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PROGRESS REPORT 3
for the period May 1995 to December 1998

Coast 2050 Region 2

WEST POINTE A LA HACHE FRESHWATER DIVERSION
BA-04

State Wetland Restoration Project

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Introduction

The Mississippi River was historically a major source of freshwater and sediment for the entire Louisiana deltaic coastal marsh system. Coastal Louisiana is actually a composite of seven different river deltas that were formed and then abandoned over the past 7,000 years. During this period, the river created approximately 14,000 mi^2 (36,260 km^2) of wetlands (Frazier 1967). The Louisiana coastal marsh system represents 96% of the deltaic wetlands on the Gulf of Mexico coast (Chabreck 1972). Unfortunately, due to a combination of natural processes such as subsidence and sea-level rise, and anthropogenic factors including canal dredging and sediment diversion, the river now funnels an annual average of $6.85x10^6$ tons ($6.21x10^{11}$ kg) of sediment over the continental shelf making it unavailable for coastal marshes (Bowman et al. 1995, Coleman 1988, Moger and Faust 1991). In addition, dam construction across Bayou LaFourche along with systematic levee building on the Mississippi River have reduced freshwater inputs by over 70% between 1901 and 1930 (Reed and Nyman 1995). The aforementioned reasons have all contributed to Louisiana having the highest rate of land loss in the United States (Wells and Coleman 1987; Dunbar et al. 1992).

Man-made diversions were designed to draw Mississippi River water into the nearby rice fields as early as the late 1800's. However, the first controlled freshwater diversion for fish and wildlife purposes was constructed at Bayou Lamoque in 1956. This project diverted freshwater into lower California Bay in the Breton Sound Basin to enhance oyster production (Bowman et al. 1995).

The essential goals of modern freshwater diversions are to enable better management of the productivity of wildlife and fishery resources by controlling salinity and to maintain marsh elevation by introducing additional freshwater and sediment to the marsh (Roberts et al. 1992). Some studies point to salinity as being the single most important factor in determining the distribution and abundance of many estuarine organisms (Gunter et al. 1974; Chatry and Chew 1985). Fishery resources depend upon movement of larval, post-larval, and juvenile organisms in the saline, brackish, and fresh/intermediate marsh nursery grounds and therefore depend on the sustained salinity gradient from fresh to saline wetlands. Several feasibility studies by the U. S. Army Corps of Engineers (USACE 1982) indicated that large-scale controlled freshwater diversions from the Mississippi River to adjacent estuarine areas were technically feasible and would result in substantial net benefits to estuarine organisms.

Marsh maintenance is achieved when freshwater and sediments enhance vegetation productivity to help balance the accretion deficit as a result of subsidence and other factors that contribute to net submergence. Marsh vertical accretion occurs through vegetative growth and mineral sedimentation (McCaffrey and Thomson 1980, Hatton etal. 1983, Bricker-Urso 1991, Nyman et al 1993, Callaway et al. 1995). Mineral sediments are believed to contribute to accretion both directly by increasing substrate elevation and indirectly by contributing bound nutrients (Bricker-Urso 1991, Nyman et al 1993, Callaway et al. 1995). The maintenance of marsh substrate elevation through both organic and inorganic accretion aids in reducing tidal water exchange and accompanying salinity, subsequently protecting freshwater and low-salinity wetland vegetation from salt-related stress (Roberts et al.1992).

Several freshwater diversions currently exist along the Mississippi River, including one on the west bank at West Pointe a la Hache, Louisiana. The West Pointe a la Hache project area contains approximately 9,300 ac (3,765 ha) of open water and 7,600 ac (3,076 ha) of brackish marsh and is located within the Barataria Basin in Plaquemines Parish. The area is bounded by Lake Judge Perez to the northwest, Bayou Grand Cheniere to the south, Socola Canal to the southeast, and the Mississippi River back protection levee to the north (figure 1). The diversion structure, located at river mile 48.9 Above Head of Passes (AHP) at West Pointe a la Hache, consists of eight 6-ft (1.8 m) diameter siphon tubes with a combined estimated maximum discharge of 2,144 cfs (60 cms). The siphons empty into a designated discharge pond with four outfall channels (Brown & Root, Inc. 1992). All siphon operations are performed by Plaquemines Parish Government (PPG) in accordance with an operations scheme developed in 1992 by Brown and Root Inc., and revised in 1993 by PPG and the Louisiana Department of Natural Resources, Coastal Restoration Division (LDNR/CRD). The revised operations scheme calls for the structure to have all eight pipes operating for all months except March and April when only two pipes are to be in operation. This reduction was primarily influenced by fishery concerns in the area.

The soils of the area consist of the Gentilly muck, Lafitte-Clovelly muck, and the Timbalier-Belle Pass association (USDA SCS [currently Natural Resources Conservation Service] 1991). The Gentilly muck is found mainly along the Grand Chenier natural ridge system and is characterized as a poorly drained, very fluid mineral soil. The Lafitte-Clovelly muck is scattered throughout the inner marsh and is characterized as a poorly drained, very fluid, slightly saline and organic soil. The Timbalier-Belle Pass association is characterized as a poorly drained organic type soil. The surface layers of these soil types are highly organic and susceptible to erosion when unvegetated (USDA SCS 1991).

Wetlands have deteriorated in the project area for the past 35 years. The average rate of change from marsh to non-marsh (including loss to both open-water and commercial development) has been increasing since the 1930's. Marsh loss rates for the Pointe a la Hache quadrangle were 0.28 mi^2/yr (0.73 km^2/yr) between 1932 and 1958, 0.75 mi^2/yr (1.94 km^2/yr) between 1958 and 1974, 0.71 mi^2/yr (1.84 km^2/yr) between 1974 and 1983, and 0.75 mi^2/yr (1.94 km^2/yr) between 1983 and 1990 (Dunbar et al. 1992).

O'Neil (1949) classified the area as brackish marsh consisting mainly of *Scirpus olneyi* (three-square grass) and *Spartina patens* (saltmeadow cordgrass). Chabreck and Linscombe (1978) classified the area as 66% saline marsh, 28% brackish marsh, and 6% non-marsh. The saltmarsh was dominated by *Juncus roemerianus* (needlerush), *S. patens*, and *Spartina alterniflora* (smooth cordgrass). The area was reclassified by Chabreck and Linscombe (1988) as brackish marsh and observations by the USDA SCS (1991) indicated that the brackish marsh was deteriorating and being encroached upon by saline marsh.

The main objective of the West Pointe a la Hache project was to reduce saltwater intrusion and wetland loss by restoring riverine inputs of freshwater, nutrients, and sediments to the marsh. Specific measurable goals established to evaluate project effectiveness include: (1) to increase marsh

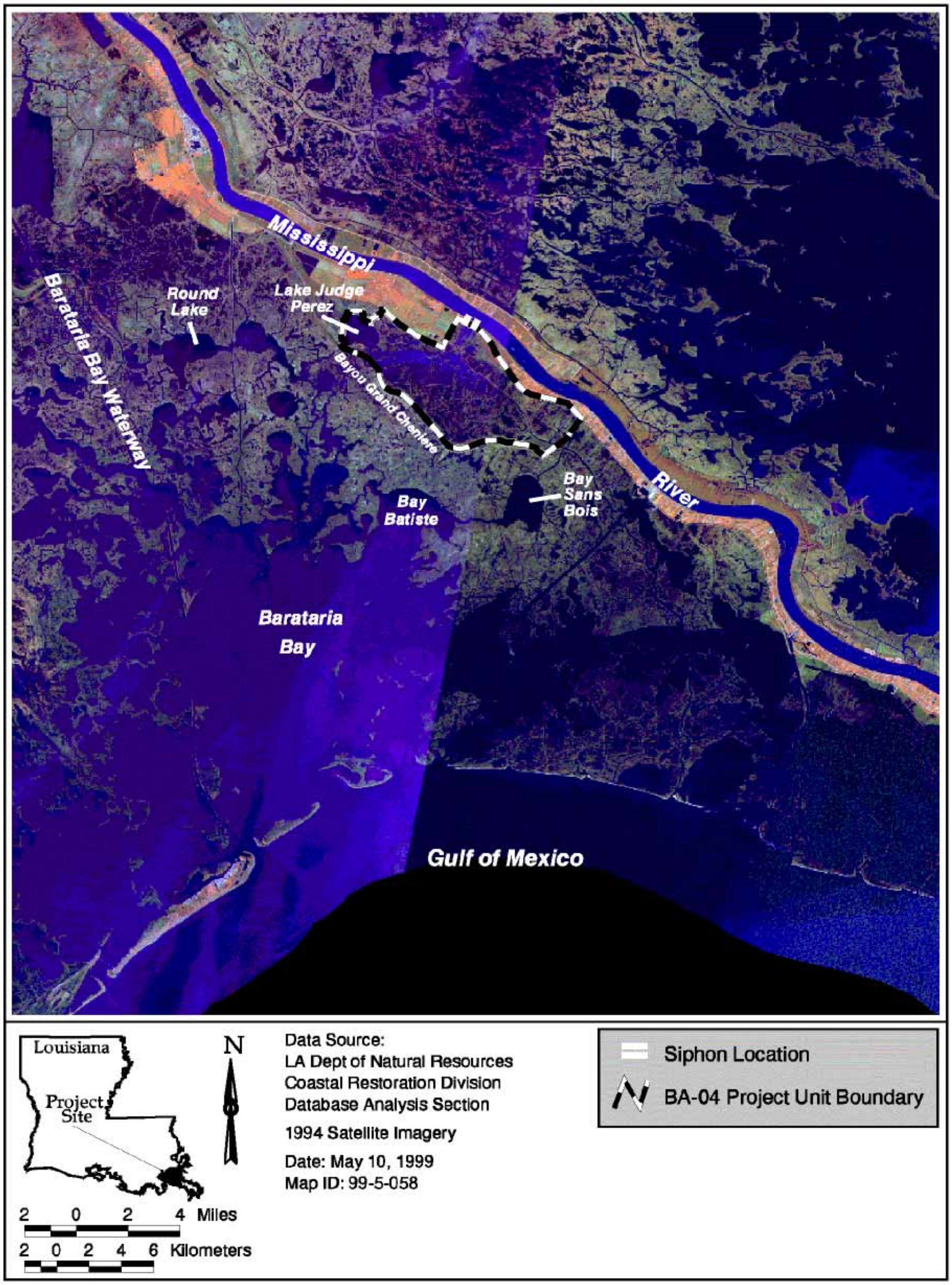


Figure 1. Location of the West Pointe a la Hache (BA-04) project area.

to open-water ratio, (2) to reduce and stabilize mean salinity, and (3) to increase relative abundance of the target plant species (*S. patens*) (LDNR 1996).

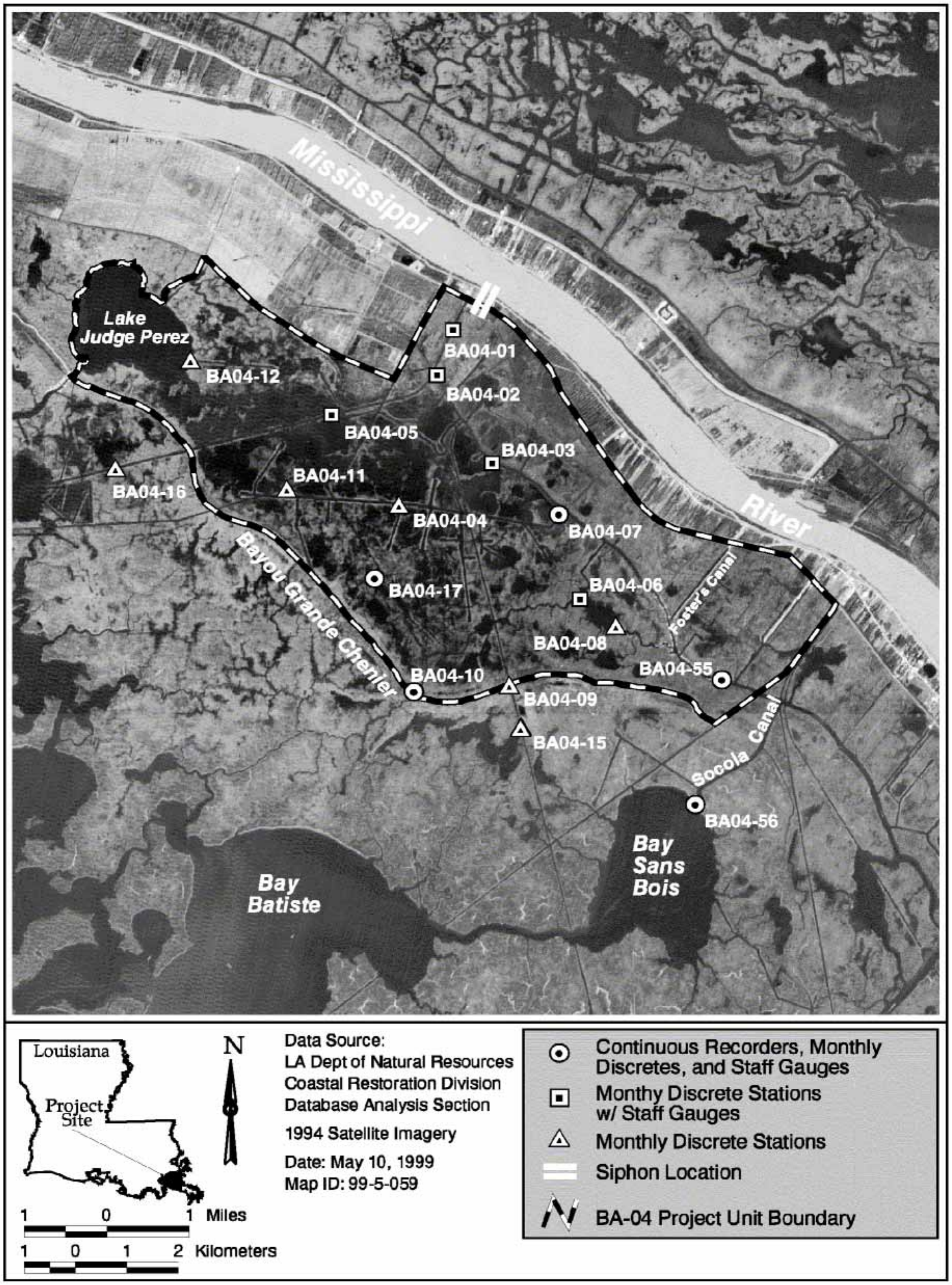
Methods

Daily siphon discharge in cubic feet per second (cfs) [cubic meters per second (cms)] have been estimated from the head differential between the river and the immediate outfall staff gauges and the number of pipes in operation since January 1993 when the diversion was first operated. Missing values for daily gauge readings or pipes operating were interpolated from known values when possible. In addition, mean monthly flow was calculated and grouped into one of three categories: noflow (0 cfs [0 cms]/month), minor discharge (0 - 1072 cfs [30 cms]/month), or major discharge (>1072 cfs [30 cms]/month). Operation strategies indicated intent to operate all 8 siphon pipes for all months except mid March through April when only 2-4 pipes would be operated.

Salinity (ppt), specific conductance (µsiemens/cm), water temperature (°C) (all measured at the surface and bottom of the water column), and water depth (ft) have been measured monthly at 17 stations throughout the project area (figure 2) by LDNR/CRD since May 28, 1992. In some instances in 1992, data were collected weekly or bi-weekly then averaged to obtain a monthly mean for each station. In addition, salinity, specific conductance, water temperature, and water level were recorded hourly at five stations (stations 7, 10, 17, 55, and 56, figure 2) beginning January 8, 1993. These data were recorded with either Hydrolab Datasonde 3, YSI Model 6000 or 6920 continuous dataloggers. Water level was measured at five staff gauge stations (1, 2, 3, 5, and 6, figure 2) surveyed to the National Geodetic Vertical Datum (NGVD) from May 1992 to October 1997 when these stations were re-surveyed to the North American Vertical Datum (NAVD). All water level data recorded in NGVD were converted to NAVD for analysis. Five additional staff gauges, one at each of the continuous recorder stations were added in October 1997.

Due to inadequate preconstruction data and lack of reference areas, salinity and water level data were analyzed across the three different categories of siphon operation to assess its effects. Bottom salinity from monthly data was used in the statistical analysis because more data were collected for bottom salinity. Daily means were calculated from hourly salinity and water level measured by the continuous recorders, and a one-way ANOVA was performed on each recorder-station data set, to compare mean salinities across three stages of siphon operation (noflow, minor discharge, and major discharge). Tukey's pairwise comparisons were used to investigate mean differences when models were found to be significant ($P < 0.05$). Water levels and mean salinity across all stations were analyzed using the same statistical model. Water level was analyzed using the same model.

Vegetative species composition and abundance were measured at 21 stations in June, 1992 using an ocular estimate method (Ensminger 1992) (figure 3). In September-October 1997, species richness, % occurance and cover were measured on $1m^2$-plots at 36 locations (figure 4) using the Braun-Blanquet sampling protocol (Mueller-Dombois and Ellenberg 1974). Because of differences in methodolology, statistical comparisons of the pre- and postconstruction vegetation surveys is inappropriate. To explore spatial effects of the siphon on the vegetation community, a group of



Data Source:
LA Dept of Natural Resources
Coastal Restoration Division
Database Analysis Section
1994 Satellite Imagery
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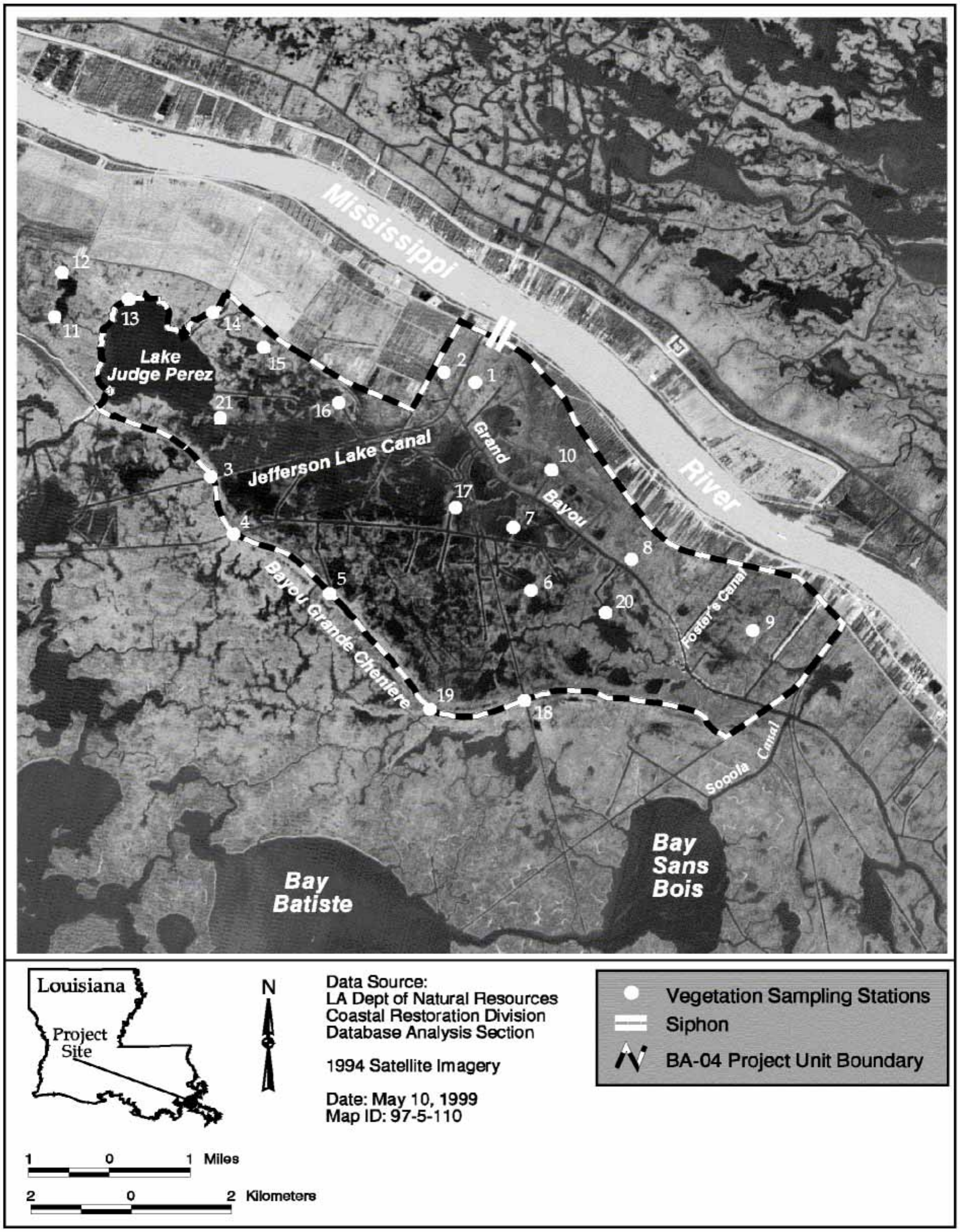
Figure 2. Location of hydrologic sampling stations at the West Pointe a la Hache project.



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LA Dept of Natural Resources
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Figure 3. Location of 1992 vegetation sampling stations in the West Pointe a la Hache project area.

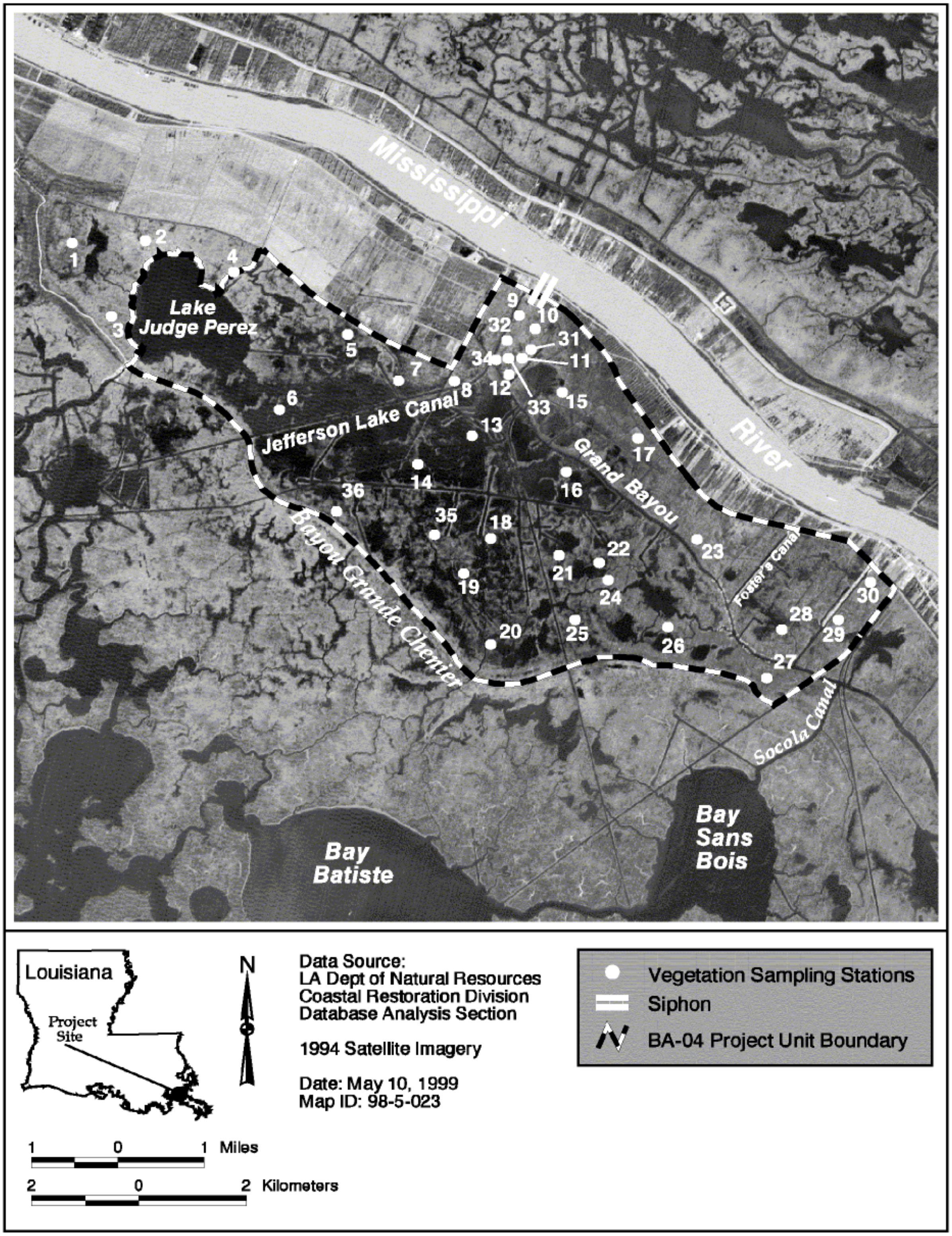

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Figure 4. Locations of 1997 vegetation sampling stations in the West Pointe a la Hache project area.

vegetation stations located in the area of greatest siphon influence, as dictated by the salinity data, were assessed separately. The analysis included vegetation stations 1, 2, 7, 10, 15, 16, and 17 from 1992 and 5, 7-13, 15-17, 31-34, from 1997. Species richness and relative abundance were qualitatively compared in an attempt to evaluate project effects on the plant community between the two sample periods. Species richness is useful as an index of environmental stress and/or shift in community type because species richness generally increases from saline to more intermediate marsh types (Palmisano and Chabreck 1972).

Aerial photography was classified to measure land to open water ratios in the project area. Photography was obtained on November 5, 1991 (preconstruction) and January 26, 1999 (postconstruction) at 1:12,000 scale. SPOT satellite imagery was used to rectify all individual photographs, which were then mosaicked together to produce a composite image of the entire project area. Areas outside of the project boundary were trimmed to smooth the appearance for the final photographic mosaic. To determine land to open water ratios, the aerial photographs were scanned and analyzed according to pixel values. A land/water classification was performed on the aerial photography which grouped all habitat types into either land or water classes. All areas characterized by emergent vegetation, wetland forest, or scrub-shrub were classified as land, while open water, aquatic beds, and non-vegetated mud flats were classified as water.

To compare historical land loss rates to those estimated from the land/water analysis, data were converted to percent of total land loss. This was accomplished by dividing the land loss rate (mi^2/yr or ac/yr) by the total amount of land present at the beginning of the time period. This allows for comparisons between areas of different sizes as is the case when comparing historical rates from the Pointe a la Hache quadrangle (Dunbar et al. 1992) to the smaller West Pointe a la Hache project area.

Results

The average siphon discharge from January 1993 through December 1998 was 735 cfs (21 cms) with mean annual discharge during this time period varying from a low of 234 cfs (7 cms) in 1995 to 1153 cfs (33 cms) in 1993 (figure 5). Monthly siphon discharge within each year was also extremely variable (Table 1). No flow conditions typically occur between August and December, when there is insufficient head differential to operate the siphons. Moreover, siphon operation was designed to be reduced to 25% during the months of March and April, although this operation scenario was not achieved. Unexpected events, such as pending litigation, suspended siphon operation from October 1994 to June 1995, further increasing monthly variability. Although mean annual and mean monthly discharge are quite variable, the operational time in each of the three flow categories was nearly equal (figure 6). The delineation fo flow categories aids in the interpretation of project effects since siphon discharge is influenced by the river stage which has seasonal effects. The effect of season is evident from data taken at St. Mary's Point located outside the project area but within the Barataria Bay. The prevalence of months of major discharge coincide with periods of high river stage (winter - mid summer) (figure 7). High river stages historically resulted in lower salinities in the estuary (Swenson and Swarzenski 1995).

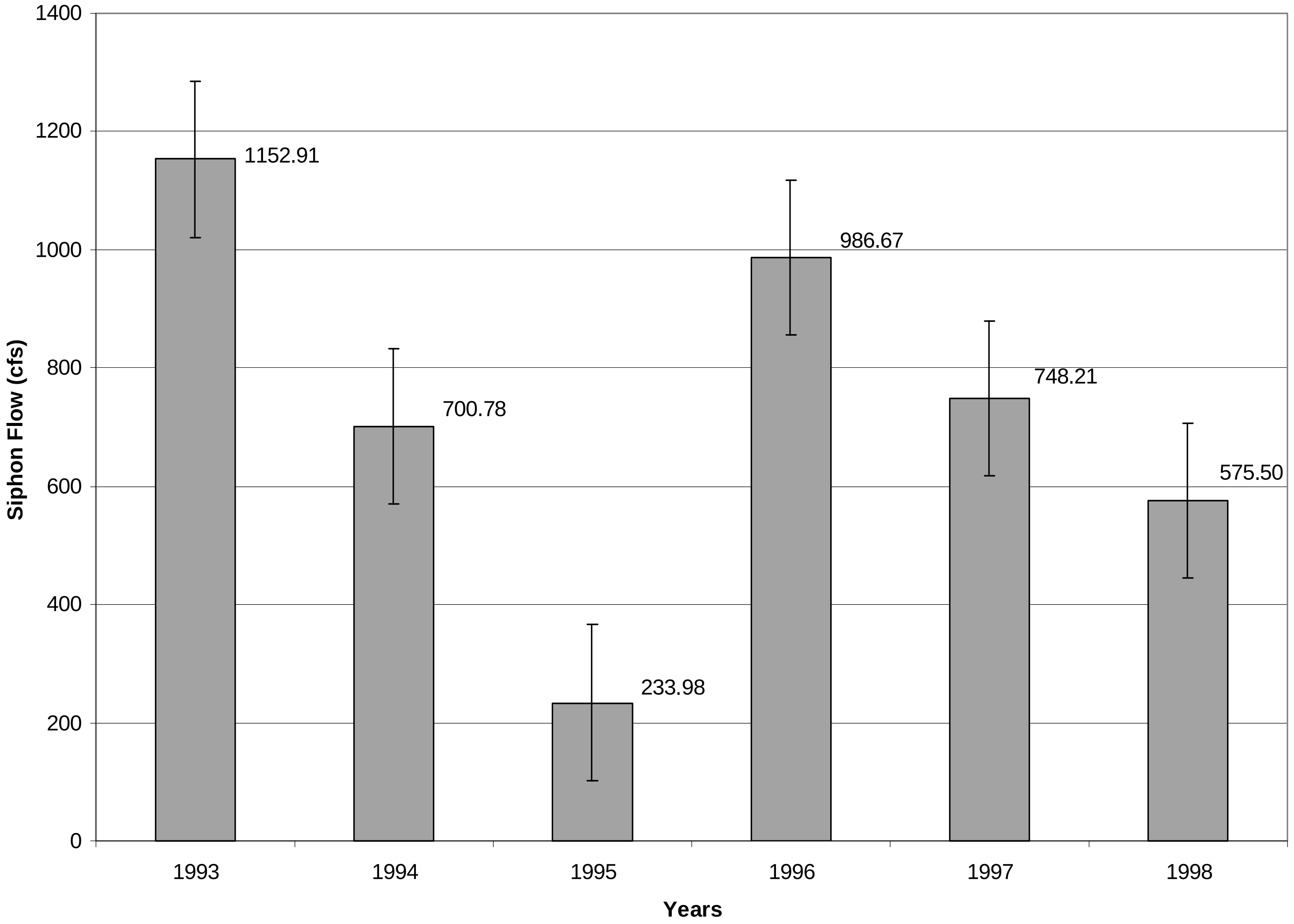


Figure 5. West Pointe a la Hache average yearly siphon flows 1993 -1998.

Table 1. Average monthly siphon discharge (cfs) May 1992 - December 1997.

Month	Avg.	Month	Avg.	Month	Avg.
May ‘92	0.00	September ‘94	393.18	January ‘97	1466.85
June ‘92	0.00	October ‘94	0.00	February ‘97	1736.73
July ‘92	0.00	November ‘94	0.00	March ‘97	1883.84
August ‘92	0.00	December ‘94	0.00	April ‘97	1073.30
September ‘92	0.00	January ‘95	0.00	May ‘97	1036.91
October ‘92	0.00	February ‘95	0.00	June ‘97	1007.60
November ‘92	0.00	March ‘95	0.00	July ‘97	unknown*
December ‘92	0.00	April ‘95	0.00	August ‘97	29.35
January ‘93	1095.9	May ‘95	0.00	September ‘97	0.00
February ‘93	1400.06	June ‘95	0.00	October ‘97	0.00
March ‘93	432.61	July ‘95	1246.03	November ‘97	0.00
April ‘93	400.42	August ‘95	812.25	December ‘97	0.00
May ‘93	1490.92	September ‘95	749.47	January ‘98	196.31
June ‘93	1313.02	October ‘95	0.00	February ‘98	856.93
July ‘93	1244.06	November ‘95	0.00	March ‘98	944.42
August ‘93	773.37	December ‘95	0.00	April ‘98	651.44
September ‘93	795.891	January ‘96	0.00	May ‘98	533.63
October ‘93	1688.71	February ‘96	892.30	June ‘98	404.21
November ‘93	1271.08	March ‘96	975.53	July ‘98	416.14
December ‘93	1929.14	April ‘96	1250.00	August ‘98	277.24
January ‘94	1482.45	May ‘96	1795.59	September ‘98	119.20
February ‘94	1868.26	June ‘96	1648.90	October ‘98	341.74
March ‘94	1968.13	July ‘96	1241.12	November ‘98	1059.52
April ‘94	1081.82	August ‘96	1268.91	December ‘98	1106.39
May ‘94	565.93	September ‘96	326.53	January ‘99	1247.77
June ‘94	603.99	October ‘96	167.81		
July ‘94	308.43	November ‘96	488.48		
August ‘94	137.27	December ‘96	1784.92		

* In July 1997, an average of three pipes remained in operation, so this month was assigned to the “minor operational” status.

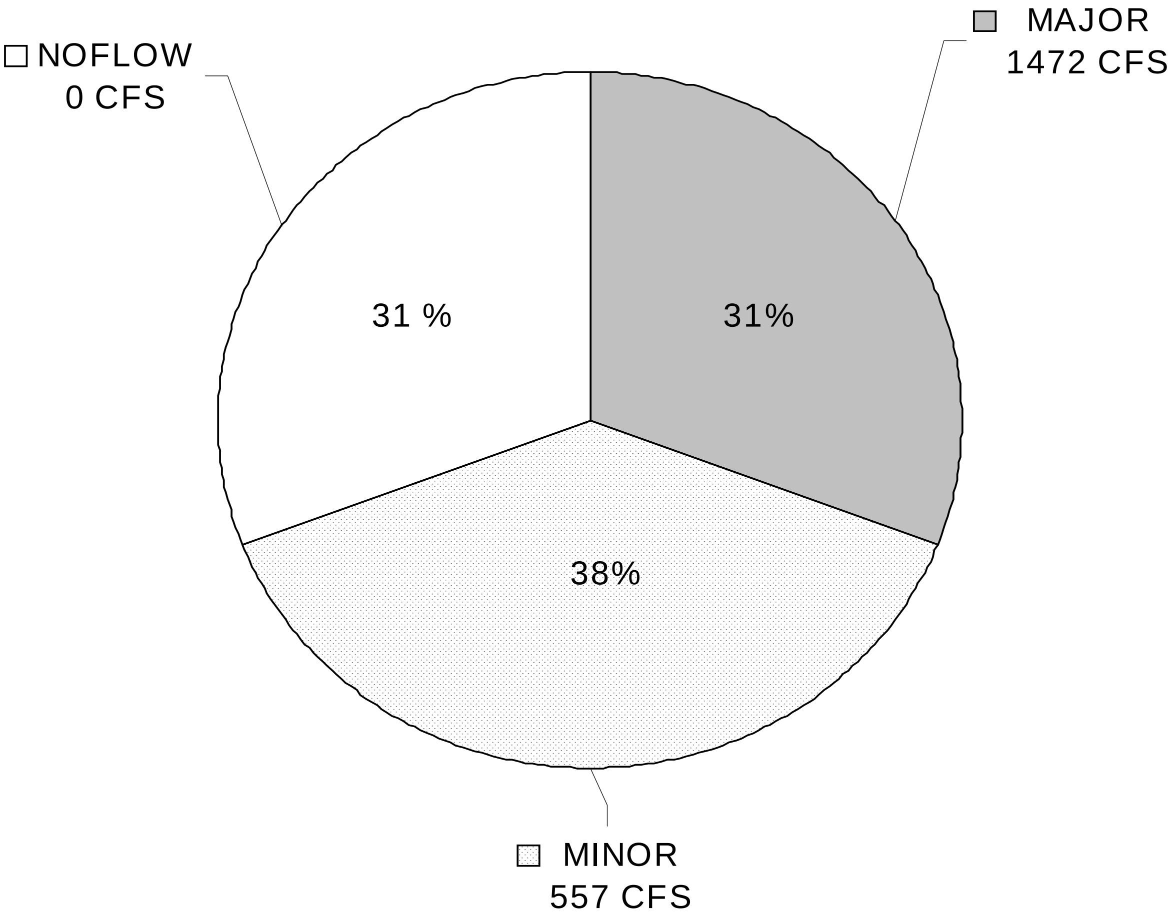


Figure 6. Average flow and relative amount of time that the West Pointe a la Hache structure was operating in each of 3 flow categories (noflow = 0 cfs, ,minor flow = 0-1072 cfs, and major flow > 1072 cfs).

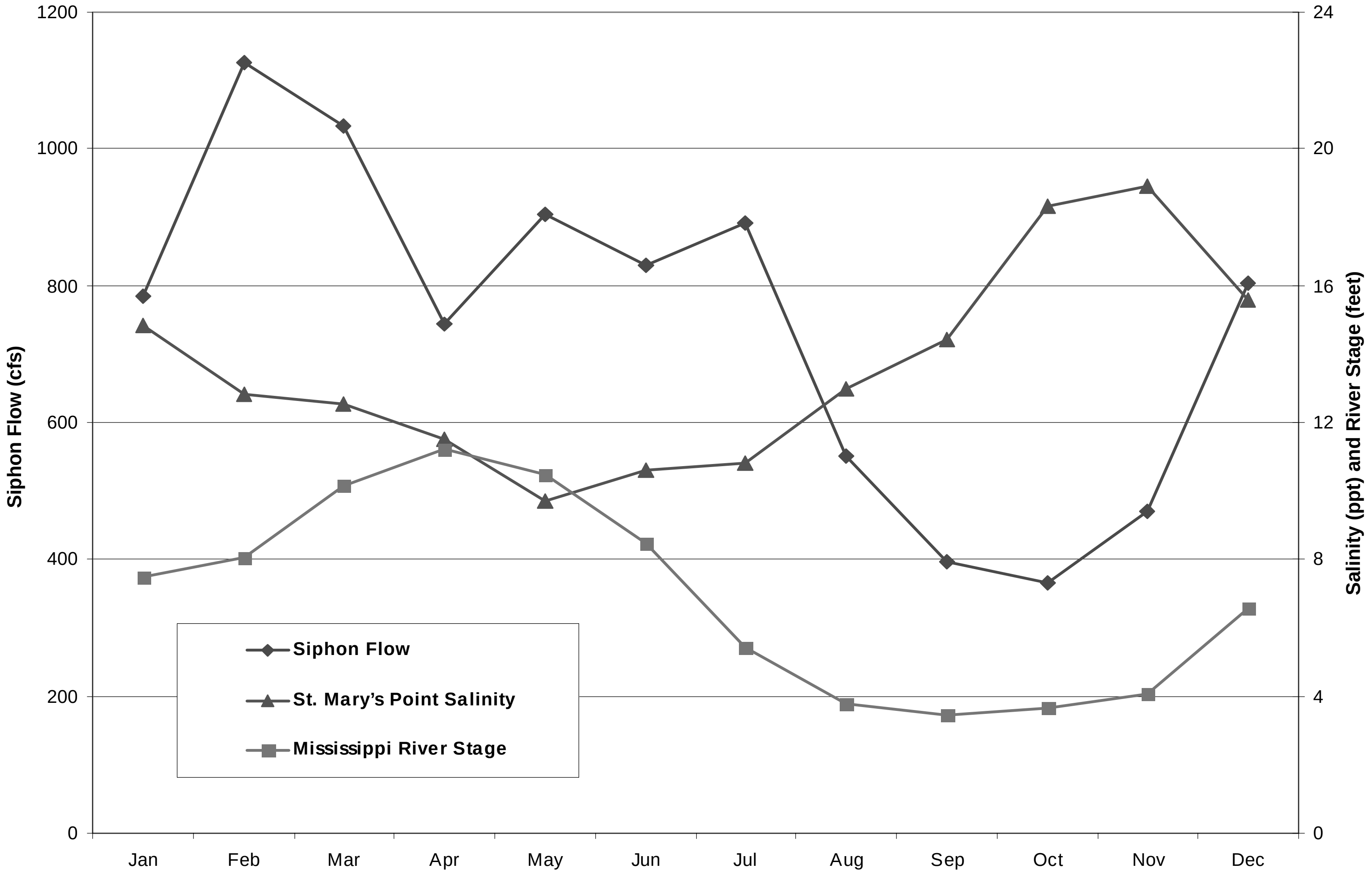


Figure 7. Mean monthly salinity at St. Mary's Point, Mississippi River stage, and siphon flow from 1993 through 1998 at West Pointe a la Hache project area.

All continuous recorder stations showed lower salinities during late winter and spring when river discharge was high (figure 8). Salinities were significantly lower ($p < 0.05$) at all five recorders during months of either major or minor flow compared to those when there was no flow (figure 9). No differences in mean salinity were found between minor and major flow periods except at station 7, the one closest to the siphon structure. Mean salinities at station 7 during major flow (6.32 ppt ± 0.16 s.e.) was significantly lower ($p < 0.05$) than periods of minor flow (7.09 ppt ± 0.13 s.e.).

Monthly discrete readings indicated significant differences in salinities amongst flow categories ($f = 188.02$, $df = 2$, $p < 0.0001$). There were no differences ($p = 0.27$) between major flow (5.39 ppt ± 0.24 s.e.) and minor flow (5.78 ppt ± 0.26 s.e.), but both major and minor flow differed ($p<0.001$) from noflow (11.77 ppt ± 0.21 s.e.). During periods of siphon operation (either minor or major), the lowest mean salinities were recorded at stations 1, 2, 3, 4, 5, 12, and 16 which are located closest to or north of the structure location. Highest salinities during periods of siphon operation occurred at stations 8, 9, 10, 15, 55, and 56 which are located farthest from the structure (figure 10).

Effect of flow category on water levels was inconsistent among two levels of siphon operation. Hourly water levels were significantly different at station 7, 17, and 56 ($p = 0.0001$) between periods of major and minor flow. No differences were found between major and minor flow at stations 10 and 55 ($p>0.05$). Hourly water level data recorded at continuous recorder stations 7, 17, 55, and 56 indicated mean water level was highest during periods of minor flow (figure 11). However, station 10 exhibited highest water level during periods of major flow. Monthly discrete readings for all stations combined however, showed no differences in water level across flow categories 1993 -1998 ($f = 2.05$, $df = 2$, $p = 0.19$) (figure 12). There was a significant interaction ($p = 0.0001$) between stations and siphon flow. Station 1, the closest to the siphon , did show a marked difference in water level amongst flow periods despite the overall non- significant result.

The preconstruction vegetation survey performed in June 1992 revealed a total of 8 species at 21 sites with a mean species richness of 2.86 (± 0.13 s.e.) per site. The project area was dominated by *S. patens*, *S. alterniflora*, and *Distichlis spicata* (saltgrass) (table 2). Trace frequencies of only five other species were encountered, and no obvious spatial patterns were noted in species composition (Ensminger 1992). The 1997 survey found 26 species at 36 sites (table 2) and mean species richness of 3.58 (± 0.27 s.e.) per site. *S. patens*, *S. alterniflora*, and *D. spicata* were also the most common species encountered in the 1997 survey, but *S. patens*, and *S. alterniflora* occured in far fewer stations. There were also notable differences in the mean percent cover (for stations where species was present) of each of these species between 1992 and 1997. Mean percent cover of *S. alterniflora* was 48% in 1992 but only 18% in 1997, while *D. spicata* (13% in 1992 to 41% in 1997) and *V. luteola* (0.1% in 1992 to 21% in 1997) were higher (figure 13). Both *D. spicata* and *V. luteola* are indicative of higher elevations and fresher water (Chabreck and Condrey, 1979). In 1997, several species more indicative of intermediate or low-salinity brackish marsh were found: *Cyperus odoratus* (fragrant flatsedge), *Polygonum punctatum* (smartweed), *Echinochloa walteri* (Walter'smillet), *Paspalum distichum* (knot-grass), *Pluchea camphorata* (camphorweed), *Pluchea purpurascens* (saltmarsh pluchea), *Aster subulatus* (saltmarsh aster), *Aster tenuifolius*, (saltmarsh aster),

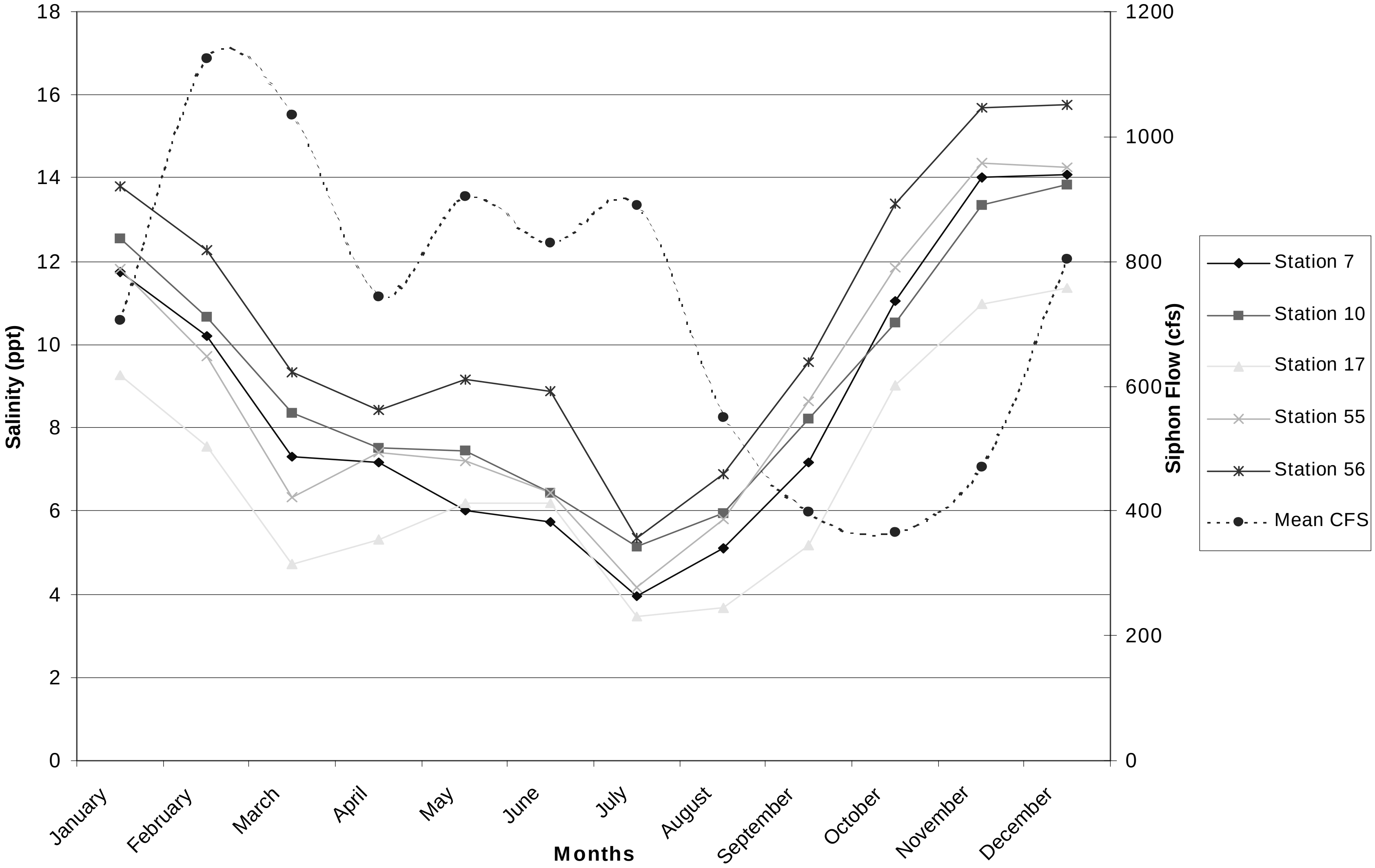


Figure 8. Mean salinity patterns by month for continuous recorder station 7, 10, 17, 55, and 56 and mean cfs over the period 1993-1998 at West Pointe a la Hache project area.

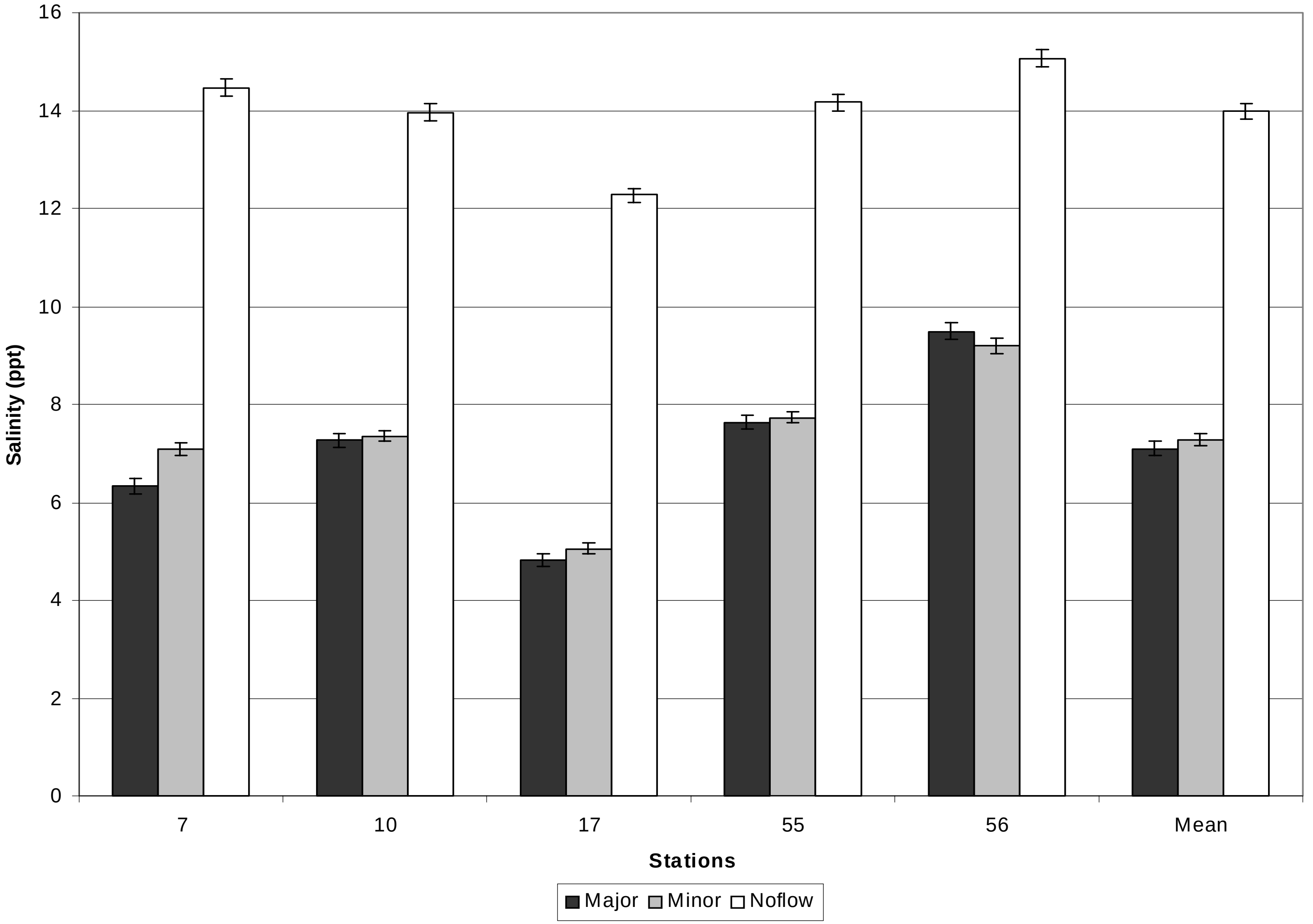


Figure 9. Comparisons of mean salinity during the period of 1993 to 1998 during the three siphon operational categories at the five continuous recorder stations at West Pointe a la Hache project area. Station "mean" represents the mean salinity of all stations combined during the three operational categories.

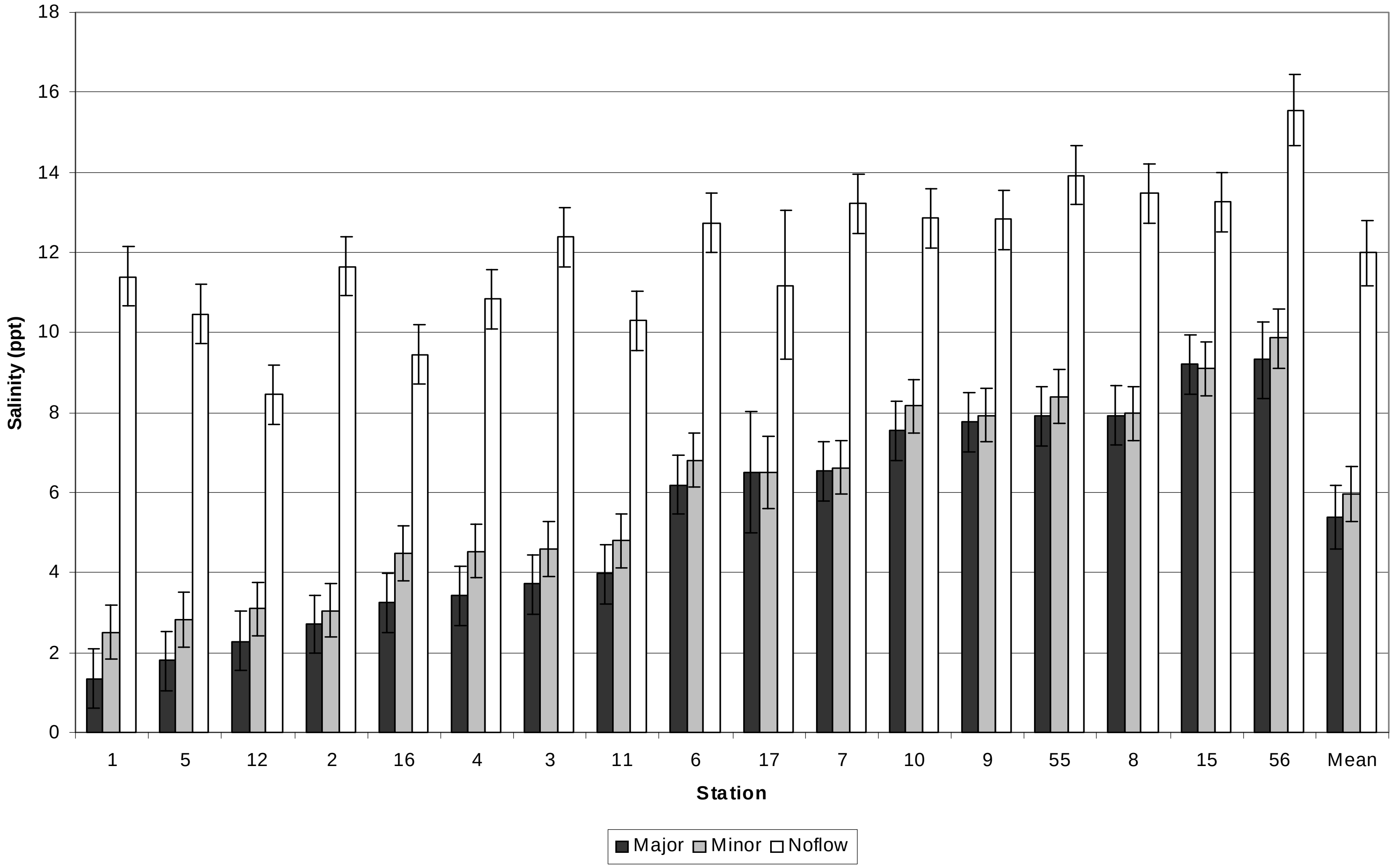


Figure 10. Salinity comparisons of the three operational categories at the 17 discrete monthly hydrologic stations at West Point a la Hache project area. Stations are sorted from left to right in ascending order by major operational mean salinity. Station "mean" represents mean salinity of all stations combined. Salinity data are averaged over the period 1993 to 1998.

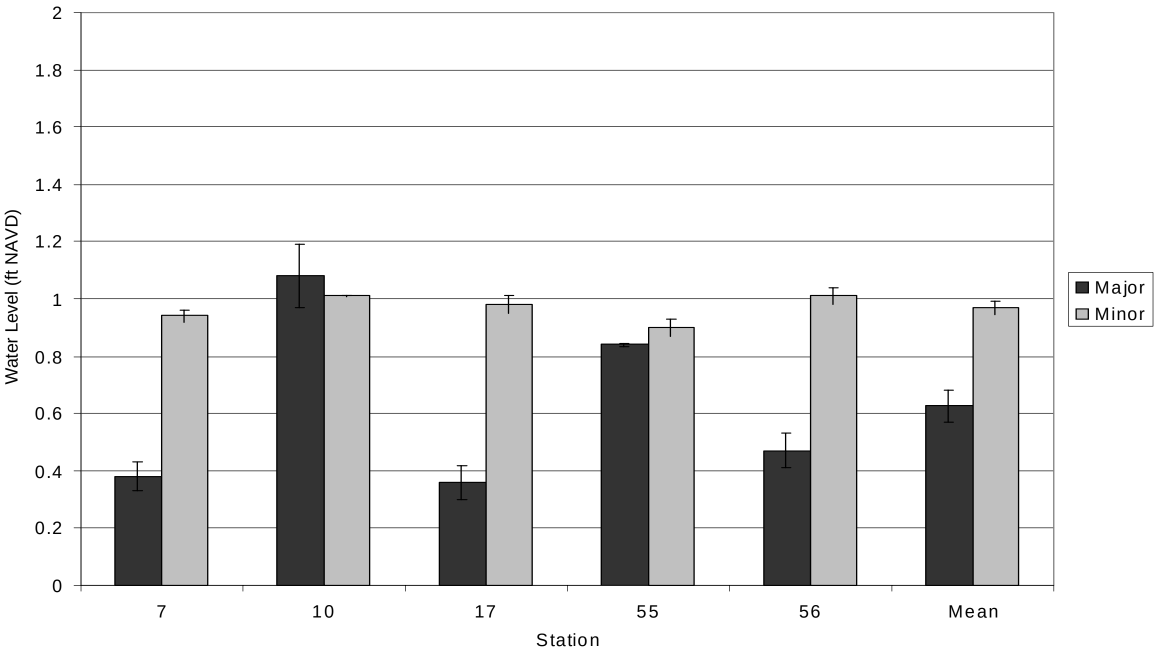


Figure 11. Continuous water level (NAVD) comparisons between major and minor discharge from October 1997 through December 1998 at West Pointe a la Hache project area. Station "mean" represents mean water level of stations 7, 10, 17, 55, and 56 combined. Noflow siphon operation did not occur during this time period.

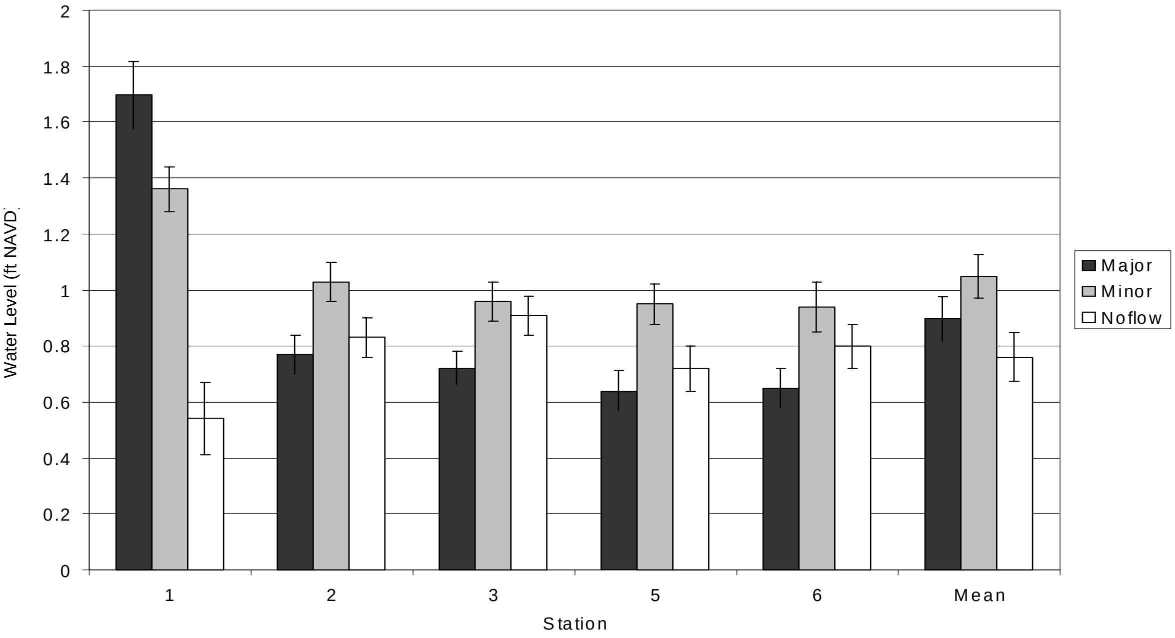
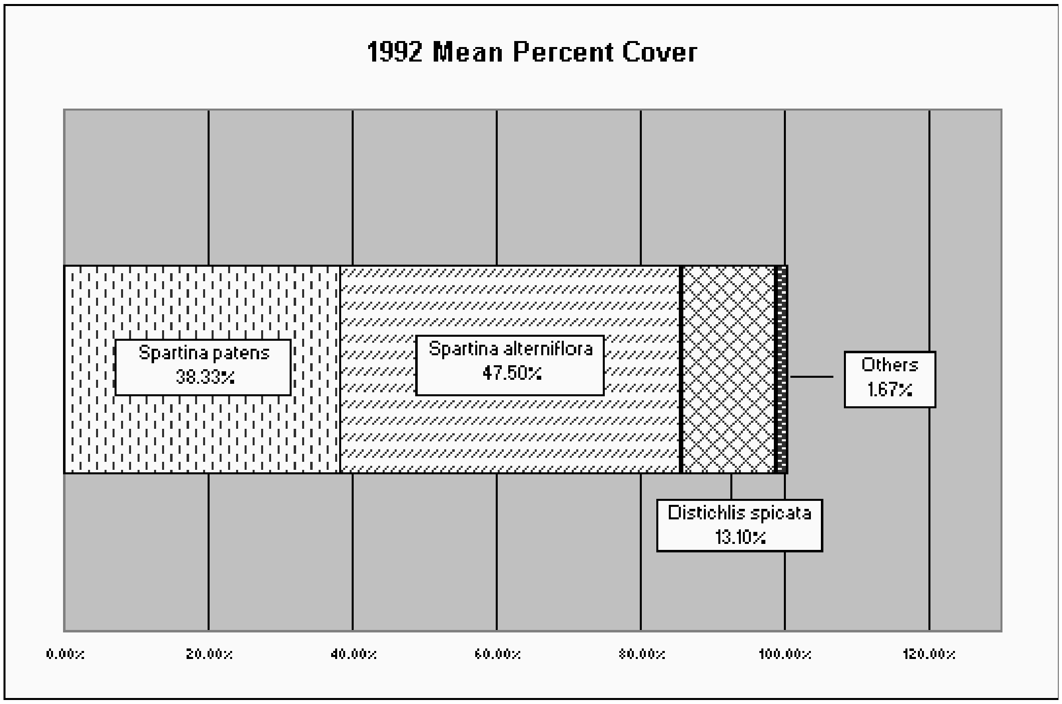


Figure 12. Discrete water level (NAVD) comparisons among major, minor and noflow discharge at West Pointe a la Hache project area from 1993 - 1998. Station "mean" represents mean water level of stations 1, 2, 3, 5 and 6 combined.

Table 2. Percent of stations where species were found and the mean percent cover within those stations (not across all stations) for 1992 and 19997 vegetation surveys of the West Pointe a la Hache area.

Species	Common Name	1992		1997	
		Stations	Cover	Stations	Cover
Alternanthera philoxeroides	Alligatorweed			2.78%	<1
Aster subulatus	Saltmarsh aster			19.44%	4
Aster tenuifolius	Perennial saltmarsh aster			11.11%	7
Baccharis halimifolia	Eastern baccharis	4.76%	2		
Cyperus odoratus	Fragrant flatsedge			25.00%	29
Distichlis spicata	Salt grass	61.90%	21	69.44%	57
Echinocloa walteri	Walter millet			5.56%	13
Hibiscus lasiocarpos	Crimsoneyed Marshmallow	4.76%	2		
Ipomea sagittata	Marsh morningglory			8.33%	7
Juncus roemerianus	Black rush, Needlegrass			8.33%	48
Kosteletzkya virginica	Seahore Marsh-mallow			5.56%	5
Ludwigia alternifolia	Seedbox			2.78%	15
Lythrum lineare	Saltmarsh loosestrife			5.56%	35
Paspalum distichum	Knot grass			11.11%	10
Pluchea camphorata	Camphorweed			2.78%	40
Pluchea purpurascens	Annual saltmarsh fleabane			2.78%	20
Polygonum pensylvanicum	Pinkweed			2.78%	20
Polygonum punctatum	Water smartweed			11.11%	38
Scirpus americanus	American bulrush	14.29%	4	2.78%	10
Scirpus maritimus	Saltmarsh bulrush	4.76%	4		
Scirpus robustus	Saltmarsh bulrush			2.78%	33
Spartina alterniflora	Saltmarsh cordgrass	90.48%	53	44.44%	37
Spartina patens	Saltmeadow cordgrass	100.00%	38	52.78%	64
Toxicodendron redicans	Poison ivy			2.78%	30
Vigna luteola	Deerpea	4.76%	2	41.67%	51
Vitis spp.	Grape			8.33%	10



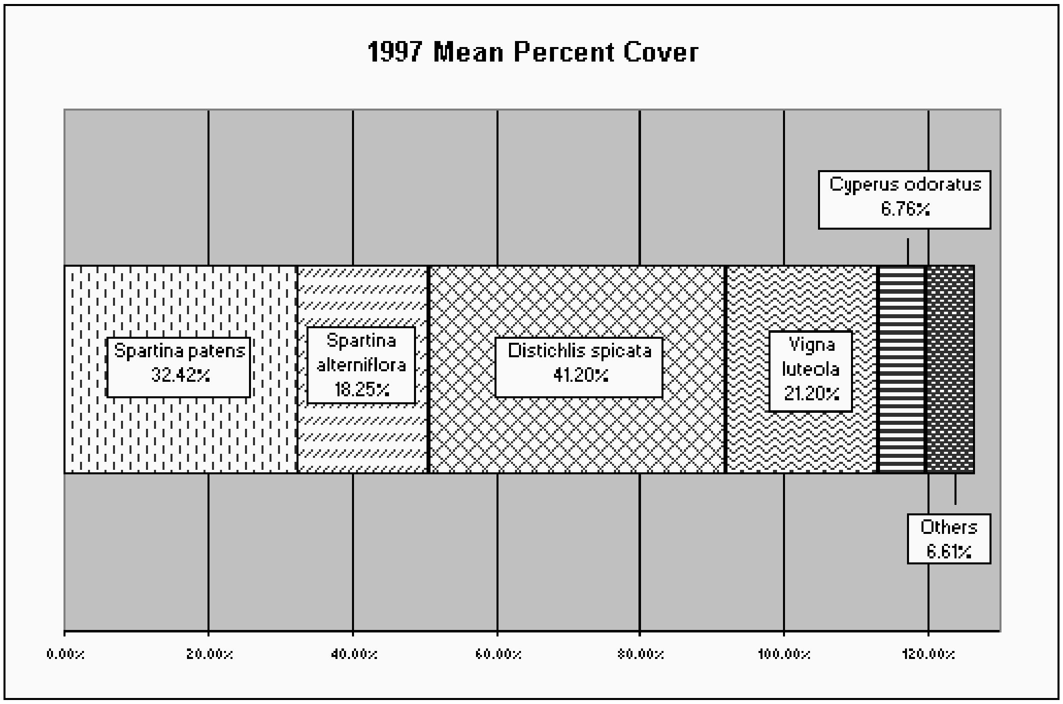


Figure 13. Comparison of mean percent cover (across entire project area) of most common species for 1992 and 1997 vegetation surveys of West Pointe a la Hache.

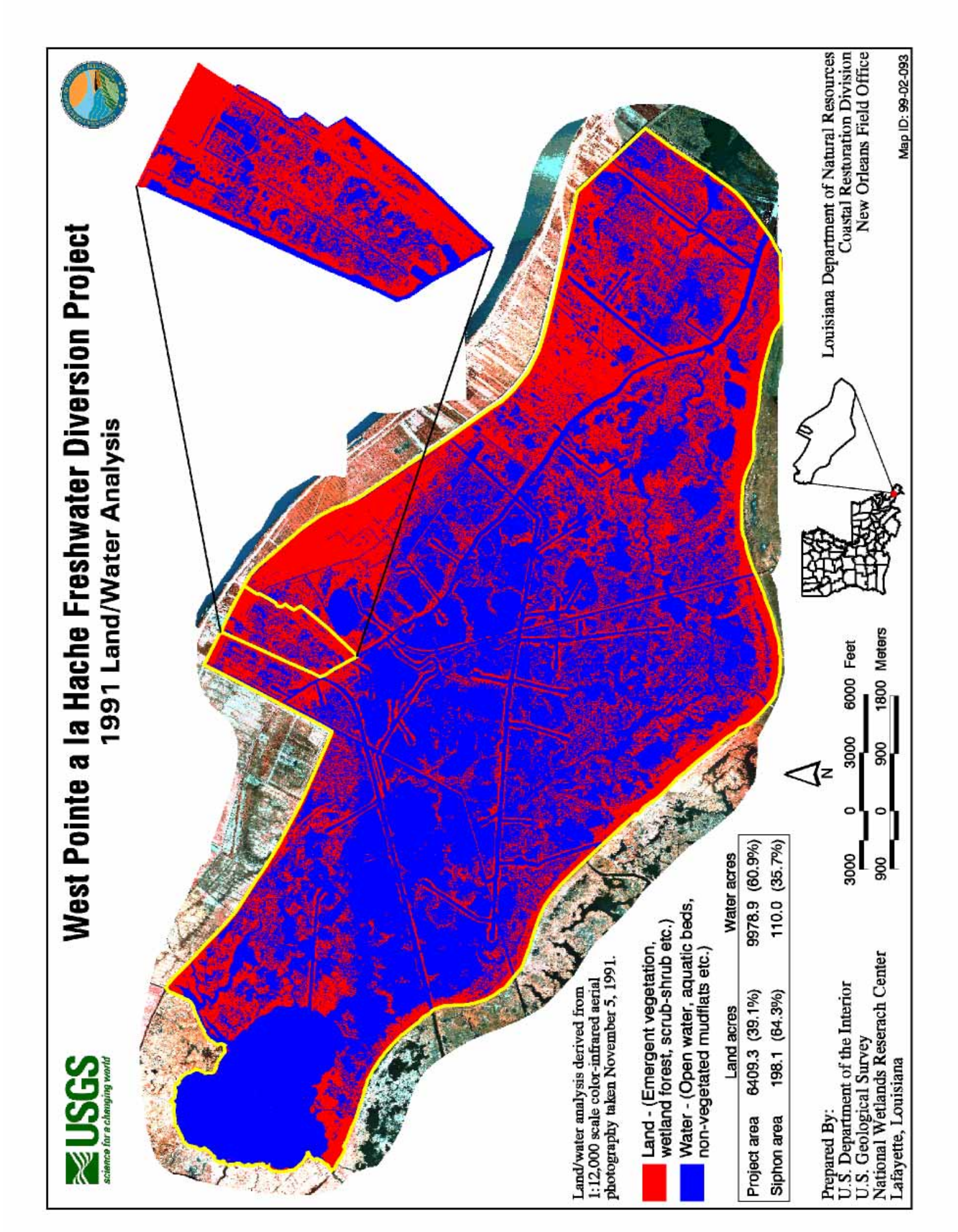
Colocasia esculenta, *Ipomoea sagittata* (marsh morningglory), and *V. luteola* (Chabreck 1970; Chabreck and Condrey 1979; Palmisano and Chabreck 1972). In most cases, these species were present in greater than trace amounts at these stations. In fact, *C. odoratus* abundance was estimated at 75% and 80% at stations 7 and 31, respectively. Clumps of *Salix nigra* (black willow) can be seen in marsh near the diversion structure. The presence of willow trees is indicative of higher elevations of developing freshwater marsh and higher levels of organic matter (White 1993). In 1992, all seven stations near the diversion were dominated by *S. alterniflora*. Of the 15 near stations from 1997, only one (station 17) was dominated by *S. alterniflora*.

Land/water analyses indicated a decrease in land in the total project area from 6,409.3 ac (2,563.7 ha) in 1991 to 5,948.9 ac (2,379.6 ha) in 1999 and a corresponding increase in water from 9,978.9 ac (3,991.6 ha) in 1991 to 10,434.5 (4,173.8 ha) in 1999 (figures 14 & 15). The small discrepancy in total acreage amounts is explained by the fit of the boundary line over the pixels composing the project area. Minor shift changes in the rectified photography tend to include edge pixels that were not incorporated into the original mosaic. The difference of 4.9 (1.9 ha) acres is equivalent to 0.03% of the total acreage for the project. These data indicate a conversion of 460.4 ac (184.2 ha) of land to water in the 7 year period. This represents a loss of 7.2% of land present in 1991 or 1.03% per year. Historical loss rates for the project area taken from the Pointe a la Hache Quadrangle were as follows: 0.18% /yr between 1932-1956, 0.54% /yr between 1956-1974, 1.10% /yr between 1974-1983, and 1.29% /yr between 1983-1990 (Dunbar et al. 1992).

Discussion

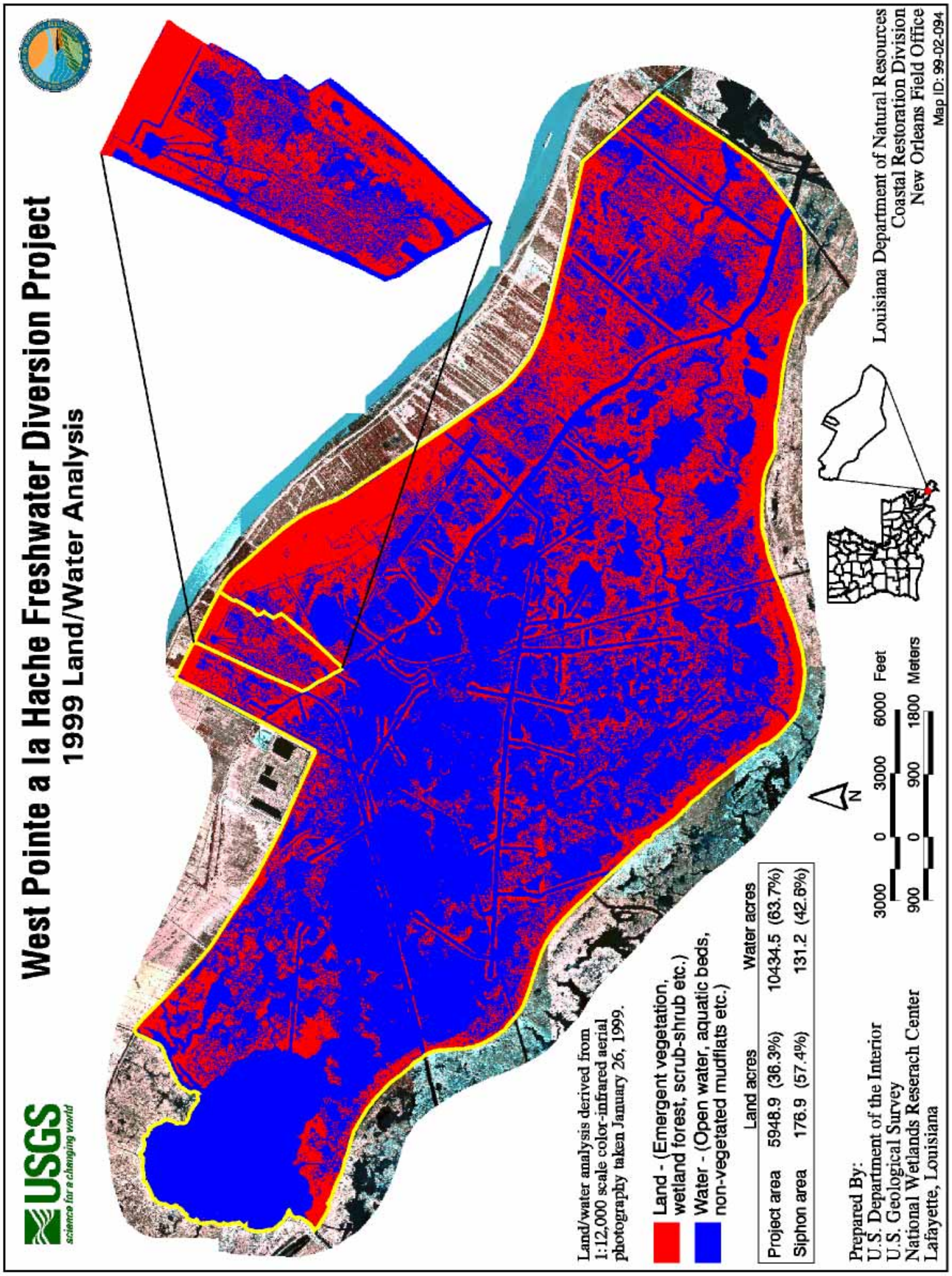
Factors that may have contributed to periods of siphon inoperation are “faulty” valves that cause air to leak into the siphon tubes, limited manpower available to operate the structure, and various oil spills on the river. This was partially influenced by the difficulties associated with operating the structure without any real-time estimates of flow. Additionally, one reason to limit flow in March and April originates from concerns over potential flooding. However, discrete water level data indicate that flooding is not as serious a problem as was thought prior to structure operation. Sediment load is relatively high in the river during this period, and consequently, increased flow should reduce marsh loss by increasing sediment introduction (Mossa and Roberts 1990). Average discharge during major and minor periods of operation collectively was 963 cfs or 45% of maximum capacity. The operation and management scheme proposed during the planning stages of the project projected an average discharge of 1105 cfs throughout the year as stated in the methods section (Brown and Root 1992). However, maximum discharge is only possible with extreme head differential between the river and the marsh. Therefore, it was not expected that the structure could maintain maximum flow throughout the year, even with all 8 pipes operating.

The siphons reduced salinity levels throughout the project area during periods of both major and minor flow. Although not surprising, there was a distinct spatial effect as stations located nearest the siphon showed the greatest reduction in salinity, whereas salinities at the stations furthest away were reduced the least. What was surprising is that salinity reduction did not vary significantly between minor flow and major flow. It may suggest that the difference in average flow between



	Land acres	Water acres
Project area	6409.3 (39.1%)	9978.9 (60.9%)
Siphon area	198.1 (64.3%)	110.0 (35.7%)

Figure 14. GIS land-water analysis of West Pointe a la Hache before construction, 1991.



	Land acres	Water acres
Project area	5948.9 (36.3%)	10434.5 (63.7%)
Siphon area	176.9 (57.4%)	131.2 (42.6%)

Figure 15. GIS land-water analysis of West Pointe a la Hache after construction, 1999.

major and minor is insignificant towards reducing salinities.

The interpretation of the direct effects of the siphon on mean project area salinity was influenced by factors other than siphon operation, particularly seasonal variability. High river stage is a characteristic of the project design, because sufficient head differential between river stage and marsh stage is necessary for proper operation of the siphons. However, the Barataria estuary is naturally fresher during this time of the year, because of the Mississippi River's influence (Swenson and Swarzenski 1995). Furthermore, variation in Mississippi River discharge from the mouth can account for 50 % of the variation in salinity within the Barataria Bay (Wiseman et al. 1990). Therefore, a source of confounding exists in the interpretation of the direct effects of the siphon on area salinity. Moreover, project area salinity is also influenced by local tide, weather, and flow conditions. A qualitative review of the salinity data as well as turbidity plumes observed from aerial photos and through field observations suggests a conservative estimate of siphon influence would be 2 - 4 miles from the diversion structure. However, we cannot quantify the magnitude (i.e., reduction in salinity) of this influence at this point. We are exploring methods to remove the confounding effects of season prior to the next comprehensive report.

There is little evidence that siphon flow affects water levels except in the immediate outfall area. Although significant differences were observed at continuous stations 7, 17, and 56, water levels during minor siphon operation exceeded those during major operation except at station 10 (figure 10). The opposite would be expected if siphon flow was affecting water level. No significant differences in monthly water levels were found except at station 1. The significant interaction between stations and siphon flow was produced by high water levels during siphon operation at this station which is located directly in the outfall channel. Water levels at other discrete stations followed a similar pattern amongst flow categories. Water levels are likely governed largely by wind and tidal events, rather than the diversion structure. In fact, strong south winds that force water into the estuaries can potentially raise water levels 0.3-0.5 m (1.0-1.7 ft) above normal; and conversely, winds from the north that force water out of estuaries can lower water levels 0.3-0.5 m (1.0-1.7 ft) below normal (Schroeder and Wiseman 1986). Another possible explanation for lack of siphon influence on water level, despite the frequent inputs of large amounts of river water, is the location of the outfall pond in relation to Grand Bayou and the Jefferson Lake canal. These are relatively wide and deep (>15ft) channels that can serve as conduits for the introduced freshwater and quickly disperse incoming river water further south, instead of allowing sheet flow across the marsh. The West Pointe a la Hache outfall management plan will address this problem (USDA SCS 1991).

By not significantly increasing water level, the potential for vegetation stress as a result of structure induced flooding is reduced. Waterlogged soils and subsequent changes in oxygen content along with other chemical conditions significantly limit the number of rooted plants that can survive in this environment (Bedinger 1981). The predominant vegetation species in 1992 were well represented in 1997. However, the addition of other species more suited for fresher environs may indicate that freshwater inputs from the siphons are causing a gradual shift in the plant community to a more intermediate - brackish vegetation assemblage. It is not clear at this time if differences in the plant community between 1992 and 1997 resulted from different sampling locations (i.e., spatial variability), number of stations, or landscape changes over time (i.e., temporal variability). The higher post construction vegetation species richness lends support to the previous salinity analyses concerning the freshening effects of the siphons. Higher species richness is generally associated with more fresh or intermediate marsh than with saline or high salinity brackish marshes (Palmisano and Chabreck 1972).

The results of the land/water analyses are ambiguous. Typically, for a project with 2 or more years of aerial photography with which to compare land/water classifications, an index map is created that combines the two datasets to visually display where change is occurring. However, in this instance several factors prevented the index from being created because of less than optimal registration between the two mosaics. (1) The time expanse between the 2 years of photography (1991 and 1999) made it difficult to locate similar features. Since coastal marshes are so sensitive to disturbance and change very rapidly, marsh changes throughout the project area were extensive. (2) The seasonality of the flights were different: preconstruction photos were acquired in November (peak biomass), while postconstruction photos were acquired in January 1999 (period of senescence). Vegetation exhibits many different patterns of vigor and growth as the winter season continues. (3) The date of the postconstruction photography coincided with the lowest water level within the project area in a 12 month period. (4) Some of the photographs had distortion introduced due to an unlevel camera angle while in flight, causing some frames to be visibly oblique. Although these factors did not affect the classification acreage, locating areas of change and determining land/loss rates between the 2 years had to be conducted on a frame by frame basis instead of a composite.

Direct comparisons to historical land loss rates were also difficult because the historical rate was based on the entire Pointe a la Hache quadrangle which contains a large portion of land outside of the project area. In fact, most of the historical marsh loss from the quadrangle occurred in the West Pointe a la Hache area. Thus, the quoted historical rates are likely deflated and do not accurately reflect historical loss conditions. If these factors are not present in the future, loss rates will be more realistic.

Conclusion

Three measurable goals were established to evaluate project effectiveness: 1) reduce and stabilize salinity, 2) increase relative abundance of target plant species, and 3) increase marsh to open water ratio. The first goal of the project, the reduction of salinity, has partially been met. Salinity levels have been reduced at data collection sites nearer the siphon compared to those further away, and salinity has been reduced during periods of minor and major flow compared to noflow conditions. However, the magnitude of the effect of the siphon on salinity has not been quantified due to the seasonal variability that occurs in the coastal waters of Louisiana. Further analyses incorporating an index of natural variability may provide a better understanding of the effects of the siphon on area salinity. A second goal of the project, increasing occurrence of *S. patens,* has likely not been met. However, greater occurrence of other brackish - intermediate species and lower *S. alterniflora* coverage may indicate a gradual shift in the plant composition to a more intermediate - brackish community which would be a favorable outcome. A longer time series of vegetation data will be necessary to determine whether a vegetation shift is occurring. Changes in plant community structure could be influenced by spatial variability in addition to siphon effects due to the different sampling methodologies between pre- and postconstruction conditions. Future sampling should remain consistent and thus reduce this source of confounding. A third goal of increasing marsh to open water ratio has not been attained. Land loss is still occurring in the project area over the period of the study. The West Pointe a la Hache Outfall Management Project, which was approved under the Coastal Wetlands Planning, Protection, and Restoration Act, should help increase freshwater retention in the project area. Future efforts concerning freshwater diversion should strongly evaluate and consider location and placement of structures in the planning process. More control of diversion flow would aid both marsh enhancement and the evaluation of diversion effects on the environment.

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