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Natural Resource Program Center

Natural Resources Foundation Report

Big Thicket National Preserve

Natural Resource Report NPS/NRPC/WRD/NRR—2010/180

ON THE COVER
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Executive Summary

In accordance with the NPS 2004 Park Planning Program Standards, parks are to prepare a *Foundation for Park Planning and Management* (*Foundation Document*) that describes its purpose, significance, primary interpretive themes and special mandates, identifying and analyzing those resources and values determined to warrant primary consideration (*Fundamental* and *Important Resources and Values*) in park planning and management. The *Foundation Document* may be developed as the first phase of a park's general management planning process or independently of the *General Management Plan*.

This Natural Resources Foundation Report is designed to support development of the *Foundation Document* for Big Thicket National Preserve (Preserve) and to be used as a reference for the *General Management Plan*, as needed.

The primary objectives of this report are to:

1) Provide background information for the Preserve's natural resources;
2) Analyze the importance, current condition, related trends and issues/threats for natural resource-based, fundamental resources that are critical to achieving the Preserve's purpose and maintaining its significance; and,
3) Define the relevant laws and policies that support management decisions for the fundamental resources and identify stakeholder interests.

Big Thicket National Preserve

Big Thicket National Preserve is a 106,384-acre national park unit located in southeastern Texas, approximately 75 miles northeast of Houston. The Preserve is composed of 15 units scattered over seven counties, a 3,500 mi^2 area, and has been referred to as a 'string-of-pearls' – that is, a series of units (pearls) connected by riparian corridors (strings). The Preserve is a remnant of the Big Thicket area of East Texas that originally covered approximately 3.5 million acres. Within this vast area, variations in geology, climate, soils, elevation and drainage have resulted in a nationally recognized area of high biological diversity; the Preserve is often referred to as a 'biological crossroads' because it is a transition zone for four distinct vegetation types – eastern hardwood forest, arid southwestern desert, tropical coastal marsh, and central prairies. The Preserve was the first property added to the national park system based on 'biodiversity'. Furthermore, the Preserve was designated a Biosphere Reserve in 1978 by the United Nations Educational, Scientific, and Cultural Organization, in large part, because of its biological importance.

Big Thicket National Preserve Purpose and Significance

The following purpose statement, which describes the specific reasons for establishing the Preserve, was generated during a scoping workshop in August, 2008 as part of the general management planning process:

> The Big Thicket National Preserve represents a portion of "the Big Thicket" in southeast Texas, known for its extensive biological diversity, and is dedicated to preserving, and enhancing the natural and ecological integrity [thereof]. The

> Preserve maintains scientific and recreational values and provides for public enjoyment.

Based on this purpose statement, the 2008 workshop developed the following significance statements:

Extraordinary Combination of Habitats and Species and Their Scientific Value
Big Thicket National Preserve, the first national preserve, was set aside for its biodiversity. The Preserve contains remnants of the Big Thicket of Texas and its diverse units are representative of the larger biogeographic region. The Preserve serves as a refuge for a combination of plants, animals, and natural communities that include elements from the southeast swamps, eastern forests, central plains, and southwest deserts. The Preserve is the only NPS unit with this combination of resources. The opportunities for scientific research at the Preserve include the study of biodiversity and disturbance resulting from land uses and natural phenomena (*e.g.*, hurricanes and fires).

Flowing Water and Associated Dependent Systems
Big Thicket National Preserve has an extensive, dynamic system of hydrologic processes and associated dependent systems important to maintain the diverse yet specific ecological make-up of the Big Thicket. These include contiguous riverine and wetland systems. The Preserve provides examples of blackwater systems, which are not typically found outside of the Amazon basin and Southeastern United States, and of rare baygall wetlands that exemplify the original and seemingly impenetrable Big Thicket.

National and International Designations
Big Thicket National Preserve has received both national and international recognition.

Visitor Experience
In a state where public lands are not widely available, Big Thicket National Preserve offers the visitor a wide array of recreational and educational opportunities in a natural setting within close proximity to large urban areas.

Cultural Resources
Big Thicket National Preserve has a rich cultural history spanning centuries and cultures – Prehistoric to modern American Indians/Native Americans, Spanish explorers, and early settlers to today's modern users. Resources include remnants of historic land use activities and structures, traces of travel corridors, and archeological sites.

Fundamental Resources

It is important for NPS units to identify the fundamental resources and values critical to achieving a particular unit's purpose and maintaining its significance. During the workshop in August, 2008, the following fundamental resources and values were identified for Big Thicket National Preserve:

- Cultural Resources
- Visitor Resources

- The Thicket
- Scientific Value
- Scenic Resources
- Flowing Water and Associated Dependent Systems.

The identification of these fundamental resources and values at the Preserve helps ensure that all planning is focused on what is truly most significant about the Preserve. For every fundamental resource and value, some basic analysis is needed to identify why the resource or value is important, assess current conditions, potential threats and the level of stakeholder interests, and determine existing policy and planning guidance. Basic analyses were developed for those natural resource-based, fundamental resources and values; namely, Flowing Water and Associated Dependent Systems, The Thicket, and Scientific Value. Such analyses are needed to identify basic management strategies that are in place and to identify issues to be addressed in general management planning or other planning processes.

Those laws and policies and the guidance they provide to these fundamental resources and values, and the stakeholders who have an interest in the Preserve and these fundamental resources and values are discussed in detail in the main body of this report. The summary, below, centers on the importance and current conditions of and the potential threats to these fundamental resources and values.

Flowing Water and Associated Dependent Systems

A relative even spread of rainfall throughout the year belies a distinct seasonal regime of flowing water in the Preserve's riparian corridors. River and stream waters typically rise to a winter peak and recede during the summer into a fall baseflow condition on an average-annual basis, despite slightly higher rains in the summer and fall period. This seasonal trend is reflective of the significant role that evapotranspiration plays in the region. Absent evapotranspiration, winter rains are more likely to recharge the shallow ground water and augment river/stream flows. Similar quantities of rain in the late spring and summer either directly evaporate or fuel the rapid vegetation growth that is characteristic of the Big Thicket.

Prolonged absence of rain or its short-term abundance can interrupt or enhance the seasonal balance between evapotranspiration and rainfall. Rainless summers hasten the desiccation of vegetation, expose wetland flats, parch floodplains, and reduce stream flows. Torrential downpours any time of the year can result in sudden and dramatic flow and stage spikes in local creeks, which combined with the region's relatively poor drainage, can lead to severe flooding.

Perhaps the most defining characteristic and process of all the waterways in the Preserve are the floodplain/riparian areas and the associated flood pulse. The rise and fall of river stage and flow sets the rhythm of the Preserve's floodplain habitats: its bottomlands, the cypress sloughs, and the baygalls (see diagram below). It happens along all the creeks of the Preserve, but is most pronounced and at a larger scale along the main stem of the Neches. Water stage and flow, sediment load within the water column, and its flooding duration and seasonal timing all play important roles in maintaining the structure and function of the riparian corridor. Plants and animals that live in the river and floodplain have adapted to routine floods and the rhythm of soaking and drying out.

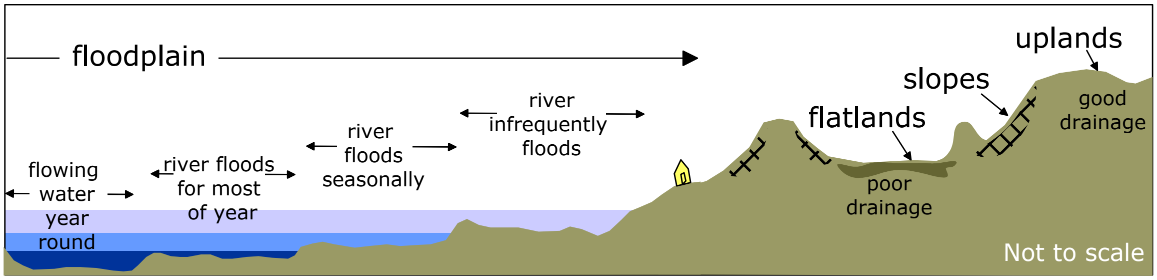

Figure A. Cross-sectional view of the floodplain along riparian corridors in Big Thicket National Preserve.

Low ridges, backwater sloughs, oxbow lakes, and terraces break up the overall flatness of the floodplain. It is these slight changes in the topography of the floodplain, coupled with the magnitude of the flood pulse that are key determinants to the ecology of the riparian corridor.

Closest to the river's edge is the bottomland forests. Water moves quickly in and out of the bottomlands, scouring the forest floor and leaving it with a sparse under story. The closed canopy filters sunlight, further discouraging ground cover.

Slightly higher in the floodplain are the swamp forests of cypress and tupelo trees, commonly called cypress sloughs. The sloughs retain water for most or all of the year, but regular flooding flushes away organic debris preventing cypress sloughs from becoming acidic.

Bogs or seeps occur where water sinks through porous sandy soils and then hits an impermeable clay layer causing water to seep out to the surface. Leaching of the saturated soils creates acidic conditions. These acid bogs or acid seeps are usually open, grassy and rich in plant species, including the four kinds of carnivorous plants that occur in Texas.

Where conditions are right, seep-fed creeks that drain bogs flow into forested swamps thick with evergreen shrubs (hollies and magnolias) – the baygalls. Baygalls are the highest-perched of the floodplain wetlands, but are considered a low-lying feature relative to the sandy uplands. River water infrequently floods into baygalls, where it sits there like a bowl. Often found at the outermost reaches of the floodplain, baygalls may also receive ground water inflow from adjacent uplands or spring seepage from the base of adjacent terraces. Whatever its source, water sits in a baygall until it dissipates through evaporation or gradual lowering.

Wetland savannas or wet grasslands occur on claypan soils that trap rainwater but dry out in the summer, creating unique conditions. In such wetland savannas, stands of longleaf pines grow with evergreen shrubs, sedges and grasses, orchids, and carnivorous plants. These wetland savannas combine flatter terrain with lower elevation and include the highest numbers of plant species measured in any natural community in Texas, yet they are one of the rarest types of habitat in Texas.

The Texas Water Development Board (TWDB) identifies ecologically unique stream segments throughout the State. Such identified stream segments are evaluated on five criteria including biological function; hydrologic function; riparian conservation areas; high water quality/exceptional aquatic life/high aesthetic value; and threatened or endangered species/unique communities. This designation means that a state agency or political subdivision of the state may not finance the actual construction of a reservoir in a specific river or stream designated as an ecologically unique stream segment. TWDB has identified virtually all of the major stream segments in the Preserve for consideration as ecologically unique stream segments, including: Big Sandy Creek; Neches River; Village Creek; Beech Creek; Turkey Creek; Menard Creek; Pine Island Bayou; and, Little Pine Island Bayou.

A casual observer may conclude that there are two primary – and separate – structures that affect the Preserve's interests along the Neches River: Town Bluff Dam and the Neches River Saltwater Barrier. These structures, operated by the U. S. Army Corps of Engineers, are located 85 river miles apart, forming the approximate upstream and downstream endpoints of the Preserve's Neches River corridor.

In actuality these structures, along with the Sam Rayburn Dam, are operated in concert with each other for the purpose of maintaining a carefully calibrated water flow and stage regime in the Neches River, thus ensuring delivery of water necessary to satisfy the water rights of end users – a large portion of which is passed through the Lower Neches Valley Authority Canal – and preventing saltwater intrusion from the heavily industrialized and dredged Sabine Lake estuary from fowling fresh water intakes.

Five dam and reservoir projects have been authorized by Congress in the Angelina-Neches Rivers basin; only three of which have been built: 1) B.A. Steinhagen Lake behind Town Bluff Dam – originally called just "Dam B" -- completed in 1953; 2) Sam Rayburn Dam and Reservoir completed in 1965; and, 3) Neches River Saltwater Barrier completed in 2003. The two other projects – "Dam A" and "Rockland" – have been authorized, but never built. A separate dam and reservoir project called the Blackburn Crossing Dam (and the upstream Palestine Lake) is located over 150 river miles north of Town Bluff Dam in the upper reaches of the Neches River Basin.

Since the 1940s, regional planners have periodically discussed the prospect of building a dam and reservoir on the Neches River 25 miles upstream of B.A. Steinhagen Lake. Most recently, LNVA raised the dual possibility of building the Rockland Dam project in tandem with enlarging B.A. Steinhagen Lake. The agency is proposing the dam to the Texas Water Development Board as a regional effort to increase water supplies for the state.

While annual flow volumes appear to be relatively unchanged before and after dam building, timing and magnitude of spring peak flows, summer base flows, and aperiodic flushing events have been altered. These changes may impact river water quality, sediment load, and riparian/floodplain habitats to varying degrees.

Prior to dam building, the Neches River typically peaked at 10,000 – 12,000 cubic feet per second (cfs) in late winter/early spring and dropped to a low-water base flow rate of 500 cfs during the summer and early fall. After dam construction in 1953, median year spring flows have tended to be repressed in magnitude with low-water base flows increased to fend off downstream saltwater intrusion and delivery of water rights.

Ecosystems are often framed relative to the last major disturbance, whether the result of a natural event (such as Hurricane Rita) or an anthropogenic one (such as recent drawdown of B.A. Steinhagen Lake), or a combination of the two. The modern day infrastructure tends to dampen the magnitude of seasonal and extreme flood and drought events, but also causes them on occasion, such as reservoir drawdown.

Aperiodic high flow events, where short-term flow rates exceeded 50,000 cfs, also played a larger role prior to dam building. They occurred at a frequency of once every five years prior to 1950, but have been non-existent at that magnitude since the mid 1950s, during which the Neches River achieved a weekly peak discharge of between 20,000 – 30,000 cfs. Thus, it stands to reason that floodplain ecology has been modified by the absence of higher order flood events. In turn, the loss of extended periods of drought has changed oxbow and wetland dynamics and other floodplain characteristics. Regardless, even under the dam-altered hydrologic regime, extreme events continue to make a lasting mark on the river corridor and floodplain.

The Thicket

The term “thicket” may have developed from early travelers who made accounts of the difficulty in crossing baygall and swampy areas. While these vegetative communities were never so expansive to warrant the name thicket for an entire region, they were likely pervasive enough for travelers to frequently encounter them, leading to the perspective of impenetrable thickets. Historical studies show that the area described as the Thicket was always a complex of ecological systems ranging from prairie to dense forest. A related issue regarding perspective and reality is the role of the Thicket as a biological “cross-roads” given the unique biological community combinations resulting from species ranges overlapping from at least three ecoregions, and some species found from more arid parts of Texas persisting in the Thicket. More recent analyses determined that species and communities found in the Thicket are predominantly shared with those of the southeastern coastal plain. What can be said is that the Thicket consists of high *alpha*- (within patch) and *beta*- (among patch) diversity, and that many species and communities are at the edge of their ranges (mostly southern and western edges of ranges). Biodiversity is the variety of life and its processes: this encompasses compositional (what is there), structural (how it is distributed in space and time) and functional (what it does) elements of ecosystems, each being manifest at multiple levels of interconnected organization ranging from genes to species, communities, ecosystems and landscapes. It is the biodiversity then that becomes the essence of “the Big Thicket.”

Taken together, it is the interplay of geology, topography, climate, water, and soils that causes abrupt transitions in composition of vegetative communities. The longleaf pine ecosystem, one of the most threatened in North America and also one of the most diverse, occurs on three main landforms: (1) uplands that are dry because of coarse soils and relatively steep terrain; (2) especially dry deep sands of old stream terraces where one can view cacti, yuccas and other plants commonly thought of as desert plants in association with the pines; and (3) wet, poorly drained flats where longleaf pine savannas occur together with a herb-rich ground layer of sedges and grasses, including carnivorous plant species. In uplands and some stream bottoms with sandy-loam soils that are well-drained, but moist most of the year, one can find magnificent stands dominated by southern magnolias and American beach. Bottomland-hardwood forests of oaks and gums are found in floodplains along rivers and creeks, and sloughs and oxbows of river and creek floodplains are dominated by bald cypress and tupelo swamps. The wetland baygall vegetation communities in the Preserve are compositionally distinct, and are poorly defined by topography and drainage; however, seepage water may be a key factor in their locations because they often occur at the base of bluffs in floodplains.

Section 4(a) of the Preserve's enabling legislation directs that the Preserve's lands, through the NPS, will be administered "in a manner which will assure their natural and ecological integrity in perpetuity…" Although a formal current condition assessment has not been conducted, and measures have not been assessed for ecological integrity of Preserve resources, clear indicators of degraded resources exist. At this time, it is estimated that about three percent of the remaining habitat in East Texas is considered intact. Urban development was a major cause of habitat loss in the early part of this century, as was logging. Bottomland forests along many rivers have been completely converted. Longleaf pine areas have been converted to loblolly or slash pine plantations or severely fire suppressed. Preserve units are fragmented on the landscape, top predators in food webs are absent, biological invasions are rampant, and extraction activities within and near the Preserve, no matter how carefully conducted, are incompatible with natural area resource persistence. Positive trends are the establishment of invasive plant control, re-establishment of fire on portions of the fire-adapted landscape, preparation of an Oil and Gas Management Plan in 2006, the reinvigoration of science manifested in resource inventories (including the All-Taxa Biological Inventory), status and trend monitoring of select resources, and the continued encouragement of research at the Preserve.

Land use legacies may have led to potential irreversible conditions. There are extirpated species from the thicket – red wolf, mountain lion, red-cockaded and ivory-billed woodpeckers, Louisiana pine snakes, and passenger pigeons. The lack of top predators is rarely offset by hunting, because of the effects predators have on prey behavior. Forests are secondary growth, leading to less structural and compositional heterogeneity.

Biological invasions represent a significant threat to the Preserve, as they can not only negatively affect individual species, but can influence ecosystem properties such as fire, and thereby change the entire nature of the Thicket. Invasive species can be native or non-native. Native species such as the southern pine beetles might be considered a natural process, except that the current restricted and fragmented state of host species and their communities demands a "hands-on" approach to managing poorly understood outbreaks. High priority non-native invaders are: Chinese tallow, Chinese privet, Japanese climbing fern, Japanese honeysuckle, kudzu, golden bamboo, Chinaberry, Chinese wisteria, Nandina, Mimosa, water hyacinth and giant salvinia. Including spring annuals, possibly a third of plant species now found in the Thicket area are non-native. Emerging plant species of concern are cogon grass and deep-rooted sedge. Non-native animals include nutria, grass carp, zebra mussels, and the imported red fire ant. Feral populations of animals represent a subset of invasions. Cats and dogs are known to disrupt wildlife behavior and predate on birds and young of other wildlife groups. Feral hogs disrupt soils and understory communities via rooting while foraging.

Fragmentation of the landscape is a continued threat. Landscape processes such as fires and floods, and predation and herbivory patterns of wide-ranging species will not occur within a natural range of variation.

Oil and gas activity along the boundary as well as within the Preserve will continue to disturb wildlife and threaten water quality. Additionally, oil and gas activity, operation and maintenance of trans-preserve pipelines, illegal fossil collecting, and adjacent land use and development are current and potential threats to geologic resources.

Scientific Value

Scientific value continues to be an important role for all protected areas. The development of science is one of the driving objectives of Biosphere Reserve designations. In short, the quest to understand nature has always accompanied the appreciation of nature in efforts to protect "special places." The Preserve provides access to scientific research in a region where there is so few public lands. The Preserve's status as a collection of protected areas within a working landscape provides opportunities to test numerous hypotheses in conservation biology and ecology. The types of research that the Preserve is particularly amenable to include:

- restoration of communities and ecosystems;
- exotic plant biology and ecology;
- ecosystem resistance and resilience to natural and anthropogenic disturbance. Of interest to managers is how resources respond to disturbances. Generally, it is helpful to know the range of variation of "natural" disturbances;
- population ecology of species at the edge of their respective ranges, and in combination with other species within assemblages; this is directly relevant to climate change research and modeling;
- landscape ecology: This includes analyses of connectedness, fragmentation, corridors and reserve design;
- ozone emissions from local (oil and gas development) sources and effects on biota;
- recreational opportunities and impacts;
- effects (in both directions) of timber harvest activities and protected area activities;
- climate change response; and
- flood pulse concept, natural flows, and flow variability.

The primary threat to the scientific value of the Preserve is the inability of science and conservation to keep up with the rapid pace of agricultural, industrial, residential, and water development growth in the Big Thicket region, and compete against the economic incentives for this growth. Economic development has resulted in loss, degradation, and fragmentation of the Big Thicket's ecology and large spatial extent. Conservation efforts have been successful to varying degrees in counteracting these effects, and a growing body of scientific knowledge has provided support to conservation measures, but lack of funding, the disparate nature of the threats, and complexity of the ecosystem makes it an on-going and difficult task. There is a need to foster a regional outlook for advocating science and conservation within the Big Thicket region in this regard, to both better protect and restore natural areas and processes within the Preserve and throughout the Big Thicket region.

Climate Change

Global warming will have particularly important impacts on the Gulf coast region's water resources. Gulf coast ecosystems are linked by the flow of water from the uplands through freshwater lakes, rivers and wetlands to the coast. Vast wetland areas require periods of flooding to maintain healthy habitats and sustain food webs. While there remains uncertainty about how global warming will affect rainfall, stream flow, soil moisture and overall water availability, human consumption of water resources is almost certain to increase as a result of the region's population growth. If climate change results in reduced runoff and lower groundwater levels for parts of the year, the consequence could be a shortage of water to satisfy both ecosystem needs and the growing and competing human demands. Other impacts could include:

- The increasing drawdown of surface water systems and underground reservoirs could combine with sea level rise to increase saltwater contamination of aquifers.
- Changing surface runoff patterns driven by changes in rainfall could alter river ecosystems. Changes in flooding patterns could also significantly affect river ecosystems. Flooding periodically rejuvenates floodplains by erosion and deposition and is essential to the health of river ecosystems. From an ecological perspective, flood pulses are not disturbances, but rather essential processes that define the biology and water quality of river ecosystems. If climate change results in more intense rainfall events, humans are likely to try to reduce flooding by increasing channelization of rivers and building dams, levees and reservoirs, all of which are functionally less effective in flood control than maintaining floodplain habitats that can receive and slow overbank flows.
- In freshwater streams, warmer temperatures and a longer growing season could reduce habitat for cool-water species. In very shallow water systems, higher temperatures could lead to oxygen depletion and cause potentially massive die-offs of fish and invertebrates.
- Primary productivity in freshwater wetlands would increase with higher concentrations of CO_2 and modestly warmer temperatures, as long as precipitation is not reduced. This may mean increased accumulation of organic matter, enhanced rates of soil formation, and – for systems close to the coast – an increased ability to cope with sea-level rise.
- Changes in climate will influence the spread of invasive species that threaten freshwater systems, affecting native plants, fish and shellfish and associated recreation and commercial fisheries.
- If droughts become more frequent or intense, the risk of wildfire could increase. In ecosystems not fire-adapted, recovery from catastrophic fires can take decades or longer. In contrast, wildfires are critical for grassland communities such as coastal prairies and bogs which are well adapted to natural cycles of burning.
- Any increase in storm and hurricane frequency could hasten forest turnover, possibly resulting in the accelerated replacement of canopy trees with different, more competitive species.

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Introduction

The approximately 106,384-acre Big Thicket National Preserve is located in southeastern Texas just north of Beaumont and 75 miles northeast of Houston (Figure 1). The Preserve is composed of 15 units scattered over seven counties, a 3,500 mi^2 area (Figure 1; Table 1). As such the preserve may be seen as a ‘string-of-pearls’ – that is a series of units (pearls) connected by riparian corridors (strings) (Figure 1). The Preserve is species-rich, including 290 birds, 54 amphibians and reptiles, and 52 mammals that have been identified from incomplete surveys (Cooper *et al.* 2004). Diggs *et al.* (2006) estimated that there are 1,826 species of vascular plants in 174 families in the Big Thicket region – an estimate that is believed to be significantly underestimated.

The Preserve is a remnant of the Big Thicket area of East Texas that originally covered approximately 3.5 million acres (Figure 2). Within this vast area, variations in geology, climate, soils, elevation and drainage have resulted in a nationally recognized area of high biological diversity; the Preserve is often referred to as a ‘biological crossroads’ because it is a transition zone for four distinct vegetation types – eastern hardwood forest, arid southwestern desert, tropical coastal marsh, and central prairies. The area provides habitat for rare species and favors unusual combinations of plants and animals. The Preserve was the first property added to the national park system based on ‘biodiversity’. Furthermore, the Preserve was designated a Biosphere Reserve in 1978 by the United Nations Educational, Scientific, and Cultural Organization (UNESCO), in large part, because of its biological importance.

Historically, the Big Thicket area was wilderness and remained undeveloped until the early 1800’s. High rainfall together with poor drainage characteristic of low, flat terrain resulted in extensive growth of wetland brush bogs – dense stands of mostly evergreen shrubs, now locally called ‘baygalls’ that made travel through the area difficult (Gunter 1971). The area gradually opened to pioneer settlement -- evidence of some of this pioneer way of life still exists today. Logging and the railroad were evident in the 1880’s and 1890’s. Nearly all of the Big Thicket has been logged at least once over the last two centuries. Much of the land formerly in natural forests is managed today as productive timberland. Nearly simultaneously with the timber boom came the oil boom in the Big Thicket.

Today, forest products and petrochemical industries remain the primary contributors to the region’s economy. Rice and soybean agriculture is increasing, creating a greater demand for agricultural land. Housing developments are pressing on the margins of the thicket, creating countless openings through its interior. Given this situation and because the Preserve is fragmented into scattered units tenuously connected by riparian corridors, the Preserve was identified in 2003 by the National Parks Conservation Association (NPCA) as the most endangered NPS unit.

The General Management Planning process for the Preserve began in August, 2008 with an internal Foundation workshop that produced a Purpose Statement for the Preserve and Significance Statements for the Preserve’s resources (natural and cultural; see below). The purpose of the Preserve is a clear statement of why Congress established the Preserve as a unit of

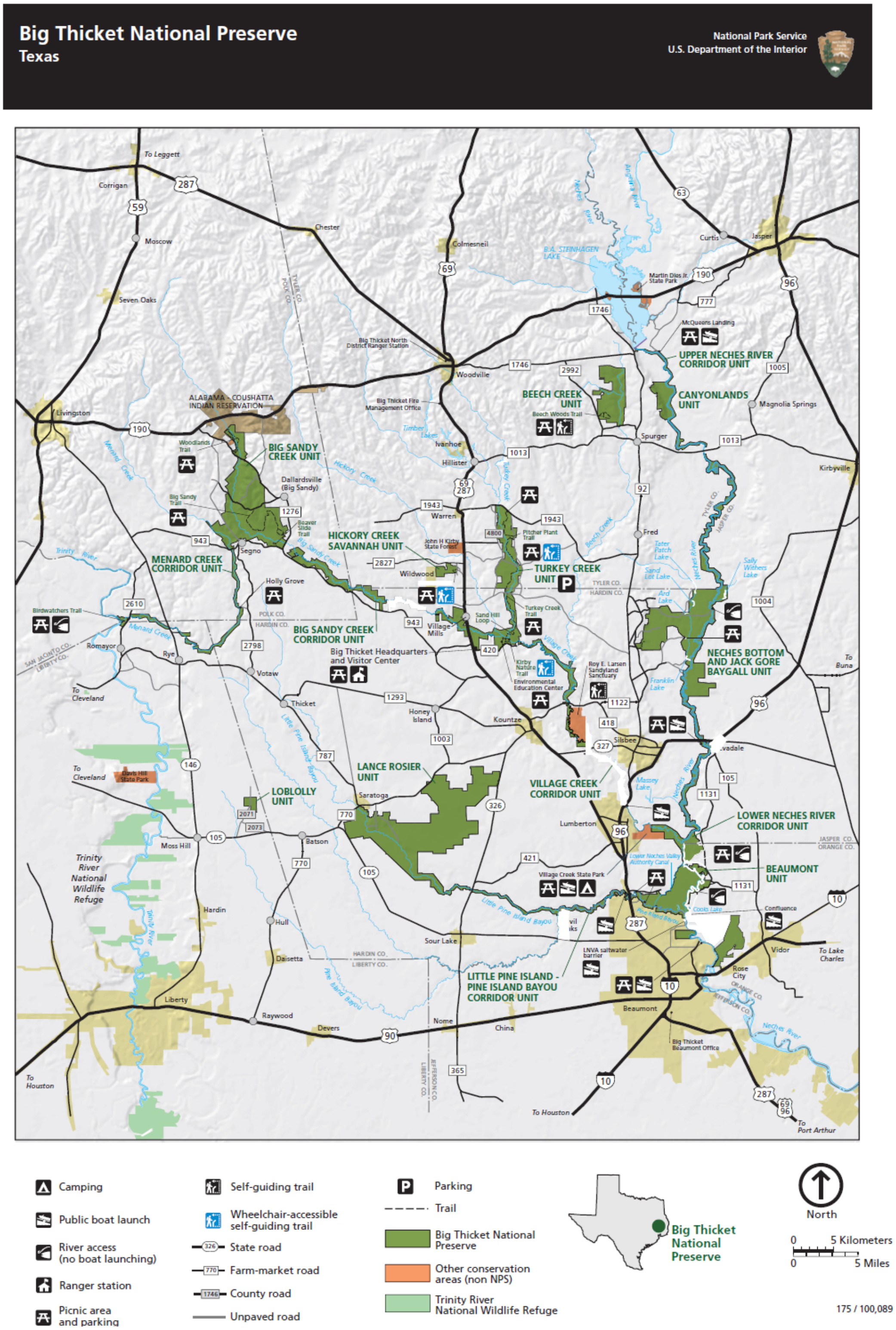


Figure 1. Map showing the location of Big Thicket National Preserve and its units in southeastern Texas.

the national park system. Significance statements define what is most important about the Preserve's resources and values, and is based on the purpose for which the Preserve was created.

Table 1. County residence and acreage of Big Thicket National Preserve management units (modified from NPS 2006). Abbreviations as follows: B = Beaumont Unit; BC = Beech Creek Unit; BSC = Big Sandy Creek Unit; C = Canyonlands Unit; HCS = Hickory Creek Savannah; L = Loblolly Unit; LNRC = Lower Neches River Corridor Unit; LR = Lance Rosier Unit; MCC = Menard Creek Unit; NBJG = Neches Bottom and Jack Gore Baygall Unit; PILPI = Pine Island Little Pine Island Bayou Unit; TC = Turkey Creek Unit; VCC = Village Creek Unit. Acreage represents the latest figures as of February, 2010 (Glenna Vigil, Intermountain Regional Office, pers. comm. to Todd Brindle, Big Thicket National Preserve).

Counties	*Preserve Units within County*	*Acres*
Hardin	VCC; BSC; TC; MCC; B; LR; NBJG; PILPI; UNRC; LNRC;	54,970
Jasper	LNRC; UNRC; NBJG	7,017
Jefferson	B; PILPI	1,603
Liberty	MCC; L	1,485
Orange	B; LNRC	7,368
Polk	MCC; BSC	18,972
Tyler	BSC; BC; C; HCS; TC; UNRC	14,969
Total		106,384

Purpose Statement

The Big Thicket National Preserve represents a portion of "the Big Thicket" in southeast Texas, known for its extensive biological diversity, and is dedicated to preserving, and enhancing the natural and ecological integrity [thereof]. The Preserve maintains scientific and recreational values and provides for public enjoyment.

Significance Statements

Extraordinary Combination of Habitats and Species and Their Scientific Value

Big Thicket National Preserve, the first national preserve, was set aside for its biodiversity. The Preserve contains remnants of the Big Thicket of Texas and its diverse units are representative of the larger biogeographic region. The Preserve serves as a refuge for a combination of plants, animals, and natural communities that include elements from the southeast swamps, eastern forests, central plains, and southwest deserts. The Preserve is the only NPS unit with this combination of resources. The opportunities for scientific research at the Preserve include the study of biodiversity and disturbance resulting from land uses and natural phenomena (*e.g.*, hurricanes and fires).

Flowing Water and Dependent Systems

Big Thicket National Preserve has an extensive, dynamic system of hydrologic processes and associated dependent systems important to maintain the diverse yet specific ecological make-up of the Big Thicket. These include contiguous riverine and wetland systems. The Preserve provides examples of blackwater systems, which are not typically found outside of the Amazon basin and Southeastern United States, and of rare baygall wetlands that exemplify the original and seemingly impenetrable Big Thicket.

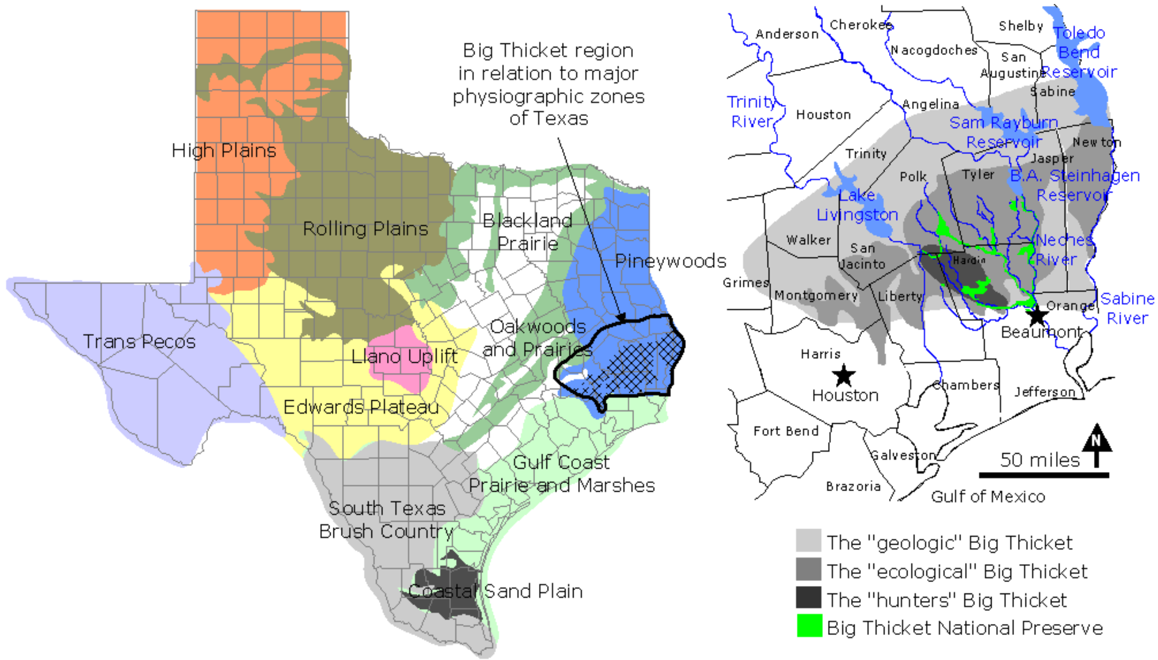


Figure 2. Maps of the Big Thicket region in relation to major physiographic zones of Texas (left) and Big Thicket National Preserve in relation to various definitions of the Big Thicket (right). Adapted from Cozine (2004) and Gunter (1993).

National and International Designations

Big Thicket National Preserve has received both national and international recognition.

Visitor Experience

In a state where public lands are not widely available, Big Thicket National Preserve offers the visitor a wide array of recreational and educational opportunities in a natural setting within close proximity to large urban areas.

Cultural Resources

In Big Thicket National Preserve has a rich cultural history spanning centuries and cultures – Prehistoric to modern American Indians/Native Americans, Spanish explorers, and early settlers to today's modern users. Resources include remnants of historic land use activities and structures, traces of travel corridors, and archeological sites.

Natural Resources Planning

In recent years, the NPS Natural Resource Program Center has been looking for ways to integrate sound science into park planning and management from a multi-disciplinary perspective. Any attempts at integration must support the NPS planning framework as defined by the 2004 *Park Planning Program Standards* and draft *Director's Order 2.1: Resource Stewardship Planning*. Within this planning framework, six discrete levels of planning are represented by six planning-related documents (Figure 3).

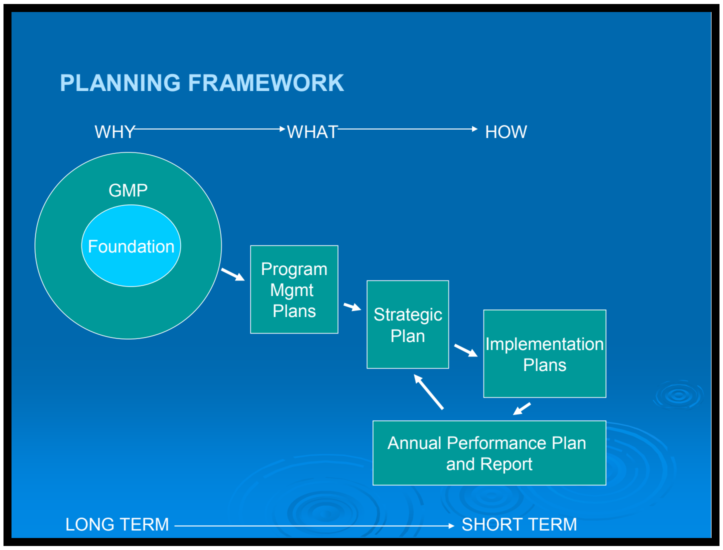


Figure 3. The National Park Service framework for planning and decision making.

The *Foundation Statement* defines the legal and policy requirements that mandate the park's basic management responsibilities, and identifies and analyzes the resources and values that are fundamental to achieving the park's purpose or otherwise important to park planning and management. This is the first step in the park planning framework and sets the stage for a park unit's *General Management Plan* and *Program Management Plans.*

The *General Management Plan* (GMP) uses information from the Foundation report to define a broad direction for resource preservation and visitor use in a park, and serves as the basic foundation for park decision-making, including long-term direction for *desired conditions* of park resources and visitor experiences.

The *Program Management Plan* tiers off the GMP identifying and recommending the best strategies for achieving the desired resource conditions and visitor experiences presented in the GMP. Program planning serves as a bridge to translate the qualitative statements of *desired conditions* established in the GMP into measurable or objective indicators that can be monitored to assess the degree to which the *desired conditions* are being achieved. Based on information obtained through this analysis, comprehensive strategies are developed to achieve the *desired conditions*. The Program Management Plan component for natural and cultural resources is the *Resource Stewardship Strategy*.

The *Strategic Plan* tiers off the Program Management Plan identifying the highest-priority strategies, including measurable goals that work toward maintaining and/or restoring the park's *desired conditions* over the next five years.

Implementation Plans tier off the Strategic Plan describing in detail (including methods, cost estimates, and schedules) the high-priority actions that will be taken over the next several years to help achieve the *desired conditions* for the park.

The *Annual Performance Plan and Report* measures the progress of projects from the Implementation Plan with objectives from the Strategic Plan.

The Natural Resources Foundation Report and its Objectives

This *Natural Resources Foundation Report* (NRFR) represents the NPS Natural Resource Program Center's attempt to integrate sound science early in the planning process (in this case at the Foundation planning level) via a multi-disciplinary approach. It is modeled after a similar report by the Water Resources Division called a *Water Resources Foundation Report*. The NRFR addresses the needs of the *Foundation Statement* for natural resources and will have utility during the rest of the GMP process and during.

The primary objectives of this *Natural Resources Foundation Report* for the Big Thicket National Preserve are to: 1) provide background information for natural resources; and 2) identify and describe the fundamental natural resources at the Preserve, along with the identification of stakeholders and laws and policies that apply to these fundamental natural resources. The natural resource-related information contained in this report is designed to better assist the Preserve with development of the *Foundation Statement* that ultimately supports the preparation of the new GMP for the park.

Description of Natural Resources

Climate

The climate of the Preserve is humid subtropical; however, the Preserve is positioned on the western edge of the humid subtropical climatic region. This humid subtropical climate is characterized by long, hot humid summers and fairly short, mild winters (average of 240 consecutive frost-free days per year). Onshore winds from the Gulf of Mexico provide maritime influence during the spring, summer, and fall. Arctic, Rocky Mountain, and Pacific storms occur frequently in the winter months and result in depressed temperatures; however, warming periods usually occur between fronts. Sub-zero temperatures are rare with typically less than a dozen freezing nights per year. The mean annual temperature is approximately 70^0 F (21^0 C). Figure 4 shows the monthly maximum and minimum temperatures and average relative humidity for the Beaumont area.

Physiography, Geology and Soils

Despite the fact that the Preserve receives abundant and well-distributed annual precipitation, the availability of water at the surface varies greatly in response to the underlying geology, soil type and topographic variation across the Preserve.

The surface formations of the Preserve are sedimentary in nature, and geologically young – only a few million years old. As glaciers advanced and retreated during the recent ice ages, sea level rose and fell along the low-lying southeast Texas coast. During warm periods (with high sea levels), the land flooded and rivers deposited vast deltas and alluvial plains of mud, sand, and silt on the seabed. During cold periods (when the ice returned and sea level fell), erosion cut into the newly deposited sediments.

The weight of increasing sediments caused the land to subside over time, slanting the layers downward into the Gulf of Mexico. The layers are exposed at the surface as broad, irregular bands paralleling the Gulf, and decrease in age as you near the coast. This trend is overlain by ancient river terraces and sea bluffs, now perched well above the modern- day water table as

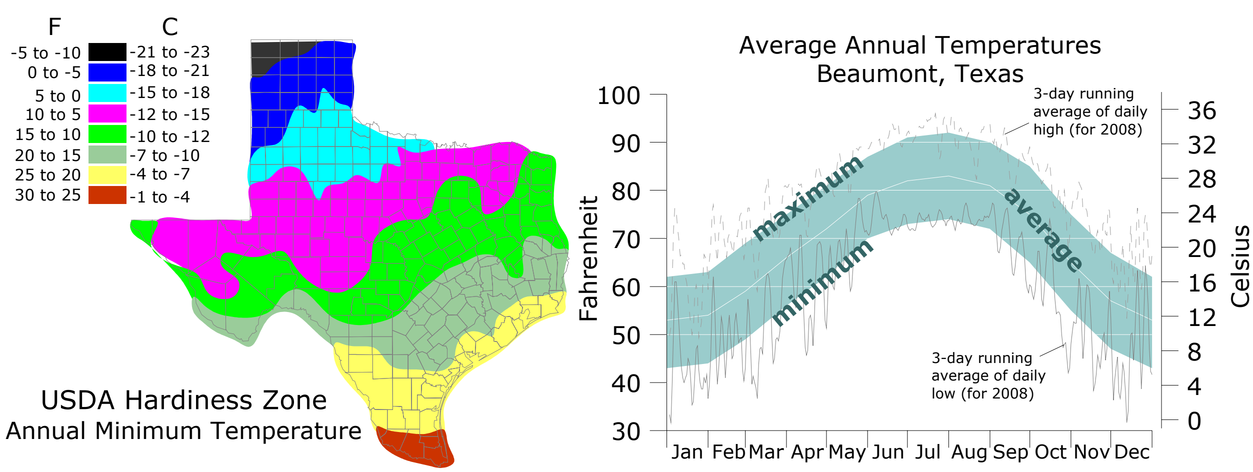


Figure 4. Annual minimum temperatures for Texas (left) and annual average temperature for Beaumont, TX, including 3-day running average of high and low temperatures for 2008.

upland high ground, and ancient, fine-grained coastal flats that impede water absorption in the lowlands and flatlands.

Geologic Background

Big Thicket National Preserve lies within the Flatwoods and Lower Coastal Plain geographic areas of Southeast Texas, situated within the relatively flat-lying Gulf Coastal Plain physiographic province. At the surface the Southeast Texas region is dominated by nearly flat-lying sedimentary strata representing Pleistocene-Holocene (Recent) deltaic sands and mud which are underlain by Miocene sediments (Wermund 1996). These deposits record sea level change and river system evolution in association with the Miocene-Holocene evolution and sea level change of the Gulf of Mexico. The vast low-lying coastal plain records a sequence of gently dipping fluvial, deltaic and nearshore marine deposits. As noted by Callicott *et al.* (2006), sea level fluctuations during the Pleistocene periodically inundated the currently exposed Southeast Texas coastal plain, leaving behind a band of sediments sorted by grain size (river floodplain silts, river outwash sands, and lagunal mud and clays). When the current Holocene coastline stabilized, a mix of clayey and sandy sediments covered the lower-lying area of the coastal plain.

The topography is nearly flat in the southern part to gently rolling in the northern part of the Preserve. Slopes in the Flatwoods Area (Beaumont and Lance Rosier Units) are generally less than one percent. Slopes in the Lower Coastal Plain Area (Jack Gore Baygall and Neches Bottom, Turkey Creek, Big Sandy Creek, and Beech Creek units) are generally one to three percent, and range from 0.5 to 12 percent. Elevation generally rises to the north and west from 5 feet (above mean sea level) in the Beaumont Unit to 365 feet at the northern tip of the Big Sandy Creek Unit and 215 feet at the northern edge of the Beech Creek Unit. Although the units of the Preserve vary widely in topography, soils, and size, most are situated along water corridors or in upland settings, or a combination of both.

Geologic maps and descriptions for the Preserve area have been produced by Shelby *et al.* (1992), Aronow (1981) and Bureau of Economic Geology (1968). Recently, the NPS Geological Resources Division completed a digital geology map for the Preserve (available at: http://science.nature.nps.gov/nrdata/quickouput.cfm?type=ds&cat=geology&key=GRE&parkcode=BITH). In stratigraphic order from lower to upper (oldest to youngest), the geologic units in the Preserve include the Miocene Fleming Formation, Pliocene-Pleistocene Willis Formation, Pleistocene Lissie Formation (subdivided into the Bentley Formation and the Montgomery Formation), Pleistocene Beaumont Formation, Late Pleistocene-Recent (Early Holocene) Deweyville Formation, and Recent alluvium (Table 2). Older strata generally outcrop farther away from the Gulf Coast and younger, overlying strata outcrop seaward (Figure 5). The thicknesses of the individual formations increase towards the Gulf of Mexico (Teas 1935). Younger, overlying deposits were incised during times of sea level fall (regressions), exposing terrace deposits, and older, underlying strata. Most of the preserve is heavily vegetated and exposures of the underlying geology (and associated paleontological resources) are likely to be found in only river and stream cut banks, gullies, or other erosional features.

The Fleming Formation (Figure 5) in the Preserve is characterized by light gray to yellowish gray clay, silt, and sand. The Fleming Formation is exposed in some of the deep gullies within the northern units of the Preserve (G. Watson, Big Thicket National Preserve, pers. comm. to J.

Table 2. Generalized stratigraphic formations in the vicinity of Big Thicket National Preserve (revised from Renfro *et. al.* 1973).

Era	System	Series	Time (millions of years ago)	Formation	Group	Approx. Depth
Cenozoic	Quaternary Q	Holocene	0	Deweyville (Qd)		
		Pleistocene	3	Beaumont (Qbc/Qbs) Montgomery Lissie (Ql) Bentley Willis		0-300′
	Tertiary	Pliocene		Citronelle Goliad		
		Miocene	11	Legarto Fleming Oakville	Fleming	~1,200′
			25	Anahuac Catahoula Frio	Catahoula	~1,800′
		Oligocene	40	Vicksburg (subsurface only)	Vicksburg	
		Eocene		Whitsett Manning McElroy Wellborn Cadell-Moody’s Ranch	Jackson	
				Yegua-Cockfield Cook Mountain Stone City Sparta Weches Queen City Reklaw Carrizo	Claiborne	6,500′ 8,500′ 9,900′
			60	**Wilcox** Calvert Bluff-Sabinetown Simsboro-Rockdale-Pendleton	Wilcox	10,000′
		Paleocene	70	**Midway** Hooper-Seguin Wills Point Kincaid	Midway	14,000′ 23,000′
Mesozoic	Cretaceous KI	Upper / Gulfian KU		**Navarro** Kemp Corsicana Nacatoch	Navarro	
				Taylor Marlbrook Pecan Gap Annona Wolfe City Ozan	Taylor	
				Austin Gober Brownstown Tokio/Blossom Bonham	Austin	
				South Bosque Eagle Ford Lake Waco	Eagle Ford	

Kenworthy 2006), and the Bureau of Economic Geology (1968) mapped Fleming exposures in the Big Sandy Creek Unit, the northern area of the Menard Creek Corridor Unit, and near the western boundary of the Upper Neches River Corridor Unit in close proximity to the B.A. Steinhagen Lake/Town Bluff Dam. The Fleming Formation is reported to be over 12 million years old (Aronow 1975) and reaches a thickness of 1,300 – 1,450 feet (Shelby *et al.* 1992). The depositional environments of the Fleming Formation are variously interpreted by authors, but are generally thought of as river deltaic deposits near marine waters (Kenworthy *et al.* 2007).

The Willis Formation (Figure 5) is characterized by red clay, silt, sand, and siliceous (silica/quartz-rich) gravel and represents the oldest Pleistocene, maybe upper Pliocene geologic unit in the Preserve area (Rigsby 1980; Shelby *et al.* 1992). The Willis Formation reaches a maximum thickness of about 100 feet (Shelby *et al.* 1992; Bureau of Economic Geology, 1968). The Willis Formation is reported to be 2 to 3 million years old (Aronow 1981). Watson (1975) also notes that the Willis Formation is deeply dissected and well-drained in the Big Thicket area. Surface exposures of the Willis Formation are dominant in the Big Sandy Creek Unit and the northern area of the Menard Creek Corridor Unit (Shelby *et al.* 1992; Bureau of Economic Geology 1968).

Moving southward, the older Pleistocene age formations, deposited between 125,000 to 2,500,000 years ago, include the Bentley and Montgomery Formations (also mapped by some authors as the Lower and Upper Lissie Formations, respectively; Figure 5). The thickness of each of these units ranges from 75 to 125 feet. The Bentley Formation overlies the Willis Formation, and is characterized by generally brown fluviatile clay, silt, sand, and a minor gravel component. The Bentley Formation is mapped in the Beech Creek Unit, Hickory Creek Savannah Unit, and Turkey Creek Unit of the Preserve (Shelby *et al.* 1992; Bureau of Economic Geology 1968).

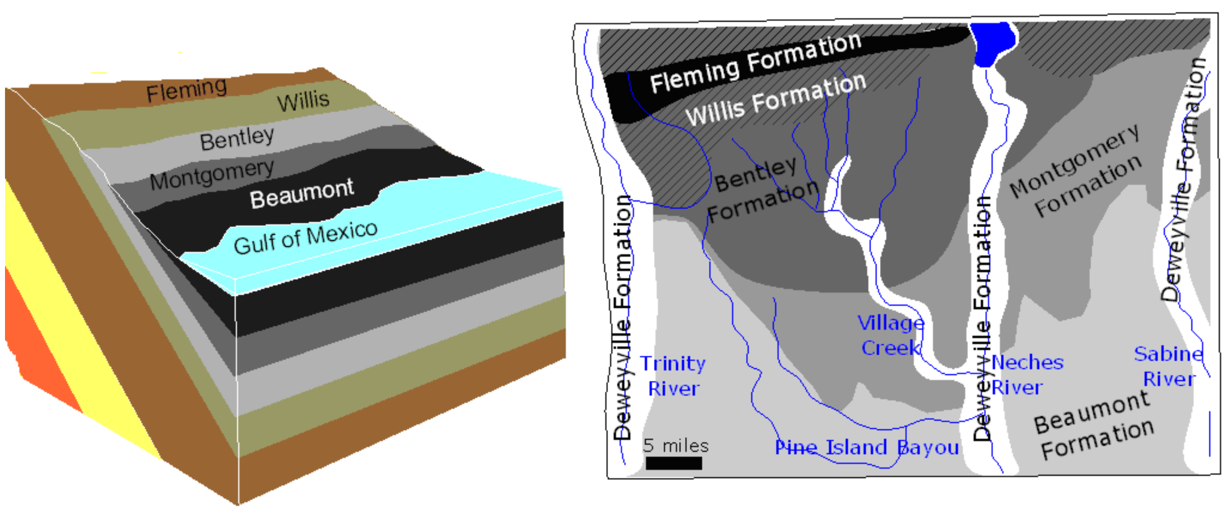


Figure 5. Three-dimensional and surficial diagrams of geological formations of Big Thicket National Preserve. Adapted from Paret (1993) and Cozine (2003).

The Montgomery Formation is found in the Lance Rosier Unit (Bureau of Economic Geology 1968), and is characterized by locally calcareous clay, silt, and sand with very minor gravel (no larger than small pebbles) component. Shelby *et al.* (1992) mapped the Pleistocene Bentley and Montgomery Formations as the undivided Lissie Formation.

The youngest, most seaward, and one of the most widespread of all the Pleistocene deposits of the Texas Gulf Coastal Plain is the Beaumont Formation (Figure 5), deposited between 70,000 to 125,000 years ago with a reported thickness of about 100 feet (Shelby *et al.* 1992; Bureau of Economic Geology 1968). The Beaumont Formation consists of predominantly fine-grained deposits, with a reported lithology of clay, silt, and some sand (Shelby *et al.* 1992). The Beaumont Formation's clay content is generally much higher than the other Pleistocene deposits and ranges in color from blue-gray to yellow-gray, to purple and various shades of red (Rigsby 1980). The Formation was mapped in extensive areas surrounding the City of Beaumont by Shelby *et al.* (1992). As such it is mapped in or adjacent to a number of Preserve units, including the Lance Rosier Unit, Pine Island - Little Pine Island Bayou Corridor Unit, Loblolly Unit, Menard Creek Corridor Unit, Lower Neches River Corridor Unit, and the Neches Bottom and Jack Gore Baygall Unit east of the Neches River. The surface of the formation is often criss-crossed by broad, low meander ridges less than 10 feet high on whose surfaces stream patterns may be discerned (Aronow 1981). Due to the high percentage of clay, the Beaumont Formation acts principally as an aquitard, or geologic unit that inhibits water penetration. However, sand lenses within the clay beds are likely to act as local aquifers (Enprotec, Inc. 1998).

The Deweyville Formation is characterized by sands, silts, clay, and some gravel found in natural levee, stream channel, and backwater swamp deposits (Shelby *et al.* 1992), and occupies filled valleys of ancient streams (Watson 1975). The Deweyville is the oldest of the Holocene age deposits in the Preserve area, and straddles the boundary between late Pleistocene and Recent. As reported by Baskin (1991), there is some dispute regarding the age of the Deweyville, but it is at least 13,000 and perhaps as many as 50,000 years old. Shelby *et al.* (1992) mapped sand and gravels of the Deweyville in the Menard Creek Corridor Unit near the Trinity River, and surface exposures also occur in the Neches Bottom and Jack Gore Baygall Unit west of the Neches River and in the lower reaches of the Village Creek Corridor Unit near the City of Lumberton.

As described by Shelby *et al.* (1992), Recent alluvium deposits in the Southeast Texas region are characterized by clay, silt, and sand sediments associated with modern streams. The surfaces of the alluvial deposits are graded to present-day sea level which was attained between 2,500 to 4,500 years ago (Aronow 1981). Alluvial deposits are mapped within the Preserve by Shelby *et al.* (1992) along the larger stream corridors in the area, primarily the Neches River, including the Beaumont Unit, Big Sandy Creek and Village Creek. The alluvial deposits contain abundant organic material in localized areas.

Soils
In general, the soils of Big Thicket National Preserve developed from Pleistocene age fluvio-marine deposits, including the Willis, Bentley and Montgomery Formations and Pleistocene to Holocene age (late Pleistocene to less than 10,000 years ago) Deweyville Formation, and more recent Quaternary age alluvium. Quaternary alluvium is thickest within the major active drainages, the Neches and Trinity Rivers. The Deweyville Formation, underlying the alluvium,

is also associated with river and stream drainages. Most soils in the Preserve developed on the Bentley and Montgomery Formations (undivided Lissie Formation) as these formations are exposed at the surface in approximately 70 percent of the Preserve (S. Aronow, Lamar University, pers. comm. to J. Kenworthy 2007).

Soils formed in floodplains range from loamy to clayey in texture, and occur on old oxbows to moderately well-drained natural levees adjacent to stream channels. Upland soils are generally loamy to sandy in texture and are found on a wide variety of landscapes. Immediately above the floodplains are sandy point bar deposits and low, mounded terraces.

Soils within the Preserve are characteristic of those developed under a mild climate, with abundant rainfall, in a mixed conifer-deciduous forest. Two broad categories of soils are found: a highly leached, acidic, sandy to loamy textured soil with a lower less-permeable zone of clay accumulation; and a more clayey textured, less permeable soil that is subject to either high water tables or periods of extensive flooding. The latter soils shrink and swell with changes in seasonal moisture. In general, the sandier soils tend to occur in uplands, and clayey textured soils are found in swales, lowlands, floodplains, and wetlands.

Deshotels (1978) produced initial soils maps of Big Thicket National Preserve based upon the park boundary at that time, and described 51 soil map units in the Preserve. Since then, the Preserve has increased in size, and soils information has been obtained by merging the various county soil surveys into one composite soil legend that reflected the boundary of the Preserve in 2007. At the present time, 89 different soil types have been recognized within Big Thicket National Preserve, and 131 soil map units are on the comprehensive soils legend (P. Biggam, National Park Service, pers. comm. 2009).

Soil wetness, depth to a high water table, ponding and flooding are issues associated with the Angelina, Aris, Babco, Bleakwood, Caneyhead, Cypress, Estes, Fausse, Iulus, Iuka, Laneville, Lelaville, Manco, Olive, Ozias, Pophers, Sawlit, Sawtown, Tyden and Voss soils. Past timber and pulpwood harvesting activities as well as oil and gas operations may have had an impact on these soils through excessive soil rutting and soil trafficablity issues. The surface horizons in these soils may have been disturbed by these activities. Many of these soils are also considered to be hydric soils and may be occurring in wetlands. The Cypress soils occur in swamps and have an organic muck surface layer that is unique in the area (P. Biggam, National Park Service, pers. comm. 2009).

Hillslope Features and Processes
Slope failures resulting from erosion occur most commonly along the steep bluffs of the Neches River (Upper Neches River Corridor Unit, Jack Gore Baygall Unit, Neches Bottom Unit, Lower Neches River Corridor Unit, and in the newly acquired Canyonlands Unit). Erosion is also occurring along bluffs adjacent to the Trinity River at Menard Creek. If the Rush Creek area (near Beech Creek) is acquired by the federal government, the Preserve will likely have additional hillslope issues due to the area's varied terrain.

Paleontological Resources
Fossils have been identified in all strata that outcrop in the Preserve, making it a high probability area for finding paleontological resources. The brief description that follows has been adapted

from Kenworthy *et al*. (2007) which presents a more thorough account of fossil occurrences and significance, as well as park management recommendations to protect paleontological resources.

The Fleming Formation outcrops in steep gullies in and around the Preserve's most northern management units. The Fleming Formation is widely known for its abundant and diverse faunal assemblage, primarily representing vertebrates such as fish, reptiles, amphibians, and mammals. Although the fossils of the Fleming Formation tend to be poorly preserved, they are significant for their use in paleo-environmental reconstructions and in establishing stratigraphic relationships.

According to Kenworthy *et al.* (2007), Miocene rhinoceros material was collected in 2002 by a local resident near, and likely in the Preserve along the banks of the Neches River in the Town Bluff area just below Dam B of the B.A. Steinhagen Lake. Dwyer (2005) reported on this discovery and also noted the potential for large pieces of petrified wood in the same area. The Miocene rhinoceros fossils are apparently now on display at the Icehouse Museum in Silsbee.

A Pleistocene-age mammoth tooth was found among reworked sediments of the Fleming Formation along the bank of the Trinity River in the Menard Creek Corridor Unit of the park. A mammoth or mastodon bone fragment was also discovered in February 2009 in the same general area. This site of the 2009 discovery also produced several small pieces of petrified wood (Dusty Pate, Big Thicket National Preserve, pers. comm. 2009).

Although all strata may contain petrified wood, the basal gravels of the Willis Formation are reported to have most of the petrified wood in the Preserve (Fay 2008). The Bentley Formation includes some marine invertebrates in small, isolated deposits. The Bentley and Montgomery formations are regionally known to preserve ice-age megafauna such as ancestral horse, mastodon, giant ground sloth, turtle, and saber-tooth cat material.

The Beaumont Formation in the Big Thicket area has produced fresh, marine, and brackish water local fauna, including invertebrates, vertebrates, as well as flora such as cypress logs. However, fossils have not yet been officially documented within the Preserve from the Beaumont Formation. Also, late Pleistocene Trinity River Terraces near the Preserve have produced an abundance of fossil material including vertebrates, aquatic invertebrates, insects, and logs. Especially interesting are the rare and well-preserved skulls of a ground sloth and a species of tapir discovered in Pleistocene gravel terrace deposits of the Trinity River now submerged under Lake Livingston (Lundelius and Slaughter 1976).

The Deweyville Formation is not known for paleontological resources, but it has produced petrified wood. In addition, undivided fluviatile terrace deposits and recent alluvium may contain a small amount of reworked older fossil material.

Unique or Culturally Significant Geologic Features

Sand mounds (also referred to as "pimple mounds" or "Mima mounds") occur throughout the Texas Gulf Coast Plain, and the highest concentration of sand mounds in the Preserve occurs in the Lance Rosier Unit. All known mounds of this region occur in-and-on the sandy surficial deposits. Despite the widespread continental (and even global) distribution of these features, their origin and mode of formation is uncertain. Sand mounds, river terraces, and other high grounds are high probability areas for finding cultural artifacts and commonly contain evidence of camps and ancient inhabitants. A different and unrelated type of mound-feature occurs to the northwest of the Preserve and is the work of the Caddoan Mound Builder Culture (Dusty Pate, Big Thicket National Preserve, pers. comm. 2008). These mound-features are approximately 10 ft (3 m) high.

As noted by Fay (2008), salt domes are important features for a variety of reasons: unique topographic highs tend to be significant in a cultural context, salt domes can produce salt licks which attract wildlife, and the features are associated with the occurrence of historically curative sulfurous water. Salt domes are historically significant and provide an excellent opportunity to interpret their origin and uses (*e.g.*, oil and gas development in the area). Salt domes are hydrologically significant because the topographic highs influence surface drainage; High Island, near the Preserve, is a good example of this (Fay 2008). Fay (2008) also noted that Sour Lake has a distinct topographic expression and its movement could have been influenced by oil and gas production (*e.g.*, Spindletop, Saratoga, and Sour Lake oil and gas fields).

Oil and Gas Development

The vast majority of oil and gas resources beneath the Preserve are non-federally owned (owned by private individuals, companies, or the State of Texas). When Preserve lands were acquired by the NPS, private entities retained the subsurface oil and gas mineral rights for most of the lands, and the State of Texas retained the subsurface oil and gas mineral rights beneath the Neches River and navigable reaches of Pine Island Bayou.

The owners and/or lessees of these mineral interests have the right to develop the oil and gas resources subject to applicable laws, regulations and policies. NPS regulations at 36 CFR Part 9, Subpart B (36 CFR 9B), promulgated in 1978, govern all activities associated with the exploration and development of nonfederal oil and gas in National Park System units where access is on, across or through federally owned or controlled lands or waters. The 36 CFR 9B regulations are “designed to insure that activities undertaken pursuant to these (nonfederal oil and gas) rights are conducted in a manner consistent with the purposes for which the National Park System and each unit thereof were created, to prevent or minimize damage to the environment and other resource values, and to ensure to the extent feasible that all units of the National Park System are left unimpaired for the enjoyment of future generations.

According to Preserve records, approximately 226 abandoned oil and gas wells are within the boundaries of the Preserve. Most wells had been plugged and abandoned before the Preserve was established in 1974. However, nonfederal oil and gas exploration and development operations (*e.g.*, geophysical surveys, exploratory well drilling, well production, transportation, reclamation, etc.) continue today in the Preserve, and there are nine active operations occurring on NPS lands. In addition, 31 oil and gas wells directionally drilled beneath the Preserve from adjacent lands are currently in operation.

Another oil and gas management issue in the Preserve involves existing oil and gas pipelines and associated rights-of-way that traverse several Preserve units. These trans-park pipelines transport crude oil, natural gas, liquid petroleum gas and natural gas liquids, refined products, and produced saltwater through the Preserve units. Most of the pipelines are not associated with the development of nonfederal oil and gas rights within the Preserve. The only management units in the Preserve that do not have trans-park pipelines are the Loblolly and Beech Creek units. There are 71 pipeline segments crossing units of the Preserve within pre-existing rights-of-way totaling 101 miles of pipelines and occupying approximately 589 acres (NPS 2006). It is important to note that at present, no statutory authority exists for granting new trans-park pipeline rights-of-way within the Preserve.

According to Schenk *et al.* (1999), additional oil and gas development will likely continue in the Preserve, and geologic formations that may be productive in the future include the Upper Cretaceous Tuscaloosa Formation, Upper Cretaceous Austin Chalk (Austin Group), the Paleocene-Eocene Wilcox Group, the Eocene Yegua Formation and other sandstones of the Claiborne Group, the Oligocene Vicksburg Formation, and the Oligocene Frio Formation.

In an effort to establish a general framework for managing the development of nonfederal oil and gas in the Preserve over the next 15-20 years, the NPS prepared an Oil and Gas Management Plan and Environmental Impact Statement in 2005 (NPS 2006). The Big Thicket National Preserve Oil and Gas Management Plan identifies resources and values most susceptible to adverse impacts from oil and gas operations; establishes performance standards and impact mitigation measures to protect and prevent impairment of Preserve resources and values; establishes performance standards and mitigation measures to avoid or minimize impacts on visitor use and enjoyment, and human health and safety; and provides pertinent information to oil and gas operators to facilitate planning and compliance with NPS and other applicable regulations.

Vegetation

The landscape types of the Preserve are dispersed in a distinctive ***regional*** pattern throughout the Big Thicket that mirrors the north-to-south depositional sequencing of its geology and the availability of water at land surface:

> *To the north* -- the higher hill country and more permeable and older Willis and Bentley formations, where higher topography and sandier soil result in rapid drainage and subsurface percolation. The longleaf pine upland favors the well-drained soils of the northern formations.
>
> *To the south* **--** the younger Montgomery and Beaumont formations have a high clay content that makes the surficial soils almost impermeable. Contiguous forests of longleaf pine give way to the pine savannah wetlands, with the exception of isolated patches of longleaf pines found locally in drier and better drained highlands. Most soils in the Preserve developed on these two formations, which are exposed at the surface in approximately 70 percent of the Preserve.
>
> In the flat and lower lying land of the pine savannah wetlands, in combination with impermeable clay soils, rainfall has no place to go, and results in standing water during rainy times of the year. Conversely, the impermeable soil prevents ground water from seeping upward, creating very dry soil conditions during dry spells. Thus, generally only annuals and certain trees with extensive root systems can thrive in the savannah wetlands.

The placement of the Preserve's landscape types is also a reflection of *local-scale* geologic features (porosity and structure):

> Perched high on old stream and river terraces that no longer flood are ancient sand hills left by earlier rivers and streams and coastal dune deposits from the times of higher sea level. Because water percolates through the deep sand, leaving a dry surface, only plants adapted to desert-like conditions can survive.
>
> At the bottom of these terrace bluffs or sand hills are seeps and springs that feed water into low spots of old river meanders or depressions, and where water collects in the bottom of a closed, poorly drained depression. Debris from surrounding vegetation seeps into the water, causing the water to become dark, clear, low in oxygen, and highly acidic.

Generally speaking, the geologic sequencing of deposition and erosion has created an undulating landscape with varying levels of permeability at the surface – and distinct differences in the availability of moisture at land surface, whether as rain, stream/river flow, or groundwater – which (combined with other ecological factors such as climate and wildland fire frequency), has manifested itself into four general landscape types with somewhat distinctive vegetation: uplands, slopes, flatlands, and floodplains. Marks and Holcomb (1981) provide a detailed description of vegetation types discussed below for each landscape type:

> *Uplands*: The Sandhill Pine Forest is found on level, deep, sandy terraces associated with river bluffs. Upland Pine Forest is found on level to gently rolling hilltops with sandy surface soils. Wetland Pine Savanna occurs within the uplands on shallow, poorly-drained depressions with slow drainage due to a subsurface clay layer (clay pans). Longleaf Pine (*Pinus palustris*) is dominant in the upland types. In the Sandhill Pine Forest, *P. palustris* is widely scattered; however, the former has a subcanopy layer of *Quercus incana* (bluejack oak), and the latter has a ground layer of wetland herbs and shrubs.
>
> *Slopes*: In the slope forests, *P. echinata* (shortleaf pine) and *P. taeda* (loblolly pine) replace *P. palustris* as the dominant species. Southern red oak (*Q. falcate*), white oak (*Q. alba*), southern Magnolia (*Magnolia grandiflora*) and American beech (*Fagus grandifolia*) are the principal understory hardwoods. Shortleaf pine, loblolly pine, and southern red oak contribute more than 50 percent of the basal area in Upper Slope Pine Oak forest. In the Mid Slope Oak forest, loblolly pine, white oak, and shortleaf pine dominate. In the Lower Slope Hardwood Pine forest, loblolly pine, American beech, magnolia, and white oak dominate.
>
> *Flatlands*: Flatlands are level, low-elevation inter-distributary flats or terraces associated with geological deposits of the ancient Trinity River. Surface drainage patterns are poorly developed because of the topography and fine soil texture, so that standing water is common after heavy rains. Basket oak (*Q. michauxii*), willow oak (*Q. phellos*), laurel oak (*Q. laurifolia*), loblolly pine, and green ash (*Fraxinus pensylvanica*) are dominant trees in Flatland Hardwood Forest. This forest is also characterized by the presence of dwarf palmetto (*Sabal minor*).

Floodplains: Collectively the vegetation types that occur in the floodplains are sometimes considered as bottomland hardwoods in the broadest sense. All of these vegetation types occur where moisture is prevalent. Floodplain Hardwood Pine Forest occurs in floodplains of smaller streams. Loblolly pine and American beech are dominant species. Shrubs are characteristically scarce in this vegetation type. Floodplain Hardwood Forest occurs in the floodplain of larger streams and the Neches River. Black oak (*Q. nigra*) and American sweetgum (*Liquidambar styraciflua*) are dominant species. Many individuals of the overstory reach great girth, an appearance accentuated by the open understory. Arboreal vines are a conspicuous feature of these forests. Swamp Cypress Tupelo Forest occurs in the deeper backswamps, sloughs, oxbows, and other depressions and along the Neches River. Swamp cypress (*Taxodium distichum*) and water tupelo (*Nyssa aquatica*) predominate. These forests are the most structurally impressive forest stands in the Big Thicket. Wetland Baygall Shrub Thicket occurs frequently in depressions where water stands for much of the year. Overstory dominants include laurel oak and black tupelo (*N. sylvatica*). Depending on overstory density, the shrub layer may vary from open to nearly impenetrable.

Hydrography

Big Thicket National Preserve lies primarily in the lower reaches of the Neches River Basin, with the exception of Menard Creek which is in the adjacent Trinity River Basin (Figure 6).

More specifically, the management units of the Preserve lie within four watersheds: the lower reaches of the main stem Neches River, Big Sandy/Village Creek and Pine Island Bayou – both of which flow into the Neches River north of Beaumont, and Menard Creek – which flows into the Trinity River Basin near Romayor (Figure 6). Barring the Menard Creek Unit, water flows from almost anywhere in the Big Thicket towards the Neches River; organic material from the thicket is carried by the river into the marshes below Beaumont, nourishing the coastal estuarine ecosystem.

In total, the Neches River flows southeast for approximately 416 miles from Van Zandt County to the Gulf of Mexico near Port Neches. A drainage area of 10,011 mi^2 and abundant rainfall over the entire Neches Basin results in an annual flow near the Gulf of approximately 6 million acre-feet. The tributary drainages generally follow dendritic patterns that are indicative of horizontal or near horizontal bedrock and gentle sloping topography. The tidal portion of the watershed extends from the confluence with Sabine Lake upstream into the southeast portion of the Beaumont Unit. Flows in the Neches River downstream of this area are also influenced by tides, water quality of the ocean, and discharges from the upper watershed. The tidal segment is highly developed, industrialized, and is dredged to maintain a navigation channel.

A casual observer may conclude that there are two primary – and separate – structures that affect the Preserve's interests along the Neches: B.A. Steinhagen Reservoir/Town Bluff Dam (operated by the U.S. Army Corps of Engineers) and the Neches River Saltwater Barrier (Figure 7; operated by the Lower Neches Valley Authority). Located 85 river miles apart, these structures form the approximate upstream and downstream endpoints of the Preserve's Neches River corridor. These structures, along with the Sam Rayburn Dam (Figure 7), are operated in

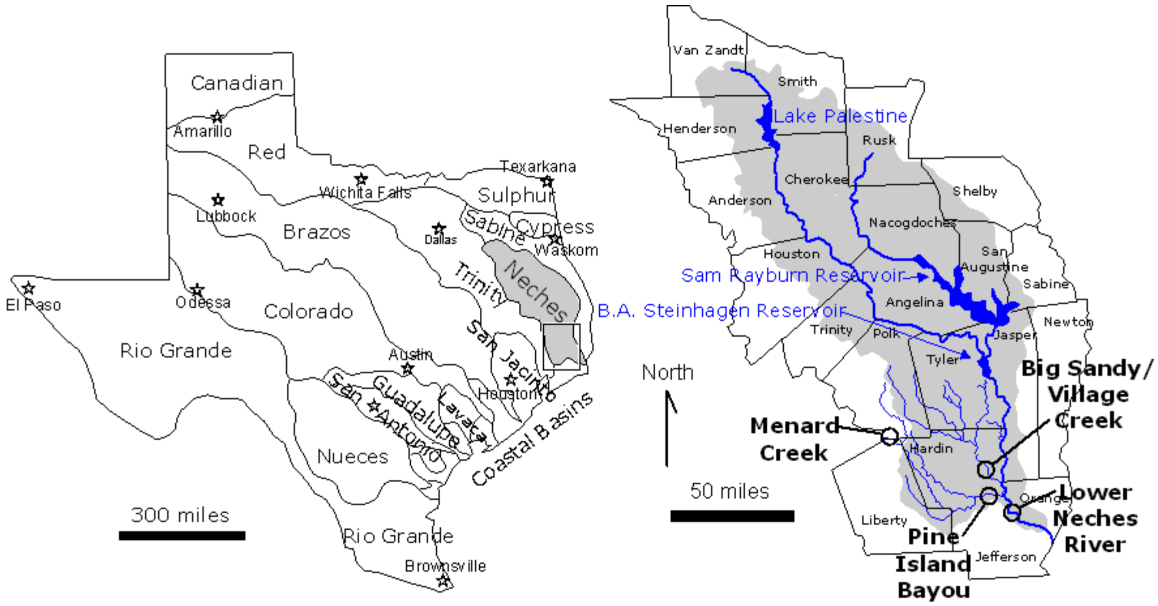


Figure 6. Major drainage basins of Texas (left) with a more detailed view of the major drainages that comprise Big Thicket National Preserve. Neches River Basin is shaded gray.

concert with each other for the purpose of maintaining a carefully calibrated water flow and stage regime in the river, thus ensuring delivery of water necessary to satisfy the water rights of end users – a large portion of which is passed through the Lower Neches Valley Authority (LNVA) Canal – and preventing saltwater intrusion from the heavily industrialized and dredged Sabine Lake estuary from fowling fresh water intakes. Thus, waters that pass through the preserve are operationally in route to satisfy water rights of agricultural, industrial, and municipal end users, to control saltwater intrusion, and also provide recreational opportunities.

The Trinity River is a 710-mile long river that flows entirely within the State of Texas. It rises in extreme north Texas, a few miles south of the Red River. The Trinity River basin drains approximately 18,000 mi^2, encompassing parts of 34 counties before entering the Gulf of Mexico. It is the second longest river entirely within one state in the U.S., trailing only Alaska's Kuskokwim River.

Surface Water Hydrology

Fluvial features and processes dominate the landscape at Big Thicket National Preserve. Fluvial processes such as channel migration, erosion, and flooding not only create a number of resource management issues, but significantly influence the community structure and composition of vegetation. For example, stream channel migration processes can cause the rivers and larger creeks, particularly the Neches River, to meander in and out of the park boundaries. Stream bank erosion and channel migration can threaten park resources and infrastructure. The extent, timing, and duration of flooding, in combination, are important in shaping the kinds of vegetative communities that exist within the floodplain.

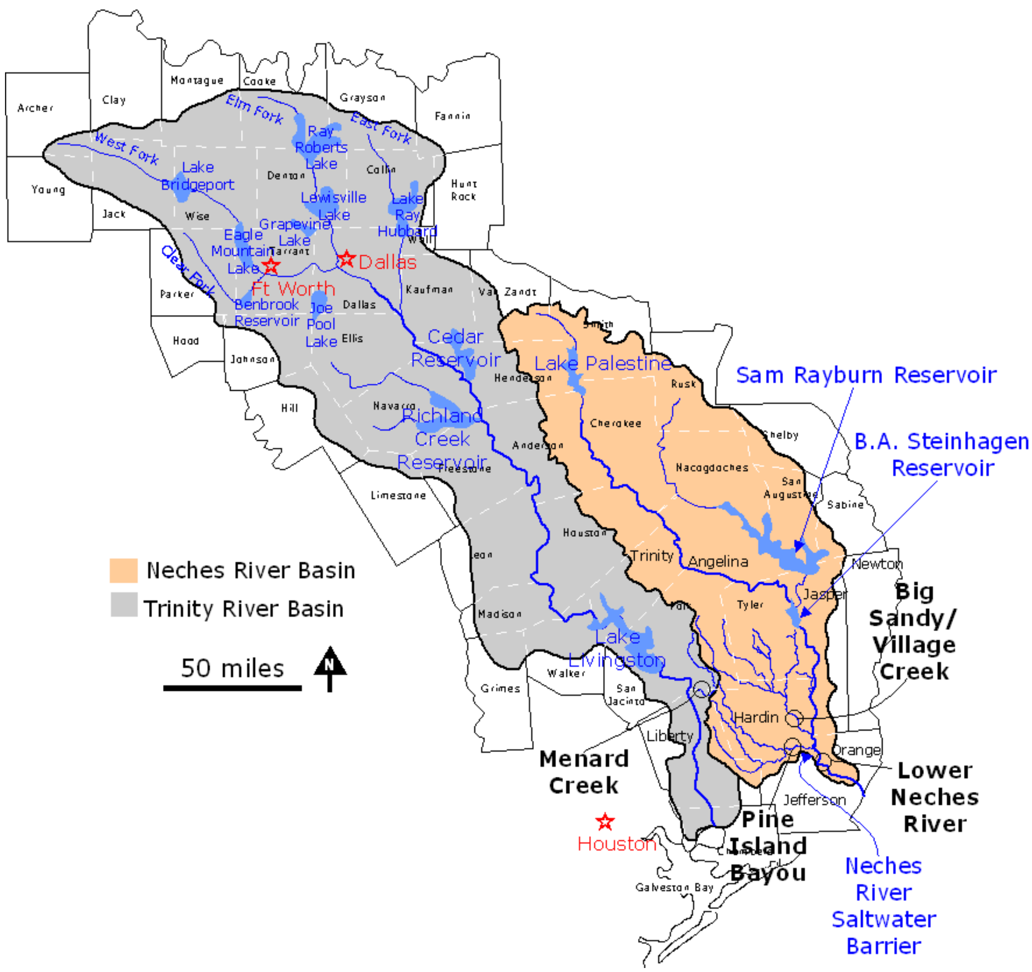


Figure 7. Map showing the four major watersheds that comprise Big Thicket National Preserve and the locations of the Neches River Saltwater Barrier, BA Steinhagen Reservoir, and Sam Rayburn Reservoir.

Flooding occurs most commonly in the summer during tropical storms and creates resource management problems in the Preserve. The severity of flood events may be exacerbated by river aggradation and debris loading of the rivers during storm events. High volume water releases from B.A. Steinhagen Reservoir (controlled by the US Army Corps of Engineers) occur intermittently and typically without notice to the NPS, resulting in incised channels, downstream aggradation, and flooding of the Neches River.

Streams and rivers in the coastal plain are characterized by strong annual cycles, with high flows occurring in winter and spring when evapotranspiration is low and low flows occurring during the summer and fall when vegetation cover in the watersheds evapotranspires much of the precipitation that falls (Figure 8). Surface water hydrology, ranging from headwater creeks to the Neches River, plays a vital role in the ecological function of the Preserve.

Although diversity and complexity of the streams in the Gulf Coast Plain make generalizations difficult, they are categorized as “warm water” streams which tend to have: (1) low gradients, (2) moderate to high discharge, (3) low turbulence, and (4) rubble-sand-mud substrates. There are

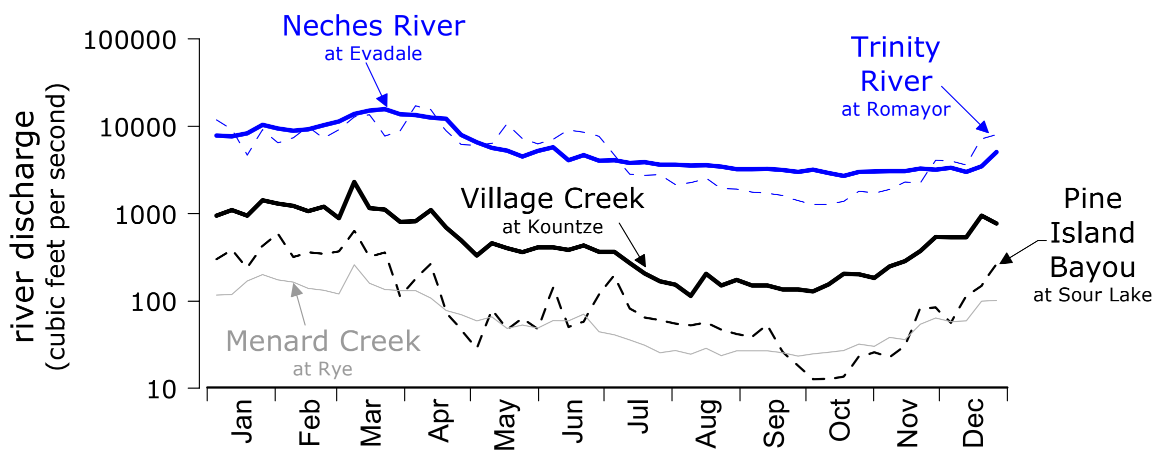


Figure 8. Weekly-calculated median discharge rates for major monitored waterways in and near Big Thicket National Preserve, 1998-2007. Data Source: U.S. Geolgical Survey.

strong seasonal variations of many properties of these streams which are related to the amount of runoff. Characteristically, there are distinct wet and dry seasons with lowest flow from August to October and highest flow from January to March (Felley 1992), and are divided into two types:

- brownwater rivers -- The larger rivers that originate in the continental interior frequently carry high amounts of suspended sediments, and are therefore turbid, chocolate brown in color, and high in conductivity. These rivers are often referred to as "alluvial" or "brownwater" rivers. The Neches River is typical of high turbidity "brownwater" rivers in the Big Thicket, but also has high-organic carbon signature more characteristic of "blackwater" tributaries that flow into it.

- blackwater streams -- The smaller streams that originate primarily within the outer coastal plain also fluctuate in flow volume, but their flow is more subject to local rainfall events. Those that drain areas of predominantly sandy, acidic soils are sometimes termed "blackwater" streams, owing to high concentrations of organic acids in the water and low turbidity. Of the streams in the study area, Village Creek is most nearly typical of blackwater streams.

Menard Creek and Little Pine Island Bayou are small and of variable flow like blackwater streams, but are more turbid and of higher conductivity like alluvial streams. The higher turbidity and conductivity may be caused by the presence of finer-textured substrates such as silts and clays in their watersheds, some of which are in high calcium.

The U.S. Geological Survey (USGS) monitors continuous water stage and flow along the Neches River at three locations – Town Bluff (since 1951; USGS Station 08040600), Evadale (since 1921; USGS Station 08041000), and Beaumont (since 2003; USGS Station # 08041780), along Village Creek at Kountze (since 1939; USGS Station #08041000), along Pine Island Bayou at two locations – Beaumont (since 2004; USGS Station # 08041749) and Sour Lake (since 1965;

USGS Station # 08041700), and Menard Creek near Rye (since 1965; USGS Station # 08066300). Seasonally, as measured at Evadale, discharge in the Neches River peaks in late winter, between 10,000 and 20,000 cfs (cubic feet per second), and recedes during the summer and fall to a flow rate between 2,000 and 3,000 cfs (Figure 8). Most of the discharge volume on the Neches at Evadale occurs from January through June (Figure 9). This is also true for the Trinity River, but to a lesser extent or not at all for the smaller drainages (Figure 9).

Rainfall

The Big Thicket's location in East Texas on the western edge of the rainiest part of the continental United States east of the Mississippi -- Louisiana's Gulf Coast region (Figure 10) – imparts it with a rather unique rainfall signature:

- <u>abundant annual rains</u>. An average-annual rainfall of approximately 53 inches (1350 mm) was recorded at the rain gage used in this study. Nationally, only the Pacific Northwest and Louisiana Gulf Coast regions have higher average annual rainfall. Statewide, Texas is defined by a steeply declining east-to-west rainfall gradient, making east Texas the rain-rich exception to an otherwise semi-arid and arid state.
- <u>even seasonal spread.</u> Rain falls fairly consistently in all seasons but from different sources. Thunderstorms occur 60 days per year, primarily during the summer from convectional heating and sea-breeze fed storms from the Gulf of Mexico; and while sustained rainfall and flooding often take place in the winter and spring from fronts moving across the continent, the most intense rain events are associated with tropical storms and hurricanes in the summer and fall (NPS 1996). At the Town Bluff gage, fall is the rainiest season and summer the most susceptible to drought (Figure 11).

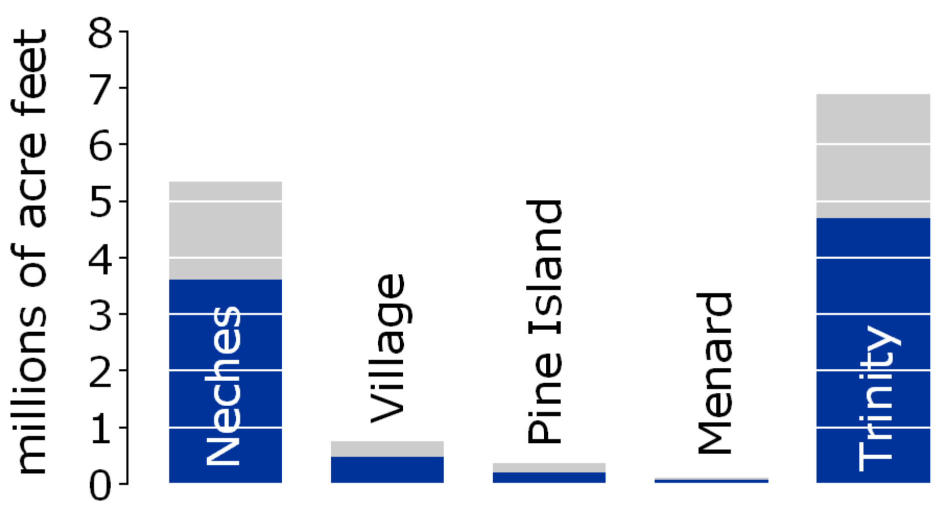


Figure 9. Ten-year average annual and half-year (January through June; blue) flow volume comparison of Neches River (at Evadale; U.S. Geological Survey Station #08041000), Village Creek (at Kountze; USGS Station # 08041500), Pine Island Bayou (at Sour Lake; USGS Station #08041700), Menard Creek (at Rye: USGS Station # 08066300), and Trinity River (at Romayor; USGS Station # 08066500) in millions of acre-feet of water, 1998-2007.

- rain-spiked peak flows. Winter rains and associated low evapotranspiration typically cause the preserve's creeks and rivers to crest in winter. This seasonal trend is complimented along the Neches by inflows from its drier headwater region (estimated 35 inches of annual rain). However, highest magnitude rains tend to occur in the summer and fall, resulting in dramatic flow and stage spikes in local creeks, which combined with the regions relatively poor drainage, has lead to severe flooding. In October of 1994, the remnants of Tropical Storm Rosa caused flood waters to rise to a record of 12.5 ft above flood stage on Pine Island Bayou. This flood caused 26 counties to be declared Federal Disaster Areas, regionally forced the evacuation of 14,000 people, and, caused over 700 million dollars in damage, and contaminated several areas by dispersing pollutants and mud (Lamar University 1996).

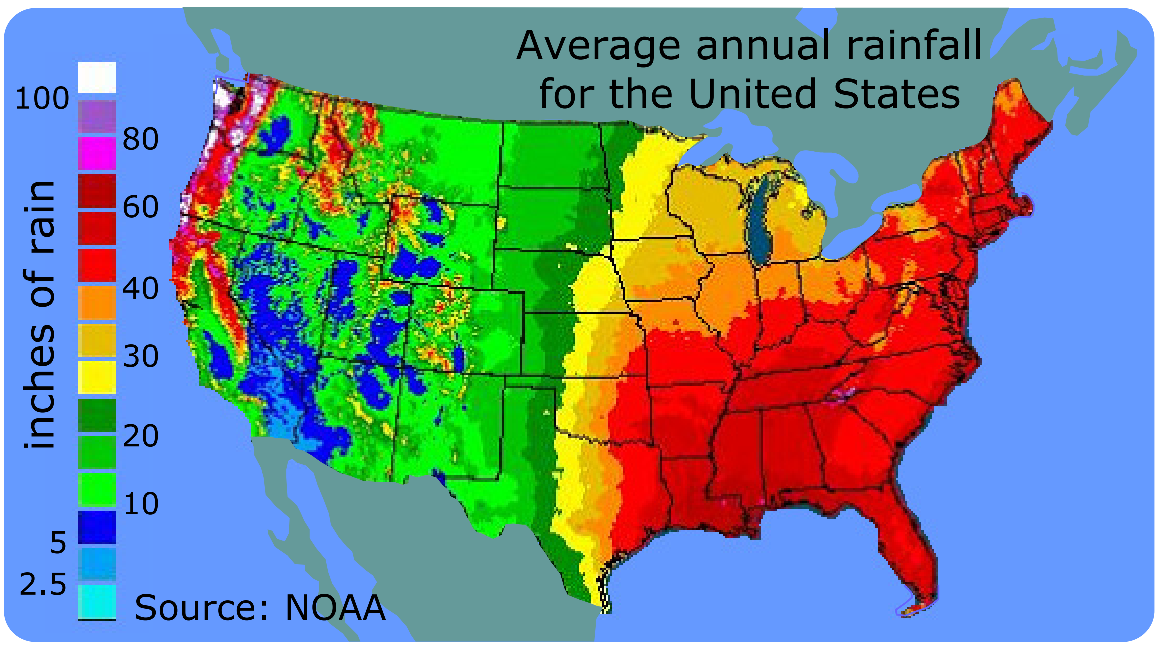


Figure 10. Average annual rainfall across the United States.

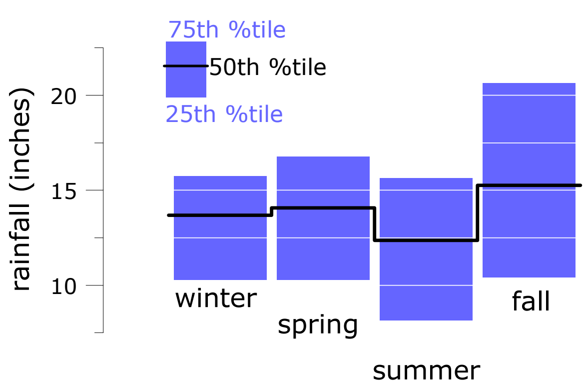


Figure 11. Seasonal rainfall distribution at Town Bluff, 1982-2007.

- drought-fueled recession to base flows. Summer dry spells and associated evapotranspiration lead to diminishing flows throughout the summer, baring major storms, during which riparian flows reflect "base flow" conditions, and in the case of the Neches River – upstream reservoir releases. Deeper and prolonged downturns in low flow conditions are not uncommon, either as a result of low rainfall years or multi-year drought cycles.

  The rain gage at Town Bluff (maintained by the U.S. Army Corps of Engineers) averaged 55 inches of annual rain from 1982-2007. For eight of those years it either exceeded 70 inches of annual rain or fell under 50 inches, underscoring the prevalence of drought and flood years (Figure 12).

It is the seasonal pattern of the abundant rainfall coupled with extended dry periods and unpredictable and torrential rains – and the region's associated high temperatures and humidity that fuels the rapid growth and decay of the Big Thicket's dense floodplain vegetation – which sets the stage for the flowing waters that course through the Preserve's riparian channels, their inundation of floodplains, and, on occasion, property damage on adjacent lands.

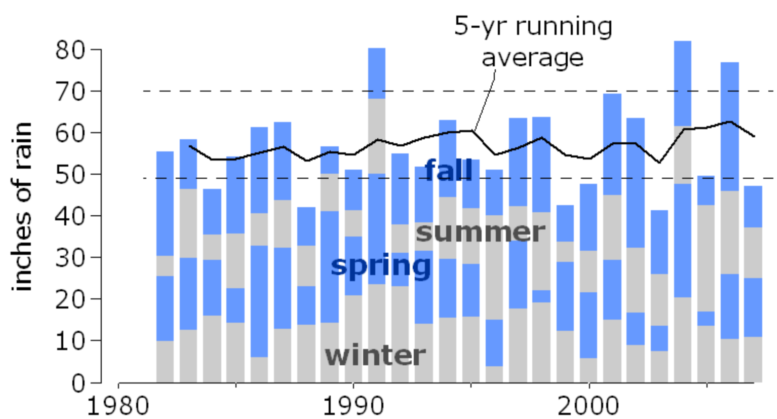


Figure 12. Annual and seasonal distribution of rainfall at Town Bluff, 1982-2007. Upper and lower dotted line highlight years with more than 70 and less than 50 inches of rain.

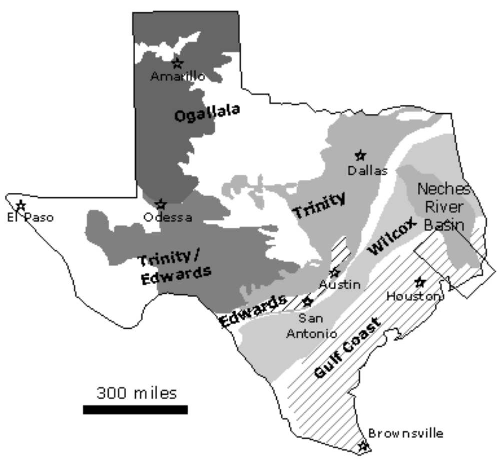
Ground Water Hydrology (excerpted from NPS 2006)

The Preserve is characterized by marine and non-marine fluvial and deltaic sedimentary deposits that are highly variable in lithology and hydraulic properties. These geologic deposits, generally consisting of alternating layers of clays, silts, sands and gravels, are hydrologically connected and compose the aquifers in the vicinity of the Preserve. Because aquifers generally consist of parts of more than one geologic formation, the sediment deposits are commonly grouped together and referred to as the Gulf Coast aquifer or Gulf Coast Aquifer System. The Gulf Coast aquifer forms a wide belt along the Gulf of Mexico, extending from Florida to Mexico, and is a major aquifer in the State of Texas (Figure 13).

The Gulf Coast aquifer contains three separate aquifers, two of which are in the Preserve. The Evangeline aquifer (Figure 13), the deepest of the three aquifers, is within the upper sands of the Fleming Formation and the lower sands of the Willis Formation. It contains fresh to moderately saline water, and supplies a moderate amount of fresh water for municipal uses in Hardin and Liberty counties, and for parts of Newton, Jasper, and Tyler counties.

Overlying the Evangeline aquifer, the Chicot aquifer (Figure 13) is a series of sand and clay beds within the Willis, Bentley, Montgomery, and Deweyville Formations, and Quaternary Alluvium. Separated by clay beds approximately 200 feet thick, the Chicot aquifer has been subdivided into upper and lower levels. The total thickness of the Chicot is roughly 425 feet, and both the thinner upper and thicker lower Chicot yield fresh to slightly saline water. The Chicot is the main source of groundwater in Orange County, although small to large quantities of fresh water are recovered in southern Liberty County. Most of the water used is drawn from the lower Chicot.

Aquifers at surface pressures are referred to as water table aquifers or unconfined aquifers, and usually occur at or near the source of recharge (Lamar University 1996). Both the Evangeline and Chicot are water table aquifers near their recharge areas, but become artesian aquifers as the water migrates toward the coast. Water table conditions exist in recharge areas where surface deposits are permeable enough to allow infiltration of precipitation. Here, water levels in the aquifer fluctuate in response to the volume in storage and oftentimes are very close to the ground surface. Recharge to both aquifers occurs primarily from precipitation, and may also occur through streams, lakes, and



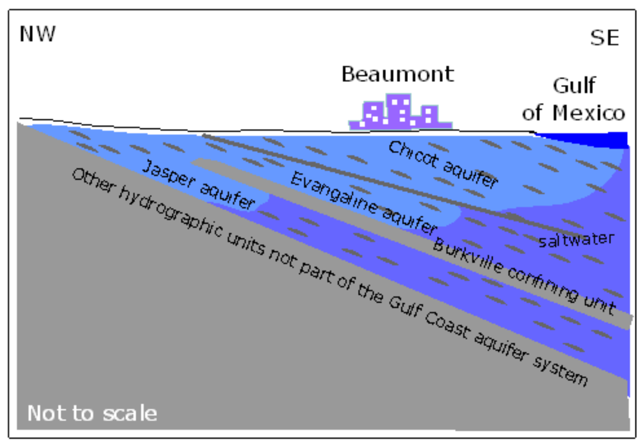


Figure 13. General location of the Gulf Coast Aquifer in Texas and its component aquifers near Beaumont and the Preserve.

lateral flow. More locally, recharge may occur as vertical flow between aquifers – where sands of one aquifer are in contact with sands of another aquifer (Blanton & Associates, Inc. 1998). Conversely, discharge occurs in topographically low areas such as springs, seeps, and streams, and in Hardin County, it represents a major loss of groundwater (Baker 1964).

In both the Evangeline and lower Chicot aquifers, water occurs under artesian conditions (Williamson *et al.* 1990; Blanton & Associates 1998). This does not mean that water will flow to the surface, but rather that groundwater is under sufficient pressure to rise above the top of the aquifer when provided with a conduit. The presence of artesian conditions indicates that the hydraulic gradient in the area increases with depth. Consequently, the preferred direction of flow is from deeper zones to the surface. As mentioned above, these aquifers become artesian aquifers as water migrates downward toward the coast.

This natural gradient can, and has been reversed in areas of extreme groundwater withdrawals. Overpumping water wells causes cones of depression to form, lowering the effective water level and may cause saltwater contamination. Cones of depression have been observed in the lower Chicot aquifer in the vicinity of Houston, Baton Rouge, and to a lesser extent, Beaumont (Williamson *et al.* 1990). Similarly, between 1941 and 1963, the industrial use of water in Orange County from the lower Chicot lowered the level of the water table approximately 45 feet (Thorkildsen and Quincy 1990). However, during a 10 year period beginning in 1977, decreased water use by industries in Orange County showed a water level increase of approximately 5 to 10 feet (Thorkildsen and Quincy 1990). However, in spite of this reverse in gradient, there is no reference to impacts on the water table which is supported by the upper Chicot aquifer. This is likely because of the thick clay layer that separates the upper and lower Chicot aquifers, and the large recharge from precipitation on the surficial aquifer.

Due to the composition and varying depths of the water-bearing formations, a wide range of water quality regimes may be encountered. Total dissolved solids values may vary from near fresh to saline and hypersaline at depth. In general, the freshest water is close to the surface and is likely encountered in the Quaternary Alluvium, near the water table present in the Bentley Formation, or in the sand lenses present in the Beaumont Formation. Water in the aquifers is generally of good quality, and receives chlorination only before use.

Groundwater can be severely impacted by both natural and human causes. Natural contaminants in southeast Texas include salt from salt domes, sulfur and associated mineral deposits, naturally radioactive materials, and the chemicals associated with petroleum deposits (Lamar University 1996). Human impacts on groundwater include: improper handling, storage, or transport of toxic, hazardous, or other contaminating substances; leaching from septic systems, sewage; agricultural runoff from fertilizer use; and contamination of water supplies by pathogenic (disease-causing) microorganisms.

Water Quality

Rivers, streams, creeks, and bayous lie at the heart of the Preserve – it contains more than 250 miles of waterways. Thus, a major aspect of managing the Preserve is to protect the water quality of these waterways.

The Preserve's narrow footprint – primarily located along or near riparian lands – makes waters within it vulnerable to agricultural, timber, oil and gas, and other industrial operations within the watershed. Increased runoff from deforestation, application of fertilizers and pesticides, leaks and spills from oil and gas operations (hydrocarbons, produced waters, chemicals, solvents and fuels), and wastewater return flows threaten to introduce sediments, nutrients, and other harmful chemicals into the water column.

Water Quality Monitoring History

A relatively large amount of water quality data exists for the major drainages in the Preserve, either as a result of (a) studies that were either very limited geographically and/or temporally, or

(b) more comprehensive monitoring programs undertaken by the USGS, NPS, and LNVA where more continuous data exists.

The USGS started sampling water quality at six locations in Preserve waterways in 1967, coinciding with the same locations it monitored stage and flow (three on the Neches and one each on Menard Creek, Village Creek, and Pine Island Bayou); but this water quality monitoring has been discontinued except at Evadale.

The NPS started sampling water quality at 21 locations in 1984, including Beech Creek, Mill Creek, Big Sandy Creek/Village Creek, Black Creek, Menard Creek, Pine Island Bayou, and 5 locations on the mainstream of the Neches River. Between 1984 and 1994, nearly monthly measurements were made at 14 of the 20 stations resulting in 1,781 records of field parameters and 678 records of laboratory parameters (Hall and Bruce 1996).

The NPS water quality sampling program culminated in a baseline water quality report by the NPS Water Resources Division (NPS 1995). This study analyzed and summarized 40,043 observations from 493 parameters collected from 41 monitoring stations in and around Big Thicket from 1959 to 1993. Of the nine stations where long-term multiple observations were made, only two were within Preserve boundaries, both on the Neches River at Evadale and at U.S. Highway 96, east of Silsbee (Myers 2005).

Despite its early success in establishing a water quality monitoring program, the Preserve's one-time flagship program languished for over a decade or more following the 1995 report as a result of staffing and funding shortfalls. Water quality sampling within the Preserve (primarily Neches River tributaries – the Neches River in the Preserve has been monitored by LNVA) has been rejuvenated through funding from the NPS Gulf Coast Inventory and Monitoring Network in partnership with the Lower Neches Valley Authority. In 2007 LNVA began quarterly monitoring of six routine stations within the Preserve (Pine Island Bayou, Little Pine Island Bayou, Turkey Creek, Village Creek and Menard Creek). Besides this monitoring of Preserve waters, LNVA's 2009 water quality monitoring program included 24 other stations with the Lower Neches River basin. In addition, Region 10 of the Texas Council for Environmental Quality (Beaumont) monitored 20 stations in the Lower Neches River basin, including sites in Village Creek and the Neches River.

Generally, water quality studies across the Preserve have shown water quality to be fair to excellent, although in some areas water quality has degraded with respect to particular parameters (Harrel 1985; Flora 1984; Flora 1985; Hughes *et al.* 1987; Hall and Bruce 1996). Compared to other rivers in Texas, the Neches River generally has lower values for ion concentrations (especially bicarbonate and calcium), hardness, specific conductance, pH, and total dissolved solids.

Hall and Bruce (1996) concluded the following:

- Collectively, 15 parameters exceeded screening criteria (EPA and NPS-WRD threshold standards) at least once within the study area. Those parameters found to exceed EPA chronic or acute criteria for the protection of freshwater aquatic life include dissolved oxygen, pH, chloride, and several metals (cadmium, copper, lead, silver, zinc, and mercury). EPA standards for drinking water were exceeded for sulfate, cadmium, chromium, lead, nickel, silver, and mercury. In addition, total and fecal coliform concentrations and turbidity exceeded the NPS-Water Resources Division screening limits for primary-body contact recreation and aquatic life.

- Rather than indicating widespread general conditions, these findings and the bulk of the surface water quality concerns observed reflect localized impacts of human activities within the watershed but outside the Preserve.
- Sewage treatment plant discharge and septic tank usage, oil and gas production, timber harvesting, and agricultural practices on surrounding and upstream lands are all potential pollution sources.
- The most consistent and chronic problems were associated with the Pine Island Bayou system and to a much lesser extent the Neches River, east of Silsbee at Highway 96.

These findings have been validated and expanded upon by more recent monitoring efforts (Rizzo *et al.* 2000; see basin highlights at www.lnva.dst.tx.us):

- Water quality in Big Sandy Creek, Turkey Creek, Village Creek, and the Neches River was generally good, but that water quality in Pine Island Bayou was impaired for much of the year.
- Elevated nutrient levels in Pine Island Bayou, primarily nitrates and ammonium that likely came from agricultural practices, led to plankton blooms followed by chronically low levels of oxygen in the water, especially during periods of low water flow. The results also indicated that the chronically low dissolved oxygen condition in the Pine Island Bayou system has worsened over time, and that ammonium concentrations have increased significantly throughout the Preserve since the NPS (1995) report, likely as a result of accelerating agriculture and associated increased use of fertilizers.
- Algal blooms of lesser extent than Pine Island Bayou also occur on the Neches River. However, higher flow through this large alluvial system coupled with considerably lower nitrate and ammonium levels prevent severe lowering of dissolved oxygen.
- U.S. Environmental Protection Agency found concentrations of dioxin exceeding the accepted risk level in fish tissue from the lower Neches River downstream from Evadale (1990).

The Preserve contains three state-designated stream segments: Neches River – 0602; Big Sandy/Village Creek – 0608; Pine Island Bayou – 0607 (Figure 14). All other streams are classified as off-segment and are subject to the same controls as the mainstem segment. Designated uses for stream segments of the Preserve are primarily for contact recreation (*e.g.*, swimming, boating), medium-to-high-quality aquatic habitat for protection of aquatic life and riparian vegetation, and for public water supply. In addition to designated uses, each stream segment has a water quality designation indicating the applicable regulatory framework. This may be either "effluent limited" which indicates that the segment is meeting its designated uses, or "water quality limited" which indicates failure to meet designated uses.

Neches River – Segment 602: Past studies concluded that total dissolved solid concentrations were relatively low (less than 132 mg/L in 50 percent of samples), dissolved oxygen (DO) was generally close to saturation with a median concentration > 8 mg/L, and nutrient concentrations were relatively low (total nitrogen and total phosphorus were < 1.8 mg/L and < 0.2 mg/L, respectively). There were small declining trends in alkalinity and calcium, and a small increasing trend in sulfate concentration (Wells & Bourdon 1985). From 1995, specific conductance and chlorides appear to have decreased, and pH may have experienced a slight increase (NPS 1995).

Seasonally, specific conductance, suspended sediment, and to some extent chloride concentrations alternately increased and decreased over the seasons, with high values in the fall and spring. DO concentrations were highest in the winter; alkalinity appeared to peak in the fall; and sulfate and manganese concentrations seemed to reach the highest levels in the spring (NPS 1995).

Designated uses for Segment 602 are contact recreation, high quality aquatic habitat, and public water supply. There are three permitted discharges along segment 602: two domestic outfalls, and one industrial outfall.

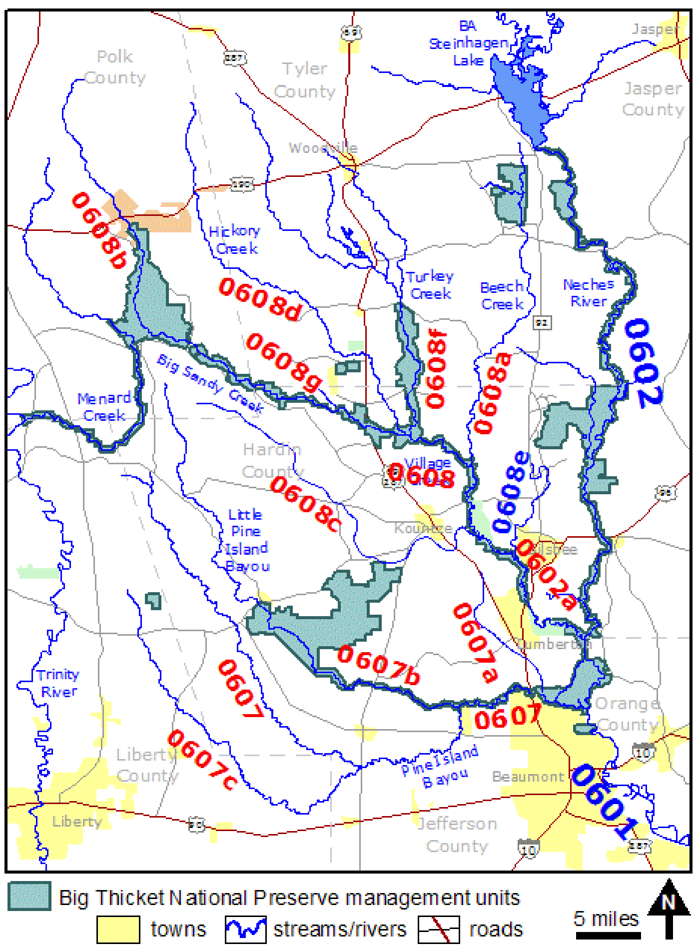


Figure 14. State-designated, stream segment identifiers for Preserve waterways.

EPA water quality criteria levels for zinc, cadmium, copper, and lead have been exceeded in some locations along Segment 602. Specifically, mean cadmium concentrations exceeded the chronic criterion in the river near Silsbee, causing nonsupport of the aquatic life designated use in that area of the river. Both total and dissolved lead exceeded EPA water quality criteria for drinking water in 12% and 56% of the samples, respectively. Additionally, sediments have been shown to be high in arsenic, manganese, mercury, nickel, selenium, and methylene chloride (Texas Natural Resource Conservation Commission 1996).

Big Sandy/ Village Creek – Segment 0608: In 1981 (Flora *et al.* 1985), surface water quality in the Big Sandy/Village Creek watershed was reported as very good. Combined, oxygen and temperature regimes would support a diverse and healthy warm-water aquatic life population. Dissolved oxygen concentrations were consistently above state standards, indicating no substantial organic pollution. Total dissolved solids, specific conductance and chloride concentrations – all indicators of contamination from oil operations – were within a range typical of southeastern Texas streams. Fecal coliform bacteria concentrations ranged from slight to moderate with only a few violations of state water quality standards for contact recreation, with all of these occurring in the upper portion of the watershed. Nutrient levels (ammonium, orthophosphate, and nitrate) were all below levels of concern.

The fish and macroinvertebrate populations indicated that Big Sandy/Village Creek was a healthy and unstressed environment, and as of 1981, there was no evidence that human activities were adversely affecting water quality.

Preliminary screening of TCEQ and USGS data as of 1996 suggested both pH and dissolved oxygen as potential problem parameters within the watershed, and a 1994 basinwide assessment added fecal coliform as a potential problem (Lower Neches Valley Authority 1994; Hall and Bruce 1996). Data from 1978 identify nearly 3,800 residents in the Village Creek Watershed as utilizing individual septic systems. Areas of concentrated use are north of Lumberton, north of Silsbee, Honey Island, Village Mills, Hillister, and Doucette. The cities of Silsbee, Kountze and Woodville utilize wastewater treatment facilities (Hall and Bruce 1996).

Designated uses for Segment 608 are contact recreation, high quality aquatic habitat, and public water supply. As of 1993, this segment contained 17 permitted NPDES wastewater discharges: 10 municipal outfalls and seven industrial outfalls.

Exceedances for EPA water quality criteria include total phosphorus (20 percent of the samples), and a sediment sample exceeded acute criteria for aluminum. Overall, indications are that regional water quality has declined somewhat, with the exception of improvements in turbidity and chlorides.

Pine Island Bayou – Segment 0607: Generally speaking, streams flowing through the Pine Island Bayou watershed are similar to other surface waters in Southeastern Texas in that seasonal flows are variable and total dissolved solids concentrations are relatively low (Flora *et al.*, 1984). In addition to natural factors, land use practices in the watershed have influenced area water quality, generally contributing to its degradation.

Hughes *et al.* (1986) summarized water quality monitoring results from 1975 to 1983, and showed that water quality in Little Pine Island-Pine Island Bayou Corridor Unit was moderately degraded with respect to specific conductance and chloride concentrations. An additional observation regarding water quality is that turbidity in Little Pine Island Bayou varied with discharge, from a low during low flows, to a high during high flows (Harrel and Darville 1978). Turbidity was lowest at the station near Sour Lake, attributed to contamination with oil field brine (saltwater), which precipitates suspended particles. Dissolved oxygen concentrations were frequently low in Little Pine Island Bayou (minimum of 0.3 mg/L); and were lowest in the summer and highest in the winter.

Stream Segments, Uses, and Permits: Segment 607 is water quality limited due to violations of existing water quality standards. Designated uses for segment 607 are contact recreation, high quality aquatic habitat, and public water supply. Since Little Pine Island Bayou is an unclassified tributary to Pine Island, it is an off-segment stretch of Pine Island Bayou with the same designated uses.

There are three NPDES permitted discharges in the water corridor unit for sewage treatment plant effluent from Pinewood Estates, Bevil Oaks and Lumberton. In 1992, eight NPDES municipal wastewater discharge permits and 11 domestic outfalls were recorded for Pine Island Bayou.

The Texas Water Commission (1989) identified dissolved oxygen, pH, and fecal coliform as potential problem areas for water quality. Depressed dissolved oxygen concentrations and elevated fecal coliform counts, which occur primarily during summer conditions when stream flows are low and the water is warmer, have resulted in non-supported designated uses. Specifically, the middle 26 miles of the segment 607, located downstream of Sour Lake wastewater discharge, has not supported high quality aquatic habitat or contact recreation due to depressed dissolved oxygen and fecal coliform (Adsit and Hagen 1978). Sediment samples collected during the intensive survey by the Texas Water Commission at two sites, one in Pine Island Bayou, and the other in Little Pine Island Bayou, were analyzed for pesticides and metals at both sites, and also for PCBs at Little Pine Island Bayou. Survey results indicated elevated levels of arsenic, manganese, and mercury, but no state or federal standards were exceeded.

Water quality of Little Pine Island Bayou was considered the worst in the region throughout its length (Hall and Bruce 1996). Little Pine Island Bayou water quality has long been impacted by saltwater (brine) in the Saratoga and Sour Lake area. An influx of brine into Little Pine Island Bayou, either from existing or abandoned oil field operations, increased specific conductance, chloride concentrations, pH, and TDS, and decreased turbidity and color (Kaiser *et al.* 1993). In July 1985, a pipeline rupture released brine which resulted in exceedingly high specific conductance readings (16,241 micromhos/cm) and a maximum chloride concentration that reached at least 1,400 mg/L in Little Pine Island Bayou. Effects of the spill were studied for 26 months, but persisted beyond that time. Eventually, the brine settled to the bottom of the channel, reducing the specific conductance levels to approximately 2,000 micromhos/cm (Hughes *et al.* 1987).

In 1978, a study determined that Pine Island Bayou complied with the fecal coliform standard of 200 organisms/100 mL less than 50% of the time during the sampling period during high and low flow conditions (Commander 1978). Fecal coliform ranged between 0 to 5,880/100 ml, with spikes observed after heavy rains (Harrel and Darville 1978).

Menard Creek Watershed -- Part of Trinity River Basin: Menard Creek is among a number of creeks in the Preserve that exhibit low alkalinity and turbidity (LNVA 1992). Additionally, total dissolved solids tended to increase on Menard Creek in the downstream direction. Periods of elevated chloride concentrations at Menard Creek have been attributed to contamination by waste brines from the Schwab oil field (Hughes *et al.* 1987).

Seasonal discharge and stream temperatures were similar to those of Little Pine Island Bayou. Dissolved oxygen concentrations tend to be greater than 5 mg/L, but occasionally drop below 4 mg/L which may be a natural occurrence in streams as influenced by high seasonal water temperatures, concurrent low flows, combined with natural organic loading (*e.g.*, decaying vegetation) (LNVA 1992). Bacterial counts were not excessive (*i.e.*, mean of 200 fecal coliform/100 mL), but were somewhat elevated.

Data are not available for Menard Creek from water quality assessment reports published by the Trinity River Authority.

As required under Sections 303(d) and 304(a) of the Clean Water Act, Table 3 identifies the water bodies in the Preserve for which effluent limitations are not stringent enough to implement water quality standards, and for which the associated pollutants are suitable for measurement of total maximum daily loads (TMDL) – the so-called 303(d) listed streams. The TCEQ develops a schedule that identifies TMDLs that will be initiated in the next two years for priority impaired waters. Issuance of permits to discharge into 303(d)-listed water bodies is described in the TCEQ regulatory guidance document *Procedures to Implement the Texas Surface Water Quality Standards* (August 2002, RG-194).

Table 3. The 303(d)-listed streams (defined by stream segment) within the Preserve as of 2008. Within each segment, specific locations (*in italics*) and the associated parameters that do not meet assigned water quality standards are listed. Category 5 generally refers to a water body that does not meet applicable water quality standards or is threatened for one or more designated uses by one or more pollutants. Three subcategories are recognized: category 5a - a TMDL is underway, scheduled, or will be scheduled; category 5b - a review of the water quality standards for this water body will be conducted before a TMDL is scheduled; and, category 5c - additional data and information will be collected before a TMDL is scheduled. Year First Listed is the assessment year that the pollutant or water quality condition in this water body initially did not meet water quality standards.

SegID	**Stream** *Stream Segment*	**Category**	**Year First Listed**
0607	**Pine Island Bayou**		
	Mouth to River Mile 5.7		
	Depressed dissolved oxygen	5b	1996
	River Mile 5.7 to Mile 12.1		
	Depressed dissolved oxygen	5b	1996

	River Mile 12.1 to Mile 35.4 at confluence with Willow Creek (0607C)		
	Depressed dissolved oxygen	5b	1996
	Bacteria	5c	2008
	River Mile 35.4 at confluence with Willow Creek (0607C) to Mile 60.4		
	Depressed dissolved oxygen	5b	1996
	River Mile 60.4 to top of segment at FM 787		
	Depressed dissolved oxygen	5b	1996
0607B	**Little Pine Island Bayou**		
	Lower 25 miles		
	Depressed dissolved oxygen	5b	2000
	Bacteria	5c	2006
0608	**Village Creek**		
	From FM 418 to Lake Kimble dam		
	pH	5b	2000
0608A	**Beech Creek**		
	Lower 20 miles of water body		
	Bacteria	5c	2000
0608B	**Big Sandy Creek**		
	Lower 30 miles downstream of US 190		
	Bacteria	5c	2000
0608C	**Cypress Creek**		
	Entire water body		
	Depressed dissolved oxygen	5b	2000
	Aluminum in water	5c	2004
	Bacteria	5c	2006
0608E	**Mill Creek**		
	Entire water body		
	Depressed dissolved oxygen	5c	2006
0608F	**Turkey Creek**		
	Lower 25 miles of segment		
	Bacteria	5c	2000

Wetland and Riparian Areas

Wetlands represent transitional environments between terrestrial and aquatic systems where the water table is at or near the surface or the land is covered by shallow water (Cowardin *et al*. 1979). Flora within these wetland systems exhibit extreme spatial variability, triggered by very slight changes in elevation. Temporal variability is also great because the surface water depth is highly influenced by changes in precipitation, evaporation and/or infiltration.

Cowardin *et al*. (1979) developed a wetland classification system that is now the standard in the federal government. In this system, a wetland must have one or more of the following attributes: (1) at least periodically, the land supports predominately hydrophytes; (2) the substrate is predominately un-drained hydric soil; and (3) the substrate is non-soil and is saturated with water or covered by shallow water at some time during the growing season of each year.

Natural riparian zones are some of the most diverse, dynamic, and complex biophysical habitats in the terrestrial environment (Naiman *et al.* 1993). The riparian zone encompasses that stream channel between low and high watermarks and that portion of the terrestrial landscape from the high watermark toward the uplands where vegetation may be influenced by elevated water tables or flooding and by the ability of the soils to hold water (Naiman and Decamps 1997). Thus, riparian zones may be classified as wetlands or, at the least, have a significant portion existing as wetland. Riparian zones are key systems for regulating aquatic-terrestrial linkages (Ward 1998) and they may provide early indications of environmental change (Decamps 1993).

Physically, riparian zones control mass movements of materials and channel morphology (Naiman and Decamps 1997). Ecologically, riparian zones: 1) provide sources of nourishment – terrestrial inputs to rivers; 2) control nonpoint sources of pollution, in particular, sediment and nutrients in agricultural watersheds; and 3) create a complex of shifting habitats (both in time and space), through variations in flood duration and frequency and concomitant changes in water table depth and plant succession (Naiman and Decamps 1997).

Wetlands, in general, and riparian habitat, in particular are important ecological components within Big Thicket National Preserve. The U.S. Fish and Wildlife Service's National Wetlands Inventory (NWI) maps for the Preserve have identified approximately 35,000 acres (40 percent of the Preserve) of primarily palustrine and riverine wetlands, and, to a much lesser extent, lacustrine wetlands (NPS 2006; Table 4). The wetland acreage for the Preserve as determined from the NWI maps is probably underestimated. NWI wetland mapping is difficult in large areas with mineral soils, facultative vegetation, and minor topographic relief, conditions similar to those found in the Preserve. The wetland boundaries on NWI maps are estimates because the area of the Preserve was mapped from a single air photograph for each topographic map; photographs taken during each of the seasons may produce different wetland boundaries.

The majority of wetlands in the Preserve are palustrine wetlands that are dominated by trees, shrubs, or persistent emergent vegetation. The palustrine wetlands of the Preserve contain nonwoody aquatic plants such as rushes (*Juncus* spp.), arrowheads (*Sagittaria* spp.), sedges (*Carex* spp.), grasses, vines, pitcher plants and other plants. The palustrine forested and scrub-shrub wetlands are also referred to as riparian wetlands. The forested and scrub-shrub wetlands are characterized by a dominance of woody vegetation including bald cypress, tupelo gum

Table 4. Wetland types (after Cowardin *et al.* 1979) and acreage within Big Thicket National Preserve (modified from NPS 2006). Wetland acres in recently added units to the Preserve are not included in this table.

Wetland Type	Acres in Preserve
Palustrine	31,710
Riverine	3,125
Lacustrine	60
Total	34,895

(*Nyssa aquatica*), black gum (*Nyssa sylvatica*), oaks (*Quercus* spp.), river birch (*Betula nigra*), sweetgum, sweetbay (*Magnolia virginiana*), sycamore (*Plantanus occidentalis*), American hornbeam, baygall holly (*llex coriacea*), red maple (*Acer rubrum*), and red bay (*Persea borbonia*). The wetlands are sustained by a high water table and flooding.

Forests within the floodplain terraces adjacent to the streams are often referred to as the Bottomland Hardwoods. These ecosystems are found wherever streams or rivers at least occasionally cause flooding beyond their channel confines, and are often identified by the presence of flaring trunks and aerial roots. In the Preserve the bottomland forests consist of two types – Floodplain Hardwood Forests and Floodplain Hardwood Pine Forests. Floodplain Hardwood Forest occurs on the low terraces along the Neches River and in strips along Little Pine Island Bayou, Village Creek and its tributaries, and Menard Creek. Floodplain Hardwood Pine Forest occurs along smaller streams.

The riverine wetlands are the wetlands and deepwater habitat within stream channels. The majority of the riverine wetlands lie within the Neches River corridor, including the Jack Gore Baygall and Neches Bottom Unit.

Floodplains

Area topography, soils, and climate all combine to produce a unique flood regime in southeast Texas. The most notable of these factors is the Preserve's proximity to the Gulf of Mexico moisture source, as well as the effects of tropical storms and easterly waves (Patton and Baker 1977). Intense storms result in large magnitude runoff events; however, flood peaks are attenuated by broad flat valleys that produce slow-moving, long-duration floods.

In the southern part of the Preserve, the land surface is nearly level and slopes are generally less than one percent. In addition, the high clay and silt content of soils in the area is a major factor contributing to the accumulation of surface runoff. The problems of poor drainage on flatlands cannot be separated from flooding problems.

Floodplains comprise roughly 50 percent of the Preserve, and most of the Preserve's wetlands are located in floodplains. Similarly, the water corridor units and riparian corridors are located in floodplains and consist primarily of floodplain forests.

Air Quality

The Preserve is designated a Class II area under the Prevention of Significant Deterioration (PSD) provisions of the Clean Air Act (CAA). Although the Preserve does not receive the highest level of protection afforded Class I areas, CAA provisions requiring regulated development of new sources of air pollution, as well as attainment of the National Ambient Air Quality Standards (NAAQS), are applicable and are intended to ensure healthy air for both humans and ecosystems. Despite this protection, air quality is sometimes significantly impaired in the Preserve. Air pollutants from both nearby industrial and urban areas, as well as from more distant regional sources are carried into the area where they cause reduced visibility and unhealthy levels of ozone. Air pollution may also harm aquatic and terrestrial ecosystems in the Preserve.

The Preserve is north of the Beaumont/Port Arthur/Orange airshed and northeast of the Houston/Galveston airshed. Air pollutant emissions from these areas are dominated by volatile organic compounds (VOCs) from vehicles and oil and gas production and refining, and nitrogen oxides (NO_x) from powerplants, vehicles, and industry. VOCs and NO_x combine in the presence of sunlight to form ozone, which is harmful to both human health and vegetation. Air quality is not monitored within the Preserve, but nearby monitors provide data. A monitor at Beaumont, TX, indicates that while ozone concentrations have decreased since the early 1990s (Figure 15), they have remained relatively unchanged from 1998-2007. Both the Beaumont/Port Arthur/Orange airshed and the Houston/Galveston airshed continue to have ozone levels that exceed the NAAQS, currently set at 75 ppb and are classified as ozone Nonattainment Areas. Part of the Preserve is in the Houston Nonattainment Area (Liberty County), while part is in the Beaumont-Port Arthur Nonattainment Area (Jefferson, Hardin, and Orange counties) (Figure 16). The Lake Charles, LA petrochemical complex, a nearby pulp and paper mill, and sources within the Preserve also contribute to air pollution in the area.

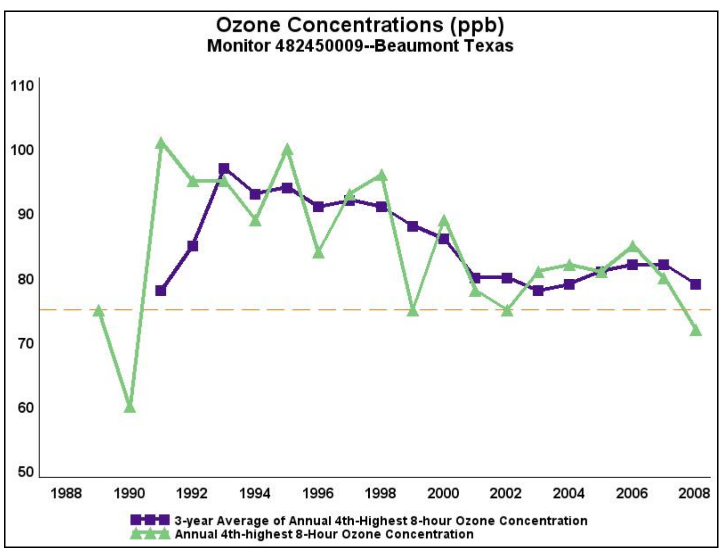


Figure 15. Trends in ozone concentrations, Beaumont TX. The ozone standard, currently set at 75 ppb, is expressed as the 3-year average of the annual 4th highest 8-hour ozone concentration.

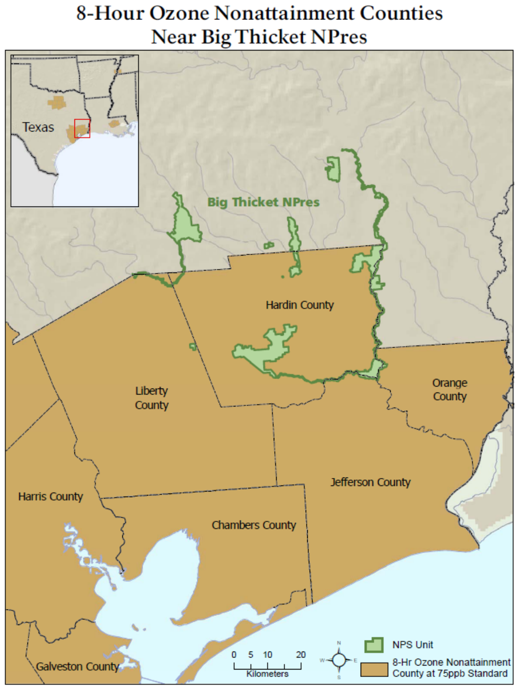


Figure 16. Map showing location of Big Thicket National Preserve and counties designated nonattainment for the ozone standard.

Recently available scientific information indicates that the current primary and secondary ozone standards of 75 ppb are not sufficiently protective of human health or welfare. In January 2010, the U. S. Environmental Protection Agency (EPA) proposed strengthening the standards, revising the “primary” standard to protect public health to a value in the range of 60-70 ppb. The State of Texas will be required to develop more stringent emissions control strategies to meet the new standard. EPA also proposed establishing a distinct “secondary” standard to protect sensitive vegetation and ecosystems. The secondary standard would be expressed as a cumulative index that is considered more biologically relevant than the 8-hour average used for the primary standard.

Ozone has been shown to reduce growth, reproduction, and water use efficiency in plants, as well as causing visible injury like stippling or bleaching (U. S. Environmental Protection Agency 2007). Common trees in the Preserve sensitive to ozone include *Liquidambar styraciflua* (sweetgum), *Sassafras albidum* (sassafras), *Pinus taeda* (loblolly pine), and *Fraxinus pennsylvatica* (green ash). A more complete list of ozone-sensitive vegetation in the Preserve is available from the NPSpecies Database. Although vegetation in the Preserve has not been evaluated for ozone injury, a 2004 assessment concluded that the risk of ozone injury to vegetation in the Preserve was high (Kohut 2007).

Fine particulate matter ($PM_{2.5}$) is formed when gases like NO_x and SO_2 transform to nitrates and sulfates in the atmosphere. In addition, carbon, ammonium, organics, dust, and heavy metals contribute to $PM_{2.5.}$ In 1996, $PM_{2.5}$ was monitored in the Preserve as part of a special study by the Texas Council on Environmental Quality, NPS, and Mexico to increase understanding of the transport of pollution to the Big Bend area of Texas. Of the 18 sites monitored during a two-month period on both sides of the U. S. – Mexico border, the Preserve exhibited the highest levels of $PM_{2.5}$. $PM_{2.5}$ contributes to haze, which reduces how far and how well one can see, as well as causing respiratory problems. Preliminary results showed that air arriving at Big Bend National Park from the Big Thicket area contained some of the highest levels of $PM_{2.5}$ of the study sites.

Biological Resources

Biological resources include the commonly referenced wildlife and vegetation. Stated more clearly, and scientifically, these resources include genes, species, and biological communities (assemblages of species). Biological resources are best placed in a management context through ecological settings. These can include the health and fitness of individual organisms in response to environmental conditions, competition and other interactions among species themselves, the response of populations to management within specific geographic boundaries, and the patterning of communities across landscapes in response to physical site conditions and abiotic processes such as floods and fire. The latter plays a significant part in defining "the Thicket" as an extraordinary ecological system. Normally, baseline information in the form of species inventories would be presented here. In the case of the Preserve, several older inventories have been conducted, but will only be summarized because the Preserve is in the process of conducting an All-Taxa Biological Survey (ATBI) that will improve on the depth of older surveys through updated collection and sampling techniques, and the breadth of older surveys by comprehensively addressing a wide range of taxa, including invertebrates.

A report on Preserve natural resource information provides a baseline (Cooper *et al*. 2004) for developing work in inventory, monitoring and planning. Excerpts from Cooper *et al.* are presented below. The entire report can be found at (http://science.nature.nps.gov/im/units/guln/docs/NRS/BITH_finalreport.pdf).

The area in and adjacent to the Preserve is characterized by diverse habitats due to high precipitation, warm temperatures and geologic, soil, and water gradients. These present conditions for species from three converging ecosystems: the eastern hardwood forest, the Gulf coastal plains, and the Midwest prairies. The Preserve has been designated as an International Biosphere Reserve, in part, for the genetic stock of its varied biological resources. The Preserve also has been designated as a Globally Important Bird Area by the American Bird Conservancy.

The plant communities and vegetation types found in the Preserve have been documented and described in many reports. These studies varied in focus from general diversity and community structure to documentation of new species for the area, and have been conducted in the Big Thicket region as well as the Preserve. The Preserve is composed of five main forest types with subcategories within -- upland pine forest (pine sandhill, pine forests, pine savanna wetland), slope forest (upper slope pine oak, mid-slope oak pine, lower slope hardwood pine), floodplain forest (stream floodplain forest, river floodplain forest, cypress-tupelo swamp), flatland forest (flatland hardwood pine, flatland hardwood), and baygalls. Various classification frameworks have been applied to assessing vegetation, and efforts are now being made by both the NPS and State of Texas to develop classification products (including maps) of vegetation. Fuel classifications for wildland fire management are also available, but products are still being adapted to new fuel model classifications. Preserve managers do have current information on major system-level terrestrial resources *via* the Land/Fire program. These systems and rare communities, listed below, provide managers with the knowledge to distinguish systems and to address specific information and management needs of those resources.

Ecological Systems

Matrix Systems[1]:

- West Gulf Coastal Plain Upland longleaf pine forest and woodland
- Gulf and Atlantic Coastal Plain floodplain systems
- West Gulf Coastal Plain longleaf pine savanna and flatwoods
- West Gulf Coastal Plain pine-hardwood forest

[1] Matrix -- Communities or systems that form extensive and contiguous cover, occur on the most extensive landforms, and typically have wide ecological tolerances.

Large Patch Systems[2]:

- West Gulf Coastal Plain pine-hardwood flatwoods
- West Gulf Coastal Plain seepage swamp and baygall
- West Gulf Coastal Plain mesic hardwood forest
- West Gulf Coastal Plain southern calcareous prairie
- Gulf and Atlantic Coastal Plain swamp systems

[2] Large Patch -- Types that form large areas of interrupted cover and typically have narrower ranges of ecological tolerances than matrix types. In contrast small patches are types that form small, discrete areas of vegetation cover typically limited in distribution by localized environmental features.

Linear Systems[3] (Note: Some of these areas also classified as Large Patches):

- Gulf and Atlantic Coastal Plain floodplain systems
- Gulf and Atlantic Coastal Plain small stream riparian systems
- Gulf and Atlantic Coastal Plain swamp systems
- West Gulf Coastal Plain stream terrace sandyland longleaf pine woodland
- West Gulf Coastal Plain upland longleaf pine forest and woodland
- West Gulf Coastal Plain flatwoods pond
- West Gulf Coastal Plain large river floodplain forest
- West Gulf Coastal Plain near-coast large river swamp
- West Gulf Coastal Plain nonriverine wet hardwood flatwoods
- West Gulf Coastal Plain small stream and river rorest
- West Gulf Coastal Plain herbaceous seepage bog

[3]Linear -- Types that occur as linear strips and are often ecotonal between terrestrial and freshwater ecosystems.

Vulnerable Biological Communities

For the biological communities below Global or G-ranks are designations that reflect both the unique nature and status:

G1 species have fewer than 6 occurrences worldwide and are critically imperiled;
G2 species have 6-20 occurrences worldwide and are imperiled and vulnerable to extinction throughout its range; G3 species have 21-100 occurrences worldwide and are either rare and local throughout their ranges or found locally in a restricted range (a single state or ecoregion), or having other factors making it vulnerable to extinction throughout its range.

- *Bigelowia nuttallii - Krameria lanceolata - Aristida dichotoma -Sporobolus silveanus* Herbaceous Vegetation (East Texas Catahoula Barrens) G1
- *Fagus grandifolia - Magnolia grandiflora - Quercus alba / Carpinus caroliniana - Ostrya virginiana - Ilex opaca var. opaca* Forest G1?
- *Fagus grandifolia - Magnolia virginiana - (Pinus palustris) / Chasmanthium sessiliflorum* Sandhill Streamhead Forest G2G3
- *Fagus grandifolia - Quercus alba / Acer (barbatum, leucoderme) / Solidago auriculata* Forest G2G3
- *Fraxinus caroliniana* Seasonally Flooded Forest G2G3?
- *Magnolia virginiana - Nyssa biflora - Acer rubrum – Liquidambar styraciflua / Myrica heterophylla* Forest G2G3?
- *Panicum hemitomon - Gratiola brevifolia Herbaceous Vegetation? G2G3?*
- *Pinus palustris - Quercus stellata - Quercus incana / Tetragonotheca ludoviciana* Woodland G2
- *Pinus palustris / Eryngium integrifolium - Rhynchospora spp. - (Ctenium aromaticum)* Woodland G2G3
- *Pinus palustris / Quercus incana - Quercus margarettiae / Vaccinium arboreum / Cnidoscolus texanus - Stylisma pickeringii* var. Pattersonii Woodland G2G3
- *Pinus palustris / Quercus incana / Schizachyrium scoparium – Croton argyranthemus* Woodland G2G3
- *Pinus palustris / Quercus incana / Schizachyrium scoparium – Liatris elegans - Opuntia humifusa var. humifusa* Woodland G1?
- *Pinus palustris / Quercus marilandica / Ilex vomitoria / Schizachyrium scoparium* Woodland G2
- *Pinus palustris / Quercus marilandica / Schizachyrium scoparium - Silphium laciniatum - Ruellia humilis* Woodland G1
- *Pinus palustris / Quercus marilandica / Schizachyrium tenerum - Muhlenbergia expansa - Bigelowia nuttallii* Woodland G1
- *Pinus palustris - Quercus stellata - Quercus marilandica - Carya texana / Tragia urens* Woodland G2
- *Pinus palustris / Rhynchospora elliottii - Lobelia flaccidifolia - Platanthera nivea - (Helenium drummondii)* Woodland G2G3
- *Pinus palustris / Schizachyrium scoparium - Bigelowia nuttallii / Cladonia* spp. Herbaceous Vegetation G1G2
- *Pinus palustris / Schizachyrium scoparium - Rudbeckia grandiflora var. alismifolia* Woodland G2G3
- *Pinus palustris / Schizachyrium scoparium - Schizachyrium tenerum - Silphium gracile* Woodland G2
- *Pinus palustris / Schizachyrium scoparium - Liatris pycnostachya* Woodland G2G3

- *Pinus taeda - (Pinus echinata) - Quercus alba - Carya alba / Acer barbatum - (Acer leucoderme)* Forest G2G3
- *Quercus alba - Quercus nigra /Ostrya virginiana / Sabal minor* Forest (Upper West Gulf Coastal Plain Subcalcareous White Oak - Dwarf Palmetto Forest) G2G3
- *Quercus laurifolia - Quercus phellos - Quercus nigra / Sabal minor - Sebastiania fruticosa* Forest G2G3?
- *Quercus phellos - Quercus nigra / Viburnum dentatum - (Sebastiania fruticosa) / Carex glaucescens* Upper West Gulf Flatwoods Forest G2G3
- *Quercus pagoda - Liquidambar styraciflua / Ulmus crassifolia – Celtis laevigata / Carex* cherokeensis Forest G2G3
- *Quercus stellata - Carya texana - (Pinus palustris) / Chasmanthium sessiliflorum - Ranunculus fascicularis* Woodland G1
- *Rudbeckia missouriensis - Grindelia lanceolata - (Liatris mucronata)* Herbaceous Vegetation G1
- *Sarracenia alata - Rhynchospora gracilenta - Rudbeckia scabrifolia - Schoenolirion croceum* Herbaceous Vegetation G2G3
- *Schizachyrium scoparium Taxodium distichum* West Gulf Coastal Plain Lakeshore Woodland G2G3?

Species

Current species lists (include some historic and unconfirmed records) that are certified for park and Gulf Coast Inventory and Monitoring Network use include (with number of species):

Amphibians	(30)
Birds	(306)
Fish	(111)
Mammals	(67)
Reptiles	(59)
Plants	(1346)

Vulnerable Species

While NPS policy avoids species-specific approaches to management, sometimes certain species require attention. Examples of such species include those known to be rare or imperiled; declining; narrowly endemic to the park and surroundings; of widely disjunct distribution; as well as, migratory species with specific vulnerabilities to habitat fragmentation. Still, other species should be addressed individually because they play critical ecological roles (such as connecting food webs; or as triggers to characteristic disturbance processes). Species that may warrant additional management attention are listed below:

Federally listed species currently known in the Preserve are:

Bald eagle	*Haliaeetus leucocephalus*	Delisted/Monitored
Piping plover	*Charadrius melodus*	Threatened
Wood stork	*Mycteria americana*	Endangered
Brown pelican	*Pelecanus occidentalis*	Endangered
Texas trailing phlox	*Phlox nivalis texensis*	Endangered

Louisiana black bear	*Ursus americanus luteolus*	Threatened
Louisiana pine snake	*Pituophis ruthveni*	Candidate
Red wolf	*Canis rufus*	Endangered
Red-cockaded woodpecker	*Picoides borealis*	Endangered

State threatened species include:

Bachman's sparrow	*Aimophila aestivalis*
Swallow-tailed kite	*Elanoides forficatus*
American peregrine falcon	*Falco peregrinus anatum*
White-faced ibis	*Plegadis chihi*
Blue sucker	*Cycleptus elongatus*
Creek chubsucker	*Erimyzon oblongus*
Paddlefish	*Polyodon spathula*
Rafinesque's big-eared bat	*Corynorhinus rafinesquii*
Northern scarlet snake	*Cemophora coccinea copei*
Timber/Canebreak rattlesnake	*Crotalus horridus atricaudatus*
Alligator snapping turtle	*Macrochelys temminckii*
Texas horned lizard	*Phrynosoma cornutum*
Louisiana pigtoe	*Pleurobema ridellii*
Sandbank pocketbook	*Lampsilis satura*
Southern hickorynut	*Obovaria jacksoniana*
Texas heelsplitter	*Potamilus amphichaenus*
Texas pigtoe	*Fusconaia askewi*
Triangle pigtoe	*Fusconaia lananensis*

Rare species known to the Big Thicket region are:

<u>Animals</u>

Louisiana pine snake	(*Pituophis ruthveni*) G2?
Louisiana black bear	(*Ursus americanus luteolus*) G5T2
Blackbelted crayfish	(*Procambarus nigrocinctus*) G1G2
Southern hickorynut	(*Obovaria jacksonia*) G2
Big Thicket emerald dragonfly	(*Somatochlora margarita*) G2
Hiliard's toothpick grasshopper	(*Achurum hilliardi*)

<u>Plants</u>

Chapman fringed orchid	(*Platanthera chapmanii*) G2
Long-sepaled dragon-head	(*Physostegia longisepala*) G2G3
Navasota false-foxglove	(*Agalinis navasotensis*) G1
Nodding yucca	(*Yucca cernua*) G1
Panicled indigobush	(*Amorpha paniculata)* G2G3
Small-headed pipewort	(*Eriocaulon koernickianum*) G2
Texas screwstem	(*Bartonia texana*) G2
Texas trailing phlox	(*Phlox nivalis* var. *texensis*) G4T2

Texas trillium (*Trillium texanum*) G2
White firewheel (*Gaillardia aestivalis* var. *winkleri*) G5T2

Aquatic Biology

Cooper *et al*. (2004) stated that little documented information exists on the herpetofauna of the Preserve. The one general survey is dated (> 30 years old); it documented 54 species of herpetofauna. NPS (1996) stated that 92 herpetofaunal species could occur in the Preserve.

Several additional studies (*e.g.*, Ford 1996; Irwin and Dixon 1996; Rudolph *et al*. 2003) have studied the ecology and distribution of reptilian species or groups of species in the Preserve area but there have been no individual studies on amphibian species in the Preserve. Aside from Lewis *et al*. (1999; 2000) studies on Big Sandy Creek that documented 40 species, there have been no recent herpetological surveys. Cooper *et al.* (2004), based on the estimates of others, stated that 85 species could exist in the Preserve. Snakes represent the most diverse group with over one-half of the Texas species inhabiting the Preserve.

Conner (1977) stated that the fish fauna of the closely associated Sabine and Neches river systems is the richest of all western Gulf of Mexico drainages between the Mississippi and Rio Grande drainages. Nine fishes reach their apparent southwestern range terminations in these drainages.

Suttkus and Clemmer (1979) conducted surveys during 1971 and 1977-1979 and documented 85 species of fish in the Preserve. Species lists were developed for each of the waterways. Suttkus (1982) documented 45 fish species from the Preserve for a 1982 sampling period. More recently the NPS (2000) declared a total of 92 species of fish in the waters of the Preserve.

Hubbs *et al.* (1996) examined the changes that occurred in the Big Thicket fish community since 1953. They found that the species existing within the various streams were very similar to one another but varied drastically from those of the Edwards Plateau in Central Texas. Changes that occurred were attributed to dredging, impoundments and hypolimnetic reservoir discharges.

Harcombe (1996) and Harcombe and Callaway (1997b) documented two state threatened species of fish, creek chubsucker (*Erimyzon oblongus*) and blue sucker (*Cycleptus elongates*) and one state endangered and federal species of concern, paddlefish (*Polyodon spathula*) in the Preserve.

Cooper *et al.* (2004) itemized studies that included fish for individual units of the Preserve, including Neches River, Village Creek, and Big Sandy Creek.

Moring (2003) most recently collected over 4,800 fish representing 68 species at 15 stream sites in the Preserve during 1999-2001. This study establishes benchmark biological monitoring at 15 sites throughout the Preserve to assess baseline biological conditions in streams and to supplement historical and ongoing water quality monitoring at these sites. Minnows (Cyprinidae) were the most abundant group. Four blue suckers were collected in a higher-gradient section of the Neches River in the tailwaters of the Steinhagen Lake Dam. Most fish species were from the downstream Neches River reach to the Neches River in the Beaumont Unit near Beaumont. The least number of fish species occurred in two Menard Creek reaches.

Abbot *et al.* (1997) stated that the waters of the Preserve represent the western distributional limit for several aquatic invertebrates and contain a diverse assemblage of rare aquatic fauna. The Big Thicket area with its unique habitats, is home to nearly half (249 species) of the 511 species of Ephemeroptera (mayflies), Odonata (dragonflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) presently known to occur in Texas. Three species in these groups are endemic to the Big Thicket region and several species, especially Trichoptera are endemic to the entire western Gulf Coastal Plain area.

Cooper *et al.* (2004) determined that a number of studies have examined the aquatic invertebrates of the Preserve-- these studies have documented 151 taxa in Village Creek; 172 in Beech Creek; 125 in Menard Creek; 107 in Turkey Creek; and, 171 in Big Sandy Creek. According to the Preserve oil and gas management plan (NPS 2006), 249 species of aquatic invertebrates have been documented during comprehensive surveys in the Village Creek drainage.

Many studies have examined the water quality within the Preserve by assessing the benthic macroinvertebrate community (*e.g.*, Harrel and Darville 1978; Flora *et al.* 1985; Barclay and Harrel 1985). Others conducted water quality surveys sampling for benthic macroinvertebrates for particular units/waterways: Village Creek (Lewis and Harrel 1978; Turkey Creek Unit (Commander 1980); Neches River (Harrel 1975; Harrel and Hall 1991); Beech Creek (Harrel 1976; Menard Creek (Bass 1979; Bass and Harrel 1981); Little Pine Island and Pine Island Bayous (Harrel and Darville 1978; Darville Harrel 1980); and Big Sandy Creek Unit (Harrel and Newberry 1981; Newberry 1982). Generally speaking these studies found a diverse benthic fauna with high water quality but some results indicated a moderately stressed benthic community.

Most recently, Moring (2003) collected a total of 9,238 benthic macroinvertebrates that make up 301 unique taxa among 14 reaches in the Preserve sampled for invertebrates -- 242 were aquatic insects, and 59 were non-insect taxa. The most frequently collected insect was the riffle beetle (*Stenelmis* spp). Of the 10 most commonly collected taxa, six were midges of the Chironomidae. The aquatic insect community proved to be more variable and dissimilar than the fish communities in the same 14 reaches. A Village Creek site had the largest number of aquatic insect taxa and the Neches River below Steinhagen Dam had the fewest number of taxa. Futhermore, Moring found that the benthic communities were not significantly correlated with land use or habitat.

Moring (2003) assessed ecological health using the benthic macroinvertebrate-based Ephemeroptera, Plecoptera, and Trichoptera (EPT) index. This commonly used index is sensitive to changes in water quality and is less variable seasonally and perennially than other metrics. The EPT index was largest for a Neches River reach and smallest for a Little Pine Island Bayou reach – one of two waterbodies in the Preserve that is on the State 303(d) impairment list.

Howells (1997) described the status of freshwater mussels (Unionidae) found in the Big Thicket region, broadly defined. He found that 42 of the 52 species found in Texas have been documented in the Big Thicket. For the Neches River system he reported 35 species with two of those introduced. Several of these species (8) were rare and classified as endangered, threatened or of special concern by the American Fisheries Society. Howells *et al*. (1999) surveyed the mussels in Steinhagen Reservoir. Steinhagen Reservoir and the Neches River immediately downstream of Town Bluff Dam support one of the most abundant and diverse unionid assemblages remaining in Texas. Village Creek contained a significant unionid population (Strecker 1931) which endured until at least 1980 (Vidrine 1990). A resurvey in 1996 found at least eight species at five locations still surviving in Village Creek. Historical pollution in Pine Island Bayou reportedly reduced bivalve populations in the past (Harrel 1993) and very few living unionids were found in 1994.

Hobbs and Whiteman (1987) described a new crayfish found in the Neches River. Hobbs (1990) examined crayfish within the Neches River and described three new species.

In 2006 the Preserve and the Big Thicket Association (BTA) founded the Thicket of Diversity All Taxa Biodiversity Inventory (ATBI). This partnership program brings together taxonomists, volunteers, and data managers to document and inventory taxonomic groups that have often been understudied, plus conduct contemporary inventories of previously surveyed groups. Projects currently underway include vascular plant inventories of newly acquired lands, pyrenomycetous fungi, parasites of aquatic ectotherms, aquatic true bugs, bryophytes, and tardigrades.

Fundamental Natural Resources and Values

It is important for NPS units to identify the fundamental resources and values critical to achieving the park's purpose and maintaining its significance. The reasons for identifying fundamental and other important resources and values are:

1) To define and understand the most important resources and values that support the park's purpose and significance. If these resources and values are degraded or eliminated, they then jeopardize the park's purpose and significance.
2) To ensure that the park and public understand the key elements that sustain the park's purpose and significance.
3) To help planning and management activities focus on larger issues and concerns regarding protection of those resources and values that support the park's purpose and significance.
4) To facilitate development of alternative management concepts by estimating how they will influence the fundamental resources and values of the park.
5) To become the building blocks in creating a future vision and management strategy for the park while being responsive to the park's needs.

During the workshop in August, 2008, the following fundamental resources and values were identified for the Preserve: 1) Cultural Resources; 2) Visitor Experience; 3) The Thicket; 4) Scientific Value; 5) Scenic Resources; and 6) Flowing Water and Associated Dependent Systems. The identification of these fundamental resources and values at the Preserve helps ensure that all planning is focused on what is truly most significant about the Preserve. For every fundamental or other important resource and value, some basic analysis is needed to identify current conditions and potential threats, the level of stakeholder interests, and existing policy and planning guidance. This analysis is needed to identify basic management strategies that are in place and to identify issues to be addressed in a GMP process or possibly another planning process. In the following sections, the analysis for those natural resource-based fundamental resources and values identified in the August, 2008 workshop (*i.e.*, The Thicket; Scientific Value; Flowing Water and Associated Dependent Systems) will answer the following questions:

1) What is the importance of these fundamental resources and values?
2) What are the current state or conditions and the related trends of these fundamental resources and values?
3) What are the current and potential threats to these fundamental resources and values?
4) Who are the stakeholders who have an interest in these fundamental resources and values?
5) Which laws and policies apply to these fundamental resources and values, and what guidance do the laws and policies provide?

Fundamental Resource: Flowing Water and Associated Dependent Systems

The opening paragraph of the enabling legislation for the Preserve does not contain any direct reference to aquatic or hydrologic terminology. In fact, the only inclusion of water-oriented language in the entire enabling legislation is the use of the terms "stream corridor" and "stream banks," but in both instances those terms are invoked from a geodetical standpoint, as reference markers delineating the boundaries of the Preserve.

However, the Preserve contains 240 miles of riparian waterways -- many of which are destinations and pathways for visitors to enjoy by foot or boat. Even to the casual visitor whose experience is limited to the visitor center, water is showcased as a major, if not central, force in shaping the unique ecology and diversity of the Big Thicket, and serving as a geographic unifier for the Preserve as well. Water has clearly served as a primary interpretive and outreach theme for showcasing the Preserve to the public since its establishment. In particular, riverways are highlighted for their ecological and historical role in 'the thicket.' Hence, despite only an insignificant reference to water-oriented terminology in the narrative portion of the Preserve's enabling legislation, water is a dominant and unifying theme of Big Thicket National Preserve.

What is the Importance of Flowing Water and Associated Dependent Systems to the Preserve?

The presence and rate of flowing water in the Preserve is most simply explained as a balance between rainfall and evapotranspiration.

A relative even spread of rainfall throughout the year belies a distinct seasonal regime of flowing water in the Preserve's riparian corridors (Figure 17). River and stream waters typically rise to a winter peak and recede during the summer into a fall baseflow condition on an average-annual basis, despite slightly higher rains in the summer and fall period.

This seasonal trend is reflective of the significant role that evapotranspiration plays in the region. Absent evapotranspiration, winter rains are more likely to recharge the shallow ground water and augment river/stream flows. Similar quantities of rain in the late spring and summer either directly evaporate or fuel the rapid vegetation growth that is characteristic of the Big Thicket.

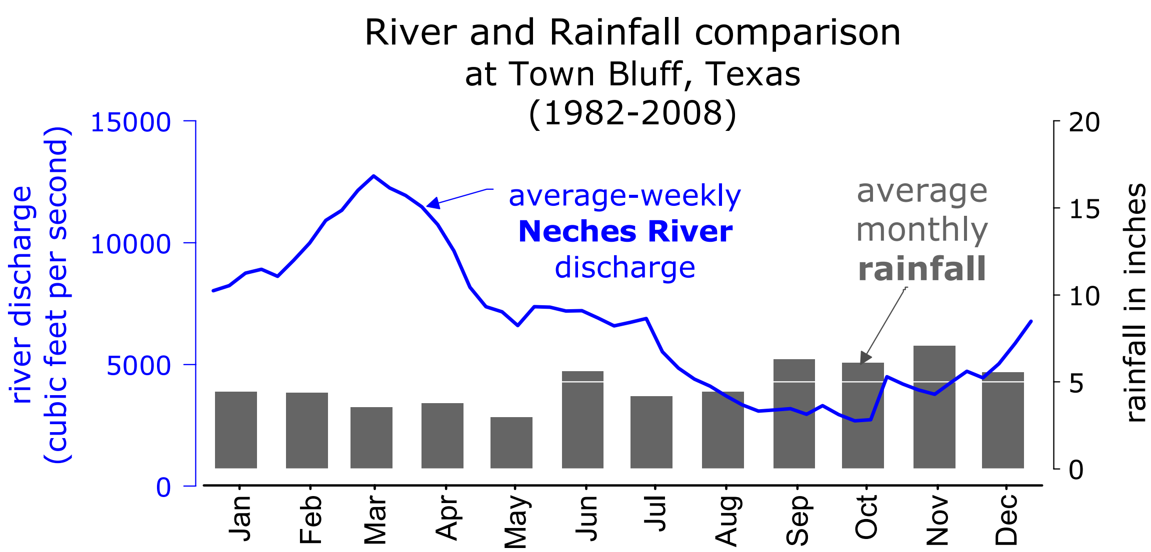


Figure 17. Comparison of average weekly discharge in the Neches River and average monthly rainfall at Town Bluff, TX (1983-2008).

Prolonged absence of rain or its short-term abundance can interrupt or enhance the seasonal balance between evapotranspiration and rainfall. Rainless summers hasten the desiccation of vegetation, expose wetland flats, parch floodplains, and reduce stream flows. Torrential downpours any time of the year can result in sudden and dramatic flow and stage spikes in local creeks, which combined with the region's relatively poor drainage, can lead to severe flooding. The data from the Town Bluff rain gage underscores the prevalence of drought and flood years: it averaged 55 inches of annual rain from 1982-2007, but for eight of those years it either exceeded 70 inches of annual rain or fell under 45 inches (see Figure 12).

It is a seasonal pattern of the abundant rainfall coupled with extended dry periods and unpredictable and torrential rain – and the region's associated high temperatures and humidity that fuels the rapid growth and decay of the Big Thicket's dense floodplain vegetation – which in turn sets the stage for the waters that flow through the Preserve's stream channels and on to its floodplains (Figure 18).

Perhaps the most defining characteristic and process of all the waterways in the Preserve are the floodplain/riparian areas and the associated flood pulse.

Floodplains include the broad, flat terraces between the bluffs of the Neches River and along some of the major streams. Floodplain Hardwood Forest occurs on low terraces along the Neches River in strips along Pine Island Bayou, Village Creek and its tributaries, and Menard Creek. This forest type is dominated in the overstory by sweetgum and water oak, often with a dense subcanopy layer formed by the small ironwood tree. Smaller stream floodplains support Floodplain Hardwood Pine Forest, with American beech and loblolly pine as important dominants, but also containing ironwood (*C. caroliniana)* as an important subcanopy tree. Swamp Cypress Tupelo Forest occurs in deep sloughs and oxbow lakes of major floodplains and

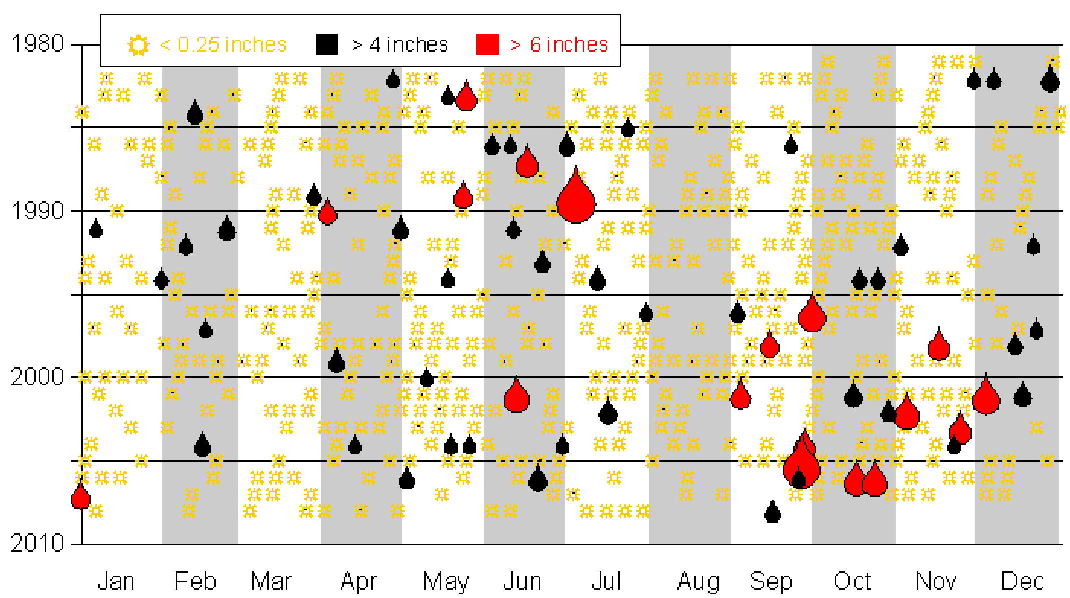


Figure 18. Calendar graph of weekly rain recorded at B.A. Steinhagen Reservoir depicting extreme flood and drought events, 1981- present. Weekly rainfall totals are coded by color (yellow, black, and red) and size.

is dominated by bald cypress and water tupelo. Wetland Baygall Shrub Thicket occurs at all physiographic positions, including floodplains, slopes, and uplands. This type forms in response to the presence of near-surface seepage water (subsurface drainage). Dominant species include black tupelo, laurel oak, red maple, and sweet bay. Floodplain Hardwood Forest is the predominant corridor type. This forest type is most frequently referred to in the scientific literature as Bottomland Hardwood Forest.

The rise and fall of river stage and flow sets the rhythm of the Preserve's floodplain habitats: its bottomlands, the cypress sloughs, and the baygalls (Figure 19). It happens along all the creeks of the Preserve, but is most pronounced and at a larger scale along the main stem of the Neches. Water stage and flow, sediment load within the water column, and its flooding duration and seasonal timing all play important roles in maintaining the structure and function of the riparian corridor. Plants and animals that live in the river and floodplain have adapted to routine floods and the rhythm of soaking and drying out.

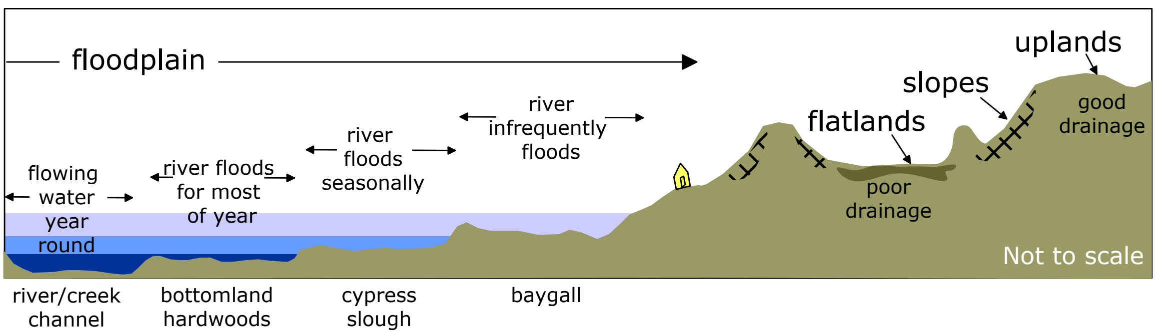


Figure 19. Cross-sectional view of the floodplain along riparian corridors of Big Thicket National Preserve.

Low ridges, backwater sloughs, oxbow lakes, and terraces break up the overall flatness of the floodplain. It is these slight changes in the topography of the floodplain, coupled with the magnitude of the flood pulse that are key determinants to the ecology of the riparian corridor.

Closest to the river's edge is the bottomland forests. Water moves quickly in and out of the bottomlands, scouring the forest floor and leaving it with a sparse under story. The closed canopy filters sunlight, further discouraging ground cover.

Slightly higher in the floodplain are the swamp forests of cypress and tupelo trees, commonly called cypress sloughs. The sloughs retain water for most or all of the year, but regular flooding flushes away organic debris preventing cypress sloughs from becoming acidic.

Bogs or seeps occur where water sinks through porous sandy soils and then hits an impermeable clay layer causing water to seep out to the surface. Leaching of the saturated soils creates acidic conditions. These acid bogs or acid seeps are usually open, grassy and rich in plant species, including the four kinds of carnivorous plants that occur in Texas.

Where conditions are right, seep-fed creeks that drain bogs flow into forested swamps thick with evergreen shrubs (hollies and magnolias) – the baygalls. Baygalls are the highest-perched of the floodplain wetlands, but are considered a low-lying feature relative to the sandy uplands. River water infrequently floods into baygalls, where it sits there like a bowl. Often found at the outermost reaches of the floodplain, baygalls may also receive ground water inflow from adjacent uplands or spring seepage from the base of adjacent terraces. Whatever its source, water sits in a baygall until it dissipates through evaporation or gradual lowering. The largest baygalls are located in the Neches Bottom and Jack Gore Baygall units.

Wetland savannas or wet grasslands occur on claypan soils (Montgomery Formation) that trap rainwater but dry out in the summer, creating unique conditions. In such wetland savannas, stands of longleaf pines grow with evergreen shrubs, sedges and grasses, orchids, and carnivorous plants. These wetland savannas combine flatter terrain with lower elevation and include the highest numbers of plant species measured in any natural community in Texas (www.texasep.org/cpft/etbogs.html) – they are one of the rarest types of habitat in Texas.

Riparian corridors within the Preserve exhibit unique characteristics as a function of local hydrographic and geologic influences. As a result they show regional differences across the Preserve:

- Sloughs are most common and wetter in the southern part of the Preserve, and may become subject to some degree by tides and freshwater ponding behind tidal structures;
- Cypress sloughs become more expansive and deeper along the southern portion of the Neches;
- The palmetto-hardwood flat is a unique floodplain type found almost exclusively in the Pine Island Bayou and Little Pine Island Bayou units. Its terrain is level and floods frequently and its soil is the impermeable clay of the Beaumont Formation. It floods for most of the year, but incredibly poor drainage resulting (from its placement on the impermeable clay) means evaporation is its only outlet, giving it fewer flowering plants than in other better drained floodplains;
- Larger rivers that originate in the continental interior frequently carry high amounts of suspended sediments, and are therefore turbid, chocolate-brown in color, and high in conductivity. There rivers are often referred to as alluvial or brown-water rivers; and,
- Smaller streams that originate within the outer coastal plain are termed blackwater streams due to a high concentration of organic acids in the water and low turbidity.

Floodplain ecology is dependent on the quantity, timing, and duration of various stages of flood pulses (Figure 20), and in particular the dynamic interaction between the water and the natural in-stream and floodplain woody structure, such as snags and other fallen debris, and water quality.

The riparian flood pulse is a fundamental hydrologic process to the Preserve. Researchers at the University of North Texas and Rice University are studying the effects of hydrologic changes in flood pulses along the Neches River that have occurred as a result of the upstream dams. They hope to determine the effects of these hydrologic changes on the vegetation communities and the overall organic carbon budget along the Neches River floodplain – important research, as there are several proposals for more dams upstream of the Preserve. See Appendix A for further discussion of the flood pulse concept and other unifying concepts in river ecology.

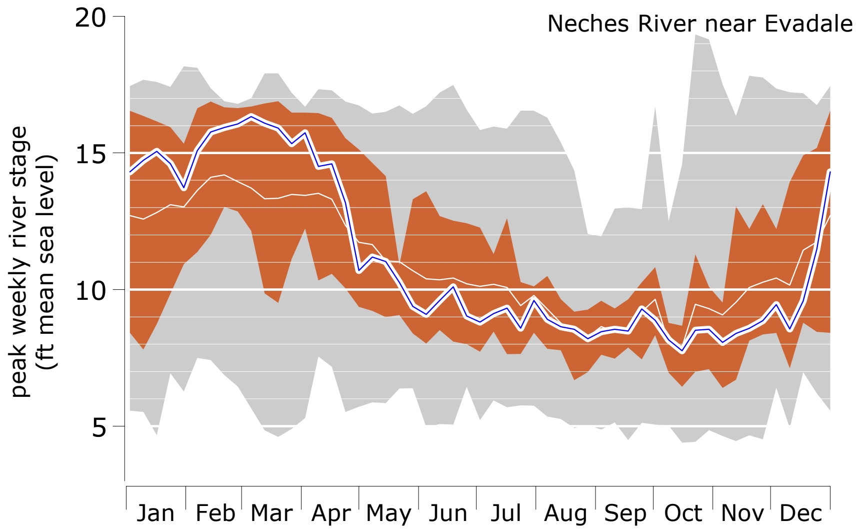


Figure 20. Peak weekly stage of Neches River near Evadale, 1995-2007. Gray encloses maximum and minimum, the red band encloses the 25th and 75th percentiles, the blue line shows the median weekly peak stage, and white line shows average weekly peak stage.

As an example of the above research, Stamatis (2007), compared the abundance of total organic carbon (TOC), dissolved organic carbon (DOC), and particulate organic carbon (POC) in the Neches River and associated waters of its floodplain. She found: 1) a distinct seasonal pattern in the DOC and POC values did not emerge; 2) organic carbon levels generally increased as discharge increases; and 3) longitudinal (upstream-downstream) and horizontal (river through floodplain) differences in organic carbon. Based on her data, she recommended that a flood pulse structure be replicated in the Neches River dam releases. Such a structure would allow organic matter to accumulate within the forest floor during low releases and allow for organic matter to wash into sloughs during larger dam releases. This scenario would essentially replicate the dam releases that took place prior to and after Hurricane Rita, where a minimum of 20,000 cfs would allow for a continuous flow between the floodplain and main river channel.

The Texas Water Development Board (TWDB) identifies ecologically unique stream segments throughout the State. Such identified stream segments are evaluated on five criteria including biological function; hydrologic function; riparian conservation areas; high water quality/exceptional aquatic life/high aesthetic value; and threatened or endangered species/unique communities. This designation means that a state agency or political subdivision of the state may not finance the actual construction of a reservoir in a specific river or stream designated as an ecologically unique stream segment. TWDB has identified virtually all of the major stream segments in the Preserve for consideration as ecologically unique stream segments:

- *Big Sandy Creek* – identified based on biological function (nominated for inclusion in the Texas Natural Rivers System based on its outstandingly remarkable fish and wildlife values); riparian conservation area (*i.e.*, presence in the Preserve); and exceptional aesthetic value.
- *Neches River* – identified based on biological function (extensive freshwater wetland habitat); riparian conservation area; exceptional aesthetic value; and threatened or endangered/unique communities (e.g., presence of state threatened paddlefish and creek

chubsucker; most abundant unionid assemblage in state; largest known population of sandbank pocketbook mussel in state; and one of largest populations of rare, endemic Texas heelsplitter freshwater mussel).

- *Village Creek* – identified based on biological function (nominated for inclusion in the Texas Natural Rivers System as having outstandingly remarkable fish and wildlife values; riparian conservation area; high aesthetic value (rated number one scenic river in East Texas); unique communities (unique, exemplary and unusually extensive natural community).
- *Beech Creek* – identified based on riparian conservation function and high water quality/exceptional aquatic life/high aesthetic value (ecoregional reference stream; diverse benthic macroinvertebrate community).
- *Turkey Creek* – identified based on riparian conservation function.
- *Menard Creek* – identified based on biological function (bottomland hardwood habitat displays significant overall habitat value and high diversity of freshwater mussels) and riparian conservation area.
- *Pine Island Bayou* -- identified based on riparian conservation function.
- *Little Pine Island Bayou* -- identified based on riparian conservation function.

There is no guidance on how many of the criteria need to be met as a prerequisite for consideration for designation as an ecologically unique stream segment. However, those Preserve streams above that meet three or more of the criteria will probably be evaluated further.

What Are the Current State or Conditions and the Related Trends of Flowing Water and Associated Dependent Systems Within the Preserve?

The "black-water" creeks in the preserve can be described as "free flowing." The quantity and timing of freshwater flows in these water ways is directly proportional to rainfall within their local watersheds and, during low water times of the year, ground discharge in the form of baseflow. Riparian-level activities such as stream bed clearing (to lessen local flooding), construction of retention ponds, or erosion and watershed-wide activities such as logging, farming, oil and gas exploration and production, or land development activities may have altered this relationship to varying degrees over time.

Of the streams in the Preserve, Village Creek is most nearly typical of blackwater streams. Flows (Figure 21) are unimpeded by diversions or retention along its entire 53-mile length. Menard Creek and Little Pine Island Bayou are small and of variable flow like blackwater streams, but are more turbid and of higher conductivity like alluvial streams. The higher turbidity and conductivity may be caused by presence of finer-textured substrates such as silts and clays.

The quantity and timing of freshwater flow in the Preserve's only "brown-water" river –the Lower Neches Valley – is influenced by weather in the upper reaches of the Neches River Valley and by structural controls with pre-date and lie outside of the Preserve's bounds (Figure 22).

A casual observer may conclude that there are two primary – and separate – structures that affect the Preserve's interests along the Neches River: Town Bluff Dam and the Neches River Saltwater Barrier. Both of these structures are operated by different districts of the U.S. Army

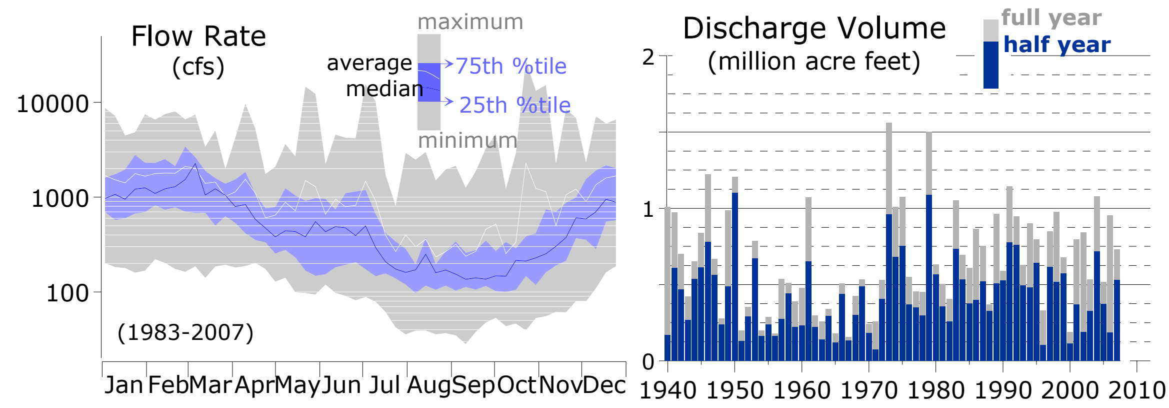


Figure 21. Annual flow rate summary (left) and historic discharge volume (right)of Village Creek at Kountze. Data source: U.S. Geological Survey.

Corps of Engineers. These structures are located 85 river miles apart, forming the approximate upstream and downstream endpoints of the Preserve's Neches River corridor.

In actuality these structures, along with the Sam Rayburn Dam, are operated in concert with each other for the purpose of maintaining a carefully calibrated water flow and stage regime in the Neches River, thus ensuring delivery of water necessary to satisfy the water rights of end users – a large portion of which is passed through the Lower Neches Valley Authority (LNVA) Canal – and preventing saltwater intrusion from the heavily industrialized and dredged Sabine Lake estuary from fowling fresh water intakes.

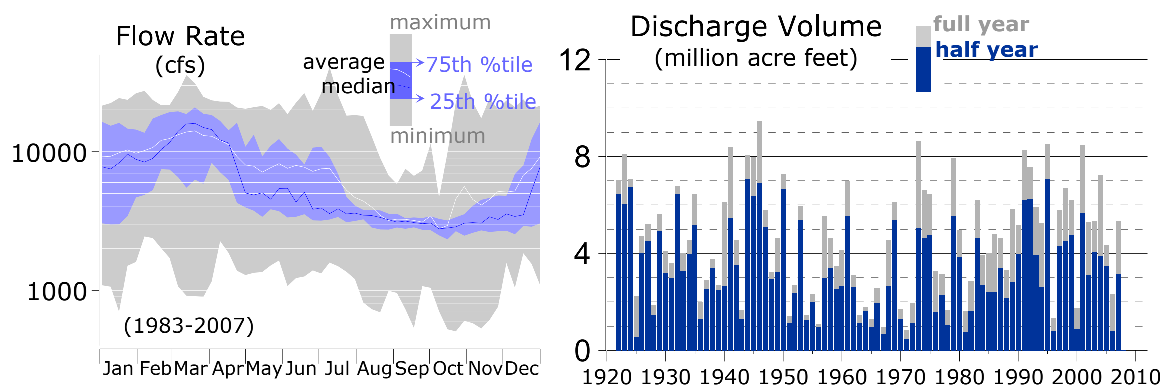


Figure 22. Annual flow rate summary (left) and historic discharge volume (right) of the Neches River at Evadale. Data source: U.S. Geological Survey.

Thus, waters that pass through the Preserve are operationally in route to satisfy water rights of agricultural, industrial, and municipal end users, to control saltwater intrusion, and also provide recreational opportunities.

Water development of the lower half of the Neches River developed under a federal/state partnership between the U.S. Army Corps of Engineers and the LNVA that dates back to the early part of the twentieth century in response to the area's economic awakening following discovery of oil at Spindletop (south of Beaumont).

Spindletop transformed east Texas into the cradle of the modern oil and gas industry. As the Beaumont-Port Arthur area became the oil refining capitol of the world in the decades that followed, access to world wide markets for products from these refineries necessitated the deepening and straightening the Neches River for ocean-going vessels to and from the Gulf of Mexico.

In turn, channel dredging served as the initial catalyst for water resource development on the Neches River. Deepening and straightening of the river altered the brackish water balance at the river's mouth, particularly during times of low flow, allowing saltwater to threaten the freshwater supply further upstream, running the risk of fowling freshwater intakes of the cities, industries and farms.

This problem created the need to systematically protect the freshwater supply from downstream saltwater, and increase upstream freshwater availability through storage and distribution systems. To accomplish this, the Texas Legislature created the LNVA in 1933 – giving it the distinction as the state's second river authority (preceded by only the Brazos River Authority in 1929).

LNVA's approach called for construction of (1) a large reservoir on the Neches River near Rockland, (2) a regulated dam near Town Bluff for the purpose of storing water and regulating the flow of the river, and (3) a canal system to transport water from these reservoirs to consumers within Jefferson, Liberty and Chambers counties; however, this approach was eventually morphed into a more far-reaching U.S. Army Corps of Engineer's plan which called for two major dams – one in the Neches at Rockland and another at McGee Bend on the Angelina River – and two smaller regulating reservoirs just downstream of the two major reservoirs.

Five dam and reservoir projects have been authorized by Congress in the Angelina-Neches Rivers basin; only three of which have been built: 1) B.A. Steinhagen Lake behind Town Bluff Dam – originally called just "Dam B" -- completed in 1953; 2) Sam Rayburn Dam and Reservoir completed in 1965; and, 3) Neches River Saltwater Barrier completed in 2003. The two other projects – "Dam A" and "Rockland" – have been authorized, but never built. A separate dam and reservoir project called the Blackburn Crossing Dam (and the upstream Palestine Lake) is located over 150 river miles north of Town Bluff Dam in the upper reaches of the Neches River Basin.

These projects are operated in concert to provide freshwater to the Lower Neches Valley Authority (LNVA) canal, pumps, and distribution network, in addition to meeting other water management needs.

Town Bluff Dam (Figure 23) is located along the main stem of the Neches River at the upstream boundary of the Preserve. Town Bluff Dam and its reservoir were authorized by the River and Harbor Act of 1945. Construction was started in 1947 and completed in 1953. In 1967, "Dam B" was renamed Town Bluff Dam and B. A. Steinhagen Lake.

The Robert D. Willis Hydropower Project at Town Bluff Dam started in 1987 and the hydropower facilities became available for commercial operation in 1989, funded in partnership with the Sam Rayburn Municipal Power Agency. The hydropower project is named in memory of Willis who served as executive director of the agency from 1980 to 1988.

Sam Rayburn Dam (Figure 23) is located remotely from the Preserve– some 20 miles northeast along the Angelina branch of the Neches (in the piney woods region of southeast Texas), but it factors in largely to the fate and movement of waters through the Preserve.

Authorized by Congress in 1955 for the purposes of flood control, hydroelectric power generation, and conservation of water for municipal, industrial, agricultural, and recreational uses as the second phase of the U.S. Army Corps of Engineers development plan for the Neches River Basin, construction of the dam began in 1956 and the conservation pool level (elevation 164.4 ft msl) was reached in 1966.

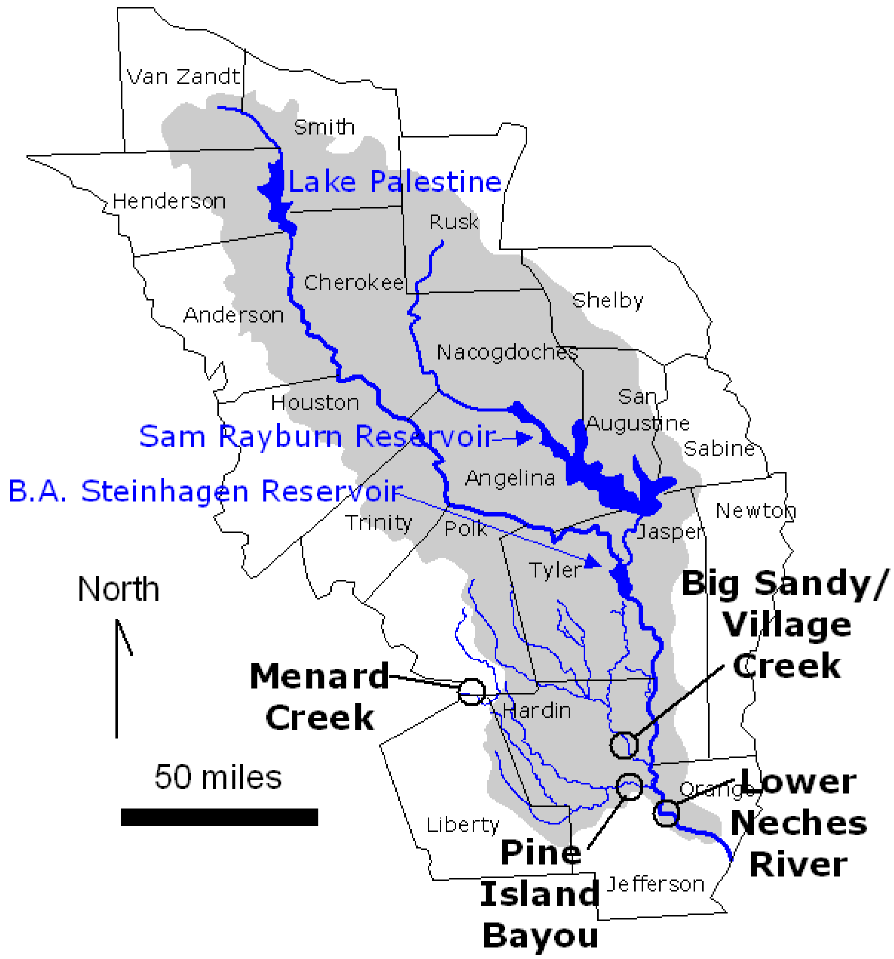


Figure 23. Locations of current dams and saltwater barriers in or adjacent to the Lower Neches River System.

The Neches River Saltwater Barrier (Figure 23) is located on the Neches mainstem just downstream of Pine Island Bayou and outside of the Preserve. The Neches River is especially vulnerable to taking on saltwater during times of low river flow or drought, a situation that has been worsened by dredging towards the river's mouth at Sabine Lake, near Port Arthur.

Historically, saltwater intrusion was prevented by flushing the river with freshwater flows from Sam Rayburn and seasonal installation of temporary saltwater barriers, installed 36 times from 1940 to 2000. Those old temporary barriers, located within the Preserve, had many problems, including construction of access roads to install and remove the temporary barriers, erosion at the shoreline caused by the temporary barriers, water pollution, disruption to fish migration, and navigation-based obstruction. The temporary barriers cost one million dollars per installation.

From a water management standpoint, saltwater barriers also became less and less effective as time progressed because:

- repeated and periodic deepening of the Sabine-Neches Waterway to Beaumont for deep draft navigation increased the surge and frequency of saltwater up the Neches River;
- seasonal droughts tend to coincide with the summer growing season when irrigational, industrial, and municipal withdrawals are at their peak; and,
- overdraft of Sam Rayburn Reservoir during periods of drought diminishes the water supply available for salinity control releases.

The permanent barrier was originally authorized under the Water Resources Development Act of 1976, but its planning phase -- and coordination between the U.S. Army Corps of Engineers and LNVA -- did not occur in earnest until the 1990s. Construction began in 2000 and was completed three years later in 2003.

Delivery of fresh surface water by the distribution system is performed by withdrawal of the water from the lower Neches River and Pine Island Bayou by 21 large pumps via the LNVA Canal. From there, the water is lifted into the canal system to a height that permits its delivery throughout most of the 400-mile canal system without further pumping. Water deliveries are made to cities, industries and farms on a continuous, 24-hours a day, 7 days a week basis. The canal system covers an area of approximately 700 square miles, principally within Jefferson, Liberty and Chambers counties.

The pumps can deliver between 20,000 and 110,000 gallons a minute (44.5-235 cfs) and can pump a total of over one billion gallons of water a day (3,070 acre feet). The pumps are driven by huge, natural gas-fueled engines in providing the freshwater to eight cities and water districts, 26 industries and over 100 irrigated farms (from www.lnva.dst.tx.us/).

Presently, the Neches River flow is controlled and diverted by Sam Rayburn Dam, Town Bluff Dam, Neches River Saltwater Barrier, and the LNVA Canal. These projects are operated individually and in unison to meet a multi-use set of water demands. Multi-use demands include providing flood control, satisfying water rights (to agricultural, industrial, and municipal end users), generating electricity, preventing saltwater intrusion, delivering flows to the estuary, and creating recreational opportunities. In recent times efforts have been undertaken to add additional storage to the river and develop more comprehensive instream flow and estuarine discharge requirements.

With regard to the Sam Rayburn Dam/Reservoir, management and operational decisions must be made in accordance with the multi-use mission, which in part explains why the lake levels fluctuate so frequently. When substantial rains create the potential for flooding, incoming waters from the Angelina River watershed (Figure 21) are retained within Sam Rayburn Reservoir's flood pool, and the lake level rises. Once the threat of downstream flooding is reduced, flood waters are released into the Angelina/Neches Rivers, which maintains higher flows (but below flood stage) in the rivers until the levels in Sam Rayburn are reduced.

The purposes of Town Bluff Dam/B. A. Steinhagen Lake are to re-regulate the intermittent power releases of Sam Rayburn Dam, provide storage for hydroelectric power and diversion into a water supply canal, and provide some water storage. The Southwestern Power Administration, U. S. Department of Energy, markets the power and energy generated by the hydropower plant to the Sam Rayburn Municipal Power Agency for distribution to its customers in Jasper, Liberty, and Livingston, Texas and Vinton, Louisiana. Water releases are utilized by the Lower Neches Valley Authority in Beaumont, Texas, for rice culture, salinity control, pollution abatement, municipal, and industrial uses.

LNVA is authorized to draw from B.A. Steinhagen a maximum of 2,000 cfs. This water allotment is available to the agency whenever needed, and in the instances of demand, the water is taken directly through the Town Bluff Dam tainter gates. However, if the lake's normal pool capacity is not adequate to satisfy the requirements over an extended period of time, Sam Rayburn Dam can release conservation water into B. A. Steinhagen Lake, which will in turn release the water to meet downstream demands.

The Lower Neches Saltwater Barrier is operated to maintain the differential in water from upstream to downstream during low flow conditions. This results in a slight slackwater pool (or reservoir) on the upstream side of the barrier, but essentially the barrier passes all water that flows from upstream to it. This even applies during times of low water. An average minimum discharge of 400 cfs is passed through the barrier to ensure downstream water quality and stream health.

The LNVA has state-approved rights to the use of essentially the entire dependable freshwater yield of Sam Rayburn Reservoir. The water is delivered through the LNVA Canal (primary canal → pumps → feeder canal network). LNVA's water allotment of 820,000 acre feet (267 billion gallons) is deemed sufficient for current and future basin needs. In comparison, the Neches River discharges at an average annual rate of 6 million acre feet per year (as measured at Evadale). Thus, 1/6th of the river's annual flow volume is allocated to LNVA water rights (not factoring in return flows, often in the neighborhood of 50 percent).

All four projects are subject to routine and aperiodic maintenance activities that may disrupt normal operations. One example would be the recent drawdown of B.A. Steinhagen Lake (2006-2007) in an attempt to control a noxious aquatic plant that had taken hold in the lake. The drawdown was performed in cooperative effort with the Texas Parks & Wildlife Department, the

LNVA, and the Southwestern Power Administration. The drawdown was extended to perform maintenance work on the dam and nearby bridges. The drawdown exposed the vegetation to summer heat and winter frost which, with the addition of herbicide treatments, is expected to reduce vegetation growth in the lake for several years. Thus, it can be assumed that future drawdowns may be required, both at B.A. Steinhagen and Sam Rayburn.

What Are the Current and Potential Threats to Flowing Water and Associated Dependent Systems Within the Preserve?

Waters and aquatic resources of Big Thicket National Preserve are subject to basin-wide and watershed-specific stressors – both of which lie outside the jurisdiction of the Preserve's predominantly riparian buffer – and riparian corridor stressors for stream reaches that lie outside but deliver waters into the preserve.

Basin-level Threats: Control and utilization of water is a major issue of state-wide importance in Texas. The flashy and unpredictable nature of its rainfall, combined with an uneven distribution of waters across the state – often least abundant where people and commercial needs lie – has resulted in a cycle of periodic floods and droughts in all areas of the state.

Recent times have been hit with the reality that water supply development may be approaching its feasible limit, with the prospect of a new breed of water issues emerging in the future, including limited water supplies, expanding populations, imbalance of water between water-rich and water-poor sections, transboundary water disputes, and potential for a drier future due to global climate change. Residents in river basins estimated to have their fifty year future needs already met fear that this excess will be diverted to the nearest metropolitan centers in other basins.

The Preserve is located in the water-rich Lower Neches River Basin, and as such, must be actively engaged in how water policies and projects handed down from the state level can affect its waters, both positively and negatively, and be poised to advocate and protect its water interests accordingly. This has special relevance for Preserve land and waters along the Neches River.

Two new reservoirs and expansion of an existing one are being considered for the Neches River; if built, they could divert water that currently flows through the Preserve, disrupting native plant communities, affecting wildlife, and compromising recreational opportunities.

Since the 1940s, regional planners have periodically discussed the prospect of building a dam and reservoir on the Neches River 25 miles upstream of B.A. Steinhagen Lake. Most recently, LNVA raised the dual possibility of building the Rockland Dam (Figure 24) project in tandem with enlarging B.A. Steinhagen Lake (Figure 23). The agency is proposing the dam to the Texas Water Development Board as a regional effort to increase water supplies for the state. The expansion of B.A. Steinhagen Reservoir is often mentioned in association with the Rockland Dam proposal, but presumably the expansion could be considered as a project by itself.

The projects would enlarge Steinhagen Reservoir from 13,000 surface acres to 21,000 surface acres and create a 100,000-surface-acre reservoir at Rockland. Combined, they would inundate a

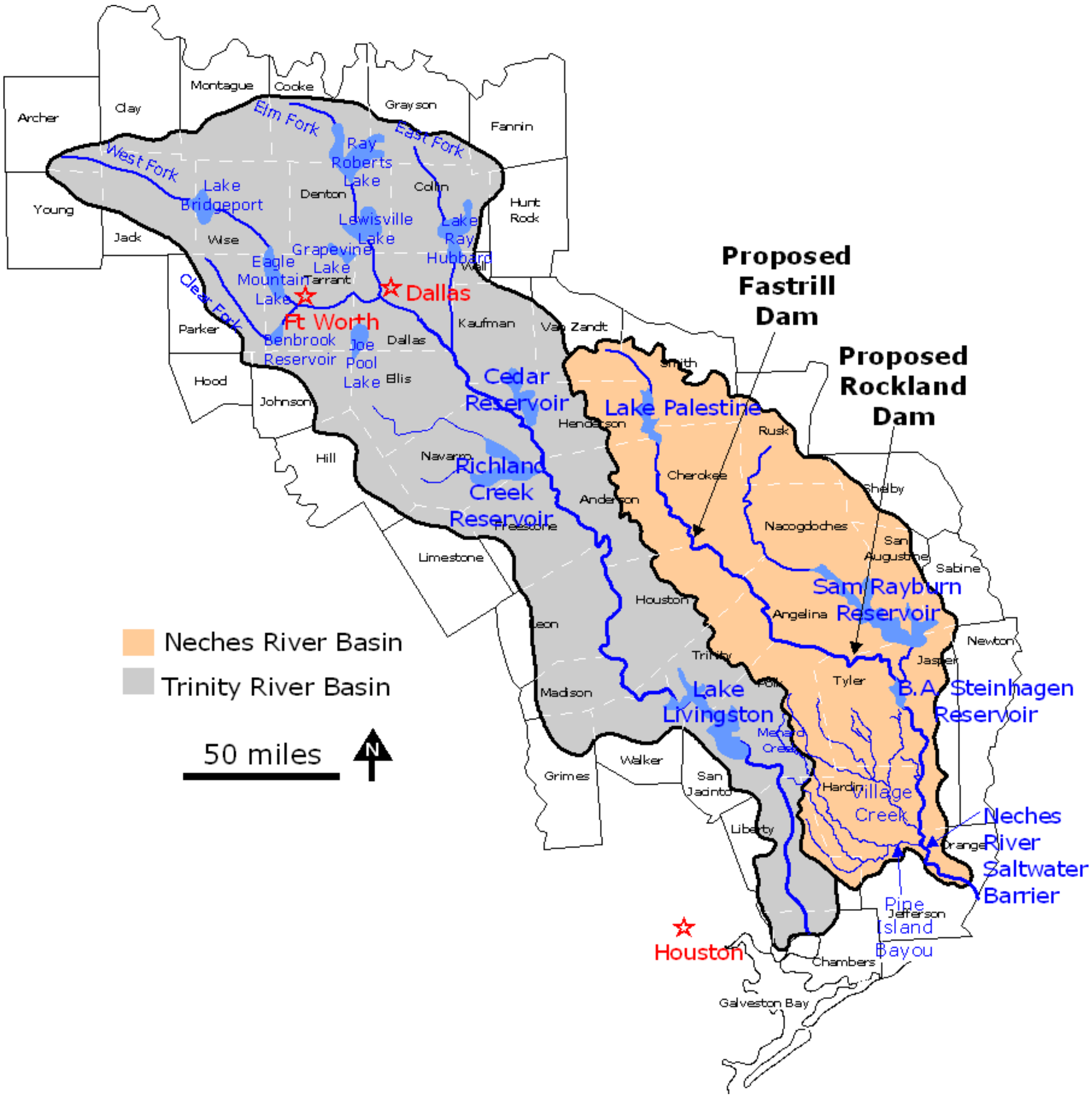


Figure 24. Existing and proposed dams and reservoirs on the Neches River.

12,000-acre Texas Parks and Wildlife Management Area above Town Bluff Dam and submerge most of Martin Dies, Jr. State Park, a heavily used recreation site that compliments recreational river use at the Preserve.

Opponents of the plan argue that not only would the reservoirs directly impact landowners through inundation of public and private lands; they would negatively alter downstream river flows. Additionally, they argue that the dams are not needed – 50-year water projections are already met. It is speculated that water would be sold out of the basin.

Since the early 1960s, plans to provide increased water to Dallas-Fort Worth – where the population is expected to double in the next 50 years – have routinely included proposals to build a dam along the upper main stem of the Neches River, about 60 miles upstream of Town Bluff Dam.

The proposed Fastrill Reservoir (Figure 24) would inundate an estimated 27,000 to 32,000 acres of prime hardwood bottomland habitat. It is usually mentioned in tandem with the proposed Marvin Nichols Dam, located in northeast Texas that in total would flood 100,000 acres of land and require 310 miles of water pipe.

The Fastrill Dam project was dealt a serious setback by a U.S. Fish and Wildlife initiative to create a 25,000-acre national wildlife refuge along 38 miles of the Upper Neches River within the proposed Fastrill Area – a move that was contested in court by the TWDB, but upheld in favor of the proposed refuge. Proponents of the refuge argue that (1) this stretch of river is vital to a wide variety of species; (2) the City of Dallas can meet its projected water needs through a combination of existing sources and basic conservation measures; and, (3) the dam/reservoir would modify habitat and river flows in one of the last "wild rivers" in Texas.

The Preserve's ability to manage its lands and waters along the Neches River requires an understanding of the whole river system, and being able to advocate its interests in operational, regulatory, and planning aspects of basin and river management schemes. The Preserve has traditionally focused on Town Bluff Dam as the direct source of water entering the Preserve, but releases and storage of water from Town Bluff are performed in concert with operations at Sam Rayburn and the Neches River Saltwater Barrier. While annual flow volumes appear to be relatively unchanged before and after dam building, timing and magnitude of spring peak flows, summer base flows, and aperiodic flushing events have been altered. These changes may impact river water quality, sediment load, and riparian/floodplain habitats to varying degrees.

Prior to dam building, the Neches River typically peaked at 10,000 – 12,000 cfs in late winter/early spring and dropped to a low-water base flow rate of 500 cfs during the summer and early fall (Figure 25). After dam construction in 1953, median year spring flows have tended to be repressed in magnitude with low-water base flows increased to fend off downstream saltwater intrusion and delivery of water rights.

Ecosystems are often framed relative to the last major disturbance, whether the result of a natural event (such as Hurricane Rita) or an anthropogenic one (such as recent drawdown of B.A. Steinhagen Lake), or a combination of the two. The modern day infrastructure tends to dampen the magnitude of seasonal and extreme flood and drought events, but also causes them on occasion, such as reservoir drawdown.

Aperiodic high flow events, where short-term flow rates exceeded 50,000 cfs, also played a larger role prior to dam building (Figure 26). They occurred at frequency of once every five years prior to 1950, but have been non-existent at that magnitude since the mid 1950s, during which the Neches River achieved a weekly peak discharge of between 20,000 – 30,000 cfs. Thus, it stands to reason that floodplain ecology has been modified by the absence of higher order flood events. In turn, the loss of extended periods of drought has changed oxbow and wetland dynamics and other floodplain characteristics. Regardless, even under the dam-altered hydrologic regime, extreme events continue to make a lasting mark on the river corridor and floodplain.

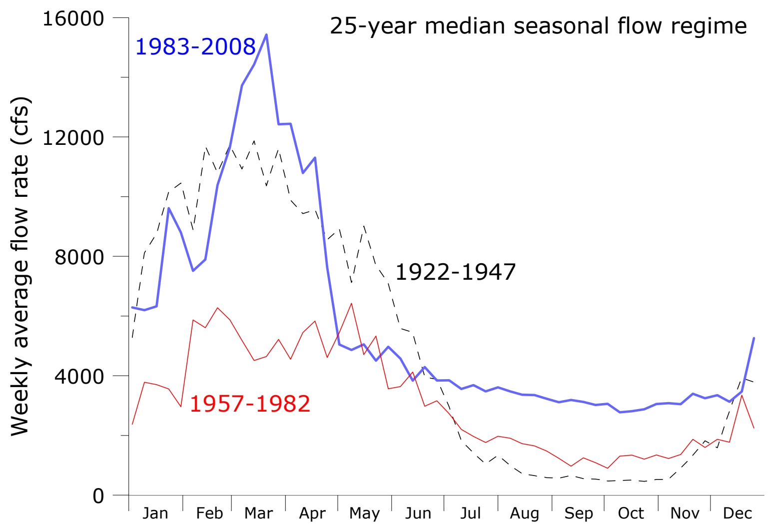


Figure 25. Hydrograph showing weekly median flow for the 25-year periods before and after construction of Town Bluff Dam on the Neches River.

Texas is considering two broad categories of environmental flows: instream flows and freshwater inflows, both of which come into play for the Preserve. Instream flow is the amount of water needed in rivers and streams to support fish and wildlife in and along our waterways. These flows also support various recreational and commercial activities, like canoeing, hunting, and fishing and protect water quality. Freshwater inflow is the amount of river and other flows of freshwater needed to maintain acceptable salinity conditions in estuarine areas.

This process started in 2003 through Senate Bill 1639, which established the Study Commission on Water for Environmental Flows. The Commission was charged to provide recommendations on how to ensure protection for environmental flows in the water permitting process. The Senate Bill 3 process for the Sabine and Neches rivers and Sabine Lake Bay recently produced a final report from the Basin & Bay Expert Science Team (BBEST) to TCEQ and the Stakeholder Committee (available at: http://www.sratx.org/BBEST/RecommendationsReport/).

Studies have been initiated on a basin by basin process that factor in seasonal and inter-annual variability to determine the amount of freshwater needed to maintain healthy and productive riverine and estuarine systems. However, the focus of both is on meeting minimum requirements – not peak events, which ecologically can be just as important, if not more so.

Downstream of Beaumont the Neches River becomes increasingly industrialized and more influenced by tides, a condition which has been artificially enhanced through historic dredging and deepening of a navigational channel in the lower Neches. Arguably this issue has been resolved by installation of a permanent saltwater barrier at the downstream end of the Preserve. However, it should be pointed out that this structure is operated in concert with upstream river releases and is a vital part of supply allocations to industrial, agricultural, and municipal interests. A newly proposed unit of the Preserve would be located downstream from, and not protected by, the permanent barrier.

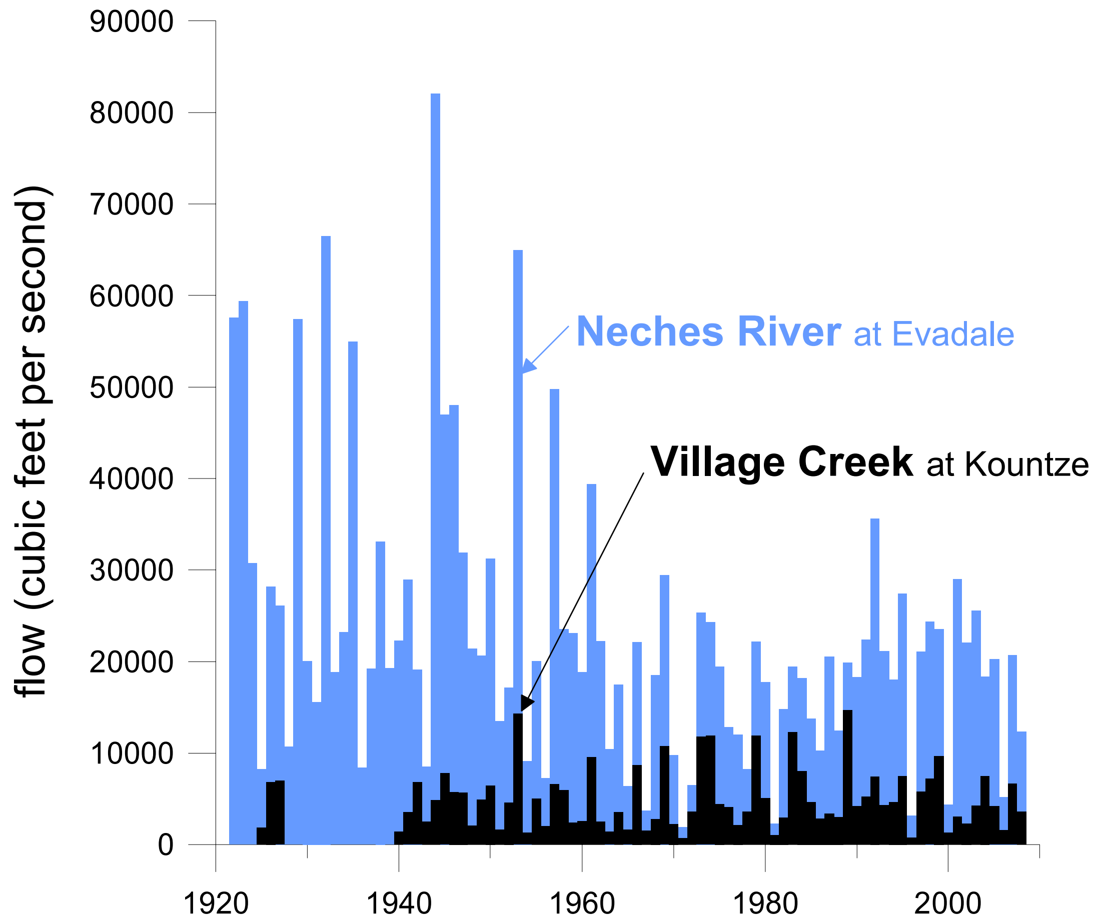


Figure 26. Peak weekly flow rates for the Neches River (at Evadale) and Village Creek (at Kountze).

Watershed-level Threats: The Preserve is defined in part by the multi-use nature of its lands and the watershed that surrounds it. The watershed that envelops the preserve units is rapidly changing. Sensitive habitats and visitor experiences along the boundaries of the Preserve have been and will be affected as adjoining lands are cleared for a variety of purposes such as pastures and residential yards or are paved for commercial development.

A case in point is the relatively recent development in 2001 and 2002, in which two of the largest landowners – Louisiana-Pacific and International Paper Company – sold much of their land. Around 2 million acres of timber company land surrounding the park have been sold or put up for sale as a result. Conversion of land to residential development is generally regarded as a greater and more permanent threat than retaining land as timber or agriculture. Thus, a key challenge for the Preserve is to develop a greater understanding of how changes in the watershed affect its land and water interests, and what can be done to mitigate them.

Oil and gas operations may result in contamination of ground and surface waters, either as a result of spills, legacy infrastructure, or historical contamination sources. In many instances this contamination may not be visible to the naked eye, or may occur suddenly by accident or acts of nature.

While hurricanes are a natural part of the ecosystem, their destructive force can alter natural regimes dramatically, and in the presence of an already altered watershed, cause unexpected and long-lasting effects to the areas within the preserve, with Hurricane Rita (2005) being the most impacting and Hurricane Ike (2008) the most recent example. There is also concern that global warming could be increasing storm strength and frequency, thereby contributing to saltwater intrusion, as was demonstrated with Hurricane Ike.

Riparian-level Threats: The riparian flood pulse is an integral process to sustaining and protecting the unique aquatic flora and fauna of the preserve. However, the Preserve's desire to maintain the floodplain of Neches (and Trinity) River tributaries in a primitive state often generates negative publicity in the surrounding communities during instances of high flows and extensive overflow of riparian waters into the floodplain.

Communities have expressed a desire to keep channels clear to maximize their drainage capacity, and in turn, these community outcries have often been met with funding from the state to help clear the channels. Instances within the Preserve have historically required a concerted level of public debate, but in lands adjacent, just outside of, or in remote corners of the Preserve may be cleared without Preserve knowledge.

In other instances, problems may be encountered in maintaining a dynamic riparian corridor in relation to a static boundary. For example, the position and width of the Neches River channel is in a constant flux, and over time has migrated away from its original alignment with Preserve boundaries, either lessening the protective buffer, or in some instances taking the river outside of that protective zone.

Small-scale dams and water control structures can impact the hydrology, water quality, and aquatic communities of tributaries streams in the Preserve. These structures also pose management threats associated with water quality and risk of failure.

Substantial impairment of either quality or quantity of water in the corridors, or major alterations in the timing of flows, will significantly affect the ability of the Preserve to maintain its current ecosystem function and exhibit its current biological diversity. Alterations to river flow via dams, clearing of river channels to lessen flooding, or serving other water or recreational needs, and degradation of water quality in the riparian corridor pose a threat to the Preserve's ecological health.

The enabling legislation of the Preserve has a clause that allows for the possibility of expansion beyond its original boundaries through land donation. The Big Thicket National Preserve Addition Act of 1993 authorized the Preserve to acquire lands along portions of Village Creek and the Neches River (about 11,000 acres). This acquisition legislation was passed before large land divestitures by timber companies, and could not take into account the effects these changes in ownership would have. A proposed expansion plan on the horizon – the Brady Bill – proposes to enlarge the Preserve boundary through willing seller provisions in order to connect, preserve, and revitalize the Preserve and the surrounding communities (Figure 27).

Who Are the Stakeholders Who Have an Interest in Flowing Water and Associated Dependent Systems?

While there are many stakeholders with vested interests and/or controlling authority of the water that courses through the Preserve, there are a few substantial ones that play an overarching role, and warrant being listed first. Major stakeholders of the State are listed first because of the prominent role that the State of Texas plays in every sphere of water development.

State of Texas: Management of Texas waters is overseen state-wide by three agencies, often referred to as the Tri-Agency, with a fourth agency – a trans-county river authority called the Lower Neches Valley Authority – representing the state within the jurisdiction of the basin. They are the:

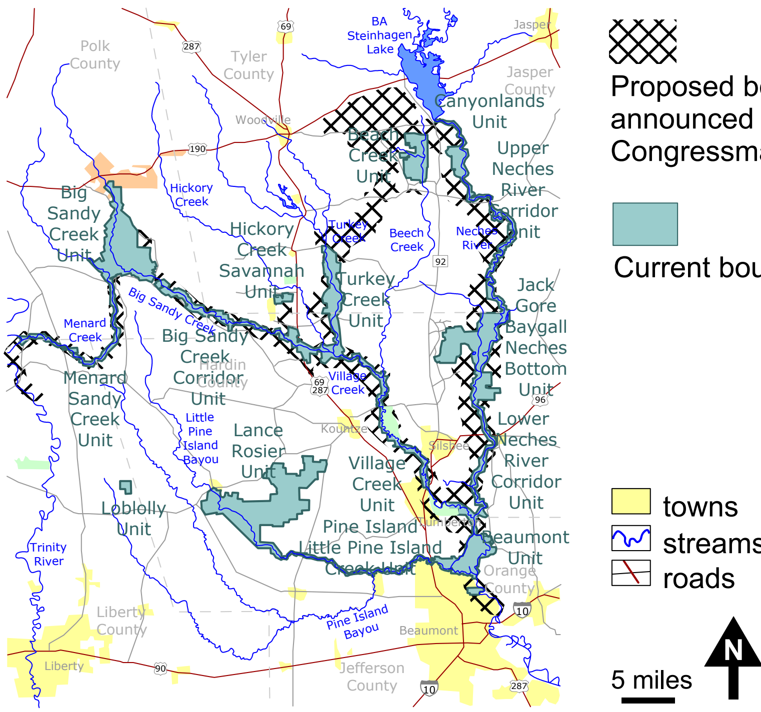


Figure 27. Generalized map of proposed additions to the Preserve as introduced under H.R. 5891 by Congressman Kevin Brady on April 26, 2008.

<u>Texas Water Development Board (TWDB)</u>

TWDB is the planning and development arm of the Tri-Agency. Its mission is to provide leadership, planning, financial assistance, information, and education for the conservation and responsible development of water for Texas. Its primary tasks are to (1) prepare and update a state water plan, (2) collect and maintain water data and technical support, and (3) administer various funds designed to help finance state and local water projects – it is often referred to as the "water bank" of Texas.

<u>Texas Commission on Environmental Quality (TCEQ)</u>

TCEQ is the environmental compliance arm of the Tri-Agency, and is responsible for administering water rights. TCEQ has 16 regional offices throughout the state. Its primary tasks are to administer the state's water quality program including granting of permits to discharge effluents into Texas waters, determine and allocate water rights to state waters, regulate dams, administer the oil and hazardous spill program and license hazardous waste disposal facilities, regulate water drillers, administer the National Flood Insurance Program, train and certify wastewater treatment operators, and establish water and sewer rates.

Texas Department of Parks and Wildlife (TDPW)
TDPW is the fish and wildlife resources arm of the Tri-Agency. It manages and conserves the natural and cultural resources of Texas and to provide hunting, fishing and outdoor recreation opportunities for the use and enjoyment of present and future generations.

State water interests, as laid out by the Tri-Agency, are administered on a regional level by the 23 river authorities. Texas' river authorities are trans-county political jurisdictions delineated along hydrographic boundaries that were modeled loosely after the Tennessee Valley Authority. Each of these river authorities have the license to conserve, store, control, preserve, utilize, and distribute the waters of its respective area for the benefit of its residents. For the Preserve the river authority is the:

Lower Neches Valley Authority
Most of the Preserve, with exception of the Menard Creek unit, falls within the Lower Neches Valley Authority (LNVA). The State Legislature, in 1933, granted authority to LNVA to operate within Tyler, Hardin, Liberty, Chambers and Jefferson counties, located within the Neches River Basin and the Neches-Trinity Coastal Basin.

The primary duties of the LNVA are to:

1) develop and manage a system that will meet the present and long-term freshwater needs of municipal, agricultural and industrial consumers; to protect water quality; to insure its affordability; and to establish conditions which will enhance economic development throughout the Authority's jurisdiction.
2) act as local sponsor of Sam Rayburn and B.A. Steinhagen reservoirs which are operated by the U.S. Army Corps of Engineers. Water stored in Sam Rayburn Reservoir for use by LNVA is released to Lake B.A. Steinhagen, flows into the lower Neches River, and on to the LNVA freshwater intakes.
3) act as local sponsor and operator of the Neches River Saltwater Barrier at Beaumont, a U.S. Army Corps of Engineers project. The saltwater barrier protects freshwater intakes from saltwater migrating upstream from the deep draft navigation channel to Beaumont.
4) deliver state-approved water rights – these water rights include both run-of-river rights and storage rights in the three Federal projects that total 1,201,876 acre-feet per year. Delivery of fresh water is made by diverting water from the Neches River and Pine Island Bayou through two primary lift stations; two secondary lift stations pump the water into a 400-mile canal system where most deliveries are made without additional pumping. The canal system covers an area of approximately 700 mi^2 within Jefferson, Liberty and Chambers counties.

Federal: There are two primary federal stakeholders that play a day-to-day role in development, monitoring, and protection of waters in the Preserve. They include the following:

U.S. Army Corps of Engineers (USACE)
The USACE is a major player in water development. It owns and maintains approximately 24 flood control dams in Texas and provides 9 million acre-feet of water storage, and manages them in collaboration with the Texas Water Development Board via local river authorities. Two of these structures – Town Bluff Dam, which forms the B.A. Steinhagen Lake and the Neches River Saltwater Barrier – are located on upstream and downstream ends of the Preserve, but are managed by the Fort Worth and Galveston districts of USACE, respectively. The water controlled by both structures is classified as waters of the state, and as such, is managed by the Lower Neches Valley Authority.

U.S. Geological Survey (USGS)
USGS has sustained a long track record of performing water resources monitoring and investigations in the Preserve, the foundation of which is its historic stream gage network which extends back a quarter of a century before the Preserve was established. Currently, the USGS monitors stream discharge in Preserve water ways, including stations along the mainstem of the Neches and stations on three tributaries. While all the stream flow gages are still active, routine water quality sampling is performed only along the Neches at Evadale.

Other Stakeholders: Other agencies play supporting and/or behind the scene roles as planners, protectors, and providers of water, and do not factor in as directly or routinely as the major stakeholders listed above. In several instances, water is only a fraction of their responsibilities – or is vetted through one of the major stakeholders. These agencies include:

Environmental Protection Agency (EPA)
The EPA develops standards for protecting the nation's water, which in the case of the Preserve as a riparian national park service unit, makes it a major player. The EPA also provides guidance to the states in terms of protecting water quality and meeting standards.

Federal Emergency Management Agency (FEMA)
FEMA's mission is to reduce the loss of life and property and protect the nation from all hazards, including natural disasters, acts of terrorism, and other man-made disasters, by leading and supporting the nation in a risk-based, comprehensive emergency management system of preparedness, protection, response, recovery, and mitigation. On March 1, 2003, the FEMA became part of the U.S. Department of Homeland Security (DHS).

Floodplain maps are a product of FEMA. While the maps will show your property's relationship to the flood plain, you should also consider hiring a surveyor to determine the elevation of your home relative to the base flood (100-year) elevation. This information is useful in determining a property's risk of flooding and in determining flood insurance requirements and rates.

Bureau of Reclamation (BOR)
The BOR, under the Department of Interior, has five dams providing water storage for over a million acres of water storage, none of which lie within the Neches or Trinity River basins.

U.S. Forest Service

The U.S. Forest Service manages approximately 675,000 acres of public land in Texas. This land is divided into four National Forests in east Texas and the Caddo-Lyndon B. Johnson National Grasslands in northeast Texas. These public lands are administered under multiple-use management to protect and obtain the greatest benefit from all forest resources: recreation, timber, range, fish and wildlife, soil and water and minerals.

U.S. Coast Guard

The Coast Guard's activities in the Southeast Texas/Western Louisiana operating area focus on the Service's four principal missions: maritime safety, maritime law enforcement, environmental protection, and national security – including in response and preparedness for tropical storms and hurricanes.

National Weather Service

The National Weather Service provides weather, marine, fire and aviation forecasts, warnings, meteorological products, climate forecasts and information about meteorology for all parts of the United States.

Alabama-Coushatta Reservation

Texas also shares water across interstate and international political entities. While this does not apply to the Preserve, it does share a border with a Native American reservation. The Alabama-Coushatta Reservation is located on 4,600 acres, home to 500 members of the Alabama-Coushatta Tribe of Texas. Once separate entities, the two tribes are both members of the Upper Creek Confederacy of Indians and are of the Muskogee Nation.

Texas Department of State Health Services (DSHS)

DSHS enforces federal standards for drinking water and monitors the quality of water distributed by all public systems.

Railroad Commission of Texas (RRC)

The RRC is the lead agency for spills and discharges from all activities associated with the development of oil and gas resources under Section 401 of the Clean Water Act and Sections 85.042, 91.101, and 91.601 of the Texas Natural Resources Code. Permits issued for oil and gas operations generally prohibit the discharge of any material that would in any way alter the quality of surface or subsurface waters, or contribute to a violation of a water quality standard. However, within the RRC's Statewide Rules, there are provisions for disposal of certain wastes.

State Soil and Water Conservation Board (SSWCB)

The SSWCB oversees a voluntary program for reduction of agricultural and silvicultural (forestry) nonpoint source pollution through the identification of problem areas by the state board or local soil and water conservation districts. Under this program, the SSWCB reviews and certifies water quality management plans – typically prepared by the Board, local soil and water conservation districts, or private entities. Approximately ten percent of these plans are checked for voluntary compliance each year (Larry Gibbs, SSWCB, pers. comm.). Within the area of the Preserve, there are seven soil and water conservation districts.

State Parks
State parks adjacent to the Preserve include Village Creek State Park and Collier Landing.

Texas General Land Office (GLO)
GLO is the oldest state agency in Texas. The Republic of Texas Congress established the General Land Office in 1836 shortly after Texas won its independence from Mexico. The General Land Office was originally responsible for managing the public domain by collecting and keeping records, providing maps and surveys and issuing land titles. Since then the GLO's duties have evolved, but its core mission is still the management of state lands and mineral-right properties totaling 20.3 million acres. Included in that portfolio are the beaches, bays, estuaries and other "submerged" lands out to 10.3 miles in the Gulf of Mexico, institutional acreage, grazing lands in West Texas, timberlands in East Texas, and commercial sites in urban areas throughout the state. In managing that property, the land office now leases drilling rights for oil and gas production on state lands, producing revenue and royalties which are funneled into the state's Permanent School Fund.

Texas Department of Transportation (TxDOT)
The TxDOT works cooperatively to provide safe, effective and efficient movement of people and goods. The Preserve lies within the Beaumont District of TxDOT. The Beaumont District plans, designs, builds, operates and maintains the state transportation system in the following counties: Chambers, Hardin, Jasper, Jefferson, Liberty, Newton, Polk, Orange, and Tyler.

Local Water Suppliers
Most of the local water suppliers fall into one of four categories: cities, municipal utility districts (MUDs), water supply corporations (WSCs), and private water suppliers. Cities play a vital role in planning and developing water supplies in the state. They generally own and operate wells and reservoirs, as well as treatment and distribution facilities. Many cities buy water from river authorities or from other water suppliers.

Municipal Utility Districts (MUDs)
In addition to city water suppliers, there are over 1,000 MUDs in Texas. They are tax-exempt political subdivisions of the state and have authority to issue bonds. MUDs develop and sell water by building reservoirs, drilling water wells, and distributing water to customers. They can also construct and operate water treatment and wastewater treatment plants.

Roy E. Larsen Sandyland Sanctuary
The sanctuary, 5,561 acres owned by The Nature Conservancy, harbors a variety of plant communities, including one of the last remaining longleaf pine communities in Texas. A rare combination of swamp, open-floor forest and Southern pinelands create a preserve with remarkable diversity, sustaining 727 plant species and 234 animal species. The sanctuary is part of a comprehensive effort to protect and restore the longleaf pine ecosystem on the West Gulf Coastal Plain.

Which Laws and Policies Apply to Flowing Water and Associated Dependent Systems, and What Guidance Do the Laws and Policies Provide?
Big Thicket National Preserve was established in 1974, along with Big Cypress National Preserve, as the first preserve units of the national park system.

Big Thicket National Preserve's opening paragraph of its enabling legislation, Public Law 93-439, and as amended by P.L. 94-578, P.L. 98-489, and P.L 103-46 is shown below. Importantly, the opening paragraph does not contain any direct reference to aquatic or hydrologic terminology:

"Be it enacted by the Senate and House of Representatives of the United states of America in Congress assembled, That (a) in order to assure the preservation, conservation, and protection of the natural, scenic, and recreational values of a significant portion of the Big Thicket area in the State of Texas and to provide for the enhancement and public enjoyment thereof, the Big Thicket National Preserve is hereby established."

In fact, the only inclusion of water-oriented language in the enabling legislation is the use of the terms "stream corridor" and "stream banks," but in both instances those terms are invoked from a geodetical standpoint, as reference markers delineating the boundaries of the preserve:

… In establishing such boundaries, the Secretary shall locate **stream corridor** unit boundaries referenced from the **stream bank** of each side thereof and he shall further make every reasonable effort to exclude from the units hereafter described any improved year-round residential properties which he determines ….

However, it should be noted that 11 of the 15 management units listed in enabling legislation include riparian terminology: including creek, creek corridor, baygall, bayou, Neches (river) bottom.

Despite the absence of water-oriented language in the enabling legislation, flowing water is omnipresent, thereby establishing water as a central focus and as a unifying theme for the Preserve.

Federal:
• The *National Park Service Organic Act* of 1916 created the NPS and includes a significant management provision stating that the NPS *shall promote and regulate the use of the federal areas known as national parks, monuments, and reservations by such means and measures as conform to the fundamental purpose of the said parks, monuments, and reservations, which purpose is to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for future generations*. The Organic Act also authorizes the NPS to *regulate the use* of national parks and develop rules, regulations and detailed policies to implement the broad policies provided by Congress. Rules and regulations for the national park system are described in the *Code of Federal Regulations* (Title 36).

• The *General Authorities Act* of 1970 strengthened the 1916 *Organic Act*, stating that lands in all NPS units, regardless of title or designation, shall have a common purpose of preservation. All water resources in the national park system, therefore, are equally protected by federal law. It is the primary duty of the NPS to protect those resources unless otherwise indicated by Congress.

• The *Redwood National Park Act* of 1978 amended the *General Authorities Act* of 1970, identifying the *high public value and integrity of the national park system* as reason to manage and protect all park system units. The act further stated that no activities should be allowed that will compromise the *values and purposes for which these various areas have been established*, except where specifically authorized by law or provided for by Congress.

• The *National Parks Omnibus Management Act* of 1998 outlined a strategy to improve the ability of the NPS to provide high-quality resource management, protection, interpretation and research in the national park system by:

o Fostering the collection and application of the highest quality science and information to enhance management of units of the national park system;
o Authorizing and initiating cooperative agreements with colleges and universities, including but not limited to land grant schools, along with creating partnerships with other federal and state agencies, to construct cooperative study units that will coordinate multi-disciplinary research and develop integrated information products on the resources in national park system units and/or the larger region surrounding and including parks;
o Designing and implementing an inventory and monitoring program of national park system resources to collect baseline information and to evaluate long-term trends on resource conditions of the national park system, and;
o Executing the necessary actions to fully and properly apply the results of scientific study to park management decisions. Additionally, all NPS actions that may cause a significant adverse effect on a park resource must conduct unit resource studies and administratively record how study results were considered in decision-making. The trend in resource condition in the national park system shall be a critical element in evaluating the annual performance of the NPS.

• *Safe Drinking Water Act* (42 USC 3001 et seq.) applies to developed public drinking water supplies. It sets national minimum water quality standards and requires testing of drinking water.

o *2006 NPS Management Policies*: These policies cover water supply systems; wastewater systems; and recreational waters. Specific guidance is provided by Director's Order 83: Public Health and its associated Reference Manuals – 83A1 (Drinking Water Standards); 83A2 (Cross Connection Control); 83A3 (Water System Security); 83B1 (Wastewater Systems); and 83B4 (Sewage Spill Response Notification).

• The 1972 *Federal Water Pollution Control Act*, also known as the *Clean Water Act*, strives to restore and maintain the integrity of U.S. waters. The Clean Water Act grants authority to the states to implement water quality protection through best management practices and water quality standards. It is in the discussion of water quality standards that the concepts of Outstanding Natural Resource Waters and anti-degradation are discussed. Section 404 of the act requires that any dredged or fill materials discharged into U.S. waters, including wetlands, must be authorized through a permit issued by the U.S. Army Corps of Engineers, which administers the Section 404 permit program. Additionally, Section 402 of the act requires that pollutants from any point source discharged into U.S. waters must be authorized by a permit obtained from the National Pollutant Discharge Elimination System (NPDES). All discharges and storm water runoff from major industrial and transportation activities, municipalities, and certain construction activities generally must be authorized by permit through the NPDES program. NPDES permitting authority typically is delegated to the state by the U.S. Environmental Protection Agency.

Section 303 discusses the requirement that states provide a regular, updated listing of its impaired waters and the reasons for impairment. This section also discusses the Total Maximum Daily Load (TMDL) process that is implemented to improve impaired waters.

o *2006 NPS Management Policies*: The NPS will determine the quality of park surface and ground water resources and avoid, whenever possible, the pollution of park waters by human activities occurring within and outside of parks.

-Work with appropriate governmental bodies to obtain the highest possible standards available under the Clean Water Act for the protection of park waters.
- Take all necessary actions to maintain or restore the quality of surface waters and ground waters within the parks consistent with the Clean Water Act and all other applicable federal, state, and local laws an regulations; and
- Enter into agreements with other agencies and governing bodies, as appropriate, to secure their cooperation in maintaining or restoring the quality of park water resources.

o *2006 NPS Management Policies:* The NPS will manage watersheds as complete hydrologic systems, and will minimize human disturbance to the natural upland processes that deliver water, sediment, and woody debris to streams. The NPS will protect watershed and stream features primarily by avoiding impacts on watershed and riparian vegetation and by allowing natural fluvial processes to proceed unimpeded.

• *Executive Order* 11990: *Wetlands Protection* requires the NPS to 1) exhibit leadership and act to minimize the destruction, loss, or degradation of wetlands; 2) protect and improve wetlands and their natural and beneficial values; and 3) to refrain from direct or indirect assistance of new construction projects in wetlands unless there are no feasible alternatives to such construction and the proposed action includes all feasible measures to minimize damage to wetlands.

o *2006 NPS Management Policies:* The NPS will manage wetlands in compliance with NPS mandates and the requirements of Executive Order 11990 (Wetland Protection), the Clean Water Act, and the Rivers and Harbors Appropriation Act of 1899, and the procedures described in Director's Order 77-1. The service will 1) provide leadership and take action to prevent the destruction, loss, and degradation of wetlands; 2) preserve and enhance the natural and beneficial values of wetlands; and 3) avoid direct and indirect support of new construction in wetlands unless there are not practicable alternatives and the proposed action includes all practicable measures to minimize harm to wetlands. The NPS will implement a "no net loss of wetlands" policy.

• *Executive Order* 11988: *Floodplain Management* has a primary objective *…to avoid to the extent possible the long- and short-term adverse impacts associated with the occupancy and modification of floodplains and to avoid direct and indirect support of floodplain development wherever there is a practicable alternative*. For non-recurring actions, the order requires that all proposed facilities must be located outside the boundary of the 100-year floodplain. Barring any feasible alternatives to construction within the floodplain, adverse impacts are to be minimized during the design phase of project planning. NPS guidance for this executive order can be found in D.O. 77-2.

o *2006 NPS Management Policies:* In managing floodplains on park lands, the NPS will 1) manage for the preservation of floodplain values; 2) minimize potentially hazardous conditions associated with flooding; and 3) comply with the NPS Organic Act and all other federal laws and executive orders related to the management of activities in flood-prone areas, including Executive Order 11988 (Floodplain Management), NEPA, applicable provisions of the Clean Water Act, and the Rivers and Harbors Appropriation Act of 1899. Specifically the NPS will:

- Protect, preserve, and restore the natural resources and functions of floodplains;
- Avoid the long- and short-term environmental effects associated with the occupancy and modifications of floodplains; and
- Avoid direct and indirect support of floodplain development and actions that could adversely affect the natural resources and functions of floodplains or increase flood risks.

When it is not practicable to locate or relocate development or inappropriate human activities to a site outside and not affecting the floodplain the NPS will:

- Prepare and approve a statement of findings, in accordance with procedures described in Director's Order 77-2 (Floodplain Management);
- Use nonstructural measures as much as practicable to reduce hazards to human life and property while minimizing the impact to the natural resources of floodplains;
- Ensure that structures and facilities are designed to be consistent with the intent of the standards and criteria of the National Flood Insurance Program (44 CFR Part 60).

o *2006 NPS Management Policies*: Natural shoreline processes (such as erosion, deposition, dune formation, shoreline migration) will be allowed to continue without interference. Where human activities have altered the nature or rate of natural shoreline processes, the NPS will, in consultation with appropriate state and federal agencies, investigate alternatives for mitigating the effects of such activities or structures and for restoring natural conditions. New developments will not be placed in areas subject to wave erosion or active shoreline processes unless 1) the development is required by law; or 2) the development is essential to meet the parks' purposes, as defined by its establishing act of proclamation, and

- No practicable alternative locations are available,
- The development will be reasonably assured of surviving during its planned life span, without the need for shoreline control measures, and
- Steps will be taken to minimize safety hazards and harm to property and natural resources.

• The *Clean Air Act* of 1970 (as amended in 1990) regulates airborne emissions of a variety of pollutants from area, stationary, and mobile sources. The amendments to the act were added primarily to fill gaps in earlier regulations pertaining to acid rain, ground level ozone, stratospheric ozone depletion and air toxics, and also to identify 189 hazardous air pollutants.

The act directs the EPA to study these pollutants, identify their sources, determine the need for emissions standards and develop and enforce appropriate regulations.

• *Fish and Wildlife Coordination Act* affords protection to water resources, and fish and wildlife. This Act applies to major federal water resources development plans (impounding, diverting, deepening the channel, or otherwise controlling or modifying streams or other bodies of water). The Act requires federal agencies to consult with the USFWS and applicable state agencies whenever such plans result in alteration of a body of water. In addition, the Act requires that wildlife conservation receive equal consideration with other features of water resource development, and it also triggers coordination with the USFWS upon application for a 404 permit.

• *Rivers and Harbors Act* of 1899 affords protection to shorelines and navigable waterways, tidal waters, and wetlands. Section 10 of the Rivers and Harbors Act of 1899 prohibits the unauthorized obstruction or alteration of any navigable waterway of the United States. In order to obstruct or alter the waterway, a person must obtain a permit from USACE. Activities requiring a permit include constructing structures in or over any waters of the U.S., excavating material from the water, conducting stream channelization, and depositing materials in such waters.

• The *National Environmental Policy Act* (NEPA) of 1969 requires that any action proposed by a federal agency that may have significant environmental impacts shall utilize a systematic, interdisciplinary approach which will insure the integrated use of the natural and social sciences and the environmental design arts in planning and in decision making which may have an impact on man's environment.

• The *Endangered Species Act* of 1973 requires the NPS to identify all federally listed endangered, threatened and candidate species that occur within each park unit and promote their conservation and recovery. The act requires that any activity funded by federal monies that has the potential to impact endangered biota must be consulted through the Secretary of Interior. It requires agencies to protect designated critical habitats upon which endangered and threatened species depend. Although not required by law, it also is NPS policy to identify, preserve and restore state and locally listed species of concern and their habitats.

• *Invasive Species* (Executive Order 13112): enhances and furthers the existing authority of the federal government to assist in preventing and controlling the spread of invasive species.

State of Texas:

- Texas Water Code

The Texas Water Code is the compendium of laws by which waters in the state of Texas are managed. The Texas Water Code was developed to resolve systematic weaknesses in the common law mix of riparian and prior appropriation doctrines. While some states have supplemented common law on a piecemeal approach – resulting in an uneasy mix of old and new – Texas undertook a comprehensive reform with its water code which replaces the common law and also continues to evolve.

Title 1: General Provisions
Title 2: Water Administration (*e.g.*, water rights, water wells, groundwater, water development, water quality control)
Title 3: River Compacts
Title 4: General Law Districts (*e.g.*, irrigation districts, navigation districts, municipal utility districts)
\Title 5: Special Law Districts (river authorities)
Title 6: Surface Water Authorities

- Water Rights Adjudication Act of 1967

The act's immediate purpose was to legally verify all surface-water claims on a state-wide basis. The act achieved this by authorizing all surface waters to be claimed by the state to be held in trust for the use of its people. Water rights were then allocated according to a first in time first in right, subject to certain clauses, as could be submitted and proved by the claimants. A water right comes with a rate, a volume, location, and time – with the earliest claims dating back to 1913.

Water in the rivers, streams, underflow, creeks, tides, lakes and every bay and arm of the Texas portion of the Gulf of Mexico is considered state water. Its use may be acquired through appropriation via the permitting process established in Texas Water Code, Chapter 11, and Title 30, Texas Administrative Code. Anyone wishing to use surface water must receive permission from the state in the form of a "water right," but which is subject to requirements (to be upheld by the claimant) and availability.

The broader purpose of the act was to put the responsibility of managing Texas waters in the hands of Texas – from both a legal and water development standpoint. Otherwise it was feared, economic stagnation would ensue or federal intervention by the USACE and BOR would play a greater role. The act set the stage for efficient management of its waters – both through an orderly system of allocating the water pie during times of drought and water development projects to expand the water pie by capturing flood runoff.

Although considered comprehensive and integrated, Texas water rights depend on whether the water is ground or surface water, with a third category – called diffuse flow falling under a separate category of lesser importance. This arrangement is not uncommon in the West, and is called a bifurcated system, and was originally founded under the premise that ground waters had unbounded potential, whereas surface water supplies were finite, and should be awarded to the claimant first in time who put those waters to use, in lands often times removed from the river channel. Thus, ground water falls under a riparian code. The basic concept is that private water rights are tied to the ownership of land bordering a natural river or stream.

Ground water is governed by the rule of capture, which grants landowners the right to capture the water beneath their property. The landowners do not own the water but have a right only to pump and capture whatever water is available, subject to reasonable use clauses, regardless of the effects of that pumping on neighboring wells. Riparian owners retain the right to use water so long as they own the land adjacent to the water. In the case of ground water, this means that the water belongs to the owners of the land above it and may be used or sold as private property.

Texas courts have adopted, and the legislature has not modified, the common law rule that a landowner has a right to take for use or sale all the water that he can capture from below his land.

Texas courts have consistently ruled that a landowner has a right to pump all the water that he can from beneath his land regardless of the effect on wells of adjacent owners – thus supporting the riparian code, under the legal presumption in Texas is that all sources of ground water are percolating waters as opposed to subterranean rivers.

More recently, however, as it has become increasingly apparent that ground water is a finite resource, interconnected with streams and subject to diminishment by larger and deeper pumps – the so called "law of the biggest pump" – thus there has been a growing concern that all Texas waters – not just surface water – be merged under a common system.

Fundamental Resource: The Thicket

What is the Importance of the Thicket to the Preserve?

The Thicket as a construct defines the Preserve. Yet, challenges exist to standing NPS perspectives regarding the Thicket. A summary of the confusion regarding a definition or delineation of the Big Thicket as an ecological or geographical entity can be found in Diggs *et al*. (2006). These authors adopt a working definition of the Thicket to further their analyses of the Thicket as a unique resource in East Texas:

The Big Thicket is thus the biological boundary at the southwestern extreme of the southeastern U. S., humid subtropical in climate, geologically and hydrologically complex, rich in species and characterized by a loblolly pine-white oak-beech-magnolia forest with many associated and often very distinct vegetation types.

This represents a more narrow description of the Thicket compared to the designation of units for the Preserve, which in fact may be more appropriately representative of the broader Pineywoods ecoregion or vegetation area in East Texas (Diggs *et al*. 2006). The term "thicket" may have developed from early travelers who made accounts of the difficulty in crossing baygall and swampy areas. While these vegetative communities were never so expansive to warrant the name thicket for an entire region, they were likely pervasive enough for travelers to frequently encounter them, leading to the perspective of impenetrable thickets. Historical studies show that the area described as the Thicket was always a complex of ecological systems ranging from prairie to dense forest (Diggs *et al*. 2006). A related issue regarding perspective and reality is the role of the Thicket as a biological "cross-roads" given the unique biological community combinations resulting from species ranges overlapping from at least three ecoregions, and some species found from more arid parts of Texas persisting in the Thicket. More recent analyses determined that species and communities found in the Thicket are predominantly shared with those of the southeastern coastal plain (MacRoberts and MacRoberts 2007). What can be said is that the Thicket consists of high *alpha*- (within patch) and *beta*- (among patch) diversity (Marks and Harcombe 1981), and that many species and communities are at the edge of their ranges (mostly southern and western edges of ranges) (MacRoberts and MacRoberts 2007).
Biodiversity is the variety of life and its processes: this encompasses compositional (what is there), structural (how it is distributed in space and time) and functional (what it does) elements of ecosystems, each being manifest at multiple levels of interconnected organization ranging

from genes to species, communities and ecosystems and landscapes (Noss 1990). It is the biodiversity then that becomes the essence of "the Big Thicket."

The geologic history and processes of the Big Thicket region, coupled with the past and current climatic regime, served as the foundation which has given rise to the Preserve's rich biodiversity and unique plant community associations characterized as a "biological crossroads." The region's varying topography and soils have been significantly influenced by its geologic history and processes, and the surficial geologic processes continue today to shape the landscape, particularly with respect to fluvial geomorphic features along the Neches River and its tributaries. Soil conditions ranging from relatively impermeable clays, such as those found in association with the Beaumont Formation, to relatively deep coarse sands found in areas of fluviatile terrace deposits, contribute significantly to the floristic diversity of the Preserve.

Taken together, the interplay of geology, topography, climate, water, and soils causes abrupt transitions in vegetation community composition. As presented by Callicott *et al*. (2006), topographic and soil conditions powerfully influence the local segregation of this rich concentration of plant species into distinctive plant communities. The longleaf pine ecosystem, one of the most threatened in North America and also one of the most diverse, occurs on three main landforms: (1) uplands that are dry because of coarse soils and relatively steep terrain; (2) especially dry deep sands of old stream terraces where one can view cacti, yuccas and other plants commonly thought of as desert plants in association with the pines; and (3) wet, poorly drained flats where longleaf pine savannas occur together with a herb-rich ground layer of sedges and grasses, including carnivorous plant species. In uplands and some stream bottoms with sandy-loam soils that are well-drained, but moist most of the year, one can find magnificent sands dominated by southern magnolias and American beach. Bottomland-hardwood forests of oaks and gums are found in floodplains along rivers and creeks, and sloughs and oxbows of river and creek floodplains are dominated by bald cypress and tupelo swamps. The wetland baygall vegetation communities in the Preserve are compositionally distinct, and are poorly defined by topography and drainage; however, seepage water may be a key factor in their locations because they often occur at the base of bluffs in floodplains (Harcombe and Marks 1979). Harcombe and Marks (1979) discussed the general relationship between topography, soils, and vegetative communities in Preserve management units.

What Are the Current State or Conditions and the Related Trends of Natural Resources in the Thicket?

Section 4(a) of the Preserve's enabling legislation directs that the Preserve's lands, through the NPS, will be administered "in a manner which will assure their natural and ecological integrity in perpetuity…" Although a formal current condition assessment has not been conducted, and measures have not been assessed for ecological integrity of Preserve resources, clear indicators of degraded resources exist. At this time, it is estimated that about three percent of the remaining habitat in East Texas is considered intact. Urban development was a major cause of habitat loss in the early part of this century, as was logging. Bottomland forests along many rivers have been completely converted. Longleaf pine areas have been converted to loblolly or slash pine plantations or severely fire suppressed. Preserve units are fragmented on the landscape, top predators in food webs are absent, biological invasions are rampant, and extraction activities within and near the Preserve, no matter how carefully conducted, are incompatible with natural area resource persistence. Positive trends are the establishment of invasive plant control, reestablishment of fire on portions of the fire-adapted landscape, preparation of an Oil and Gas Management Plan (NPS 2006), the reinvigoration of science manifested in resource inventories (including the All-Taxa Biological Inventory), status and trend monitoring of select resources, and the continued encouragement of research at the Preserve.

While limited research and monitoring data are available that documents the current conditions and trends of the geologic resources in the Preserve, anecdotal information suggests that that such resources are in a fairly good and stable condition over much of the Preserve. Natural processes of weathering, and fluvial erosion and deposition are the predominant forces affecting geologic resources in the Preserve.

However, geologic resources, primarily soils, have been degraded in specific locations as a result of nonfederal oil and gas exploration, production and transportation. Radian Corporation (1985) conducted natural resource site assessments at 125 abandoned oil and gas wells in the Preserve, ranging from 0.25 to 4.0 acres in size, and conducted similar assessments on an estimated 15 miles of abandoned access roads. Radian noted many of the abandoned well sites and access roads require restoration action, including removal of imported non-native surface material (*e.g.*, crushed oyster shell, gravel, etc.) and debris (*e.g.*, pipes, drums, cable, concrete footing, lumber, etc), aerating compacted soils, remediating contaminated soils, and reestablishing natural contours. Fountain and Rayburn (1987) conducted a study on the impacts of oil and gas development on vegetation and soils of the Preserve, and determined that the presence of foreign material (such as boards, plastic, crushed shell) on 12 of 45 abandoned oil and gas well pads investigated was a primary impediment to the reestablishment and succession of natural vegetation species. In addition, soils at select locations in the Preserve have also been subject to contamination resulting from the release of produced oil and saltwater at specific well sites and as a result of pipeline ruptures. The frequency of contaminant releases at active oil and gas well sites in the Preserve is diminishing due to park staff monitoring of producing oil and gas wells and strict application of the 36 CFR 9B regulations. However, the aging pipeline infrastructure in the Preserve is cause for concern.

Nonfederal oil and gas development continues in the Preserve, and future geophysical exploration, exploratory well drilling, well production, and product transportation will likely occur in the future. A total of 40 active oil and gas operations exist in the Preserve; nine operations on NPS lands, and approximately 31 wells directionally drilled beneath the Preserve from well pads located on adjacent lands. Recent trends indicate that the majority of future oil and gas wells in the Preserve may likely be drilled from external surface locations due to advances in directional drilling technology coupled with the presence of numerous narrow corridor management units in stream floodplains. However, geologic factors alone indicate that additional oil and gas exploration and production operations will be proposed in the Preserve.

With respect to fluvial geomorphic processes occurring along the Neches River, park staff has observed that bank erosion and stream channel migration at specific locations has caused the river to encroach upon, and in some cases transgress, boundaries of the Preserve. Geomorphic processes of the Neches River have also exposed the oil and gas well casing of three abandoned wells; these abandoned wells are now in the river. In addition, bank erosion at specific sites is also exposing previously buried segments of active oil and gas pipelines. These are important management issues for the Preserve.

The Miocene and Pleistocene paleontological resources in the Preserve are presumed to be in fairly good condition because the dense vegetative cover precludes extensive exposures of fossil-bearing deposits. However, as previously noted, several natural erosional areas of the park including river banks, bluffs, and gullies afford access to these deposits. Areas of particular concern include the Upper Neches River Corridor Unit near Town Bluff and the Menard Creek Corridor Unit near the Trinity River. Unauthorized collection of fossils could be occurring in these areas, and perhaps in other areas of the Preserve as well due to the high level of public interest in such irreplaceable resources.

What Are the Current and Potential Threats to the Thicket Within the Preserve?

Land use legacies may have led to potential irreversible conditions. There are extirpated species from the thicket – red wolf, mountain lion, red-cockaded and ivory-billed woodpeckers, Louisiana pine snakes, and passenger pigeons. The lack of top predators is rarely offset by hunting, because of the effects predators have on prey behavior. Forests are secondary growth, leading to less structural and compositional heterogeneity.

Biological invasions represent a significant threat to the Preserve, as they can not only negatively affect individual species, but can influence ecosystem properties such as fire, and thereby change the entire nature of the Thicket. Invasive species can be native or non-native. Native species such as the southern pine beetles (*Dendroctorus frontalis*) might be considered a natural process, except that the current restricted and fragmented state of host species and their communities demands a "hands-on" approach to managing poorly understood outbreaks. For example, suppression of the population is recommended if it is within ¼ mile of private land or if it threatens to kill cavity trees of red-cockaded woodpeckers (Cooper *et al*. 2004). High priority non-native invaders are: Chinese tallow, Chinese privet, Japanese climbing fern, Japanese honeysuckle, kudzu, golden bamboo, Chinaberry, Chinese wisteria, Nandina, Mimosa, water hyacinth and giant salvinia. Including spring annuals, possibly a third of plant species now found in the Thicket area are non-native. Emerging plant species of concern are cogon grass and deep-rooted sedge (Eric Worsham, Big Thicket National Preserve, pers. comm. 2009). Non-native animals include nutria, grass carp, zebra mussels, and the imported red fire ant. Feral populations of animals represent a subset of invasions. Cats and dogs are known to disrupt wildlife behavior and predate on birds and young of other wildlife groups. Feral hogs disrupt soils and understory communities via rooting while foraging.

Fragmentation of the landscape is a continued threat. Landscape processes such as fires and floods, and predation and herbivory patterns of wide-ranging species will not occur within a natural range of variation. Many operational problems for Preserve staff stem from the fragmented nature of the Preserve:

- Increasing number of landowners on the boundary with whom Preserve staff must coordinate with and inform of management actions. New land uses on adjacent lands must also be addressed.
- Encroachment

- Confusion over landownership – there are 560 linear miles of boundary and not enough staff to patrol.

Oil and gas activity along the boundary as well as within the Preserve will continue to disturb wildlife and threaten water quality. Additionally, oil and gas activity, operation and maintenance of trans-preserve pipelines, illegal fossil collecting, and adjacent land use and development are current and potential threats to geologic resources.

Nitrates, ammonium, and sulfates from the atmosphere can deposit into ecosystems through rain, snow, or dryfall, and cause acidification or eutrophication (unnatural enrichment) of waters and soils. Although soils and waters are likely to be well-buffered from acidification in the Preserve, nitrogen from nitrates and ammonium may cause unwanted fertilization of ecosystems in the Preserve. Excess nitrogen alters competitive interactions that may cause native plant species to be lost, with subsequent decrease in species richness and biodiversity. Wetlands often contain a disproportionately high number of rare plant species that have evolved under nitrogen-limited conditions. Species better able to utilize excess nitrogen, including invasive species, may displace native species (EPA 2008). Atmospheric nitrogen deposition is monitored by CASTNet (http://www.epa.gov/castnet) in Hardin County, Texas. Total inorganic nitrogen deposition at that site is estimated to be 4.5-5.0 kg/ha/yr, significantly elevated above preindustrial deposition of about 0.5 kg/ha/yr, the deposition at which many native plant species evolved.

Atmospheric deposition of mercury has the potential to harm fish and wildlife in the Preserve. Burning of coal in powerplants is the primary source of mercury to the atmosphere and, once deposited into ecosystems, mercury may be transformed into a very toxic form, methylmercury. Conditions in the Preserve, including extensive wetlands and high dissolved organic matter, promote mercury methylation and subsequent uptake and bioaccumulation in aquatic organisms. A 2007 survey by the Texas Department of State Health Services (DSHS) found high levels of mercury in fish from Village Creek in the Preserve and concluded that consumption of black crappie, gar, and largemouth bass from the creek posed an apparent hazard to human health (http://www.dshs.state.tx.us/seafood/PDF2/Risk%20Characterization/VillageCreekRC2007.pdf). Texas DSHS recommended that pregnant women, women who may become pregnant, and women who are nursing an infant, should eat no crappie, gar, or largemouth bass from Village Creek; that small children (those at or below 12 years of age or who weigh less than 75 pounds) should limit consumption of crappie, gar, and largemouth bass to two four-ounce meals per month from Village Creek; and that adult men and women past childbearing should limit consumption of crappie, gar, and largemouth bass to two 8-ounce meals per month from Village Creek.

Who Are the Stakeholders Who Have an Interest in the Thicket?

The following stakeholders will likely have an interest in the Thicket and its representation in the Preserve:

- Lamar University
- Rice University
- Stephen F. Austin State University
- Sam Houston State University
- University of Texas Bureau of Economic Geology

- Texas A&M University
- University of North Texas
- Big Thicket Association
- Alabama-Coushatta Tribe of Texas
- Texas Memorial Museum
- The Nature Conservancy
- Oil and gas operators
- Trans-park pipeline operators
- Natural Resources Conservation Service
- U.S. Geological Survey
- Residents along waterways
- Adjacent landowners
- Timber companies
- Texas Railroad Commission
- Texas General Land Office
- Texas Historical Commission
- Texas Department of Transportation
- Texas Natural Resources Conservation Commission
- Texas Water Development Board
- Texas Forest Service
- Researchers – geology and paleontology
- Sierra Club
- U.S. Army Corps of Engineers
- U.S. Coast Guard (navigable waters)
- U.S. Fish and Wildlife Service
- Texas Parks and Wildlife Department
- Federal Energy Regulatory Commission (pipelines)
- U.S. Environmental Protection Agency
- U.S. Department of Transportation (pipelines)
- National Parks and Conservation Association

Which Laws and Policies Apply to the Thicket, and What Guidance Do the Laws and Policies Provide?

- National Park Service Organic Act: *see page 68*
- General Authorities Act: *see page 68*
- Redwood National Park Act: *see page 68*
- National Parks Omnibus Management Act: *see page 69*
- NPS 2006 Management Policies: *see pages 69-71*
- Clean Air Act: *see page 71*
- Executive Order 13122 Invasive Species: *see page 72*
- Endangered Species Act: *see page 72*

Park System Resources Protection Act (PSRPA): This act affords protection to any living or non-living resource that is located within the boundaries of a unit of the National Park System, except for resources owned by a nonfederal entity. The Park System Resource Protection Act makes any person who destroys, causes the loss of, or injures any park system resource strictly liable to the United States for response costs and for damages resulting from such destruction, loss, or injury. A park system resource includes any living or non-living resource located within the boundaries of a NPS unit, except for resources owned by a non-federal entity. Because the statute imposes strict liability the only defenses arise when an act of nature or war caused the damage, a third party who constituted neither an employee or nor an agent of the owner/operator solely caused the damage, or an activity authorized by federal or state law caused the damage.

The PSRPA authorizes the Secretary of the Interior to request the Department of Justice to file a civil action for the costs of replacing, restoring or acquiring the equivalent of a park system resource; the value of any use loss pending its restoration; replacement, or acquisition, the cost of damage assessments; and the cost of response including actions to prevent, to minimize, or to abate injury. Response costs include actions taken by the NPS "…to prevent or minimize destruction, loss of, or injury to park system resources; to abate or minimize the imminent risk of such destruction, loss or injury; or to monitor ongoing effects of incidents causing such destruction, loss or injury."

Antiquities Act of 1906: This act affords protection to cultural, historic, archeological and paleontological resources. The Antiquities Act constituted the first general act providing protection for archeological, historic and prehistoric ruins or monuments, and paleontological resources on federal lands. The act prohibits excavation, destruction, injury or appropriation of such resources without the departmental secretary's permission. It also authorizes the President of the United States to proclaim as national monuments public lands having historic landmarks, historic and prehistoric structures, and other objects of historic or of scientific interest. The Antiquities Act also authorizes the President to reserve federal lands, to accept private lands, and to accept relinquishment of unperfected claims for that purpose.

Paleontological Resources Protection Act: This act requires federal agencies to 1) promulgate regulations as soon as practicable; 2) develop plans for fossil inventories, monitoring, and scientific and educational use; 3) manage and protect paleontological resources on federal land using scientific principles and expertise; 4) establish a program to increase public awareness about the significance of paleontological resources; 5) manage fossil collection via specific permitting requirements; 6) curate collected fossils in accordance with the Act's requirements; 7) implement the Act's criminal and civil enforcement, penalty, reward and forfeiture provisions; and 8) protect information about the nature and specific location of fossils where warranted.
Migratory Bird Treaty Act (MBTA): This act implements various treaties and conventions between the United States, Canada, Japan, Mexico, and Russia for the protection of migratory birds. Unless permitted by regulations, under the MBTA a person cannot attempt or succeed at pursuing, hunting, taking, capturing, killing, possessing, offering to sell, selling, bartering, purchasing, delivering, shipping, exporting, importing, transporting, carrying or receiving any migratory bird, body part (*e.g.* feathers), nest, egg, or product.

Oil Pollution Act (OPA): This act expands the federal role in spill response, establishes contingency planning requirements for vessels and certain facilities, establishes the Oil Spill Liability Trust Fund, increases liability for spills of oil or hazardous substances from vessels and facilities, creates requirements for double hulls on new tankers, and increases requirements for research and development of spill response technologies. The OPA imposes liability for removal costs and damages resulting from discharge of oil into the U.S.'s navigable waters, its adjoining shorelines, or the exclusive economic zone. Damages incurred include injuries to natural resources, loss of natural resources, and loss of use of natural resources. Natural resources include land, fish, wildlife, biota, air, water, groundwater, drinking water supplies, and other resources belonging to the U. S., state, local, foreign governments or Native American tribes.

The OPA provides new requirements for government and industry oil spill contingency planning. The "National Oil and Hazardous Substances Pollution Contingency Plan" was expanded to encompass a three-tiered approach. The federal government directs all public and private response efforts for certain types of spill events. Area committees, composed of federal, state, and local government officials, must develop detailed, location-specific Area Contingency Plans. Owners or operators of vessels and certain facilities that pose a serious threat to the environment must prepare their own facility response plans.

The OPA may require operators of nonfederal oil and gas operations in units of the National Park System to develop contingency plans. Contingency plans developed to meet the requirements of OPA may also satisfy the NPS 9B requirement for a contingency plan. NPS would determine if the OPA required plan meets NPS requirements as part of the 9B plan approval process.

Resource Conservation and Recovery Act (RCRA): This act seeks to promote the protection of health and the environment and to conserve valuable material and energy resources. RCRA regulates the management of hazardous waste from generation to final disposal. The law consists of nine subtitles.

The requirements of Subtitle C apply if the waste falls under EPA's criteria governing hazardous waste. EPA codified the regulatory criteria for hazardous waste at 40 C.F.R. Parts 260 and 261. EPA codified a list of hazardous wastes (known as listed wastes) in Subpart D of Part 261. Subpart C of Part 261 establishes the criteria for determining whether a solid waste constitutes a hazardous waste by exhibiting a characteristic of corrosivity, reactivity, ignitability, or toxicity (known as characteristic waste). EPA can regulate a solid waste because it either appears on the hazardous waste lists or displays a characteristic of a hazardous waste.

The 1980 amendments to RCRA excluded certain oil, gas, and geothermal drilling and production wastes from the hazardous waste requirements of Subtitle C. The amendments specifically exempt drilling fluids, produced water, and other drilling and production wastes. In 1988, the EPA decided to keep the exemption for oil and gas exploration and production wastes. State agencies regulate the exempted wastes under the less strict Subtitle D governing nonhazardous waste.

In addition, the RCRA exemption from Subtitle C for oil and gas drilling and production waste does not exclude these wastes from the operation of RCRA section 7003. Section 7003 allows EPA to compel any person who contributed or contributes to the handling, storage, treatment, transportation or disposal of the hazardous waste in a manner that causes an imminent and substantial danger to take any action to protect human health and the environment. Because this can include expensive cleanup actions to protect human health and the environment, operators should handle waste from their operations in such a way that it does not contaminate the environment either now or in the future.

Regardless of oil and gas exploration and production wastes' exemption from Subtitle C regulation, the NPS will likely require operators to dispose of all wastes associated with the oil and gas operation outside of the park. NPS requirements for waste disposal in an operator's plan of operations will provide for the strict protection of park resources and values.

Fundamental Value: Scientific Value

What Is the Importance of Scientific Value to the Preserve?

Scientific value continues to be an important role for all protected areas. The development of science is one of the driving objectives of Biosphere Reserve designations. In short, the quest to understand nature has always accompanied the appreciation of nature in efforts to protect "special places." The Preserve provides access to scientific research in a region where there is so few public lands. The Preserve's status as a collection of protected areas within a working landscape provides opportunities to test numerous hypotheses in conservation biology and ecology. The types of research that the Preserve is particularly amenable to include:

- restoration of communities and ecosystems;
- exotic plant biology and ecology;
- ecosystem resistance and resilience to natural and anthropogenic disturbance -- of interest to managers is how resources respond to disturbances -- generally, it is helpful to know the range of variation of "natural" disturbances;
- population ecology of species at the edge of their respective ranges, and in combination with other species within assemblages; this is directly relevant to climate change research and modeling;
- landscape ecology -- this includes analyses of connectedness, fragmentation, corridors and reserve design;
- ozone emissions from local (oil and gas development) sources and effects on biota;
- recreational opportunities and impacts;
- effects (in both directions) of timber harvest activities and protected area activities;
- climate change response; and
- flood-pulse concept, natural flows, and flow variability.

What Are the Current State or Conditions and the Related Trends of Scientific Research in the Preserve?

Trends for bringing science into the Preserve are improving after a period of little activity and loss of some research projects. The NPS Fire Program has been collecting fire effects data, the All Taxa Biological Inventory and status and trend monitoring are underway, and researchers are coming back to the Preserve. Biosphere Reserve oriented research has not been developed, but renewed interest in the Man and the Biosphere program in the U.S. may result in additional coordination support for this work. Additional work should be pursued with partners to study natural ecosystem dynamics, management actions, and ecological restoration. There is also the issue of researchers not complying with the conditions of their permits (*e.g.*, staying within the limits of their permits, turning in reports, etc.).

Like any NPS unit, management efforts in the Preserve are enhanced by a baseline of historical data and hindered to varying degrees by gaps of key resource information. Hydrologic monitoring is relatively robust, and the biological inventory is making progress, but many information gaps and uncertainties require further attention. For example, clear boundary descriptions are needed, as well as, information on historic land use. Formal land surveys and acquisition of historical aerial imagery are necessary for understanding and planning. Imagery exists, and dates to the 1930s but it is extremely expensive – the whole suite of images costs about $140,000 just for the 1930s, when most of the logging damage was done at this point. Environmental histories are effective in rounding out datasets to provide context to known shifts in resource patterns, conditions and processes.

What Are the Current and Potential Threats to Scientific Value Within the Preserve?
While there is never a threat to the need for more knowledge, there is always a concern that budget restrictions will lead to lower prioritization for research. This does not mean that staff may care less about science, but they may not have the capacity to facilitate science.

The primary threat to the scientific value of the Preserve is the inability of science and conservation to keep up with the rapid pace of agricultural, industrial, residential, and water development growth in the Big Thicket region, and compete against the economic incentives for this growth. Economic development has resulted in loss, degradation, and fragmentation of the Big Thicket's ecology and large spatial extent. Conservation efforts have been successful to varying degrees in counteracting these effects, and a growing body of scientific knowledge has provided support to conservation measures, but lack of funding, the disparate nature of the threats, and complexity of the ecosystem makes it an on-going and difficult task. There is a need to foster a regional outlook for advocating science and conservation within the Big Thicket region in this regard, to both better protect and restore natural areas and processes within the Preserve and throughout the Big Thicket region.

Who Are the Stakeholders Who Have an Interest in the Scientific Value of the Preserve?
Big Thicket's national recognition as a unique physiographic region has motivated a wide array of governmental, academic, educational and conservation organizations (and others) to implement and steward scientific and conservation efforts both within and surrounding the Preserve. Baseline collection of scientific and conservation information is considered particularly important in the Preserve because it puts the larger context of the Big Thicket – and the role that the Preserve plays in it – in perspective, and provides a foundation for guiding specific scientific and conservation efforts. Such collection includes the following:

- U.S. Geological Survey measures stream flow along major and tributary water ways within the Big Thicket region. Such measurements are valued not only for their functionality towards tracking flow and stage levels in real-time flow, thereby assessing flood and drought severity, but also as a historic baseline for better understanding natural hydrology prior to water control efforts, and utilization by a wide range of researchers.
- The Big Thicket Association has partnered with the Preserve to develop an All Taxa Biodiversity Inventory of the Preserve. This effort draws on a wide range of experts, usually assembled in taxonomic working groups, and will result in a comprehensive baseline for understanding and guiding future management and research in the Preserve.
- The National Park Service's Gulf Coast Inventory and Monitoring Network has partnered with Lower Neches Valley Authority to monitor water quality in tributary waters of the

Preserve that when combined with historical data provides an invaluable water quality baseline.

Other research and conservation efforts also form key pieces to understanding the scientific and conservation aspects of the Big Thicket, but in most cases have not maintained the historic continuity of the primary baseline efforts listed above. Examples include:

- Local and regional universities
- Local public schools
- Local residents
- Recreation groups
- Consulting firms
- Big Thicket Association
- Mycological Society
- BEST – "Butterfly Enthusiasts from SE Texas"
- Black Bear Task Force
- The Nature Conservancy (owns easements and property within the Preserve's
- administrative boundary – the intent is to eventually pass property to Preserve)
- The Conservation Fund
- Houston Wilderness
- Sierra Club
- Texas Parks and Wildlife
- U.S. Fish and Wildlife Service
- U.S. Environmental Protection Agency
- Timber investment firms
- Oil and Gas operators

Which Laws and Policies Apply to the Scientific Value of the Preserve, and What Guidance Do the Laws and Policies Provide?

- The Preserve's enabling legislation
- National Parks Omnibus Management Act: *see page 69*
- NPS Management Policies of 2006: *see pages69- 71*
- Executive Order 13122 on Invasive Species: *see page 72*
- Endangered Species Act: *see page 72*

Climate Change and Big Thicket National Preserve [adapted from Twilley *et al*. (2001)]

Twilley *et al.* (2001) explored the potential risks of climate change to Gulf Coast ecosystems through an understanding of the most likely ecological consequences. The two climate scenarios used in their report both predict warmer temperatures and an increase in the rate of sea-level rise over the next 100 years. Summer high temperatures are projected to rise between 3 and 7^{o} F and winter low temperatures to warm by as much as 5^{o} F in the east to 10^{o} F in the western gulf. Sea-level rise along the Gulf Coast is projected to range from over 8 to almost 20 inches. Considering regional subsidence, this range expands to 15 inches along most of the Gulf Coast to as much as 44 inches along the Mississippi Delta.

Global warming will have particularly important impacts on the region's water resources. Gulf coast ecosystems are linked by the flow of water from the uplands through freshwater lakes, rivers and wetlands to the coast. Vast wetland areas require periods of flooding to maintain healthy habitats and sustain food webs. While there remains uncertainty about how global warming will affect rainfall, stream flow, soil moisture and overall water availability, human consumption of water resources is almost certain to increase as a result of the region's population growth. If climate change results in reduced runoff and lower groundwater levels for parts of the year, the consequence could be a shortage of water to satisfy both ecosystem needs and the growing and competing human demands. Other impacts could include:

- The increasing drawdown of surface water systems and underground reservoirs could combine with sea level rise to increase saltwater contamination of aquifers. The risk of saltwater intrusion increases especially if these underground freshwater levels are declining because of greater human consumption and lower recharge rates. This risk is greatest if climate turns drier, but it will remain significant even if the climate grows wetter, because of human water use and sea-level rise are certain to increase.
- Changing surface runoff patterns driven by changes in rainfall could alter river ecosystems. Changes in flooding patterns could also significantly affect river ecosystems. Flooding periodically rejuvenates floodplains by erosion and deposition and is essential to the health of river ecosystems. From an ecological perspective, flood pulses are not disturbances, but rather essential processes that define the biology and water quality of river ecosystems. If climate change results in more intense rainfall events, humans are likely to try to reduce flooding by increasing channelization of rivers and building dams, levees and reservoirs, all of which are functionally less effective in flood control than maintaining floodplain habitats that can receive and slow overbank flows.
- In freshwater streams, warmer temperatures and a longer growing season could reduce habitat for cool-water species. In very shallow water systems, higher temperatures could lead to oxygen depletion and cause potentially massive die-offs of fish and invertebrates. Low-oxygen conditions would become more extensive in a warmer climate with longer periods of low flow, and the consequences for stream ecosystems could be severe.
- Primary productivity in freshwater wetlands would increase with higher concentrations of CO_2 and modestly warmer temperatures, as long as precipitation is not reduced. This may mean increased accumulation of organic matter, enhanced rates of soil formation,

and – for systems close to the coast – an increased ability to cope with sea-level rise. However, increased plant growth in response to higher CO_2 varies among species, and higher CO_2 could change the mix of species and interactions within aquatic communities.
- Changes in climate will influence the spread of invasive species that threaten freshwater systems, affecting native plants, fish and shellfish and associated recreation and commercial fisheries.

Gulf Coast upland ecosystems are particularly sensitive to potential changes in the water cycle and fire frequency. Variations in soil moisture are important factors in forest dynamics and composition: many natural pine forests can tolerate low soil moisture while oak-pine and oak-gum forests require medium to high soil moisture. Over time, increasing temperature and decreasing soil moisture would almost certainly change the distribution of trees and other plant species in these systems.

If droughts become more frequent or intense, the risk of wildfire could increase. In ecosystems not fire-adapted, recovery from catastrophic fires can take decades or longer. In contrast, wildfires are critical for grassland communities such as coastal prairies and bogs which are well adapted to natural cycles of burning.

Any increase in storm and hurricane frequency could hasten forest turnover, possibly resulting in the accelerated replacement of canopy trees with different, more competitive species.

Climate changes such as warmer temperatures, fewer freezes and changes in rainfall or storm frequency will tend to shift the ranges of plant and animal species and alter the makeup of biological communities. With increasing temperatures, many invasive tropical species are likely to extend their ranges northward. Native plants and animals already stressed and greatly reduced in their ranges could be put at further risk by warmer temperatures and reduced freshwater availability.

Twilley *et al*. (2001) use the Preserve as a specific case study. Climate change has the potential to impact the Preserve's diverse plant communities by altering the growth rates of species, changing the intensity and frequency of disturbance, and potentially facilitating invasion by exotic plant species. Historically, fire played a critical role in determining the dominant vegetation in the Preserve by preventing encroachment of hardwood saplings into pine forests and allowing successful recruitment of young pines. Fire frequency is likely to increase if climate change leads to drier conditions in the area. With greater demand for water in the Neches River and higher moisture deficits, invasion by Chinese tallow trees is likely to intensify. Climate change will also influence the spread of pests, especially the southern pine beetle. Moreover, any barriers to dispersal or migration by plants and animals would hinder their ability to respond to changes in climate.

Long-term monitoring at the Preserve is helping to understand coastal forest response to climate change (Guntenspergen and Burkett 1997). Data collected from permanent study plots suggest that increases in drought associated with changing climate may significantly alter understory seedling populations in bottomland forests and recruitment into the sapling layers, and ultimately influence overstory canopy structure.

Increased disturbance associated with flooding and storms may favor early successsional shade-intolerant species at the expense of shade-tolerant species. More importantly, increased disruptions to the forest canopy will provide recruitment opportunities for exotic woody species, enhancing their rate of invasion into natural stands.

Literature Cited

Abbott, J. and K. Stewart. 1996. A preliminary account of the aquatic insects of the Big Thicket. Big Thicket Science Conference, Biodiversity and Ecology of the West Gulf Coastal Plain Landscape. Beaumont, TX, 10-13 October.

Adsit, W. and L. Hagen. 1978. Intensive surface water monitoring survey for segment 0607 (Pine Island Bayou). Texas Dept. Water Resources. Austin, TX.

Allan, J. 1995. Stream ecology – structure and function of running waters. Chapman and Hall, New York, NY.

Aronow, S. 1975. Outline of the physical setting of the Big Thicket *in* The Big Thicket: Participants handbook for the contemporary science seminar. Houston Museum of Natural Science and University of Houston in cooperation with Big Thicket Association.

Aronow, S. 1981. Notes on the Geologic Units, Big Thicket National Preserve. Final Report to Big Thicket National Preserve, National Park Service. Lamar University, Beaumont, TX.

Baker, E. 1964. Geology and ground-water resources of Hardin County, Texas. Texas Water Commission, Austin.

Barclay, C. and R. Harrel. 1985. Effects of pollution effluents on two successive tributaries and Village Creek in Southeastern Texas. Texas Journal of Science 37:165-188.

Bass, D. 1979. Physiochemical conditions, fecal bacteria, and benthic macroinvertebrates of Menard Creek in the Big Thicket National Preserve. Thesis. Lamar University, Beaumont, TX.

Bass, D. and R. Harrel. 1981. Water quality of a Southeast Texas stream. Hydrobiologia 76:69-79.

Bayley, P. 1995. Understanding large river-floodplain ecosystems. BioScience 45:153-158.

Blanton and Assoc., Inc. 1998. Environmental assessment of a proposed three-dimensional seismic survey within the Beaumont Unit of the Big Thicket National Preserve. Prepared for Duncan Energy Co. Houston, TX.

Blum, M., R. Morton, and J. Durbin. 1995. Deweyville terraces and deposits of the Texas Gulf Coastal Plain. Transactions of the Gulf Coast Association of Geological Societies 45:53-60.

Bureau of Economic Geology. 1968. Geologic atlas of Texas, Beaumont sheet, 1:250,000 scale. University of Texas at Austin, Austin, TX.

Callicott, J., M. Acevedo, P. Gunter, P. Harcombe, C. Lindquist, and M. Monticino. 2006. Biocomplexity in the Big Thicket. Ethics, Place and Environment 9 (1): 21-45.

Commander, D. 1978. An evaluation of the fecal coliform loads and instream densities of coliform organisms in Pine Island Bayou. Lower Neches Valley Authority Tech. Rept. No. 78-3.

Commander, D. 1980. Physiochemical conditions, fecal bacteria, and macrobenthos of streams in the Turkey Creek Unit of the Big Thicket National Preserve. Lamar University, Beaumont, TX.

Conner, J. 1977. Zoogeography of freshwater fishes in western gulf slope drainages between the Mississippi and the Rio Grande. Ph. D. dissertation, Tulane University. New Orleans, LA.

Cooper, R., S. Cederbaum, and J. Gannon. 2004. Natural Resource Summary for Big Thicket Preserve. Warnell School of Forest Resources University of Georgia, Athens, GA.

Cowardin, L., V. Carter, F. Golet, and E. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. FWS/OBS-79/31, U.S. Dept. of the Interior, Fish and Wildlife Service, Washington, D.C.

Darville, R. and R. Harrel. 1980. Macrobenthos of Pine Island Bayou in the Big Thicket National Preserve, Texas. Hydrobiologia 69:213-223.

DeCamps, H. 1993. River margins and environmental change. Ecol. Appl. 3:441-425.

Deshotels, J. 1978. Soil survey of Big Thicket National Preserve. Soil Conservation Service, U.S. Department of Agriculture and Texas Agricultural Experiment Station.

Diggs, G., Jr., B. Lipscomb, M. Reed, and R. O'Kennon. 2006. Illustrated Flora of East Texas. Botanical Research Institute of Texas, Fort Worth, TX.

Dwyer, K. 2005. Rhino's river. Beaumont Enterprise newspaper, Beaumont, TX. May 21, 2005.

Enprotec, Inc. 1998. Plan of operations: proposed 3-D geophysical exploration program, Beaumont Unit of the Big Thicket National Preserve. Continental Geophysical Services and Duncan Energy Company.

Fay, L. 2008. Geologic resources inventory scoping summary, Big Thicket National Preserve. Geologic Resources Division, National Park Service, Denver, CO.14 pp.

Felley, J. 1992. Medium-low-gradient streams of the Gulf Coastal Plain. Pp. 233–269, *In* C.T. Hackney, S.M. Adams, and W.H. Martin (Eds.). Biodiversity of the Southeastern United States: Aquatic Communities. John Wiley and Sons, NY.

Flora, M. 1984. Development of a water quality monitoring program for the Big Thicket National Preserve, TX. National Park Service Water Resources Field Support Laboratory, Colorado State University, Fort Collins, CO.

Flora, M., S. Lawrence, and M. Cavendish. 1985. A summary of water quality for the Big Sandy Creek Unit, Beech Creek Unit, and Turkey Creek Unit of Big Thicket National Preserve, Texas (1975-1981). National Park Service, Water Resources Division, Fort Collins, CO.

Ford, N. 1996. Evaluation of habitat modification on amphibian and reptile populations in East Texas. Big Thicket Science Conference, Biodiversity and Ecology of the West Gulf Coastal Plain Landscape. Beaumont, TX, 10-13 October.

Guntenspergen, G. and V. Burkett. 1997. Coastal wetlands and global change: overview. U.S. Geological Survey, FS-089-97.

Gunter, P. 1971. The big thicket: a challenge for conservation. Viking Press, NY.

Hall, R. and K. Bruce. 1996. Characterization of water quality in the water corridor units of the Big Thicket National Preserve. Rice University, Houston, TX.

Harcombe, P. 1996. Characterization of the biological resources of the water corridor units of the Big Thicket National Preserve. Rice University, Houston, TX.

Harcombe, P. and G. Callaway. 1997a. Management assessment of the water corridor units of the Big Thicket National Preserve - final report. Rice University, Houston, TX.

Harcombe, P. and G. Callaway. 1997b. Water corridors management assessment: management assessment of the water corridor units of the Big Thicket National Preserve. Rice University and Ekistics Corporation, Houston, TX.

Harrel, R. 1975. Water quality and salt water intrusion in the lower Neches River. Texas Journal of Science 26:107-117.

Harrel, R. 1976. Preliminary limnological survey of streams in the Big Thicket National Preserve (April 21, 1975-February 1, 1976). Lamar University, Beaumont, TX.

Harrel, R. 1985. Effects of a crude oil spill on water quality and macrobenthos of a Southeast Texas Stream. Hydrobiologia 124:223-228.

Harrel, R. 1993. Origin and decline of the estuarine clam Rangia cuneata in the Neches River, Texas. American Malacological Bulletin 10:153-159.

Harrel, R. and R. Darville. 1978. Water quality monitoring in the Big Thicket National Preserve (June, 1977-August, 1978). Southwestern Region, National Park Service, Santa Fe, NM.

Harrel, R. and W. Newberry. 1981. Water quality monitoring in the Big Thicket National Preserve, Big Sandy Creek Unit. Southwestern Region, National Park Service, Santa Fe, NM.

Harrel, R. and M. Hall. 1991. Macrobenthic community structure before and after pollution abatement in the Neches River Estuary (Texas). Hydrobiologia 211:241-252.

Hawkes, H. 1975. River zonation and classification. Pages 213-274 *in* B. Whitton, ed., River Ecology, Blackwell, Oxford, England.

Hobbs, H. 1990. On the crayfishes (Decapoda, Cambaridae) of the Neches River basin of Eastern Texas with the descriptions of 3 new species. Proceedings of the Biological Society of Washington:573-597.

Hobbs, H. and M. Whiteman. 1987. A new, economically important crayfish (Decapoda, Ambaridae) from the Neches River basin, Texas, with a key to the subgenus *Fallicambarus*. Proceedings of the Biological Society of Washington 100:403-411.

Howells, R. 1997. Status of freshwater mussels (Family Unionidae) of the Big Thicket Region of Eastern Texas. Big Thicket Science Conference, Biodiversity and Ecology of the West Gulf Coastal Plain Landscape. Beaumont, TX, 10-13 October.

Howells, R., C. Mathers, and J. Bergmann. 1999. Impacts of dewatering and cold on freshwater mussels (Unionidae) in B. A. Steinhagen Reservoir, TX. Big Thicket Science Conference, Biodiversity and Ecology of the West Gulf Coastal Plain Landscape. Beaumont, TX, 7-10 October.

Hubbs, C., E. Marsh-Mathews, W. Mathews, and A. Anderson. 1996. Changes in the fish fauna in Big Thicket streams since 1953. Big Thicket Science Conference, Biodiversity and Ecology of the West Gulf Coastal Plain Landscape. Beaumont, TX, 10-13 October.

Hughes, J., M. Cavendish, and M. Flora. 1986. A summary of water quality for the Menard Creek Corridor Unit, Lance Rosier Unit and Little Pine Island Bayou Corridor Unit of Big Thicket National Preserve, TX (1975-1983). Water Resources Report No. 86-88. National Park Service, Water Resources Division. Fort Collins, CO.

Hughes, J., M. Flora, and J. Woods. 1987. Big Thicket National Preserve: water quality report 1984-1986. National Park Service, Ft. Collins, CO.

Illies, J. and L. Botosaneanu. 1963. Problems et methods de la classification et de al sonation ecologique des eaux courantes, considerees surtout du point de vue faunistique. Mitt. Int. Ver. Theor. Angew. Limnol. 12:1-57.

Irwin, K. and J. Dixon. 1996. Preliminary observations on timber harvest effects on a bottomland hardwood forest herpetofaunal community. Big Thicket Science Conference, Biodiversity and Ecology of the West Gulf Coastal Plain Landscape. Beaumont, TX, 10-13 October.

Johnson, B. W. Richardson, and T. Naimo. 1995. Past, present and future concepts in large river ecology. BioScience 45:134-141.

Junk, W., P. Bayley, and R. Sparks. 1989. The flood pulse concept in river-floodplain systems. Can. Spec. Publ. Fish. Aquat. Sci. 106:110-127.

Kaiser, R., S. Alexander, and J. Hammitt. 1993. Study of the adequacy of Texas water quality standards for protection the water and water-related resources of the nine units of the National Park System in Texas. Draft Report prepared for the National Park Service, Southwest Region, Santa Fe, NM.

Kenworthy, J., V. Santucci, and C. Visaggi. 2007. Paleontological resource inventory and monitoring, Gulf Coast Network. National Park Service TIC#D-750.

Kohut, R. 2007. Ozone risk assessment for vital signs monitoring networks. Appalachian National Scenic Trail, and Natchez Trace National Scenic Trail. NPS/NRPC/ARD/NRTR – 2007/01. National Park Service, Fort Colllins, CO.

Lamar University. 1996. In: a guidebook for the Southwestern Association of Student Geological Societies field trip, R. Cooper, J. Stevens, D. Owen, and J. Westgate, eds. Lamar University Geological Society and Department of Geology. Beaumont, TX.

Lewis, S., and R. Harrel. 1978. Physiochemical conditions and diversity of macrobenthos of Village Creek, TX. Southwest Naturalist 23:263-272.

Lewis, D., R. Fleet, and F. Rainwater. 1999. Herpetofaunal assemblages of four forest types in the Big Thicket of southeastern Texas. Big Thicket Science Conference, Biodiversity and Ecology of the West Gulf Coastal Plain Landscape. Beaumont, TX, 7-10 October.

Lewis, D., R. Fleet, and F. Rainwater. 2000. Herpetofaunal assemblages of four forest types in the Big Sandy Creek Unit of the Big Thicket National Preserve. Texas Journal of Science 52:139-150.

Lower Neches Valley Authority. 1992. Regional assessment of water quality, Lower Neches River basin and Neches-Trinity Coastal basin. Prepared in cooperation with the Texas Natural Resource Conservation Commission under the Authorization of the Clean Rivers Act.

Lower Neches Valley Authority. 1994. Regional assessment of water quality, Lower Neches River basin and Neches-Trinity Coastal basin. Prepared in cooperation with the Texas Natural Resource Conservation Commission under the Authorization of the Clean Rivers Act.

Lundelius, E., Jr. and B. Slaughter. 1976. Notes on American Pleistocene tapirs *in* Churcher, C. S. Athlon: Essays on palaeontology in honour of Loris Shano Russell. Royal Ontario Museum, Toronto. Life Sciences Miscellaneous Publication: 226-240.

MacRoberts, M. and B. MacRoberts. 2007. Phytogeography of the Big Thicket, East Texas. Journal of Botanical Research Institute of Texas 1:1149-1155.

Marks, P. and P. Harcombe. 1981. Forest vegetation of the Big Thicket, Southeast Texas. Ecological Monographs 51:287-305.

Minshall, G., R. Petersen, K. Cummins, and others. 1983. Interbiome comparisons of stream ecosystem dynamics. Ecol. Monogr. 53:1-25.

Moring, J. 2003. Baseline assessment of fish communities, benthic macroinvertebrate communities, and stream habitat and land use, Big Thicket National Preserve, Texas, 1999-2001. U.S. Geological Survey, Water-Resources Investigations Report 03-4270. Austin, TX.

Naiman, R., H. DeCamps, and M. Pollock. 1993. The role of riparian corridors in maintaining regional biodiversity. Ecol. Appl. 3:209-212.

Naiman, R. and H. DeCamps. 1997. The ecology of interfaces: riparian zones. Ann. Rev. Ecol. Systematics 28:621-658.

National Park Service 1995. Baseline water quality data inventory and analysis, Big Thicket National Preserve. Tech. Rept. NPS/NRWRD/NRTR-95/39. Water Resources Division. Fort Collins, CO.

National Park Service 1996. Resources Management Plan. Big Thicket National Preserve. Beaumont, TX.

National Park Service. 2006. Final oil and gas management plan and environmental impact statement, Big Thicket National Preserve. U.S. Department of the Interior, Washington, D.C.

National Research Council. 2002. The Missouri River ecosystem: exploring the prospects for recovery. National Academy of Science Press, Washington, D.C.

Newberry, W. 1982. Physiochemical conditions, fecal bacteria, and benthic macroinvertebrates of Big Sandy Creek in the Big Thicket National Preserve. Thesis. Lamar University, Beaumont, TX.

Newbold, J., J. Ellwood, R. O'Neill, and W. Van Winkle. 1981. Measuring nutrient spiraling in streams. Can. J. Fish. Aquat. Sci. 38:860-863.

Noss, R. 1990. Indicators for monitoring biodiversity: a hierarchical approach. Conservation Biology 4:355-364.

Patton, P. and V. Baker. 1977. Geomorphic response of Central Texas stream channels to catastrophic rainfall and runoff. In: Geomorphology in Arid Regions, D. Doehring, ed. Publication in Geomorpholgy, Fort Collins, CO.

Poff, N., and many others. 1997. The natural flow regime: a paradigm for conservation and restoration. BioScience 47:769-784.

Renfro, H., D. Feray and P. King. 1973. Geological highway map of Texas. United States geological highway map series, map. no. 7. American Association of Petroleum Geologists, Tulsa, OK.

Richter, B., J. Baumgartner, R. Wigington, and D. Braun. 1997. How much water does a river need? Freshwater Biology 37:231-249.

Rigsby, C. 1980. A brief overview of the Quaternary stratigraphy and geomorphology of the southeast Texas-southwest Louisiana coast. Holocene depositional environments of the southeast Texas, southwest Louisiana Gulf Coast. Lamar University Geological Society, Beaumont, Texas. Southwestern Association of Student Geological Societies Field Conference Guidebook April 24-27, 1980: 9-33.

Rizzo, W. P. Rafferty, and M. Segura. 2000. Surface water quality of the major drainage basins of Big Thicket National Preserve, Texas. Texas J. of Science 52(4) (Supplement):79-82.

Rudolph, D., R. Schaefer, D. Saenz, R. Conner, and S. Burgdorf. 2003. Arboreal behavior in the timber rattlesnake, *Crotalus horridus*, in eastern Texas. Big Thicket Science Conference, Biodiversity and Ecology of the West Gulf Coastal Plain Landscape. Beaumont, TX, 9-12 October.

Schenk, C., R. Charpentier, and J.W. Schmoker. 1999. Remaining oil and gas resources beneath Big Thicket National Preserve. Apendix E Final report to the Geologic Resources Division, National Park Service, U.S. Geological Survey, Denver, Colorado *in* National Park Service, 2005, Final oil and gas management plan and environmental impact statement, Big Thicket National Preserve. U.S. Department of the Interior, Washington, D.C.

Sedell, J. and J. Frogatt. 1984. Importance of streamside forests along large rivers: the isolation of the Willamette River, Oregon, USA, from its floodplain by snagging and streamside forest removal. Verhandlungen der Internationalen Vereinigung fur Theoretische and Angewandte Limnologie 22:1828-1834.

Shelby, C., M. Pieper, S. Aronow and V. Barnes. 1992. Geologic atlas of Texas, Beaumont sheet, 1:250,000 scale. Bureau of Economic Geology, University of Texas at Austin, Austin, TX.

Sparks, R. 1995. Need for ecosystem management of large rivers and their floodplains. BioScience 45:168-182.

Stamatis, A. 2007. Organic carbon dynamics of the Neches River and its floodplain. Ph.D. dissertation, University of North Texas, Denton, TX.

Suttkus, R. 1982. Fish Collections obtained from Big Thicket area 16-18 September 1982. Environmental Science Center, Riverside Research Laboratories, Belle Chase, LA.

Suttkus, R. and G. Clemmer. 1979. The fishes of the Big Thicket National Preserve Final Report Fishes Big Thicket National Preserve. Environmental Science Center, Riverside Research Laboratories, Belle Chase, LA.

Teas, L. 1935. Natural gas of Gulf coast salt dome area. Geology of natural gas. American Association of Petroleum Geologists: 683-740.

Texas Natural Resource Conservation Commission. 1996. The state of Texas water quality inventory. SFR-50, Vol. 2.

Texas Water Commission. 1989. Ground water quality of Texas: an overview of natural and man affected conditions. Report 89-01. Texas Water Commission, Austin, TX.

Thorkildsen, D. and R. Quincy. 1990. Evaluation of water resources of Orange and Eastern Jefferson counties, Texas. Texas Water Development Board, Report 320.

Twilley, R. and many others. 2001. Confronting climate change in the gulf coast region: prospects for sustaining our ecological heritage. Union of Concerned Scientists, Cambridge, MA and Ecological Society of America, Washington, D.C.

U.S. Environmental Protection Agency. 2007. Review of the national ambient air quality standards for ozone: policy assessment of scientific and technical information. EPA-452/R-07-007.

U.S. Environmental Protection Agency. 2008. Integrated science assessment for oxides of nitrogen and sulfur – ecological criteria. EPA/600R-08/082F.

Vannote, R., G. Minshall, K. Cummins, J. Sedell, and C. Cushing. 1980. The river continuum concept. Can. J. Fish. Aquat. Sci. 37:130-137.

Vidrine, M. 1990. Fresh-water mussel-mite and mussel-Ablabesmyia associations in Village Creek, Hardin County, Texas. Proc. Louisiana Acad. Sci. 53:1-4.

Ward, J. and J. Standford. 1985. The serial discontinuity concept: extending the model to floodplain rivers. Regul. Rivers Res. Management 10:159-168.

Ward, J. and J. Standford. 1983. The serial discontinuity concept of lotic systems. Pages 29-42 *in* T. Fontane and S. Bartell, eds. Dynamics of Lotic Ecosystems. Ann Arbor Science Pub., Ann Arbor, MI.

Ward J. 1998. Riverine landscapes: biodiversity patterns, disturbance regimes and aquatic conservation. Biological Conservation 83:269-278.

Ward, J. and K. Tockner. 2001. Biodiversity: towards a unifying theme of river ecology. Freshwater Biology 46:897-919.

Ward, J., C. Robinson, and K. Tochner. 2002. Applicability of ecological theory to riverine ecosystems. Verh. Internat. Verein. Limnol. 28:443-450.

Watson, G. 1975. Correlation of Big Thicket vegetation with its geologic formations *in* The Big Thicket: Participants handbook for the contemporary science seminar. Houston Museum of Natural Science and University of Houston in cooperation with Big Thicket Association.

Wells, F. and K. Bourdon. 1985. Summary of statistical and trend analysis of selected water quality data collected near the Big Thicket National Preserve, southeast Texas. U.S. Geological Survey, Open-File Report 85-183. Austin, TX.

Wermund, E. 1996. Physiographic map of Texas. Bureau of Economic Geology, University of Texas at Austin, Austin, TX. Map 5.

Williamson, A., H. Grubb, and J. Weiss. 1990. Ground water flow in Gulf coast aquifer systems, south central United States: a preliminary analysis. Water Resources Investigation Report 89-4071, U.S. Geological Survey.

Appendix
Unifying Concepts in River Ecology and the Neches River

Despite the importance of large rivers, understanding of how they function and how human activities influence river processes is limited (Johnson *et al.* 1995). Large rivers have not received the attention that small streams with regard to ecological studies. As a consequence, river ecologists, until recently, perceived river courses as stable, single-thread channels with virtually no consideration of floodplains or adjacent ground water aquifers (Ward and Tockner 2001). This lack of study may have resulted, in part, from the difficulty in sampling large rivers versus small streams. In addition, there was no clear theoretical basis for how large river ecosystems operated (Johnson *et al.* 1995).

Given that unidirectional flow is the defining feature of rivers, downstream changes in the structure of biological communities from headwaters to the lower reaches has been a dominant theme in running water ecology (Hawkes 1975). The European perspective on this topic has been zonal, *i.e.*, delineating more-or-less discrete communities separated by transitional boundaries (Illies and Botosaneanu 1963). In North America, the River Continuum Concept (Vannote *et al.* 1980) posits that river systems have a longitudinal structure that results from a gradient of physical forces along which the biota are predictably structured, thereby approaching longitudinal changes from a clinal rather than a zonal perspective. According to the model, biodiversity should have maximum values in the middle reaches (stream order 4 to 7) with lower biodiversity both in the headwaters (stream order 1 to 3) and in the lower reaches (stream order > 7). Low biodiversity in the headwaters is attributed to low light, low nutrients and a less variable temperature regime. In the lower reaches biodiversity is constrained by a shifting and homogeneous substrate, high turbidity, and oxygen deficits. In contrast, the middle reaches have adequate light and nutrient levels, high water clarity, and a more diverse and patchy substrate. Also, the middle reaches show the highest variability in temperature regime.

Subsequently, two additional concepts, nutrient spiraling (Newbold *et al.* 1981, 1982) and the serial discontinuity concept (Ward and Stanford 1983), were developed that are corollaries of the River Continuum Concept. Nutrient cycling in running waters must take into account downstream transport – the passage of an element as dissolved in the water column is transported some distance as a solute, then becomes incorporated into the biota and eventually is returned to the water column in dissolved form. A spiral best describes this cycle of downstream transport. Smaller streams favor nutrient retention and uptake because they have a lower flow, higher streambed areas to channel volume, and more permeable substrates. In contrast, the throughflow of stored materials is favored by the opposite conditions that exist in larger rivers. This corollary would then expect decreasing retentiveness along a continuum from small stream to large river (Allan 1995) – some results appear to support this expectation (Minshall *et al.* 1983, Naiman *et al.* 1987).

The serial discontinuity concept is a model for rivers whose natural dynamics have been suppressed by flow regulation via dams. This regulation induces major discontinuities to longitudinal resource gradients. Biodiversity patterns along regulated rivers are characterized by major declines at riverine sites immediately downstream from dams, followed by relatively rapid increases concomitant with the recovery of environmental conditions (Ward *et al*. 2002). Stream regulation alters virtually all environmental variables downstream; the sublethal effects of modified flow and temperature regimes are paramount in structuring biotic communities below many dams.

The River Continuum Concept and its corollaries lacked a floodplain perspective, *i.e.*, the interactions between the river channel and its floodplain (Ward and Tockner 2001, Ward 1998). [Also, the River Continuum Concept was postulated for streams in the deciduous forest biomes of the Pacific Northwest, which is decidedly different than the river systems of the Big Thicket area.] It was the study of tropical rivers (*e.g.*, Junk et al. 1989) coupled with historical investigations of temperate rivers (e.g., Sedell and Frogatt 1984) that allowed river ecologists to recognize the importance of the lateral dimension in large river ecology (Ward and Tockner (2001). With this in mind, Ward and Stanford (1995) revised their serial discontinuity concept to include alluvial floodplains, thereby encompassing dynamics of the lateral dimension. With this revision the River Continuum Concept now linked the biota in the river the floodplain. They postulated a three-reach model (canyon-constrained headwater, braided, and meandering). The meandering reach is expected to have the highest biodiversity. Different types of water bodies, indeed different successional stages within them, contribute to biodiversity as the biota exploit the predictable spatial and temporal variability (Ward 1998).

However, Junk *et al.* (1989) were the first to incorporate floodplain dynamics by formulating the Flood-Pulse Concept. The Concept is perhaps the major unifying descriptive model that links, hydrology, biogeochemistry, and the ecology of riverine organisms in large rivers with extensive floodplains. It proposes that the pulse of river discharge (seasonal flooding) is the major controlling factor in river-floodplain-biota interactions. The concept emphasizes the importance of alternating dry and wet phases in enhancing biodiversity and productivity as well as the dynamic edge effect created by the 'moving littoral'. The moving littoral is the river water's edge with the land as it moves across the floodplain during flooding and its recession.

Central to the Flood Pulse Concept is: 1) the hydrological linkage or connectivity (both surface and ground water) between the floodplain (a source of organic energy, nutrients and habitat) and the river channel (primarily an avenue to feeding, nursery, spawning areas and refugia); and 2) flooding is part of the natural hydrologic regime and is not a disturbance – it is the prevention of floods in a floodplain river that constitutes a disturbance (Sparks 1995). In the former, natural disturbance induced by flooding, enhances ecological connectivity – the transfer of energy and matter – and biodiversity.

Rising flood waters inundate formerly distinct aquatic habitats (maximum connectivity). As the flood waters recede, the different types of habitats slowly recover their distinctive properties (including habitat features and biota (Ward and Tockner 2001). The balance between wet and dry phases of the floodplain sustains a diversity of successtional stages and high biological productivity (Bayley 1995). Each of these stages contains distinctive biota that increases biodiversity. In contrast river regulation reduces the wet phase, *i.e.*, the floodplain is isolated from the river; this lost connectivity arrests the formation of new floodplain aquatic habitats and, and upsets the balance such that the system experiences reduced biodiversity (low seral diversity; Ward and Tockner 2001). The latter is recognition that the flow regime is the grand structuring factor in rivers and that aspects of the regime's frequency, duration, magnitude and timing, in combination, control biotic associations along rivers and influences the riverine food web (Poff *et al*. 1997, Richter *et al*. 1997, Ward 1998).

The applicability of the Flood-Pulse Concept as a unifying concept for the Missouri River was recently acclaimed in a publication National Research Council (2002). What can the recognition and understanding of the Concept do for management of the Neches River and its associated water-dependent systems? Essentially, it can provide us with a conceptual understanding of what has been or continues to be lost from the Neches River ecosystem. Apart from this, there may be little else to gain in testing the tenets of this Concept on the Neches River. The Neches River may be so adversely affected that it has mostly destroyed our ability to study its natural ecology. In cases such as this, Bayley (1995), a co-author of the Flood Pulse Concept, believes that we cannot gain more useful information without first attempting to restore or at least emulate the natural hydrological regimes. He believes that funding for experimental restoration and evaluation should take priority over ecological research on severely impaired river-floodplain systems. This begs the question – Is the Neches River a severely impaired river-floodplain system?

Ligon *et al.* (1995) would seem to concur with Bayley (1995), albeit from a different perspective. In their case geomorphologic changes are the key to understanding the ecological consequences of dams. Their premise: " … by minimizing the alteration of the physical dynamics and morphology of rivers, many complex species interactions and physical requirements can be maintained without scientists' understanding or even acknowledging their importance. If the physical foundation of the stream ecosystem is pulled out from under the biota, even the most insightful biological research program will fail to preserve ecological integrity. Minimizing or mitigating the physical geomorphic changes may often be crucial to protecting the biological integrity of a river."

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