habitat acreage and the HSI for that species;

6) if it is assumed that either acreages or HSI's will change over time, Average Annual Habitat Units (AAHU) are calculated by averaging HU's for each year over the period of concern.

This outcome of this procedure is sensitive to the number and identity of representative species used and how sample sites are selected within a habitat type, together with the methods used and effort expended in measuring habitat parameters. In addition, the assumptions made in preparing a particular analysis may strongly affect its outcome. For example, the U.S. Fish and Wildlife Service analysis of the Lake Bosque site assumes that both acreages and HSI's will remain the same for all habitat types during the life of the project (1990-2040) if the reservoir is not built. AAHU's for the various habitat types change considerably if different assumptions about land future land use is used.

For these reasons we regard the habitat values in Habitat Units (HU), presented in Table 4-4 as providing a general assessment which is open to interpretation based on regional environmental conditions and on data collected during the Baseline Ecology Survey of the reservoir site. Although we do not believe these HEP results to be biologically or statistically definitive, for the present purpose, the U.S. Fish and Wildlife Service analysis appears to provide values for the important habitat types (bottomland and upland deciduous woodland) that are unlikely to be substantially improved by additional analysis.

4.5.2.2 Construction Effects

Construction of Lake Bosque will result in the direct loss of approximately 192 acres of terrestrial vegetation through construction of the dam, spillway, and related facilities (Table 3-3). Reservoir maintainence at the conservation pool level (830 MSL) will inundate an additional 4564 acres of existing vegetation. The majority of this 4765 acres consists of cropland (22%), native grassland (32%), and improved pasture (20%). Riparian and bottomland woodlands account for 17% of the affected vegetation and less than 8% is upland woodland. Vegetation between the conservation pool elevation and the level of the 100 year flood (841.3 MSL) is not expected to be substantially affected because of the very short duration (<1 week) of flood inundation above 830 MSL. Floodwaters will be rapidly drained from the reservoir following an inflow event by the 250 foot wide uncontrolled service spillway.

The most extensive and economically important vegetational units on the site are native grassland, improved pasture, and cropland. The loss of these areas will not constitute an economically significant impact considering the approximately 500,000 acres of these habitats in Bosque

Table 4-4 Summary of U.S. Fish and Wildlife Service HEP Analysis of Major Habitat Types on the Proposed Lake Bosque Site

Species/Habitat	Area (acres)	HSI	HU
Dove/NP	2,277.00	0.84	1912.68
Dove/IP	1,247.00	0.51	635.97
Dove/CR	1,180.00	0.78	920.40
Kestrel/NP	2,277.00	0.87	1980.99
Kestrel/IP	1,247.00	0.85	1059.95
Kestrel/CR	1,180.00	0.49	578.20
S-T Flycatcher/NP	2,277.00	0.98	2231.46
S-T Flycatcher/IP	1,247.00	0.74	922.78
S-T Flycatcher/CR	1,180.00	0.78	920.40
B-C Chickadee/DF	202.00	0.81	163.62
B-C Chickadee/DFW	899.00	0.82	737.18
Barred Owl/DF	202.00	0.77	155.54
Barred Owl/DFW	899.00	0.89	800.11
Raccoon/DFW	899.00	0.94	845.06
Fox Squirrel/DF	202.00	0.68	137.36
Fox Squirrel/DFW	899.00	0.8	719.20
W-T Deer/CR	1,180.00	0.12	141.60
W-T Deer/DF	202.00	0.37	74.74
W-T Deer/DFW	899.00	0.5	449.50
Cottontail/NP	2,277.00	0.45	1024.65
Cottontail/IP	1,247.00	0.03	37.41

Note: Area assessed includes dam, spillway and lake area up to 100 year flood pool.
NP = native (unimproved) pasture
IP = improved pasture
CR = cropland
DF = (upland) decidous forest
DFW = decidous forested wetlands (bottomland forest)
Dove = mourning dove
Kestrel = American Kestrel
S-T = Flycatcher = scissor-tail flycatcher
B-C = Chickadee = black-capped chickadee (Parus atricapillus)
Cottontail = eastern cottontail

Source: U.S. Fish and Wildlife Service

County. The native grasslands tend to be overgrazed, except in the extreme northeast section of the project area, as evidenced be the abundance of numerous plant species indicative of wastelands and disturbed areas. Improved pastures, on the other hand, are reseeded on a regular basis or maintained with desirable forage species. Row crops occupy the majority of the cropland habitat and are almost entirely limited to the bottomlands since the valley slopes and uplands are unsuited to this land use.

While open plant communities may be adequate or even excellent habitat for a number of wildlife species (e.g. mourning dove, American kestrel, etc.), they tend to be impoverished in terms of native plant species. Projected losses of cropland and improved pasture habitats can be expected to result in insignificant losses to native plant populations while native pasture losses will tend to be limited to local increasers and weedy species. Bosque County presently contains about 142,000 acres of cropland and over 450,000 acres of native and improved pasture. Historical data indicates that changes in agricultural practice probably have a more pronounced effect on plant species diversity than will the inundation of 3589 acres of cropland and pastureland.

A large proportion (75%) of the habitat value in Table 4-4 is accounted for by crop, pasture and grazing land which may or may not be overvalued by that analysis, but is certainly very common in Bosque County and in Central Texas generally. We do not believe that removal of these areas will result in any significant impacts to important vegetational communities or species, or to wildlife populations dependant on those habitat types.

In terms of species density, diversity, and locally adapted species assemblages, the most significant habitat impacted

is bottomland woodland. Although the project site (up to 830 MSL) only contains 799.8 acres of this habitat type (including 6.9 acres of pecan cropland), the loss through inundation will be substantial when considering the large scale reduction in bottomland forest that has occurred throughout Texas. This area also contains 109.73 acres of upland decidous forest which has also been substantially reduced in Central Texas by agricultural practices and which is regarded as important wildlife habitat.

Table 4-5 presents AAHU's for the with and without project alternatives as estimated by U.S. Fish and Wildlife Service for the two decidous forest habitats on the reservoir site. Net habitat loss is shown as the difference between the with and without project columns. Also included is a column showing net change calculated on the assumption that either acreage or HSI's will decline by 25% over the life of the project. Based on past trends and agricultural practices, and the fact that most of the bottomland forest habitat is located on prime farming soils, we believe that this scenario is conservative and at least as likely as the assumption of no change.

Site preparation and construction is not expected to produce any substantial impacts to vegetation outside of the construction site, borrow areas and haul roads (about 430 acres, all of which are included in the conservation pool). Dust, or materials such as oil and grease found in run-off from haul roads, is not anticipated to have any detectable effects on terrestrial vegetation.

4.5.2.3 Operation Effects

Long-term operation effects of Lake Bosque are not anticipated to have much effect on terrestrial vegetation where inundation is not complete. Little or no change due

Table 4-5 Habitat Values in Average Annual Habitat Units (AAHU) and Net Change for Deciduous Forest Portions of the Lake Bosque Site With and Without the Proposed Project

Species/Habitat	AAHU Without	AAHU With	AAHU Net	AAHU Net (25%)
B-C Chickadee/DF	163.62	79.87	-83.75	-71.5
B-C Chickadee/DFW	737.18	125.94	-611.24	-526.8
Barred Owl/DF	155.54	75.92	-79.62	-68.0
Barred Owl/DFW	800.11	136.69	-663.42	-572.2
Raccoon/DFW	845.06	144.37	-700.69	-604.6
Fox Squirrel/DF	137.36	67.05	-70.31	-60.1
Fox Squirrel/DFW	719.20	122.86	-596.34	-513.8
W-T Deer/DF	74.74	36.48	-38.26	-32.7
W-T Deer/DFW	449.50	76.79	-372.71	-319.3
Total	4,082.31	865.97	-3,216.34	-2,769.0

DF = (upland) decidous forest
DFW = decidous forested wetlands (bottomland forest)
B-C = Chickadee = black-capped chickadee (Parus atricapillus)

Source: U.S. Fish and Wildlife Service, Paul Price Associates, Inc.

to flooding of vegetation above the conservation pool (830.0 foot contour) is projected since periods of inundation are not expected to be of significant frequency or duration. Reservoir operation studies indicate only two periods of inundation above 831 MSL lasting more than five days over the 20 year simulation period. Terrestrial habitat values in this zone will therefore be retained to a substantial extent, depending on the mix of affected cover types and the management practices applied.

The majority of the area disturbed during construction of the dam and spillway will be reseeded, providing habitat similar to the improved pastures presently found in the project area.

Below the dam, the riparian streambed and woody vegetation along the margins of the river may be subjected to less pronounced fluctuations in streamflow, although high flows sufficient to scour the channel will continue to occur. This should result in more stable stream edge plant communities. Lowland species such as box elder, green ash, and pecan will be expected to produce moderately well since spills from the reservoir and lateral inflows from tributaries and the valley alluvium will continue to maintain a high water table. These trees, and others present in existing riparian woodland strips, are known to have high transpiration rates and require ample and dependable moisture supplies. They are not, however, dependent on annual inundations by the Bosque River as evidenced by the current 2-5 year return interval for flooding of riparian soils. Thus, flora associated with downstream woody habitats should remain essentially unaffected.

4.5.2.4 Effects on Important Species and Habitats

At present, no federally listed endangered or threatened plant species are known to occur in the Lake Bosque project area. Therefore, the construction and operation of the lake will not adversely affect any of these important species.

Of the habitats present in the project area, riparian and bottomland woodlands are considered the most productive in terms of both diversity and density of plant species. Since the majority of the bottomlands in this area have already been cleared for agricultural purposes, the remaining acreage should be considered of high value.

4.5.3 Wildlife

4.5.3.1 Effects of No Action

The no action alternative will prevent both the adverse and beneficial impacts of construction and operation related to the proposed Lake Bosque project. In the absence of the project, the area will probably remain largely in its present state with livestock grazing and farming being the predominant activities affecting wildlife. Wildlife utilization of the proposed site will reflect the changes or lack thereof, in plant communities on the site due to land use practices during the period 1990-2040.

4.5.3.2 Construction Effects

Construction of the dam, spillway and associated facilities will result in the removal of about 192 acres of existing wildlife habitat. Filling of the lake after dam construction will result in the inundation of about 4564 acres at conservation pool elevation (830 feet, MSL). As is

typical of the entire project area, most (75%) of the affected habitat is open herbland including improved pasture, cropland, and native pasture. As such, it is already greatly affected by human disturbance. However, certain wildlife species do well in these habitats, with native pasture generally being of greater wildlife value than improved pasture and cropland. It is important to note, however, that these habitat types are abundant and that the populations of species typical of such areas will not be significantly altered when considered on a countywide or regional basis.

As a result of construction activities in the area of the dam, spillway, and borrow areas (522 acres), resident wildlife will be destroyed or displaced from the area depending on the mobility of individual species involved. It is commonly understood that organisms most likely to be killed directly by such activities include species of amphibians, reptiles, and small mammals. If construction occurs during the breeding season, nestling and fledgling birds will also be affected to the extent that those areas are utilitized for reproductive activities. During the process of lake filling, more species should be able to disperse from the site. However, if periods of rapid filling occur there may still be some direct mortality.

The fate of individual animals that escape direct injury is less commonly understood. The concept of carrying capacity is well established in wildlife population ecology and is important in considering the future of displaced individuals. Carrying capacity is a fluctuating level (within limits) of population density that can be supported by a given habitat (Gills 1971, Dempster 1975). As the population of a wildlife species (for example, white-tailed deer) increases and approaches local carrying capacity, a number of population control factors increase in their

effect. Food and other resource shortages can result from overcrowding, in turn increasing competitive stresses, resulting in both direct and indirect reductions in fecundity and increases mortality (Dempster 1975). Absorption of displaced individuals into surrounding habitats will depend on the condition of those habitats and on the conspecific population densities already resident there (i.e., the local carrying capacity and how closely it is already approached). While survival of refugee individuals may be a function of local conditions and recent historical circumstances, we can expect no change in the long-term average population sizes in surrounding areas unless carrying capacity is altered by environmental changes. This means that over the long term we should regard the removal of a portion of the species habitat (in this case that affected by construction of the lake) as removing that part of the population resident in the affected area.

4.5.3.3 Operation Effects

Wildlife impacts from the operation of Lake Bosque will be primarily positive over the long term. The presence of the lake will provide aquatic and some riparian (lake littoral) habitat which will be of high value to species such as wintering and migratory waterfowl, fish-eating birds, aquatic- associated reptiles and amphibians, and other similar aquatic species.

Over the long term, vegetational succession in the vicinity of the shoreline can, if properly managed, produce riparian communities of increasing wildlife value as woody species develop and various aspects of habitat diversity are increased. These include food and cover availability and diversity, foliage height (structural) diversity, and a broader range of microclimates as more mesic conditions

prevail. This will have the effect of increasing the carrying capacity of terrestrial environments adjacent to the lakeshore for some of the species adversely affected by reservoir construction. Additional beneficial changes could be realized through implementation of appropriate land use and management practices in selected areas.

The potential downstream changes that might occur as a result of stream-flow alterations are not considered significant. If vegetational communities are affected by reduced peak flows downstream, then wildlife inhabiting those areas will also be indirectly affected. However, inundation frequency for existing riparian woodlands is presently 2-5 years so there is little reason to expect major shifts in dominant vegetation in downstream areas and wildlife inhabiting those areas should be relatively unaffected.

Barclay (1980) under contract with UFSWS can come to no definite conclusions with regard to the downstream effects of impoundment in south-central Oklahoma. He hypothesized that impoundment might indirectly simplify downstream terrestrial riparian systems but the data for birds showed that "...reduction of stream fluctuation downstream from the reservoirs had little detectable effect on the avian communities studied." He also states that his reptile and amphibian survey did "...not provide any clear evidence of impoundment effects." Mammal sampling was similarly inconclusive.

4.5.3.4 Effects on Important Species and Habitats

No federally listed endangered or threatened species are expected to be adversely affected by either construction or operation of the proposed Lake Bosque project, since none are known, or are likely, to inhabit the area at present.

One species, the bald eagle, is likely to be favorably affected by the substantial increase in its preferred wintering habitat. The bald eagle winters at various reservoirs throughout Texas, and it is not unlikely that they will utilize Lake Bosque for feeding and resting.

Of the state listed species, the Texas horned lizard has been observed in the immediate vicinity of Lake Bosque. If members of this species are present in construction or borrow areas, or within the conservation pool, individuals could be lost.

Adverse impacts will occur with regard to all terrestrial game and furbearing species that currently inhabit the project site due to inundation of currently occupied habitat. However, these impacts are not of great significance when viewed on a countywide or regional basis. For example, based on game population indices, comparisons between the Lake Bosque site and the Cross Timbers and Prairies Ecological Region indicate that game populations in the project area are typical or somewhat low for the region. Habitat Evaluation Procedure results (Table 4-2) showed that even the bottomlands (generally the best deer habitat) had a habitat suitability index (HSI) for white-tailed deer of only 0.50. Bottomland HSI values for two smaller species, the fox squirrel and northern raccoon, were better (between 0.80 and 0.94) but the requirements for these species are typically in ample supply in any older bottomland forest with water.

Conclusions of the baseline studies indicated that open habitat game species such as mourning dove and bobwhite are similar in abundance in the project area and in the region in general. This was supported by the HEP data (USFWS 1985) for the mourning dove which shows relatively high HSI's for two of the three open cover types.

In terms of value per acre, the most significant and valuable habitats of the project area are bottomland and riparian woodlands. These cover types are considered by wildlife biologists to be of particular concern due to the statewide trend of reduction and because of their overall higher wildlife diversity and production. Thus, even though the bottomlands of the project area have been mostly cleared due to agriculture, the remaining acreages are considered to have high value.

4.6 Socioeconomics and Land Use

4.6.1 Effects of No Action

4.6.1.1 Population

During the 1960s and 1970s the two county study area grew at rates lower than did the State as a whole. If the proposed reservoir is not built, growth in the area is expected to continue at a slower rate of increase than during the 1970s. Even without additional growth, communities relying on groundwater as the sole source of supply (all the project participating entities except the City of Waco), will in the next 10 to 30 years begin experiencing severe water quality supply problems, which could restrict local population growth. If these entities grow at the rate projected by the TWDB (either the high or the low series) an additional source of water will be necessary in even less time. All the other known alternatives now cost more than the Lake Bosque Project and future costs are likely to increase beyond present estimates.

Restricted population growth due to lack of water will discourage young people from remaining in the area or migrating to the two counties. The evential result,

particularly in Bosque County, will be low population growth characterized by an increasing proportion of elderly people.

4.6.1.2 Local Economy

The effect of no action upon the local economy of areas depending on ground water will be extensive. The local economy will continue as it has during the last 20 years until overdrafting of the Trinity Aquifer curtails water supplies and restricts development. Continued growth or even water use at present levels will require the development of additional water sources. Future manufacturing growth will require a source of water more reliable and ample than available through ground water.

In 1980, 56% of all Bosque County families were in the two lowest (out of 5 possible) income brackets while the State average was 40%. Without economic growth this trend can be expected to continue and possibly become even more extreme. Income levels in McLennan County are not too different from the state average. However, without continued population and economic growth, these income levels may decline.

4.6.1.3 Community Facilities and Services

The tax base for education in the two county area will remain unchanged if the proposed reservoir is not built. Restricted population growth caused by water shortages will decrease the number of children in the area. Required investments in the education system will decrease as the number of children declined. However, it is possible that as the number of people in the area declines, the rate of taxation required to maintain a minimum level of service could increase.

Fire protection in the study area will decline as overdrafting of the Trinity Aquifer continues. Effective fire-fighting necessitates a reliable high pressure water system.

4.6.1.4 Public Finance

As discussed in the previous sections the effect of no action upon project participants and Bosque and McLennan Counties' population and economy would likely cause area growth trends to decline and even stagnate. If this were to occur it is possible that tax rates would increase in order to continue providing the minimum level of required public services.

4.6.1.5 Recreation and Aesthetics

Public access to water for recreation purposes is extremely limited in the vicinity of the proposed reservoir. There are no public access points to the Bosque River in the vicinity of the proposed site. There is no reason to believe that this condition will change if the proposed reservoir is not built.

Local views will probably continue to consist of a pastoral valley landscape dominated by strong horizontals and inhabited by plants and animals typical of Central Texas.

4.6.1.6 Land Use

Insufficient water supplies could restrict urban development, specifically, development growth in existing communities relying solely on ground water.

4.6.2 Construction Effects

4.6.2.1 Population

HDR Infrastructure, Inc., consulting engineer for the owner, has estimated construction time for the proposed Lake Bosque at about two years. Because of the project's short construction time and proximity to the labor force of the Dallas-Fort Worth area and other surrounding communities, it is unlikely that a significant number of project workers will migrate to the area. It is more likely that workers will commute to the proposed project site as it is not uncommon for construction workers to average 50 miles one way in daily commuting. Therefore, substantial impact to housing availability, infrastructure, public safety, health services and schools is not anticipated from this source.

4.6.2.2 Local Economy

It is estimated that construction of the proposed project will provide approximately 145 temporary jobs, of which about 12% (18 jobs) would occur during the pre-construction stage and 88% (116 jobs) would occur in the construction phase. Peak employment of approximately 79 jobs would occur during the early phase of construction, employment for any one construction phase would range from 4 to 60 jobs.

Direct economic impacts of constructing the proposed reservoir would be limited by the project's relatively small construction crew and short construction time. Direct employment benefits (i.e., job creation) would be determined by the location of the contractor responsible for constructiong the dam. Undoubtedly, a small proportion of semi-skilled and unskilled jobs would be filled locally, but the majority of supervisory and highly-skilled positions

(the best paying jobs) would be filled from within the contracting company's area of employment.

The presence of additional workers in the local area would be expected to generate a temporary demand for local acquisition of miscellaneous goods and services, i.e., food and beverages, gas, etc.

4.6.2.3 Community Facilities and Services

If Lake Bosque is built, Walnut Springs, Iredell and Meridian Independent School Districts (ISDs) would lose a small portion of their tax base. The percent of net ISD taxes accrued from lands affected by the proposed Lake Bosque site ranges from 2.40% to 3.86% of each ISD's tax revenue assuming that tax revenue reduction would be equal to reduction in the area of the tax base. We believe this to be a reasonable approximation because of the countervailing effects of higher bottomland values versus the usual location of improvements above the area affected by the reservoir. The existing tax rate for each school district ranges from 40% to 55% of the maximum $1.50 per $100 valuation tax rate and could be increased if needed. However, increases in property value associated with recreational and residential use of lands near Lake Bosque are expected to offset these losses.

Construction of the proposed reservoir would affect only 11 single family homes and a number of other structures largely related to farming activities. The market value of homes definitely located within the 100 year flood elevation ranges from $27,190 to $84,460.

As proposed, reservoir construction would require the relocation of small sections of county and state roadways, as well as abandonment of several county roads which cross

the proposed site. Several powerlines would also be relocated. Construction generated traffic would not adversely affect major roads accessing the site because traffic counts for these roads are relatively low.

4.6.2.4 Public Finance

Approximately 54 landowners owning 13,629 acres will be affected to some extent by the proposed Lake Bosque. In some cases all of a particular land parcel will be inundated; in other cases, only a portion of the parcel. Eleven homes and 6,143.26 acres of the 13,251 acres will be included in the proposed Lake Bosque up to the 100 year flood elevation (841.3 feet, MSL).

Total 1985 property assessments for Bosque County stood at $385,630,342. The proposed project will remove about 4756 acres from the county tax roles, assuming that only flood easements will be obtained for land above the conservation pool elevation. The property removed from the tax roles by the construction of the proposed reservoir will be about 35% of the 13,629 acres partially affected by the project. The 1985 assessed property valuation of the 13,629 acres was $2,827,655, thirty-five percent of which would be $989,679, or 0.26% of the county's tax base. This could be offset by increases in property values and sales tax revenues resulting from residential and recreational development associated with Lake Bosque.

Municipal tax bases will not be affected by construction of the project as the site does not lie within the boundaries of a municipal jurisdiction. However, to finance the project, tax or water rates in the participating municipalities are expected to rise.

4.6.2.5 Recreation and Aesthetics

Recreational opportunities in the vicinity of the proposed Lake Bosque are severely restricted by the private ownership of everything except county roads and the stream bed. Construction activities are not expected to have significant adverse effects on local recreation since there is no public access to the dam and borrow areas. The approximately 500 acres included in these areas might support two to six deer leases if it were fully utilized. There is no public access to the Bosque River in the vicinity of the dam site.

Adverse effects of construction on local aesthetics will be temporary. Visual and audial disturbances will occur from construction machinery and workers. The dam is about seven miles from the nearest community and there are about 20 houses within a three mile radius. Because of the small number of people in the immediate vicinity, impacts on aesthetics from dam construction are expected to be slight.

The site would be transformed from a pastoral valley landscape into a 4,564 surface acre lake encompassed by gently sloping, flat-topped hills with local relief of about 200 feet. Thus, the waters of Lake Bosque, varying in color and textural quality with the seasonal and climatic extremes of the region and supporting an otherwise restricted aquatic community, will have a beneficial impact on local viewsheds and constitute an aesthetic amenity.

4.6.2.6 Land Use

Construction of the proposed Lake Bosque will change 4,756 acres of privately owned agricultural land into public water supply and recreation land. The Brazos River Authority will also obtain flood easement on an additional 1,387 acres up

to the 100 year flood elevation that would be inundated occasionally.

The 4,756 acres to be occupied by the dam and spillways and the conservation pool account for about 0.8% of the county's 595,172 acres of cropland, pastureland, hayland and rangeland. This includes a rough estimate of about 3,000 acres of prime farming land, approximately 1.5% of the county total. Fifty-four landowners owning 13,351 acres would be affected to varying degrees. Eleven homes and 6,143.26 acres (45%) of the 13,251 acres would be impacted by the proposed Lake Bosque's conservation pool and 100-year floodplain.

4.6.3 Operation Effects

4.6.3.1 Population

Dam operation will require one or two full time employees living at or near the site. Some additional employment will result from recreational and residential development stimulated by the reservoir. However, these jobs would most likely be filled from the local area and therefore result in an insignificant impact upon the area's population.

Developed recreation areas would be expected to attract new visitors to the area, but no parks or other facilities are presently known to be planned. It is expected that such facilities would be developed by private interests or local governments in response to the demand identified in the 1985 Texas Outdoor Recreation Plan (TORP).

Residential development and consequent population growth in response to reservoir construction depends on several site specific factors including: availability of waterfront property, proximity to established population centers,

access, aesthetics and the presence of recreational or other entertainment opportunities. Lake Bosque will have privately owned waterfront and view property and is within an hour's drive, about 50 miles, of the Waco metropolitan area.

Lake Granbury, located on the Brazos River about 35 miles southwest of Fort Worth, is an example of a reservoir in close proximity to an urban area with available, private waterfront property. Since construction in 1969, about 140 residential developments have been built on the 30 miles of lakeshore nearest the City of Granbury. These developments include approximately 31,078 lots, 3,672 single family homes and 3,494 mobile homes (PPC, 1984). Realtors in the Granbury area report that the current population mix is evenly distrubuted among seasonal residents, retired couples, commuters, and those who are locally employed.

Lakes O. C. Fisher and Proctor are both located in Central Texas, and are similar in size and location to the proposed Lake Bosque. However, these lakes were built by the U. S. Army Corps of Engineers and do not have private waterfront acreage available for purchase and development. Area realtors report only minor residential development of view lots near these lakes.

Because Lake Bosque is located relatively near Waco (1980 population was 101,261), will have property available for purchase and will have reasonably good access by SH 6, its development potential must be considered moderate to high. This potential may be limited to some extent by building restrictions below the 100 year flood elevation and by the relatively large, frequent changes in water surface elevation likely to be experienced during reservoir operation at less than maximum demand conditions. Waterfront property will presumably become more attractive

for development as system demand increases and Lake Bosque surface elevation becomes more stable.

4.6.3.2 Local Economy

Following completion of construction, operation of the reservoir would require a work force of one or two people. These individuals would be responsible for reservoir operation and maintenance and would live near the site. The presence of these individuals and their familiiies will generate an insignificant demand for local goods and services and possibly require the purchase or construction of a permanent residence.

The major effect on the local economy will result from expenditures associated with recreational activities. In 1986, yearly visits to Lakes O. C. Fisher and Proctor totaled 552,732 and 983,170, respectively. The higher the percentage of nonlocal visitors to Lake Bosque, the greater the economic impact on the local area economy. Potentially, the economic impact of these visitors could be great.

4.6.3.3 Facilities and Services

Operation of the proposed reservoir would require that at least one or two employees live near the site. From this source, impact on the area's education system, public safety, health services and facilities, transporation system and local housing would be negligible. Depending on the number of nonlocal visitors drawn to the lake for recreation purposes and on possible population increases due to residential development, impacts on public safety, health services and facilities, and transportation could be significant. Bosque County is relatively well equipped to handle an influx of visitors and permanent residents, as the county has a surplus of medical personnel, two hospitals and

well maintained roads with low traffic volumes. The only potential inadequacies could result from the relatively small police and fire-fighting force and from the presently low availability of rental housing and temporary lodging.

Increases in land value resulting from recreational and residential development over the life of the project are expected to offset losses in ISD tax bases caused by construction of the proposed reservoir. At least as much land as is removed by the reservoir will either have views of the proposed lake or else direct access to water, making the property potentially suitable for land uses other than agriculture.

Operation of the proposed Lake Bosque will significantly enhance the amount of available water supplies in the area. Currently, project participating municipalities, except the City of Waco, rely solely on ground water supplies. Operation of Lake Bosque will help end overdrafting of the Trinity Aquifers and insure the availability of a secure water source.

4.6.3.4 Public Finance

Reservoir construction and operation will remove about 0.26% of the county's tax base and not impact municiapal tax bases. As discussed with regard to school taxes, land values near the proposed site could increase and offset the initial reduction of the county's tax base. A secure water supply will insure that ample water is available for future population expansion and area development.

Property values near the proposed Lake Bosque site are not expected to be be adversely impacted by operation of the lake. On the contrary, land values could increase significantly in response to residential and recreational

demand. Realtors experienced in reservoir associated development indicate that land up to three miles distance from a lake shore, if suitable views are available, can be marketed as water oriented, or recreational, property.

Lakeview property within one to three miles of Lakes Proctor and O.C. Fisher reportedly range in price from $9,000 to $11,000 per acre for small, relatively undeveloped acreages, to $50,000 for developed residential lots. Realtors report prices for developed residential property at Lake Granbury ranging from $40,000 to $600,000, with mobile homes and lake view sited homes occupying the lower range and single family waterfront homes accounting for the higher price range. Residential development adjacent to the proposed Lake Bosque will most likely result in development intensities and property values that fall within the range observed at Lakes Proctor, O.C. Fisher and Granbury.

4.6.3.5 Recreation and Aesthetics

The proposed site is situated on private land and is not open for public use. Operation of the reservoir will displace possibly 20 deer leases within the conservation pool. Water oriented recreation in the vicinity of the Lake Bosque site is currently available only to individuals with access to private lands bordering the North Bosque River. Since the Brazos River Authority will provide two public access points to Lake Bosque, and since the lake will be suitable for a much wider range of activities and will accommodate many more people than the river (4500 acres of reservoir vs 160 acres of stream bed), the net effect on recreational opportunities is expected to be beneficial.

Although Lake Bosque is located near major population centers (Waco and the Dallas Fort Worth area) over 50,000 surface acres in Lakes Whitney, Waco, Aquilla, Limestone and

other popular recreation lakes are present in the Texas Outdoor Recreation Plan Region 11. While total lake acreage and boat launching facilities are considered adequate in Region 11, lake access is not, particularly on a local basis, and provision for enhanced access is a listed priority in the recreation plan.

Visitation records from existing reservoirs indicate that if recreational amenities are available, visitations in the range of 500.000 to 1,000,000 per year could occur at Lake Bosque. Although many, if not most of these visitors will be local residents, this level of activity is expected to generate a strong demand for miscellaneous goods and services (food and beverages, gas, camping equipment, recreation equipment, boat equipment, hotel acommodations, etc.), as well as increased demand for health and public safety services.

Factors influencing the visitor count to Lake Bosque will include proximity to a major population center, convenience of access and the availability of recreational facilities. No recreational facilities are known to be planned at this time but it is anticipated that private interests will construct some of the types of recreational facilities needed at Lake Bosque. Meridian State Park does provide camping facilities and is located within 10 miles of the site.

4.6.3.6 Land Use

Operation of the proposed Lake Bosque will result in conversion of some existing agricultural lands in the vicinity of the reservoir to recreational, residential and commercial uses. The extent to which this is likely to occur and the major factors influencing the outcome have been discussed in preceeding sections. Land within three

miles of the lakeshore is most likely to be affected. The extent to which recreational facilities are provided, either by public or private interests, will have an effect on the rapidity and degree to which such changes take place.

4.7 Cultural Resources

4.7.1 Effects of No Action

In the absence of Lake Bosque, archaeological sites in the vicinity of the proposed reservoir will continue to be adversely affected by climatic forces and soil processes such as erosion and solution, bioturbation, and cultural disturbances including development and agricultural activities. Site loss from pot-hunting might be enhanced by location and recording of the 145 sites.

4.7.2 Construction Effects

Table 3-8, reproduced from the Archaeological and Historical Survey (Lone Star Archaeological Services, 1987), summarizes the type and magnitude of potential impacts to be expected on the Lake Bosque site. As a result of construction activities, 15 (seven National Register eligible) sites located in the immediate vicinity of the embankment and borrow areas will be lost by disturbance or deep burial. An additional 57 sites, 29 of which appear to be National Register eligible, will be covered by water within the conservation pool of Lake Bosque. The adverse, neutral or beneficial nature of this effect is dependent on the nature of the site.

Sites located between the conservation elevation (830 feet MSL) and the 100 year flood elevation (841.3 feet MSL) will tend to be exposed to increased erosion from wave action. The magnitude of this effect will vary from a maximum at

sites located at 830 feet to vanishingly small at 841.3 feet where 0.5 inundations lasting about one day are expected over the 50 year life of the project. The nature of the site, its geologic and soil context and its orientation will substantially influence the effectiveness of wave induced erosion. Increased public access to this zone could result in increased site disturbance, but its inclusion in a 100 year floodplain will tend to reduce disturbance from construction activities. The 39 sites located above 843.1 feet MSL will not be directly affected by the construction of Lake Bosque.

4.7.3 Operation Effects

Direct effects to archaeological sites, other than those outlined in the preceeding section, are not expected to result from reservoir operation under maximum demand conditions. During less than maximum demand conditions, when releases would be made from Lake Bosque to stabilize Lake Waco, those sites located in the zone of frequent drawdown will be subject to accelerated erosion, slumping and human disturbance as artifacts are exposed on the surface.

Indirectly, enhanced residential and recreational development in the vicinity of the reservoir could lead to increased rates of site disturbance and loss. No effects on cultural resources downstream of the proposed dam site are expected to result from Lake Bosque operation.

5.0 Mitigation Plans

The following proposals address the balance of potential adverse and beneficial impacts resulting from construction and operation of the proposed Lake Bosque. Adverse impacts identified in foregoing sections may be avoided by modification of some aspect of the project; they may be mitigated to reduce the severity of the effect; and they may be compensated for in those cases where substantial impacts cannot be avoided. These types of actions are summarized below in a series of mitigation plans that will be carried out by the Brazos River Authority when the permits necessary for construction and operation of the proposed project have been obtained.

Substantial mitigation has already been accomplished through the generation of site specific data sets and analysis of that data in a regional context during the baseline studies of the Lake Bosque site. The aquatic surveys provide information on habitats, fisheries, and invertebrate assemblages unique in the North Bosque River. Likewise, no other data set for the region exists that is comparable to that for terrestrial communities on the reservoir site. These studies contain both taxonomic and quantitative population information that is considered in the context of regional physical and biotic conditions together with human influences.

The Cultural Resources survey has resulted in the location and description of 145 additional archaeological sites, resulting in a substantial increase in the number of recorded sites in Bosque County. Even in the absence of further study, this additional information is expected to add to our understanding of the lifeways of both aboriginal and European inhabitants of the area.

5.1 Aquatic Communities

I. Avoidance or Mitigation of potentially adverse impacts

A. To avoid violations of Stream Segment Standards downstream of the dam, and associated impacts, a multilevel withdrawl structure will be used to insure that dissolved oxygen concentrations remain above 5.0 mg/l in reservoir releases.

B. The multilevel withdrawl structure will also be used to maintain seasonal temperature patterns in reservoir releases within the normal ranges reported in existing North Bosque River water quality data. Suggested seasonal temperature limits for releases from the dam, based on seven years of monthly temperatures records at a station near Clifton, Texas, are as follows:

Dec-Feb	< 15° C
March	10-20
April	15-25
May-August	22-32
Sept-Oct	15-25
Nov	10-20

II. Measures to compensate for unavoidable adverse impacts

A. When inflows are available (see Table 4-1) during the April-August reproductive period, up to a total of 2.0 cfs will be continously maintained in the channel below the dam. A minimum of 0.5 cfs will be maintained in the channel below the dam at all times regardless of inflows. Fish populations can be maintained at levels reasonably near their present levels by providing a 0.5 cfs low flow augmentation sufficient to maintain pools at their "full" level at all times. The 2.0 cfs flow during April-August

will inundate the shallow runs and assure access to creek mouths, which will provide additional space and sheltered habitat for the development of the year's juveniles.

5.2 Terrestrial Communities

Significant avoidance or mitigation of adverse impacts to terrestrial environments beyond that discussed in Section 5.0 is of limited feasibility for this project. A plan to compensate for these unavoidable effects is therefore proposed.

I. Significant, unavoidable impacts to be compensated for

A. As discussed in the preceeding sections, we believe that loss of the deciduous woodland areas of the reservoir site constitutes a significant adverse impact. We further agree with the USFWS that a net decrease in the vicinity of 3,000 Average Annual Habitat Units (Table 4.5) represents a reasonable index of that impact.

B. Although other areas are also to be affected by Lake Bosque, the quality and abundance of these habitat types is such that vegetation and wildlife impacts will be insignificant, even on a local basis. We do not believe that the potential costs of compensating for impacts to pasture and cropland is justified by the wildlife benefits that could be obtained.

II. Proposed Compensation

A. The Brazos River Authority intends to acquire a contiguous tract of land that, with appropriate management over the life of the Lake Bosque project, will produce a net gain in habitat value comparable to the losses described above. In addition, ancillary acreages acquired in the

vicinity of the dam for other purposes will be managed appropriately, where possible, to complement the efforts in the main compensation tract.

B. The tract will probably be acquired fee simple and conveyed to an appropriate governmental agency (e.g., Texas Parks and Wildlife Department) for stewardship following any necessary initial management actions. Some other mechanism of acquisition and protection could be used if practical and necessary in a particular circumstance.

C. Several candidate tracts have been examined and two have been evaluated by USFWS personnel. We believe one of these will produce sufficient habitat value (in AAHU) to compensate for the Lake Bosque impacts with the application of an appropriate planting and management plan. Production of sufficient net habitat value on any given tract is understood to be a function of its size, initial condition, potential productivity and required managment inputs.

D. The Brazos River Authority is continuing to examine potential compensation tracts, as they have a responsibility to the project participants to seek an optimum solution. From this standpoint it is desirable to minimize not only land costs but also long term management and commitments to reforestation efforts having significantly uncertain outcomes. Preliminary search criteria for compensation tracts are listed below:

1) Minimum size, 1,000 contiguous acres
2) Soils must be at least occasionally flooded (2-5 years) sandy or silty clay bottomland soils. The local Soil Conservation Service office to be contacted to ascertain if any significant soil impairment is known.
3) The tract should be reasonably accessible for management activities.

4) High quality bottomland hardwood tracts are to be avoided unless they are very large, since potential net change in habitat value would be small.
5) Other factors being equal, tracts closer to Lake Bosque or in the Bosque River basin are preferred.

E. As candidate tracts are identified, HEP evaluations by the U.S. Fish and Wildlife Service and input from Texas Parks and Wildlife Department may be requested as necessary to evaluate acreage requirements and aid in development of appropriate management strategies. Target date for final selection of a compensation tract is by the end of the year.

5.3 Cultural Resources

The Archaeological and Historical Survey Report presents in detail a proposed plan to mitigate or compensate for the impacts of Lake Bosque on area Cultural Resources. Input from concerned state and federal agencies has been sought during the planning process. The specific methods used and the locations investigated will be approved by the appropriate authorities before the study begins.

In summary, this plan involves a standardized, limited sampling program at 34 sites to be affected by dam construction and inundation and at 12 sites within the 100 year flood pool to establish equivalent units. This will provide information on the diversity and relative density of cultural material within and among sites and allow the sites to be compared quantitatively. A subset of these sites will be excavated *in toto*. The results of this effort will provide the data to attempt the synthesis of a comprehensive history of this segment of the North Bosque River Valley.

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