Wetland Needs Assessment

Strategy for Water Quality Improvement and Wetland Enhancement in Bayou Chinchuba and the East Tchefuncte River Marsh

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Prepared by
Comite Resources, LLP
11643 Pride Port Hudson Rd.
Zachary, LA 70791
225-654-8847
225-658-0029 fax

For
Edward J. Price III, Mayor
City of Mandeville
3101 East Causeway Approach
Mandeville, LA 70448 3592

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Dr. John W. Day, Jr.	Louisiana State University
Dr. Paul H. Templet	Louisiana State University
Dr. G. Paul Kemp	Louisiana State University
Christopher Brantley	Louisiana State University

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Foreword

This report is the culmination of almost three years of effort to access comprehensively the scale, scope, and characteristics of water quality, wetland loss, shoreline erosion, wildlife habitat, and wetland wastewater loss in the wetlands north of Lake Pontchartrain and south and west of Mandeville, St. Tammany, Louisiana. It provides the most comprehensive assessment of this issue ever assembled for our parishes' wetlands. With this information, we have the opportunity to make a real difference in the actions this parish takes to address this important issue.

These results provide a valuable context for a host of ongoing and planned activities addressing estuarine eutrophication, wetland loss, and wildlife habitat loss, including a Comprehensive Water Quality Plan for St. Tammany Parish, the 1998 state and federal approved coastal restoration plan, *Coast 2050: Toward a Sustainable Coastal Louisiana*; The Coastal Wetlands Planning, Protection and Restoration Act (Public Law 101-646, Title III-CWPPRA); and the state's development of Unified Watershed Assessments and Watershed Restoration Priorities as part of the Clean Water Action Plan.

As important as the results themselves are the processes used to acquire this information. The approach explicitly recognized that much of what is known about these problems resides within knowledge and experience of experts around the Lake Pontchartrain Basin. Hence, many organizations, state, local and federal, provided information. This report is an example of type of activity that is needed to better bridge the gap between scientists and resource managers.

Edward J. Price III, Mayor
City of Mandeville, Louisiana

Executive Summary

The East Tchefuncte wetlands are a viable ecosystem that lies just west of the City of Mandeville. It is bounded on the south by Lake Ponchartrain, the west by the Tchefuncte River, the north by highway 22 and the east by the Sanctuary Ridge. It contains approximately 1400 acres. The possibility of using these wetlands for waste water assimilation is so important to the environment and health of the City of Mandeville that the city commissioned Dr. John W. Day to do a wetlands needs assessment based on the Use Attainability Analysis carried out by Dr. Day and his colleagues at LSU. This wetlands needs assessment demonstrates that the East Tchefuncte wetlands form a highly productive natural ecosystem that is part of the larger Lake Pontchartrain estuary with which it interacts. The wetland ecosystem functions as a unit and is made up of fresh to brackish water marshes, forested wetlands, shallow open water areas, and the elevated ridge along the southern boundary of the wetland bordering Lake Pontchartrain. All of these habitats are integral parts of the East Tchefuncte wetland ecosystem. Wetland wastewater assimilation will improve water quality and improve habitat. The wetland provides a number of direct and indirect benefits to the citizens of Mandeville.

The East Tchefuncte Wetland Ecosystem

The ecosystem contains brackish and fresh marshes and freshwater forested wetlands. The balance of fresh and salt water maintains the salinity gradient. The growth of wetlands provides food for animals living in the area.

Marshes and forested wetlands of this area provide valuable habitat to many animals and birds because of the food source and cover found in these areas. Research in the Atchafalaya Basin indicates bottomland forests can support two to five times as many game animals as pine-hard wood regions. Studies have shown that this area has suffered wetland loss over the past several decades, likely due to rising sea level and salt-water intrusion.

The natural elevated shoreline along Lake Ponchartrain forms an important part of this ecosystem. It is a place of refuge for many wildlife species (such as birds, mammals, and herptiles) which feed in the wetland. Bird populations are especially important in regulating populations of animals (fish and benthic organisms) in the wetlands. The very shallow near-shore part of the lake and the shallow channels leading into the wetland limit flushing of the wetland area because of the low capacity of the channels to carry water. The ridge is low now and over topped by storm surges that are important to periodic inputs of sediments to the wetland area that help the wetland keep up with sea level rise. The wetlands of the system provide a storm buffer, and thus protecting citizens of Mandeville against flooding.

The East Tchefuncte wetland ecosystem functions as an ecological unit. Many studies have shown that fragmentation of ecosystems results in a decrease in ecosystem function including changes in hydrology, water quality and species diversity. This ecosystem forms an integral part of the larger Lake Pontchartrain system. Fresh and salt water are exchanged with the lake. Important fishery species use the area for a nursery habitat, food is exported to the lake, and water quality of Lake Ponchartrain is improved. The continued improvements to the water quality of Lake Ponchartrain is a direct benefit to the City of Mandeville which has its southern boundary along the shores of the lake.

The Larger Lake Pontchartrain Basin System

Of the 37 estuaries in the Gulf of Mexico area, the Lake Pontchartrain Basin is characterized as having one of the highest levels of eutrophic conditions in the Gulf of Mexico region. These coastal waters are warm, with low tidal energy and shallow water depths. Land-use activity in the Basin is more and more dominated by increased urbanization. The future outlook to 2020 indicates Lake Pontchartrain is one of the estuaries to develop worsening conditions.

Expanding eutrophic conditions in the Lake Pontchartrain Basin are influenced by such factors as low tidal energy, low flushing rates, and increased nutrient inputs. An integrated management plan is needed to address the problems of Lake Pontchartrain. An important aspect of such a plan is the proper management of areas interacting with Lake Pontchartrain. This includes the Mandeville area. One can think of the Mandeville area as an ecosystem in itself including developed areas and natural wetlands. A proper integration of the developed areas and the wetlands, through wetland assimilation in this case, will result in a more positive impact on the larger lake ecosystem and greater benefits to the citizens of Mandeville.

A Lake Pontchartrain Basin strategy, which incorporates the results of this assessment, should be developed to help set priorities and to support decision-making at the local, state and national level. The strategy should focus on management, monitoring, and research, and should effectively integrate with regional, state and local programs.

Wetland Wastewater Assimilation in the East Tchefuncte Wetland Ecosystem

Wetland assimilation of treated municipal wastewater can efficiently remove nutrients and improve water quality. The nutrients stimulate marsh growth leading to more food production for wildlife and fisheries and to a higher rate of accretion to offset sea level rise. The fresh water introduced in the effluent helps maintain the salinity gradient, especially during dry periods.

Thus, wetland loss due to sea level rise and saltwater intrusion can be reduced through implementation of wetland wastewater assimilation. Forested areas downstream of wetland assimilation discharges benefit from the fertilizing discharge. In addition to the ecosystem benefits of wetland assimilation, this approach is also more economical. Thus, there are ecological and economic benefits of wetland assimilation.

Effects of the Proposed Lakefront Development

Shoreline development would alter the hydrology and likely lead to a less efficient removal of nutrients in wastewater. Deep channels would provide openings and promote saltwater intrusion during dry periods and lead to rapid drainage when the lake level is low, thus leading to short-circuiting of the hydrology. Any future development would have to be very low-density. This will protect the shallow nature of the near-shore area and channels, and preserve the natural habitat of the low ridge so animal populations would be maintained. Development of the shoreline would also likely result in a decrease in animal populations in the area. In general, the shoreline development would decrease ecosystem function and compromise the ability of the wetlands to efficiently assimilate nutrients in the effluent.

Summary

In summary, the East Tchefuncte wetland ecosystem provides both economic and environmental benefits to the citizens of Mandeville. Utilization of the wetlands for wastewater assimilation will lead to economic savings, improved water quality, and enhanced habitats. Citizens also benefit aesthetically from having a healthy natural ecosystem adjacent to the city that also acts as storm buffering which helps protect the population from flooding. As management of the East Tchefuncte wetland ecosystem improves its health and functioning, it contributes to the improvement of the larger Lake Pontchartrain estuary bringing with it the benefits of such things as clean water, improved fisheries, and better swimming condition.

Introduction

This report presents the results of a comprehensive assessment to address the problem of water quality and wetland loss. The assessment includes evaluations of planning, hydrology, water and sediment, vegetation, aquatic fauna, and terrestrial fauna.

The Wetland Assessment

This report presents the results of *A Use Attainability Analysis of Municipal Discharge to Coastal Wetlands at Mandeville, Louisiana* (UAA) submitted to the City of Mandeville, February 23, 2000 to address the problem of water quality and wetland loss. The UAA was begun in September 1998 by the Coastal Ecology Institute, Department of Oceanography and Coastal Sciences, Louisiana State University, Baton Rouge and the US Army Corps of Engineers, Environmental Planning and Compliance Branch, New Orleans District and the City of Mandeville.

About Wetland Wastewater Assimilation of Treated Domestic Wastewater

Wetlands have been used to treat wastewater for centuries, but only in the past several decades has the response to such use been scientifically analyzed in a comprehensive way (Richardson & Davis 1987). The ability of wetlands to perform certain water purification functions has been well established for natural watersheds (Conner et al. 1989; Kadlec and Alvord 1989; Kemp et al. 1985; Khalid et al. 1981 a&b; Knight et al. 1987; Nichols 1983; Richardson & Davis 1987; Richardson & Nichols 1985; U.S. EPA 1987, Kadlec and Knight 1996, Faulkner and Richardson 1989). Studies in the southeastern United States (Wharton 1970; Shih and Hallett 1974; Kitchens et al. 1975; Boyt 1976; Nessel 1978; Yarbro 1979; Nessel and Bayley 1984; Yarbro et al. 1982; Tuschall et al. 1981; Kuenzler 1987) have shown that wetlands chemically, physically, and biologically remove pollutants, sediments and nutrients from water flowing through them. Recently Hesse et al. (1998) showed that cypress trees which have received wastewater effluent for 50 years at Breaux Bridge, Louisiana, had a higher growth rate than trees not receiving effluent.

This report is designed to answer a number of key questions:

Key Questions

1. What is the severity and extent of poor water quality and wetland loss conditions in the Lake Pontchartrain Basin?
2. To what extent is poor water quality and wetland loss caused by human activities?
3. Can water quality be improved by implementing a wetland assimilation management program?
4. Can a wetland wastewater assimilation program reduce wetland loss in the north-shore marsh?
5. What is the percent reduction of water nutrients from the source to the wetland outflow?
6. Are the East Techfuncte wetlands an integral part of the ecosystem?
7. What is the net primary production (litterfall + wood production) in the swamp?
8. Can the wetland assimilate wastewater nutrients and benefit from the discharge?
9. Is wetland wastewater assimilation feasible and economical?
10. If this shoreline were developed would this detrimentally impact natural functions of the ecosystem?
11. Could the wetland assimilation project proceed if the shoreline were not part of the project area or developed?
12. Could shoreline development be designed to minimize environmental impacts?

Water Quality and Wetland Loss: Background to the Problem

The study area (Figure 1) consists of wetlands north of Lake Pontchartrain, and south and west of Mandeville, St. Tammany Parish, Louisiana. The total wetland area to be used in the wetland wastewater assimilation is 2,520 acres. The adjacent wetland areas are privately owned and include palustrine forested, palustrine scrub-shrub, palustrine emergent, and estuarine emergent wetlands (Cowardin et al. 1979).

Hydrologic inputs to the wetland include precipitation, drainage from the surrounding uplands, and occasional backwater flooding from Lake Pontchartrain. The treatment area receives approximately 1.9 million gallons/day from the Facility.

The area has undergone rapid urbanization upon completion of the first span of the Lake Pontchartrain Causeway in 1958. Much of the land use change has been from agricultural and forested tracts to large residential subdivisions. Some commercial development has been experienced within the Bayou Chinchuba watershed. Much of the area is currently forested but has been historically logged. The potential for logging in the future exists as the timber matures, and silva culture would add an additional mechanism for removing nutrients stored in tree tissue.

Lake Pontchartrain shoreline

Wetland wastewater assimilation refers to the ability of wetlands to remove nutrients form inflowing water is primarily dependent on the nutrient concentration and volume of the input water and the area of wetlands. Nutrient uptake is also influenced by temperature and the hydrology of the specific wetland site.

Although much of the wetland is privately owned, the Bayou Chinchuba and the East Tchefuncta River Marsh are clearly wetlands which have flood storage, habitat, and other natural values which would make the legality of wetland alteration or development questionable. The uplands adjacent to the wetlands include Lewisburg, which is east of Bayou Chinchuba, the Sanctuary residential development, which is currently under construction, and the area north of the East Tchefuncta River Marsh. All three of these areas either contain low-density housing or plan to be developed in this manner

East Tchefuncte Marsh and Bayou Chinchuba Wetlands

This assessment characterizes the overall wetland conditions and water-quality issues associated with wetland assimilation of treated municipal wastewater effluent. A core group of wetland ecologist collaborated with the City of Mandeville in developing methods to assess the feasibility of improving water quality and restoring marsh and forested wetlands through a wastewater assimilation program.

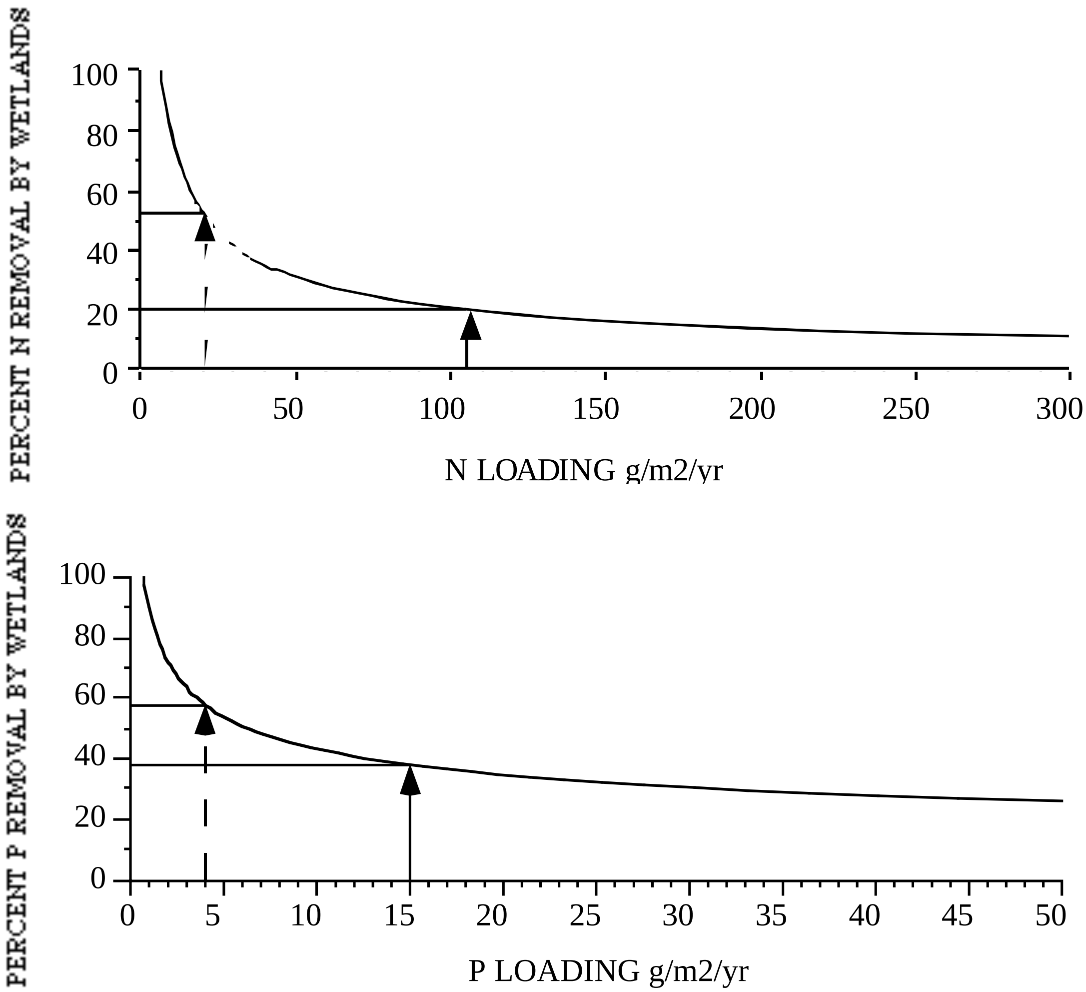
The ability of wetlands to remove nutrients from inflowing water is primarily dependent on the nutrient concentration and volume of the input water and the area of wetlands. Nutrient uptake is also influenced by temperature and the hydrology of the specific wetland site.

The inflow into a wetland is normally expressed as a loading rate, which integrates the concentration and volume of the inflow and the area of the receiving wetland. Loading rate is expressed as the amount of nutrient introduced per unit area of wetland per unit time; normally as g N or P m^{-2} y^{-1}. Loading rate incorporates residence time since it has units of time.

Nutrient removal is inversely related to loading rate. Richardson and Nichols (1985) reviewed a number of wetland wastewater treatment systems and found a clear relationship between loading rate and nutrient removal efficiency (Figure 2). Nutrient removal efficiency is the percentage of nutrients removed from the overlying water column and retained within the wetland ecosystem or released into the atmosphere. The relationship between nutrient removal efficiency and loading rate efficiency decreases rapidly with loading rate. The relationship is not linear and there is very efficient removal at low loading rates but removal efficiency decreases rapidly with loading rate.

The curves of Richardson and Nichols (1985) are for wetland sewage treatment systems located in many different parts of the United States. There are a number of studies from Louisiana where loading rates have been reported for coastal wetlands. Breaux and Day (1994) provided estimates of loading rate and removal efficiencies for forested wetlands near Thibodaux and Breaux Bridge where secondarily treated sewage was being discharged. Nutrient uptake has also been demonstrated for the Caernarvon freshwater diversion, which is similar to the above-cited studies. Wetlands of the Caernarvon area, and those of the sewage treatment systems are ecologically similar to wetlands within and surrounding the Mandeville area. Therefore, the loading rates reported in these studies were used to estimate water quality improvement associated with the different alternatives.

The figures below show nitrogen and phosphorus removal efficiency as a function of loading rate (Richardson & Nichols, 1985). The arrows indicate the loading rate and the expected percent nutrient removal of the Atchafalaya River basin (Gosselink & Gosselink, 1985) (solid line) and for forested wetlands receiving municipal wastewater (dashed line) near Thibodaux, LA (Day & Breaux, 1994).



In order to estimate nutrient removal, the concentrations of total nitrogen (TN), total phosphorus (TP), and the area of wetlands are needed. TN and TP values are not available for the Mandeville treatment plant, therefor average values for secondarily treated wastewater of 20 mg/l TN and 10 mg/l TP were used (Richardson and Nichols 1985). These values are somewhat high compared to results from Louisiana. Thus, our uptake estimates are conservative. Total amounts of nitrogen and phosphorus discharged from the treatment plant were calculated based on the TN and TP concentrations given above and the discharge of the treatment plant (1.9 million gallons per day).

The area of wetlands used in the loading rate calculations was based on the areas of the Bayou Chinchuba, the East Tchefuncte Marsh, and the total of these two areas (See table 1). Finally, the curves of Richardson and Nichols were used to get an estimate of retention.

Table 1. Mandeville Loading Rate Calculations.

Location	Area in ha (acres)	Loading rate $g/m^2/yr$ N	Loading rate $g/m^2/yr$ P
Bayou Chinchuba	98 (242)	56.91	24.46
East Tchefuncte	345 (853)	17.65	18.04
Total Treatment	443 (1095)	12.59	6.29
Total Marsh	1020 (2520)	5.47	2.73

Based on these calculations, the loading rate for the Bayou Chinchuba wetland is excessive and retention in the wetland is probably between 20 - 30%. When the three areas are used, the loading rate falls to values close to what we have measured in other wetland assimilation systems. Actual loading is likely to be lower since we used average concentrations of TN and TP. These will have to be measured before more accurate loading rates can be calculated.

Based on the nutrient retention efficiency curves of Richardson and Nichols, the uptake of N and P should be between 60 and 80%. If a larger area of wetland is used, higher retention efficiencies would be achieved. Also if the primary form of inorganic nitrogen is nitrate, the probable uptake for inorganic nitrogen will near 100%.

Swamp forest on upper Sawmill Canal

Natural Resources Values and Land Use

The major natural resource values and land use for this wetland area are for habitat, flood storage, material processing, and, in the future, possibly timber harvesting. Timber species in the area are flood-tolerant (Hook 1984) and might be considered insensitive to sewage loading (Kuenzler 1987). From other studies in the southeastern United States, we can expect that leaf area index and biomass of understory plants may increase (Ewel 1984), and the growth of trees may be increased (Nessel and Bayley 1984, Hesse et al. 1998) or not be consistently affected (Straub 1984).

Geomorphology and Wetland Identification

The wetland classifications of the study area include palustrine forested, palustrine scrub-shrub, palustrine emergent, and estuarine emergent (Cowardin et al. 1979). Bayou Chinchuba is mostly a broadleaf and needle-leafed deciduous forested wetland dominated by water tupelo (*Nyssa aquatica*), swamp blackgum (*Nyssa biflora*), and baldcypress (*Taxodium distichum*). Bayou Chinchuba and to a lesser degree Bayou Castine exhibit vegetation zonation from the upper portion of the watershed to the lower portion. Swamp blackgum typically dominates the upper floodplain portion of both watersheds, and water tupelo and baldcypress become much more dominant as the distance downstream increases. Water tupelo is sensitive to water salinities. As the distance to Lake Pontchartrain becomes shorter, baldcypress becomes the dominant forest tree in the lower floodplain.

The areas in the lower Bayou Chinchuba floodplain and near higher elevations of the East Tchefuncte River Marsh are scrub-shrub dominated, the predominant vegetation being wax myrtle (*Myrica cerifera*). The East Tchefuncte River Marsh has several vegetative communities, probably segregated on the basis of nutrient availability and salinity. The palustrine emergent zone is generally dominated by saw grass (*Cladium jamaicense*), but there are several areas near residential developments that have stands of cattail (*Typha* sp.). Researchers in the Everglades where saw grass was a predominant feature on the landscape, have noticed a trend for increasing areal extent of cattail at the expense of saw grass communities, presumably due to nutrient introduction (Craft et al. 1995, Daoust and Childers 1999). The East Tchefuncte River Marsh exhibits attributes of saw grass community decline from cattail encroachment along the north and wiregrass (*Spartina patens*) dominated marsh near the shoreline of Lake Pontchartrain.

Wetland Boundaries/Delineation

The entire area is classified as wetland. The proposed treatment area encompasses 443 ha (1095 acres) of wetland. In addition, the total area of surrounding marsh is 1020 ha (2520 acres). Net water flow will be southwest, towards the marsh area and eventually to Lake Pontchartrain.

Wetland Morphometry

There are several connections between the wetlands and Lake Pontchartrain. One is the mouth of Bayou Chinchuba and most of the flow of the bayou flows into the lake at this point. The other connections are to the west of this point and most of the water from the East Tchefuncte River marsh drains here. The elevation of much of the wetland is near sea level, and water levels in the wetlands are often determined by lake levels. These factors indicate that there will be considerable overland flow and thus effective wetland treatment.

Subsidence of Wetlands

There is a high relative sea level rise along the Louisiana coast that is caused mostly by regional subsidence. This, combined with vertical accretion of the wetland surface, means that a significant portion of the material deposited on the surface of the wetland will be buried and permanently lost from the system. This represents a pathway of permanent loss, which is not available for non-subsiding wetlands. Zilkoski and Reese (1986) reported apparent subsidence amounting to 0.74 to 0.88 cm year^{-1} in the vicinity of New Orleans as indicated by analysis of geodetic leveling data. Therefore, the potential sink for nutrients via a burial pathway can be important. The wetland area near Mandeville is near the Pleistocene uplands and thus subsidence is expected to be lower.

Surface Water Inflows/Outflows

The area receives water from several primary sources; rainfall, stream flow from Bayou Chinchuba, local upland runoff, flood tides, and wastewater/ stormwater from the Mandeville wastewater treatment facility.

Average annual precipitation (P) in the area is 151.4 cm (59.62 inches) for Slidell and 157.2 cm (61.88 inches) for New Orleans. Rainfall near this site varies seasonally through the year with average monthly amounts ranging from a low of about 7.7 cm and 7.8 cm (3.03 and 3.05 inches) per month in October at Slidell and New Orleans, respectively to a high of almost 15.7 cm (6.17 inches) in July and August at Slidell and New Orleans, respectively (NOAA 1997). However, rainfall in a given year can vary greatly from these averages. The flow in the bayou varies greatly. An assumed low normal flow of 28 m^3 (1000 cfs) for Bayou Chinchuba was reported in a 1994 letter to the Lewisburg Civic Association from the Waldemar S. Nelson Company. In that same letter, the maximum flood flow for Bayou Chinchuba was estimated to be 224 m^3 (8000 cfs). U.S. Geological Survey measurements during 1998 indicated that during a majority of the year, there is no discernible flow downstream of West Causeway Approach in Bayou Chinchuba. However, after two rainfall events measuring 25.1 cm (9.9 inches) on 6-7 March 1998 and 8.5 cm (3.35 inches) on 14-15 July 1998, flow in Bayou Chinchuba at West Causeway Approach was measured at 1.8 m^3 (64 cfs) on 10 March 1998 and 1.0 m^3 (35 cfs) on 15 July 1998 (USGS 1998).

Flood tides typically enter the marsh through the mouth of Bayou Chinchuba, and through other cuts in the beach berm along the north shore of Lake Pontchartrain, and from the Tchefuncte River. Tides at Manchac Pass to the west typically show a 9.1 to 12.2 cm (0.3 to 0.4 feet) range (Gibson and Gill 1988), however storm tides associated with hurricanes can increase tides to much higher levels. Lastly the average annual effluent flow from the Facility is used to estimate the hydraulic loading to several of the wetland areas. Presently the wastewater is discharged into Bayou Chinchuba.

Table 3. Potential contribution of significant hydrologic inputs to Bayou Chinchuba and the Tchefuncte Marsh wetlands. Effluent data is annual average for 1997.

Input Source	Potential Hydrologic Contribution
Precipitation	157.2 cm $year^{-1}$ or 0.018 cm $hour^{-1}$
Bayou Chinchuba (low normal)	249.0 cm day^{-1} or 10.4 cm $hour^{-1}$
Tides (average range)	12.2 cm day^{-1} or 0.51 cm $hour^{-1}$
Effluent to Bayou Chinchuba	0.67 cm day^{-1} or 0.028 cm $hour^{-1}$
Effluent to East Tchefuncte Marsh	0.07 cm day^{-1} or 0.003 cm $hour^{-1}$

The Bayou Chinchuba Swamp is hydrologically controlled by stream flow and potentially from back flooding via the Lewisburg Canal. While the forest area around the main channel can be frequently flooded, the majority of the flow was observed in the bayou channel. The area to the southeast of the Facility does not have a deep channel area and therefore has greater contact with the surrounding forest areas.

The area seems to be dominated by sheet flow with irregular ponds and channels. Rainfall and runoff likely dominate the hydrology. The presence of wiregrass (*Spartina patens*) in the southern portion near the Lewisburg Canal indicates that back flooding occurs from Lake Pontchartrain and that low salinity water periodically affects the area.

The East Tchefuncte wetland is dominated by sheet flow with irregular ponds and channels. During site visits, the majority of the flow down the Sawmill Canal was discharging from two main channels entering from the northeast. The hydrology in this area includes rainfall and likely runoff from adjacent uplands. The outflow from this wetland is restricted by the dredged spoil bank on the northwest side of the Sawmill Canal. There was outflow from the two main channels and several other low areas of the spoil bank (Figure 1).

Methods and Sampling Design

Three separate monitoring sites were established in the Mandeville area (Figure 1). The Chinchuba site consists of the lower Bayou Chinchuba drainage basin, generally from West Causeway Approach Road to Lake Pontchartrain. The Facility currently discharges into the Bayou Chinchuba wetland. The floodplain system is hydrologically distinct from adjacent wetland areas due to higher elevation ridges to the southeast and northwest.

A second monitoring site was established in the East Tchefuncte River Marsh wetland. This area was selected for monitoring due to the potential for future wastewater assimilation in this area.

The third monitoring site was established in the lower Bayou Castine drainage basin to the east of the City of Mandeville. This site was selected as a proximate control for the Bayou Chinchuba area. At each of these sites, replicate stations were established, and for some sampling stations, replicate plots were fixed. Temporal sampling regime and sample replication for the flora, fauna, sediment, water and hydrologic variables are documented in their respective sections.

Water and Sediment

Samples for water chemistry analysis were collected on a seasonal basis with sampling dates of September and November of 1998, and January, March, April, May and July 1999. Sediment samples were collected during the early summer of 1999. Sediment cores were taken with a 7.5 cm plastic corer from all sample sites.

Accretion

Accretion was determined by the accumulation of material over feldspar marker horizons (Baumann et al. 1984). A total of 3 accretion sites were established (Bayou Castine, Bayou Chinchuba, and East Tchefuncte Marsh) in the vicinity of the water level recorders. Three 0.25 m^2 plots were placed in each of the three sites. Two to three cm of feldspar potash was applied to the soil surface.

Marsh Productivity

The primary production of the East Tchefuncte River Marsh was determined by collecting vegetation samples. Clip plots were collected at 5 sites in the marsh, with 5 replicates (A, B, C, D, E) at each site. For each site, clipped live vegetation was separated from dead, and both live and dead material was sorted by species, dried at 60°C and weighed. Annual primary productivity was estimated as equivalent to the harvested live material (Peak-standing-crop method) and reported as mean g dry weight m^{-2} $year^{-1}$.

Forest Productivity

In forested sites, biomass production is defined as the sum of the leaf and fruit fall and aboveground wood production (Newbould 1967). A total of 4 forest vegetation sites were established (Bayou Castine, Downstream, Upstream, and Outfall in Bayou Chinchuba), each with east and west plots. Each plot contained 5 litter boxes and was 20 m by 20 m, comprising an area of 400 square meters. To estimate aboveground productivity, litterfall was collected from 0.25 m^2 boxes with 1 mm mesh bottoms. There are a total of 10 litter boxes at each site. The boxes were elevated to a height of 2 m above the forest floor to prevent inundation during high water periods. Litterfall was collected monthly beginning in August 1998. Litter was separated into leaves, reproductive material, and woody material, dried at 60°C for 48 hours, and weighed. The leaves were sorted by species. Individual litterfall-trap data were converted to g/m^2 and then log transformed to normalize the data and reduce correlations between means and variance. A 1-way analysis of variance (ANOVA) was conducted to determine if litterfall varied among the eight plots, and an a-posteriori Tukey multiple comparisons test was employed to detect significant differences among plots.

Benthos

Benthic macroinvertebrate sampling locations were set up at seven stations. Stations were at the East Tchefuncte River Marsh site, Bayou Chinchuba site, and Bayou Castine site (Fig. 1). At the marsh site and Bayou Chinchuba site, a middle, upper, and reference zones were sampled. A reference station was sampled at Bayou Castine. The upper zones were located near the wastewater discharge or the proposed discharge while the middle zones were downstream of the discharge or expected discharge impact area. The reference stations were located outside the discharge or expected discharge impact area. Four replicate core samples (43 cm^2 inner diameter) were collected at these stations October 9, 1998 and May 10, 1999. Cores were randomly collected from 20 meter transects. These transects were located in areas away from other research activity, in areas of homogenous mud, and at least 1 meter from trees.

Cores were filtered through a 500 μm sieve in the field and preserved in a 10% buffered formalin solution. Rose bengal was used to facilitate sorting as recommended by Mason and Yevich (1967). In the laboratory, the samples were again passed through a 500 micron sieve. All material not passing through the sieve was examined and benthic organisms were removed for identification. All macroinvertebrates were identified to species level or lowest practical taxonomic level when possible (Brigham et. al. 1982, Pennak 1989, Epler 1992, 1996, Merritt and Cummins 1996).

Analysis of Benthic Community

Univariate metrics used on the identified taxa included: total number of individuals, total number of taxa, species richness, Shannon-Wiener diversity, and eveness (Washington 1984, Clarke and Warwick 1994). Non-parametric multivariate statistical techniques were used because benthic community data from this study did not meet all assumptions of multivariate normality required for parametric statistics. Ordination was performed using non-parametric multi-dimensional scaling (MDS, Clarke and Green 1988) to construct a configuration of the samples in two dimensions that represents the similarity between the benthic community data in each sample. The percent similarity of replicates within and among stations was determined by hierarchical agglomerative clustering (Clarke and Warwick 1994). A fourth root transformation was applied to the data to reduce the similarity contribution of abundant taxa (thousands of specimens) and increase the contribution of rarer taxa (single to tens of specimens). These techniques were available in the Plymouth Routines In Multivariate Ecological Research (PRIMER); a computer program developed by the Plymouth Marine Laboratory, UK (Clarke and Warwick 1994).

Nekton

Nekton stations were set up with the benthic stations. Two replicate throw net samples (950 cm^2, 0.8 mm mesh; Kushlan 1981; Hartman, 1984) were collected from areas of open water at all stations on October 9, 1998 and on May 10/May 13, 1999. The spring sampling was done at the Bayou Chinchuba and Bayou Castine stations on May 10; the spring sampling for the East Tchefuncte Marsh stations was conducted on May 13. Four replicate throw net samples were taken at the Bayou Castine site during the spring sampling date. Nekton was removed from the throw net with a dip net (1.6 mm mesh), put in plastic bags, and stored on ice. The samples were frozen until identification. All nekton was identified to species level when possible (Cook 1959; Douglas 1974; Hoese and Moore 1977). Total abundance and fork length of each organism was recorded. Only abundance data are reported at this time.

Analysis of Nekton Community

Univariate metrics used on the identified taxa included: total number of individuals, total number of taxa, species richness, Shannon-Wiener diversity, and eveness (Washington 1984, Clarke and Warwick 1994). Non-parametric multivariate statistical techniques were used because nekton community data from this study did not meet all assumptions of multivariate normality required for parametric statistics. Ordination was performed using non-parametric multi-dimensional scaling (MDS, Clarke and Green 1988) to construct a configuration of the samples in two dimensions that represents the similarity between the nekton community data in each sample. The percent similarity of replicates within and among stations was determined by hierarchical agglomerative clustering (Clarke and Warwick 1994). A fourth root transformation was applied to the data to reduce the similarity contribution of abundant taxa and increase the contribution of rarer taxa. These techniques were available in the Plymouth Routines In Multivariate Ecological Research (PRIMER); a computer program developed by the Plymouth Marine Laboratory, UK (Clarke and Warwick 1994).

Hydrology

Water levels generally fluctuate in response to rainfall events on the order of 75 cm (29.5 inches) at the Bayou Chinchuba location and 35 cm (13.8 inches) at the Tchefuncte Marsh. The Bayou Chinchuba gage had a higher degree of water level fluctuation than the East Tchefuncte Marsh gage presumably because of the greater tidal influence experienced at the marsh location

Lewisburg canal leading into Lake Pontchartrain

Water

Results of the water nutrient analyses show that nutrient levels in the study area are generally low with the exception of the outfall from the Facility into Bayou Chinchuba and at outfalls from private residential plants. When effluent concentrations are greater than concentrations in the eventual receiving body, it is more appropriate to calculate percent reduction from the source to the wetland outflow. For Bayou Chinchuba, the percent reduction of nitrate-nitrite was approximately 75% between the outfall station (Station 7) and Lake Pontchartrain at Bayou Chinchuba (Station 5), for most sampling periods. The percent reduction of NH_4 between stations 7 and 5 was approximately 90% for many of the sampling periods. Phosphate percent reductions were also high during most sampling periods. Percent reductions in SiO_2, TSS, and Chl a also occurred between stations 7 and 5 along Bayou Chinchuba, but to a lesser degree than the nitrogen and phosphorus components. The lowest reduction percentages generally corresponded to times when weather events decreased the residence time of water from Bayou Chinchuba into Lake Pontchartrain.

As discussed previously, nutrient removal is inversely related to the loading rate. At low loading rates (which incorporates residence time) nutrient removal efficiency is high. But, as loading rates increase, nutrient removal efficiency decreases rapidly (see Figure 2).

Vegetation and Marsh Productivity

The East Tchefuncte Marsh community west of the Sanctuary Subdivision is a typical fresh to brackish marsh for wetlands bordering Lake Pontchartrain. Species composition and biomass are comparable to other fresh to brackish marshes along Lake Pontchartrain (Conner et al. 1980, Cramer et al. 1981, White and Simmons 1988, Platt and Brantley 1989). The highest biomass measurements occurred at plots 1 and 5, which were dominated by *Spartina patens*, a brackish marsh species that generally has the highest biomass values for coastal Louisiana marsh plants. Plots 1 and 5 were located the closest to Lake Pontchartrain, where higher salinities are expected. The other plots contained bulltongue (*Sagittaria lancifolia*), saw grass (*Cladium jamaicense*), smartweed (*Polygonum punctatum*), and some cattail (*Typha* sp).

Introduction of secondarily treated effluent to this marsh will most certainly effect species composition, especially in proximity to the discharge location. As mentioned previously, research in the Everglades has indicated that due to nutrient introduction, saw grass has declined and cattail has increased in areal extent (Craft et al. 1995, Daoust and Childers 1999). The East Tchefuncte River Marsh shows signs of this same type of saw grass community decline from cattail encroachment along the north where several residential subdivisions input nutrient introductions. Salinity incursions from Lake Pontchartrain probably also affect this saw grass community, as it is mostly a fresh to intermediate salinity marsh plant. Introduction of the effluent to this marsh will likely create a cattail dominated marsh buffer near the site of effluent discharge. The saw grass community will likely displace south and west towards Lake Pontchartrain and begin to displace some of the wiregrass marsh community near the lakeshore, as the nutrient-stripped freshwater begins to buffer much of the salinity levels noticed near the lake.

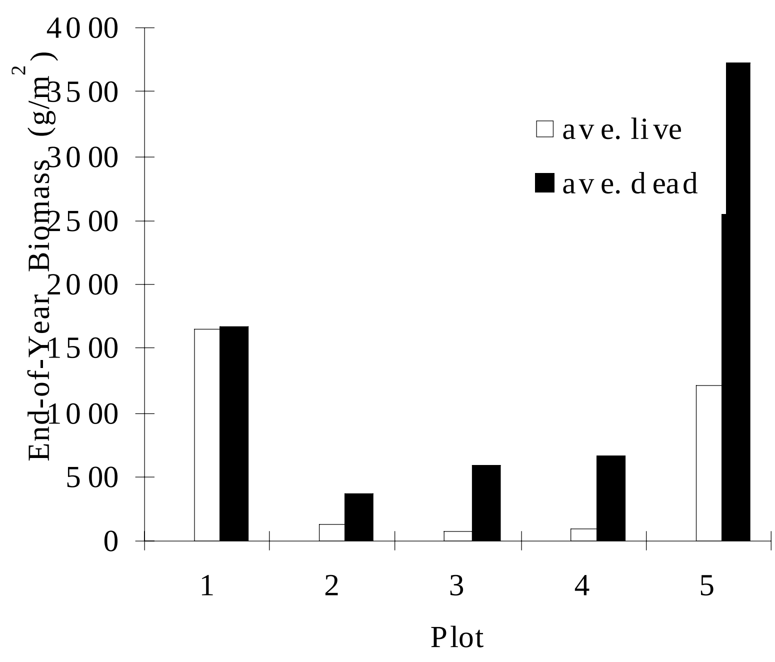


Figure 11. End of year standing crop biomass for plots in the East Tchefuncte Marsh.

Scrub-Shrub Percent Cover

Measurements of percent cover along several transects in the scrub-shrub zone between the marsh and the swamp forest were taken (Table 4). This is an area that has a mix of small trees and a thick, diverse understory of fresh to intermediate marsh vegetation. The area probably receives frequent inundations of higher salinity water from Lake Pontchartrain and nutrient poor freshwater from upland sources, resulting in small woody vegetation that can tolerate some salinity. There has been some wetland loss in this area and is likely due to relative sea level rise and/or salt water intrusion. Implementation of a wetland assimilation program should serve to reduce these effects in this zone of vegetation as higher salinity water is buffered by the freshwater effluent

Table 4. Percent vegetation cover data for transects in the Sawmill Canal and Sanctuary wetlands. T1 thru T7 represent the transects from 1 to 7.

	Sawmill Canal wetland				Sanctuary wetland		
Trees	**T1**	**T2**	**T4**	**T7**	**T3**	**T5**	**T6**
baldcypress (*Taxodium distichum*)		18				13	15
red maple (*Acer rubrum* var. *drummondii*)		5		5		5	20
Shrubs							
wax myrtle (*Myrica cerifera*)		40				50	10
Sea myrtle (*Baccharis halimifolia*)				10			10
sweet gum (*Magnolia virginiana*)						1	
Herbaceous							
bulltongue (*Sagittaria lancifolia*)	33	27	88	35	10	50	50
marsh purslane (*Ludwigia palustris*)	34	50	23	25	40	35	53
sensitive joint vetch (*Aeschynomene virginica*)	40	18	13	7			35
dotted smartweed (*Polygonnum punctatum*)					80		
saltmarsh (*Aster subulatus*)							
southern blue flag (*Iris virginica*)			3			10	2
common dodder (*Cuscuta gronovii*)			5				
Rushes							
spikerush (*Eleocharis* spp.)		60					
soft rush (*Juncus effusus*)				5			5
Grasses							
wiregrass (*Spartina patens*)							
saw grass (*Cladium jamaicense*)	30		90	40			

Swamp Forest Productivity

The forest community structure at Bayou Chinchuba and Bayou Castine are shown in Table 5. Bayou Chinchuba and Bayou Castine have stem density and basal area measurements that are similar to other forested wetlands in the southeastern U.S. (Conner and Day 1982). These forest structure indices are also similar to or higher than at the

Amelia wastewater treatment site (Day et. al 1997) and the Breaux Bridge wastewater treatment site (Delgado-Sanchez 1995), and much higher than at the Thibodaux wastewater treatment site (Day et. al. 1993). The forest composition at Bayou Chinchuba and Bayou Castine appears to be correlated with the floodplain width and distance from Lake Pontchartrain (salinity). As noted by Rheinhardt et al. (1998), for other low-order streams in the coastal plain, swamp blackgum usually dominates these forested wetlands in the headwaters, while water tupelo and baldcypress typically dominate mid-reach portions. This is readily apparent in the Bayou Chinchuba plots, as the relative density and relative dominance of swamp blackgum decreases from the upstream to the downstream plots, and both water tupelo and baldcypress dominate the outfall and downstream plots. Based on forest community structure, the Bayou Castine reference plot is situated between the upstream and outfall forest plots of Bayou Chinchuba.

Initial dbh measurements were taken in February 1999 when trees were dormant. Measurements of dbh will be taken again in January 2000 during the dormant season to determine a change in biomass in the forest plots. Change in biomass represents annual wood production and will be used with annual litterfall to determine the production in each plot. This information will be included as part of the supplemental report.

Litterfall is another measure of productivity of a forest. The litterfall at the four swamp sites are similar to levels found in other alluvial, flowing water systems in the southeastern U.S. Litterfall peaks differed according to species composition. Plots with a large component of swamp blackgum (Upstream and Outfall) peaked during September-October, whereas plots with a large cypress component either peaked in December-January or were bimodal with a peak in the fall and a peak in the winter. Results of the ANOVA indicated that there are significant litterfall differences between forest plots, including between the east and west plots at the same locality ($F=17.51$, $df = 7,32$, $P<0.001$). Plots that had similar litterfall production ($P>0.05$) were the Upstream West and Outfall West plots, and the Outfall East and Castine West plots (Figure 12). Clearly, the two downstream plots on Bayou Chinchuba were very productive, likely due to the fertilizing effects of the discharge. The other highly productive plot was Castine East that was situated near several old-growth baldcypress trees.

The herbaceous vegetation under the swamp forest canopy included marsh purslane (*Ludwigia palustris*), smartweed (*Polygonum punctatum*), marsh spider lily (*Hymenocallis crassifolia*), lizard's tail (*Saururus cernuus*), pennywort (*Hydrocotyle* sp.), bedstraw (*Galium* sp.), and duck weed (*Lemna minor*). In general, the understory biomass was low due to the high forest basal area on most plots. Herbaceous understory biomass will be added to the stem production and litterfall figures to arrive at an estimate of total production for the forest plots.

Aquatic Fauna

Benthic Community

The benthic community sampling in the fall of 1998 collected a total of 1,312 organisms in 34 taxonomic groups (Table 6). The five most abundant taxa were naididae (oligochaeta), Palpomyia sp. (ceratopogonidae), Musculium sp. (bivalve), tubificidae (oligochaeta), and nematoda. Ten taxa represented 90 percent of the total abundance identified.

Univariate metrics can be used to show general trends among locations and stations. Bayou Chinchuba generally had higher total number of species, total number of individuals, and species richness than did the marsh location. The Shannon diversity indices exhibit an overlapping distribution among locations. The Bayou Chinchuba upper (outfall) and middle (downstream) stations show higher total number of species and species richness relative to the reference station. The total number of individuals was higher at the middle station than at other stations. The Shannon diversity index shows little difference among stations. The marsh stations are similar in total number of species, total number of individuals and species richness among stations. Shannon diversity was slightly higher at the upper and middle marsh stations relative to the reference station.

Multidimensional scaling (Figure 15) exhibits general trends among the upper, middle, and reference stations within each of the marsh and Bayou Chinchuba locations. The relative trend of the marsh location stations extends from the middle to upper and finally to the reference stations, while the Bayou Chinchuba stations extend from the upper to middle to reference stations. The Bayou Castine reference samples are located near the Bayou Chinchuba samples.

Nekton Community

The SIMPER analysis identifies which taxa contribute to the similarity and dissimilarity among locations and stations. Largely sailfin molly, crawfish, and mosquito fish contribute the similarity within samples collected in the fall while the similarity among samples collected in the spring is contributed largely by mosquito fish, least killifish, and sheepshead minnow. Mosquito fish and sheepshead minnow express the similarity at marsh stations in the spring. Crawfish and mosquito fish express the similarity at Bayou Chinchuba stations in the fall, and least killifish in the spring.

Combining data from the two seasons, the similarities at the station locations can be evaluated. Mosquito fish at the middle station, and sailfin molly and sheepshead minnow at the reference station express the similarity at marsh stations. The similarity at Bayou Chinchuba stations is expressed by mosquito fish, crawfish, and least killifish at the upper station, mosquito fish and crawfish at the upper stations; and least killifish and mosquito fish at the reference station. Mosquito fish, sailfin molly, and least killifish express seasonal differences. In the marsh, mosquito fish and least killifish contribute the seasonal difference while in Bayou Chinchuba, least killifish, crawfish, and mosquito fish express it. Differences between the marsh and Bayou Chinchuba are contributed by crawfish and sailfin molly in the fall and least killifish and mosquito fish in the spring. Crawfish and mosquito fish contribute differences between Bayou Chinchuba and Bayou Castine in the fall, and mosquito fish and least killifish in the spring.

Differences among marsh stations are contributed by sailfin molly, silversides, and mosquito fish between middle and upper stations; by sailfin molly, sheepshead minnow, and mosquito fish between middle and reference stations; and by sailfin molly, sheepshead minnow, mosquito fish, and gulf killifish between the upper and reference stations. Differences among Bayou Chinchuba stations are contributed by mosquito fish, crawfish, and least killifish between middle and upper stations; by mosquito fish, grass shrimp, and least killifish between middle and reference stations; and by mosquito fish, crawfish, grass shrimp, and least killifish between the upper and reference stations.

Terrestrial Fauna

Species Composition

Forested wetlands and marshes are known to provide valuable habitat to wildlife mainly because of the abundance of food and cover found in these areas (Harris et al. 1984). Unfortunately, however, there is a lack of information pertaining to the wetland habitat requirements of most species living in these areas with the exception of nutria, beaver, and some species of waterfowl (Sather and Smith 1984).

Frequency of Occurrence

Studies in the Atchafalaya Basin indicate that bottomland forests can support from two to five times as many game animals as pine-hardwood areas, and during the winter may contain ten times as many birds per acre as pinelands (Harris et al. 1984). No known studies have been performed on this forested wetland site, thus there is no site-specific data available.

Species Diversity

Some animals are completely dependent on wetlands for food, protection, resting areas, reproductive sites, and other life requisites (Sather and Smith 1984). Although some animals spend their entire lifetime in a particular wetland, others are resident for only part of their life cycle, or as temporary residents as they travel from one place to another. Wetlands also provide critical habitat for many rare and endangered species of animals. Reasons for the high diversity of animals within a wetland depend on many factors, including the structure and diversity of the vegetation, surrounding land uses, spatial patterns within the wetland, vertical and horizontal zonation, size of the wetland, and water chemistry (Sather and Smith 1984).

Characteristic bird species found in these wetland forests include numerous passerine species, several birds of prey, several upland game birds, and a variety of birds associated with aquatic habitats. The number of mammal species generally ranges from 5-30 with population densities varying greatly from area to area. A typical forested wetland site may include several furbearers, a few small and medium sized mammals, and one or more large mammals. Amphibians and reptiles have generally been neglected in favor of the more economically important animals. However, these latter groups are important in aquatic food chains and are becoming more recognized as valuable indicators of environmental quality (Orser and Shure 1972, Dodd 1978). Partial descriptions of wildlife communities have been reported, but thorough characterizations are not available for most wetland areas (Brinson et al. 1981). While there are no known studies concerning the fauna on this wetland site, we know that wetlands provide habitat for a wide variety of wildlife.

Conclusions

The Wetland Needs Assessment provides a picture of poor water quality conditions and wetland loss in the Lake Pontchartrain Basin. These conclusions are based on data and information about water quality conditions, the influence of natural and human-related factors, estuarine use impairments, and management recommendations complied for Bayou Chinchuba and the East Tchefuncte River Marsh. The results, which were reviewed by expert wetland ecologist, provide a comprehensive assessment of the magnitude and consequences of eutrophication in the Basins wetlands.

Eutrophic Conditions in the Basin

Of the 37 estuaries in the Gulf of Mexico area, the Lake Pontchartrain Basin is characterized as one of the highest-level eutrophic conditions in the Gulf of Mexico region. These coastal waters are warm, with low tidal energy and shallow water depths. Land-use activity in the Basin is more and more dominated by increased urbanization.

Key Findings

1. *One of the high expressions of eutrophic conditions in the Gulf of Mexico area.*
2. *This results in a negative effect on water quality and ecosystem health.*
3. *Future outlook to 2020 places Lake Pontchartrain as one of 6 out of 38 estuaries to develop worsening conditions.*

Wetland Wastewater Assimilation Can Remove Nutrients

Wetland assimilation of treated municipal wastewater can efficiently remove nutrients and improve water quality. Wetland loss due to sea level rise and saltwater intrusion can be reduced through implementation of wetland wastewater assimilation. Forested areas downstream of wetland assimilation discharges benefit from the fertilizing discharge.

Key Findings

Wetland assimilation can efficiently remove nutrients and improve water quality.
Wetland loss due to sea level rise and saltwater intrusion can be reduced with wetland wastewater assimilation of treated municipal wastewater.
Downstream forest areas can benefit from the fertilizing discharge of the

Species Diversity Higher In Treatment Areas

The Bayou Chinchuba area receiving treated effluent had a higher total number of species and individuals than did the non-treatment area.

Key Finding

Species richness is higher in the treatment area.

Shorelines are important ecosystem components

Elevated shorelines serve as a place of refuge for many birds and mammals, which feed in the wetlands. The near-shore area of the lake and the shallow channels opening into the wetland limit flushing of the wetlands. Deep channels would provide openings and promote saltwater intrusion during dry periods and lead to rapid drainage in dry periods and when the lake is low. The shoreline ridge is low now and often over topped by storm waters that are important to introduction of sediments to the wetland area.

Key Findings

Shorelines are vital elements of ecosystems.

Birds and mammals use the shoreline for refuge.

The near-shore area and the shallow channels limit water influx.

Deep channels would allow saltwater intrusion.

Shoreline Development Detrimental to the Ecosystem

Shoreline development would alter the hydrology and may lead to a less efficient removal of nutrients in wastewater. Any future development would have to be very low-density to protect the shallow nature of the near-shore area and channels and the preserve the natural habitat of the low ridge so animal populations would be maintained.

Key Findings

Shoreline development would alter the hydrology and result in less efficient removal of nutrients.

***Future development would have to be low**-density to preserve the shallow nature of the near-shore area and channels and protect the natural habitat.*

Forested Wetlands Provide Valuable Habitat to Wildlife

Forested wetlands provide valuable habitat to many animals and birds because of the food source and cover found in these areas. Research in the Atchafalaya Basin indicates bottomland forests can support two to five times as many game animals as pine-hard wood regions.

Key Findings

Forested wetlands provide valuable habitat.

Research indicates bottomland forests can support two to five times the number of game animals compared to pine hardwood areas.

High Species Diversity Dependent on Many Factors

Key Finding

1. *Animal species diversity in a wetland is depend on many factors such as vegetation, land-use, type and size of wetland and water quality.*

High species diversity of animals in a wetland depend on many factors such as the structure and diversity of the vegetation, adjacent land-use, spatial patterns with the wetland, vertical and horizontal zonation, size of wetland, and water chemistry.

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