EVALUATION OF
BAYOU LAFOURCHE WETLANDS
RESTORATION PROJECT

COASTAL WETLANDS PLANNING, PROTECTION AND RESTORATION ACT PROJECT PBA-20

SUMMARY REPORT
SEPTEMBER, 1998

**U.S. ENVIRONMENTAL PROTECTION AGENCY
REGION 6**

PRELIMINARY DRAFT

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SUMMARY REPORT
SEPTEMBER, 1998

Report prepared in cooperation with the Louisiana Department of Natural Resources

Report prepared by Lee Wilson and Associates, Inc.
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Report based on contributions by:

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Louisiana State University
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Louisiana Universities Marine Consortium
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EXECUTIVE SUMMARY

Introduction

Bayou Lafourche is a natural distributary channel of the Mississippi River that historically connected the river to coastal wetlands. This connection was dammed off in 1904, an action that contributed to the subsequent rapid loss of wetlands in the lower Terrebonne and Barataria Basins. The bayou was partially reopened in 1955 when a pump and siphon station was built in Donaldsonville. The resulting diversion of river water to the bayou averages less than 200 cubic feet per second (cfs). The diversion is the source of drinking water for more than 200,000 persons, and provides aesthetic, recreation, and other benefits to the communities that lie along the banks of the bayou.

In 1996, a Task Force created by the Coastal Wetlands Planning, Protection and Restoration Act (CWPPRA) selected for funding a project to divert additional fresh water down Bayou Lafourche in order to help restore coastal wetlands. The concept of this project is consistent with the CWPPRA Restoration Plan for at least four reasons: 1) diversion projects are considered one of the essential elements in coastal restoration; 2) past and future marsh losses in parts of the Terrebonne and Barataria Basins appear to be directly related to the loss of freshwater flow in Bayou Lafourche; 3) near lower Bayou Lafourche there is a large acreage of marshes that require an influx of freshwater to survive; and 4) Bayou Lafourche is unique in being a presently functioning conveyance channel that can directly connect the Mississippi River to the marshes most in need of freshwater.

The original project selected in 1996 would have siphoned 2,000 cfs during times of high Mississippi River flow. It would have raised water levels above historic water levels, and would not have provided additional water to the wetlands in critical times of high salinity. For these reasons, among others, the original project raised significant public comment and concern. The U.S. Environmental Protection Agency (EPA) was tasked to prepare an advanced design evaluation of the project. EPA's studies, and the specifics of a conceptual redesign of the project, are presented in this report.

Outcome of conceptual redesign: the optimized project

Concept. The conceptual redesign of the Bayou Lafourche Project has the objective of providing the maximum diversion (hence wetlands benefits), without causing a rise in water levels or other potentially adverse impacts to properties along the bayou. The result of this conceptual redesign is termed the "optimized project", and is sized at 1,000 cfs, which appears to be the largest diversion that can be conveyed within the existing bayou banks.

The optimized project will substantially expand the existing diversion of freshwater from the Mississippi River at the head of the bayou. The diverted water will flow down Bayou Lafourche and through a number of natural channels and man-made canals to wetlands in the lower Terrebonne and Barataria Basins. In effect, the optimized project will provide the same volume of water to the wetlands as the original project, but the flow will be a year-round supply of 1,000 cfs due to use of both siphons and pumps, instead of a seasonal supply of 2,000 cfs.

Features. The major features of the optimized project include the following.

- The 1,000 cfs of diversion capacity will be achieved by a first phase to upgrade the existing 340 cfs pump station at Donaldsonville and operate it at full capacity; and by a second phase to construct a new 660 cfs pump/siphon station adjacent to the existing facility. Diversion rates will be increased progressively to a maximum of 1,000 cfs, or channel capacity, whichever is less.

- Channel capacity will be expanded to 340 cfs, and then up to 1,000 cfs by the combined actions of eliminating the existing fixed weir at Thibodaux, and extensive dredging of the channel within its existing banks. The dredged material will be discharged to the Mississippi

River or to cane fields where landowners desire fill material. Several utility lines will be replaced or protected as part of the dredging program. Limited bank stabilization will be provided; the primary basis for assuring bank stability is to limit dredging and to include adjustable weirs to control water levels (see below).

- There will be substantial investment in facilities that will allow for effective management and maintenance of the channel. These include:
  - operation of five monitoring stations to provide continuous information on water levels and other bayou conditions;
  - installation of two adjustable weirs to control water levels as necessary in order to eliminate a current cause of bank instability problems, and to facilitate the passage of storm runoff;
  - construction of a sand trap in Donaldsonville, which will be routinely dredged to remove sediments and thereby control siltation of the main channel; and
  - development through public input of an effective plan for project operation and bayou management, which will be implemented with local government participation and oversight.

All management actions will be part of the initial 340 cfs phase of the project and will be in place before expansion to 1,000 cfs will begin.

Impacts to bayou. Computer models developed for EPA indicate that, for the assumptions made, the optimized project will result in future water levels in the bayou that will be at or below those observed in the recent past. Water quality will be improved by increased flushing of the bayou with river water, and drainage will be improved by the enlargement of bayou capacity.

However, some important questions about the project impacts cannot be fully resolved except through design-level evaluations that were beyond the scope and funding of the current study. Among these questions are whether relatively weak soils known to occur at depth in some parts of the bayou pose a concern to the stability of the dredged channel; and whether factors of bank stability, narrow channel banks and existing water levels will make it impractical to dredge a

1,000 cfs channel in some areas. These design-level evaluations will verify whether the 1,000 cfs project is practical or a smaller alternative amount of water is appropriate.

Benefits. Benefits to wetlands will occur because the addition of fresh river water will nourish the marshes, will provide some sediment accretion, will stimulate organic productivity, and will help counteract saltwater intrusion. These effects collectively will help maintain vegetative health and the vertical accumulation of marsh surface that is essential to avoid wetlands loss.

The optimized project has undergone a formal CWPPRA Wetlands Value Assessment, which quantified wetland benefits as 705 average annual habitat units (AAHUs). Benefits attributable to this project are greater than for the original project because diverted water will be pumped or siphoned year-round, rather than being diverted only during spring high flows.

For comparison to projects that are being considered for funding on the current CWPPRA priority list, it is appropriate to modify the benefit number to include the synergistic effects of an already approved project, which is proposed along Grand Bayou and Cutoff Canal. EPA's estimate is that with that adjustment, the Bayou Lafourche diversion will provide wetland benefits on the order of 784 AAHUs.

Costs and cost-effectiveness. EPA's estimates of project costs are in the process of being reviewed by CWPPRA agencies. EPA's current estimate is that the full project will cost $37 million to build, and $0.6 million per year to operate (1998 dollars). Based on adjustments that are common to all CWPPRA projects, these values equate to a fully funded cost that approaches $60 million, an annual average cost of about $4.5 million, and a cost-effectiveness ratio of about $5000 for each average annual habitat unit.

Reflecting project benefits to water supplies and drainage, there is potential for significant cost sharing among the non-wetland beneficiaries of the project. In particular, cost-sharing could offset most of the annual operating expense of the project, which will result in reduced fully funded and average annual costs, and will improve cost-effectiveness.

Overview of this report

The information summarized above is presented in substantially more detail in this report. The first six chapters lead the reader through the process by which EPA conceptually redesigned the project.

- Chapter 1 provides a brief description of Bayou Lafourche, and the wetlands loss problem that is being addressed by a new diversion project. It also summarizes EPA's program of public involvement and technical studies that led to the optimized project.
- Chapter 2 summarizes the extensive information that EPA has obtained regarding the water resources in Bayou Lafourche, including characteristics of water flow and water quality in the channel.
- Chapter 3 provides information relating to the general principles for design and operation of any project that will divert Mississippi River water into Bayou Lafourche at Donaldsonville.
- Chapter 4 describes the computer models and other methods that EPA has relied on to quantify the effects of increased diversions on Bayou Lafourche, and on the wetlands.
- Chapter 5 summarizes the design characteristics of the optimized project, presents the analysis of wetland benefits, and presents EPA's working estimates of the project costs.
- Chapter 6 discusses a number of alternatives to the optimized project, including No Action, and diversions that would be less than 1,000 cfs; these smaller diversions would have lower costs and benefits than the optimized project, and could pose fewer uncertainties.

The remaining portions of the report include: an update to EPA's 1996 responsiveness summary that addresses questions and concerns that have been raised about the project during the public involvement process; an appendix that abstracts the numerous technical studies upon which this report is based; and a list of references.

Status of the Project

Public meetings regarding the project were conducted in September 1998 by the Coalition to Restore Coastal Louisiana and the Barataria-Terrebonne National Estuary Program. EPA presented project concepts to the public, and is receiving comments. These comments, along with this report, will be presented to the CWPPRA Task Force in October, 1998. The Task Force will give consideration to the best options for the project.

One scenario for going forward with a project to benefit Bayou Lafourche and its associated wetlands is to initiate project design in 1999, including detailed geotechnical studies, for the purpose of making a final determination of the safe capacity that can be developed in Bayou Lafourche. Concurrent with this design, actions would be taken to secure cost-share funding, and to develop a publicly supported management plan. Cost-shares would be sought from the Bayou Lafourche Freshwater District and the benefited parishes; and possibly from other sources of federal and state funding. Under this scenario, costs and benefits of the largest practical diversion project would be finalized in the year 2000 and Phase I could be operational in 2001.

1. INTRODUCTION

1.1 OVERVIEW OF BAYOU LAFOURCHE AND OF CHAPTER 1

Bayou Lafourche is a former channel of the Mississippi River that extends about 110 miles from Donaldsonville, Louisiana, to the Gulf of Mexico. The bayou name in French indicates that it was known by early explorers simply as a fork of the great river. Figures 1.1-1 (map) and 1.1-2 (satellite photograph) show the location of the bayou with respect to area landmarks.

The bayou is the axis of a wide alluvial ridge created by the former river, and in its natural condition fed a large number of distributary channels (shown on Figure 1.1-2). The ridge built by the old river channel slopes gently to the adjoining swamps of the Terrebonne and Barataria Basins. There is extensive commercial and residential development along the highways that parallel the bayou for most of its length. Between this development and the swamps the land is primarily sugar cane fields. Characteristics of the areas along the bayou are illustrated by a topographic profile (Figure 1.1-3) and by representative photographs (Figure 1.1-4).

Bayou Lafourche connects the Mississippi River with areas of coastal wetlands that are experiencing a high rate of loss. Currently, the upper part of the bayou typically carries a flow of 100-200 cfs[1] or more of slow-moving water that is diverted from the Mississippi River and conveyed to water supply intakes along the channel. This is the source of drinking water for more than 200,000 persons in five parishes. The bayou is thus literally the lifeblood for a large population. The bayou also provides aesthetic, recreation, drainage and navigation benefits to the communities that have developed along its banks.

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1. cfs stands for cubic-feet per second. 100 cfs = about 65 million gallons/day

During the past two years, the United States Environmental Protection Agency (EPA) has conducted an extensive study of Bayou Lafourche, to determine if and how the channel might be enlarged to carry greater amounts of water from the Mississippi River in order to benefit deteriorating marshes in the lower Terrebonne and Barataria Basins. The study results are presented in this report.

Chapter 1 of the report provides an introduction to the study results as follows.

- Existing water problems in the bayou relate to wetlands survival, water supply, and drainage. The nature of these problems is briefly summarized in Section 1.2.
- Beginning in 1996, EPA and others have developed and investigated specific approaches to solving these problems, by increasing the capacity and flow of Bayou Lafourche. The history, objectives and components of the investigation are reviewed in Section 1.3. Section 1.3 introduces the <u>optimized project</u> that EPA is putting forth for public comment. This project will provide year-round wetlands benefits without causing an increase in water levels, and will benefit drainage and water supply conditions in the bayou.
- The results of EPA's investigation include this report, which will be subject to extensive public review in the near future. Section 1.4 introduces the main body of the report, and describes EPA's plans for the next steps in the review and decision process.

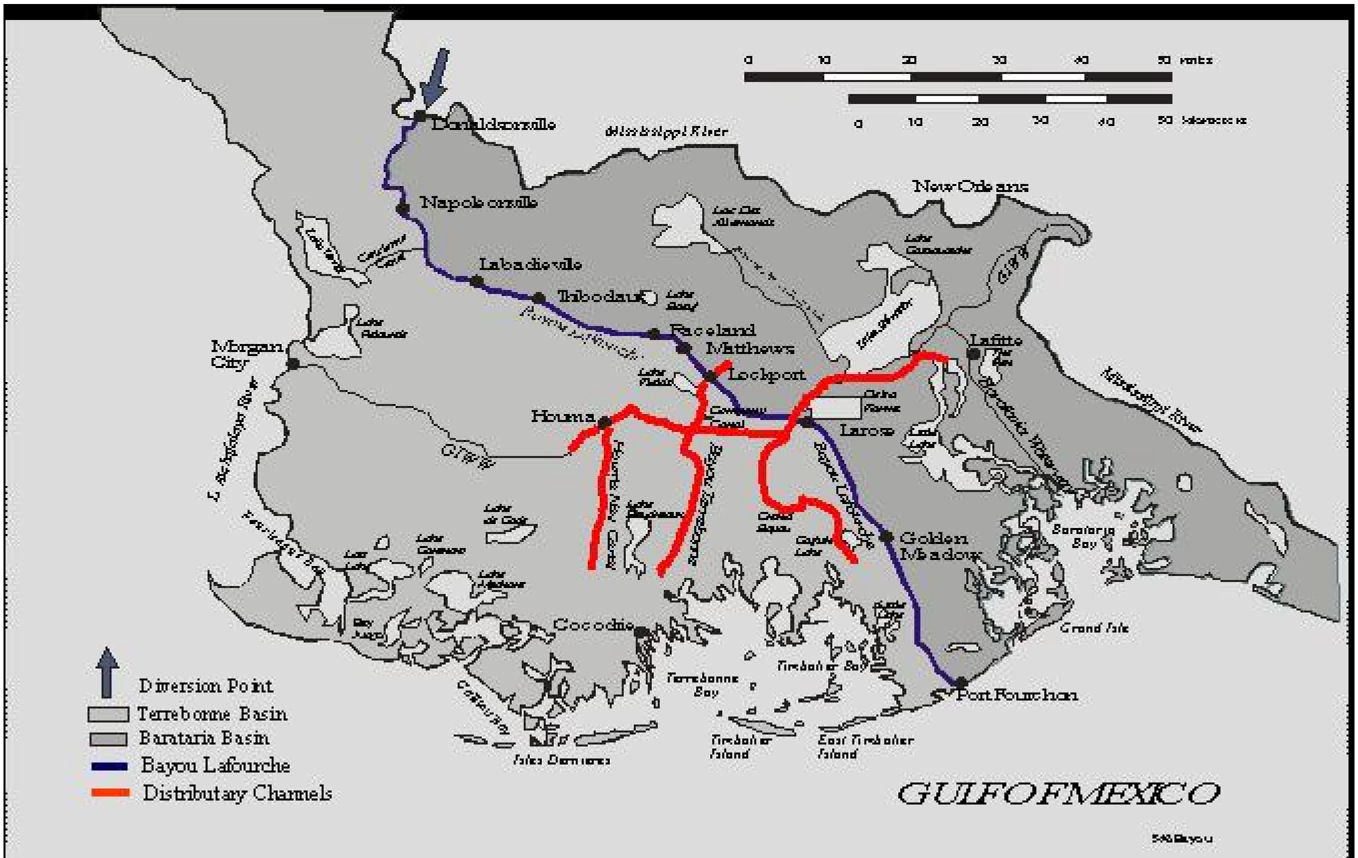

Figure 1.1-1.Location Map

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Figure 1.1-2. Regional features

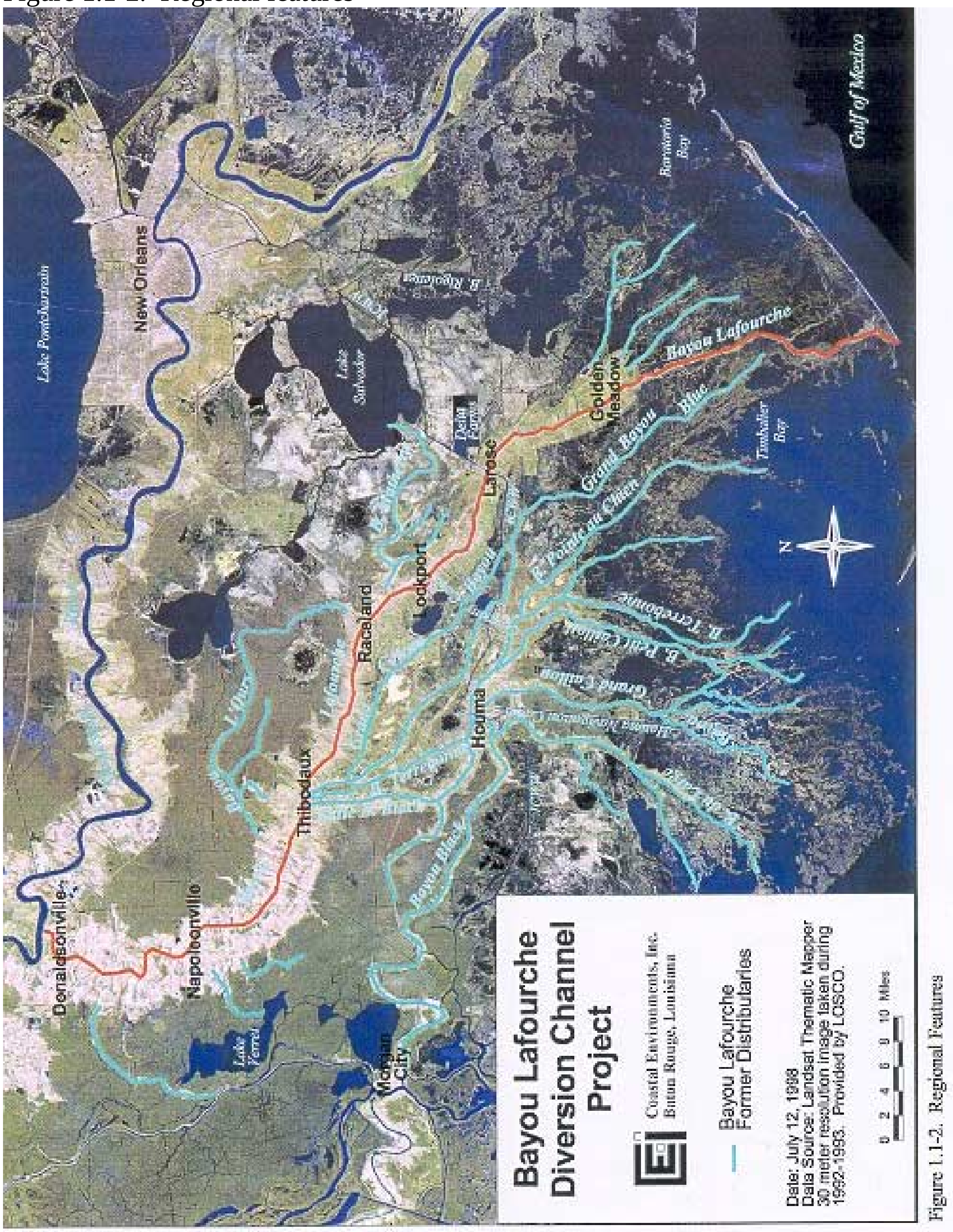

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Figure 1.1-3. Typical profile across the Bayou Lafourche alluvial ridge. Near Labadieville.

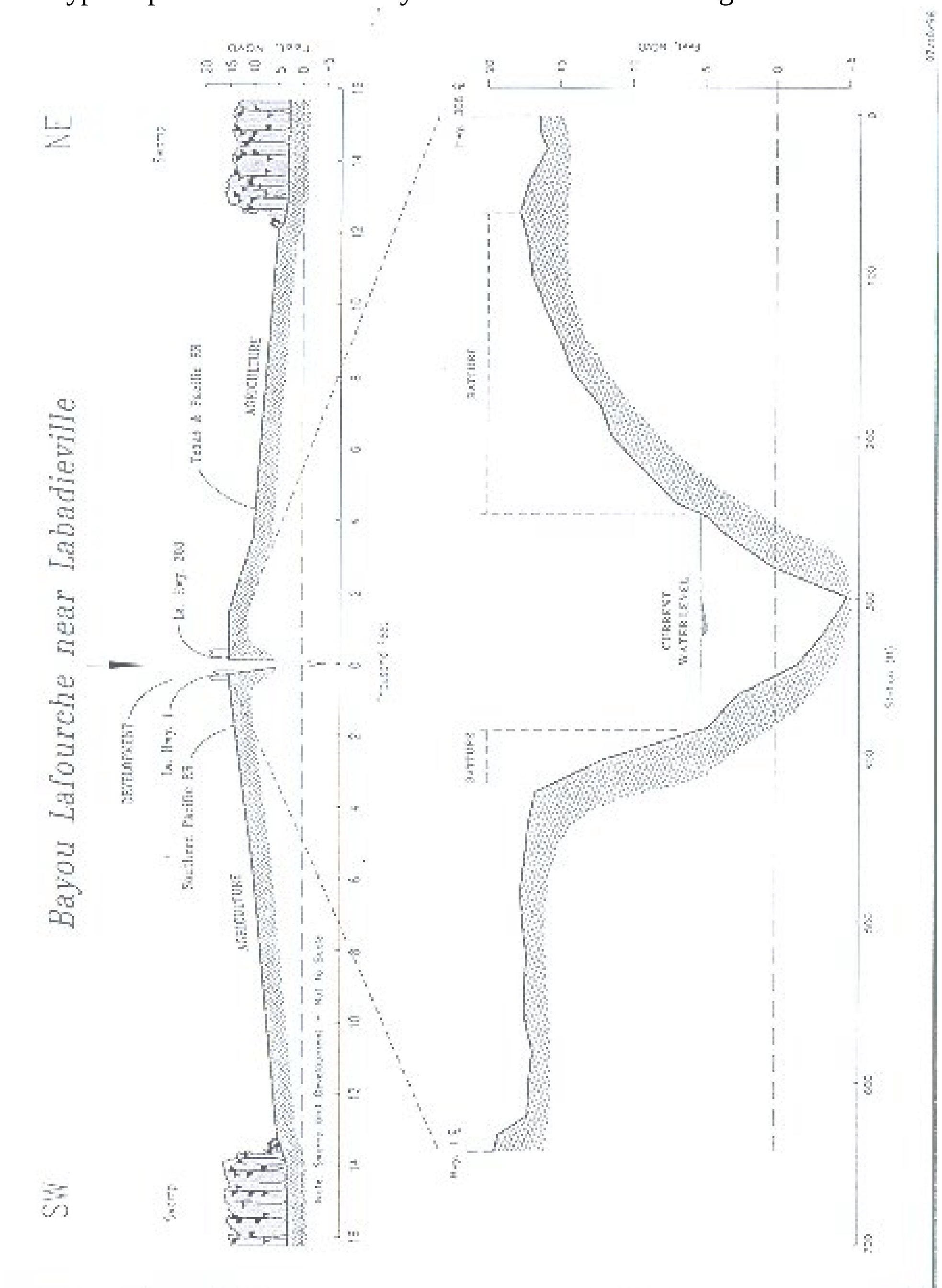


FIGURE 1.1-4. Photographs of project area.

Figure 1.1-4a. Oblique aerial photograph showing the head of the bayou at Donaldsonville. A flood control levee completely separates the bayou from the Mississippi River, which is seen at the bottom of photo. The Bayou Lafourche Freshwater District (FWD) operates a siphon and pump station to divert river flow into the Bayou; the station is on the levee, in the right foreground of the photo. The existing diversion outfall and beginning of bayou are in center of photo. The grassy bank of the bayou in the upper left of the photo is the “boat launch” reach, discussed elsewhere in this report (with respect to the sand trap location).


Figure: 1.1-4a

Figure 1.1-4b. Oblique aerial photograph showing a typical reach of the bayou. This photograph is looking in a downstream direction, at a point just below the boundary between Ascension Parish and Assumption Parish, about four miles below the head of the bayou in Donaldsonville. Highway 308 is on the left side of the photo and LA 1 is on the right. Development occurs along the highways, while agricultural activities dominate in the remaining areas of the alluvial ridge. Note the disposal of waste materials along the western (right) bayou bank near the bottom of the photo. The extensive development along Bayou Lafourche arguably makes it the "longest main street" in the United States.

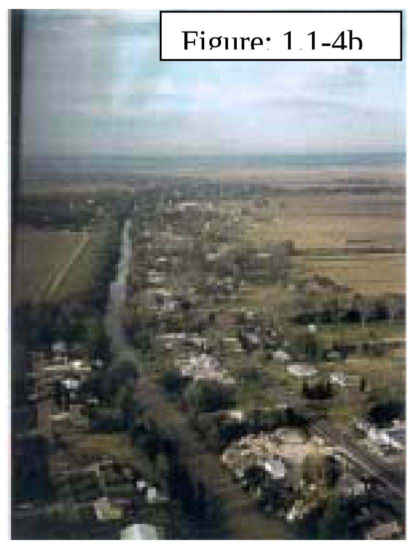


Figure: 1.1-4b

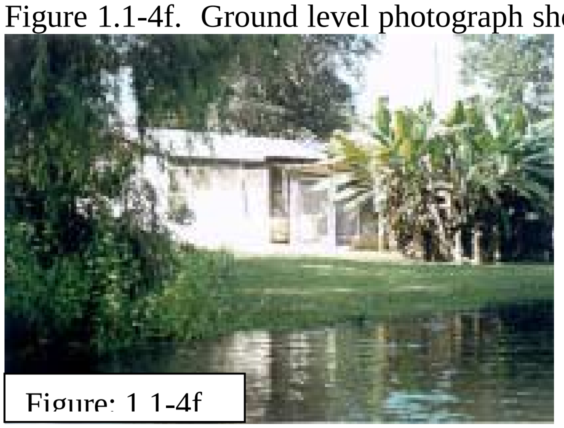
Figure 1.1-4c. Oblique aerial photograph showing the bayou as it flows (right to left) through Thibodaux. The photograph is looking southwest; LA 1 and downtown Thibodaux are in the upper part of the photo. A weir (small dam) separates flows in the upper bayou from flows in lower reaches; it provides a reservoir to hold water levels high during times when the diversion is not operating. A portion of the Thibodaux water plant is visible in the lower-center of the photo.


Figure: 1.1-4c

Figure 1.1-4d. Oblique aerial photograph showing the bayou at Larose. View is looking upstream at the intersection with the Gulf Intercoastal Waterway (GIWW), which is seen in the middle-ground of the photo. (The GIWW here is oriented east-west, or in the photo, right-left.) The Larose flood gate is visible in the channel below the GIWW (lower right portion of photo).

Figure 1.1-4e. Ground level photograph that shows a typical bayou reach of open water with heavily wooded banks. Location is below Donaldsonville. Note that while tree cover is extensive in this reach, some development is evident on the left bank: a dock in the foreground and a cleared area of batture in the middle ground.

Figure 1.1-4f. Ground level photograph showing a structure located in the lower part of the batture. Most development in the batture involves docks, decks, gardens, sheds, kennels, and the like; the open, grassy batture is typical of many backyards along the bayou.



1.2 EXISTING WATER-RESOURCE PROBLEMS

EPA considers that the diversion of Mississippi River water into Bayou Lafourche is a tool to help reduce the rate of deterioration of Louisiana's coastal wetlands. The linkage between the bayou and wetlands loss is discussed in Section 1.2.1. In order to develop appropriate alternatives for using the bayou to help the marshes, the study also has considered other water-resource problems along the bayou. These relate to water supply (Section 1.2.2) and drainage (Section 1.2.3). Additional information relative to the bayou's water resources is provided in subsequent parts of the report; see especially Chapter 2.

1.2.1 The damming of Bayou Lafourche contributed to the loss of coastal wetlands

The following discussion summarizes the strong link between the flow of river water in Bayou Lafourche and the health of marshes in lower Terrebonne and Barataria Basins, and documents the basis for concluding that these marshes are highly vulnerable to continued deterioration.

Louisiana's coastal wetlands. The swamps and marshes of the Terrebonne and Barataria Basin represent the largest wetlands areas among Louisiana's four million acres of coastal wetlands. The following facts regarding these wetlands are an important consideration in directing EPA's study of Bayou Lafourche.

- The wetlands are a national treasure. They provide unrivaled fisheries and wildlife habitat that in turn has sustained a high-value commercial fishery and a unique culture. The marshes provide storm protection to a large population and to some of the highest value petroleum and navigation infrastructure in the world.

- The wetlands are rapidly disappearing, in part because human actions have interfered with the processes that naturally built and sustained the wetlands. Recent loss rates of up to 40 square miles per year account for 80% of all coastal wetlands loss in the United States, and if continued would lead to almost complete destruction of the Louisiana coastal ecosystem within a few centuries.

- There is strong support from citizens and governments in Louisiana to build coastal restoration projects that rectify the problems caused by human actions.

Marsh losses and Bayou Lafourche. Bayou Lafourche represents one of the old courses of the Mississippi River that built the Mississippi Delta, and helped sustain the resulting wetlands. In 1882, a major Mississippi River flood caused all the marshes near Bayou Lafourche to be flooded (Figure 1.2-1). These marshes received an infusion of freshwater, nutrients and sediment. In 1904 the Bayou was dammed and no longer brought river water to the marsh. In 1927 there was another major flood (Figure 1.2-2). In 1927, most marshes near lower Bayou Lafourche received no flood waters.

Black lines have been added to Figure 1.2-2 to show the area near Bayou Lafourche that was flooded in 1882 but not in 1927. The major hydrologic change between the two floods was the damming of Bayou Lafourche in 1904. Absent evidence to the contrary, the comparison of the two maps indicates that the damming of the bayou eliminated the river-marsh connection for the area between the black lines.

An extensive data base has been developed regarding the history of wetlands loss in coastal Louisiana, and projections have been made regarding the rates and likely locations of future loss. Figure 1.2-3 shows historic loss patterns in the Barataria and Terrebonne Basins that border Bayou Lafourche. Many of the marshes in these basins have been devastated, and some of the greatest losses have been observed near lower Bayou Lafourche. The black lines from Figure 1.2-2 are shown (using a yellow color) on Figure 1.2-3. The area most impacted by the damming of Bayou Lafourche (between the lines) is among the areas of greatest wetlands loss (concentration of red and orange patterns).

The wetlands near lower Bayou Lafourche have experienced some of the highest rates of wetlands loss in all of coastal Louisiana. Based on Figure 1.2-3, **there is a close correspondence between locations that lost their river connection when Bayou Lafourche was closed, and areas where wetlands loss has been greatest.**

The cause-effect linkage between marsh loss and Bayou Lafourche is as follows.

1. The natural supply of freshwater from Bayou Lafourche was a major factor in promoting the organic productivity of the marshes in the eastern Terrebonne Basin and the western Barataria Basin. The vertical accumulation of organic matter (plus some sediment accretion) was the most essential process allowing the marshes to remain emergent, despite high rates of local land subsidence.

2. The delicate balance in which vertical accumulation kept up with subsidence was lost when Bayou Lafourche was dammed. The impacts of this change might have taken a longer time to develop, but hydrologic modifications (e.g. dredging of canals) caused significant stresses to the local marshes, and thereby greatly hastened vegetative death and marsh loss.

3. Under this concept, the damming of Bayou Lafourche was a contributing cause to a marsh loss problem that also results from natural subsidence and hydrologic modification.

<u>Prognosis for marshes near lower Bayou Lafourche</u>. Figure 1.2-4 is a map showing projected areas of future wetlands loss, following assumptions set forth in the draft Coast 2050 Plan. The projections indicate that wetlands near Bayou Lafourche will continue to experience severe degradation. The black lines from Figure 1.2-2 are superposed to show that the area most impacted by the damming of Bayou Lafourche is among the areas of greatest future wetlands loss.

Figure 1.2-4 confirms the close correspondence between locations that lost their river connection when Bayou Lafourche was closed, and areas where wetlands loss will be greatest. The wetlands near lower Bayou Lafourche will continue to experience some of the highest rates of wetlands loss in all of coastal Louisiana, absent an effective restoration effort.

Wetlands loss has been progressive, in that certain areas have experienced deterioration first, and the problem has then extended into adjoining areas of intact marsh. Figure 1.2-5, showing marshes south of Larose, illustrates this pattern. In Figure 1.2-5a, marshes in the distance are largely gone, and those in the mid-ground are severely degraded. The healthy marshes in the foreground are projected to be lost in the next decades, absent some type of restoration effort. Figure 1.2-5b shows the ultimate result of continued loss.

The objective of increasing the capacity of Bayou Lafourche to deliver water to the wetlands is to help keep healthy marshes, such as in the foreground of Figure 1.2-5a, from turning into degraded marshes of the type seen in Figure 1.2-5b. The term "target marshes" is applied here to denote wetlands that are hydrologically influenced by Bayou Lafourche and for which restoration literally means the difference between life and death.

1.2.2 Bayou Lafourche is vulnerable to water supply interruptions and water quality problems

The damming of Bayou Lafourche in 1904 turned a once vibrant stream into a stagnant ditch. Isolation of the bayou from its source stream became permanent when promised funds to construct a lock were never made available. While the dam relieved local flooding, it also deprived people along the bayou of a reliable source of fresh water.

To meet the growing water demands of people along the bayou, and to restore supplies lost when the bayou was cut off, the Bayou Lafourche Freshwater Management District (FWD) was formed. The FWD built a pumping station and in 1955 began to pump and siphon water into the head of the bayou at Donaldsonville (see Figure 1.1-4a). This facility has a capacity of 340 cfs and has provided municipal and industrial water to the bayou for more than 40 years. The current diversion is effective in providing the entire drinking water supply for all of Assumption and Lafourche Parishes, for much of Terrebonne Parish, for Ascension Parish in the Donaldsonville area, and for Grand Isle.

As discussed more fully in Chapter 2, there are several factors that potentially impact the continued freshwater supply in the bayou. These factors need to be considered when developing a project to use the bayou as a means of delivering river water to the marshes.

- The original pumps are now more than 40 years old and in need of repair or replacement. Also, certain aspects of the original facility and pumps are inherently inefficient.
- The capacity of the channel has diminished over time. This makes it more difficult to convey water through the bayou to the points of need, and contributes to drainage problems discussed in Section 1.2.3.
- In response to chemical spills in the Mississippi, it can be necessary to shut down the diversion of river water. This leads to a comparatively rapid decline in water levels in the bayou, which in turn can adversely impact the stability of some channel banks.
- There is an increasing load of pollutants into the bayou from sources such as septic tanks (almost none of the area along the bayou is sewered) and runoff from urban areas and cane fields.
- While the current facilities have the capacity to meet existing and projected water supply needs for the parishes that depend on Bayou Lafourche, the facilities do not have capacity to block saline intrusion up the bayou under worst-case conditions.

1.2.3 Limited channel capacity impedes drainage and has caused bayou water levels to rise

One result of the damming of Bayou Lafourche, and its very limited reopening, is that a once large channel has filled in, at least in part from natural processes. In addition, the flood control provided by the damming has made it possible for bayou-side residents to fill in the batture and further encroach upon the channel. Not all of this fill has been done in accordance with required environmental permits. Still another recent factor has been the proliferation of aquatic vegetation in the channel.

Collectively, these changes have reduced the capacity of the channel so that FWD must use higher rates of diversions in order to meet water needs down the bayou. The combined effect of higher diversion rates and impeded drainage is that water levels along the bayou have substantially increased.

As discussed more fully in Chapter 2, higher water levels have reduced the ability of the bayou to carry storm runoff that originates from the developed areas along LA 1 and 308, and have virtually eliminated gradients that would allow drainage to the bayou from cane field areas. Incidents of bayou water topping the low bank and impacting batture properties have increased. These conditions indicate that the bayou does not have the capacity to carry additional water to the wetlands, unless channel capacity is substantially increased. That fact has obvious implications for any project that would divert more water down the bayou.

FIGURE 1.2-1. FLOOD OF 1882
Areas overflowed in coastal Louisiana
(Based on Cowdrey, 1977)

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FIGURE 1.2-2. Flood of 1927: areas overflowed in coastal Louisiana.
(Based on Cowdrey, 1977)

FIGURE 1.2-3. Areas of historic wetlands loss (shown in red and orange) in the Terrebonne and Barataria basins. (from http://www.lacoast.gov)

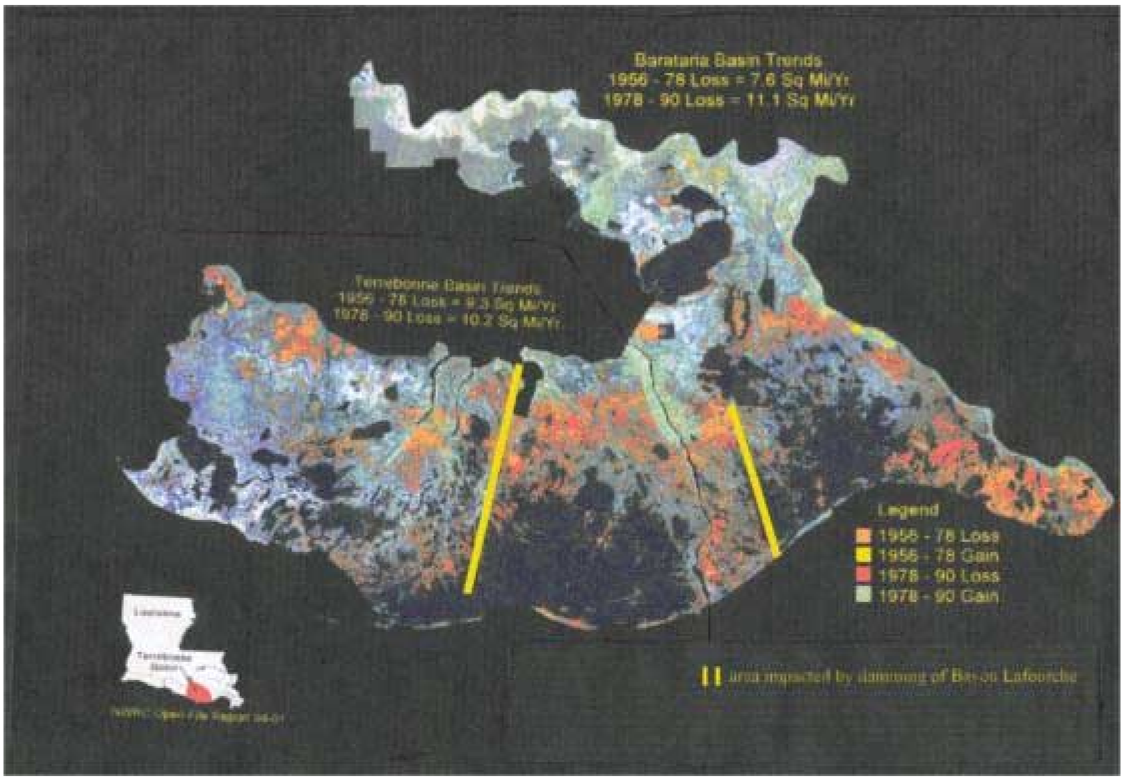


FIGURE 1.2-4. Areas of projected future wetlands loss (shown in red) in the Terrebonne and Barataria basins (from The Natural Systems Energy Laboratory, LSU, September 1997).

Yellow/black lines are in same location as black lines in Figure 1.2-2, and represent the area most impacted by the damming of Bayou Lafourche in 1904.

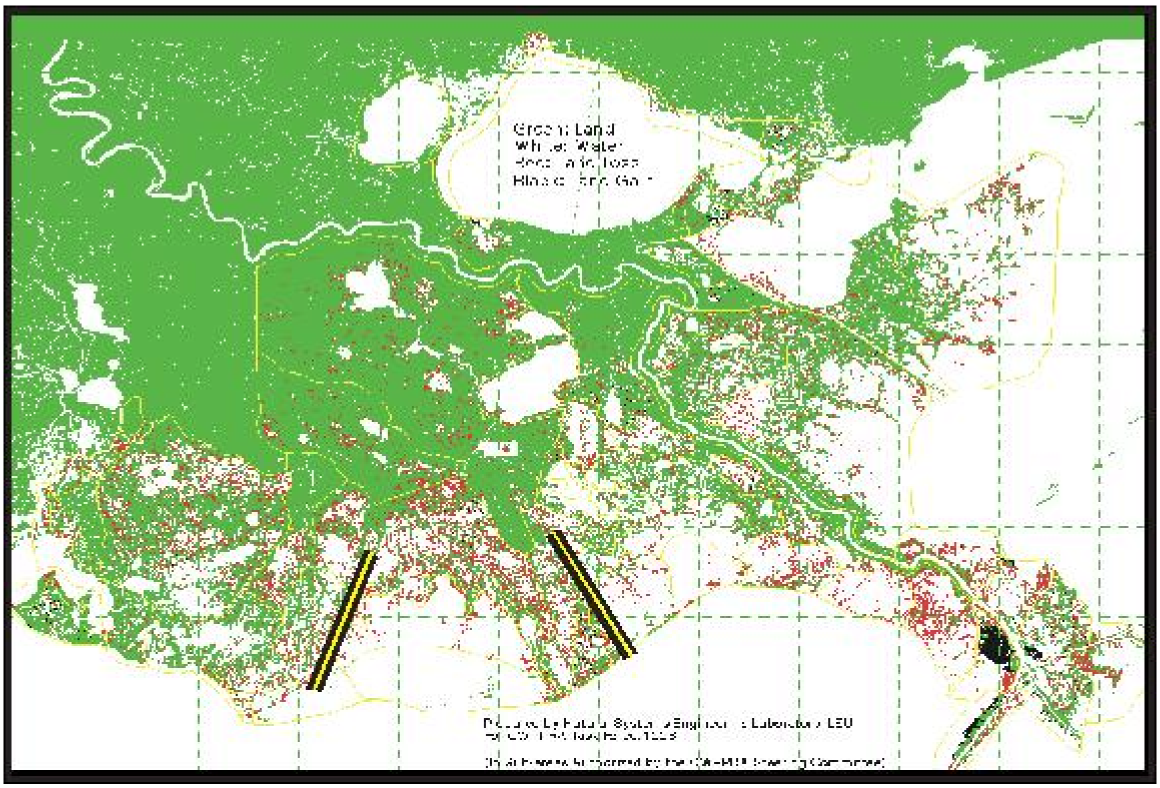


Figure 1.2-5. Photographs of wetlands in southeastern Terrebonne Basin.

Figure 1.2-5a. Marshes south of Larose, in the vicinity of Grand Bayou canal (area known as North Bully Camp). Marshes in foreground are intact, those in mid-ground are breaking up, and those in far distance are in a relatively advanced stage of degradation.

Figure 1.2-5b. Pt. Au Chien area. The once healthy marshes of this area have virtually disappeared in the last few decades. Spoil banks along canals are the major emergent landform that is visible.

1.3 DEVELOPMENT OF A SOLUTION TO THE PROBLEMS

EPA's initial development of a diversion project for Bayou Lafourche reflected a focus on restoration of coastal wetlands, in accordance with the CWPPRA Restoration Plan; see Section 1.3.1. The specific project that was selected (Section 1.3.2) generated substantial public comment and concern (Section 1.3.3). As a result, EPA conducted an extensive evaluation of the existing problems and solutions, which is described in Section 1.3.4. As summarized in Section 1.3.5, the optimized project that EPA is now bringing to the public is smaller but more effective than the original project, and it provides benefits to properties along the bayou, rather than the potential adverse impacts.

1.3.1 The project concept in the CWPPRA Restoration Plan

CWPPRA. The acronym CWPPRA stands for the Coastal Wetlands Planning, Protection, and Restoration Act. CWPPRA provides federal funds that, with local match, are used to plan and build projects that will protect and restore Louisiana's coastal wetlands. Congress passed CWPPRA in recognition that these wetlands are nationally important, are experiencing rapid loss, and need restoration.

Responsibility for implementing CWPPRA is assigned to a six-member Task Force consisting of a representative of the Governor of Louisiana, and representatives of five Federal agencies:

- the U.S. Army Corps of Engineers (USACE), in overall charge;
- the National Resources Conservation Service (NRCS - formerly called the Soil Conservation Service);
- The National Marine Fisheries service (NMFS);

- the Fish and Wildlife Service (FWS); and
- the Environmental Protection Agency (EPA).

Each year, the Task Force adopts a priority list which has the effect of committing funds to the construction of specific projects. As of 1997, the Task Force had adopted seven annual Priority Lists that selected more than 70 specific restoration projects, at a cost of nearly $300 million.

The CWPPRA Restoration Plan. In 1993, the Task Force completed a Comprehensive Restoration Plan to identify projects for consideration in the project-selection process. The Restoration Plan recognizes that the problems described regarding Bayou Lafourche in Section 1.2 are common along the coast. Specifically, Louisiana's coastal wetlands were directly or indirectly built by the Mississippi River, and many of them were naturally sustained over a large area and long timeframe by periodic inputs of freshwater, nutrients and sediment from the river. However, in recent decades the river's ability to build and sustain wetlands has been substantially reduced for a number of reasons, including the severance of river inflows to the marshes as a result of flood control projects. This loss of freshwater, nutrients, and sediment input is one factor believed to be important in causing the high rate of marsh loss along the coast.

A fundamental principle of the Restoration Plan is that, because the river built Louisiana's coastal wetlands, and because loss of the river-marsh linkage is one of the significant causes of current problems, **it is essential to the restoration of the coast that the river be reconnected to its marshes**. Consequently, "diversions" -- projects to siphon, pump, or otherwise discharge river water into wetlands -- are a major component of the CWPPRA Program.

Unique opportunity offered by Bayou Lafourche. Section 1.2.1 discusses the role of Bayou Lafourche in benefiting coastal wetlands. From a restoration perspective, Figure 1.2-4 is especially important in showing that in the absence of projects, there will be substantial additional wetlands loss in exactly those areas that were most impacted by the damming of the bayou in 1904. Although modern Bayou Lafourche is only a small remnant of what was once the main course of the Mississippi River, it remains as the only natural channel capable of linking the current river to the target marshes.

The natural distributary network of the bayou has been highly modified by creation of man-made channels such as the GIWW, Company Canal, Houma Navigation Canal and Barataria Bay Waterway. Figure 1.3-1 shows the areas that receive the greatest hydrologic influence from Bayou Lafourche under current conditions; refer to Section 4.4 for a discussion of the computer model that was used to generate this figure.

The heavy lines on Figure 1.3-1 are at the same locations as on Figure 1.2-4, and identify the area where the impacts of damming Bayou Lafourche were greatest. Based on Figure 1.3-1, the existing channel network has the potential to provide freshwater, nutrients and some sediment to exactly those marshes that are most in need of additional nourishment. This would help maintain vegetative health and the vertical accumulation of marsh surface that is essential to avoid wetlands loss.

Two other factors make the linkage between Bayou Lafourche and the marshes especially important.

1. Opportunities to implement diversions along the coast are limited because of potential conflicts between the hydrologic changes caused by diversions, and the human activities impacted by those changes. For this reason, <u>any</u> diversion opportunity needs to be explored to determine if it can be implemented without causing significant cultural and economic disruption.
2. As noted above, in 1955 some flows in Bayou Lafourche began to be restored when a pump station was built in Donaldsonville to provide freshwater supplies to communities and industries along the bayou. Thus the precedent exists for considering diversions into Bayou Lafourche.

The Restoration Plan recognized the importance of river diversions in general, and the unique opportunities offered by Bayou Lafourche in particular. The Plan identified a conceptual project, designated PBA-20, for the purpose of diverting freshwater down Bayou Lafourche to benefit marshes in the Terrebonne and Barataria Basins. The Restoration Plan presented no estimates of project size, cost or benefits.

Summary. Bayou Lafourche is an obvious location to consider for restoring freshwater supplies to Louisiana's coastal wetlands, because historically it was a vital river-marsh connection, because there is severe devastation of marshes along its lower reaches, and because diverting water into the bayou has proven feasible. The inclusion of Project PBA-20 in the CWPPRA Restoration Plan was also a logical consequence of the strategy that diversion projects are a vital element of the restoration program.

1.3.2 Project PBA-20 on Priority List 5

As noted, only a conceptual Bayou Lafourche Wetlands Restoration Project was described in the Restoration Plan. In 1995, a more specific proposal was developed by the United States Environmental Protection Agency (EPA) in cooperation with the Bayou Lafourche Freshwater District (FWD). The listed project has the following features.

- New siphons with 2,000 cfs capacity would be built at the site of the existing pump station at the head of Bayou Lafourche in Donaldsonville. These would operate only during months of high river stage (typically six-seven months each year, December-June).

- The channel would be improved to a limited extent, so that the effect of increasing flows to 2,000 cfs would be to raise water levels along the bayou. At the head of the bayou, the increase would be on the order of five feet. The seasonal turning on and off of the project could contribute to bank slumping.

- The total fully funded cost for construction and 20-years of operation of Project PBA-20, including contingencies, was estimated at approximately $24.5 million, exclusive of property-related costs.

Additional information on the original project is presented in Section 6.3.1.

The CWPPRA Task Force selected PBA-20 for the Fifth Priority List. As part of its selection decision, the Task Force specified that EPA conduct additional evaluations of project engineering and design, which would consider (among other matters) alternatives to improve the project effectiveness. EPA initiated these evaluations in the spring of 1996.

1.3.3 Public concerns and comments on the original project

As part of its evaluation, EPA conducted four well-attended public meetings held in 1996, in Larose (April 30), Napoleonville (May 1), Donaldsonville (May 2) and Thibodaux (May 9). After the public meetings, EPA prepared a summary report that stated EPA's opinions or intentions with respect to each issue that had been raised. This summary report, termed a "Responsiveness Summary", was distributed to the public in August 1996.

Within the lengthy list of issues addressed in the responsiveness summary, the following are considered by EPA to be among the questions of greatest interest.

1. Do we understand the hydrology of the bayou sufficiently well to be able to predict the impacts from diversions? (This question was of particular public concern because of a recent rise in water levels.)

2. Given current hydrologic conditions, can Bayou Lafourche safely convey 2,000 cfs?

3. What will be done to mitigate impacts to properties that are located along the bayou or that depend on drainage to the bayou?

4. Will impacts, if mitigated, be acceptable?

5. If impacts are mitigated, will the project become too expensive?

6. Will the diverted water, nutrients and sediment really get to the marsh and provide benefits?

7. How much of the diversion will be taken to meet the water supply needs of the cities and industries along the bayou?

8. Can another water source be used instead, such as Atchafalaya River flows conveyed in the GIWW?

9. Has the project been integrated with other efforts (e.g. the Lower Atchafalaya River Study which may divert water into Bayou Lafourche through Cancienne Canal)?

10. What can be done to ensure that the project is safe and effective?

Reflecting these concerns, and the analysis of problems presented in Section 1.2, it is clear that in developing a project to use Bayou Lafourche to restore coastal wetlands, it will be important to provide enough channel capacity so that water can be conveyed to the wetlands without adverse impacts (such as flooding and impaired drainage) along the bayou. Moreover, for water supply purposes, it is appropriate to consider actions to modernize the existing diversion works, provide reliability during chemical spill events, and expand diversion capacity to dilute pollutants and provide additional salinity control.

1.3.4 EPA's evaluation of a Bayou Lafourche diversion project

EPA designed its evaluation of the Bayou Lafourche diversion project with the purpose of answering the questions listed above, in order to identify the best overall diversion project (the one with the most benefits and least impacts) and to determine if that project is cost-effective. The purpose of this report is to summarize the results of the evaluation.

EPA conducted or supervised numerous and varied studies as part of its evaluation. Table 1.3-1 is a brief list of the studies, along with those earlier studies which led to the development of the original project proposal presented to the CWPPRA Task Force. Summaries or abstracts of each report are provided in Appendix A.

Because many of the reports are lengthy, technical, and/or contain detailed data files and/or maps, it would be extremely expensive to copy each document and distribute it to the several hundred persons who have asked to be on the Project mailing list. Instead, master copies of the materials have been assembled for public inspection at repositories that are identified in the transmittal letter that accompanies this report.

To perform many of the studies listed in Table 1.3-1, EPA entered into direct agreements with government or non-profit agencies. The U.S. Army Corps of Engineers (USACE), New Orleans, provided engineering services and performed much of the computer modeling. The U.S. Geological Survey (USGS), Baton Rouge, performed most of the field surveys of existing hydrologic conditions, and also compiled historic data. Louisiana State University (LSU), Baton Rouge, performed additional computer modeling and specialized studies of dredging and drainage.

For the remaining studies, EPA utilized the services of its Region 6 level-of-effort contractor, Lee Wilson and Associates (LWA). Under this contract, EPA has direct access to three other organizations that are authorized subcontractors to LWA: Coastal Environments Inc. (CEI) of Baton Rouge, the Louisiana Universities Marine Consortium (LUMCON) in Cocodrie, and Pyburn and Odom, Engineers (P&O), Baton Rouge.

LWA issued subcontracts to additional organizations to accomplish specific tasks, including LSU, Coastal Engineering and Environmental Consultants (CEEC) in Houma, and Nicholls State University (NSU), Thibodaux. The subcontract with LUMCON was used to obtain the services of Dr. Michael Waldon of the University of Southwestern Louisiana, Lafayette, and Dr. Denise Reed of LUMCON's Cocodrie center. A few of the studies listed in Table 1.3-1 were performed prior to the current evaluation; these include work done by or for the Bayou Lafourche Freshwater District (FWD), Thibodaux, and work done by or for the Louisiana Department of Environmental Quality (DEQ), in Baton Rouge and Raceland.

EPA also coordinated its study efforts with other programs, including:

- the Barataria-Terrebonne National Estuary Program (BTNEP);
- two USACE studies, the Lower Atchafalaya Reevaluation Study (LARS) and the Morganza to the Gulf Study (part of LARS);
- two CWPPRA feasibility studies, regarding Mississippi River Sediment, Nutrient and Freshwater Reintroduction, and Barrier Shorelines; and
- the Coast 2050 Plan, a unified effort of the CWPPRA Task Force and the State of Louisiana Wetlands Authority to integrate coastal restoration into the economic and cultural needs of Louisiana's coastal population.

During the course of its evaluation, EPA held periodic meetings at which representatives of the entities conducting the study presented interim results to other members of the study team. These meetings also were attended by representatives of CWPPRA agencies and the FWD. EPA used these meetings to measure the progress of the evaluation, and relied on the advice of meeting participants to help guide ongoing study components.

Only portions of the study results are included in this summary report. The information used in the report falls into two broad categories.

- Basic hydrology. The objective of much of the work listed in Table 1.3-1 was to improve the scientific and technical understanding of the hydrology of Bayou Lafourche. EPA's evaluation developed scientific and engineering information on the character of the bayou as it has changed over the years, and as it could change in the future, with and without increased flows. The evaluation included consideration of linkages between the bayou and wetlands in Terrebonne and Barataria Basins.
- Project effects and alternatives. Most of the remaining work listed in Table 1.3-1 addressed specific alternatives for restoring Bayou Lafourche, and alternatives to using the bayou. This work included identification of certain costs, impacts and/or benefits.

Most citations in this report are to studies listed in Table 1.3-1. References consulted by the individual studies are listed in the study reports. A comprehensive list of the references from the individual studies has been compiled and is included in this report.

1.3.5 Outcome of the study with respect to key issues: introduction to the optimized project

EPA is putting forward what is termed the "optimized" project. As discussed in detail in Chapter 5, the optimized project would involve a year-round diversion by siphon and pump, without increasing water levels. The project would be phased, and would have a capacity of 340 cfs initially (the same as the existing facilities), and 1,000 cfs ultimately.

A simple way to compare EPA's proposal to the original plan is that the optimized project would provide about half the flow, but for twice the time, and thus roughly the same overall amount of water resources to the marshes. Moreover, freshwater would reach the wetlands at times of low river stage, when saline intrusion is most a problem. There would be substantial improvements to the channel, including extensive dredging, installation of water monitoring and management facilities, and development of an operations plan that is sensitive to water level conditions in the bayou. Thus resources would be provided to the wetlands without causing damage to property along the bayou. Phasing would demonstrate that a bayou diversion can be operated safely and effectively, before the diversion rate is increased above 340 cfs.

Figure 1.3-1. Distribution of Bayou Flows

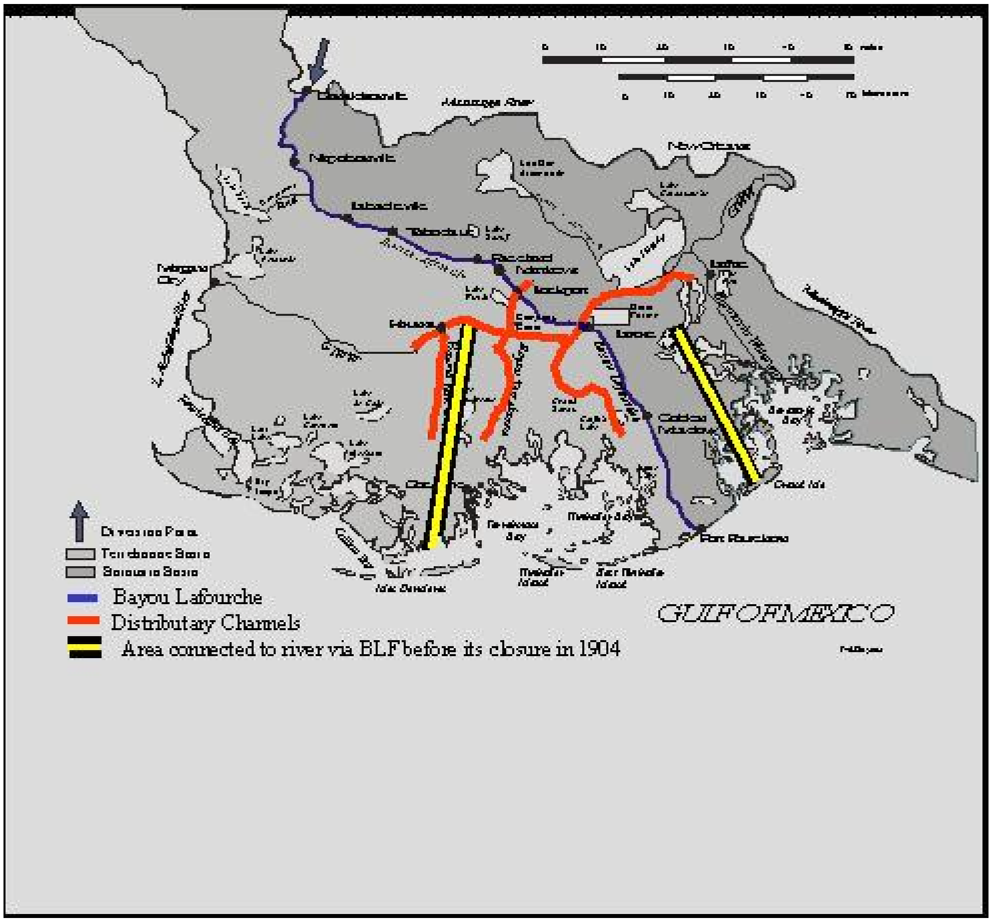


Table 1.3-1. List of studies related to EPA's evaluation of the Bayou Lafourche Project.

Study/date	Title	Content
U.S. Geological Survey (USGS)		
1998 (C.M. Swarzenski and D.K. Demcheck)	Data summaries: hydrology and water-quality characteristics of Bayou Lafourche; and additional data on Mississippi River, Atchafalaya River, GIWW and other channels	Maps, graphs and tables. (Note: Provisional draft only provided to date. A formal report will be prepared and published by USGS, in accordance with agency procedures.)
U.S. Army Corps of Engineers (USACE)		
December 1994	Bayou Lafourche water management study	Application of hydrologic modeling to evaluate current and future water supply needs, the existing hydraulic capacity of the Bayou, alternatives for diversions, and changes in the Bayou that might be associated with diversions.
January 1997 (C. Shadie)	Bayou Lafourche siphon design	Preliminary conceptual hydraulic designs for siphons with 1,000 cfs, 2000 cfs, and 3000 cfs capacity, determination of monthly stage durations, and when siphons would flow. EPA comments are attached.
January 1997 (H. Winer)	Daily 8AM stage at Houma on the GIWW	Provides graphs covering 1987 through 1996, and highlights events and information available through interpretation of the graphs.
April 1997 (H. Winer)	UNET modeling of flows in Bayou Lafourche in combination with Atchafalaya River and Barataria Estuary flows	Preliminary results of hydrologic modeling using UNET to evaluate direction and magnitude of relative flows in the major channels (Bayou Lafourche, GIWW, Company Canal, etc.) under various projected flows for Bayou Lafourche, Atchafalaya via the GIWW, and Davis Pond.
May 1997 (H. Winer)	TABS modeling of flows and salinity in the Grand Bayou area	Preliminary results of hydrologic modeling using TABS to evaluate changes in salinity at various locations in the Grand Bayou marsh area to the west of Bayou Lafourche under various projected flows (which in turn reflect contributions from Bayou Lafourche, Atchafalaya via the GIWW, and Davis Pond), and with and without a structure to restrict flow in the Cutoff Canal above the Pointe au Chien ridge.

Table 1.3-1. Continued.

Study/date	Title	Content
U.S. Fish and Wildlife Service (USFWS)		
January 1997 (R. Paille)	Lower Atchafalaya Basin re-evaluation study: a planning aid report on Freshwater inflows to the Terrebonne Basin	During moderate to high stages, water from the Lower Atchafalaya River flows northeastward into the Gulf Intracoastal Waterway (GIWW). A substantial portion of that flow escapes to the Gulf of Mexico via the Houma Navigation channel (HNC) at Houma, while the remainder flows eastward toward Larose. During high river stages, freshwater may flow further eastward to Lake Salvador via Harvey Canal Number 2 and to Bayou Perot via the GIWW.
Louisiana Department of Environmental Quality (LDEQ)		
January 1992 (G. Asuquo and J.T. Baker)	Survey report for the Bayou Lafourche low flow time-of-travel study	Summarizes a tracer-dye time-of-travel study conducted in June, 1991, when stream flow averaged 156 cfs. Flows were measured at three cross-sections and dye arrival was measured at eight stations.
March 1995 (D. Everett and F. Lee)	High flow time of travel survey on Bayou Lafourche …	Summarizes a tracer-dye time-of-travel study conducted in May, 1994, 1991, when stream flow averaged 327 cfs. Flows were measured at three cross-sections and dye arrival was measured at seven stations.
Louisiana State University (LSU)		
September 1996 (H.S. Mashriqui and G.P. Kemp)	Restoring the capacity of Bayou Lafourche to convey increased discharges from the Mississippi River	Use of hydrologic modeling to evaluate what type of channel modifications could be used to reduce water level increases associated with increased flows.
June 1997 (H.S. Mashriqui and G.P. Kemp)	Open-channel hydraulic modeling to support selection and preliminary design of coastal restoration projects (Bayou Lafourche)	Assuming an “optimum” channel, modeling identified potential obstructions, examined the effect of the weir at Thibodaux, and looked at bank elevations. Suggest the need for normal stages to be lowered to accommodate large volumes of stormwater, as well as the amount of development within the channel.
September 1998 (H.S. Mashriqui and G.P. Kemp)	Bayou Lafourche freshwater diversion wetlands restoration project (PBA-20) - HEC-RAS and HEC-6 hydrologic modeling, draft final report	Used engineering input on slope stability and cross-section slope requirements to develop iterative model runs to optimize the dredging plan in terms of location and quantity while maintaining water levels for passage of 1,000 cfs at or below historic levels. Modeling of the revised dredged channel was also used to estimate locations and quantities of sediment deposition on a periodic basis to characterize the need for maintenance dredging.

Table 1.3-1. Continued.

Study/date	Title	Content
Nicholls State University (NSU)		
August 1996 (D.L. Schultz)	A survey of the fish fauna of Bayou Lafourche	Species composition, distribution and abundance of fishes along Bayou Lafourche from August 1994 through July 1995, and associated habitat characteristics, including prevalence of aquatic vegetation.
February 1997 (D.L. Schultz and D. A. Schultz)	A description and analysis of the vegetation of the bayou	A survey of the species composition, distribution, and relative abundance of submerged aquatic vegetation of Bayou Lafourche in November 1996.
September 1997 (D.L. Schultz and D.A. Schultz)	A description and analysis of the vegetation of the bayou: a follow-up survey	Documentation of the amount and type of vegetation during late 1997, after vegetative cutting by the Bayou Lafourche Freshwater District.
Univ. of Southwestern Louisiana (USL)		
March 1998 (M.G. Waldon)	Water quality impact of proposed diversion of water from Lake Verret to Bayou Lafourche	This study evaluates the potential water quality impacts of diverting water from Lake Verret into Bayou Lafourche via the Cancienne Canal.
Coastal Environments, Inc. (CEI)		
June 1996 (S.M. Gagliano)	Public meetings to aid in the evaluation, engineering and design of the Bayou Lafourche wetlands restoration project	Provides information presented at the public meetings, including Dr. Gagliano's presentation, charts and photographs, and meeting handouts.
January 1997 (H. Castille and L. Nakashima)	Historical changes in Bayou Lafourche	Documents changes in flow and channel morphology largely due to the construction of artificial levees, pumps and weirs to accommodate land uses; provides numerous channel cross-sections.
March, 1997	Bayou Lafourche project: required regulatory approvals and possible agency concerns	Lists and describes permits that would be required to implement the Bayou Lafourche project.
April 1997	Cancienne Canal cross-sections	This report documents a survey of the Cancienne Canal as the initial phase in assessing the viability of increasing flow into Bayou Lafourche from the Verret Basin.

Table 1.3-1. Continued.

Study/date	Title	Content
October 1997 (J. Ryan)	Impacts to cultural resources of proposed pumping facility at head of Bayou Lafourche	Evaluation of historical maps and interview with the State Regional Archaeologist to locate and determine likelihood of construction impacts to what was Fort Butler.
April 1998 (H. van Beek)	Diversion of freshwater into Bayou Lafourche from Lake Verret via Cancienne Canal; requirements and impacts	The report evaluates the alternative of pumping of 500 cfs from Lake Verret through the Cancienne Canal into Bayou Lafourche; it is assumed that this would supplement 500 cfs diverted from the Mississippi River at Donaldsonville.
Pyburn & Odom (P&O)		
May 1997	Bayou Lafourche sediment grab sample testing	Determination of particle size composition of sediment samples taken along Bayou Lafourche.
May 1997	Vertical and horizontal control network survey of Bayou Lafourche	A survey to establish accurate current contours and elevations of the Bayou, establish elevation references, compare these results to previous surveys (e.g., by DOTD, Plaisance), and determine whether any recent changes have occurred in dimensions of the Bayou.
September 1997	Bayou Lafourche wetlands restoration project, proposed diversion facility study	Evaluates adding pumping capability to the diversion facility; routing diversion flows through two embankment bayou crossings; and inclusion of a sediment trap. Provides estimates of monthly diversion flows and estimates of facilities costs.
September 1998	Final report, Bayou Lafourche wetlands restoration project facilities	This report is a consolidation of memoranda that were prepared subsequent to the 1997 reports above. The memoranda discuss: operational capacity of the system; operational costs; sand trap design; bank stability; dredging template; utility replacements; weirs; schedule; and costs for new pumps.
Coastal Engineering & Environmental Consultants		
September 1995	Bayou Lafourche Siphons - A freshwater diversion from the Mississippi River to Bayou Lafourche	Reconnaissance survey of bayou at Donaldsonville, of bayou drainage, and of existing river gage data to initial conceptual design and cost estimate for proposal of project to CWPPRA.

April 1996	Bayou Lafourche wetlands restoration project: a freshwater diversion from the Mississippi River into Bayou Lafourche	A "Project Briefing Booklet", which provides: a brief history of the bayou; project features and costs (prior to changing the diversion from 2,000 cfs to 1,000 cfs); and a summary of benefits.
January 1997	Bayou Lafourche drainage plan - existing drainage into Bayou Lafourche from Donaldsonville to the Company Canal	Characterization of all drainage in the Bayou within specified reach, including location of drainage structures, invert elevations, and patterns of drainage. Includes companion atlas.
April 1997	An alternative analysis to increase the conveying capacity of Bayou Lafourche	A preliminary evaluation of potential dredging options and logistics in Bayou Lafourche that would allow a discharge of 2,000 cfs through Bayou Lafourche without a significant increase in water levels; and consideration of introducing freshwater by diverting drainage from the eastern side of the Bayou.
September 1997	Bayou Lafourche freshwater diversion: preliminary dredging plan	Formulation of a preliminary dredging plan that would allow a discharge of 1,000 cfs through Bayou Lafourche without a significant increase in water levels.
July 1998; revised September 1998	Bayou Lafourche water diversion project, water control gate structure	Conceptual drawings and cost estimates for two gated water control structures as alternatives for managing water levels in association with a freshwater diversion into Bayou Lafourche.
Lee Wilson and Associates (LWA)		
April, 1997	Freshwater supply issues, Bayou Lafourche	Summarizes data on present withdrawals of water from Bayou Lafourche by public and private suppliers, and presents projections of future withdrawals.
Environmental Protection Agency (EPA)		
May, 1996	Responsiveness summary 1996 public meetings	Summarizes comments from four public meetings and presents EPA's responses
August 1998	Cost evaluation, Phase I construction - Bayou Lafourche diversion project	Descriptions, cost estimates, and supporting information for project features associated with Phase I of the Bayou Lafourche diversion project, including upgrading existing pump station; construction of sediment trap; channel dredging; utility relocations; removal of weir at Thibodaux; installation of deployable weirs; monitoring stations; and add-ons such as contingency, engineering, agency oversight, and permitting.

Study/date	Title	Content
September 1998	Cost evaluation, Phase II construction - Bayou Lafourche diversion project	Descriptions, cost estimates, and supporting information for project features associated with Phase II of the Bayou Lafourche diversion project, including construction of new pump station; additional channel dredging; bank stability analysis and costs; utility line protection and relocation; costs related to bridges; land costs; and add-ons such as contingency, engineering, agency oversight, and permitting.
September 1998	Cost evaluation, total and annual costs - Bayou Lafourche diversion project	Operation and maintenance costs of Phase I; total and average annual costs of Phase I; operation and maintenance costs of Phase II; total and average annual costs of Phase II; and cost summary and consideration of cost-shares.

1.4 OVERVIEW OF REPORT AND OF EPA'S PLANS FOR PUBLIC INPUT

1.4.1 Structure of this report

In addition to this introductory chapter, EPA's report on its evaluation of the Bayou Lafourche diversion project contains the following chapters.

- Chapter 2 summarizes the extensive information that EPA has obtained regarding the water resources in Bayou Lafourche, including characteristics of water flow in the channel, and the nature of past problems.

- Chapter 3 provides information relating to the general principles for design and operation of any project that would divert Mississippi River water into Bayou Lafourche at Donaldsonville.

- Chapter 4 describes the methods that EPA has relied on to quantify the effects of increased diversions on Bayou Lafourche, and on the wetlands.

- Chapter 5 summarizes the engineering and design characteristics of the optimized project.

- Chapter 6 presents information on a wide array of alternatives that EPA has considered with respect to a Bayou Lafourche diversion, including the alternative of No Action.

- Chapter 7 provides an update to the responsiveness summary that was prepared in 1996, and thus gives current answers to the many questions and concerns that have been raised by the public.

In addition, the report includes an executive summary, list of references, list of acronyms and measurement units, and an Appendix that summarizes the various studies that were conducted as part of the evaluation.

1.4.2 EPA's plan to seek and consider further public input

EPA recognizes that its evaluation of a Bayou Lafourche diversion addresses a complex subject and that not all questions related to this project, or to any major project, can be answered with unequivocal certainty. The findings presented in this report are considered preliminary, pending public review and comment and, if necessary, additional investigations to resolve any uncertainties which are integral to decision-making. Four specific activities have been identified for the purpose of addressing public concerns about the project.

First, EPA intends to use this report as the focus of a public outreach program to be conducted in 1998. Public input received at that time will be fully considered before EPA completes its evaluation of the project. EPA will coordinate the meetings with affected local governments to the extent practicable.

EPA will give close consideration to all public input in reaching its decision of whether to recommend that the CWPPRA Task Force pursue the project as proposed here, modify the project, not build the project, or seek to build the project with funding from sources other than CWPPRA. EPA's final judgment will be based on the technical merits of public opinions and information regarding support or opposition, and on the extent to which local governments, in formal consultation, make formal recommendations.

Second, before any project is constructed, EPA also will be required to complete an environmental assessment and/or impact statement in conformance to the National Environmental Policy Act. The current evaluation report will contribute to the environmental requirements but does not represent the environmental compliance document. Provisionally, EPA considers that an environmental assessment may be appropriate for the initial 340 cfs phase of the project, but that a full impact statement will be needed for the 1,000 cfs project.

Third, the performance of the initial phase will be used to verify that the project can be operated safely and as intended. Indeed, an important reason for phasing is that the initial phase excludes those aspects of the full project that may be perceived to pose the highest risk. As appropriate, results from the initial phase will be used to refine the design of the 1,000 cfs project, so that the Bayou Lafourche diversion can achieve its intended benefits while minimizing adverse consequences.

Fourth, final design of the full project will occur in conjunction with implementation of the initial phase. This will allow EPA to conduct important technical studies necessary to verify critical design aspects of the full project. Such studies do not represent a commitment to build the full project; but rather a commitment to complete the design before a final decision is made.

2. WATER RESOURCE CHARACTERISTICS OF BAYOU LAFOURCHE

2.1 OVERVIEW OF CHAPTER 2

Bayou Lafourche was a natural distributary of the Mississippi River until dammed in 1904, and it was reopened to a limited degree by construction of a freshwater diversion (pump-siphon system) in 1955. Today the bayou seems to be a simple channel that flows without any branches for nearly 60 miles from Donaldsonville to Lockport. In fact, flows reflect many complex factors, including: inflows from storm water runoff as well as river diversions; removal of water from the channel at water-supply intakes and some at-grade canals; constraints to flow from man-caused structures (crossings and a weir) and from nature (vegetation and coastal water levels). At and below Lockport, flows are distributed in a complex array of channels, including the bayou, Company Canal, the GIWW, and other canals and bayous. Collectively these factors influence water flow, water quality and water use.

Knowledge and understanding of the water resources of Bayou Lafourche has been greatly improved by the relevant studies listed in Table 1.3-1, especially the CEI study of historic geomorphology; the USGS surveys of the bayou; and the NSU surveys of bayou vegetation. Information from these studies is summarized in Chapter 2, in order to provide the foundation for subsequent discussions about the effects of a diversion project.

Chapter 2 is organized as follows.

- Section 2.2 summarizes the history of Bayou Lafourche, and in particular the reduction in flow and channel capacity that has occurred over the past 150 years.

- Section 2.3 characterizes the existing channel conditions that are important to the conveyance of flow down Bayou Lafourche.
- Section 2.4 presents data that characterize the flow of the modern bayou during dry periods, i.e. when the water in the channel is primarily from the Mississippi River, and the discharge is a few hundred cfs or less.
- Section 2.5 provides information to characterize drainage to and from the bayou, and flow during storm periods when discharge can exceed 2,000 cfs for brief periods.
- Section 2.6 provides information regarding an important recent event that impacted flow in Bayou Lafourche, namely the clogging of the channel by vegetation, and the subsequent removal of vegetation by mowing.
- Section 2.7 provides data regarding the quality of water found in Bayou Lafourche, and briefly comments on concerns whether Mississippi River water is "clean enough" for Bayou Lafourche.
- Section 2.8 summarizes how water in the bayou is used for water supply purposes, and quantifies the extent to which diverted water is likely to be withdrawn before reaching the wetlands.
- Section 2.9 presents information on three subjects that are related to the issue of bank stability: patterns of erosion and sedimentation with the channel; the nature of bed and bank materials; and drawdown rates when the existing diversion is shut down.
- Section 2.10 provides brief discussions of selected other subjects: uses of the bayou for purposes other than water supply; interconnections with ground water; and distribution of flow below Lockport.

2.2 HISTORICAL CHANGES IN FLOW, CROSS-SECTION AND PROFILE

This section is based primarily on the CEI report on "Historical Changes in Bayou Lafourche" cited in Table 1.3-1 and abstracted in Appendix A.

2.2.1 Prior to 1904

There is an extensive literature on the geologic history of the Mississippi Delta, including one of its main distributary channels, Bayou Lafourche. The literature demonstrates that somewhere around 2,000 years ago (plus or minus several hundred years), the course of the Mississippi River began to occupy what is now Bayou Lafourche. This channel remained a primary distributary of the Mississippi River until about 800-1,000 years ago, when it was gradually replaced by the modern course (which flows past what is now New Orleans).

While it was active, the Lafourche distributary built a large natural levee. The levee elevation ranges from over 20 feet NGVD near Donaldsonville, to barely 1 foot near the mouth of the bayou. It is on the high banks of this levee that European settlement began in the 1700s, and upon which modern Highways 1 and 308 are now found.

As the river shifted to its modern course, the Lafourche channel was gradually abandoned, so that over time it carried less water, the channel decreased in size, and extensive marsh building ceased. Nonetheless, in both 1851 and 1858, discharge in Bayou Lafourche was measured at 6,000-11,000 cfs at high stages of the river. Thus, while the channel may not have carried 10-15% of the total river flow as sometimes reported, it remained a major conduit by which freshwater, nutrients and sediment were transported to the coastal wetlands. Despite the reduced flow, the bayou also was extensively used for navigation; in part this reflected its role as one route within the Barataria and Lafourche Canal system, which was constructed in the 1830s and 1840s and which includes modern-day Company Canal.

Flows continued to decrease during the 19th century and by 1887 a bar had developed at the head of the bayou, which restricted flow and navigation. This led to annual dredging by the Corps of Engineers. The natural levee along the bayou was not sufficient to protect settled areas from flooding, and plantation owners gradually built up levees along most of the length of Bayou Lafourche. These often did not function satisfactorily. By the late nineteenth century, the flood problems along Bayou Lafourche associated with increased development, began to overshadow the usefulness of the channel for navigation.

Because of the increased flooding problems, in 1902 federal approval was given to construct a temporary dam across the head of the bayou. The intent was to replace this dam with a lock, in order to enable continued navigation. In 1903 a major crevasse flood occurred along the upper bayou, which led local residents to dam the head of the channel in 1904. This dam was maintained over the years, and attempts to construct the lock were never successful. Eventually the ‘temporary’ dam was replaced by the Mississippi River flood control levee, which today represents a total barrier to natural flow into the bayou from the river.

To help put a new diversion project in context, EPA has made rough calculations to estimate the discharge into Bayou Lafourche at Donaldsonville prior to damming of the bayou. For high flow conditions, the calculation is as follows.

- Assume a 300 ft wide channel at the top and sides sloping to a 100 ft wide level bottom. Assume the river stage is at 25 ft NGVD, and the bottom of the bayou channel is at 5 ft. Then the cross-sectional area for flow from the river to the bayou would be about 4,000 square feet.
- For an assumed velocity of about 3 feet per second, the high-flow discharge down the bayou would be about 12,000 cfs. This is similar to the USACE estimates of maximum

discharge for the bayou prior to closure. In extreme floods, even higher values would be expected.

For low flow conditions, the calculation is as follows.

- Same channel as assumed above, except river stage is assumed to be 10 feet NGVD. The cross-sectional area would be about 600 square feet.
- For an assumed velocity of about 1.5 feet per second, the low-flow discharge down the bayou would be about 900 cfs. This is the low-flow that was freshening marshes in the lower Barataria and Terrebonne basins in late summer and in fall.

Average discharge prior to closure may have been on the order of 5,000 cfs, based on higher flows in peak periods and lower flows most of the year. This compares to the estimated inflow of freshwater in the Barataria and Terrebonne Basins of no more than 10,000 cfs at present (excluding recent increases in Atchafalaya flows that did not occur in the 1800s). The information indicates that a century ago, the bayou provided a significant portion of the freshwater inputs to the Barataria/Terrebonne basins. A diversion on the order of 1,000 cfs would be similar to the low-flow condition prior to closure and thus would be expected to convey a beneficial amount of freshwater, sediment, and nutrients to marshes.

2.2.2 1904-1955

For more than half a century after its closure, Bayou Lafourche was a stagnant ditch, with the only water being contributed as rainfall, storm runoff and waste discharges. The water in the bayou was of poor quality for drinking and industrial use. Periodic attempts to pump or siphon water from the Mississippi River to the bayou did not succeed, although some dredging did maintain limited navigation uses.

With flood problems essentially solved by the dam, the artificial levees were knocked down, settlement on the natural levees greatly expanded, and some development began to occur into the batture (i.e. below the natural high water line). Perhaps most important for this study, the blocking of Mississippi River inflow to Bayou Lafourche had significant implications for hydrologic conditions in the coastal wetlands (see Section 1.2 and Figures 1.2-1 and 1.2-2).

2.2.3 1955-recent

Around 1950, in response to the poor condition of the bayou, the Bayou Lafourche Freshwater District (FWD) was formed. In 1955, FWD's pumping station (see Figure 1.1-2a) was put into operation to siphon and/or pump Mississippi River water into the bayou and thereby to meet water supply needs and combat saline intrusion. The rated capacity of the pumping station is 400 cfs, but the practical maximum is approximately 340 cfs. Actual diversions vary, and are quantified subsequently (see discussion of Figure 2.4-1).

Following reconnection of the bayou in 1955, there have been at least four significant changes to the physical conditions in the channel.

- In 1968 a weir was constructed adjacent to the City of Thibodaux's water treatment plant (see Figure 1.1-2c). This maintained water levels in the upstream bayou at relatively high level at all times, including periods when the diversion works shut down.
- In the late 1980's flood gates were installed at Larose and Golden Meadow (see Figure 1.1-2d). The effect of these gates (operational as of 1991) was to partially isolate the lower bayou from the effects of upstream diversions, while also restricting saline intrusion up the bayou from the gulf.
- In the early 1990's the Freshwater District dredged sediments from the upper three miles of the bayou channel. The material was disposed of along the banks.
- In the 1990's, the bayou experienced a significant increase in water levels due to clogging by aquatic vegetation; this important event is discussed separately; see Section 2.6.

2.2.4 Long-term changes in channel geometry

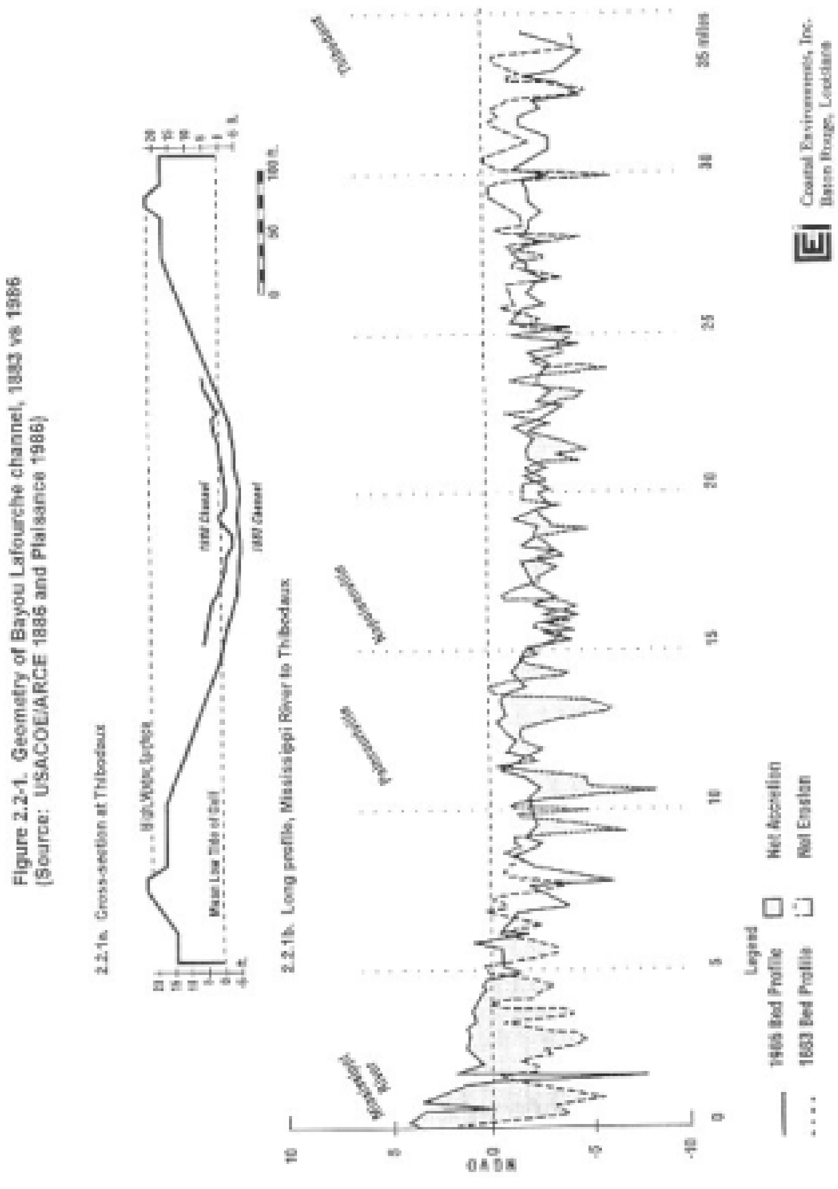
As any natural stream experiences reduced flow, the normal and natural response is for the channel to silt in and narrow. Along Bayou Lafourche this trend has been exacerbated by fill and development activities in the batture. Figure 2.2-1 illustrates these changes. When surveys from 1883 and 1986 are compared, the cross-section (Figure 2.2-1a) at Thibodaux shows a decrease in channel depth of 15 feet and a decrease in channel width of 255 ft. Changes are proportionally greater closer to Donaldsonville, whereas the channel remains relatively wide in the Raceland-Lockport reach.

The long profile of the channel (Figure 2.2-1b) is marked by deposition in most of the upper reaches, and especially near Donaldsonville where net accretion ranged from 3 to 8 feet over an approximately 100 year period. Deposition in this reach is expected, as flow velocities in Bayou Lafourche are less than in the Mississippi River. Thus the diverted water drops much of its coarser sediment load in the first several miles of the bayou.

Short-term changes in channel geometry are discussed in the context of cross-sections that were surveyed as part of EPA's evaluation; see Section 2.3.2.

Figure 2.2-1. Geometry of Bayou Lafourche channel, 1883 vs. 1986.
(Sources: USACE annual reports, various years; Plaisance, 1986)

2.2-1a. Cross-section at Thibodaux and 2.2-1b. Long profile, Mississippi River to Thibodaux



2.3 GENERAL PATTERNS OF WATER CONVEYANCE IN BAYOU LAFOURCHE

2.3.1 Principles of water conveyance in an open channel

Several parameters determine the rate at which water moves through an open channel such as Bayou Lafourche, especially: channel width, channel depth, channel roughness, and the slope of the water surface. The ability to convey flow increases with the cross-sectional area of the channel; i.e., channels with greater width and depth carry more water than smaller channels. Discharge also increases when the velocity of the flow increases; velocity increases with a steeper water surface and in a deeper channel, and decreases as channel roughness increases.

When water is diverted into Bayou Lafourche, the effect is to increase the elevation of the water surface near the outfall, when compared to conditions without a diversion. This increases the slope of the water surface from the outfall to the channel mouth, and it also increases the depth of water and thus the channel cross-section. Both factors lead to an increase in flow velocity. The increase in velocity and channel area greatly increases the amount of water that can be conveyed. Note that, in the short-term, the channel does not respond with a marked change in width (because the channel banks are relatively fixed) or in roughness (which reflects bed and bank materials, among other relatively constant factors).

Of all the parameters, water depth is arguably the most significant in evaluating flow conditions in Bayou Lafourche, because it impacts both cross-sectional area and velocity. (It can be shown mathematically that for simple channel configurations, flow rates (in cubic feet per second) increase with depth (in feet) to the 1.6 power; no other variable has an equivalent importance in the basic flow equations.) An increase in depth of flow (as by dredging) is one of the primary means available for increasing channel capacity.

2.3.2 Current cross-sections along Bayou Lafourche

Based on the above discussion, it obviously is important to know the current channel cross-section that is available to convey diverted water through Bayou Lafourche. Fifty channel cross-sections were surveyed as part of EPA's evaluation (see citation to Pyburn and Odom surveying report in Table 1.3-1). Typical channel dimensions as surveyed by P&O are listed in Table 2.3-1 and illustrated in Figure 2.3-1. The table includes water levels as actually measured by P&O on various dates in April, 1997, along with water levels interpolated from measurements made on a single date (November 21, 1996) by the U.S. Geological Survey. The November data are considered to be a good indication of conditions in the bayou at a time when the channel was severely clogged with aquatic vegetation. The water levels shown on the cross-sections in Figure 2.3-1 reflect these November conditions.

Note that the cross-sections have a vertical exaggeration, so that a one foot difference in elevation appears to be much larger than a one foot difference in width. With this relationship in mind, the cross-sections can be described as showing a channel that is typically wide and relatively shallow, with levee banks that are substantially higher than the water surface. The channel is smallest at the upstream end, where widths are less than 70 feet and depths typically about 5-6 feet. At Thibodaux the channel is wider (150 feet) and deeper (as much as 9.3 feet). By Larose the channel is 220 feet wide and more than 11 feet deep. The recent survey did not extend farther downstream, but prior studies have shown that this pattern continues; at Belle Pass, the mouth of Bayou Lafourche, the channel is approximately 300 feet wide and 25 feet deep (see USACE, 1994).

Most of the cross-sections shown in Figure 2.3-1 were taken at locations where FWD had previously surveyed the channel in 1986. Figure 2.3-2 compares the cross-sections at two locations for the two surveys, and thus illustrates changes to channel conditions over a nine-year period under the current flow regime. The surveys show differences of a few to several inches, but these are variable in terms of whether the channel bottom is now apparently higher or lower than before. These differences appear to reflect the errors intrinsic in the surveys and show no pattern of erosion or fill along the channel. Based on that observation, the 1986 cross-sections are considered as reasonably representative of current conditions. (This conclusion is important because the 1986 sections were utilized in prior computer models of the bayou developed by USACE, and modified for application to the current study; see Section 4.3.)

2.3.3 Specific constraints to flow in Bayou Lafourche

The flow of water below Donaldsonville is impacted by the following constraints.

- Immediately below the diversion outfall, the bayou is crossed by a highway embankment and a railroad embankment. At both locations water is conveyed through culverts and at both locations there is a local impoundment of water behind the embankment. The bayou water level falls about 1.5 feet through the La. 3089 crossing and about 0.5 feet through the Union Pacific crossing.

- Table 2.3-2 is a list of bridges that cross the bayou between the railroad embankment in Donaldsonville and Lockport; the data come from Mashriqui and Kemp (1997), abstracted in Appendix A. These are fixed span bridges in the upper reaches, and movable or pontoon types in the lower reaches. All of the bridges can pass at least 2,000 cfs without modification. Additional bridges that occur further downstream were not inventoried for this study; this reflects the scope of computer models discussed in Chapter 4.

- A weir located at the Thibodaux water plant (see Figure 1.1-2c) is an important factor that holds water at a relatively high level throughout the reach from Donaldsonville to Thibodaux. At current flows, the weir entirely isolates the upper bayou from tidal fluctuations. Under normal conditions, water in the channel is two to three feet higher above the weir than below it. The weir effectively attenuates and buffers the downstream effects of any change in diversion quantity that occurs in Donaldsonville.

- A major constriction to flow occurred in the mid 1990’s, when the channel became clogged with vegetation (especially in the Raceland area). This event is discussed in Section 2.6.

- At Lockport the channel intercepts Company Canal and at Larose it intercepts the GIWW. Water levels in these large channels is highly variable depending on tide and wind conditions, and other factors such as inflow from the Atchafalaya River. Figure 2.3-3 presents water levels at the stage gage at Houma; these data were provided by Harley Winer of the USACE. The GIWW water levels typically fluctuate between 1 to 2 feet NGVD. There may be an upward trend, with stages averaging closer to 1 foot in the 1980's and closer to 2 feet in the 1990s. Values beyond the normal range can occur under certain conditions. Low water (0.5 feet or, very rarely, even lower) can occur at times when northerly winds push water out of the estuaries. High water (2.5 feet (or, rarely, even higher) can occur at times of strong onshore winds.

- As levels in the GIWW rise and fall, the levels in the lowermost reaches of Bayou Lafourche also rise and fall. Thus the slope of the bayou water surface can be very flat in high water conditions (and GIWW water can actually move up the bayou), or it can be steeper than average in low-water conditions.

- Flood gates in the bayou at Larose significantly restrict water flow from the upper to lower bayou.

It is expected that flow through the channel will be increasingly constrained over time by the relative rise of sea level that is pervasively impacting the Louisiana coast, and that results from land subsidence, natural eustatic sea level rise, and any additional rise associated with global warming. The computer modeling done for this study has not included an allowance for such changes, because of the relatively short (20-year) project lifetime.

Figure 2.3-1. Channel cross-sections, Bayou Lafourche. Sections were measured in 1997; water levels are for November 21, 1996.

Figure 2.3-1. Channel cross-sections surveyed in 1997, Bayou Lafourche

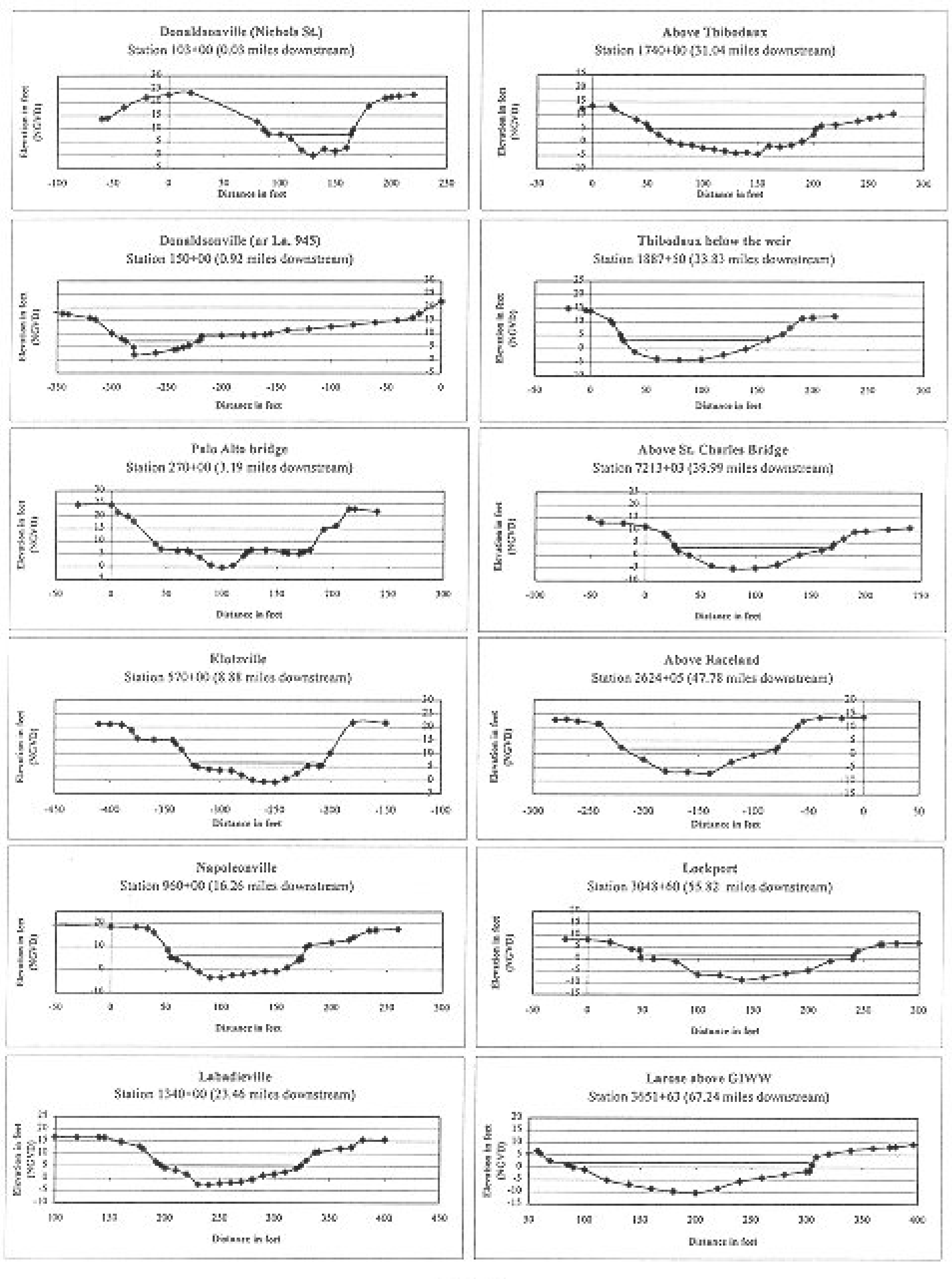


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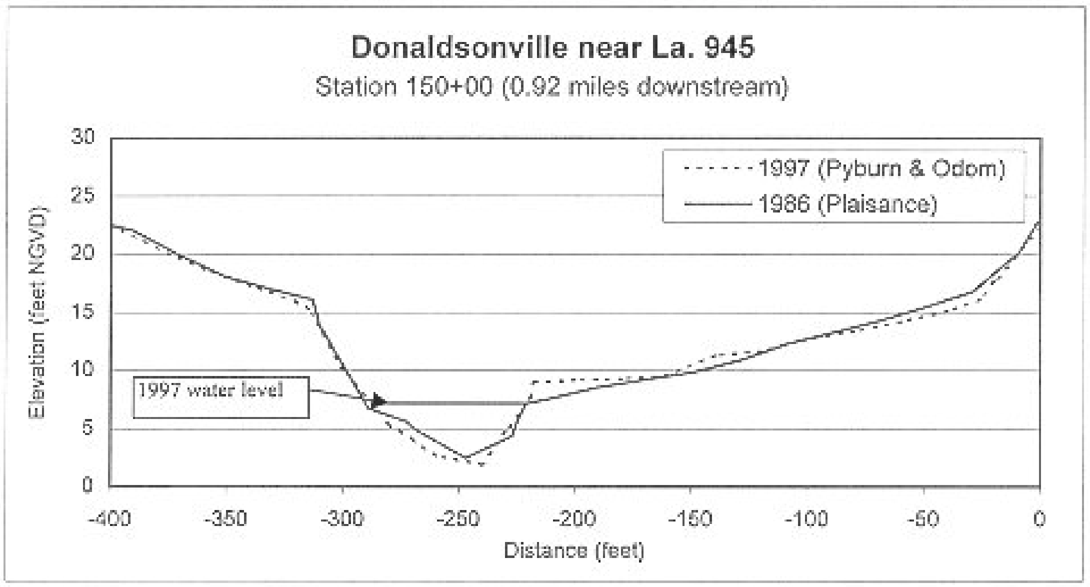
Figure 2.3-2. Comparison of channel cross-sections measured in 1997, with those measured in 1988.

Figure 2.3-2. Comparison of surveyed cross-sections, 1997 and 1986



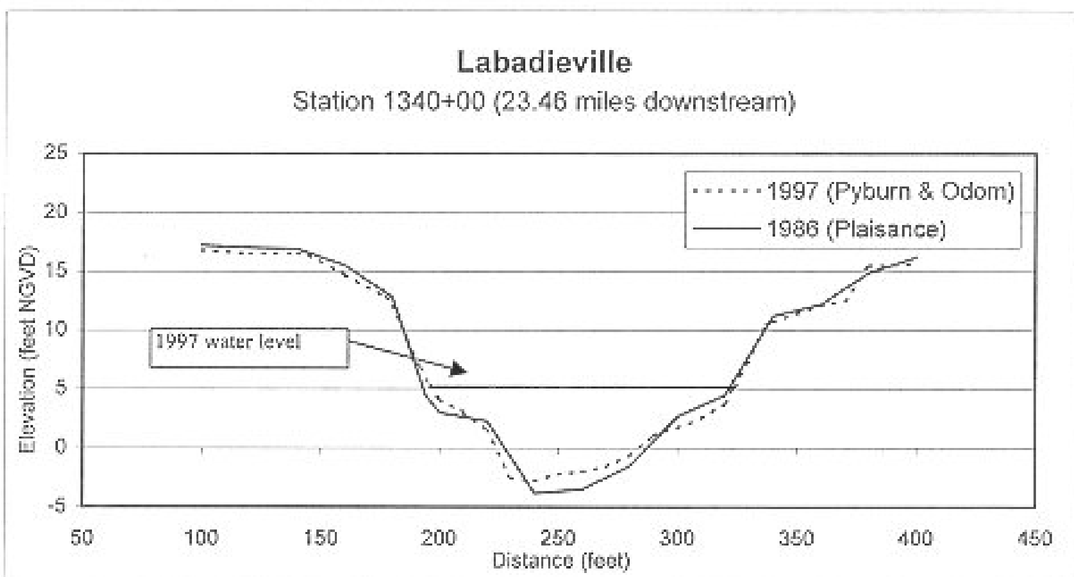


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Figure 2.3-3. Stages in GIWW near Houma.

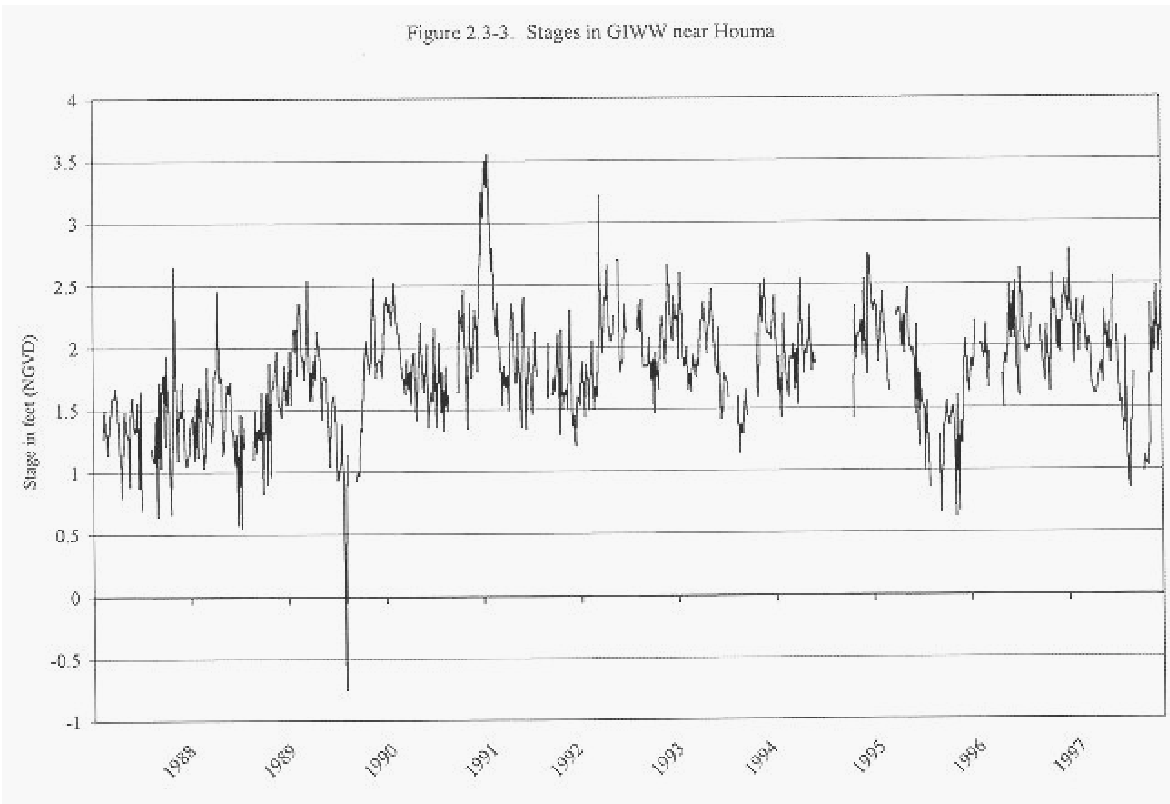

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Table 2.3-1. Recent cross-sections along Bayou Lafourche.

Measured by Pyburn and Odom (1997b).

Location (miles from head)	Width at water level (feet)	Water depth at deepest point (feet)	Average water depth (feet)	Elevation of water surface NGVD (feet)	Date of measure	Water surface elevation 11/21/96
Donaldsonville (1.9)	63	8.0	4.1	7.8	7-Apr-97	7.3
Donaldsonville (2.8)	66	5.2	2.4	7.1	2-Apr-97	7.2
Belle Rose (5.1)	52	6.0	2.8	5.6	3-Apr-97	6.9
Paincourtville (10.8)	116	6.3	2.6	5.5	8-Apr-97	6.6
Napoleonville (18.2)	117	8.5	4.7	5.1	9-Apr-97	6.0
Labadieville (25.4)	128	8.0	4.1	5.2	10-Apr-97	5.1
Above Thibodaux (33.9)	150	9.3	5.5	4.9	14-Apr-97	4.0
Thibodaux blw weir (35.6)	131	7.5	4	3.4	15-Apr-97	3.4
Abv St. Charles Bridge (41.9)	142	8.4	3.9	3.2	15-Apr-97	3.2
Abv Raceland (49.7)	142	9.5	4.5	2.4	16-Apr-97	2.0
Blw Lockport (57.7)	193	10.3	4.8	1.4	17-Apr-97	2.0
Larose abv GIWW (69.2)	220	11.3	5.2	0.9	18-Apr-97	2.0

Table 2.3-2. Bridges over Bayou Lafourche above Lockport.

Reported by Mashriqui and Kemp (1997)

Serial #	**River mile**	**Elevation of deck bottom (NGVD)**	**Description**
1	0.45	8'	2 x (8' x 8' x 149.4') box culvert
2	0.51	8'	2 x (9' x 166.2') CMP (metal pipes) and 1 x (5'W x 6' H x 121.2) box culvert
3	1.27	22'	(35' x 190') concrete bridge
4	3.16	18'	Palo Alto Bridge; (32.6' x 180') concrete bridge
5	6	21'	(35’ x 171’) bridge on LA 998
6	9.79	16'	(85.2' x 199.7') bridge on LA 70
7	10.36	19'	(35' x 171') bridge on LA 403
8	12.06	16'	(47.2' x 199.7') concrete bridge
9	12.25	17'	(26.7' x 171.4') bridge on SPUR 70
10	14.91	20'	(35.1' x 170.7') bridge on LA 402
11	15.66	19'	(9.2' x 194.3') foot bridge on Foley Avenue
12	15.85	17'	(31.3' x 239') bridge on LA 1008
13	20.02	17'	(21' x 176') bridge on LA 1010
14	22.86	18'	(35' x 209.2') bridge on LA 1011
15	25.13	16'	(34' x 220.8') concrete bridge
16	29.87	12'	(27.3' x 151.9') concrete bridge
17	32.9	14'	(27.3' x 171.2') concrete bridge
18	33.6	15'	(36' x 224') concrete bridge
19	33.88	13	(27.3' x 190.4") concrete bridge
20	34.78	13'	(38' x 227.9') concrete bridge
21	35.78	15.5'	(35' x 199.8') concrete bridge
22	37.9	22'	(20.5' x 178.6') steel and timber railroad bridge
23	40.8	9'	(19.8' x 228.4') steel and concrete draw bridge
24	48.17	9.5'	(32.2' x 195.6') concrete and steel draw bridge
25	48.71	11'	(36.3' x 240') concrete and steel draw bridge
26	55.85	8'	(25.8' x 251.4') concrete steel swing span bridge
27	57.5	9'	(37.5' x 290') concrete steel swing span bridge

2.4 REPRESENTATIVE DRY-WEATHER FLOW CONDITIONS

The following discussion characterizes flow conditions observed in Bayou Lafourche at times when diversions from the FWD represent the primary source of water, and there are no special obstructions to flow.

2.4.1 Diversions into the bayou

Data on monthly diversions into Bayou Lafourche are reported by the FWD. As part of their study of bayou hydrology, USGS compiled these data for the period 1988-1997; the results are shown in Figure 2.4-1.

During the early part of the period diversions were typically less than 200 cfs, which indicates that two siphons or pumps were operating. By 1995 the diversion had increased, and while FWD policy is normally to reserve at least one pump as a backup, at times all four siphons or pumps were operating. In most years the maximum diversion occurred in October-December, a time when water demands are highest and the risks of salinity encroachment greatest (see Sections 2.7 and 2.8).

2.4.2 Bayou flow

Direct, long-term measurements of flow in Bayou Lafourche are available only from the gaging station located above the Thibodaux weir. Figure 2.4-2 is a plot of measured discharges at the gaging station during the period 1985 through early 1998, which includes the period of the diversion records plotted in Figure 2.4-1. (These data extend beyond the timeframe of the study done by USGS, because they are part of the routine USGS monitoring programs for which data can be downloaded from the Internet.)

Based on Figure 2.4-2, bayou flows typically fluctuate within a range of 100 to 300 cfs. Flows averaged about 200 cfs in the mid-1980s and 100 cfs in the late 1980s. In the 1990s the flow gradually increased to around 300 cfs in early 1995, after which flows markedly decreased back to 100 cfs for a time. For the period when concurrent data are available, this decrease and subsequent increase in flow can be accounted for by changes in the rate at which FWD diverted Mississippi River water into the bayou (Figure 2.4-1).

Superimposed on the long-term pattern in Figure 2.4-2 are shorter-term fluctuations. Most of these represent a change on the order of several tens of cfs from week to week or month to month. Such variations may partly reflect changes in diversion rates, but also are likely to represent the effects of small storm events, variations in the rate at which water supply facilities withdraw water, and errors in the data (as, for example, when strong winds push the water up or down the channel). In addition, there are times (often just one day) when the flows are substantially larger (100 cfs or more) than just before or after. These represent larger storm runoff events. Stormwater flows are discussed further in Section 2.5.

2.4.3 Water stages (levels)

The term "stage" is used by hydrologists to refer to the level of water in a channel. For Bayou Lafourche, stage data are available continuously at the USGS gaging station at Thibodaux and daily for the staff gages maintained by the FWD. In addition, as part of the current evaluation USGS measured water level profiles along the bayou on several dates.

The continuous record of stage at Thibodaux is shown in Figure 2.4-3. The data indicate that higher water levels correspond with high discharges on Figure 2.4-2. In turn, that means that short-term rises in water levels relate to storm runoff; and long-term changes primarily reflect diversion rates by FWD.

Data from the daily records from the FWD staff gages are illustrated in Figure 2.4-4. Based on discussions with area residents, it is considered useful to plot conditions as they existed in 1990 (considered a time of relatively low water), 1996 (high water) and 1998 (current). The data confirm that there was a noticeable rise in water level from 1990 to 1996, and that current levels are somewhat below the 1996 peak. The graphs show that the water-surface elevation slopes downstream, and drops substantially across the Thibodaux weir.

Data from the USGS surveys is plotted in Figure 2.4-5. Figure 2.4-5a plots every profile measured in Bayou Lafourche by the agency. Two particular profiles are isolated in Figure 2.4-5b, in order to allow for ease of discussion of what is shown by the data. The profiles show that the weir at Thibodaux represents a fixed point in the water surface. Water levels were lower in the June, 1996 survey than in November, 1996, for two reasons: 1) above the weir, the main factor is that diversions were much higher on November 21st than on June 27th, hence the elevation (stage) of the water surface at Donaldsonville was about 1 foot higher in November; 2) below the weir, the main factor is that the tide in the GIWW was more than one foot higher during the November survey than in the June survey.

2.4.4 Velocity and discharge

One particularly useful source of information on flow velocities in Bayou Lafourche is contained in a pair of time-of-travel studies done for the Louisiana Department of Environmental Quality (see abstracts in Appendix A). One study was in June, 1991, when FWD diversions were quite low, and the other was in May, 1994, when diversions rates were comparatively high (see Figure 2.4-1). The studies included measurements of discharge and also observations of movement of a tracer dye. In contrast to flows discussed in Section 2.6 below, the channel was not significantly obstructed by vegetation at the times the measurements were made.

The following chart briefly summarizes the very detailed measurements of discharge and velocity that were made at the Canal Street Bridge in Thibodaux; the values have been rounded to simplify the discussion.

	6/18/91	5/16/94
Channel width (feet)	146	147
Average depth (feet)	4.4	4.9
Total area (square feet)	642	720
Average velocity (feet per second)	0.29	0.46
Total discharge (cubic feet per second)	186	331

This chart shows that a much larger flow (78% larger) in 1994 was carried with only an 11 percent increase in water level (from 4.4 feet to 4.9 feet). The major difference between the two discharge measurements was flow velocity, which increased by almost 59%. The velocity increase was presumably a complex response to the greater channel depth and (unmeasured) changes in slope. The chart helps illustrate the particular importance of channel depth as a controlling factor in water conveyance.

Note that DEQ performed another survey of the bayou in the Spring of 1998. Dugan Sabins of that agency has advised EPA regarding the preliminary results of the survey, which are consistent with those of the earlier studies.

2.4.5 Slope (gradient)

Based on the DEQ studies and more recent USGS surveys, the typical elevation of the water surface in Bayou Lafourche is about 7 or 8 feet NGVD in Donaldsonville (depending on the diversion rate), and 1 to 2 feet in Lockport (depending on tides and winds). This results in an extremely flat slope or water-level gradient of 5 to 7 feet in about 58 miles. Because of the low gradient, flows in the channel typically have a low velocity (0.25 to 0.5 feet per second or less). Steeper gradients occur in the narrow upper channel near Donaldsonville, where at high rates of diversion, velocities can exceed 1 foot per second.

2.4.6 Roughness

Roughness reflects the nature of bed and bank material and the presence of vegetation. Flow is faster (and the total discharge for a given area greater) for channels with a smooth side and bottom, than channels that are irregular. (This is why many man-made channels are built with smooth concrete, with a roughness coefficient around 0.012.)

Recent modeling of Bayou Lafourche (see Section 4.3) has used a roughness factor of 0.021 for Bayou Lafourche. However, the DEQ dye studies discussed above are more consistent with a roughness coefficient closer to 0.03. Both values allow for relatively free flow (but not as efficient as a concrete channel, for example). For a channel cross-section that is 160 feet wide and five feet deep, the difference between a roughness of 0.02 and 0.03 is that the rougher channel will carry about 30% less water.

Figure 2.4-1. Average monthly diversions into Bayou Lafourche at Donaldsonville 1988-mid 1996.

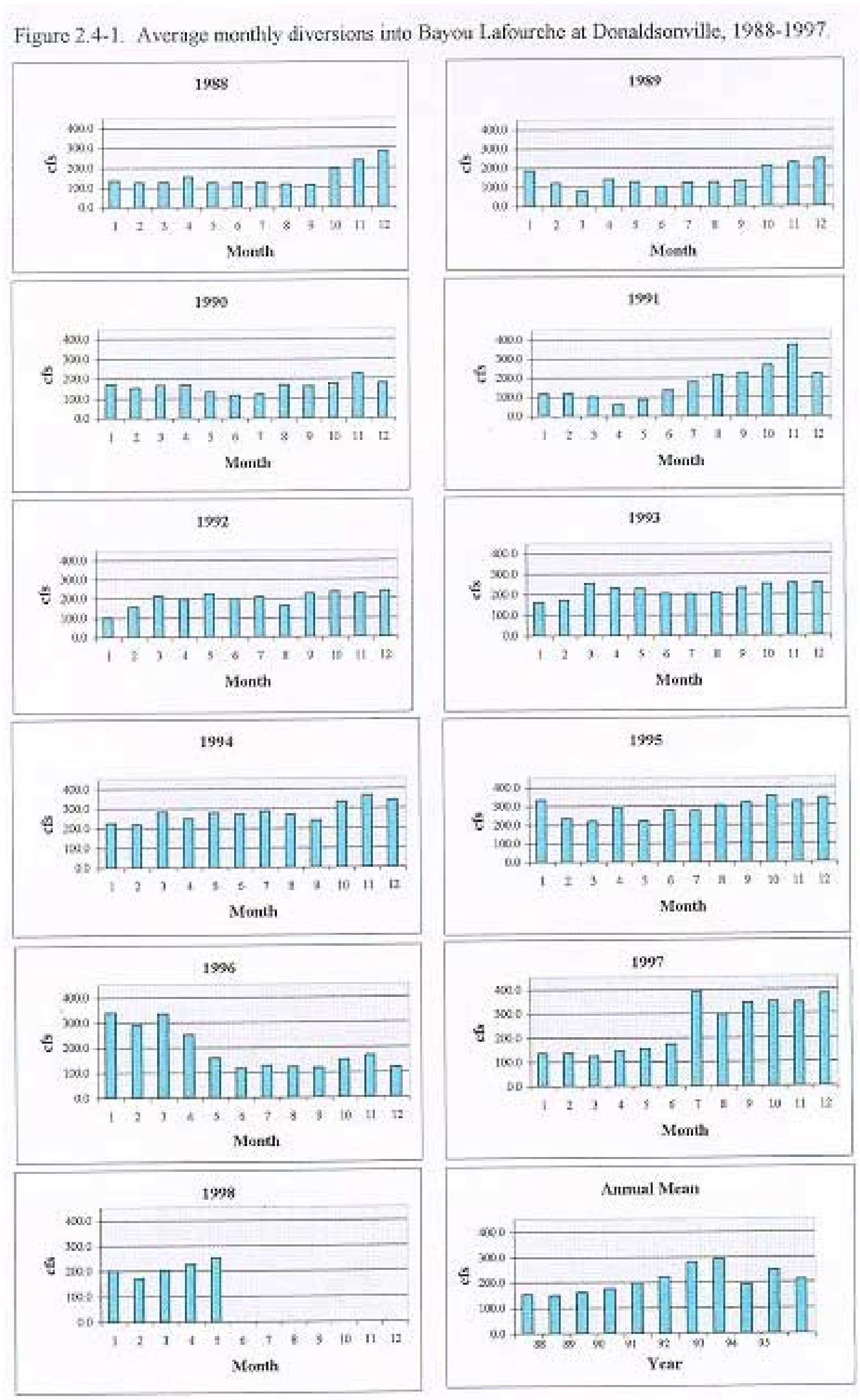

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Figure 2.4-2. Daily Discharge (cfs) of Bayou Lafourche at Thibodaux
(above the weir), 1985-early 1998

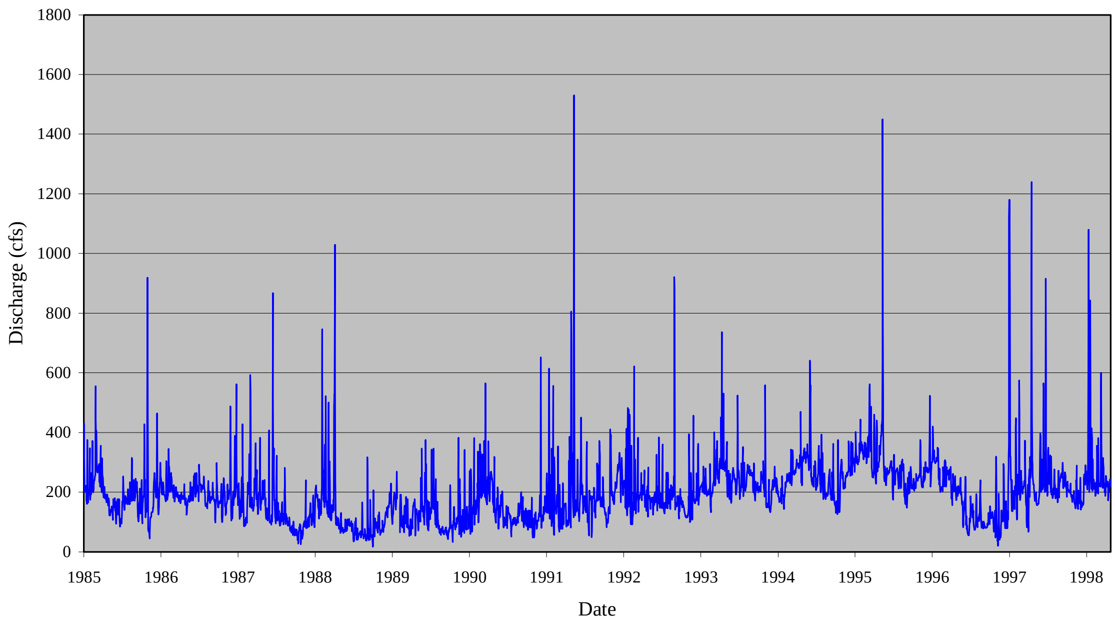

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Figure 2.4-3. Daily Water Surface Elevations (stage - feet NGVD) of Bayou Lafourche at Thibodaux (above weir), 1985-early 1998

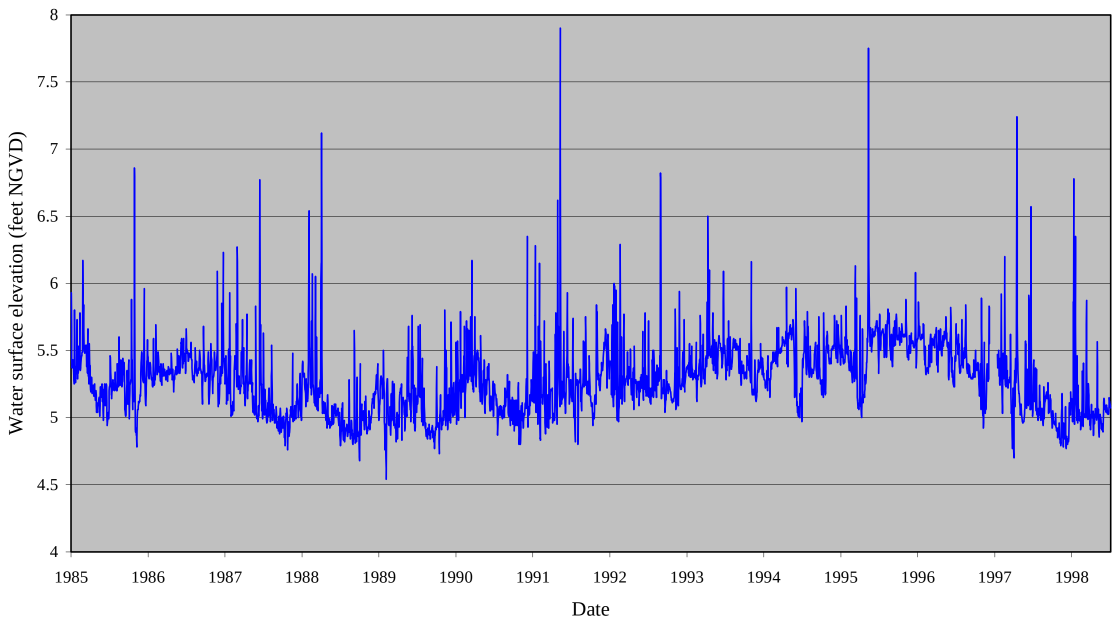

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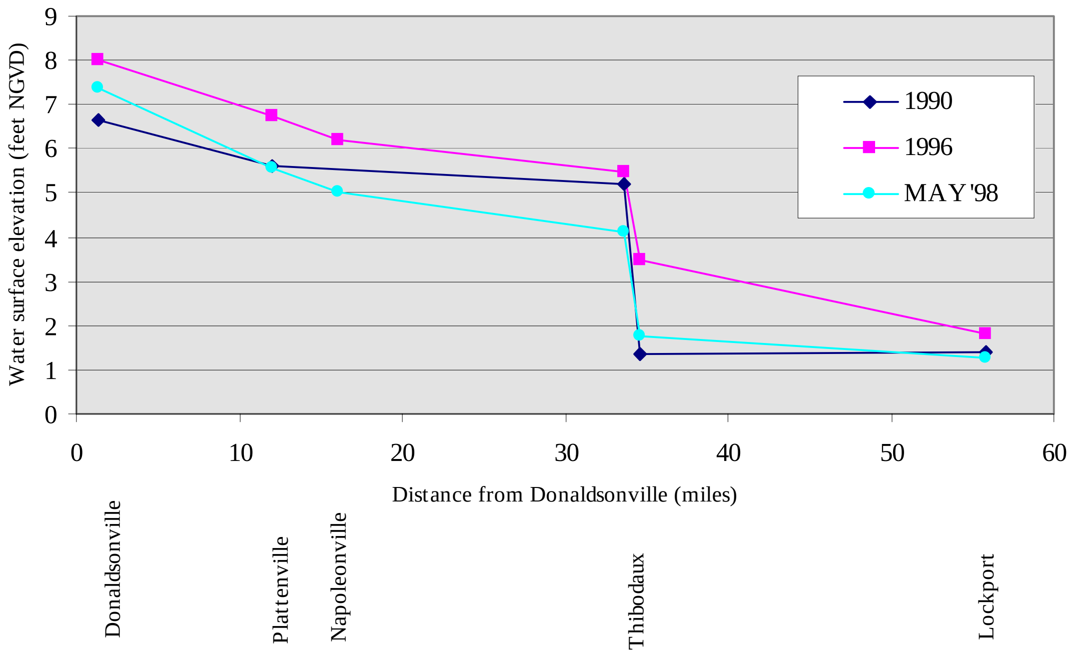
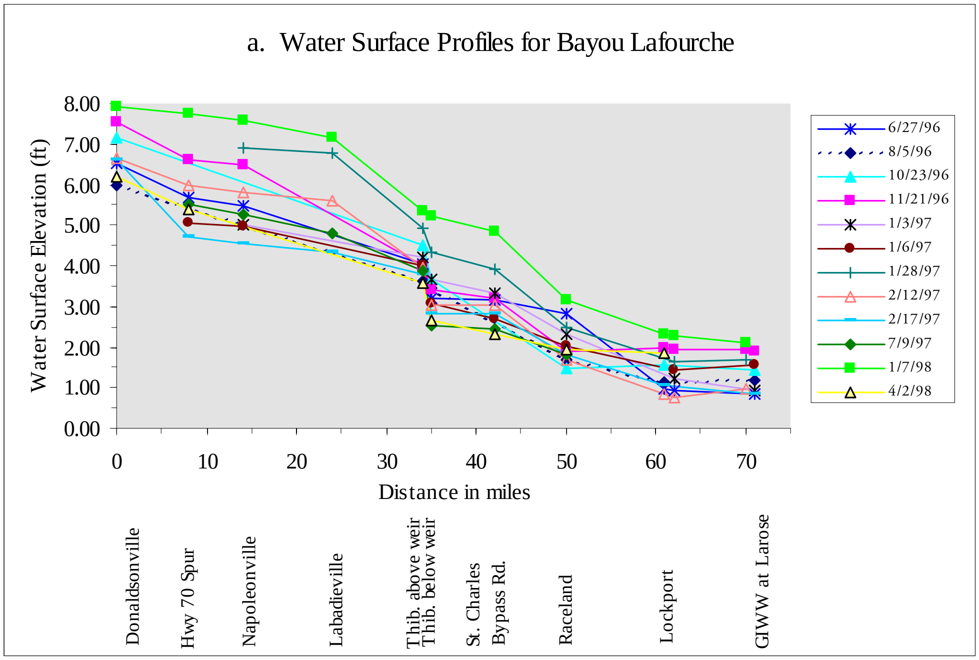
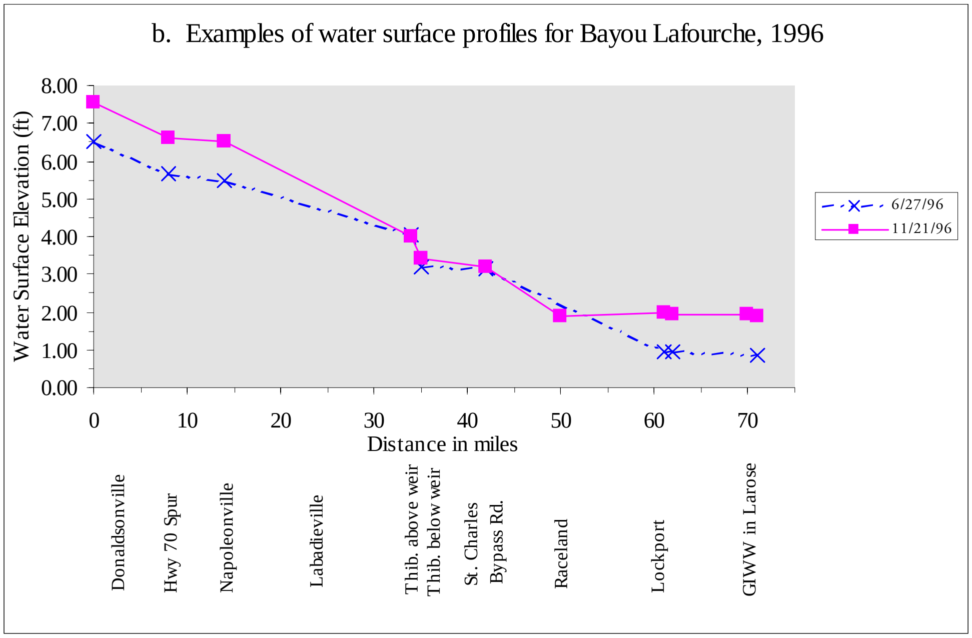
Figure 2.4-4. Water surface profiles for Bayou Lafourche, based on FWD records. Data are for maximum monthly water level



PRELIMINARY: DRAFT

Figure 2.4-5. Water surface profiles for Bayou Lafourche, measured by USGS.





2.5 WET-WEATHER FLOWS

2.5.1 Categories of drainage to bayou

The following discussion characterizes flow conditions observed in Bayou Lafourche at times when storm runoff is a significant source of water. In addition to direct rainfall on the bayou surface, storm runoff reaches Bayou Lafourche through short, steeply sloping drainage ditches and culverts; and through at-grade canals. Figure 2.5-1 illustrates the drainage features for a representative area (near Madewood Plantation, downstream of Napoleonville).

Steep ditches and culverts. Based on studies done as part of EPA's evaluation, more than 400 culverts and drainage ditches carry storm water into Bayou Lafourche from the high ground that parallels the highways on either side of the bayou (CEEC, 1997c). Collectively these culverts and ditches drain the land between the high part of the adjoining natural levees (which often crest a few hundred feet beyond the highways), and the bayou channel. An exception occurs in urban areas such as Donaldsonville, where at least some of the storm drainage is gathered from areas of the city that are more distant from the bayou.

The short arrows in Figure 2.5-1 show a typical pattern of these features, which are numerous and which occur on both sides of the bayou. The ditches and culverts slope steeply from the bayou side of the highways to the bayou. Because of this very steep slope, neither the flow gradient in the ditches or the rate of discharge is sensitive to changes in bayou levels. Changes to the bayou from additional diversions and/or from dredging thus would not be expected to impact the ability of the side ditches and culverts to drain the land, but they would impact the ability of the bayou to then convey the drained water.

At-grade canals. Behind the natural levees on both sides of the bayou, the land slopes gradually toward the interior wetlands of the Terrebonne (west) and Barataria (east) basins (see

Figure 1.1-3). For the area shown in Figure 2.5-1, the drainage along this slope is illustrated by two long, solid black lines and arrows. It is typical that the water eventually drains to a canal that is cut into the land. Unlike the culverts and ditches discussed above, these canals have a nearly flat slope. They are referred to as “at grade” because their slope is more or less the same as Bayou Lafourche.

The network of canals is complex, but for many canals flow can occur either to Bayou Lafourche from the wetlands and/or alluvial ridge, or it can occur away from Bayou Lafourche. The principal exceptions to this pattern occur where a canal has been blocked at the bayou end by silt, vegetation or a constructed structure.

The bi-directional drainage is illustrated in Figure 2.5-1, which shows the Baker Canal. The Baker Canal connects Bayou Lafourche to a canal (also known as the Baker Canal) that is located at the margin between the Bayou Lafourche natural levee and the adjoining wetlands. This particular canal is no longer open at the bayou end. When the canal was open and the bayou was low, water could be discharged to the bayou from the Baker Canal. On the map, flows originating in the Baker Canal are shown with dashed lines and arrows. Before the canal was blocked, water also could flow away from Bayou Lafourche when the bayou was high; on the map, flows of water originating in Bayou Lafourche are shown with dotted lines and arrows.

Not all at-grade canals go through the uplands to the wetlands. Some canals originate in cane fields and simply drain to the Bayou. Where these canals are open, the same principles apply. When the bayou is low, runoff on the land can eventually discharge to the bayou. When the bayou is high, there can be a net discharge to canals from the bayou and the upland drainage must go to the canals that are in the wetlands.

Based on field checks done by CEEC, there are nearly 50 at-grade canals that have the potential to drain to the bayou, or from the bayou, depending on hydrologic conditions; the full inventory of these points is provided in CEEC (1997c). The inventory did not determine which canals are open at this time; but it appears that only a few are completely severed from the bayou, as occurs at Baker Canal.

2.5.2 Implications of bi-directional drainage in at-grade canals

The low-lying lands of coastal Louisiana pose a challenge in water drainage. For example, the upper Barataria Basin is surrounded by higher lands (on the levees of the Mississippi River and Bayou Lafourche), and it also contains uplands along old distributary ridges (such as the Chackbay community). Rainfall on these lands must drain toward the wetlands, where there are few channels and a very flat gradient. It is common that wetland flows are slow, so that lower-lying areas on the ridges drain slowly during major storms, Where the problems have become severe, drainage has been augmented by pumps and ring dikes.

Three situations can occur in which the condition of Bayou Lafourche could impact local and regional implications to drainage. These situations all assume that the at-grade canals would be open. First, if bayou levels were low (as might result from dredging), more drainage from back-bayou areas could discharge to the bayou through the at-grade canals. This could relieve pressure on wetlands drainage. Second, if bayou levels were comparable to those in the wetlands, then the at-grade canals would effectively be blocked at the bayou end, and could not drain to the bayou. Third, if the bayou were high (as from a new diversion that is not compensated for by dredging), there could actually be increased drainage from the bayou through the at-grade canals, which could add to drainage problems.

Locally, this means that Bayou Lafourche has the potential to effectively control the ultimate ability of the at-grade canals to provide drainage. Two specific locations have been identified where drainage impediments or reversal can contribute to local flooding that may be associated in part with Bayou Lafourche. One is the Rienzi Canal in Thibodaux; this canal is now blocked to prevent any flow from the bayou that could impact local properties. The second is the Marais area above Labadieville. A third area of local impact that is definitely related to Bayou Lafourche is the Lafourche Crossing of LA 308. There, when the bayou is very high during storms, water overflows the channel banks and can overlap a low spot in the road. The records of the LDODT in Raceland indicate this road was closed (for a period of hours or more) due to flooding at least four times in recent years: December 1996, April 1997, January 1998, and April 1998.

The overall pattern of regional drainage also can be impacted by the bayou. One specific example of this effect is in the area of the Donaldsonville Hospital. There, the lowest cost drainage alternative would be through an at-grade canal to Bayou Lafourche. However, given typical water elevations, there is inadequate gradient in the canal to handle the storm water. This fact forced the decision to direct drainage to the wetlands (St. James Canal), at an increased cost.

2.5.3 Flow and stage: examples from three storm events

Although the ribbon of land that always drains to the bayou is narrow, it is nearly 60 miles long. Thus a single heavy rainstorm can generate tens of millions of cubic feet of water that will run off to the bayou. Figures 2.4-2 and 2.4-3, presented previously, show how the discharge and water surface of Bayou Lafourche can increase sharply for short periods, in response to such storm runoff.

For this study, EPA has considered three particular runoff events, in order to characterize the bayou’s response to heavy rainstorms: May, 1995; December, 1996; and January, 1998. Figure 2.5-2 plots the daily discharge measured at the Thibodaux gage during each of these storms; FWD rainfall records also are plotted.

May, 1995. The highest flows measured in Bayou Lafourche in the 1990s were observed on May 9th, 1995, when the average daily flow exceeded 1,400 cfs and the discharge exceeded 2,000 cfs for a few hours. Figure 2.5-2a plots discharge at Thibodaux during an approximately two-week period that includes days before and after the storm. Before the storm, the flow was about 400 cfs. Within two days after the peak flow, runoff had returned to this level, and flow subsequently declined to less than 300 cfs.

The heavy rainfall associated with this storm was concentrated near Thibodaux, where nearly 10 inches was measured on May 9th; in contrast, the rainfall at Donaldsonville was less than 5 inches, and near Raceland, only about 1 inch. In the upper bayou (e.g. Napoleonville and above), water levels rose about 1 foot during this storm, and a similar response was observed near Raceland; but in Thibodaux, near the center of the storm, the increase in stage was greater than 2 feet.

The weir at Thibodaux was submerged during this event, but the Bayou Lafourche crossing was not. The FWD typically receives reports when there is flooding along the bayou. The only areas known to have experienced problems were the Marais area (where 26 homes were affected) and Rienzi Canal (which had not then been closed, and where streets were flooded). It is assumed that if properties along the bayou were impacted, the effects were short-lived and minor. There was flooding in back-levee areas near the bayou, but to the best of EPA's knowledge this reflected the intense rainfall and limits in upland drainage, rather than flows from Bayou Lafourche.

December, 1996. Figure 2.5-2b plots the Thibodaux gage over an approximately two week period that includes December 26-27th. This event is of special interest because at the time, CEEC (on behalf of EPA) had a survey crew in the field for the purpose of studying bayou drainage. Detailed data were obtained showing the extent to which bayou water levels from this storm impacted at-grade canals. During this event, the weir at Thibodaux was submerged and the road at Lafourche Crossing was closed.

The FWD rain gages indicate there were about four inches of rainfall spread more or less evenly along the bayou. Figure 2.5-2b indicates that this precipitation caused a flow of 1,100 cfs to be sustained for nearly a week, including several days after the rain stopped.

It is possible and perhaps likely that the flows during this storm are over-estimated because in December, 1996 Bayou Lafourche was severely choked with vegetation (see more details in Section 2.6, following). Water levels were high before the storm, and the channel had little capacity for providing drainage. For at least part of the period, there would have been a high stage at the Thibodaux gage because of storm water backing up behind the vegetation. This would have been read at the gage as an indication of high flow, when in fact the flow was probably limited.

CEEC recorded bayou stages during this storm event at several locations and interpolated the data to provide estimates of the water surface at each at-grade canal that it surveyed. Based on this information, CEEC determined whether a particular structure would have been submerged during the storm. The following discussion of the presumed submerged structures is taken from the CEEC report (CEEC, 1997a).

- No structures were noted in Ascension Parish.
- Site A-59 in Assumption Parish is adjacent to LA 1, on the south side of Napoleonville on LA 401, which drains the rear part of the Assumption Parish Chamber of Commerce Building. A rise in Bayou Lafourche coupled with a moderate to heavy rainfall could cause street flooding in this area.
- Site A-80 is perhaps the most critical structure on the LA 1 side of the Bayou and drains a residential area known as the “Marais”. Street elevations there are approximately +8 feet but the neighborhood is surrounded by higher areas, lying between the 10 and 15 ft contour lines. Approximately 2,000 acres of agricultural land drain into Bayou Lafourche

through this area. There is a proposal to replace the existing structure with two 9’ x 9’ box culverts. It is clear that this area will require special consideration if normal bayou stage is increased.

- Drainage structure A-157 on the LA 308 side is connected to the Baker Watershed, which is tied to Bayou Lafourche by Baker Canal; it is south of the canal shown on Figure 2.5-1. Because of overgrowth, the preliminary investigation was unable to determine whether the canal is dammed off or is still connected through pipe structures below the surface. A similar conclusion applies to the Valance (A-153) and Cecil (A-167) Canals.

- The final area of concern in Assumption Parish is on the La 308 side of Bayou Lafourche at canal A-168, which is plugged on the east side of the highway. The concern in this area is that a prolonged rise in Bayou Lafourche may deteriorate the highway foundation.

- Drainage Structure L-1 in Lafourche Parish is a large lateral canal, 200 feet south of the parish line (Thomas Naquin Tract). It presumably connects a large drainage system to Bayou Lafourche. Elevations on the west end of this drainage system are needed to determine the effects on this area if water levels are increased in Bayou Lafourche.

- Drainage structures L-28, L-34, L-47, L-51, L-52, L-53, and L-55 along LA 308 are associated with canals that appear likely to experience problems if water levels are high in Bayou Lafourche. Further evaluation would require obtaining elevations the east end of these canals.

- Drainage structure L-64 connects to a large drainage system on the LA 1 side. Elevations on the west end of this drainage system are needed to determine the effects of increased water in Bayou Lafourche on this area. The Dugas Canal ties Bayou Lafourche to Bayou Cut Off, the Forty Arpent Canal, and the Bayou Folse Watershed Drainage System. The connection is approximately 200 feet west of LA 1 through a concrete structure (L-68) with three 48” gates in the closed position. This structure prevents bayou water from flowing into the drainage system. The gates can be opened when the water level in Bayou Lafourche is low enough to relieve the drainage system after periods of heavy rain. The top of this structure is 5 feet 4 inches above the bayou water during normal conditions. High stages and significant flows are assumed to have caused the bank erosion observed around the structure.

- The Lefort Canal (L-77) ties in Bayou Lafourche to the junction of Bayou Cutoff (Forty Arpent Canal) and the Hollywood Canal (Bayou Folse Watershed). Terrebonne Parish Water Plant draws its water supply from the west end of Lefort Canal. A weir was constructed near the water intake to prevent Bayou Lafourche from flowing into the drainage system and to allow the drainage system to use Lefort Canal as a relief artery into Bayou Lafourche. High Bayou Lafourche waters in 1991 overflowed the weir into the drainage system which necessitated the installation of two large culverts and gates on the east end of Lefort Canal. During normal conditions, these gates remain open. During periods of high water, these gates are kept closed and the reservoir between the gates and weir temporarily supplies water for the plant. If Bayou Lafourche remains high for a longer period of time, the Terrebonne Parish Water District will have to redesign and reconstruct their water intake system. An alternate would be to levee off the canal and increase the weir elevation.

- The Rienzi Canal is south of Thibodaux, along LA 308. It adjoins the Rienzi Plantation Subdivision. The canal ties in Bayou Lafourche (L-186) to the Forty Arpent Canal. A similar flow relationship may occur in the Laurel Valley Plantation Canal (L-195) which is a few miles south of this location. As noted previously, the exchange of water between the bayou and Rienzi Canal is now blocked.

- A number of laterals tie in to the Bayou from Laurel Valley Plantation to the Company Canal including L-207.

January, 1998. Figure 2.5-2c plots the Thibodaux discharge during the first 13 days of 1998. This event is of interest because: 1) it is very recent (and thus presumably well remembered); 2) bayou water levels were much higher than commonly observed; 3) the problem of vegetation clogging did not occur; 4) this is one of the few events known to have forced the closing of Lafourche Crossing; and 5) during the peak of the storm, the U.S. Geological Survey measured the water surface profile of the entire bayou, thus providing the most useful single data set with respect to storm impacts.

The first significant rainfall associated with this event was on January 5th. Rain continued at least through the 8th and for the several day period was in the range of 7-10 inches along the entire bayou. The bayou began to rise on the 5th and reached its maximum level on the 7th, when the flow exceeded 1,000 cfs. Levels dropped quickly at the end of the storm, and flow was about 300 cfs by January 9th. This rapid decline contrasts with Figure 2.5-2b, and indicates the effectiveness of the vegetation control program.

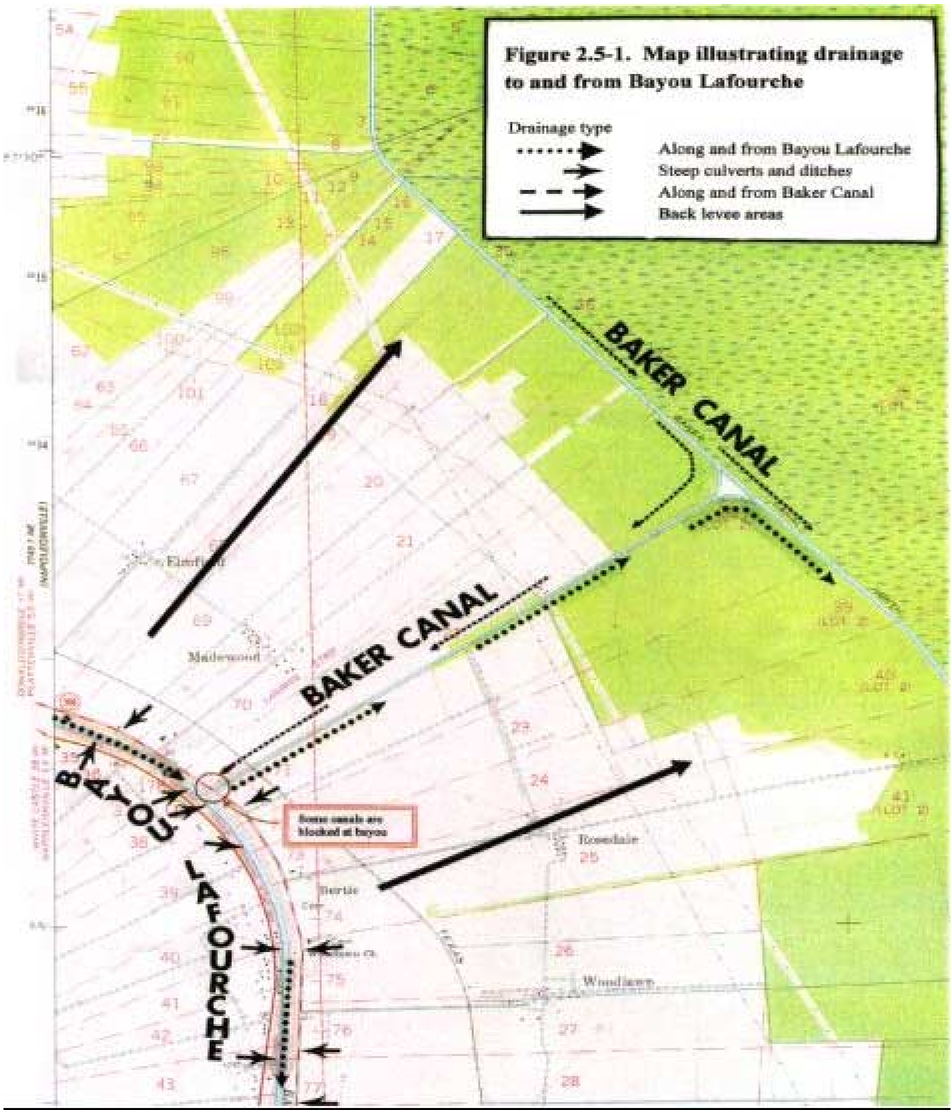
The January 8th data can be compared to other stages measured by USGS; see Figure 2.4-5. The January, 1998 water levels were the highest observed by that agency in their nearly two years of study. This is likely due to the fact that the rainfall and runoff lasted many days, so that the bayou continued to rise; whereas in May, 1995, the storm ended and the period of peak runoff was not sustained. FWD data indicate the rise in stage was typically 1 to 1.5 feet for the length of the bayou, which also suggests that levels were somewhat higher than average before the storm began.

2.5.4 Flow velocity and gradient during storm events

The data suggest that a sustained (i.e. 24-hour or more) increase in flow from a few hundred to 1,000 cfs is associated with a rise in bayou levels of 1.5 feet or more. A simple calculation can show that the rise in stage and increase in channel depth must be associated with a flow velocity in the range of 2 to 3 feet per second in order to convey the additional flow. The increase in overall flow gradient is small, at most a foot or two over 60-plus miles; the main change that provides for additional channel capacity is the greater channel depth and associated faster water flow.

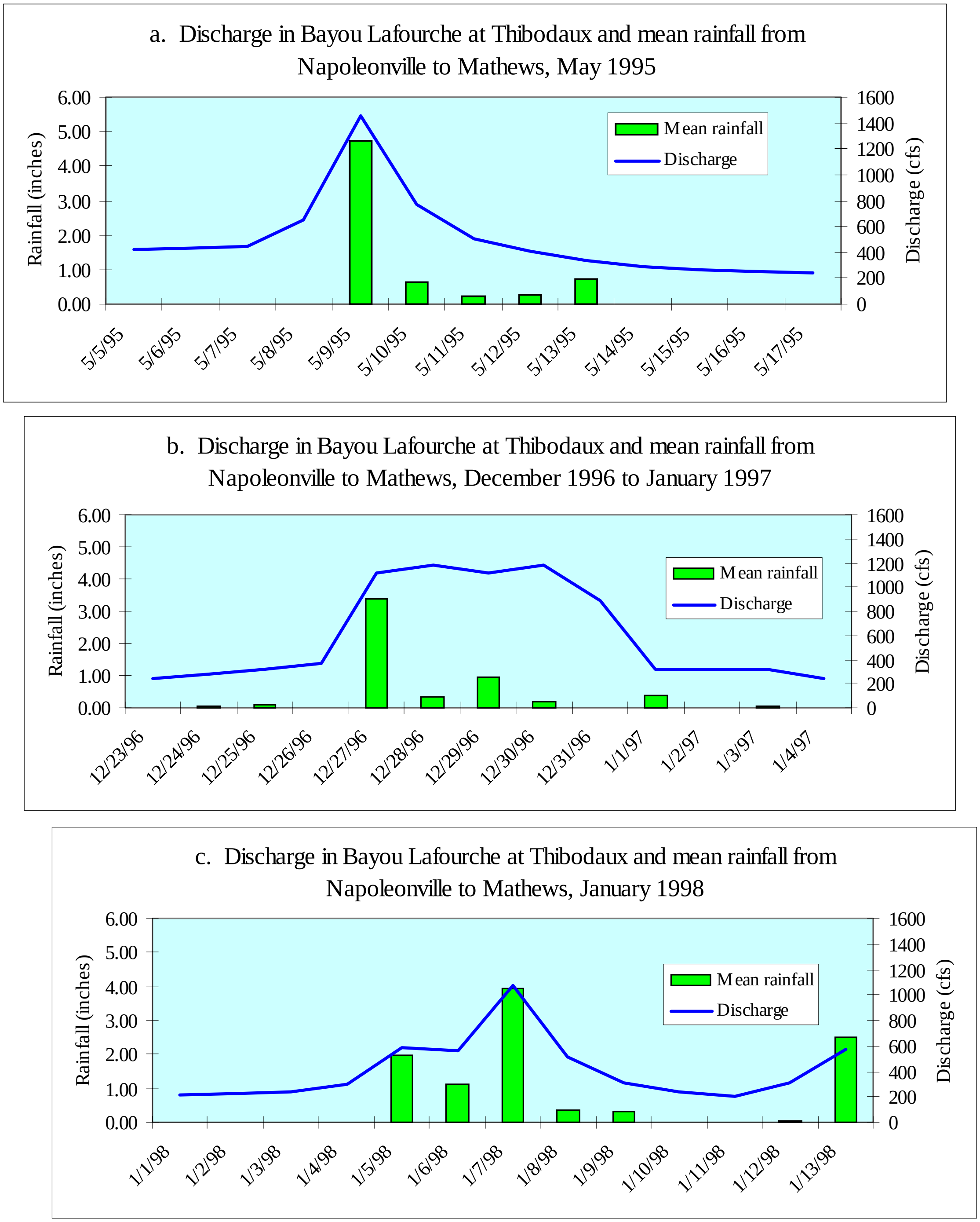
Figure 2.5-1.

CEEC map to show bi-directional drainage



PRELIMINARY: DRAFT

Figure 2.5-2. Daily discharges (cfs) in Bayou Lafourche at Thibodaux (above the weir) and mean rainfall from Napoleonville to Mathews during storm events



PRELIMINARY: DRAFT

Table 2.5-1 At-grade channels, Bayou Lafourche

Critical drainages identified by CEEC (1997a) survey and field checked by Pyburn and Odom (1997b).

Item #	River mile	Description and location	Elevations in feet (NGVD)		
			Object		Water surface
			Invert	Top	12/27/1996[1]
#8	3.8	Two 48" box culverts of Smoke Bend, nth side of Sagona's Gift Shop	5.87	9.87	7.6
#9	3.8	7' round culvert at 3074 La. Hwy 1	5.65	12.65	7.6
#13	4.9	6' culvert at 1515 La. Hwy 1	2.97	8.97	7.6
#20	2.5	RR xing, La. Hwy 308 Donaldsonville, 6' deep x 5' wide box culvert	5.37	11.37	7.6
#21A	2.7	2' CMP north of New bridge	7.46	9.46	7.6
#21B	2.7	1.5' CMP south of New bridge	9.60	11.10	7.6
#23	5.7	Napoleon Bayou 1.5' CMP south of New Bridge	3.35	4.85	7.6
A - 34	12.3	36" culvert at La. Hwy 1 and Westfield Road	10.27	13.27	7.6
A - 59	18.2	36" culvert at La. Hwys 1 and 401 behind Assumption Area Chamber	2.63	5.63	6.9
A - 80	24.8	72"x60" box culvert at 3227 La. hwy 1 (Marais Area)	-0.52	5.48	6.6
A - 85	26.7	6' x 6' box culvert at La. Hwy 1 and Locust Street	2.34	8.34	6.4
A - 90	27.7	6' x 6' box culvert at La. Hwy 1 and Pear Street	2.53	8.53	6.4
A - 138		Baker Canal at La. Hwy 308			6.4
A - 153	24.8	Under La. Hwy 308 bridge 1000' nth of La. Hwy 1011, Bayou bottom	2.04		6.6
A - 157	26.3	4' box culvert at 2828 La. Hwy 308	1.11	5.11	6.4
A - 167	28.2	2' box culvert at 2405 La. Hwy 308	1.92	3.92	6.4
A - 168	28.4	3' culvert at 2373 La. Hwy 308	1.72	4.72	6.4
L - 1	29.5	3' culvert below water at La. Hwy 1 200' south of Parish line	-0.32	2.68	6.4
L - 7	32.0	24" culvert 7' below La. Hwy 1 on south line of Donald Peltier	6.48	8.48	6.3
L - 8	32.0	36" box culvert 8' below La. Hwy 1 150' north of Dixie Rd	6.60	9.60	6.3
L - 13	34.1	36" box culvert 9' blw La. Hwy 1 on Waverly-Leighton Plantation Line 300' south of Winder Rd	3.77	6.77	6.2
L - 28	29.5	36" culvert below 1954 La. Hwy 308	6.35	9.35	6.4
L - 34	30.9	36" culvert at La. Hwy 308 250' north of Dixie Road	2.24	5.24	6.3
L - 47	33.0	5' steel drainage canal between 1922 and 1924 La. Hwy 308 at Thompsonville Construction Co.	-0.03	4.97	6.2
L - 51	34.1	48" box culvert at La. Hwy 3185 bridge at La. Hwy 308	5.42	9.42	6.2
L - 52	34.1	48" culvert at 960 La. Hwy 308	2.03	6.03	6.2
L - 53	35.6	4' concrete box culvert at West Thibodaux Water booster station on La. Hwy 308	4.53	8.53	6.1
L - 55	35.0	2 culverts 14' under La. Hwy 1 50' north of City of Thibodaux sign across from FWD office			6.1
L - 59	35.6	6' box culvert under Canal Blvd (Thibodaux)	0.63	6.63	6.1
L - 64	37.7	3' large box culvert submerged 200' nth of La. Hwys 648 & 1	-0.17	2.83	4.5

Table 2.5-1, continued

			Elevations in feet (NGVD)		
			Object		Water surface
Item #	River mile	Description and location	Invert	Top	12/27/1996[1]
L - 68	38.0	Dugas Canal at 1072 La. Hwy 1, 6' concrete culvert	-4.68	1.32	4.3
L - 77	39.7	Sluice gates and weir ties at Lefort Canal 400' north of Lefort By-Pass Road, 6' CMP	-3.63	2.37	4.1
L - 117	45.5	Theriot Canal ties Bayou Lafourche to Bayou Cutoff Sluice Gate, 12.5' deep x 8' wide	-4.66	7.84	3.4
L - 186	36.0	2- 4' box culvert at 310 La. Hwy 308	-1.35	2.65	5.9
L - 195	38.0	Laurel Valley Canal at La. Hwy 308 next to Old Fountain Missionary Baptist Church	0.01		4.3
L - 201	39.7	Lafourche Crossing La. Hwy 308			4.1
L - 207	39.9	36" culvert at La. Hwy 308, 800' north of St. Charles Bridge	0.05	3.05	4.1
L - 219	45.5	Large lateral canal at La. Hwy 308 south side of Third Zion Church, Raceland			3.4
L - 229	49.7	60" culvert under La. Hwy 308 200' sth of Brocato Ln, Raceland	-0.36	4.64	2.9
L - 231	49.7	36" culvert at La. Hwy 308 at Gazzo Canal	-0.48	2.52	2.9
L - 237	50.7	Large open canal below La. Hwy 308 bridge south side of Central Crude Raceland Terminal	-5.50		2.7
L - 238		36" culvert at La. Hwy 308 1000' south of L - 237	-0.21	2.79	
L - 240	51.7	48" culvert at La. Hwy 308 1000' north of La. Hwy 90 Raceland	-0.23	3.77	2.6
L - 243	53.7	48" culvert at La. Hwy 308 and Amerada Hess Road	-0.24	3.76	2.3
L - 245		3' culvert at La. Hwy 308 1/2 mile north of 4839 Church and Cemetary Mathews	1.39	4.39	
L - 249	55.7	48" culvert at La. Hwy 308 South Side Water Plant in Lockport (filled 1/2 way w/concrete)	-0.11	3.89	
L - 250	57.8	Company Canal Bottom	-2.29		

1 Interpolated water surface elevation (CEEC) on 12/27/96.

2.6 THE RECENT CLOGGING OF THE BAYOU BY VEGETATION

In the mid-1990s, Bayou Lafourche experienced a dramatic increase in water levels when the bayou became clogged with vegetation. This change was reported at the public meetings held by EPA in 1996, commented upon by numerous persons contacted during this study, and cited as a potential fatal flaw to any diversion project. As summarized below, EPA studied this event in order to verify that vegetation was the cause of the problem, and to consider in turn the reason why the vegetation was able to take over the channel. The discussion that follows also summarizes the results of the successful FWD program to solve the problem.

2.6.1 History and cause of recent rise in water levels

Data documenting the rate and timing of the water-level rise. Figure 2.6-1 compares stages above and below the Thibodaux weir over time. The above-weir graph was presented previously in Figure 2.4-3; the stage at that location is held steady by the weir and thus provides a good reference against which to assess changes downstream of the weir. The discussion that follows concentrates on the changes observed at the gage below the weir.

Except during runoff events (shown by the spiked lines in Figure 2.6-1), the average stage (or water level) below the Thibodaux weir was just above 2 feet NGVD in 1988. This increased to about 3 feet as of the end of 1994. Thus there was rise in water levels at a rate of roughly 1 foot in 6 years. In 1995-96, a much more rapid increase was observed. By the end of 1996 the stage during dry weather conditions had approached 5 feet, a rise of about two feet in two years.

Figure 2.6-2 shows the distribution of this rise as measured at staff gages along the bayou. The increase in 1988-94 occurred throughout the bayou but, beginning around 1993, was most pronounced in the reach near Raceland (shown by the difference between conditions at Thibodaux and Mathews).

Cause of change, 1988-94. The gradual change in stage from 1988 through 1994 can be explained by the quantity of flow in the bayou. Figure 2.4-2, presented previously, shows the discharge rate measured by the USGS above the Thibodaux weir for the identical period as the stage data in Figure 2.6-1; and Figure 2.4-1 shows the quantity of freshwater diversions for much of the same period. The increase in diversions from less than 100 cfs in 1988 to nearly 300 cfs in 1994 can readily explain the observation that stages in Thibodaux increased by one foot during the same period.

However, in 1995, as the stage problem began to be widely noticed, the Freshwater District substantially reduced its pumpage, so that flows at Thibodaux dropped to less than 100 cfs in much of 1996 (Figure 2.4-2). Nonetheless, as shown in Figure 2.6-1, water levels continued to stay high (except at Donaldsonville), and in some locations the rise continued for several months after the flow had been largely shut down (see especially the data for Mathews). Clearly the 2 foot rise that occurred in 1995-96 was not dependent on the rate of diversions into the bayou at Donaldsonville.

Cause of change, 1995-96. There seems to be little doubt that the water level rise was caused by the growth of aquatic vegetation in the channel, especially submerged species such as *Hydrilla*. This vegetation so clogged the channel that water was essentially blocked from flowing through the bayou from Donaldsonville to Larose. Water backed up behind the clogged channel, causing the water level-rise. The following evidence is available regarding this event.

- The proliferation of aquatic vegetation in the channel was very visible and has been commented on by numerous persons who were contacted during EPA's study. Figure 2.6-3 shows photographs that illustrate the vegetative occurrences, and the resulting increase in water levels. Vegetative clogging was so extensive that in some reaches it became impossible to navigate the bayou using an ordinary outboard-motor powered boat. The visual observations indicated the greatest vegetative growth was below Thibodaux and above Raceland.

- The proliferation of aquatic vegetation in the channel was quantified through studies done by Dr. David Schultz at Nicholls State University. Figure 2.6-4 provides representative results from these studies. In the section of the bayou from about river mile 25 (between Labadieville and Thibodaux) to about river mile 57 (above Larose), the abundance of aquatic vegetation increased by two- to four-fold between 1995 and 1996. As a result, the central portion of this reach of the bayou, from the St. Charles Bridge to Raceland, had at least 90% of the bottom covered by aquatic vegetation in 1996.

- The effects of vegetation on channel flow were quantified by measurements made by the USGS. For example, on the 27th of July in 1996, USGS measured a flow at Thibodaux of 140 cfs. On the same date, the flow at Lockport was 27 cfs. On that date, almost no water passed through the channel from Thibodaux to Lockport. Impacts of vegetation also are illustrated by: the high water stages shown on many dates in Figure 2.4-5; the prolonged high stage for the storm event plotted in Figure 2.5-2b; and the sustained high stages on Figure 2.6-2, following the time when FWD decreased the rate of diversions into the bayou.

- The fact that channel flows were blocked was also demonstrated by the fact that sediment no longer was being transported through the system. The result was a marked change in the clarity of the water, with the greatest effects being seen in the most heavily clogged reaches. Figure 2.6-5 quantifies data on water clarity along the bayou for two periods, one before and one during the time of vegetative clogging.

- The clogging reached the point that water levels rose to (and in some locations) above the banks of the bayou. During runoff events, of course, levels were even higher. Thus there were concerns about and in some cases actual incidents of flooding of docks and other low-lying structures.

During the period of maximum clogging, the reach experienced inflows on the order of 100 cfs (see data on discharge at the Thibodaux weir, Figure 2.4-2) while there was essentially no outflow measured by USGS. Therefore, more than 400,000 cubic feet per day were blocked by the vegetation. This is enough water to cause a rise in water levels of 1 to 2 inches per day. Since it took several months for the actual levels to rise by 2 feet, it is clear that much of the flow below Thibodaux must have discharged from the bayou to the at-grade canals and interior marshes of the Barataria and Terrebonne Basins.

2.6.2 Decline in water levels resulting from mowing of vegetation

On November 4, 1996, the Freshwater District began to use two Corps of Engineers cutting machines to remove *Hydrilla* and other submerged aquatic plants. Figure 2.6-6 provides photographs that illustrate the operation of these machines. The operations were akin to 'mowing' in that plants were effectively detached from their roots and simply discarded into the bayou.

It took several months before the machines were able to clear a channel through the vegetation. However, eventually the mowing was effective in opening up the bayou to more normal flow, increasing water turbidity, and lowering water levels. The following evidence is available regarding the vegetative cutting.

- The reduction in aquatic vegetation in the channel was very visible, as was the return of turbid water conditions and the opening of the bayou to boat traffic. Dr. Schultz at NSU quantified the change in vegetative cover, species composition and water clarity; see Figures 2.6-7, 2.6-8 and 2.6-9. The mowing reduced vegetation, especially Hydrilla, and caused a return of turbid conditions. There had been concerns that mowed plants would simply recolonize the bayou downstream of the point where they were dumped into the bayou. This did not occur, even though the plant roots would not be removed by cutting. Dr. Schultz observed that the channel center has no roots remaining, which he attributed to increased turbidity and reduced light penetration that killed the roots. Note that there is still extensive vegetation next to the banks in many locations.

- The effects of vegetation control on channel flow and water levels were quantified by measurements made by the USGS. These data show a substantially greater flow after the mowing than before, yet water levels were less than during the height of the clogging event.

2.6.3 Causes of the vegetative clogging

The invasion of bayous and other water bodies by species such as *Hydrilla* has been a reasonably common occurrence in Louisiana in recent years (Brassette, 1997). *Hydrilla* was introduced to U.S. coastal waters relatively recently and can generally out-compete native species in many environmental settings. In a sense, its appearance in any one bayou or pond is simply a matter of time and does not need any special explanation.

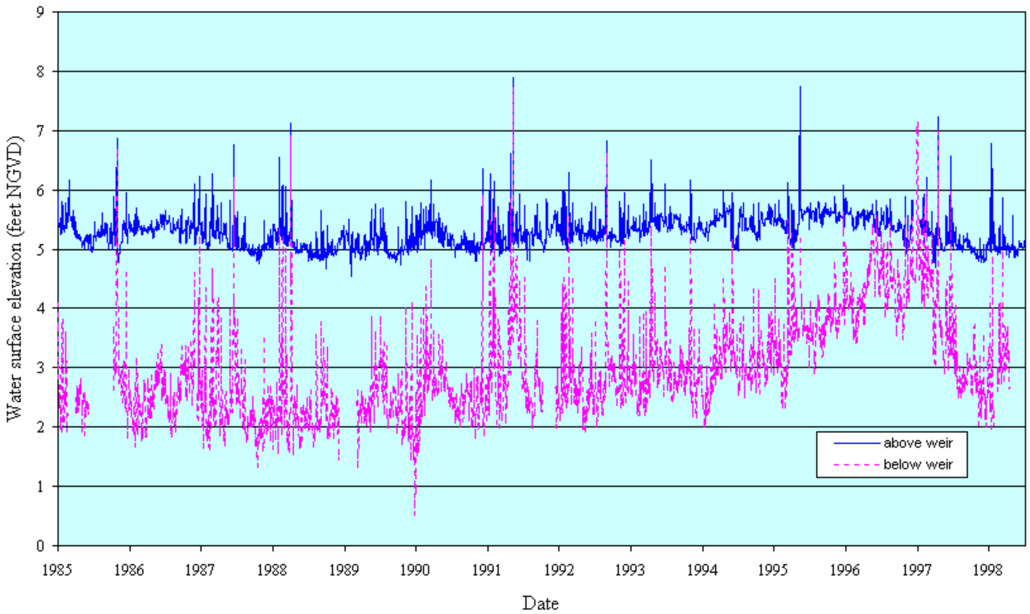
In the case of Bayou Lafourche, the timing of the recent *Hydrilla* incursion may have an explanation. Although Hydrilla can reproduce in turbid water, their competitive advantages are especially prominent during conditions of relatively clear-water in the early growing season (e.g. late winter, early spring). Such clear-water conditions appear to have occurred in Bayou Lafourche in the early 1990's. For example, Figure 2.6-10 provides data that indicate a reduction in turbidity in the bayou in 1994-1995, compared to prior years. (These data are based on monthly grab samples and may only approximate true average long-term conditions.)

The lower turbidity in Bayou Lafourche corresponds to similar turbidity patterns in the Mississippi River. Moreover, during the early 1990's the river stages rose relatively late in the year, so that maximum turbidity in Bayou Lafourche occurred after the initial growing season. Thus conditions were favorable to proliferation of *Hydrilla* and other submerged aquatic species. Once the bayou flows began to be impacted, water clarity improved even more and there was essentially no natural process that could control the vegetative growth.

The success of the recent mowing of submerged plants may be explained, at least in part, by the fact that in 1997 the river had a normal early stage, so that turbidity levels in the recently re-opened bayou were comparatively high during the early growing season. This fact, coupled with the increased velocity of flow, may have helped suppress recolonization of the bayou by aquatic plants.

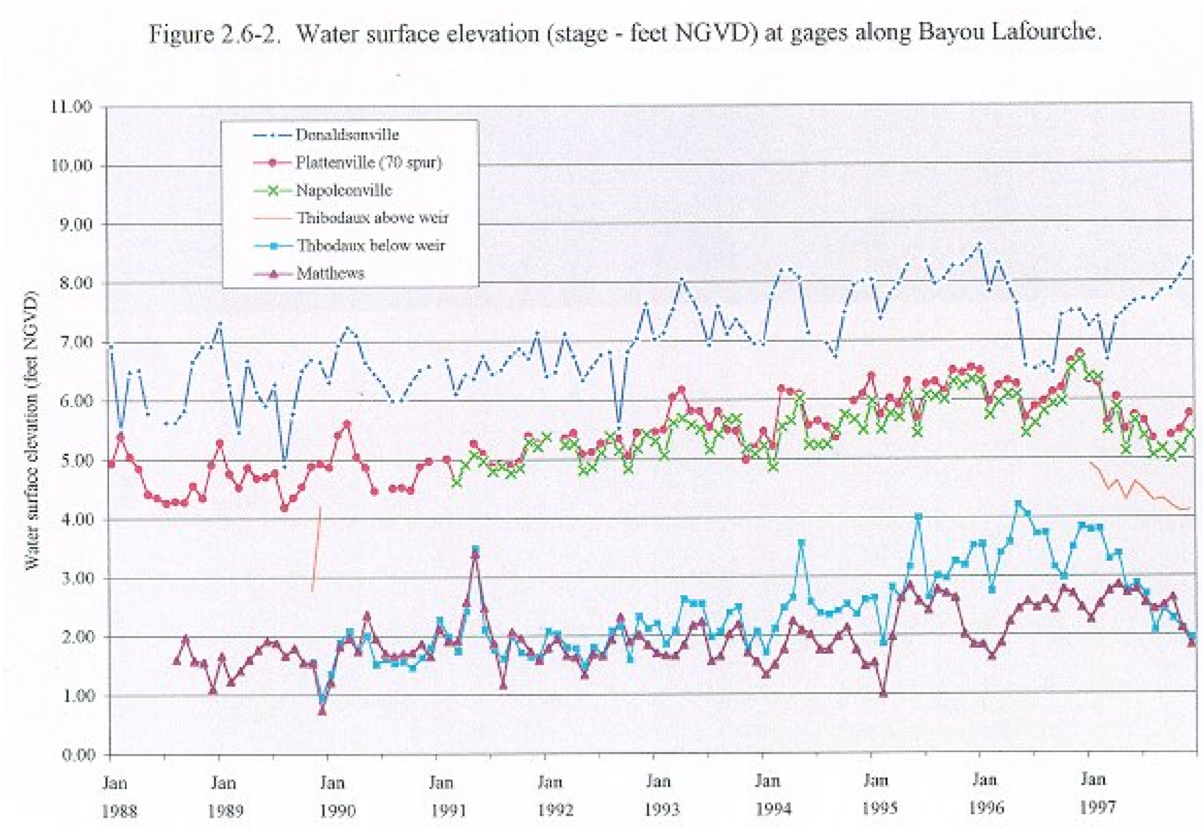
Presumably, vegetative growth may recur in the bayou at any time when turbidity levels are comparatively low during the growing season. Increasing the rate at which water would be diverted should increase turbidity levels and thus contribute to the control of vegetation. This is because higher diversion rates lead to greater flow velocities and transport of suspended sediments. However, it seems very likely that an active program of vegetative mowing will be necessary in at least some bayou reaches in at least some future years, if *Hydrilla* and other species are to be prevented from clogging bayou flows. Note the possibility also exists to control *Hydrilla* through herbicides that have been approved for use in association with drinking water supplies (such as fluoridone, which is marketed as Sonar). No such control has been proposed for Bayou Lafourche.

Figure 2.6-1. Daily Water Surface Elevations (stage - feet NGVD) of Bayou Lafourche at Thibodaux, 1985-1998



PRELIMINARY: DRAFT

Figure 2.6-2. Stages along Bayou



PRELIMINARY: DRAFT

Figure 2.6-3. Photographs to illustrate vegetative clogging

2.6-3a. Floating mats of vegetation near Raceland. Boat passage through these mats and the axxociated submerged vegetation was extremely difficult when this photo was taken in 1996. Note that the water shows no signs of turbidity.

2.6-3b. Example illustrating high water levels along Bayou Lafourche observed in 1996. This is just north of the U.S. 90 Bridge, between Mathews and Raceland.

Figure 2.6-4. Amount of aquatic vegetation before and during vegetative clogging of Bayou Lafourche

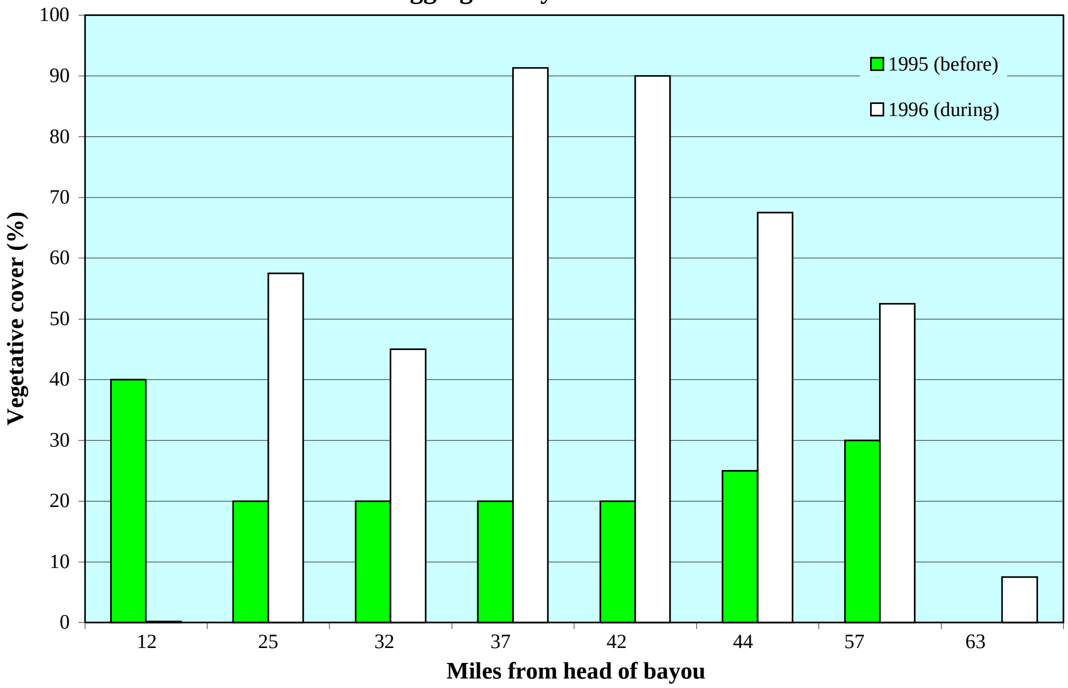
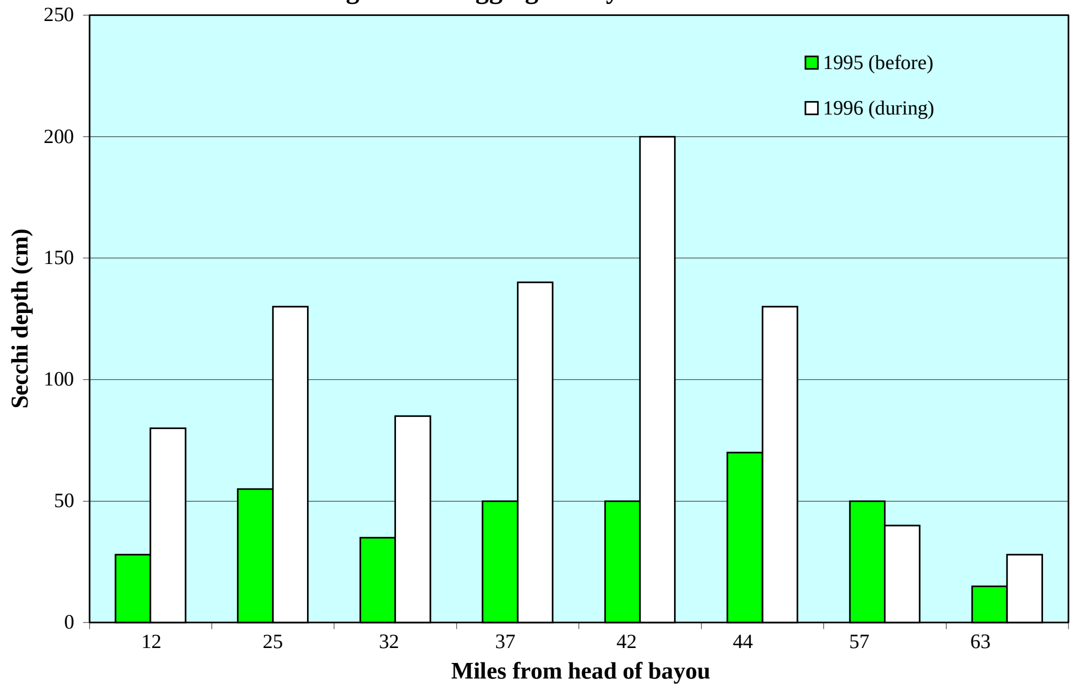


Figure 2.6-5. Effect of aquatic vegetation on water clarity before and during vegetative clogging of Bayou Lafourche



PRELIMINARY: DRAFT

Figure 2.6-6. Photographs of machine used to cut aquatic vegetation in Bayou Lafourche in 1996-97.

2.6-6a. Side view. The cutting apparatus is to the right and is in the raised position. When lowered into the water, vegetation is effectively mowed (plant stems separated from roots).

2.6-6b. Rear of machine, showing conveyor that dumps cut vegetation into Bayou. The alternative exists to discard vegetation into a small barge, which would then need to be towed to a bankside disposal site.

Figure 2.6-7. Amount of aquatic vegetation before, during, and after vegetative clogging of Bayou Lafourche

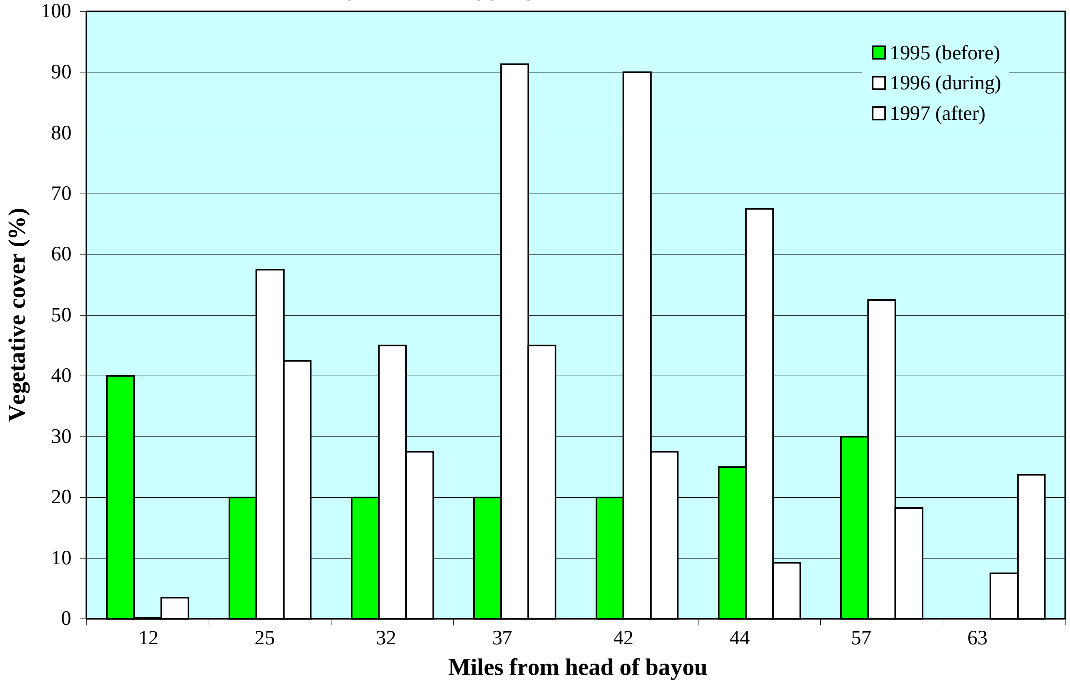
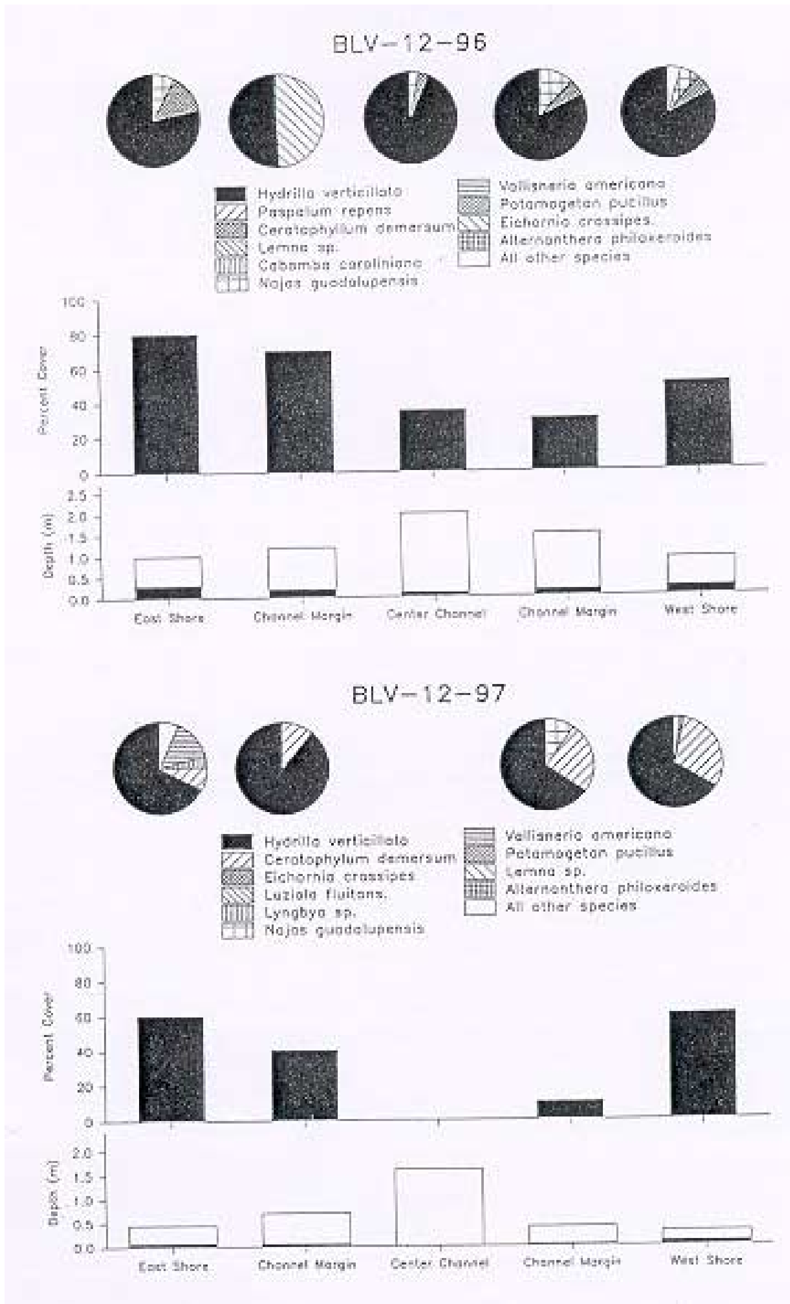
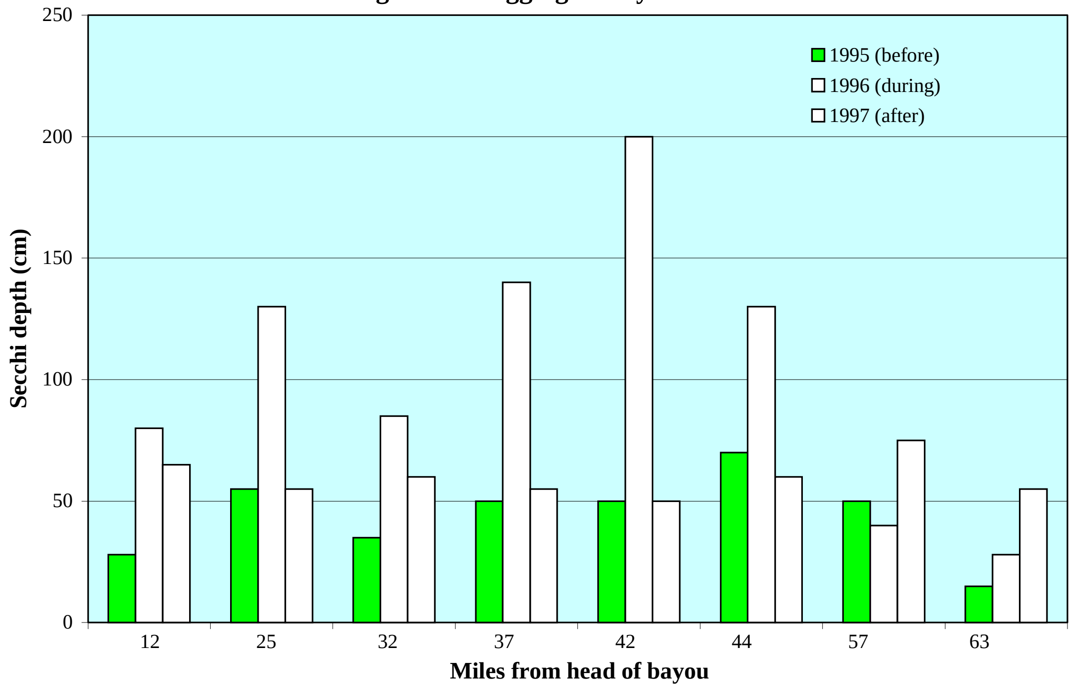


Figure 2.6-8. Comparison of species composition of aquatic vegetation during (1996) and after (1997) vegetative clogging of Bayou Lafourche. The selected station (BLV-12) is located about 25 miles downstream of Donaldsonville, and is a site that was heavily affected by vegetative clogging.



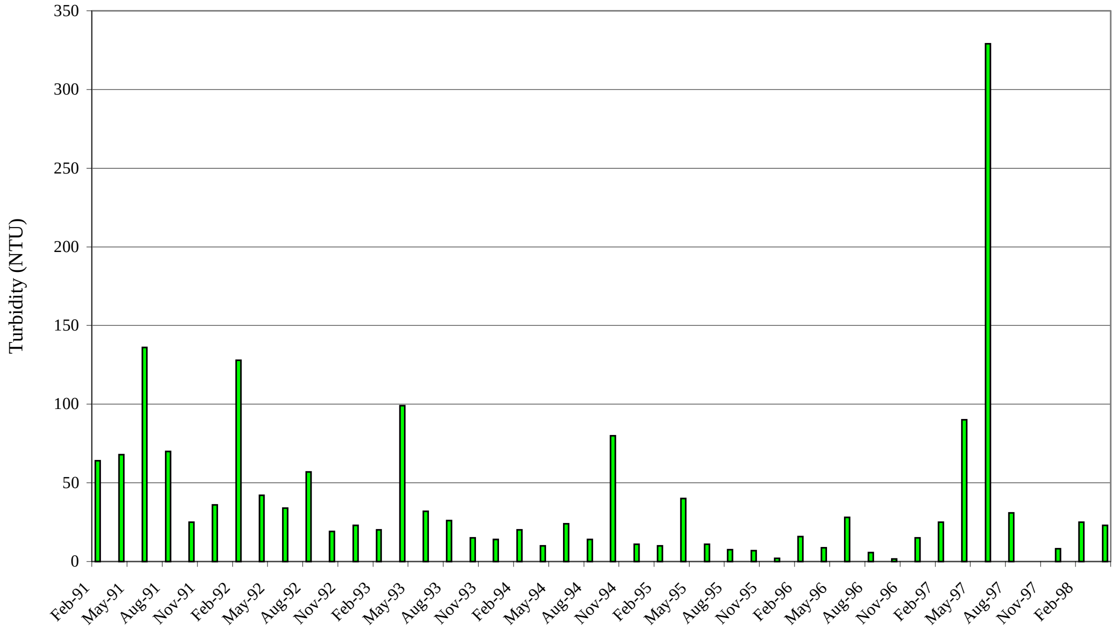
PRELIMINARY: DRAFT

Figure 2.6-9. Effect of aquatic vegetation on water clarity before, during, and after vegetative clogging in Bayou Lafourche



PRELIMINARY: DRAFT

Figure 2.6-10. Turbidity in Bayou Lafourche at Thibodaux from 1991 to 1998 based on data collected by USGS



PRELIMINARY: DRAFT

2.7 THE QUALITY OF WATER IN BAYOU LAFOURCHE

During the first half of the 20th century, Bayou Lafourche was a stagnant ditch that reportedly contained water of poor quality. Since the bayou was reopened, it has been successfully used as a public water supply source for more than 40 years. The principal water-quality problems that have been reported are coliform bacteria and nutrients above Lockport; and salinity below Lockport. For both problems, the effect of Mississippi River diversions appears to be to dilute contaminants. No substantive concerns about the quality of diverted water were identified in the extensive networking conducted as part of EPA's evaluation, which included meetings with every public water supply agency, and those state agencies with water-quality oversight responsibilities.

2.7.1 Attainment of designated uses

Bayou Lafourche from Donaldsonville to Larose, identified as stream segment code 020401 in the LDEQ Environmental Regulatory Code, has designated uses that include primary contact recreation, secondary contact recreation, propagation of fish and wildlife, and drinking water supply (LDEQ, 1997). The State's 1994 water quality inventory, done under Section 305(b) of the Clean Water Act assessed this segment of Bayou Lafourche as not supporting the uses of primary contact recreation and drinking water supply; secondary contact recreation was partially supported. Note that this does not mean that bayou water is unsuitable as a source of drinking water; only that it must be treated (as in fact it is) prior to that use (LDEQ, 1994).

LDEQ indicated that the primary sources of pollutants are non-point sources, including non-irrigated crop production, pastureland, septic tanks, construction (highways, roads, and bridges), and highway maintenance. "Minor" industrial and municipal point sources were also indicated. From these sources, the major causes of non-support of designated uses were listed as:

- pesticides;
- nutrients;
- siltation;
- organic enrichment and low dissolved oxygen (DO);
- salinity, total dissolved solids, and chlorides;
- pathogen indicators;
- suspended solids;
- noxious aquatic plants; and
- turbidity.

EPA has investigated these problems in three ways: by looking specifically at the parameter of greatest immediate concern to drinking water and recreation, coliform bacteria; by interpreting an extensive data base compiled by the USGS (see abstract in Appendix A); and by briefly considering the issue of whether Mississippi River water is "clean-enough" to be diverted to the bayou and wetlands.

2.7.2 Fecal coliform bacteria

It is not expected that high fecal coliform levels are introduced with river water, as based on USGS data from 1954-95, median concentration of fecal coliforms in Mississippi River water in the vicinity of Donaldsonville range between about 80/ and 210 colonies/100 ml (Swarzenski and Demcheck, 1998). Nonetheless, elevated coliform bacteria levels are observed in the bayou. Based on long-term LDEQ data, Waldon (1998; see abstract in Appendix A) found the average abundance of fecal coliform bacteria in Bayou Lafourche to be as follows.

	Period of record	Median fecal coliforms (MPN[1]/100 ml)	Geometric mean fecal coliforms (MPN/100ml)
Donaldsonville	1978-97	790	785
Thibodaux	1991-97	700	740
Raceland	1978-97	330	442
Lockport	1991-97	170	191

[1] MPN = most probable number

The Donaldsonville values are far above what can be explained by the diversion of river water, indicating that local sources such as storm runoff must be an important source. Further, since fecal coliforms disappear rapidly in the environment, the continued high level of coliforms between Donaldsonville and Thibodaux also suggests the presence of local sources, which probably include septic tanks. *The data indicate that diversion of additional Mississippi River water into the bayou would reduce the problem of fecal coliform contamination by diluting contaminated water and increasing flushing through the bayou*.

The water quality regulations for primary contact recreation (LDEQ, 1997) prohibit more than 25% of annual samples to exceed 400 colonies/100 ml. Thus, coliforms between Donaldsonville and Thibodaux may exceed this regulation. The limitations for drinking water supply are less stringent (monthly arithmetic mean of MPN not exceeding 10,000/ml), and are probably not usually exceeded in the bayou. Moreover, conventional water treatment processes are very effective in meeting the coliform standard.

2.7.3 Data compiled and collected by USGS

For this initial evaluation, EPA's primary focus was to obtain data to help explain the hydrology of the bayou, such as: the occurrence of turbidity in relationship to clogging by aquatic vegetation (see Section 2.6); the fate of nutrients that might be of value to the wetlands (discussed below); and the nature of salinity spikes that impact water supply uses and that can be controlled by freshwater diversions (also discussed below).

The data were obtained by the U.S. Geological Survey (see abstract of Swarzenski and Demchek, 1998, in Appendix A). USGS collected water quality samples along the bayou at six sites on June 27 and eight sites on October 23, 1996. Synoptic (same-time) surveys were conducted at 12 sites along the bayou and the GIWW on July 16 and September 6, 1996. Selected records were compiled from water supply districts along the bayou, and from the Nicolaus Paper Company. The latter firm operates the lowest point of significant withdrawal along the Bayou (between Lockport and Larose) and engages in intensive salinity monitoring during salinity spike events.

The results of the USGS work are briefly summarized below as follows: water quality reaches; salinity; turbidity; nutrients and organic material; chlorophyll and carbon; metals, and pesticides. The issue of sediment chemistry is also discussed, in the event the bayou is dredged and material must be disposed of.

Water quality reaches. Based solely on the 1996 sampling, Swarzenski and Demcheck (1998) found the bayou to have the following distinct reaches above Larose: upper, middle and lower.

- The upper reach, above Thibodaux, was close to the Mississippi River in quality. It clearly showed the impacts of diverted water.

- The middle reach, from Thibodaux to Lockport, had water quality characteristics more indicative of a eutrophic lake than a bayou. The data were obtained when the bayou was severely clogged by aquatic vegetation (see Section 2.6), and the bayou had lost its free-flowing character in this reach.

- The lower reach, from Lockport to Larose, was characterized by water quality influenced by multiple water sources, including the GIWW.

The bayou below the GIWW may be considered a fourth reach, which was studied only to a limited degree in the current evaluation.

Salinity. Figure 2.7-1a shows the results of the 1996 USGS sampling for chloride. Typically the water in the bayou is extremely fresh, reflecting levels in the Mississippi River. Maximum monthly chloride levels at both the Thibodaux and Lockport water supply intakes seldom exceed 40 mg/l, as shown in Figure 2.7-1b.

However, salinity spikes (short periods of high salinity) have been observed in the lower reaches of Bayou Lafourche. The salinity spikes typically occur in fall, when freshwater inflow from the Atchafalaya River through the GIWW is low. This is shown on Figure 2.7-2, which is based on data collected by the Nicolaus Paper Company at Valentine. At Larose, salinity levels frequently exceed 0.5 ppt, a level that is likely to begin to affect taste, and that is far too salty for the paper company. Levels over 2 ppt would render water undrinkable to humans under normal circumstances. Levels in the range 0.5 - 2.0 ppt are found in intermediate marsh. Further information on the spikes is presented in Section 2.3.6.

Turbidity (sediment). Figure 2.7-3a summarizes the results of the 1996 USGS sampling for turbidity. The figure shows relatively high turbidities in the upper and lower reaches, while turbidity in the middle reach of the bayou was very low. Such extremely low turbidity in the middle reach is abnormal, and differs from historic levels.

Figure 2.7-3b compares the 1996 USGS grab sample data to long-term monthly grab sample data from USGS and LDEQ. The data confirm that the extremely low turbidities observed in 1996 (less than 5 NTUs in the middle reach) were anomalous when compared to long-term data (25-40 NTU) in the same reach. This unusual event is attributed to vegetative clogging that was occurring at the time. However, historic data show that even under typical circumstances, turbidities in the middle reach are slightly less than the upper reach, which is directly influenced by the Mississippi River, and less than the lower reach near Larose, which is influenced by the GIWW.

Figure 2.7-4 shows maximum and minimum turbidities at the Thibodaux and Lockport water supply intakes. The data are consistent with Figure 2.6-10 in showing that turbidity has decreased during much of the 1990s. In support of this, analysis of long-term (1978-1993) secchi depth data from Bayou Lafourche by the Barataria-Terrebonne National Estuary Program (BTNEP) show a small but significant increasing trend in light penetration (i.e., decreasing turbidity) in the bayou from Donaldsonville to Larose (Rabalais et al., 1995). This pattern may be important to understanding vegetation events in the bayou. Increasing light penetration would have allowed a slow but progressive flourishing of aquatic vegetation, accounting for the lush growth in the spring of 1996 when turbidities were low.

Nutrients and organic materials. Based on data collected specifically for this study, inorganic nitrogen levels (nitrates plus nitrites) in the upper reach Bayou Lafourche show influence of the (comparatively) nutrient-rich waters of the Mississippi River; concentrations were 2 mg/l or greater in June 1996, and somewhat lower in October 1996 (Figure 2.7-5a). Based on USGS data from 1954-95, Swarzenski and Demcheck (1998) show levels of nitrate plus nitrite in the Mississippi River in the vicinity of Donaldsonville average about 1.4 mg/l (range 0.02-5.1 mg/l).

The concentrations in Bayou Lafourche are higher than typical nitrate and nitrite concentrations in other Louisiana streams (Demcheck et al., 1996). In contrast, analysis by

BTNEP of long-term LDEQ nutrient data from Bayou Lafourche between Donaldsonville and Thibodaux show slightly lower values for nitrate plus nitrite, ranging between 0.5 and 1.3 mg/l, with concentrations decreasing downstream (Rabalais et al., 1995). Most of the nutrients tested showed no significant trend over time, though a few (e.g., organic nitrogen at Donaldsonville, inorganic nitrogen at Raceland) showed slight decreasing trends.

When the middle reach of the bayou was clogged with aquatic vegetation and behaving like a linear lake in 1996, dissolved nitrate plus nitrite concentrations were almost non-existent there (Figure 2.7-5a). This is expected to reflect uptake of nutrients by the aquatic vegetation. In the lowest reach of the bayou sampled, below the zone where aquatic vegetation was prevalent, nitrates and nitrites again increased in the water column, but not to levels as high as in the upper bayou (Figure 2.7-5a). This may be a result of the influence of the GIWW and of tidal waters on this lower portion of the bayou.

Orthophosphate concentrations showed an increase in the middle reach of Bayou Lafourche near Mathews, where growth of aquatic vegetation was greatest (Figure 2.7-5b). It is possible that more orthophosphate is available in the water column here due to release by decomposing vegetation. The levels reached at this location (0.15 to almost 0.25 mg/l) are indicative of eutrophic conditions.

To evaluate another aspect of eutrophication, BTNEP used a system that incorporates dissolved oxygen concentrations and organic loading (measured by biological oxygen demand (BOD)) to classify water quality of various streams in the Barataria and Terrebonne Basins. The classification system is as follows.

Descriptive water quality	Water quality class	Oxygen saturation (%)	BOD (mg/l)
Good	I (oligosaprobic)	>70	<3
↓	II (beta-mesosaprobic)	50-70	3-5.9

	III (alpha-mesosaprobic)	30-49	6-12
Poor	IV (polysaprobic)	<30	>12

Reaches in the poorer classes could be expected to have significant problems of algal and/or vegetative growth in the event that diversions to the bayou were reduced, and stagnant flow conditions were allowed to develop. Five locations along Bayou Lafourche were classified as moderately to highly eutrophic, as follows.

	Class I	Class II	Class III	Class IV
Raceland				■
Thibodaux				■
Lockport			■	
Larose			■	
Cutoff		■		

Comparable information from Donaldsonville was not available for classification. It is likely that the moderate to poor water quality for conventional pollutants presented for the middle and lower reaches of Bayou Lafourche reflect local inputs, possibly from leaky septic systems, rather than quality of Mississippi River water, where BOD has shown a downward trend (Rabalais et al., 1995).

Chlorophyll a and carbon. Chlorophyll a and total organic carbon (TOC) concentrations in the water column also were high from Mathews to Lockport (Figure 2.7-6). These are indicative of greater a abundance of phytoplankton in the water below Thibodaux, characteristic of low-flow habitats such as lakes (in contrast to free-flowing streams). Although flows were also low at Raceland, chlorophyll a levels were not high there, presumably because the great abundance of submerged aquatic vegetation took up most of the free inorganic nitrogen, effectively competing with phytoplankton and suppressing a bloom.

Metals. Water quality of Bayou Lafourche with regard to contaminant levels is acceptable and broadly comparable to other Louisiana streams. Of all the locations sampled for water quality in Bayou Lafourche from about 1978-93 by LDEQ, EPA's EMAP-E program, and Mussel Watch, none were classified as having contaminants at levels of concern (Rabalais et al., 1995). BTNEP did report the average concentrations of mercury and copper in waters from Donaldsonville and lead in waters from Cutoff to be more than two standard deviations higher than the overall mean for the Barataria and Terrebonne Basins (based on 1981 LDEQ data). To examine actual metals concentrations, data collected or compiled as part of this study are presented in Table 2.7-1a.

None of the water concentrations of metals other than mercury exceed any water quality criteria, and are not expected to represent contamination of concern within the bayou. Mercury concentrations similar to the range reported for Bayou Lafourche were found throughout the Barataria and Terrebonne Basins in the BTNEP water quality assessment (Rabalais et al., 1995). Thus, levels in Bayou Lafourche are typical for the region, and do not represent a unique or local problem. It also should be noted that elevated concentrations of mercury in environmental samples are often the result of contamination that occurs during the sampling or analytical process, and may not be indicative of actual environmental conditions.

Concentrations of metals in Mississippi River water are similar to those in Bayou Lafourche in most cases. For example, Garbarino et al. (1995) reports the average concentration of dissolved lead from the river near Belle Chase to be about 0.26 ug/l. Dissolved copper was reported at about 2.6 ug/l; dissolved mercury was at about 0.006-0.008 ug/l. Swarzenski and Demcheck (1998) summarized dissolved metals data from the river near St. Francisville and Luling for the period from 1954-95. Means were not calculated because of some questionable data points; however, median values were <20 ug/l for copper and zinc, and <5 ug/l for lead. LDEQ (1994) reported the averaged water concentrations of these metals in the Mississippi River near Plaquemines, just upstream of Donaldsonville, to be 1.4 ug/l for arsenic; 0.4 ug/l for cadmium; 0.7 ug/l for chromium; 1.7 ug/l for copper; 0.4 ug/l for lead; and 0.3 ug/l for mercury.

Pesticides. The Mississippi River is a source of triazine herbicides, particularly atrazine, to Bayou Lafourche (Swarzenski and Demcheck, 1998). Concentrations in the river show a classic seasonal pulse, peaking in June or July. This reflects seasonal application to agricultural crops in the mid-continent of the United States. Peak concentrations sometimes briefly exceed EPA's Maximum Contaminant Level (MCL) of 3.0 ug/l, but average annual concentrations do not violate the standard. Atrazine concentrations in the upper reach of Bayou Lafourche are influenced by inputs from the river, though in July 1996, concentrations only ranged from 1.29 to 1.42 ug/l (Figure 2.7-7). In the middle reach of the bayou, atrazine concentrations increased to 3.19 ug/l in July, suggesting local sources. In the lower reach, atrazine concentrations reflect influence of GIWW water.

In July, 1991, a major fish kill occurred in Bayou Lafourche south of Lockport. The event is attributed to storm drainage from agricultural lands; the runoff followed a period when organophosphate insecticides (e.g. azinphos methyl) had been applied to combat a severe infestation of the cane borer (St. Pé, 1991).

Sediment chemistry. EPA's review of documents and networking with water-quality professionals identified no concerns about potential contamination of sediments in Bayou Lafourche that might be dredged in order to increase channel capacity.

In 1991-92, USGS sampled the bottom sediments of Bayou Lafourche for trace metals, as well as for natural characteristics (such as particle size and concentration of iron and manganese oxides) that largely determine the natural background concentrations of metals in sediments (McGee and Demcheck, 1995). Comparison of expected sediment concentrations based on sediment characteristics to measured concentrations provided a basis for determining where metals concentrations were elevated over background levels. McGee and Demcheck (1995) found arsenic, copper, lead, and zinc in elevated concentrations in sediments from one or more stations in Bayou Lafourche between Donaldsonville and Golden Meadow. Table 2.7-1b summarizes the average sediment concentrations for these metals for locations where concentrations exceeded expected background levels.

Most of the metals concentrations observed fall in the moderately polluted range of the EPA sediment classification guidelines presented in the above table. Although EPA (1977) does not give a guideline for moderate pollution with mercury, other sediment guidelines developed for various Canadian provinces (Persaud et al., 1993; EC and MOE, 1992) give 0.2 mg/kg of mercury as a "lowest effects level" or "minimal effect threshold". McGee and Demcheck (1995) cite several potential agricultural and industrial sources for arsenic, copper, lead, and zinc within the upper to middle reach of the bayou. Elevated levels of mercury were only found in the lower reach of the bayou, near Golden Meadow, where McGee and Demcheck (1995) suggest that fishing and marine industries may be contributing sources.

One might question whether metals contaminants in sediments come from suspended sediments diverted from the Mississippi River. Higher metals concentrations tend to associate with finer sediments (e.g., silts and clays), which would be diverted with river water. However, Garbarino et al. (1995) reported lead concentrations associated with suspended silts in river water from St. Francisville and Belle Chase in the range of 25-35 ug/g (= mg/kg). This is lower than the sediment concentrations observed downstream in the bayou.

2.7.4 Is the Mississippi River "clean enough" for Bayou Lafourche?

An issue often raised with regard to diversion projects in general, and thus for a Bayou Lafourche diversion, is whether the Mississippi River is "clean enough" to put into the bayous and wetlands of coastal Louisiana. People who are concerned that the Mississippi is contaminated cite the widespread occurrence of industrial, municipal and agricultural discharges to the river, and the occurrence of a "dead zone" that lies offshore of the existing delta.

Based on the best information now available, EPA believes that, within the context of all established regulatory criteria, the river is unquestionably "clean enough" for Bayou Lafourche. A detailed consideration of this issue is being developed as part of the Mississippi River Sediment, Nutrient, and Freshwater Reintroduction Study, which is expected to be completed in 1999. Important recent information on the subject comes from a publication by the U.S. Geological Survey on contaminants in the Mississippi River (Meade, 1995), a 1997 conference on Mississippi River Water Quality (LPBF, 1998; see especially Sabins, 1998), and an educational program developed by the LSU Agricultural Center Water Quality Advisory Committee (Coreil, 1998).

In general, the facts supporting a determination that the river is suitable for diversion into Bayou Lafourche are as follows. (The first five bullets below are based on Sabins, 1998.)

- The amount of information on river quality is extensive. The data consistently show that the quality of the water meets very stringent standards and is suitable for all uses except direct contact recreation (e.g. swimming). The recreation problem is because fecal coliform levels can exceed the standard at some stations at some times. However, over time, coliform levels in the river have been decreasing. Organic compounds, such as pesticides, are rarely detected in river samples, and individual concentrations rarely if ever exceed water quality criteria. The one ongoing concern is seasonally high levels of the herbicide atrazine. Concentrations of this pesticide fall below EPA guidelines for drinking water.

- A recent study by the Louisiana Department of Environmental Quality (LDEQ), in cooperation of EPA, tested whether river water was toxic to fathead minnow larvae and daphnid crustaceans (e.g. whether there were adverse effects on survival, growth or reproduction of these species). Most tests showed no adverse impacts, and the data as a whole showed no pattern that would be evidence of ongoing toxicity.

- Another recent DEQ study evaluated whether there is contamination of the flesh in river fish. 130 compounds were tested. Over 95% of the fish sampled showed none of the compounds, and concentrations in the remaining fish were extremely low, falling below action levels specified by the Federal Food and Drug Administration. Based on the study and on risk assessment of the data, the Louisiana Department of Health and Hospitals and DEQ concurred in determining that there is no need for a fish consumption advisory from the river. Because fish tend to be a sensitive indicator of chronic, long-term water pollution, EPA considers this clean bill of health to be significant. Note that in general all recent studies of the Mississippi River show healthy fish populations including important recreational and commercial species such as bass and catfish.

- A 1992 study by the Louisiana Tumor Registry and LSU Medical Center found that incidence of cancers along the “industrial river corridor” between Baton Rouge and New Orleans is the same as or significantly lower than the national rates. With the exception of lung cancer among white males, river parish residents had a lower than average risk of developing the most common types of cancer. High death rates from cancer in the river corridor were related to lack of early detection and limited access to health care, and not to high incidence rates.

- Historically, a large quantity of designated toxic compounds have been discharged to the Mississippi River in Louisiana, causing the state to rank at or near the top of the national Toxic Release Inventory. However, the majority of this material is acid that is extremely diluted by the very large flow of the river. The total quantity of toxic releases has decreased substantially in recent years.

- Numerous diversions of Mississippi River occur without causing reported water quality problems (e.g. Caernarvon). Where problems have been reported, such as short-term algal bloom in Lake Pontchartrain when the Bonnet Carre Spillway is open, they relate to diversion into a large, open water body, not into a channel system.

- As indicated in the data comparisons presented previously, the quality of Mississippi River water is typically better than the existing quality of water in Bayou Lafourche. This is true for a wide array of pollutants, including nutrients, organic matter, fecal coliforms, heavy metals and pesticides.

- The drinking water that is produced from bayou diversions meets all standards.

- Arguably the most significant concern over quality in the Mississippi River is its high load of nutrients, which is the basic cause of the dead zone problem. These nutrients are harmful when discharged into open water bodies with a weak circulation; because they stimulate the growth of nuisance algae. But they can be beneficial when discharged into wetlands, where they will stimulate the growth of marsh grasses. As long as Bayou Lafourche is kept open, so that there is steady flow down the channel and into the wetlands, the nutrients would not be expected to stimulate the growth of nuisance vegetation.

- Nationwide and in Louisiana, the effects of the Clean Water Act and other efforts to improve water quality have resulted in rivers, lakes and estuaries that are now considerably cleaner than they were 25 years ago. EPA expects this trend to continue.

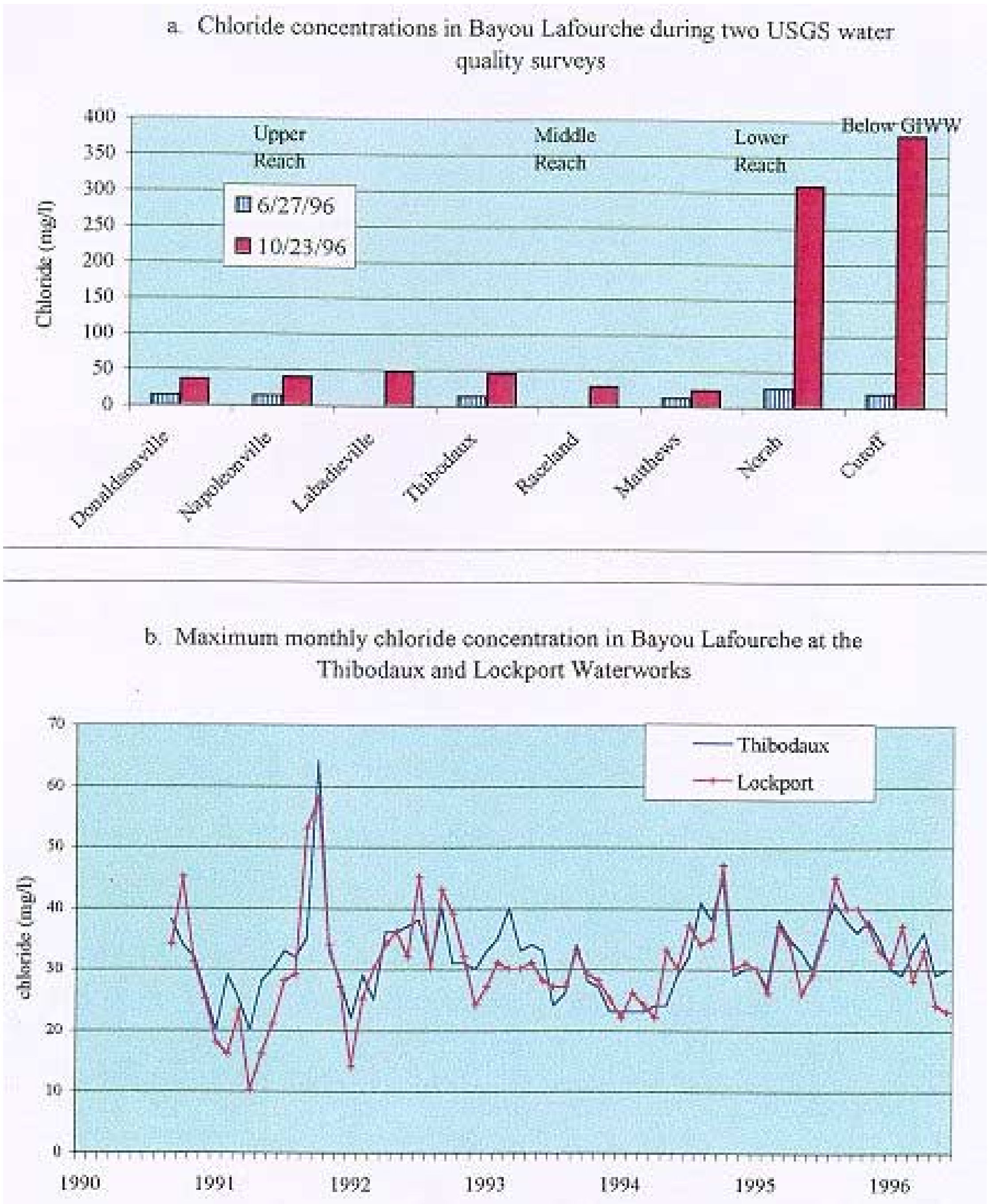
While the river is judged fully “clean enough” for diversion to the bayou under normal conditions, there is one potentially significant risk to bayou water quality that can arise from transfer of Mississippi River water. This is the risk that toxic contaminants could result from a barge accident and spill in the river above Donaldsonville. Such risks are real: in 1997, an incident with a barge carrying benzene caused the FWD to cease pumping for a period of time, to avoid introducing spilled benzene into Bayou Lafourche and contaminating the drinking water supply.

The key to minimizing the risk of toxic spills is to have sufficient warning to allow shut-down of the facilities. There is an Early Warning Organic Compound Detection System (EWOCDS) operational on the river between Baton Rouge and New Orleans that is a cooperative effort between water treatment plants, industries, and the Louisiana Department of Environmental Quality (LDEQ). EWOCDS was developed in 1986 to provide timely warning to public water treatment plants of contamination on the river from spills or releases. It involves the collection and analysis of water samples twice daily from five industrial sites and four water treatment plants between river miles 232 and 95.8.

The water intakes on the river at Donaldsonville for the existing FWD pump station and for the proposed diversion are in the middle of this sampling and warning network. The network has functioned effectively in the past and, to EPA’s knowledge, will continue to provide the existing FWD diversion, and any new diversion, with notice of a spill or release in a location on the river upstream of Bayou Lafourche. This does not reduce the risk of contamination to zero since, for example, if an accident occurred very near the diversion intake, some quantity of polluted water could be conveyed into the bayou before the diversion facility could be shutdown.

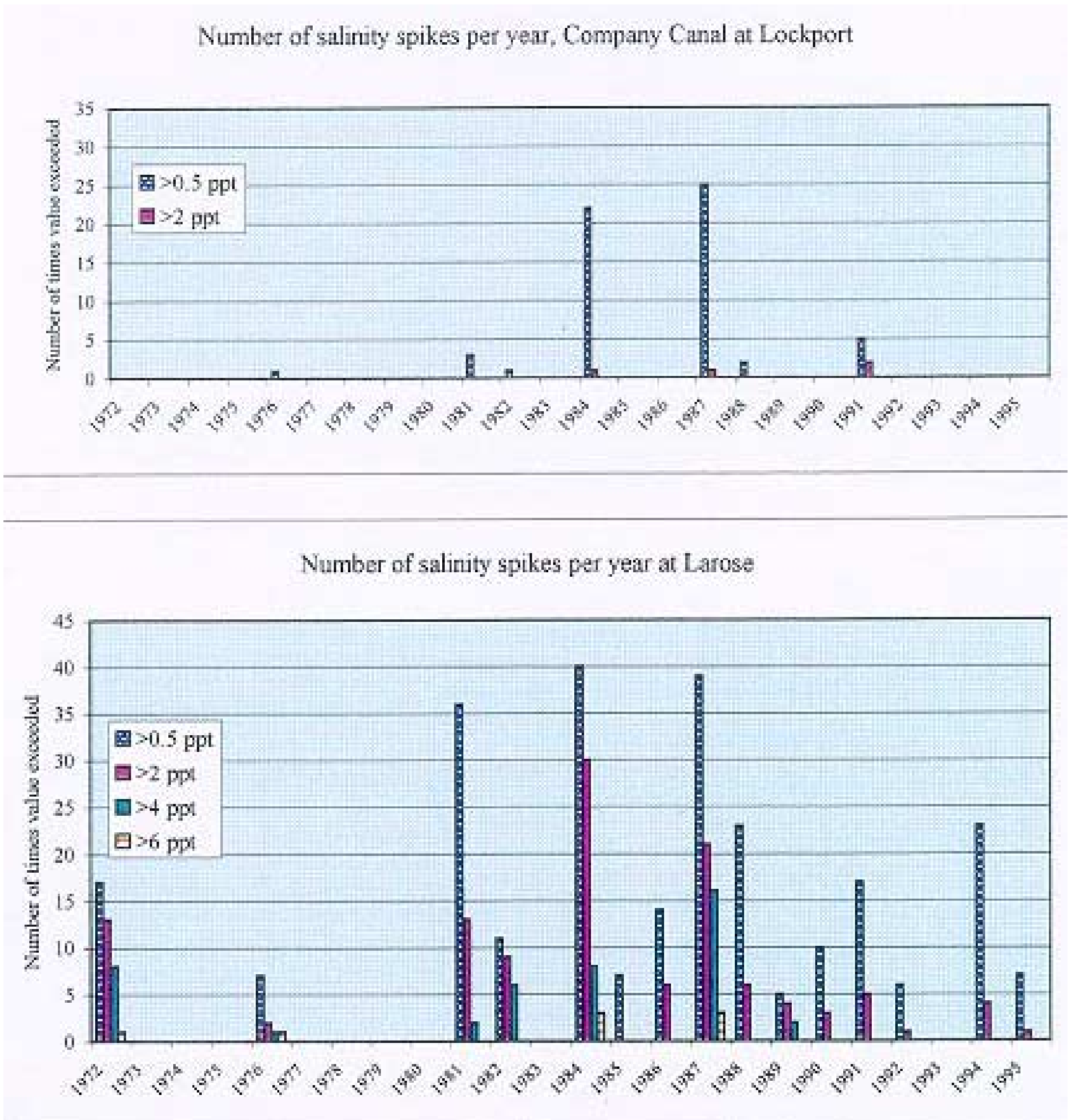
While pump shut-downs protect the bayou against toxic pollutants, the resulting drop in bayou water levels has raised concerns about bank stability. There is no reasonable alternative to a project operation that protects drinking water quality; thus it is appropriate to consider ways in which bayou-side properties can be protected against bank slumping when necessary pump shut-downs occur.

Figure 2.7-1. Salinity in Bayou Lafourche.



PRELIMINARY: DRAFT

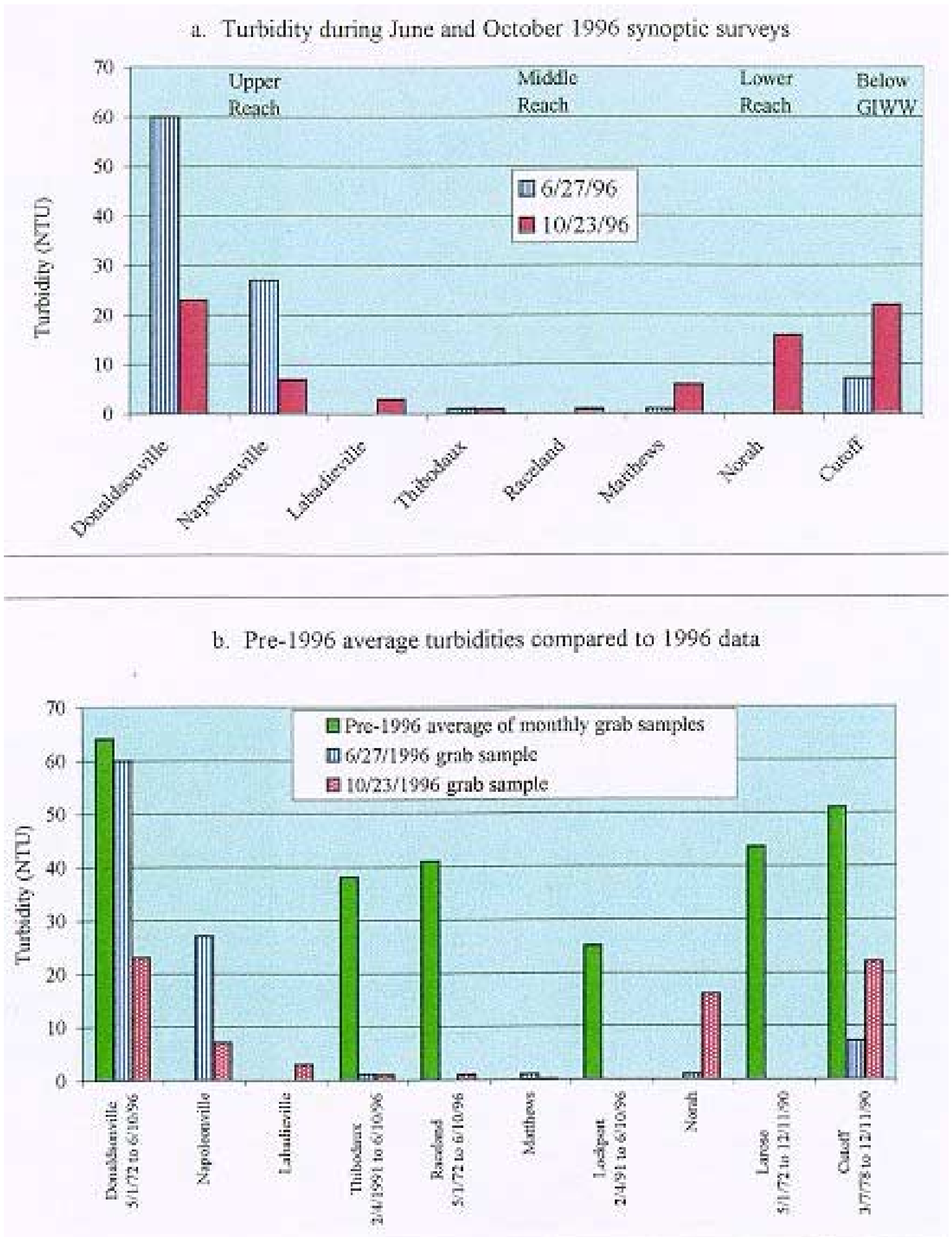
Figure 2.7-2. Salinity spikes at Lockport and Larose.



Salinity levels reported	Marsh type typically associated with the reported salinity levels
>0.5 ppt	intermediate
>2 ppt	intermediate
>4 ppt	intermediate to brackish
>6 ppt	brackish

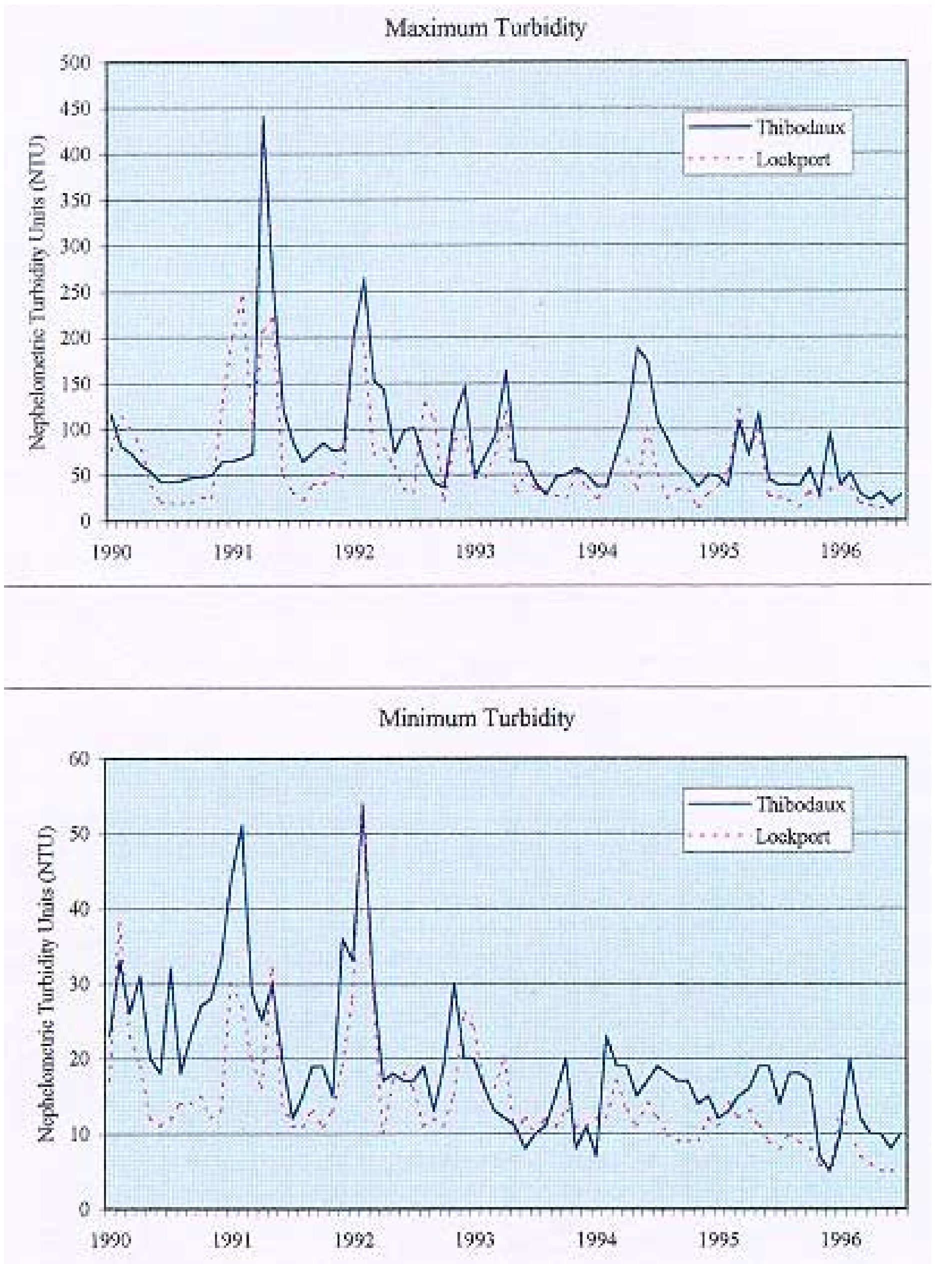
PRELIMINARY: DRAFT

Figure 2.7-3. Turbidity data for Bayou Lafourche



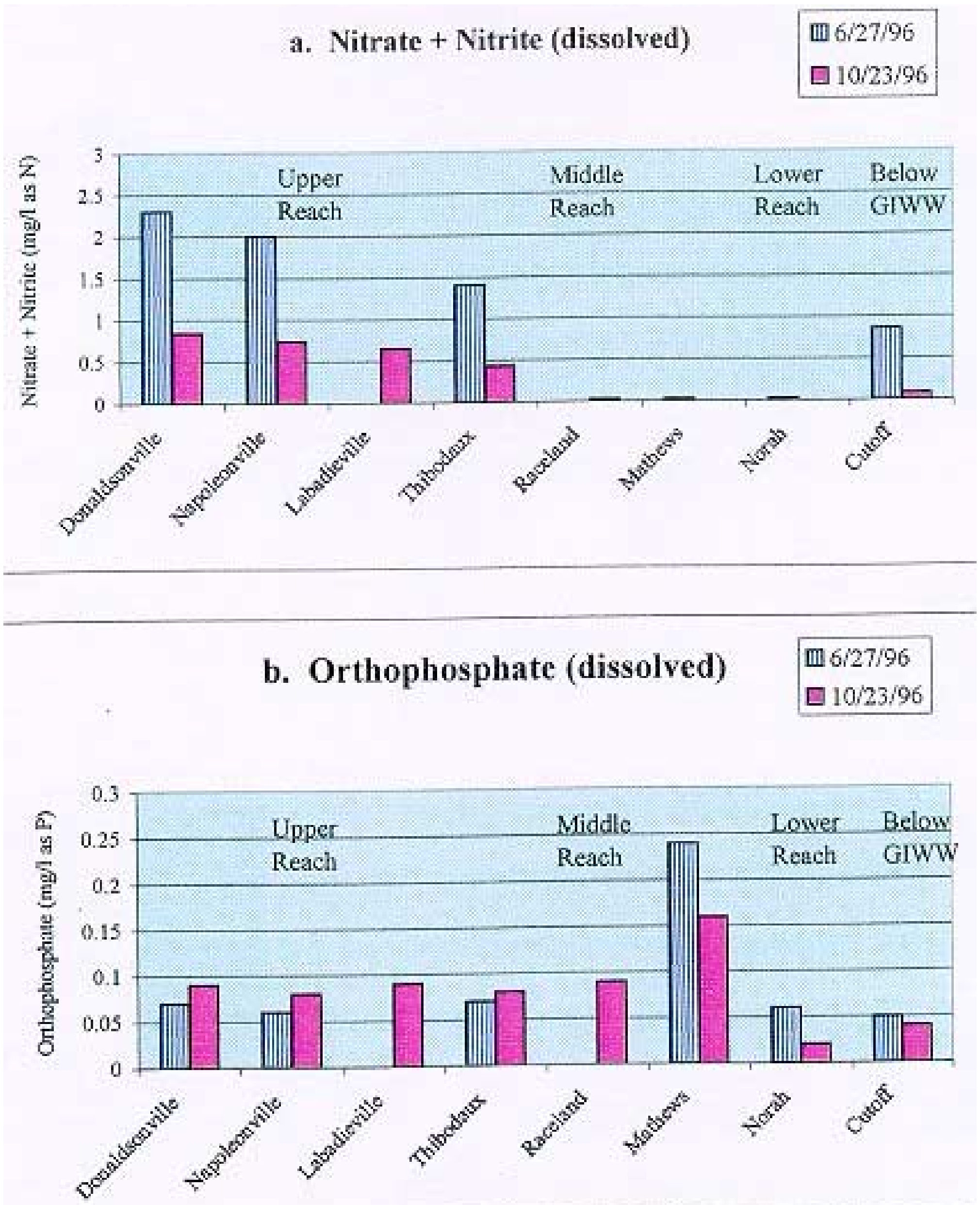
PRELIMINARY: DRAFT

Figure 2.7-4. Maximum and minimum turbidity at Thibodaux and Lockport waterworks



PRELIMINARY: DRAFT

Figure 2.7-5. Nutrient levels in Bayou Lafourche



PRELIMINARY: DRAFT

Figure 2.7-6. Chlorophyll a and total organic carbon levels in Bayou Lafourche

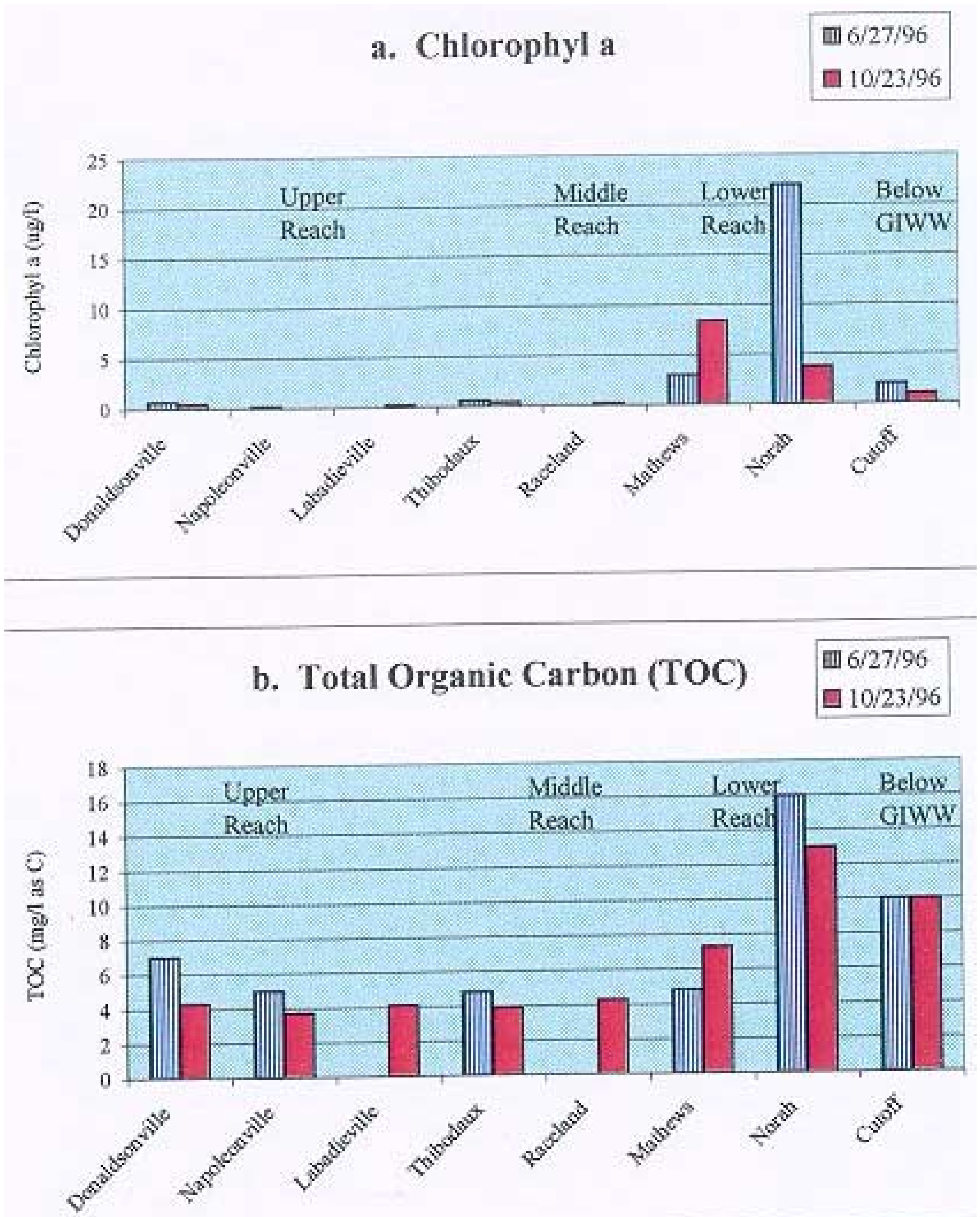
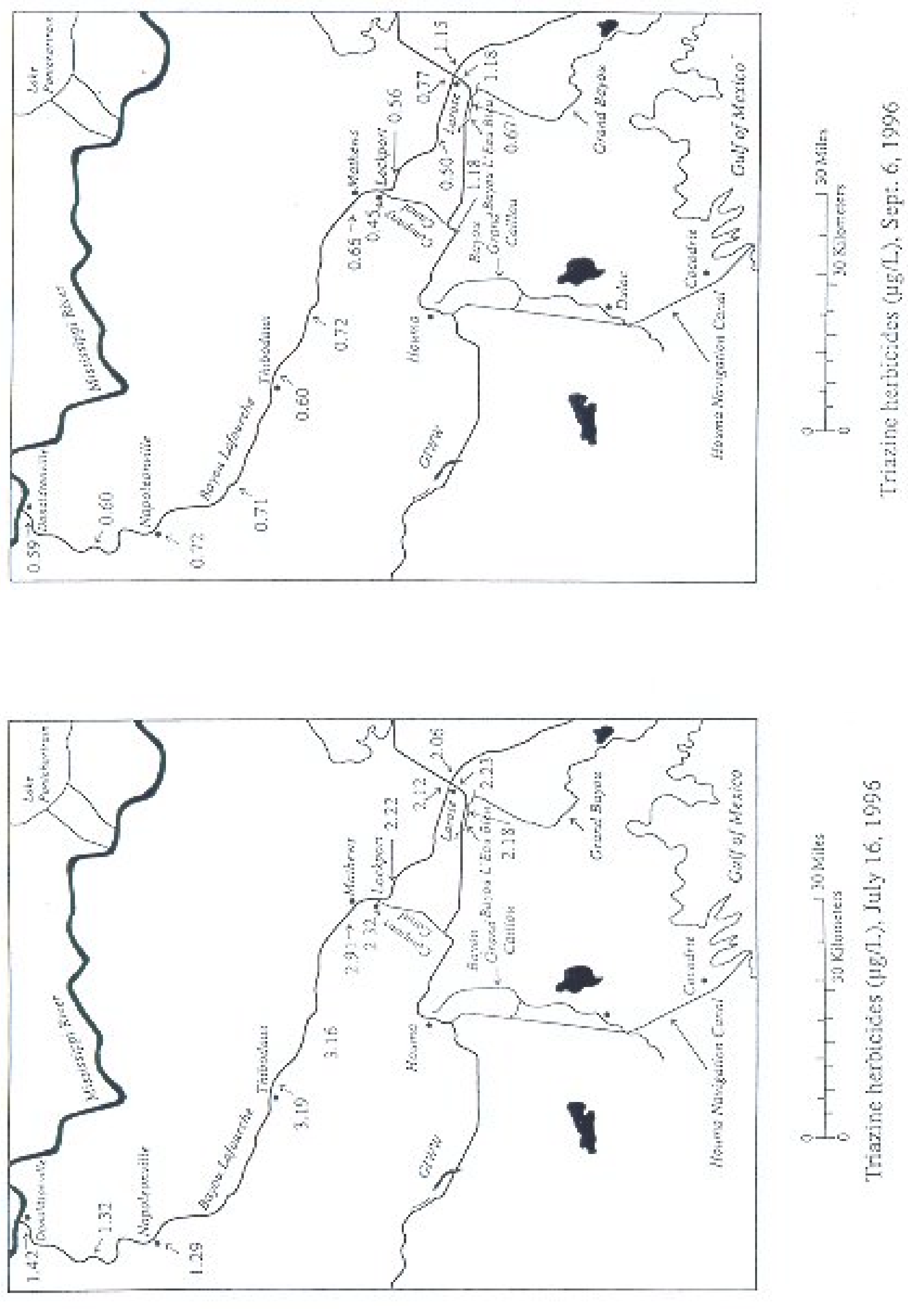


Figure 2.7-7. Concentration of triazine herbicides in Bayou Lafourche



PRELIMINARY: DRAFT

Table 2.7-1. Data on heavy metals in Bayou Lafourche.

A. Dissolved metals in water. In addition to data collected by USGS in two 1996 synoptic surveys, the table includes LDEQ monitoring data collected since 1991 and summarized by BTNEP (Rabalais et al., 1995), and LDEQ data collected in 1992-93 (LDEQ, 1994) are also presented.

Dissolved metals (ug/l)	USGS[2] - 6/27/96	USGS[2] - 10/23/96	LDEQ[3] - 1991 (BTNEP)	LDEQ[3] - 1992-93 (LDEQ, 1994)	EPA freshwater criteria (acute/chronic)	Louisiana freshwater criteria (acute/chronic)
Arsenic	3	2-3	1.5-2	<0.3-4.4	360/190	360/190
Cadmium[1]	<1	<1	0.08-0.11	0-0.3	3.9/1.1	15.4/0.66
Chromium[1]	<1l	<1	0.3-0.5	<0.2-2.0	16/11 (VI)	16/11 (VI)
Copper[1]	1.7-1.8	1.2-2.4	1.1-1.7	0.4-5.3	18/12	9.9/7.1
Lead[1]	<1	<1	0.31-0.33	0.2-0.9	82/3.2	34/3.2
Mercury	<0.1	na	0.074-0.078	0-0.7	2.4/0.012	2.4/0.012
Zinc[1]	<1-1.2	<1-1.4	na	na	120/110	65/59

1 hardness dependent criteria; criteria for chromium is hexavalent form.

2 range of values measured at Donaldsonville, Raceland, and Cutoff

3 range of values measured at Donaldsonville, Thibodaux, Raceland, and Lockport

B. Metals in sediment. All concentrations are in mg/kg.

	Arsenic	Copper	Lead	Mercury	Zinc
Donaldsonville					92 mg/kg
Klotzville	12 mg/kg	29 mg/kg			134 mg/kg
Labadieville	13 mg/kg	31 mg/kg			139 mg/kg
Thibodaux (above weir)	16 mg/kg	31 mg/kg	50 mg/kg		153 mg/kg
Golden Meadow	10 mg/kg	53 mg/kg	57 mg/kg	0.2 mg/kg	208 mg/kg
EPA (1977) Region 5 Great Lakes Guidelines for “moderately polluted” classification	3-8 mg/kg	25-50 mg/kg	40-60mg/kg	NA	90-200 mg/kg

2.8 USE OF BAYOU LAFOURCHE FOR WATER SUPPLY

To evaluate the use of Bayou Lafourche for water supply purposes, EPA's consultants interviewed representatives of each public water supplier along the bayou, as well as the General Manager of the Bayou Lafourche Freshwater District, and representatives of the Nicolaus Paper Company. Data were compiled from FWD records, and from data bases maintained by the U.S. Geological Survey. Aspects of this work are summarized in a short report prepared by Lee Wilson and Associates; see citation in Table 1.3-1 and abstract in Appendix A.

2.8.1 Existing conditions

Overview of FWD facilities and operations. The Bayou Lafourche Freshwater District (FWD) was formed by Act 113 of the 1950 Louisiana Legislature. The primary purpose for the FWD is to divert Mississippi River water into Bayou Lafourche for municipal and industrial uses. A secondary mandate in the authorizing legislation for the FWD is to provide basic maintenance of the bayou channel and its water quality.

To these ends, the FWD spends more than $600,000 per year to divert water and to undertake tasks such as removal of downed trees and, recently, mowing of vegetation. The District's income comes primarily from water sales and property taxes. Water sales are charged only to the municipal users, at three cents per thousand gallons (except for Terrebonne Parish, which pays a sliding scale, beginning at one cent per thousand gallons). Industrial users pay for water through property taxes.

Table 2.8-1 summarizes information about the FWD diversion facilities at Donaldsonville. FWD records contain engineering drawings that show a profile of the facility. These are not reproduced here because, except for the size of the pipes, they are identical with the proposed facility that is shown in Figure 3.2-1.

The plant operates in the siphon mode at times of high river stage (>15.7 feet), and in the pumping mode at other times. The plant has a nominal capacity of 400 cfs (the maximum siphon rate) and a practical capacity of 340 cfs (the maximum pumping rate). A diversion rate of 340 cfs is equivalent to nearly 220 million gallons per day (MGD). As shown in Figure 2.4-1, in recent years the FWD typically has diverted at least 150 cfs of Mississippi River water into Bayou Lafourche FWD and the diversion rate has averaged more than 100 MGD.

Users and use of water. Table 2.8-2 summarizes data regarding withdrawals of bayou water. Annual values for each user are given for 1984, 1989 and 1994, and monthly values for 1994 (the most recent year with comprehensive data). The data can be summarized as follows, with facilities listed north to south. (Note that the Terrebonne facility is not on or near the bayou, but draws water through the Lefort Canal.)

PUBLIC USERS	AVERAGE USE, MGD
Peoples Water Service (Ascension Parish)	1.64
Assumption Parish WD #1	3.14
Thibodaux Municipal Water Plant	3.29
Lafourche Parish Water District	7.94
Terrebonne Parish Water District	8.50
Lockport Filtration Plant	0.22
PRIVATE USERS	
Savoie Sugar Industries	2.64
Glenwood Sugar Coop.	2.14
Supreme Sugars	5.66
Lafourche Sugars	0.08
Raceland Sugars	2.77
Nicolaus Paper Inc.	2.13

Several additional sugar refineries identified in Table 2.8-2 are not listed above, as they did not operate in 1984. Some refineries report difficulties in obtaining water from the bayou; these problems appear to relate to factors such as clogging of intake canals, rather than conditions within the bayou itself. Municipal water systems report that the combination of raw water quality and conventional treatment is sufficient to meet drinking water requirements. However, some treatment problems are encountered when large amounts of “black water” (drainage from swamps) enters the bayou, as through Theriot Canal from Lake Bouef.

The total combined withdrawal of nearly 40 MGD is equivalent to a bayou flow of 61 cfs. Peak withdrawals occur during the sugar refining season, which is from the end of September to the end of December. The peak monthly demand in 1994 was in November, at an equivalent of 112 cfs (or about 72.5 MGD).

Collectively the public water supply facilities listed above meet essentially all of the public water supply needs of Assumption and Lafourche Parishes; the needs of Ascension Parish south (west) of the Mississippi River (i.e. Donaldsonville); much of the needs of Terrebonne Parish (which also is served by a plant near Houma); and the needs of Grand Isle in Jefferson Parish (which is hooked into the Lafourche Parish system). Water service is provided to approximately 250,000 persons.

One industrial facility of particular interest is Nicolaus Paper, which is: 1) potentially the user most sensitive to salinity, as they require a supply with chloride levels of 150 mg/l or less; 2) the lowermost withdrawal point along the bayou, and along with the Lockport plant the most commonly impacted by high salinity; and 3) planning to expand, with the potential to use 2 billion gallons/year in the future.

In the past, water diverted by sugar refineries was returned to the bayou, but is now disposed of toward the wetlands. The only registered point source of discharge to the bayou is the very small backwash flow at the Thibodaux water plant.

The fact that FWD often diverts 150-250 cfs or more, but downstream withdrawals are only 61 cfs on average, reflects two operating considerations: the need to provide sufficient head (water elevation) at the various intakes; and the seasonal objective of providing salinity control at the lowermost facilities

2.8.2 Projected need for rehabilitation and expansion of FWD facilities

Need for water based on growth in demand. Population projections for the area indicate growth of about 1 percent per year (see report by Wilson and Associates, Appendix A). Water demand for public water supplies may not grow at the same rate, due to the increasing importance of conservation programs, and the possibility that Grand Isle may be served by Jefferson Parish. But assuming growth at 1%/year, then over a 20 year period the maximum withdrawals of water from the bayou for public supply purposes would increase by 5 MGD to 30 MGD, on an average annual basis.

The only known increase in industrial demands is that Nicolaus Paper expects to approximately double their withdrawals in the near future. This would be an increase of about 2 MGD (3 cfs). That increase could be more than offset if the sugar refining industry continues to decline; such declines would be especially important in reducing withdrawals in the late fall. Overall, projecting a continued withdrawal of 15 MGD for industrial purposes is considered reasonable.

On balance, then, the projected increase in future withdrawals is on the order of 5 MGD, or about 8 cfs. This would bring total withdrawals to an average of 69 cfs, and a peak of perhaps 120 cfs.

A future water withdrawal of 69 cfs with a peak of 120 cfs would be substantially less than the existing 340 cfs capacity of the FWD. It will be many decades, if ever, before the District needs additional diversion capacity to satisfy the demand for municipal and industrial water along the bayou. Note that a portion of the diversion is discharged to the bayou or to wetlands, through means such as subsurface flow from septic tank leach fields.

Need to upgrade diversion facilities. The existing pumps at the Bayou Lafourche Freshwater District are now more than 40 years old, and experience numerous operational and maintenance problems, some related to the equipment type (there are no pumps designed to operate at variable speed and some to equipment age (parts are increasingly difficult to find). In recent years, the FWD has overhauled two of the pumps and can be expected to continue this practice in the future.

At this time, no other major rehabilitation needs have been identified. One significant need at the facility, for a modern control system, was addressed with improvements that were completed in the mid-1990s. The intake works has an inefficient design, but no known structural problems; there also are no known problems with the outlet pipes. However, a detailed inspection of these facilities has not been performed by FWD or EPA.

Need for plant expansion for salinity control. Bayou Lafourche periodically experiences the intrusion of salt water from the Gulf of Mexico (see Figure 2.7-2). This adversely impacts some freshwater users along the lower reaches of the bayou, especially the Lockport water plant and Nicolaus Paper. The same salinity that impacts water supply also is a significant threat to wetlands sustainability.

Thus, there is a need for freshwater to be conveyed down Bayou Lafourche for two reasons: to combat salinity impacts to wetlands, and to combat salinity impacts to water supplies. Consequently, any project to divert water for wetlands benefits will also provide benefits to the FWD. The converse is equally true: the nearly 50 years of diversions done by the FWD to date have undoubtedly benefited the wetlands.

USACE (1994, cited in Table 1.3-1) projected that FWD could eventually need to increase its diversions to 780 cfs for the purpose of providing salinity control during late fall. Thus under rare and extreme circumstances, up to 780 cfs of diversion capacity that results from a combined FWD and CWPPRA investment could be considered to have benefits to both wetlands and water supply. Note that with respect to salinity control, there is no loss of wetlands benefits if there are also water supply benefits; water that flows to the wetlands effectively provides the water supply benefit while en route.

Table 2.8-1. Description of existing diversion facilities

Information extracted from the files of the Bayou Lafourche Freshwater District

Facility name: Walter Lemann Memorial Pumping Station.

Plant utilizes vertical pumps to deliver water from a gravity suction through pipes over the levee into Bayou Lafourche. Three creosoted timber pile dolphins were driven in the river to protect the intake structure from navigation. The intake section of the pumping station consists of four 60-inch wrought iron pipes supported on timber pile bents near the river. These lines are each approximately 477 feet long. The center of the suction lines is at elevation minus 3.5 MSL. Intake to these 60-inch wrought iron pipes is accomplished through a single hood sector type compartmented wrought iron structure fastened to the four pipes. This structure is submerged to allow floating drift to pass over it at all times. The trash rack is set at approximately thirty degrees with the horizontal; this allows a greater area normal to the screen and prevents drift from catching on the trash rack. For safety from future scour and possible unstable river bank conditions and for stability five 14-inch by 14 ½-inch steel H-bearing piles at 89 pounds per foot, 58 feet long, driven to minus 55 feet MSL were used to support the intake. Wrought iron was used throughout for pipes and intake lines because it was thought to offer the best protection against corrosion.

The entire intake structure, with about 200 feet of each of the four intake pipelines attached, was fabricated at a plant seventy miles down the river. It was floated up the river by tugs and sunk to line and grade in a flooded trench. The trench was later diked at the land end and dewatered to allow construction of the remainder of the inlet line and connection to the reinforced concrete pump pits in the dry.

Soil borings at the pump pit site showed that since the time the Mississippi River had occupied Bayou Lafourche the bed of its former channel had filled to a great depth with sand, making a pile foundation for support of the pit unnecessary. The pump pit was constructed to provide four separate 11-foot by 11-foot pits. The overall outside dimensions at the base are 16-foot by 6-inch by 54-foot by 9-inch. Interlocking steel sheet piling, US M115 section, with wide flange beam waters, was used for the cofferdam construction and left in place as the outside forms for the underground section of the concrete pit. A tremied concrete seal was poured as a base in the cofferdam to prevent blowup from the river during dewatering operations. Each of the four pump pits are separated from one another by concrete walls. At the 60-inch pipe entrance into each pit, sluice gates were installed so that any pump pit could be dewatered for inspection and maintenance without interfering with the operation of the pumps in other pits.

Table 2.8-1. Continued.

The dimensions of the top floor of the pump pit structure on which rests the control house and office are 33 feet by 65 feet, part of this floor is cantilevered out from the walls of the pit. Each pumping unit consists of a 48-inch, 45,000 gpm axial flow vertical pump powered by a 250 H.P. Motor. These pumps are 51.0 feet in length and are about the second longest of their type and size in the United States. A 5.0 HP Vacuum pump is provided at each of these units to exhaust the air from the discharge line so that the siphon will go into effect. The vacuum pump must also remove any air that accumulates in the line during discharge of the 45,000 gpm unit. On the deck is a 15-ton overhead crane for handling pumps and motors when they are overhauled or repaired. There are three of the 45,000 gpm pumps in place with provision for installation of a fourth unit.

Each of the 45,000 gpm units discharge through right-angle elbows into 48-inch inside diameter wrought iron pipelines which carry the discharge from the pumps, a distance of approximately 875 feet, into the discharge basin in Bayou Lafourche. The center line of the discharge pipes is at elevation 40.0 MSL where they leave the pumps. For the 160 feet between the pump pit and the crown of the levee they remain at the elevation. During the next 114 feet they drop to elevation 20.0 MSL, falling another ten feet in the next 422 feet to elevation 9.06 MSL. From the latter point they rise in 125 feet to elevation 25.42 MSL and thence in 53 feet discharge into the discharge basin at elevation minus 1.0 MSL. The length of the respective pipes between the pumping station and the levee is supported on three concrete pile bents. On these bents the pipe supports rest on bronze plates and are free to move in any direction, thus providing for expansion and contraction. A Farval central grease lubricator provides for lubrication of the contact face between bronze plates and the pipe supports.

From the foregoing elevations of the pipelines it is evident that there is a sump between the levee and the discharge basin and a second siphon near the latter. The purpose of the sump is to provide a water seal to facilitate vacuum priming. Between the levee and the discharge basin the pipes are underground. Access to the inspection manholes, of which there are two to each pipeline, and to the vacuum and compound gages and corporation cocks, which were installed for observation purposes, is through grated structures placed over the pipelines.

The discharge structure of reinforced concrete measures 30 feet by 36 feet on the inside, the bottom is at elevation minus 5.00 MSL with the end sill at elevation plus 5.00 MSL. In this structure most of the energy of discharge is dissipated. The original design of the discharge basin placed the end sill at elevation 0.0 MSL, the bottom at minus 10.0 MSL and the outlet of the discharge pipes at minus 6.0 MSL. From this structure the water flows over the end sill into the bayou. There is considerable energy to be dissipated as the velocity at the discharge end of each 48-inch pipe is upwards of a minimum 8.3 feet per second depending on the head available.

TABLE 2.8-2: USE OF FRESHWATER FROM BAYOU LAFOURCHE, 1994

Source: U.S. Geological Survey

WATER DISTRICTS & CO.	AVERAGE FOR YEAR (MGD)			AVERAGE FOR MONTH, 1994 (MGD)											
PUBLIC WATER SUPPLY	1984	1989	1994	JAN 94	FEB 94	MAR 94	APR 94	MAY 94	JUN 94	JUL 94	AUG 94	SEP 94	OCT 94	NOV 94	DEC 94
Lafourche Parish Water District No. 1	6.977	7.944	7.939	7.896	7.700	7.745	7.893	8.286	8.084	7.812	7.849	7.881	7.798	8.085	8.238
Assumption Parish Water District No. 1	2.830	2.628	3.136	3.070	2.924	3.074	3.035	3.164	3.188	3.115	3.192	3.230	3.144	3.261	3.235
Peoples Water Service	1.521	1.567	1.636	1.521	1.634	1.648	1.689	1.588	1.492	1.594	1.626	1.748	1.714	1.848	1.531
Thibodaux Municipal Water Plant	3.341	2.624	3.294	3.183	2.872	3.463	3.379	3.545	4.521	3.461	3.018	3.189	3.206	2.976	2.714
Lockport Filtration Plant	0.260	0.200	0.216	0.209	0.236	0.239	0.242	0.259	0.233	0.224	0.240	0.247	0.237	0.235	0.226
Terrebonne Parish Water District	8.250	9.170	8.495	10.353	7.150	7.236	8.023	8.402	8.938	9.116	8.560	7.939	9.433	8.828	7.961
TOTAL PUBLIC	23.18	24.13	24.72	26.23	22.52	23.41	24.26	25.24	26.46	25.32	24.49	24.23	25.53	25.23	23.91
PRIVATE USERS															
Caldwell Sugars Co-op Inc.	0.184	0.025	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Lafourche Sugars	2.192	1.644	0.081	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.322	0.333	0.322
Raceland Sugars	0.000	0.000	2.766	0.557	0.617	0.557	0.024	0.023	0.024	0.023	0.023	0.833	8.361	12.960	9.197
Supreme Sugars	0.000	0.000	5.162	3.061	1.178	2.029	1.933	3.329	5.563	7.590	8.706	7.613	5.977	7.650	7.319
Glenwood Sugar Cooperative	1.381	1.734	2.144	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	8.361	11.360	6.006
Savoie Sugar Industries	2.520	2.375	2.642	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	12.516	12.933	6.250
Georgia Sugar Refinery	0.000	5.479	0.000												
South Coast Sugars	0.000	2.414	0.000												
Valentine Pulp	1.786	3.295	0.000												
Valentine Sugars	0.000	0.794	0.000												
Nicolaus Paper Inc.	0.000	0.000	2.133	1.792	1.862	2.146	2.057	1.908	3.131	1.983	2.227	2.378	2.420	2.407	2.275
TOTAL PRIVATE	5.69	16.89	14.85	5.41	3.66	4.73	4.01	5.26	8.72	9.60	10.96	10.82	37.64	47.31	31.05
TOTAL	28.87	41.02	39.56	31.64	26.17	28.14	28.28	30.50	35.17	34.92	35.44	35.06	63.17	72.54	54.95
cfs equivalent	45	63	61	49	40	44	44	47	54	54	55	54	98	112	85

Source: U.S. Geological Survey

PRELIMINARY: DRAFT

2.9 EROSION, SEDIMENTATION AND CHANNEL MATERIALS

This section briefly discusses erosion and sedimentation patterns in the bayou (2.9.1), the materials that are known to occur along the channel and on its banks (2.9.2), and what is known regarding existing conditions of bank stability (2.9.3).

2.9.1 Erosion and sedimentation patterns

The dynamics of erosion and sedimentation in a stream are related to water velocity and turbulence, sediment load, particle sizes of the sediment and characteristics of the stream bed and bank material. The evidence for Bayou Lafourche is that collectively the stream dynamics provide a regime in which erosion is rare. Thus, the channel has the tendency to fill in with sediment. Based on the principles of sediment transport, the coarsest materials (sand and larger silt particles) would drop out in the upper part of the bayou; finer silts would tend to deposit throughout the bayou; and clays would tend to stay in suspension.

The available channel cross-sections indicate fill has occurred throughout the length of the bayou, at least down to Lockport, and probably to the Gulf. A comparison of the 1883 long-profile of the bayou, and the current profile (Figure 2.2-1b) shows that there has been a disproportionately large increase in the elevation of the channel bottom in the upper five miles, i.e. the area where deposition of coarser sediments should be concentrated. The increase in channel bottom elevation in approximately 100 years was as much as 8 feet.

The observed velocities of flow of bayou water are consistent with the conclusion that the stream regime will not cause large-scale erosion. For example, the USACE (1994; see abstract in Appendix A) estimated that the bed and banks of Bayou Lafourche would be stable, i.e. not susceptible to erosion, if water velocity in the bayou remained below 2.5 feet per second (fps).

This was based on the assumption that bank sediments were primarily sand. Under typical dry weather flow conditions, velocities in the bayou above Lockport are 1 foot per second or less (USACE, 1994; see also Section 2.4.4), and thus the threshold for erosion is not even approached. If velocities do reach 2.5 fps during storms, any effects are very short-lived and localized. Actual gaging records by USGS indicate that even during times of storm runoff, maximum velocities are not much above 1 foot per second.

Schultz (1996) did not observe newly deposited sediment in the upper reach. This observation may be explained by the fact that the area was dredged by FWD in the early 1990s.

2.9.2 Bed and bank materials

Information on bed and bank materials has been obtained from several sources: a survey done by David Schultz at Nicholls State University (Schultz, 1996; see abstract in Appendix A); sediment cores taken and analyzed under the supervision of Pyburn and Odom (P&O, 1997a; see abstract in Appendix A); soils surveys published by the U.S. Soil Conservation Service (an agency now known as the Natural Resources Conservation Service; see citations in references-section of this report); and discussions with the Bayou Lafourche Freshwater District (FWD).

Materials survey by Schultz (1996). During a survey of fish fauna of Bayou Lafourche conducted from 1994 to 1995, Schultz (1996) described the character of bottom materials in the bayou based on bottom coverage of the side-channel areas by mud, sand, shell, gravel, rubble, logs, and vegetation. Figure 2.9-1 summarizes his results. The term “mud” was used to distinguish fine-grained materials, such as silt and clay, from other materials.

At the head of the bayou (the first 5 km (3 miles) near Donaldsonville), the character of exposed bottom material along each side of the central channel was a combination of sand and mud (about half and half). From there to Golden Meadow, exposed mud was the predominant bottom type, ranging in coverage from about 40% to 90%, but varying mostly around 60% to 70%. If most of the bottom vegetation observed during this survey was rooted in mud, then the mud bottom type would cover from 80% to 90% of the bayou bottom in this reach. The predominance of mud suggests a stable or depositional environment.

Examples of bottom coverage by gravel, rubble, and shell that was apparently "dumped to stabilize the bottom or the bank" (Schultz, 1996) occurred throughout the bayou (Figure 2.9-1). Specific instances can be seen in Figure 2.9-1 at km 25 (near Napoleonville), km 45 (near Thibodaux), km 65 (just above Raceland), and km 75 (near Lockport). Tree debris on the bottom also is common from Napoleonville to Lockport (Figure 2.9-1). Apparently, shell on the bottom between Golden Meadow to Fourchon (about bayou km 118 to 150) represents naturally occurring oyster reefs (Schultz, 1996). Based on discussions with FWD and LDEQ, the occurrence of trash on the bayou is not widespread, and tends to be concentrated near bridge crossings; but may occur locally in almost any area.

The bottom of the bayou from about 10 km (about 6 miles) below Donaldsonville to Galliano (about 110 km or 66 miles below Donaldsonville) has substantial coverage by vegetation, which tends to stabilize bottom material and reduce erosion. Cutting of submerged aquatic vegetation was initiated by the FWD in November 1996, and while a re-survey of vegetation in the bayou in 1997 showed that density of vegetation was much reduced, vegetation still covered 15% to 45% of the bottom between bayou kilometers 40 and 100 (between about Thibodaux and Larose).

Sediment samples. A series of sediment samples were collected along Bayou Lafourche in May 1997 by Pyburn & Odom (1997a) as a part of this study. Two samples were taken from each of 50 locations between Donaldsonville and Larose - one toward the left bank and one toward the right bank. Results of particle size analyses were averaged for the two samples from each location, and are summarized in Figure 2.9-2.

The uppermost sampling location, in the immediate receiving area of the pump station, had mixed sediments with about half mud (silts and clays) and half coarser sediments including sand and gravel. Sediments with substantial proportions of coarse particles (e.g., shell) were also found further downstream, between Lockport and Larose; . Sediments in the intervening reach, between Donaldsonville and Lockport, were variable, but were on the average predominantly muds. The average particle size composition ranged between about 60% and 80% silts plus clays (Figure 2.9-2).

Variability in the distribution of sand along the bayou is clear in this figure. Based on these data, the reach between miles 2 and 5 consistently has the least sand in bottom sediments, possibly because this largely coincides with the reach that was dredged in the early 1990s. Dredging would have removed the existing mix of muds and sands; subsequent deposition would likely reflect a more uniform distribution of muds. The presence of at least 10% sand in most samples may reflect local sediment sources, such as material transported by storm runoff through highway culverts or at-grade channels.

There was often a relatively large variation in sediment composition between the left and right banks at a location. Figure 2.9-3 shows the locations samples for which there was a difference of more than 15% in the amount of sand in the sediments from the left and right banks. This may reflect locations of culverts and at-grade canals that are the source of the sands; and/or natural variations due to meanders in the channel bottom.

An additional sample was obtained after the work described above was completed. This sample was taken from material that had been dredged from just above the Thibodaux weir. The material was 50% fine sand, 25% silt and 25% clay.

Bank material based on soils data. Soils surveys conducted by the U.S. Soil Conservation Service (Spicer et al., 1976; and Mathews, 1984) identify the typical characteristics of materials found along Bayou Lafourche. From Donaldsonville to below Cutoff, the banks of the bayou are identified as Commerce soils. Commerce soils represent sediments deposited on natural levee ridges, and due to their proximity to the waterway, tend to have more sand and to be better drained than other soils on the natural levee. They are described as "somewhat poorly drained, moderately permeable, firm, mineral soils that formed in loamy alluvium.

Commerce soils have an erosion factor of 0.43 at the surface to 0.32 at depth; these are moderately high numbers on a scale of 0.05 to 0.69, where higher numbers indicate greater erosion potential. The soils are classified in hydrologic group C, meaning they have a slow rate of water transmission. They tend to be wet with limited bearing strength and permeability, presenting limitations for development of roadways, dikes or levees, and septic systems.

Freshwater District. Reaches of the bayou with bank materials that vary substantially from the Commerce soils certainly occur, though exact locations of every variation cannot be determined without literally coring every foot of the bank. However, some specific exceptions are known based on observations of FWD personnel who are responsible for maintenance of the channel.

One area of different conditions occurs in the reach of the upper bayou from the pump station to the Palo Alto bridge 3 miles downstream of Donaldsonville, where FWD disposed of material that was dredged in the early 1990s. This material might be expected to have characteristics similar to existing bottom sediments.

The FWD has reported the existence of numerous reaches along the bayou, especially where there is existing residential or commercial development, where fill has been placed to extend land area. Many of these areas are also where manmade and/or natural levees have been excavated or leveled to accommodate development. The characteristics, including stability, of such stretches of bayou bank would depend on factors such as the type of material used, how materials were placed, and slope of the final bank. The FWD has reported fill materials to include building materials, tires, roofing shingles, concrete rip rap, brick and mortar, appliances and other trash, sugar mill refuse, and others. Such non-native materials would tend to be less stable than native bank material.

2.9.3 Bank stability

Even though many of the banks of Bayou Lafourche are comparatively high and/or steep, significant bank slumping or caving is not observed. The principal stability problems that have been reported apparently result when the FWD is forced to shut down its pumps in response to a barge spill in the Mississippi River. In the upper part of the bayou, this leads to rapid drawdown in bayou water levels, and a consequent rapid drainage of soil water that had stabilized at a particular level. (Farther downstream, bayou levels are stabilized by the weir at Thibodaux.) Some properties above the Palo Alto Bridge may have experienced small-scale problems of this type. However, as the problems are the subject of litigation between property owners and the FWD, EPA is not able to conduct independent evaluations of the issue.

There is no evidence to indicate that significant bank stability issues arise from causes other than described above: e.g. a combination of weak material and steep, exposed banks; erosional scour; or boat wake erosion. Note that these conclusions regarding apparent stability under current conditions do not negate the need to assess bank stability impacts from a new diversion project, especially if that project involves any change in channel and bank conditions.

Figure 2.9-1. Characteristics of bottom materials (Schultz)

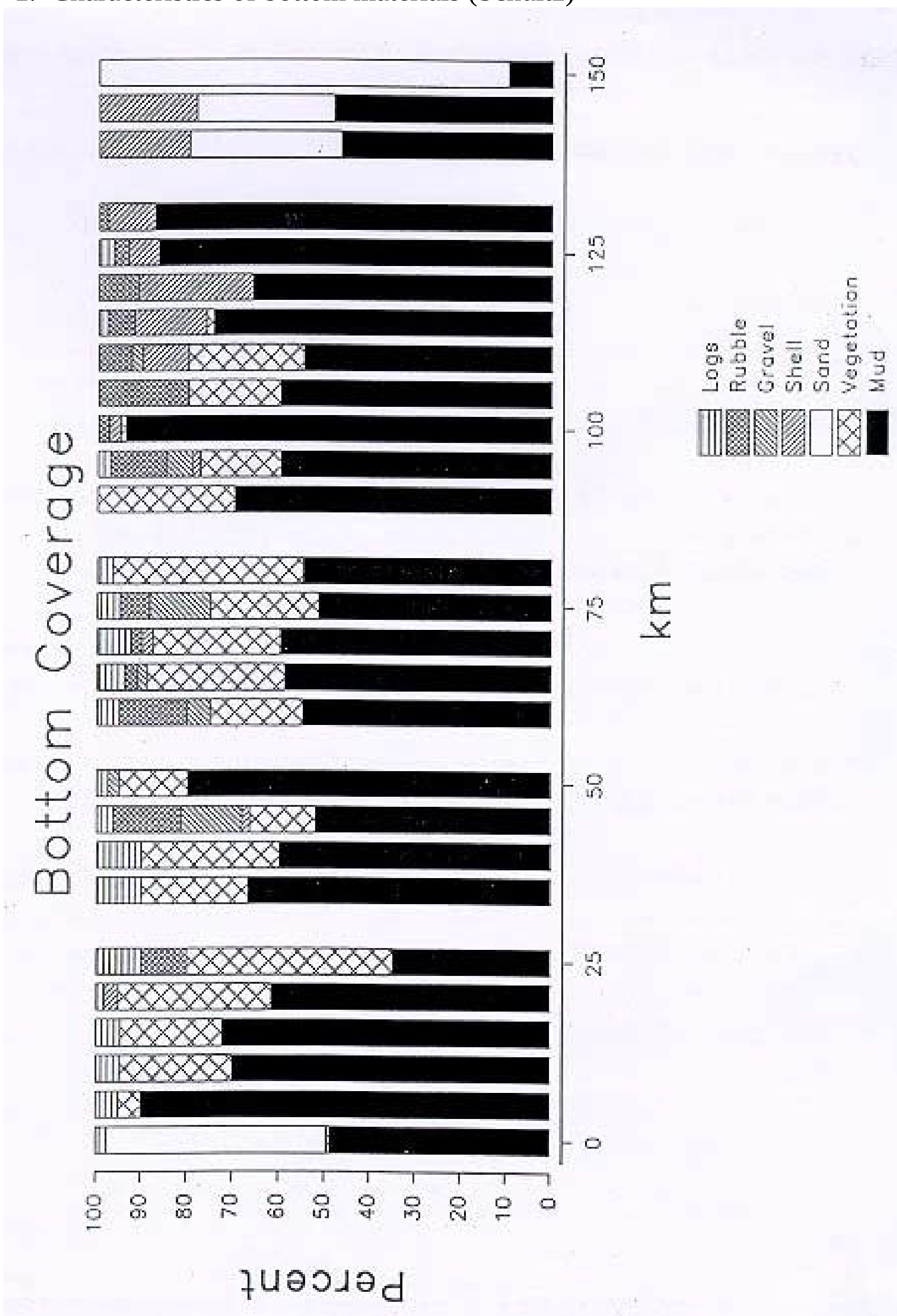


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Figure 2.9-2. Particle size characteristics of sediments collected in may 1997 from Bayou Lafourche from Donaldsonville to Larose

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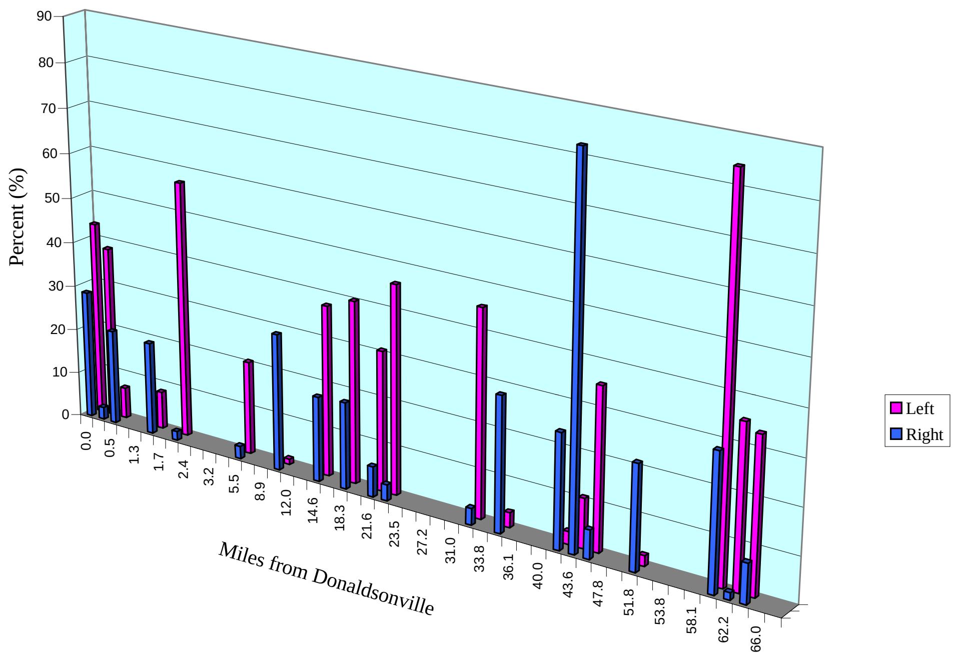
Figure 2.9-3. Percent of sand in sediments collected from the left and right banks of the Bayou Lafourche channel from Donaldsonville to Larose



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2.10 ADDITIONAL CONSIDERATIONS

This section presents information on characteristics of Bayou Lafourche that are in addition to those discussed previously: uses of the bayou; interconnections with ground water; and distribution of flows below Lockport.

2.10.1 Uses of the bayou

The focus of EPA's evaluation has been on the role of Bayou Lafourche as a conveyance channel for freshwater. The bayou has other uses, as well.

- The bayou provides some capacity for drainage of storm water; see discussions in Section 2.5. The developed land uses along the natural levees that benefit from this drainage fall primarily into two categories: urban and agricultural. The urban uses represent communities, businesses and residences along the highways on both sides of the bayou. These areas extend onto the levee back-slopes near the larger communities, especially Thibodaux. The agricultural uses dominate most levee back-slopes, with sugar cane fields being most common.

- Schultz (1996; see abstract in Appendix A) has surveyed recent species composition, distribution and abundance of fishes along Bayou Lafourche from August 1994 through July 1995. Table 2.10-1 summarizes the results of this survey; the cited report contains additional information in the form of 118 computer generated maps showing fish distribution. Schultz commented that high flow rates associated with diversions would tend to benefit species such as spotted bass, blue catfish, and channel catfish, at the expense of species such as bantam sunfish. These effects would occur primarily above the GIWW.

- Reflecting the healthy fishery, there has been increased recreation on Bayou Lafourche, especially below Raceland. Trophy bass (winners of regional bass tourneys) have been caught between Raceland and Lockport (personal communication, Kerry St. Pé, BTNEP). Recreational use above Raceland remains minor, when compared to many other parts of Louisiana, but has increased in recent years.

- When not clogged with vegetation, Bayou Lafourche is an attractive water course that undoubtedly contributes positively to the quality of life of the citizens who live near it. This aesthetic value presumably explains why bayou-side properties are often more expensive than other properties.

- Navigation is extensive in the reach below Larose, but extends upstream to above Raceland. The larger ships on the bayou are associated with fishing fleets or shipyards.

2.10.2 Interconnections with ground water

A quantitative analysis of ground water conditions was not conducted as part of this evaluation, based on the expectation that a diversion project would not change water levels in the bayou. The following discussion presents qualitative conclusions.

The geology of Bayou Lafourche allows free exchange of bayou water with the local ground water. Therefore, the ground water level near Bayou Lafourche will be near the level of the bayou surface. A profile along the at-grade canals between the bayou and the wetlands taken during dry conditions will approximate the lowest point in the regional water table. A rise in water levels in the bayou will lead to a rise in water levels in the bank, and this rise will be transmitted away from the bayou over time. The converse is true, and means that since water levels in the bayou do not fluctuate greatly, noticeable changes in ground water levels that are directly related to the bayou occur only very near the channel.

There are areas along the bayou where high water levels are a problem, because they cause soil water-logging, impede construction, restrict the drainage of on-site wastewater systems, or otherwise interfere with human uses of the land surface and subsurface. Such effects could be exacerbated, or alleviated, if a diversion project were to change bayou water levels.

2.10.3 Flow distribution below Lockport

Diversions into Bayou Lafourche stay within a single channel to Lockport. The flow pattern changes markedly at that location, because the bayou intersects Company Canal, and again at Larose, where the bayou intersects the GIWW. Company Canal in turn intersects the GIWW, and the GIWW crosses the Houma Navigation Canal, Bayou Terrebonne, Bayou L'Eau Bleu, and various channels in the Barataria Basin, including Bayou Perot, Bayou Rigolettes, Bayou Barataria and the Barataria Waterway. Thus, water diverted into the head of Bayou Lafourche at Donaldsonville can potentially flow to, or influence the flows in, many different channels.

Data collected or compiled in the USGS studies that are summarized in Appendix A establish two primary patterns of flow associated with Bayou Lafourche. First, Bayou Lafourche flows typically split at the intersection with Company Canal. Second, within the GIWW, the dominant flow direction is to the east. Flows down Bayou Lafourche thus reach the GIWW at Larose area in two ways, through Company Canal (then to the GIWW) and through the main bayou channel.

The GIWW is the largest of these channels and therefore is a dominant factor in the hydrology of the region. Unpublished data in the records of the United States Geological Survey show that the GIWW can carry several hundred to several thousand cfs eastward from the Atchafalaya River. This flow occurs even though the water level near Morgan City is only 0.5 to 1.5 feet higher than it is in the vicinity of Bayou Lafourche (a distance of more than 40 miles), and the resulting slope of the water surface is less than one-half inch per mile.

The exact amount of flow, and its distribution down side channels such as the Houma Navigation Canal (HNC), depends on a number of factors that influence water levels, such as Gulf tides, and strong northerly (low-water) or southerly (high-water) winds. While these later factors can cause water levels to rise or fall by two feet or more in extreme circumstances, they do not alter the basic physical relationship in which, on average, a vary flat gradient in the GIWW moves a large amount of water a long distance. Data and calculations show that a water level change in Houma of only a few tenths of an inch is sufficient to push an extra 250 to 500 cfs down the HNC.

The variations in water levels related to tides, storms and other factors can be important in the short-term, however. For example, records of salinity spikes have shown salt moving up the Houma Navigation Canal and then easterly along the GIWW at times when offshore winds are pushing Gulf water inland against the regional flow gradient. Salt has reached the Lockport area of Bayou Lafourche both by flowing up the Company Canal (counter to the normal direction) and up the bayou from the GIWW at Larose (also counter to the normal direction). Salt water movement up lower Bayou Lafourche (e.g. past Golden Meadow) does not appear to be a major factor in the historic salinity spikes, especially since the lower channel is now constrained by two flood gates.

Because of the complexity of flow conditions once Bayou Lafourche flows reach Lockport, EPA has relied on computer models to estimate where diverted water will flow (see Section 4.4).

Table 2.10-1. Fish species collected in Bayou Lafourche (Schultz, 1996). Species are listed by family, scientific name and common name. Also listed is the number of individuals sampled, the number of samples in which each species was found, and a summary description of the distribution of the species in the bayou. Distributional categories are abbreviated as follows: UB = upper bayou, UCB = upper and central bayou, CB = central bayou, CLB = central and lower bayou, LB = lower bayou, SD = split distribution in upper and lower bayou, U = ubiquitous.

Family ***Scientific name*** **(common name)**	**Number sampled**	**Sites sampled**	**Distribution**
Dasyatidae			
Dasyatis sabina (Atlantic stingray)	16	8	LB
Anguillidae			
Anguilla rostrata (American eel)	2	2	UB
Lepisosteidae			
Lepisosteus oculatus (spotted gar)	16	12	CB
Lepisosteus platostomus (shortnose gar)	1	1	UB
Elopidae			
Elops saurus (ladyfish)	2	2	LB
Clupeidae			
Alosa chrysochloris (skipjack herring)	7	7	U
Brevoortia patronus (Gulf menhaden)	7560	19	CLB
Harengula pensacolae (scaled sardine)	1	1	LB
Dorosoma cepedianum (gizzard shad)	35	15	U
Dorosoma petenense (threadfin shad)	54	14	U
Engraulidae			
Anchoa mitchilli (bay anchovy)	5975	48	CLB
Synodontidae			
Synodus foetens (inshore lizardfish)	7	4	LB
Cyprinidae			
Cyprinus carpio (common carp)	2	2	CB
Cyprinella iutrensis (red shiner)	424	9	UCB
Cyprinella venusta (blacktail shiner)	10	3	UB
Hybognathus hayi (cypress minnow)	1	1	UB
Hybognathus nuchalis (silvry minnow)	21	2	UB
Hybopsis aestivalis (speckled chub)	8	5	UB
Hybopsis storeriana (silver chub)	11	4	UB
Lythrurus fumeus (ribbon shiner)	78	10	UCB
Notemigonus crysoleucas (golden shiner)	14	4	UCB
Notropis amnis (pallid shiner)	11	2	UB
Notropis atherinoides (emerald shiner)	21	5	UCB

Family ***Scientific name* (common name)**	**Number sampled**	**Sites sampled**	**Distribution**
Cyprinidae (Continued)			
Notropis shumardi (silverband shiner)	13	3	UB
Notropis volucellus (mimic chiner)	10	2	UB
Opsopoedus emilae (pugnose minnow)	254	23	UCB
Pimephales vigilax (bullhead minnow)	341	23	UB
Ictaluridae *Ameiurus melas* (black bullhead)	1	1	UB
Ameiurus natalis (yellow bullhead)	2	2	CB
Ictalurus furcatus (blue catfish)	13	6	SD
Ictalurus punctatus (channel catfish)	92	28	SD
Noturus gvrinus (tadpole madtom)	21	11	UCB
Ariidae *Arius felis* (hardhead catfish)	25	6	LB
Aphredoderidae *Aphredoderus sayamus* (pirate perch)	1	1	UB
Batrachoididae *Opsanus beta* (Gulf toadfish)	1	1	LB
Porichthys plectrodon (Atlantic midshipman)	1	1	LB
Gobiesocidae *Gobiesox strumosus* (skilletfish)	4	2	LB
Belonidae *Strongylura marina* (Atlantic needlefish)	16	9	LB
Cyprinodontidae *Adinia xenica* (diamond killifish)	3	3	LB
Cyprinodon variegates (Sheepshead minnow)	8	2	LB
Fundulidae *Fundulus chrysotus* (golden killifish)	12	5	CB
*Fundulus grandis (*Gulf killifish)	101	7	LB
Fundulus similes (longnose killifish)	11	5	LB
Lucania parva (rainwater killifish)	80	8	CB
Poeciliidae *Gambusia affinis* (western mosquitofish)	440	31	UCB
Poecilia latipinna (sailfin molly)	198	22	SD
Heterandria Formosa (least killifish)	55	17	UCB
Atherinidae *Menidia beryllina* (inland silverside)	1964	60	U
Membras martinica (rough silverside)	296	8	LB

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Family ***Scientific name* (common name)**	**Number sampled**	**Sites sampled**	**Distribution**
Atherinidae (Continued) *Labidesthes sicculus* (brook silverside)	4	3	UB
Hemiramphidae *Hyporhamphus unifasciatus* (halfbeak)	1	1	LB
Syngnathidae *Syngnathus scovelli* (Gulf pipefish)	53	24	UCB
Syngnathus louisianae (chain pipefish)	3	3	LB
Moronidae *Morone saxatilis* (striped bass)	5	4	SD
Morone chrysops (white bass)	1	1	UB
Serranidae *Centropristis philadelphica* (rock sea bass)	1	1	LB
Centrarchidae *Chaenobryttus gulosus* (warmouth sunfish)	65	26	UCB
Lepomis cyanellus (green sunfish)	3	3	UB
Lepomis humilis (orangespotted sunfish)	5	3	UCB
Lepomis macrochirus (bluefill sunfish)	1240	53	UCB
Lepomis megalotis (longear sunfish)	1651	54	UCB
Lepomis microlophus (redear sunfish)	142	29	CB
Lepomis punctatus (spotted sunfish)	203	28	CB
Lepomis symmetricus (bantam sunfish)	27	10	CB
Micropterus punctulatus (spotted bass)	13	6	UB
Micropterus salmoides (largemouth bass)	94	36	UCB
Pomoxis annularis (white crappie)	2	2	CB
Pomoxis nigromaculatus (black crappie)	27	16	CB
Percidae *Etheostoma proeliare* (cypress darter)	1	1	UB
Etheostoma asprigene (mud darter)	1	1	UB
Etheostoma chlorosoma (bluntnose darter)	5	2	UB
Etheostoma fusiforme (swamp darter)	9	3	UB
Percina caprodes (logperch)	1	1	UB
Stizostedion canadense (sauger)	1	1	UB
Carangidae *Caranx hippos* (crevalle jack)	1	1	LB
Oligoplites saurus (leatherjacket)	1	1	LB
Selene vomer (lookdown)	1	1	LB
Choroscombrus chrysurus (Atlantic bumper)	1	1	LB

Family ***Scientific name* (common name)**	**Number sampled**	**Sites sampled**	**Distribution**
Lutjanidae			
Lutijanus griseus (gray snapper)	1	1	LB
Gerreidae			
Eucinostomus argenteus (silver jenny)	75	7	CLB
Sparidae			
Lagodon rhomboids (pinfish)	17	4	LB
Archosargus probatocephalus (sheepshead)	13	8	LB
Sciaenidae			
Micropogonias undulates (Atlantic croaker)	1542	21	CLB
Bairdiella chrysura (silver perch)	1	1	LB
Cynoscion nebulosus (spotted seatrout)	43	11	LB
Cynoscion arenarius (sand seatrout)	63	14	LB
Leiostomus xanthurus (spot)	593	14	LB
Pogonias cromis (black drum)	11	5	LB
Sciaenops ocellatus (red drum)	457	14	CLB
Menticirrhus americanus (southern kingfish)	30	2	LB
Aplodinotus grunniens (freshwater drum)	9	6	UB
Ephippidae			
Chaetodipterus faber (Atlantic spadefish)	3	3	LB
Mugilidae			
Mugil cephalus (striped mullet)	187	29	CLB
Mugil curema (white mullet)	4	2	LB
Uranoscopidae			
Astroscopus y-graecum (shouthern stargazer)	1	1	LB
Eleotridae			
Dormitator maculates (fat sleeper)	12	7	CB
Gobiidae			
Gobionellus oceanicus (highfin goby)	24	12	LB
Gobionellu shunfeldti (freshwater goby)	30	9	CB
Gobionellu boleosoma (darter goby)	225	10	LB
Gobionellu bosc (naked goby)	10	6	CLB
Microgobius gulosus (clown goby)	10	4	CLB
Stromateidae			
Peprilus burti (gulf butterfish)	1	1	LB
Triglidae			
Prionotus rubio (blackfin searobin)	1	1	LB
Prionotus tribulus (bighead searobin)	31	3	LB

Family ***Scientific name* (common name)**	**Number sampled**	**Sites sampled**	**Distribution**
Bothidae *Citharichthys spilopterus* (bay whiff)	129	17	CLB
Citharichthys macrops (spotted whiff)	1	1	LB
Paralichthys lethostigma (southern flounder)	7	4	CLB
Soleidae *Trinectes maculates* (hogchoker)	13	8	CB
Cynoglossidae *Symphurus plagiusa* (blackcheek tonguefish)	23	4	LB
Tetraodontidae *Sphoeroides parvus (*least puffer)	86	8	LB