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Restoration success of backfilling canals in coastal Louisiana marshes

Joseph Baustian
Louisiana State University and Agricultural and Mechanical College

RESTORATION SUCCESS OF BACKFILLING CANALS IN COASTAL LOUISIANA MARSHES

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Joseph Baustian
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Abstract

The need for effective marsh restoration techniques in Louisiana is a pressing issue as the state continues to lose coastal wetlands. Returning spoil banks to canals, known as “backfilling”, is an attractive restoration option because it restores marsh, prevents future wetland loss, and is cost effective. The direct conversion of marsh to canals and spoil banks accounted for over 22% of Louisiana’s wetland loss from 1930 to 1990, and the indirect losses associated with canal dredging are even larger. The restoration success of 30 canals, backfilled twenty years ago, was examined in this study and compared to restoration success shortly after backfilling. Ultimately, the success of backfilling was controlled by the amount of spoil returned to the canal and the position of the canal in the marsh. Up to 95% of the spoil area was restored to marsh when the spoil banks were adequately removed, but only 5% of the spoil area was restored at sites where spoil removal was poor. Restoration of organic matter, bulk density, and water content of the former spoil areas was also constrained by the adequacy of spoil removal. Backfilling restored 80% of the organic matter and 94% of the bulk density and water content after twenty years at sites where spoil was properly removed. The plant species on the former spoil areas often did not match those of the surrounding marsh, and the differences were directly correlated with the amount of spoil removed. Canals backfilled in areas of more intact marsh showed greater restoration success than canals backfilled in highly degraded marshes. This study indicates that the benefits of backfilling continue to increase over time, although complete restoration will take longer than twenty years, particularly for soils. Improving the completeness of spoil removal, coupled with appropriate site selection, could speed up the restoration process and enhance the success of future backfilling projects.

Introduction

Long-term monitoring is essential to determine the success of wetland restoration projects. Projects often lack monitoring longer than a few years (Simenstad and Thom, 1996; Craft et al., 2003; Zedler and Callaway, 1999), and a project's true success, or failure, may go undocumented (Mitsch and Wilson, 1996). Traditional restoration techniques have centered around the re-instatement of previous abiotic settings (Suding et al., 2004), the idea being that the system will design itself and return to its pre-disturbance condition (Zedler, 2000). Backfilling dredged canals in coastal Louisiana is a restoration technique that follows this "self-design" model.

Backfilling is the return of material to the canal from which it was dredged, and has been used to restore marsh and reduce wetland loss in a coastal Louisiana landscape decimated by oil and gas activity (Neill and Turner, 1987a). The material removed as a canal is dredged is placed alongside the canal to form continuous levees known as spoil banks (Bahr et al., 1983). These spoil banks alter hydrology, and may have detrimental effects on the marsh. They restrict water flow above and below the marsh surface, and can cause both increased flooding and drying of the marsh behind them (Swenson and Turner, 1987). Increased flooding can lead to conditions that create stress on marsh vegetation, (Mendelssohn et al., 1981; Mendelssohn and McKee, 1987), while drying the soil increases subsidence through the oxidation of organic matter (Turner, 2004).

Canals and spoil banks have played both a direct and indirect role in Louisiana's land loss problem. Directly, canals have turned marsh to open water, and spoil banks have replaced marsh with an upland environment (Craig et al., 1979). Indirectly, spoil banks have caused wetland loss by altering marsh flooding patterns. This hydrologic alteration can limit sediment

deposition, stress marsh vegetation, and lead to marsh deterioration (Bahr et al., 1983; Turner, 1987).

Estimates of the total wetland loss attributed to canals and spoil banks in Louisiana vary, particularly in regards to the indirect losses, but the extent of marsh canalization is not trivial. Turner and Streever (2002) reported that the area of canals and spoil banks was 80,426 ha in 1978, with 1.2 ha of spoil bank for every 1 ha of canal. In 1990 approximately 10% of Louisiana's coastal marsh was canal and spoil bank (Baumann and Turner, 1990). Britsch and Dunbar (1993) reported that the area of canals alone was 45,866 ha in 1990, but no estimates of spoil bank area were given. However, using the canal to spoil area ratio of 1:1.2 for the 1990 data, the area of canals and spoil banks would have been 100,905 ha (Turner and Streever, 2002). To put that into perspective, approximately 395,232 ha of land turned to open water in Louisiana between the 1930's and 1990 (Britsch and Dunbar, 1993). Adding to that the area of marsh lost from spoil bank building, the direct conversion of marsh to canals and spoil banks would account for over 22% of the total land lost. Indirect losses from canals and spoil banks are even greater than the direct losses (Turner, 1987; Turner and Rao, 1990), and drastically increase the amount of land loss caused by canals and spoil banks.

The purpose of backfilling is to restore marsh on the former spoil bank areas, create beneficial shallow water habitat in the canal, and prevent future land loss by restoring hydrologic conditions via removal of the spoil banks. However, obtaining the proper elevation of the backfilled spoil banks is crucial. Spoil left higher than the surrounding marsh can be recolonized by shrubs and trees, and spoil left lower than the surrounding marsh turns to open water.

Sediments from the spoil banks, which have undergone dewatering and oxidative processes since they were dredged, have a greatly reduced volume (Gosselink, 1984), and backfilling the

spoil banks alone often does not completely fill the canal with sediment. However, this does not detract from backfilling as a viable restoration technique, because the canal becomes shallower and provides excellent habitat for a variety of wildlife (Neill and Turner, 1987a). In addition to backfilling the spoil banks, a few more recent projects have added dredged sediments from nearby lake bottoms to further reduce canal depth, and promote growth of emergent vegetation. Although these types of projects are relatively new, they appear to have great success at restoring the canal area to marsh.

Past studies examining the restoration of backfilled canals after five years (Neill and Turner, 1987a) and after ten years (Turner et al., 1994) found varied levels of success. It was the intention of this study to: (1) survey these same canals, (2) re-evaluate the restoration success twenty years after backfilling, and (3) identify the factors leading to successful backfilling.

Methods

The restoration success of thirty canals, backfilled at least twenty years ago, was examined in this study. The sites were chosen from a set of thirty-three canals backfilled between 1979 and 1984, and represent the earliest know examples of backfilling (Neill and Turner, 1987a). Data were collected on soil structure, vegetation, and canal depth during the summer of 2004. All sites were sampled on the former spoil bank areas and also in the surrounding marsh to provide reference values.

The marsh and former spoil bank soils were sampled in six locations at each site using a 50 cm^3 piston corer with three cores per sample. Samples were analyzed for water content, bulk density, and organic matter. The water content was reported as the percent of weight lost after drying the sample at 60° C until a constant weight was reached. The bulk density was determined on a dry weight per volume basis ($g \cdot cm^{-3}$), and organic matter was reported as the percentage of dry sample weight lost after one hour of ignition at 550° C.

The percent recoveries of bulk density, water content, and organic matter were calculated with the formula:

$$\% \text{ Recovery} = \frac{NR - S}{NR - M} \times 100$$

where NR = the value of bulk density, water content, or organic matter of an unrestored spoil bank. NR was 0.925 $g \cdot cm^{-3}$ for bulk density, 10% for water content and 8.9% for organic matter – typical values of a 25 year old unrestored spoil bank

S = the value of bulk density, water content, or organic matter measured on the restored spoil bank area

M = the value of bulk density, water content, or organic matter measured from the reference marsh.

The spoil bank area was classified into one of three categories: spoil vegetation, marsh vegetation, or open water as determined from infrared aerial photographs taken in 2000, oblique aerial photographs from the Spring of 2004, and ground observations from the Summer of 2004.

The vegetation composition on the marsh and former spoil bank areas were compared by determining the species richness from six 1 m^2 plots from each area. Three evenly-spaced plots were surveyed on each side of the canal for the spoil bank and marsh vegetation estimates.

The canal depths were measured using a surveying rod in three evenly-spaced transects across each canal, five measurements per transect, and averaged to give one estimate of the average canal depth. A laser level surveying system was used to determine the canal water surface elevation relative to the marsh surface elevation, and the canal depths were then adjusted relative to the mean marsh elevation by subtracting the difference between the canal surface and marsh surface elevations.

The status of a plug was noted at each canal. Sites were considered plugged if the plug was intact and prevented water exchange during normal tidal fluctuations. Sites were considered unplugged if no plug was constructed, or if the plug had deteriorated and allowed water exchange for at least 15 years as determined from aerial photographs.

All statistical tests were done using Statistical Analysis System (SAS, 2003) software. A two sample t-test ($\alpha = 0.05$) was used to compare species richness between the restored spoil banks and the surrounding marsh, and to compare canal depths between canals with and without plugs. Comparisons of soil property restoration between marsh types was done using Least Square Differences (LSD) with Tukey-adjusted p-values to control the error rate. Comparisons between the data collected in 1984 by Neill and Turner (1987a), and the data collected in this study were made using two sample t-tests, with a Bonferoni adjustment ($\alpha = 0.006$).

Results

The backfilled canals examined in this study occurred in all coastal marsh types, and varied greatly in length and direct impact (Tables 1 and 2). There were 16 sites in brackish marsh, 4 sites in salt marsh, and 5 sites in both intermediate and fresh marshes. The longest backfilled canal was the Pecan Island West site (1859 m); this site also had the greatest direct impact (11.6 ha). The shortest canal was the Lower Mud Lake site (120 m), and the canal with the smallest direct impact was the Lafitte site (1.7 ha).

The restoration of marsh soils on the former spoil areas was incomplete (Table 1). The former spoil areas had higher bulk densities, lower organic matter contents, and lower water contents than the surrounding marsh at all sites except at Tigre Lagoon. A recent deposit of highly organic material on the former spoil area accounts for the high levels of soil restoration at the Tigre Lagoon site. The percent recovery of bulk density, water content, and organic matter, Tigre Lagoon excluded, on the former spoil bank areas ranged from 18.9% to 94.0%, 41.2% to 94.9% , and 2.5% to 80.4% respectively (Table 2). The recovery of water content and bulk density was related to the recovery of organic matter (Figure 1).

Backfilling restored marsh on a portion of the former spoil bank area at all thirty sites, and restored marsh in a portion of the canal at 16 sites (Table 2). The area of spoil bank restored to marsh varied from 5% to 95%, with an average of 58%, and was limited by the area of spoil bank actually backfilled (Figure 2). The restoration of marsh in the canal was inconsistent, ranging from 0% to 100%, with an average of 13% cover. However, two sites had their canal area completely restored to marsh conditions - Dupree Cut and Lower Mud Lake. Overall, 3.3% to 77% of the direct impacts of canal dredging were restored to marsh by backfilling.

Table 1. Soil properties of the former spoil and marsh areas from the thirty canals backfilled between 1979 and 1984. n= number of samples,nd= no data, Brack.= brackish marsh, and Inter.= intermedieate marsh.

					Spoil			Marsh		
Site Name	Marsh Type	Length (m)	Canal Depth (m)	n	Bulk Density ($g \cdot cm^{-3}$)	% Water Content	% Organic Matter	Bulk Density ($g \cdot cm^{-3}$)	% Water Content	% Organic Matter
Hellhole Lake	Salt	1432	nd	nd	nd	nd	nd	nd	nd	nd
Boston Bayou N.	Brack.	243	0.7	6	0.53	54.8	19.8	0.14	83.6	35.1
Boston Canal	Brack.	365	0.7	4	0.35	66.7	18.3	0.10	87.8	49.0
Tigre Lagoon	Brack.	152	1.0	6	0.14	84.5	52.3	0.22	76.5	37.9
Golette Bay	Brack.	300	1.0	6	0.14	85.3	52.7	0.08	91.3	63.4
Grand Lac L'Huit	Fresh	487	nd	nd	nd	nd	nd	nd	nd	nd
Mallard Bay West	Fresh	354	nd	nd	nd	nd	nd	nd	nd	nd
Mallard Bay East	Fresh	295	nd	nd	nd	nd	nd	nd	nd	nd
Mermentau River	Brack.	229	0.7	5	0.57	53.6	16.1	0.45	59.9	22.4
Mosquito Bay	Brack.	152	0.7	6	0.35	66.8	20.0	0.31	69.8	24.4
Vermilion River	Inter.	670	0.7	6	0.52	55.3	21.8	0.12	86.2	43.2
Bayou Long	Inter.	457	0.9	6	0.28	71.2	33.3	0.20	77.6	36.2
Four Isle Bay	Salt	426	1.5	6	0.28	72.0	28.2	0.17	82.3	34.4
Pecan Island West	Brack.	1859	0.3	6	0.39	63.6	17.5	0.24	73.7	23.5
Lafitte	Brack.	152	nd	nd	nd	nd	nd	nd	nd	nd
Dupree Cut	Brack.	152	0.0	5	0.93	30.0	8.9	0.15	82.6	44.7
Buckskin Bayou	Brack.	609	1.4	6	0.67	46.0	12.2	0.37	65.4	19.0
Falgout Canal	Inter.	400	1.3	6	0.20	79.6	35.0	0.07	92.4	62.7
Catfish Lake	Salt	457	0.8	6	0.78	40.5	9.8	0.15	84.1	45.9
Fourleague Bay	Brack.	304	0.9	6	0.34	67.5	21.8	0.20	78.6	34.9
ICWW/Oaks Canal	Brack.	399	0.5	6	0.42	61.9	21.3	0.18	80.2	30.4
Lower Mud Lake	Salt	120	0.0	6	0.50	57.2	16.2	0.31	69.0	22.8
Boston Bayou S.	Brack.	609	0.6	6	0.29	71.4	22.8	0.19	78.9	29.6
Iberia Canal	Inter.	1219	1.3	6	0.27	74.6	36.8	0.09	89.5	69.7
Delta Farms	Fresh	434	nd	nd	nd	nd	nd	nd	nd	nd
Rainey Refuge	Brack.	173	1.1	5	0.60	50.9	18.2	0.07	92.2	65.1
Pecan Island East	Brack.	826	nd	nd	nd	nd	nd	nd	nd	nd
Superior Bridge	Inter.	457	1.4	6	0.53	55.7	17.2	0.09	90.3	58.4
Long Island	Fresh	457	nd	nd	nd	nd	nd	nd	nd	nd
Point a la Hache	Brack.	664	0.7	4	0.23	76.5	39.5	0.08	90.6	60.0
Mean		495	0.8		0.42	63.0	24.5	0.18	81.0	41.5

Table 2. General canal information, and percent recoveries of soil properties and site area. Canal depths were measured in 2004. The "Direct Impact" is the original area impacted by canal and spoil placement, and "% of Site Restored to Marsh" refers to the percent of the direct impact restored to marsh. *Dupree Cut may have been filled with sediment from an adjacent canal, not its own spoil banks. nd = no data.

	Direct	% Recovery					% of Site	Age at
Site Name	Impact (ha)	Organic Matter	Bulk Density	Water Content	% Marsh on Spoil	% Marsh in Canal	Restored to Marsh	Backfilling (years)
Hellhole Lake	10.6	nd	nd	nd	90	0	61	0.9
Boston Bayou N.	4.3	41.5	50.1	60.8	6	0	4	19.3
Boston Canal	5.0	23.4	70.2	72.9	20	5	17	0.3
Tigre Lagoon	1.9	149.4	111.3	112.0	56	0	55	0.3
Golette Bay	3.1	80.4	92.7	92.6	65	0	46	0.5
Grand Lac L'Huit	4.2	nd	nd	nd	88	55	77	18.3
Mallard Bay West	3.7	nd	nd	nd	80	0	54	0.6
Mallard Bay East	3.3	nd	nd	nd	95	5	68	0.2
Mermentau River	4.5	53.4	76.3	87.4	65	5	48	5.0
Mosquito Bay	2.4	71.6	94.0	94.9	80	0	57	0.2
Vermilion River	6.2	37.7	50.9	59.4	83	3	61	1.9
Bayou Long	4.5	16.2	88.9	90.4	10	2	8	6.3
Four Isle Bay	4.5	75.8	85.1	85.7	93	0	66	7.3
Pecan Island West	11.6	59.0	77.3	84.2	93	40	77	34.1
Lafitte	1.7	nd	nd	nd	15	0	9	8.4
Dupree Cut*	2.2	nd	nd	nd	15	100	42	4.3
Buckskin Bayou	4.6	32.9	45.6	65.0	75	0	52	0.2
Falgout Canal	3.8	48.5	84.5	84.5	83	0	57	8.3
Catfish Lake	3.5	2.5	18.9	41.2	50	0	31	2.8
Fourleague Bay	2.5	49.6	81.1	83.8	95	0	57	21.9
ICWW/Oaks Canal	4.3	57.9	67.8	74.0	90	45	76	1.5
Lower Mud Lake	4.5	52.4	69.3	80.0	75	80	76	0.8
Boston Bayou S.	5.7	67.1	86.1	89.1	50	2	37	18.6
Iberia Canal	11.1	45.8	78.5	81.3	30	1	22	2.1
Delta Farms	4.2	nd	nd	nd	5	0	3	1.4
Rainey Refuge	2.1	16.5	37.4	49.8	55	2	37	2.0
Pecan Island East	5.4	nd	nd	nd	5	0	3	40.1
Superior Bridge	5.9	16.9	46.8	57.0	78	7	62	nd
Long Island	3.9	nd	nd	nd	50	30	43	nd
Point a la Hache	5.9	59.8	82.9	82.5	50	5	36	0.0
Mean	4.7	50.4	71.2	77.6	58	13	45	7.4

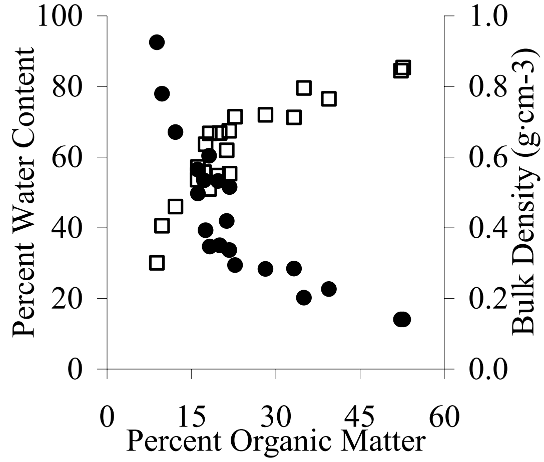

Figure 1. Soil bulk density (●) and water content (□) as a function of soil organic matter on the former spoil areas.

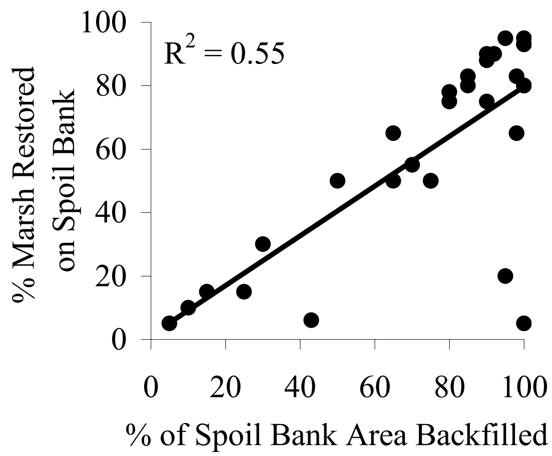

Figure 2. The percent of marsh restored on the former spoil area as a function of the area of spoil bank backfilled. The three sites that do not appear to follow the trend are sites where spoil was backfilled too deep and open water persists.

The plant species richness on the former spoil area did not match that of the reference marsh. The average number of species on the former spoil bank areas was significantly higher ($p < 0.05$) than the reference marsh (Figure 3).

Marsh type had no significant effect on soil restoration (Figure 4). The percent recovery of organic matter, bulk density, and water content did not differ significantly ($p > 0.05$) between marsh types. There were also no significant differences ($p > 0.05$) in canal depths between marsh types, but canal depths were impacted by the presence, or absence, of a plug with unplugged canals being significantly ($p < 0.05$) shallower than plugged canals (Figure 5).

There were no significant differences between 1984 and 2004 for the percent cover of marsh, spoil vegetation, or water on the former spoil area, percent cover of marsh in the canal, canal depth, or percent recovery of water content (Figures 5 and 6). However, the percent recoveries of organic matter and bulk density were significantly greater in 2004 than in 1984 (Figure 6).

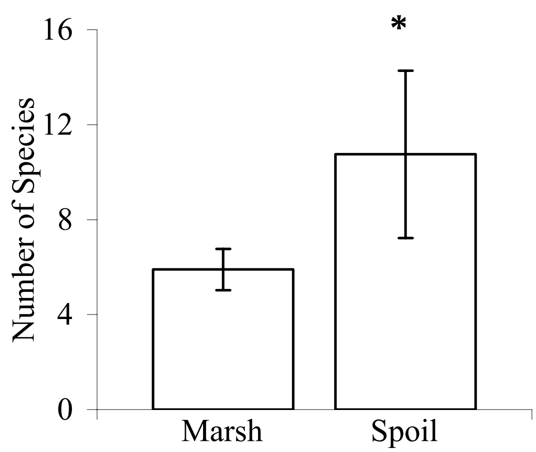

Figure 3. The mean number of emergent macrophyte species found in the natural marsh and backfilled spoil bank. Error bars are the 95% confidence intervals, and an “*” indicates a significant difference (Students t-test, $p < 0.05$).

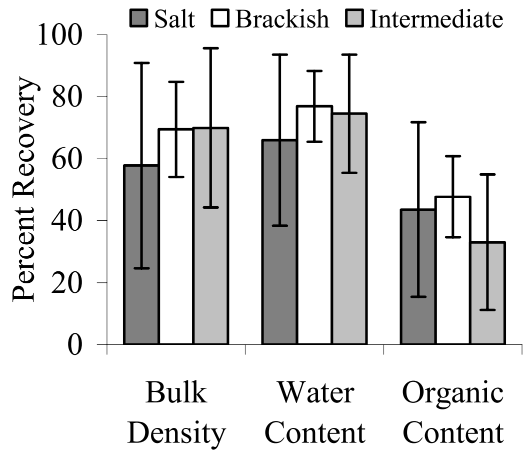

Figure 4. A comparison of soil restoration between different marsh types. Error bars are the 95% confidence intervals, and there were no significant differences between marsh types (LSD, $p > 0.05$).

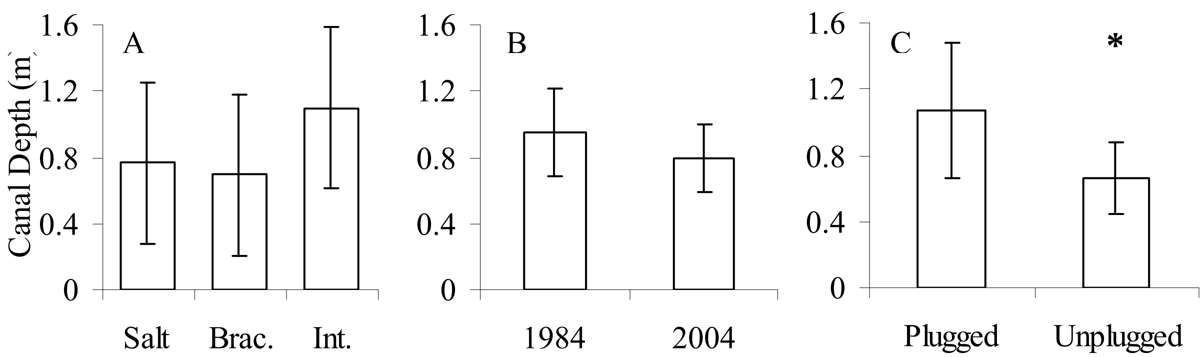

Figure 5. Comparisons of canal depth between marsh types (A), sampling years (B), and plug status (C). Brac. = brackish marsh and Int.= intermediate marsh. Error bars are the 95% confidence intervals, and an "*" indicates a significant difference (Students t-test, $p < 0.05$).

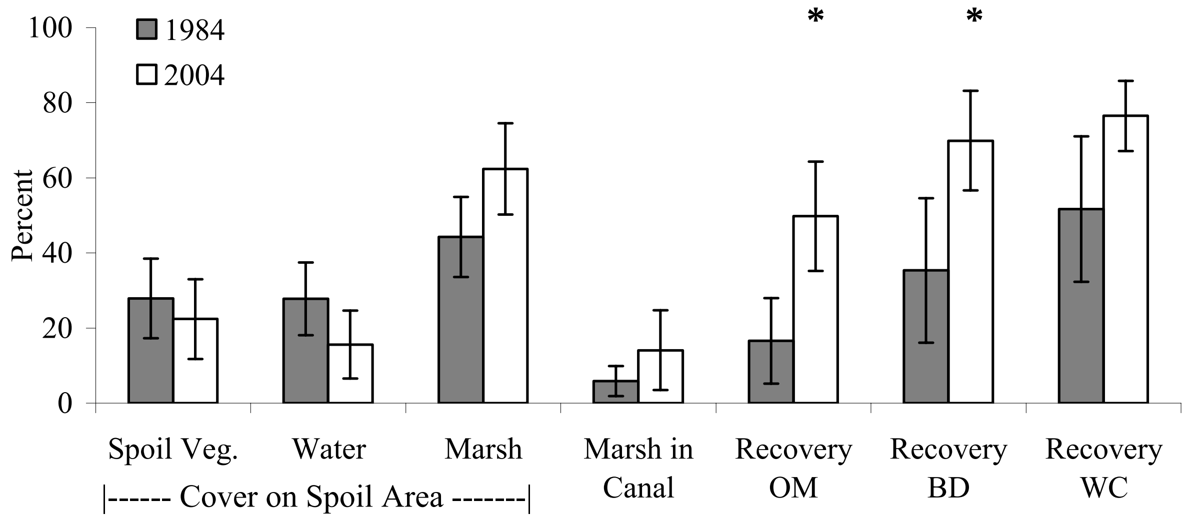

Figure 6. Comparisons of vegetative cover on the former spoil areas, marsh in canal and recovery of soil properties between 1984 and 2004. OM = organic matter, BD = bulk density, WC = water content. Error bars are the 95% confidence intervals, and an "*" indicates a significant difference ($p < 0.006$, Students t-test with Bonferoni correction).

Discussion

The amount of marsh restored on former spoil areas was limited by the completeness of spoil removal (Figure 2). There were many sites where elevated spoil remained simply because it was missed by the dredge operator. A barge mounted dredge was used in the early years of backfilling which put a constraint on the area of spoil bank reachable with the dredge. As a result, dredge operators were not always able to reach the back edges of the spoil banks, and an elevated rim of spoil remained around the outside of the canal (Figure 7).

To improve the completeness of spoil removal marsh buggies have been used in more recent backfilling efforts. The marsh buggy gives its operator a greater range of movement than the barge mounted dredge, and allows the operator to reach the back edges of the spoil banks. Abernethy and Gosselink (1988) realized the improved efficiency of the marsh buggy during the backfilling of the Louisiana Offshore Oil Port pipeline, but thought its uses would be limited to backfilling canals in intact marshes with highly mineral soils. Intact marshes and marshes of high mineral content are not the norm in Coastal Louisiana, but marsh buggies have been successful at backfilling canals in other marsh types. For example, a marsh buggy was used to effectively backfill two canals at Jean Lafitte National Park (Figure 7), which is in an area of highly organic fresh marsh soils with low mineral content.

The restoration of soils on the former spoil areas is a lengthy process that depends on the build up of organic matter (Figure 1). An increase in organic matter correlates with a decrease in bulk density (Craft, 2000), and organic matter is recognized to increase the soil's water holding capacity (Neill and Turner, 1987a). At optimal conditions, backfilling restored 80% of the organic matter and 94% of the soil's bulk density and water content after 20 years (Table 2).

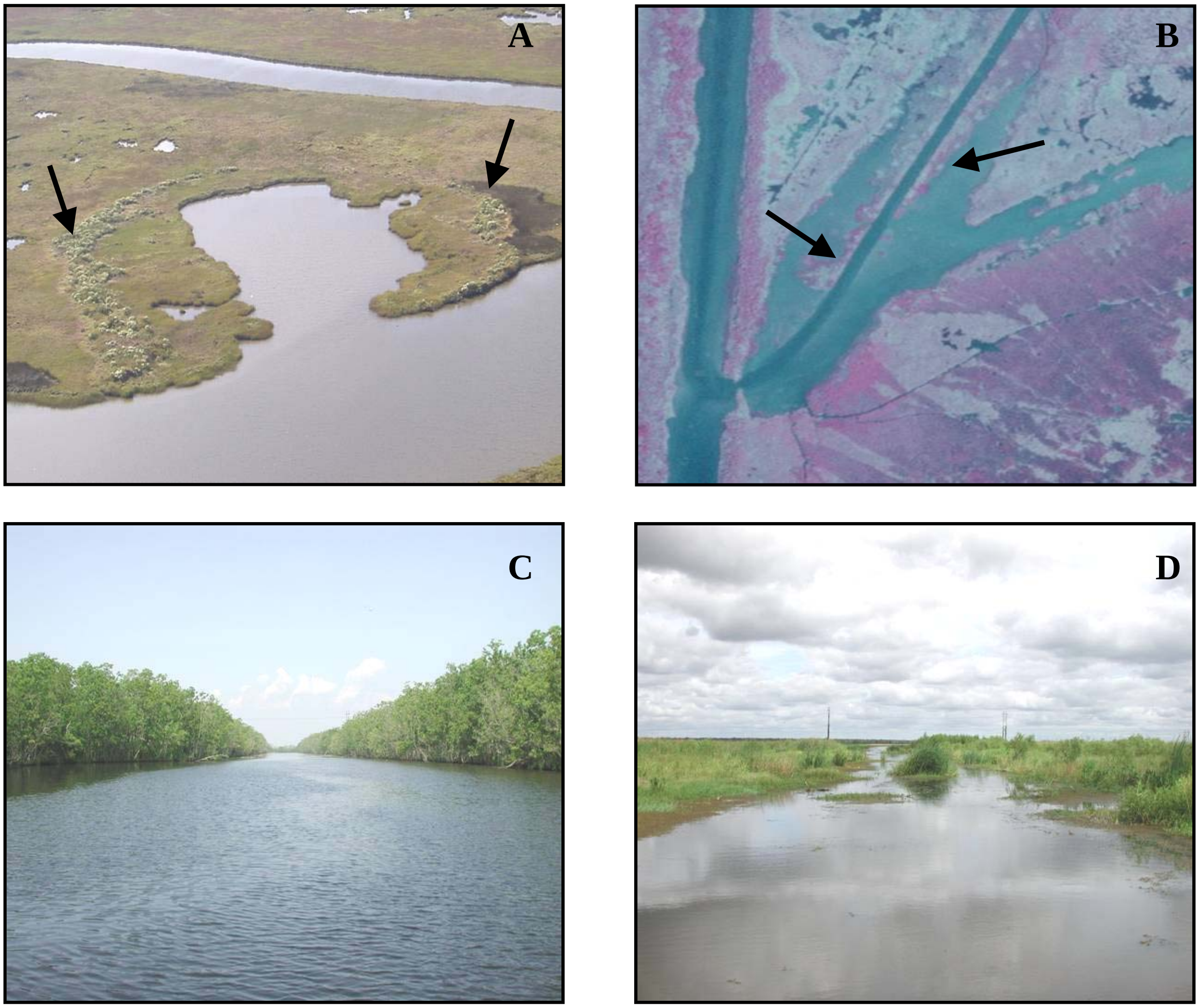

Figure 7. The Mosquito Bay backfilled canal (A), the arrows point to a rim of elevated spoil not reachable by the barge mounted dredge. A portion of the Pecan Island West backfilled canal (B), the arrows point to marsh building in the canal through over-bank flooding. A canal at Jean Lafitte National Park before (C) and two years after being backfilled with a marsh buggy (D).

This length of time for soil restoration may seem long, but it is by no means unusual. Craft et al. (2003) reported significantly lower organic matter pools in a constructed North Carolina salt marsh, compared to a nearby reference marsh, even after 28 years.

Plant communities on the former spoil bank areas rarely matched those of the surrounding marsh; the former spoil areas had significantly more species (Figure 2). At many sites this was due to incomplete spoil removal, which allowed for a higher species richness (Figure 8).

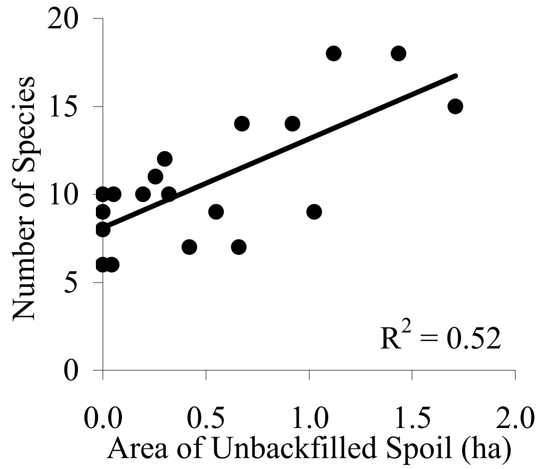

Figure 8. The number of plant species present on the former spoil areas as a function of the area of elevated spoil remaining after backfilling.

At several sites the backfilled canal acts as a stream conveying water through the marsh. Natural over-bank flooding processes occur at these sites, and the canal and adjacent backfilled spoil areas are the recipient of heavier inorganic sediments, similar to a natural streamside levee (Figure 7). The former spoil areas, as a streamside marsh, may develop plant communities and soil properties that will never be equivalent to the surrounding marsh. The streamside marsh created may not be identical to the marsh reference site, but it is a restored wetland and provides more wetland habitat value than the elevated spoil bank.

Canals backfilled in intermediate marshes were deeper than canals backfilled in brackish or saline marshes, but the differences were not significant (Figure 5). Neill and Turner (1987a) also found that canals backfilled in intermediate marsh tend to be the deepest, but this is likely the result of incomplete spoil removal and local hydrologic conditions at these sites, and is not due to differences in marsh types. No significant differences were found between marsh types for the percent recoveries of soil properties (Figure 4). The three sites with the highest percentages of

site recovery to marsh occurred in fresh, brackish and salt marshes, respectively (Tables 1 and 2), indicating that marsh type, per se, has little effect on backfilling success.

Although backfilling can be successful in any marsh type, the marsh location may be relevant. The Chenier Plain of western Louisiana is a particularly attractive location for backfilling, because the generally higher bulk densities and lower subsidence rates mean more spoil material is available to fill canals there compared to the Deltaic Plain.

Backfilled canals that had an intact plug were significantly deeper ($p < 0.05$) than canals that were not plugged, or which had a deteriorated plug (Figure 5). Canals were originally plugged to reduce erosion from boat wakes, wave action, and tidal scour, all of which are processes thought to lead to the deepening of canals. However, unplugged backfilled canals actually tend to accumulate sediments over time which may lead to them being shallower than plugged canals (Reed and Rozas, 1995). A plug could be beneficially used during backfilling to help keep sediments from escaping the canal, and then later breached to allow water exchange.

Leaving canals unplugged, or at least partially unplugged, has benefits for wildlife as well. Backfilling canals creates shallow water habitat which can be utilized by waterfowl, fish, and crustacean species. Neill and Turner (1987b) found that plugging canals limited the amount of nursery habitat available to migrant fish species, and fewer fish were found in plugged canals than in adjacent open areas (Adkins and Bowman, 1976). Along with the shallow water habitat, backfilling creates marsh edge habitat, which is valuable in its own right, and allows nekton access to marsh habitat (Peterson and Turner, 1994).

The percent cover of marsh on the former spoil area, and in the canal, increased between 1984 and 2004, but the difference was not significant due to the high variation of the data (Figure 6). The percent recovery of all measured soil properties also increased between 1984 and 2004,

and the recovery of organic matter and bulk density was significantly higher (Figure 6). The comparisons between the 1984 and 2004 data suggest that the restoration process after backfilling has continued for 20 years. The monitoring in this study painted a brighter picture of backfilling's success as restoration of soils continued to occur, and marsh took a greater hold on the former spoil areas. Much would have been missed if the monitoring of these canals in 1984 was the only data available on the success of backfilling.

The relationship between canal age and depth after backfilling becomes increasingly important as the average age for canals in Louisiana continues to increase. Figure 9 shows that older canals will be shallower after backfilling, and a similar relationship has been found for backfilled pipeline canals (Reed and Rozas, 1995). The amount of spoil material available for backfilling decreases over time as a result of erosion and subsidence, but older canals (>5 years) can still produce shallow water in the canal even with the decrease in spoil volume available for backfilling.

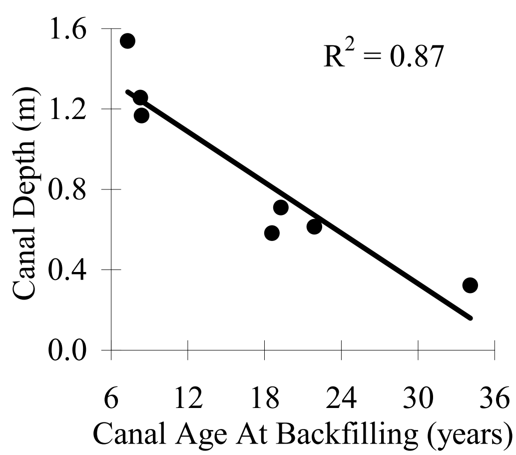

Figure 9. The water depth in canals greater than seven years of age decreased linearly after backfilling.

In this study the success of backfilling was controlled primarily by two factors: (1) the dredge operator's efficiency at spoil bank removal, and (2) the position of the canal in the

landscape. Returning spoil banks to the proper elevation during backfilling is essential, because the future success depends so heavily on the initial restoration action. Backfilling the spoil banks to marsh elevation allows for faster recolonization by marsh vegetation, which begins the process of soil restoration, and permits a more regular hydrologic regime. Surveys done during backfilling could help ensure that proper elevation is reached and the restoration potential is maximized.

Backfilling was most successful in areas where the canal density was moderately low, and the indirect effects of canals, spoil banks, subsidence, and other factors had not claimed a large portion of the surrounding marsh. Although canals that were backfilled within large oil fields or impounded areas restored marsh on the spoil banks, backfilling showed little hydrologic benefit to the surrounding marsh. The immense hydrologic modifications in those areas could not be overcome by the backfilling of one canal alone. However, backfilling multiple canals in one area is a strategy that could be used to maximize local hydrological restoration. This would provide increased benefits to surrounding marshes as natural drainage patterns reemerge, and marshes receive sediment from more regular flooding cycles.

Conclusions

Backfilling is a restoration technique that creates marsh and restores local hydrologic conditions by removing spoil banks and shallowing the canal. Marsh created from backfilling 20 years ago has been sustained, and additional marsh has since been restored. The increased success of backfilling over time illustrates how ecological processes often operate on longer timescales than those allowed for by restoration monitoring plans.

The damage to Louisiana marshes caused by canals and spoil banks is widely acknowledged, but there has been a disconnect between the known causes of land loss and the focus of coastal restoration. If the direct land losses from canals and spoil banks account for 22% of the total land loss, then it seems reasonable to conclude that a comparable effort be put towards canal and spoil bank restoration. Yet, backfilling abandoned oil and gas canals has been overlooked and under utilized by restoration managers. The thirty sites in this study, for example, actually represent the majority of all known backfilled canals.

This study clearly demonstrates that backfilling can restore marsh where spoil once existed, but the degree of restoration depends on the original spoil removal effort. The success of backfilling was often limited by incomplete spoil removal, not a deficiency of the technique. Backfilling is a simple, yet effective, restoration technique that can be used to mitigate the effects canals and spoils banks have on coastal marshes, and the information in this study can help restoration managers make more informed decisions on the best restoration techniques available.

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Appendix: An Atlas of Backfilled Canals

This appendix is an updated atlas of all canals known to be backfilled through 1984 as identified by "An Evaluation of Backfilling Canals as a Means of Mitigating the Environmental Impact of Canals in South Louisiana: Atlas of Backfilled Canals" submitted to the Louisiana Department of Natural Resources in April 1985 by Christopher Neill and R. Eugene Turner.

This updated atlas contains general information about canal locations, canal dimensions, and dates when the canals were backfilled. Each canal is accompanied by two photographs, an infrared image of the canal taken in 2000, and an oblique aerial photograph taken from a small plane in 2004.

1 – Hellhole Lake

Coastal Use Permit Number: P800402
U.S. Army Corps of Engineers Permit Number: Old Oyster Bayou 2
Applicant: Peltex Oil Company
Landowner: Louisiana Land and Exploration Company
Well Name: LL&E Number 1
Location: 29°12’6” North, 91°6’00” West
Length: 1433 m
Area Disturbed: Canal – 3.4 ha, Spoil Banks – 7.2 ha
Marsh Type: Salt
Date Canal Dredged: May 1981
Date Canal Backfilled: April 1982
Aerial Inspection: 25 October 2004
Ground Inspection: None
Percent of Spoil Bank Returned to Marsh Elevation: 90%
Average Canal Depth After Backfilling: NA
Vegetation Cover on Backfilled Spoil Banks: Marsh – 90%, Spoil – 8%, Water – 2%

Site Characteristics

Interpreted information is from aerial imagery because no ground evaluation was performed at this site. This site is dissected by a large marsh pond with the spoil banks being effectively returned to marsh elevation on 90% of the non-pond segments of the canal. The plant species on the leveled spoil bank portions were unknown, but appeared similar to the surrounding marsh. Where elevated spoil remained the species composition was different and included shrubby species such as *Iva frutescens* and *Baccharis halimifolia*.

Figure 10. An infrared image of the backfilled canal at Hellhole Lake, noted by the arrow, that runs from Hellhole Lake at the top of the picture, dissects a large marsh pond, and terminates a few hundred m from the Gulf of Mexico. The image was taken in 2000.

Figure 11. The Hellhole Lake backfilled site in October 2004.

2 – Boston Bayou North

Coastal Use Permit Number: P800217
U.S. Army Corps of Engineers Permit Number: Cameron Parish Wetlands 352
Applicant: Quintana Petroleum Corporation
Landowner: John Nugier et al.
Well Name: Nugier Number 4
Location: 29°49’30” North, 92°03’00” West
Length: 244 m
Area Disturbed: Canal – 1.3 ha, Spoil Banks – 3.0 ha
Vegetation Type: Brackish
Date Canal Dredged: November 1962
Date Canal Backfilled: February 1982
Aerial Inspection: 21 April 2004
Ground Inspection: 2 June 2004
Percent of Spoil Bank Returned to Marsh Elevation: 6%
Average Canal Depth After Backfilling: 0.7 m
Cover on Backfilled Spoil Banks: Marsh – 6%, Spoil – 57%, Water – 37%

Site Characteristics

Canal: The site showed almost no signs of being backfilled. Trees lined both sides of the canal, except where a stream drained the marsh on the west side of the canal. The original site evaluation in 1984 indicated that only the inner half of the spoil banks were backfilled, leaving a continuous elevated spoil ridge along the outer edge. The portions of spoil bank that were removed were dug too deep and are now open water. The canal ranged in depth from 0.5 to 1.3 m with an average depth of 0.7 m. Submerged aquatic vegetation was present in the canal.

Spoil Banks: The portion of the spoil banks that were not backfilled were thickly vegetated with trees and other upland vegetation. Chinese Tallow (*Sapium sebiferum*) was the dominate species with Hackberry (*Celtis occidentalis*), Wax Myrtle (*Myrica cerifera*), Groundsel Bush (*baccharis halimofolia*), Holly bushes (*Ilex sp*.), and other under-story species present. The species present on the marsh edge of the spoil banks included: bull-tongue (*Sagittaria lancifolia*), Goldenrod (*Solidago sempervirens*), Bulrush (*Schoenoplectus californicus)*, Giant Cutgrass (*Zizaniopsis miliacea*), Common Three-square (*Schoenoplectus americanus*), Marshhay Cordgrass (*Spartina patens*), and Marsh Morning Glory (*Ipomoea sp.*).

Marsh: The canal is in an intermediate to brackish marsh with heavy localized canalization and many ponds of varying size. The marsh consisted of bull-tongue (*Sagittaria lancifolia*), common three square (*Schoenoplectus americanus*), Marshhay Cordgrass (*Spartina patens*), and traces of Deer Pea (*Vigna luteola*), Smartweed (*Polygonum sp.*), and Marsh Morning Glory (*Ipomoea sp.*).

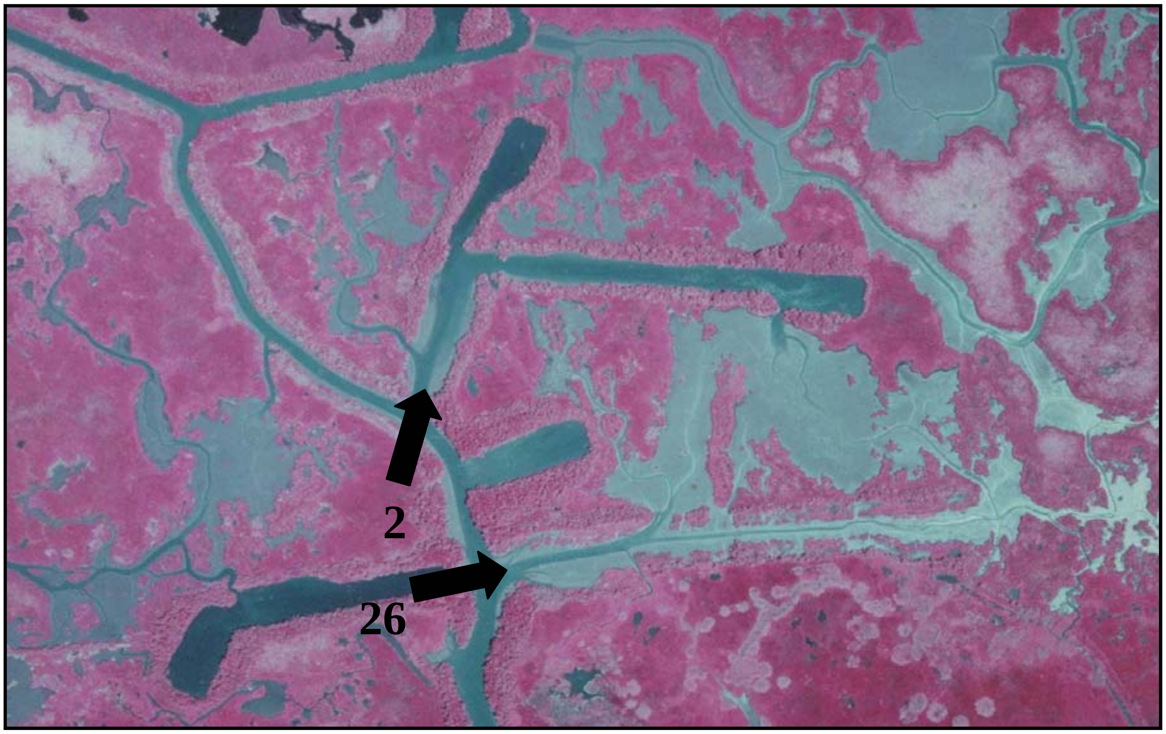

Figure 12. An infrared image of the Boston Bayou North, number 2, backfilled canal taken in 2000. The backfilled canal Boston Bayou South, number 26, can also be seen, along with numerous un-filled canals.


Figure 13. The Boston Bayou North backfilled site in April 2004.

3 – Boston Canal

Coastal Use Permit Number: P810029
U.S. Army Corps of Engineers Permit Number: Vermilion Parish Wetlands 114
Applicant: Lyons Petroleum, Inc.
Landowner: Vermilion Parish School Board
Well Name: Vermilion Parish School Board Number 1
Location: 29°49'17" North, 92°03'54" West
Length: 366 m
Area Disturbed: Canal – 1.1 ha, Spoil Banks – 3.9 ha
Vegetation Type: Brackish
Date Canal Dredged: July 1981
Date Canal Backfilled: November 1981
Aerial Inspection: 21 April 2004
Ground Inspection: 2 June 2004
Percent of Spoil Bank Returned to Marsh Elevation: 20%
Average Canal Depth After Backfilling: 0.7 m
Cover on Backfilled Spoil Banks: Marsh – 20%, Spoil – 5%, Water – 75%

Site Characteristics

Canal. The canal was nearly indistinguishable from the many other marsh ponds in the area. The canal was shallow, 0.6 to 1.4 m, and was thickly vegetated with submerged aquatic plant species such as Eurasian Milfoil (*Myriophyllum spicatum*) and Widgeon-grass (*Ruppia maritima*).

Spoil Banks. The spoil banks were completely removed over 95% of their area, with 20% of the area leveled to marsh elevation, and 75% removed to below marsh elevation. Where elevated spoil remained, plant species included: Chinese tallow (*Sapium sebiferum*), Groundsel Bush (*Baccharis halimifolia*), and Rattlebush (*Sesbania drummondii*). Where the spoil bank was returned to marsh, the plant species included Marshhay Cordgrass (*Spartina patens*), Soft Rush (*Juncus effuses*), Common Three-square (*Schoenoplectus americanus*), and Bull-tongue (*Sagittaria lancifolia*). The open water portions of the spoil bank consisted of the same submerged aquatic plant species as the canal.

Marsh. The marsh surrounding the canal was a highly fragmented brackish marsh with many large and small ponds. The percent cover in the marsh was 85% Marshhay Cordgrass (*Spartina patens*), 5% Soft Rush (*Juncus effuses*), and traces of Salt Marsh Loosestrife (*Lythrum lineare*), and Marsh Morning Glory (*Ipomoea sagittata*).

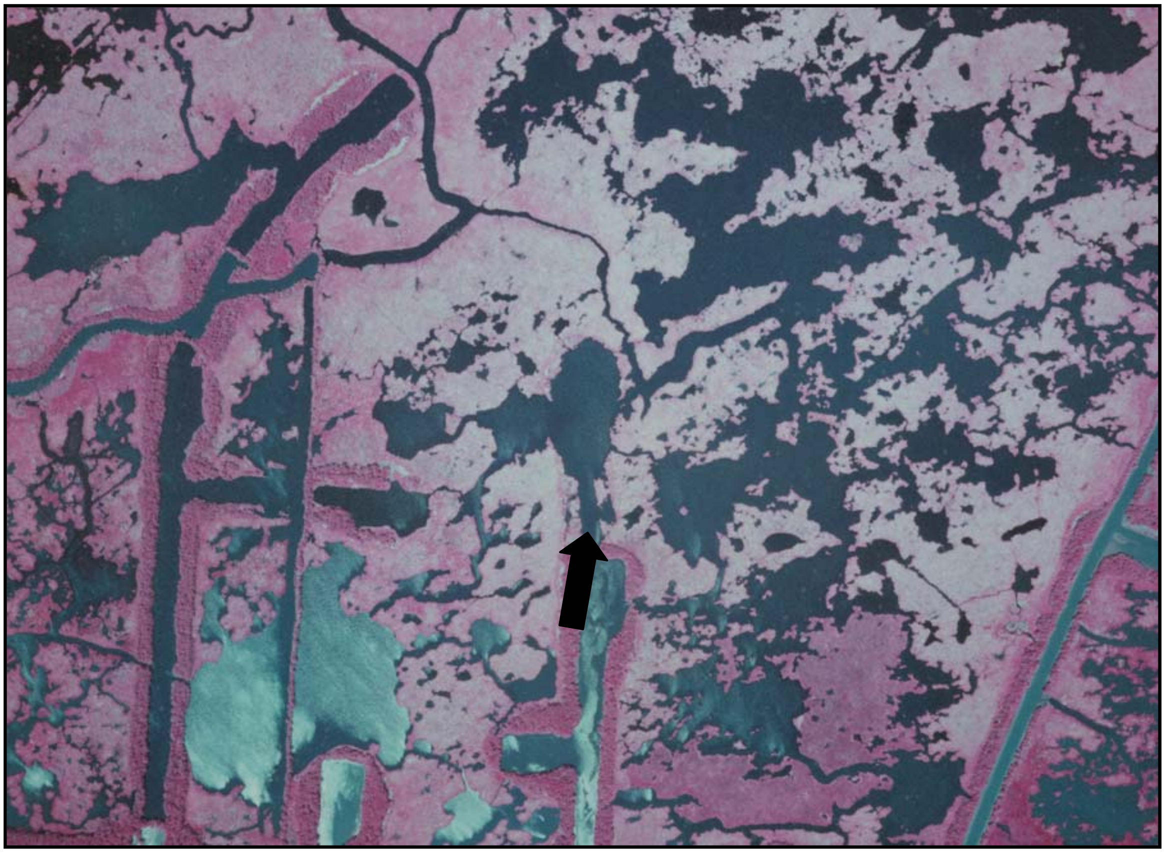

Figure 14. An infrared image of the Boston Canal backfilled canal, noted by the arrow, taken in 2000.

Figure 15. The Boston Canal backfilled site in April 2004.

4 – Tigre Lagoon

Coastal Use Permit Number: P810713
U.S. Army Corps of Engineers Permit Number: Iberia Parish Wetlands 66
Applicant: MGF Oil Corporation
Landowner: Vermilion Bay Land Company
Well Name: Vermilion Bay Land Company Number 2
Location: 29°49’18” North, 91°55’37” West
Length: 152 m
Area Disturbed: Canal – 0.6 ha, Spoil Banks – 1.3 ha
Vegetation Type: Brackish
Date Canal Dredged: July 1981
Date Canal Backfilled: November 1981
Aerial Inspection: 21 April 2004
Ground Inspection: 16 June 2004
Percent of Spoil Bank Returned to Marsh Elevation: 80%
Average Canal Depth After Backfilling: 1.0 m
Cover on Backfilled Spoil Banks: Marsh – 80%, Spoil – 0%, Water – 20%

Site Characteristics

Canal. The site was originally more than 300 m from the shoreline of East Cote Blanche Bay, but the shoreline has since retreated, and the canal now has a direct connection to the bay. This direct connection has increased the depth of the canal, and it is now subject to a more energetic wave environment.

Spoil Banks. The open water portion on the former spoil banks is due to the loss of the southern spoil bank because of shoreline retreat. The eastern spoil bank was formally open water, but has recently formed a bar of rich organic “coffee grounds” material that supports emergent vegetation of Millet species (*Echinochloa sp.*). The western spoil bank consisted of more diverse vegetation including: Marshhay Cordgrass (*Spartina patens*), Sawgrass (*Cladium jamaicense*), Common Three-square (*Schoenoplectus americanus*), *Paspalum distichum*, Bull-tongue (*Sagittaria lancifolia*), and Marsh Morning Glory (*Ipomoea sagittata*).

Marsh. The brackish marsh surrounding the canal consisted of a few large ponds and drainage creeks. The plant species present included: 40% Marshhay Cordgrass (*Spartina patens*), 31% Common Three square (*Schoenoplectus americanus*), 12% Salt Marsh Bulrush (*Schoenoplectus robustus*), 8% Marsh Morning Glory (*Ipomoea sagittata*), and traces of Smartweed (*Polygonum* sp.) and Deer Pea (*Vigna luteola*).

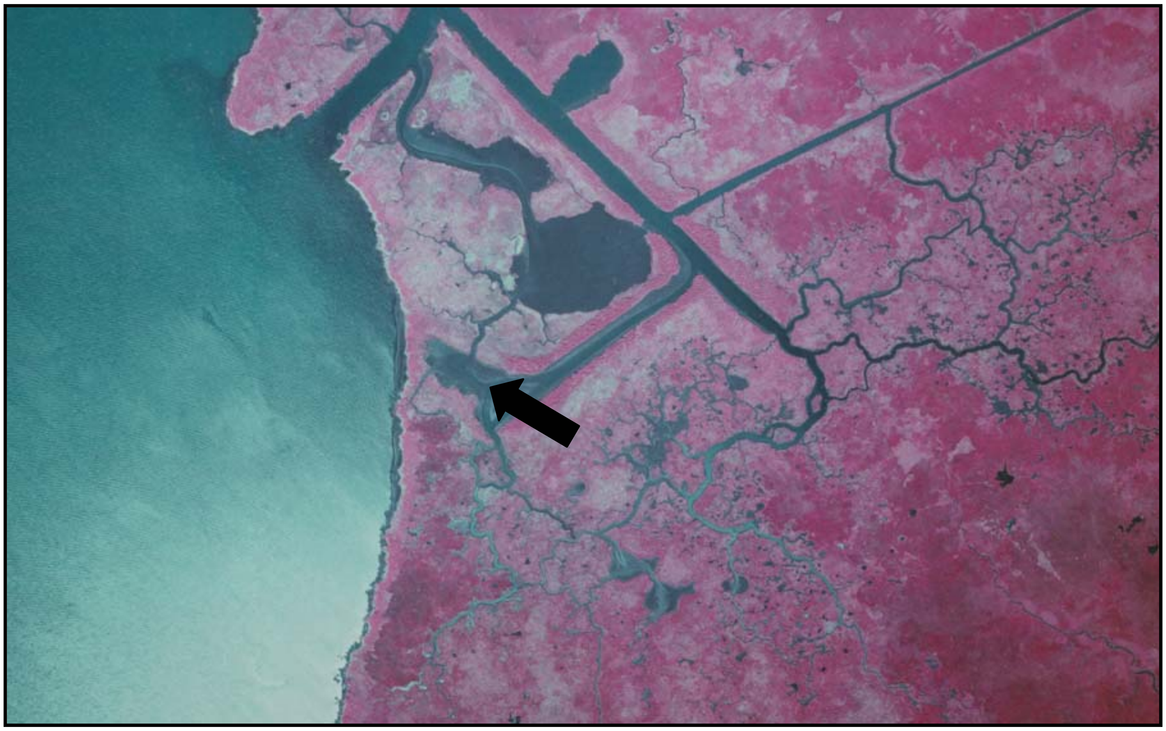

Figure 16. An infrared image of the Tigre Lagoon backfilled canal, noted by the arrow, taken in 2000.

Figure 17. The Tigre Lagoon backfilled site in April 2004 with its newly established connection to the Gulf of Mexico.

5 – Golette Bay

Coastal Use Permit Number: P810801
U.S. Army Corps of Engineers Permit Number: Jefferson Parish Wetlands 96
Applicant: LGS Exploration Incorporated
Landowner: Rigolets Cooperative Fur Company
Well Name: Rigolets Number 1
Location: 29°34’20” North, 90°00’42” West
Length: 300 m
Area Disturbed: Canal – 0.9 ha, Spoil Banks – 2.2 ha
Vegetation Type: Brackish
Date Canal Dredged: October 1981
Date Canal Backfilled: April 1982
Aerial Inspection: 5 October 2004
Ground Inspection: 31 May 2004
Percent of Spoil Bank Returned to Marsh Elevation: 65%
Average Canal Depth After Backfilling: 1.0 m
Cover on Backfilled Spoil Banks: Marsh – 65%, Spoil – 2%, Water – 33%

Site Characteristics

Canal. The canal was in a brackish marsh on the southern edge of a large oilfield. The canal remained deepest in the middle, and was shallower near the former spoil banks. No emergent vegetation was present in the canal.

Spoil Banks. The spoil banks were removed to, or below, marsh elevation over 98% of their area, with 65% being at marsh elevation and sustaining emergent marsh vegetation. Portions of the former spoil bank area that are now open water (as a result of removing to much spoil material) contained submerged aquatic plants, including Eurasian Milfoil (*Myriophyllum spicatum*). The portions of the spoil bank that were at marsh elevation consisted of: Marshhay Cordgrass (*Spartina patens*), Black Needle Rush (*Juncus roemerianus*), with traces of Marsh Loosestrife (*Lythrum lineare*), and Salt Grass (*Distichlis spicata*).

Marsh. The marsh was an intact brackish marsh with few small ponds. The vegetation included 63% Marshhay Cordgrass (*Spartina patens*), 15% Black Needle Rush (*Juncus roemerianus*), 18% Common Three square (*Schoenoplectus americanus*), and a trace of Marsh Loosestrife (*Lythrum lineare*).

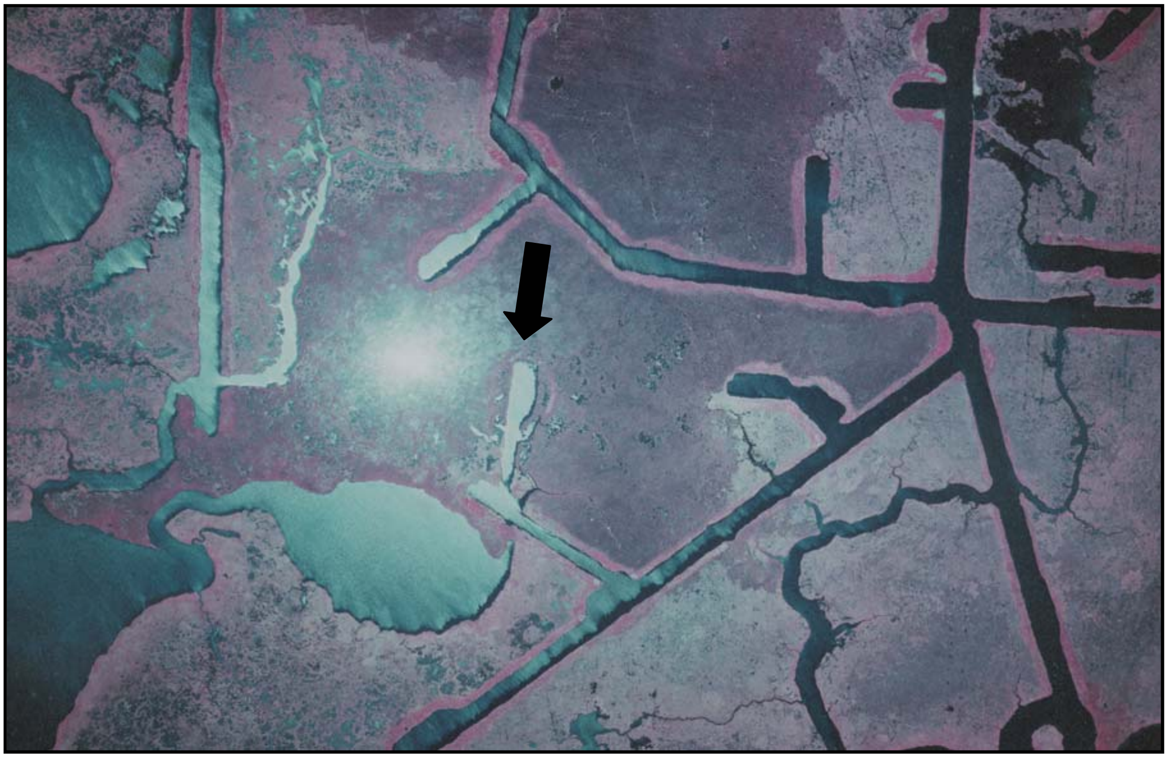

Figure 18. An infrared image of the Golette Bay backfilled canal, noted by the arrow, taken in 2000.

Figure 19. The Golette Bay backfilled site in October 2004.

6 – Grand L'ac Huit

Coastal Use Permit Number: Not issued
U.S. Army Corps of Engineers Permit Number: NA
Applicant: Houston Oil and Minerals Corporation
Landowner: Miami Corporation
Well Name: NA
Location: 29°45'50" North, 92°39'00" West
Length: 488 m
Area Disturbed: Canal – 1.4 ha, Spoil Banks – 2.8 ha
Vegetation Type: Fresh
Date Canal Dredged: August 1963
Date Canal Backfilled: After October 1978, but before December 1981
Aerial Inspection: 21 April 2004
Ground Inspection: 14 July 2004
Percent of Spoil Bank Returned to Marsh Elevation: 88%
Average Canal Depth After Backfilling: NA
Cover on Backfilled Spoil Banks: Marsh – 88%, Spoil – 10%, Water – 2%

Site Characteristics

A normal ground inspection was not performed at this site because of adverse field conditions. Emergent vegetation has grown out over portions of the canal, making travel by boat impossible, and water levels in the marsh made passage by foot difficult. Visual inspection revealed that the spoil banks were effectively returned to marsh elevation over nearly 90% of their area. The only elevated spoil remaining was along the outer edge of the spoil banks surrounding the turning basin. Overall the site was backfilled well. The canal has become narrower as emergent vegetation encroaches from the sides. Floating and submerged vegetation was also present in the canal.

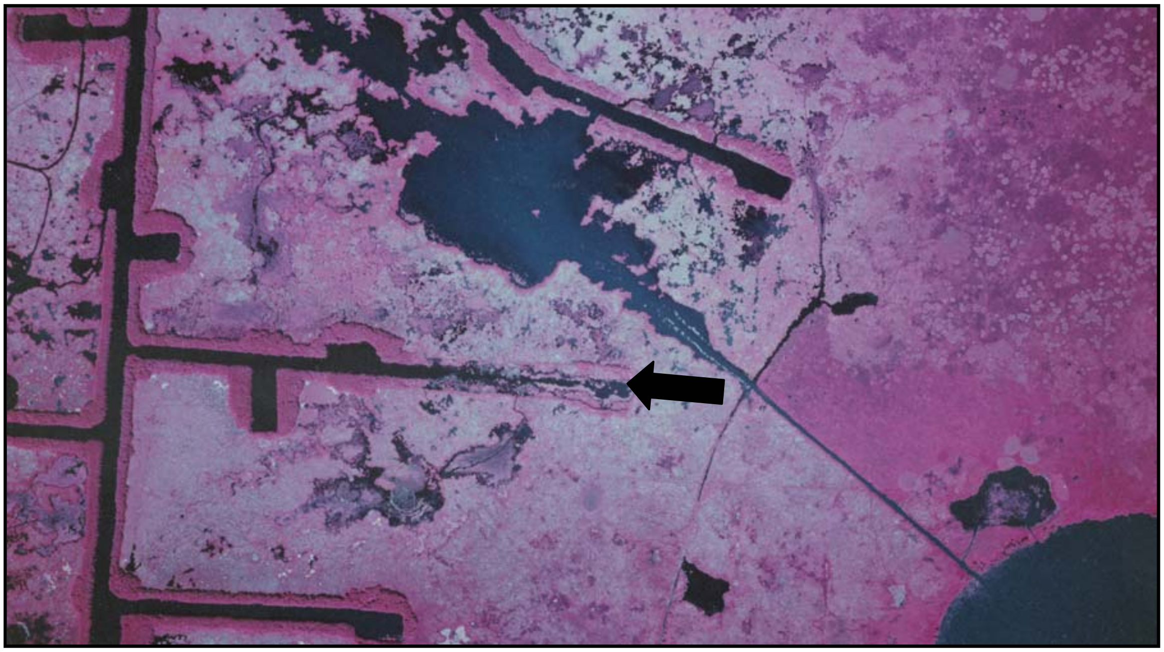

Figure 20. An infrared image of the Grand L'ac Huit backfilled canal, noted by the arrow, taken in 2000.

Figure 21. The Grand L'ac Huit backfilled seen in April 2004.

7 – Bayou Carlin

Coastal Use Permit Number: P812021
U.S. Army Corps of Engineers Permit Number: Bayou Carlin 23
Applicant: Stone Oil Corporation
Landowner: Weeks and Associates
Well Name: Weeks and Associates Number 2
Location: 29°59’09” North, 91°49’47” West
Length: 147 m
Area Disturbed: Canal – 1.5 ha, Spoil Banks – 3.3 ha
Vegetation Type: Intermediate
Date Canal Dredged: July 1982
Date Canal Backfilled: NA
Aerial Inspection: 21 April 2004
Ground Inspection: 15 June 2004
Percent of Spoil Bank Returned to Marsh Elevation: NA
Average Canal Depth After Backfilling: NA
Cover on Backfilled Spoil Banks: NA

Site Characteristics

This site was not backfilled at time of the original backfilling study in 1984, but was included because it was supposed to be backfilled shortly after the study. The site visit to this canal, and examination of aerial imagery, revealed no signs of backfilling, so it was not included in this study.

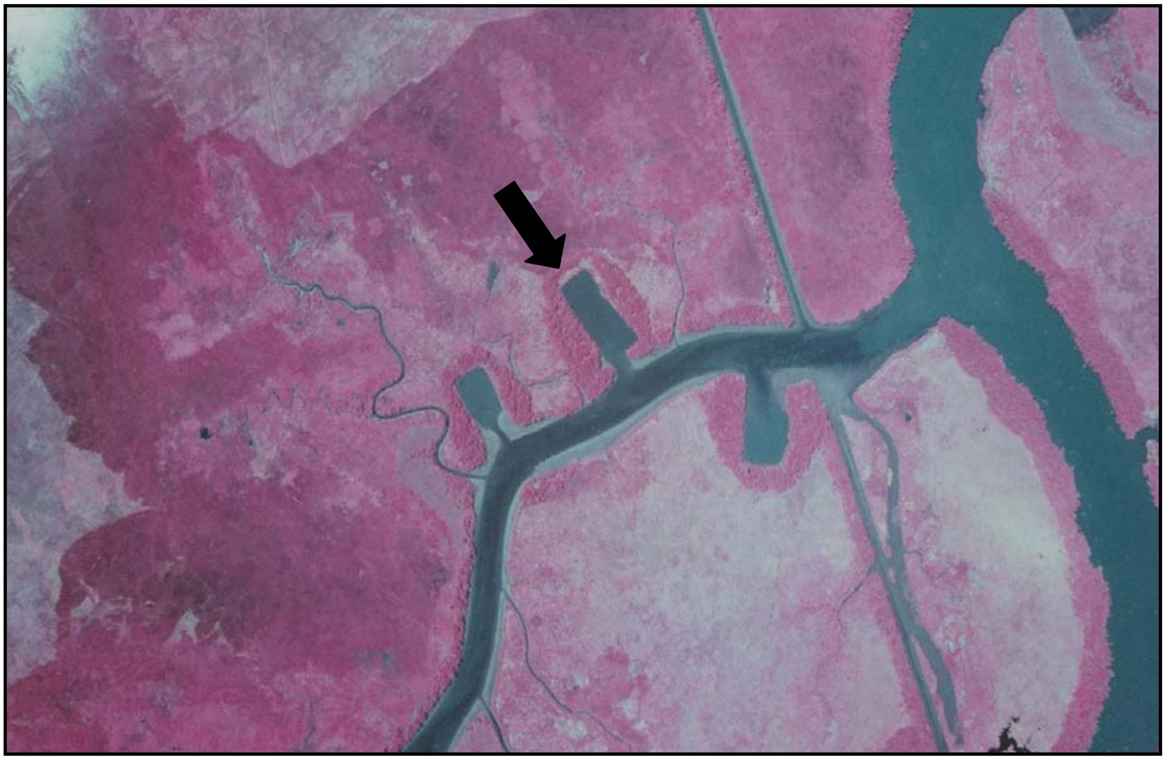

Figure 22. An infrared image of the Bayou Carlin canal, noted by the arrow, taken in 2000.

Figure 23. The Bayou Carlin site, on the right, in April 2004.

8 – Mallard Bay West

Coastal Use Permit Number: P821702
U.S. Army Corps of Engineers Permit Number: Cameron Parish Wetlands 560
Applicant: Conoco Incorporated
Landowner: Mary O. Long et al.
Well Name: Mary O. Long et al. Number 1
Location: 29°53’48” North, 92°38’13” West
Length: 354 m
Area Disturbed: Canal – 1.2 ha, Spoil Banks – 2.5 ha
Vegetation Type: Fresh
Date Canal Dredged: January 1983
Date Canal Backfilled: August 1983
Aerial Inspection: 21 April 2004
Ground Inspection: NA
Percent of Spoil Bank Returned to Marsh Elevation: 80
Average Canal Depth After Backfilling: NA
Cover on Backfilled Spoil Banks: Marsh – 80%, Spoil – 0%, Water – 20%

Site Characteristics

No site evaluation was conducted at this canal, all data collected was from aerial observations. The spoil banks appeared effectively leveled with no elevated spoil remaining. The vegetation on the former spoil bank areas looks similar to that of the surrounding marsh, and includes a few patches of Roseau Cane (*Phragmites australis*). There are small ponds in the former spoil bank area where spoil was removed to deeply on either side of the turning basin.

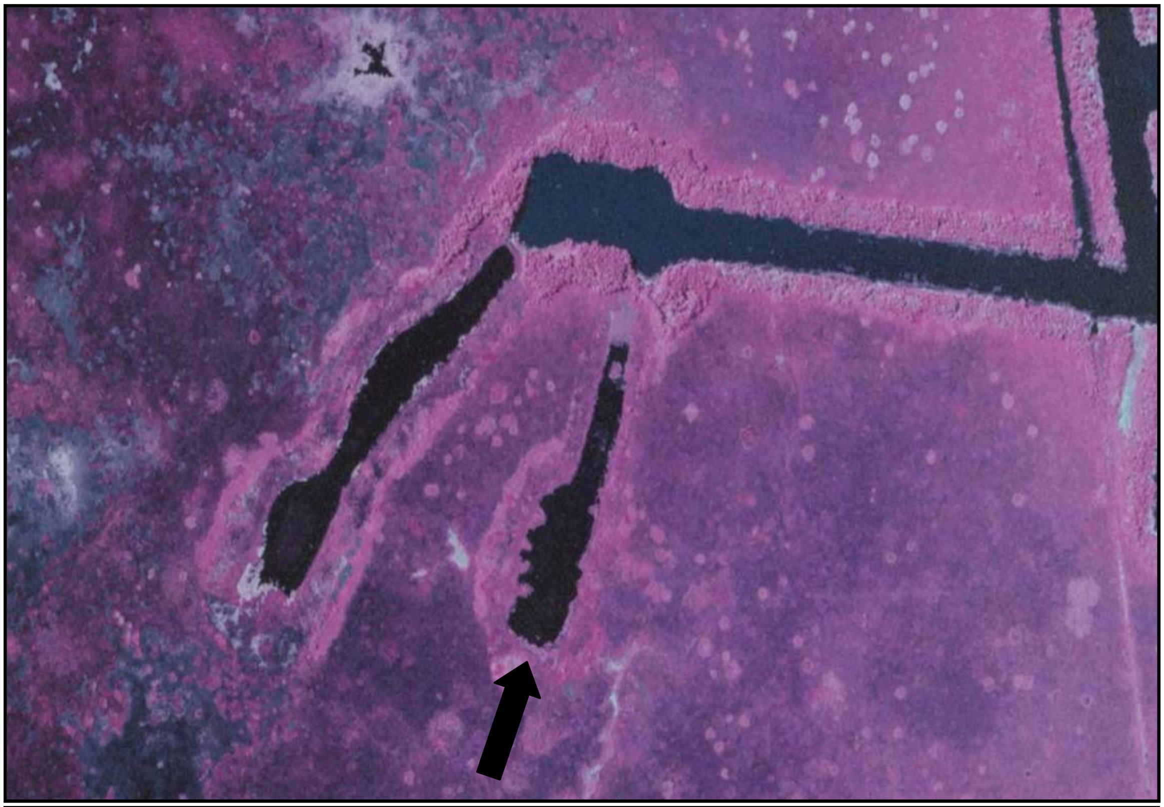

Figure 24. An infrared image of the Mallard Bay West backfilled canal, noted by the arrow, taken in 2000.

Figure 25. The Mallard Bay West backfilled site in April 2004.

9 – Mallard Bay East

<u>Coastal Use Permit Number</u>: P800303
<u>U.S. Army Corps of Engineers Permit Number</u>: Cameron Parish Wetlands 407
<u>Applicant</u>: Hilliard Oil and Gas Corporation
<u>Landowner</u>: Mary O. Long et al.
<u>Well Name</u>: Mary O. Long et al. Number 1
<u>Location</u>: 29°53'43" North, 92°38'06" West
<u>Length</u>: 296 m
<u>Area Disturbed</u>: Canal – 1.0 ha, Spoil Banks – 2.3 ha
<u>Vegetation Type</u>: Fresh
<u>Date Canal Dredged</u>: April 1981
<u>Date Canal Backfilled</u>: June 1981
<u>Aerial Inspection</u>: 21 April 2004
<u>Ground Inspection</u>: NA
<u>Percent of Spoil Bank Returned to Marsh Elevation</u>: 95
<u>Average Canal Depth After Backfilling</u>: NA
<u>Cover on Backfilled Spoil Banks</u>: Marsh – 95%, Spoil – 5%, Water – 0%

Site Characteristics

No site evaluation was conducted at this canal, and all data collected was from aerial observations. This canal was actually dredged and backfilled on two separate occasions. The data above is from the canal as it was originally dredged. The dashed line in Figure 27 indicates the separation between the original canal boundary and the extension of the canal after it was re-dredged. The spoil banks appeared effectively leveled with only a few spots of elevated spoil remaining that harbored spoil vegetation. The vegetation on the former spoil bank areas looks similar to that of the surrounding marsh, and includes a few patches of Roseau Cane (*Phragmites australis*). There are small ponds in the former spoil bank area where spoil was removed to deeply on either side of the turning basin.

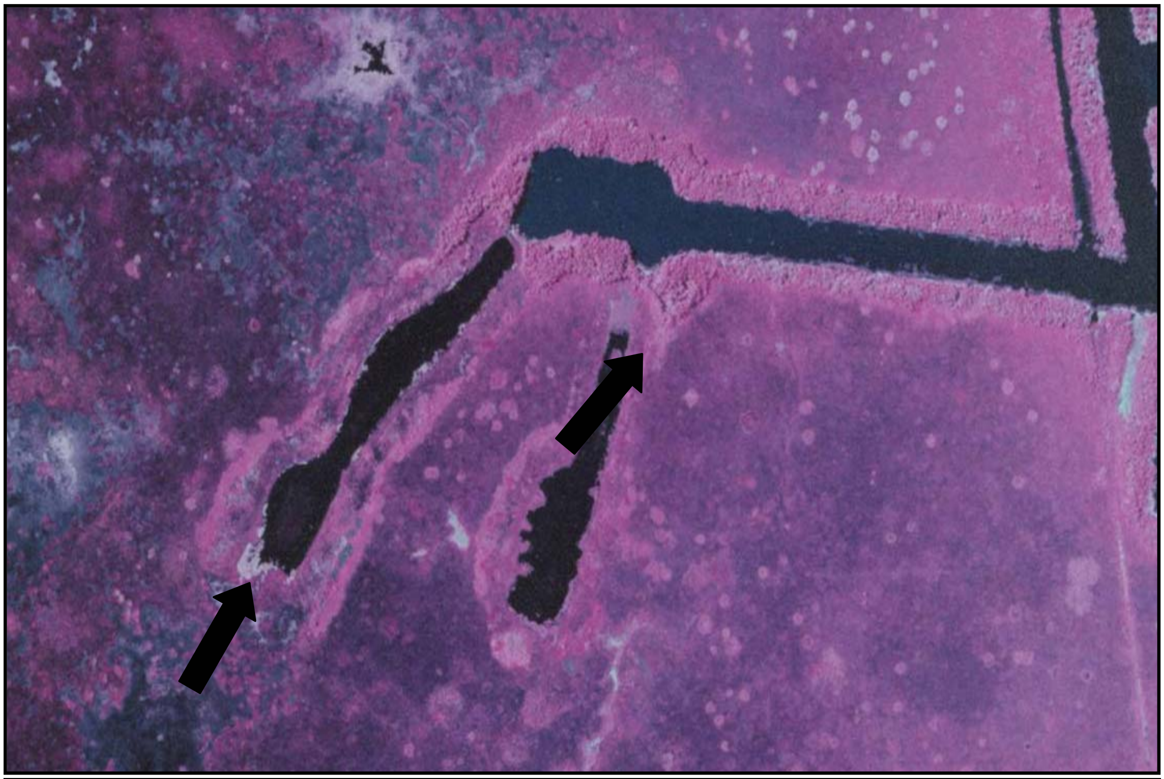

Figure 26. An infrared image of the Mallard Bay East backfilled canal, noted by the arrow, taken in 2000.

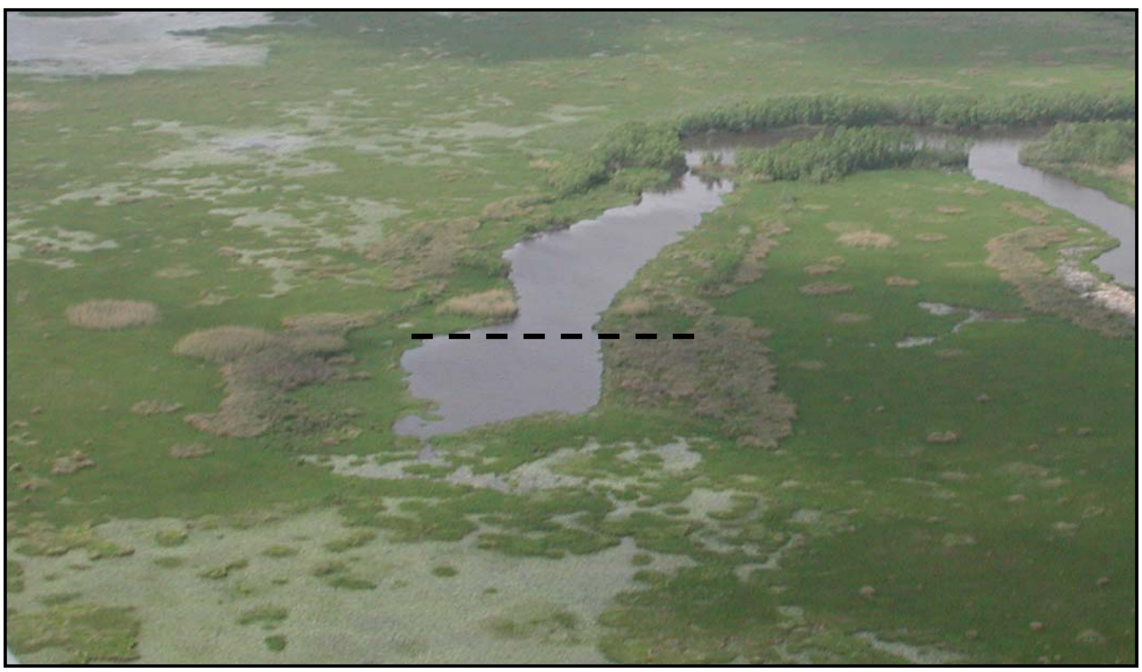

Figure 27. The Mallard Bay East backfilled canal in April 2004. The dashed line indicates the newer canal portion, which was dredged after the original backfilling, and the entire canal was then backfilled once more.

10 – Mermentau River

Coastal Use Permit Number: P830479
U.S. Army Corps of Engineers Permit Number: Cameron Parish Wetlands 521
Applicant: Samedan Oil Company
Landowner: Dr. S. O. Carter Estate
Well Name: Dr. S. O. Carter Estate Number 2
Location: 29°44’52” North, 93°04’17” West
Length: 229 m
Area Disturbed: Canal – 1.3 ha, Spoil Banks – 3.2 ha
Vegetation Type: Brackish
Date Canal Dredged: July 1978
Date Canal Backfilled: July 1983
Aerial Inspection: 21 April 2004
Ground Inspection: 24 June 2004, 2 July 2004
Percent of Spoil Bank Returned to Marsh Elevation: 65%
Average Canal Depth After Backfilling: 0.7 m
Cover on Backfilled Spoil Banks: Marsh – 65%, Spoil – 35%, Water – 0%

Site Characteristics

Canal. The canal was in an intact area of brackish marsh with minimal oil and gas activity. The canal width was reduced in many places, except the turning basin, and there were patches of emergent vegetation present near the mouth of the canal. No submerged vegetation was observed in the canal. The depth ranged from 0.5 to 0.8 m with an average of 0.7 m.

Spoil Banks. The inner portions of the spoil banks were effectively returned to marsh elevation. An elevated narrow spoil ridge remained along the outer edge of the spoil area that was nearly 0.5 m higher than the surrounding marsh, but no more than three to five m wide. The vegetation on the elevated portions of spoil was unique; with species appearing there that appeared at no other backfilled sites. The distinctive vegetation can be attributed to the high spoil elevation, and the cattle that graze the area. The cattle may bring in seeds from nearby beach ridges and wooded areas, or from their other pasture areas. Plant species on the returned portions of the spoil banks included: Marshhay Cordgrass (*Spartina patens*), Salt Grass (*Distichlis spicata*), Smooth Cordgrass (*Spartina alterniflora*), Soft-stemmed Bulrush (*Schoenoplectus tabernaemontani*), Spikerush (*Eleocaris* sp.), Marsh Elder (*Iva frutescens*), and Salt Marsh Bulrush (*Schoenoplectus robustus*).

Marsh. The marsh surrounding the canal was heavily impacted by cattle with countless potholes from the cattle’s hoof prints. The plant species in the marsh included many of the same species as the low portions of the spoil banks in the following proportions: 56% Marshhay Cordgrass (*Spartina patens*), 26% Salt Grass (*Distichlis spicata*), and a trace of Smooth Cordgrass (*Spartina alterniflora*), Soft-stemmed Bulrush (*Schoenoplectus tabernaemontani*), and Salt Marsh Bulrush (*Schoenoplectus robustus*).

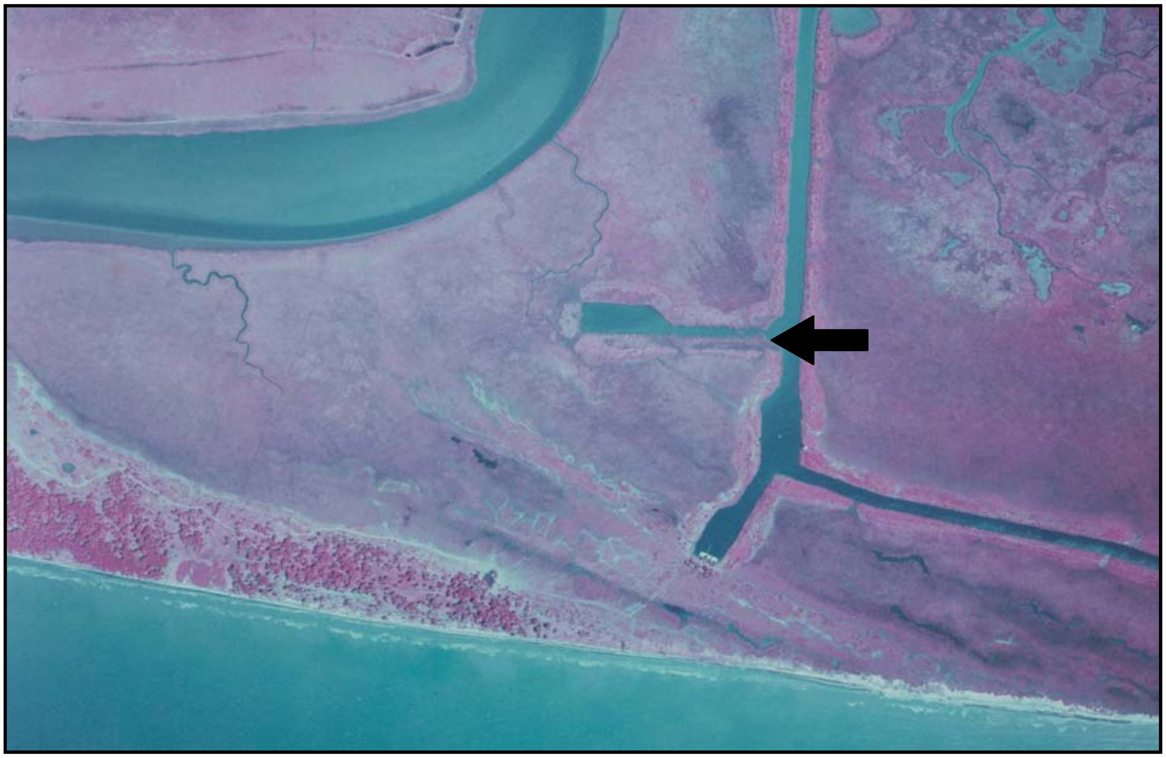

Figure 28. An infrared image of the Mermentau River backfilled canal, noted by the arrow, taken in 2000.

Figure 29. The Mermentau River backfilled site in April 2004.

11 – Mosquito Bay

Coastal Use Permit Number: Not issued
U.S. Army Corps of Engineers Permit Number: Mosquito Bay 15
Applicant: Alcorn Production Company
Landowner: John M. Smyth Company et al.
Well Name: John M. Smyth Company et al. number 1
Location: 29°15'59" North, 91°12'17" West
Length: 152 m
Area Disturbed: Canal – 0.6 ha, Spoil Banks – 1.7 ha
Vegetation Type: Brackish
Date Canal Dredged: May 1980
Date Canal Backfilled: July 1980
Aerial Inspection: 25 October 2004
Ground Inspection: 30 June 2004
Percent of Spoil Bank Returned to Marsh Elevation: 80%
Average Canal Depth After Backfilling: 0.4
Cover on Backfilled Spoil Banks: Marsh – 80%, Spoil – 15%, Water – 5%

Site Characteristics

Canal. The canal is near Mosquito Bay on Point Au Fer Island, and is in an area of brackish marsh with minimal oil and gas activity. The canal was shallow, and supported submerged aquatic vegetation. The depth ranged from 0.4 to 0.5 m with an average of 0.4 m.

Spoil Banks. Except for a thin ridge of elevated spoil supporting Groundsel Bush (*Baccharis halimifolia*) bushes, the spoil banks were leveled to marsh elevation or below. A visual analysis of old site photographs indicates much of the backfilled spoil bank that was originally open water has since been colonized by emergent vegetation. The dominate vegetation types on the portions of the spoil bank that were leveled to marsh elevation were Marshhay Cordgrass (*Spartina patens*), Smooth Cordgrass (*Spartina alterniflora*), Salt Grass (*Distichlis spicata*), and Salt Marsh Bulrush (*Schoenoplectus robustus*).

Marsh. The marsh surrounding the canal was an intact brackish marsh with few small ponds. The dominate plant species were 34% Marshhay Cordgrass (*Spartina patens*), 25% Salt Grass (*Distichlis spicata*), 13% Common Three-square (*Schoenoplectus americanus*), 18% Black Needlerush (*Juncus roemerianus*), with traces of Salt Marsh Bulrush (*Schoenoplectus robustus*), Salt Marsh Aster (*Aster* sp.), and Smooth Cordgrass (*Spartina alterniflora*).

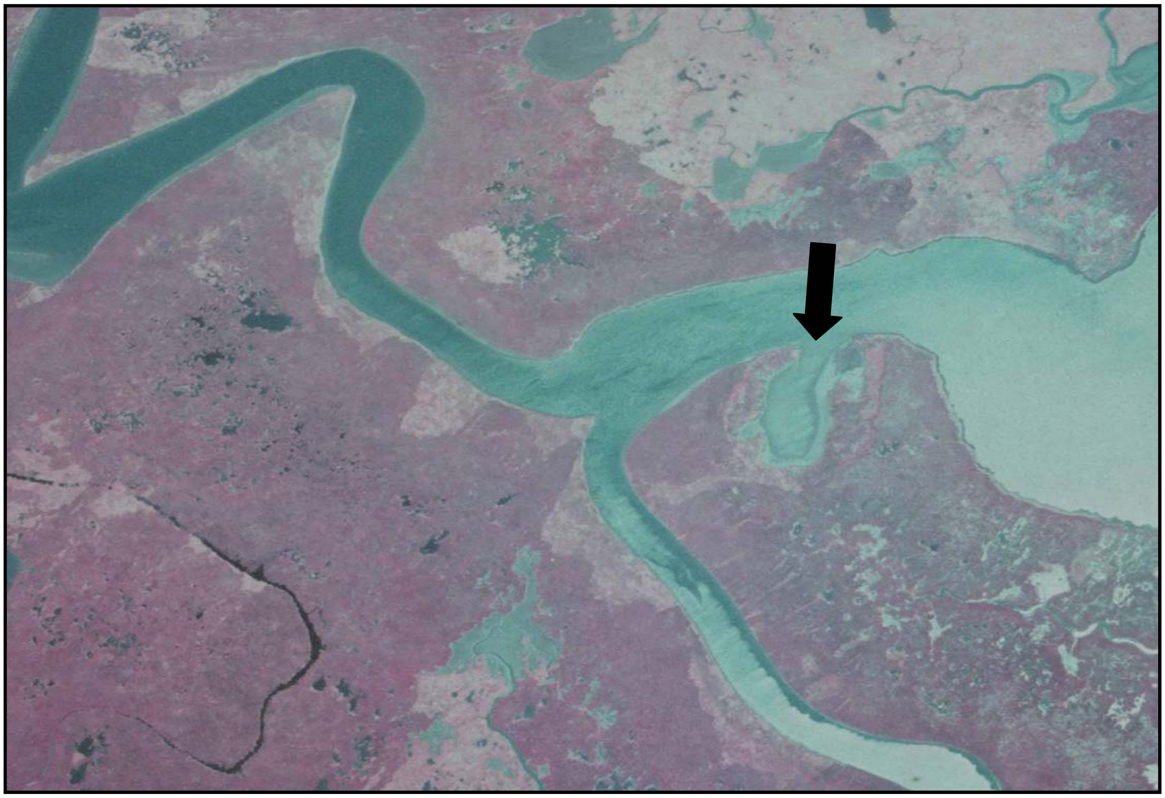

Figure 30. An infrared image of the Mosquito Bay backfilled canal, noted by the arrow, taken in 2000.

Figure 31. The Mosquito Bay backfilled site in October 2004.

12 – Lake Point Bayou

Coastal Use Permit Number: Not issued
U.S. Army Corps of Engineers Permit Number: St. Mary Parish Wetlands 56
Applicant: Exxon Corporation
Landowner: Hugh H. Kelso, Jr.
Well Name: Kelso Number 1
Location: 29°42’00” North, 91°34’00” West
Length: 610 m
Area Disturbed: Canal – 1.6 ha, Spoil Banks – 2.7 ha
Vegetation Type: Fresh
Date Canal Dredged: May 1969
Date Canal Backfilled: August 1980
Aerial Inspection: 21 April 2004
Ground Inspection: 17 June 2004
Percent of Spoil Bank Returned to Marsh Elevation: 45%
Average Canal Depth After Backfilling: 1.6 m
Cover on Backfilled Spoil Banks: Marsh – 45%, Spoil – 50%, Water – 5%

Site Characteristics

There was active drilling at this site, and the canal may have been re-dredged to allow drilling equipment to be brought in. The average canal depth was 1.6 m, but depths in the middle of the canal approached 3 m. Aerial photography from 1990 show the spoil banks to be mostly open water with a few trees not touched by backfilling. Photographs from 2000 and 2004 show drilling platforms in the canal and the open water portions of the spoil bank have become trees or marsh. This evidence suggests that material may have been moved from the bottom of the canal and placed along its sides, decreasing water depth on the former spoil banks, and allowing emergent vegetation to grow on the newly elevated areas. The data collected at this canal was not used in any of the data analysis because of the active drilling and possible re-dredging.

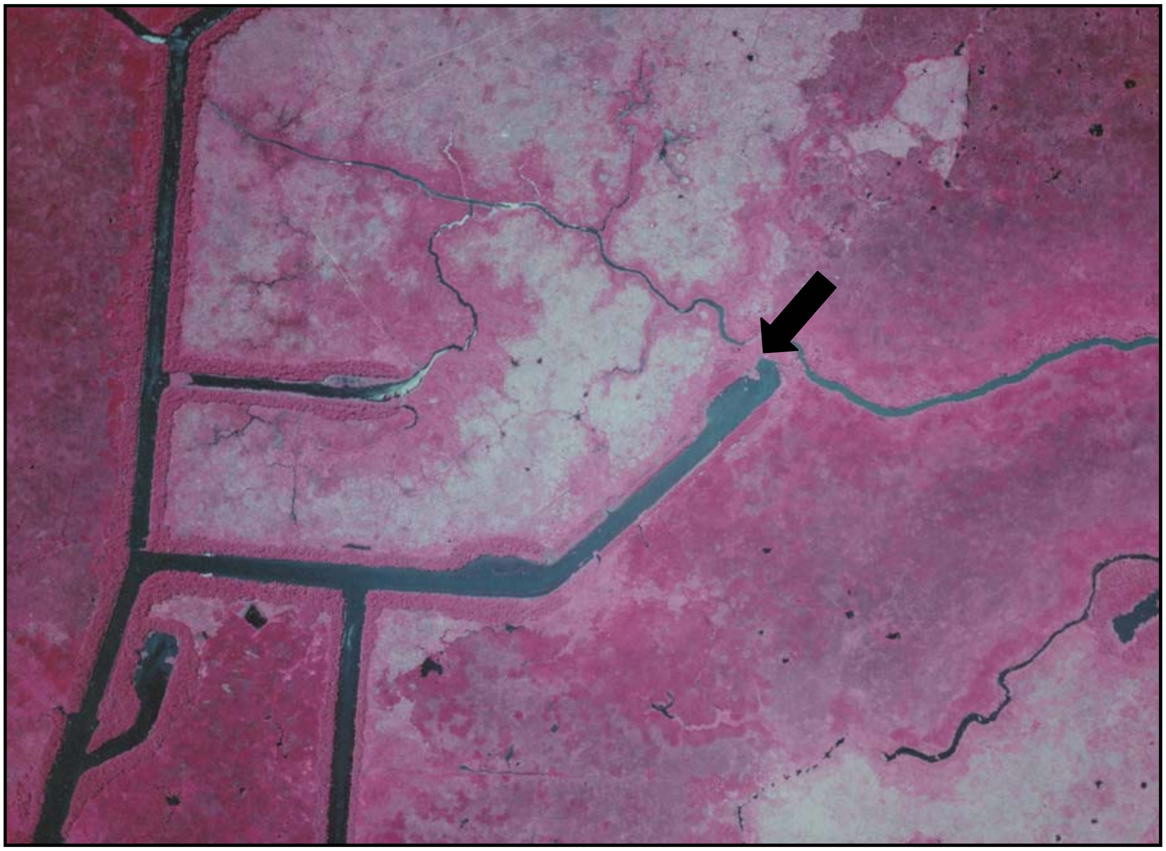

Figure 32. An infrared image of the Lake Point Bayou backfilled canal, noted by the arrow, taken in 2000.

Figure 33. The Lake Point Bayou backfilled site in April 2004.

13 – Vermillion River

Coastal Use Permit Number: Not issued
U.S. Army Corps of Engineers Permit Number: Vermilion Parish Wetlands 80
Applicant: McCormick Oil and Gas Corporation
Landowner: Fred Stovall Estate
Well Name: Stovall Estate Number 6
Location: 29°46’30” North, 92°09’00” West
Length: 671 m
Area Disturbed: Canal – 1.7 ha, Spoil Banks – 4.5 ha
Vegetation Type: Intermediate
Date Canal Dredged: September 1978
Date Canal Backfilled: August 1980
Aerial Inspection: 21 April 2004
Ground Inspection: 26 May 2004
Percent of Spoil Bank Returned to Marsh Elevation: 83%
Average Canal Depth After Backfilling: 0.7 m
Cover on Backfilled Spoil Banks: Marsh – 83%, Spoil – 15%, Water – 2%

Site Characteristics

Canal. The canal had an average depth of 0.7 m and ranged from 0.5 to 1.1 m. The canal has narrowed in the portions were the spoil was removed effectively and no elevated spoil remains.

Spoil Banks. The spoil banks had several areas that were left higher than marsh elevation and supported spoil vegetation such as Chinese Tallow Trees (*Sapium sebiferum*), Marsh Elder (*Iva frutescens*), Brambles (*Rubus sp.*), and Goldenrod (*Solidago sp.*). The portions of the spoil bank that were at marsh elevation were predominately covered by Roseau cane (*Phragmites australis*), with Sawgrass (*Cladium jamaicense*), Marshhay Cordgrass (*Spartina patens*), Mock Bishopweed (*Ptilimnium capillaceum*), Marsh Morning Glory (*Ipomoea sagittata*), and Bull-tongue (*Sagittaria lancifolia*) also present.

Marsh. The marsh surrounding the canal was an intact intermediate marsh with minimal oil and gas activity and a few small ponds. The dominate plant species in the marsh was Marshhay Cordgrass (*Spartina patens*) covering 69% of the area, Spikerush (*Eleocharis* sp.) covered 10%, Bull-tongue (*Sagittaria lancifolia*) covered 7%, and there were traces of Pennywort (*Hydrocotly umbellata*), Marsh Morning Glory (*Ipomoea sagittata*), Common Three square (*Schoenoplectus americanus*), Mock Bishopweed (*Ptilimnium capillaceum*), and Deerpea (*Vigna luteola*).

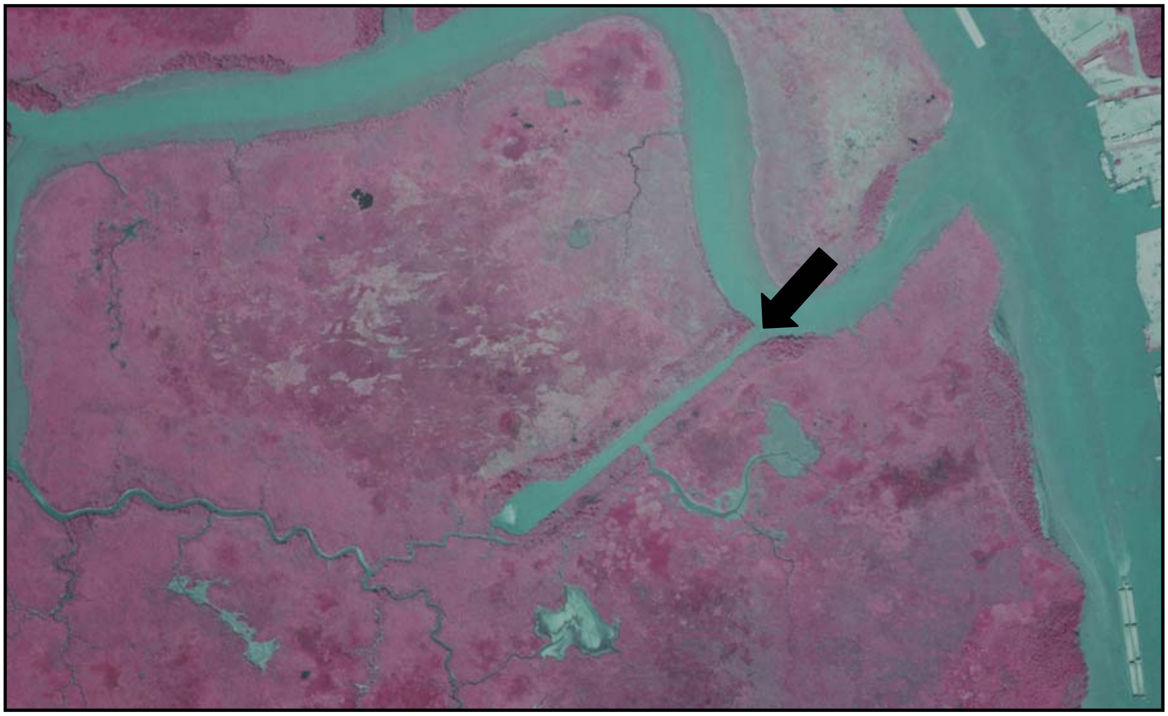

Figure 34. An infrared image of the Vermilion River backfilled canal, noted by the arrow, taken in 2000.

Figure 35. The Vermilion River backfilled site in April 2004.

14 – Bayou Long

Coastal Use Permit Number: Not issued
U.S. Army Corps of Engineers Permit Number: Bayou Long 65
Applicant: Resources Investment Corporation
Landowner: E. N. Kearney
Well Name: E. N. Kearney Number 1
Location: 29°40’30” North, 91°36’15” West
Length: 457 m
Area Disturbed: Canal – 1.3 ha, Spoil Banks – 3.2 ha
Vegetation Type: Intermediate
Date Canal Dredged: August 1975
Date Canal Backfilled: December 1981
Aerial Inspection: 21 April 2004
Ground Inspection: 18 June 2004
Percent of Spoil Bank Returned to Marsh Elevation: 5%
Average Canal Depth After Backfilling: 0.9 m
Cover on Backfilled Spoil Banks: Marsh – 5%, Spoil – 95%, Water – 0%

Site Characteristics

Canal. The canal ranged in depth from 0.6 to 1.0 m with an average depth of 0.9 m. There was emergent marsh vegetation growing out over portions of the canal with such species as: Alligator Weed (*Alternanthera philoxeroides*), Marsh Purslane (*Ludwigia* sp.), and Giant Cutgrass (*Zizaniopsis miliacea*). There were numerous floating species present in the canal including: Water Hyacinth (*Eichhornia crassipes*), Salvinia (*Salvinia sp.*), and Duckweed (*Spirodela polyrhiza*). Submerged aquatic species were also present.

Spoil Banks. The spoil banks remained elevated above marsh level and supported trees and other spoil vegetation. The spoil banks were dominated by Black Willow (*Salix nigra*), with Chinese Tallow (*Sapium sebiferum*) and Wax Myrtle (*Myrica cerifera*) present. The edges of the spoil bank contained plant species similar to the marsh including: Elderberry (*Sambucus Canadensis*), Bull-tongue (*Sagittaria lancifolia*), Elephant Ear (*Colocasia antiquorum*), Common Three-square (*Schoenoplectus americanus*), Rice Cutgrass (*Leersia oryzoides*), Alligatorweed (*Alternanthera philoxeroides*), Smartweed (*Polygonum sp.*), Deer Pea (*Vigna luteola*).

Marsh. The canal was in an area of floating intermediate to fresh marsh with many small ridges which harbored shrubs and spoil species. The ridges are thought to have developed after Hurricane Andrew as the storm forced the floating marsh to fold on top of itself, leaving small ridges 0.8 m higher than the surrounding marsh. The marsh was comprised of a diverse assortment of species including: Common Three-square (*Schoenoplectus americanus*), Elephant Ear (*Colocasia antiquorum*), Alligatorweed (*Alternanthera philoxeroides*), Smartweed (*Polygonum sp.*), Deer Pea (*Vigna luteola*), Rice Cutgrass (*Leersia oryzoides*), Bull-tongue (*Sagittaria lancifolia*), Pennywort (*Hydrocotly umbellata*), and Marshhay Cordgrass (*Spartina patens*).

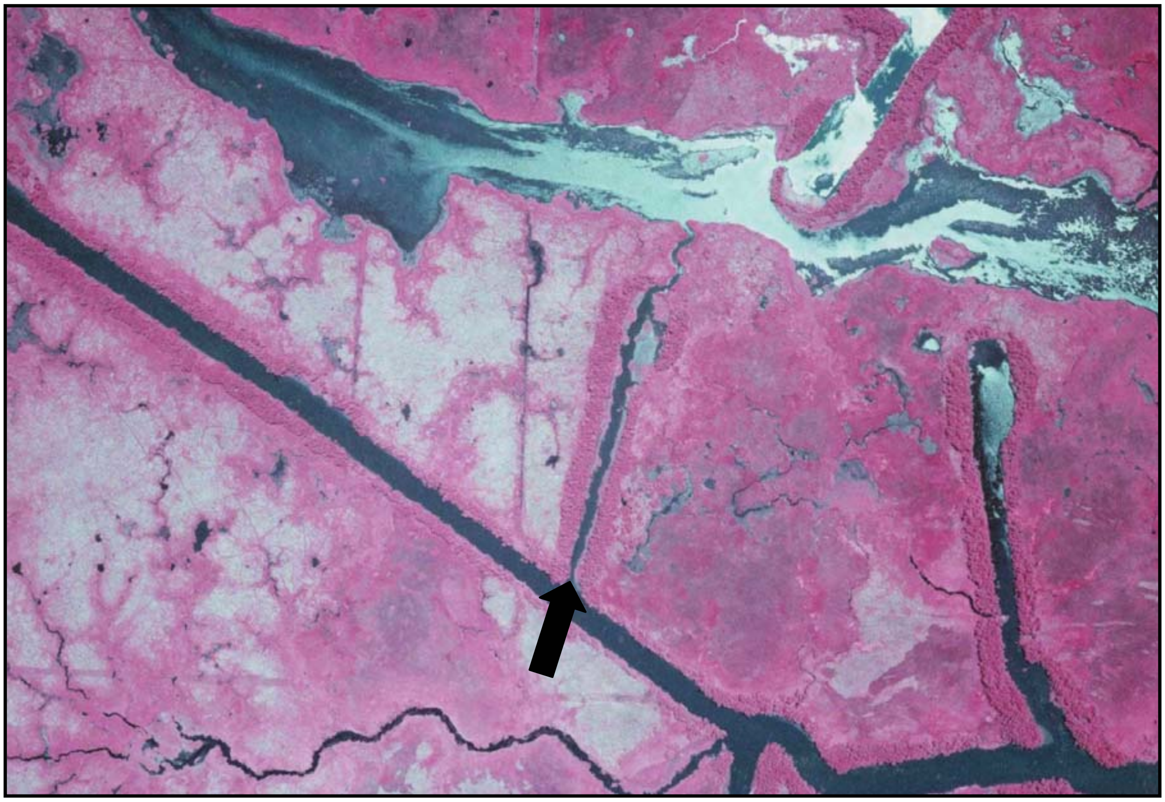

Figure 36. An infrared image of the Bayou Long backfilled canal, noted by the arrow, taken in 2000.

Figure 37. The Bayou Long backfilled site in April 2004.

15 – Four Isle

Coastal Use Permit Number: Not issued
U.S. Army Corps of Engineers Permit Number: Terrebonne Parish Wetlands 366
Applicant: Tenneco Oil Company
Landowner: Terrebonne Land Development Corporation
Well Name: Terrebonne Land Development Corporation Number 2
Location: 29°16’00” North, 90°49’00” West
Length: 427 m
Area Disturbed: Canal – 1.3 ha, Spoil Banks – 3.2 ha
Vegetation Type: Salt
Date Canal Dredged: November 1975
Date Canal Backfilled: February 1983
Aerial Inspection: 8 November 2004
Ground Inspection: 28 May 2004
Percent of Spoil Bank Returned to Marsh Elevation: 92%
Average Canal Depth After Backfilling: 1.5 m
Cover on Backfilled Spoil Banks: Marsh – 92%, Spoil – 0%, Water – 8%

Site Characteristics

Canal. The canal ranged in depth from 0.8 to 1.9 m and had an average depth of 1.5 m. Submerged aquatic vegetation was present in the canal.

Spoil Banks. The spoil banks were effectively leveled to, or below, marsh elevation over the entire length of the canal. There were many places along the spoil bank where too much material was removed leaving shallow water ponds. Where the spoil was returned to marsh elevation, species composition was similar to the surrounding marsh and included: Smooth Cordgrass (*Spartina alterniflora*), Marshhay Cordgrass (*Spartina patens*), Saltgrass (*Distichlis spicata*), Black Needlerush (*Juncus roemarianus*), Salt Marsh Loosestrife (*Lythrum lineare*), Marsh Morning Glory (*Ipomoea sagittata*), Marsh Elder (*Iva frutescens*), and one large patch of Roseau Cane (*Phragmites australis*).

Marsh. The canal was in an area of highly fragmented salt marsh, but in the immediate vicinity the marsh was intact. The marsh was dominated by 59% Marshhay Cordgrass (*Spartina patens*), 8% Smooth Cordgrass (*Spartina alterniflora*), 17% Saltgrass (*Distichlis spicata*), 13% Marsh Morning Glory (*Ipomoea sagittata*), and a trace of Salt Marsh Loosestrife (*Lythrum lineare*).

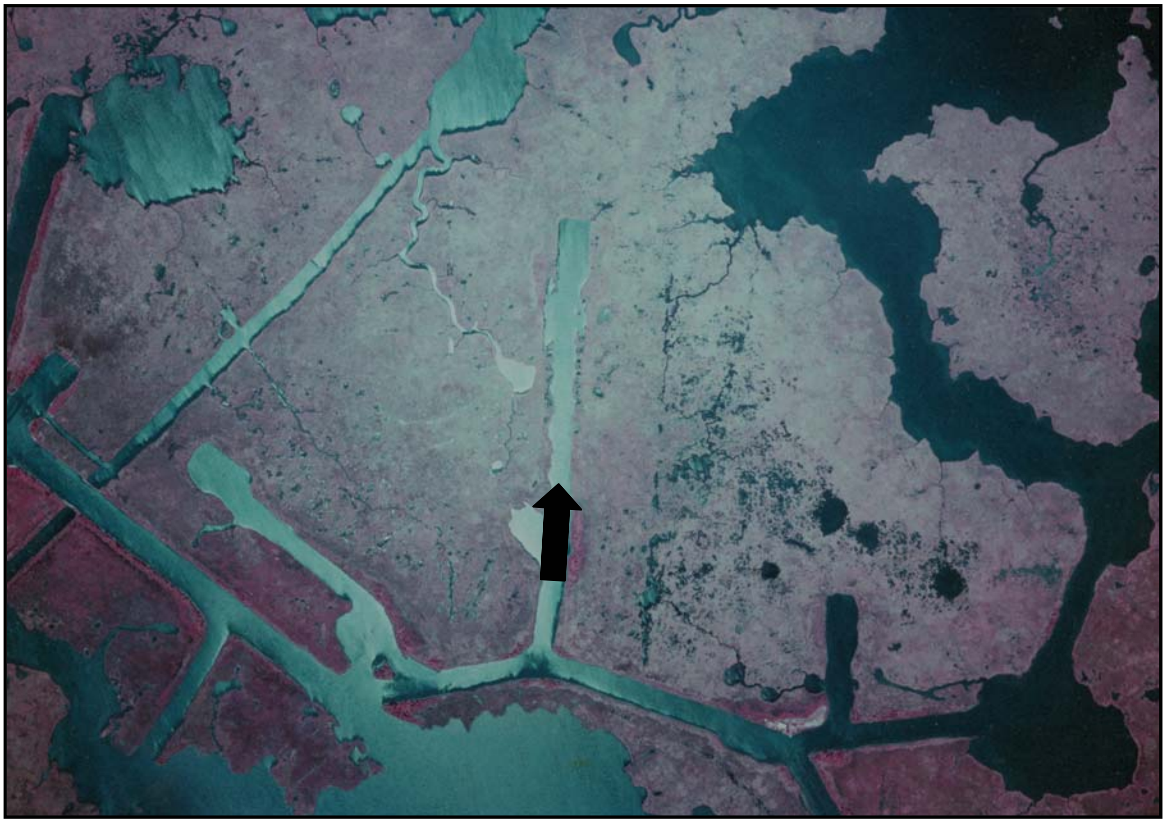

Figure 38. An infrared image of the Four Isle backfilled canal, noted by the arrow, taken in 2000.

Figure 39. The Four Isle backfilled site in November 2004.

16 – Pecan Island West

Coastal Use Permit Number: Not issued
U.S. Army Corps of Engineers Permit Number: Vermilion Parish Wetlands 97
Applicant: Exxon Corporation
Landowner: Exxon Corporation
Well Name: Louisiana Furs Incorporated Number 6
Location: 29°35’30” North, 92°22’30” West
Length: 1869 m (portions of three canals)
Area Disturbed: Canal – 3.6 ha, Spoil Banks – 8.0 ha
Vegetation Type: Intermediate
Date Canal Dredged: 1945
Date Canal Backfilled: July 1979
Aerial Inspection: 21 April 2004
Ground Inspection: 27 May 2004
Percent of Spoil Bank Returned to Marsh Elevation: 93%
Average Canal Depth After Backfilling: 0.4 m
Cover on Backfilled Spoil Banks: Marsh – 93%, Spoil – 0%, Water – 7%

Site Characteristics

Canal. This site was made up of three different canals that are all connected and all backfilled. All three canals have emergent vegetation growing in them, and all three canals have also become narrower. The most northerly canal has an extensive colony of clams in its channel. All canals were very shallow, ranging from 0.2 to 0.6 m except for portions of the southerly canal. The most southerly canal had a narrow, deep (1.4 m) channel that carried water north to south, and was building land by over-bank flooding from this channel in the middle of the canal outwards. Submerged aquatic vegetation was present in the canals.

Spoil Banks. The spoil banks were effectively leveled, leaving 100% of the spoil banks at or below marsh elevation. The vegetation immediately next to the open water portions of the canal was mostly Roseau Cane (*Phragmites australis*), and Sedges (*Cyperus* sp.); while behind that Marshhay Cordgrass (*Spartina patens*) was the dominate species with Joint Paspalum (*Paspalum distichum*), and Smartweed (*Polygonum* sp.) also present.

Marsh. The canal occurred in an area of intermediate marsh with many small ponds and significant oil and gas activity. The dominate plant species were: 75% Marshhay Cordgrass (*Spartina patens*), 13% Roseau Cane (*Phragmites australis*), with traces of Sedges (*Cyperus* sp.), Morning Glory (*Ipomoea sagittata*), and Deer pea (*Vigna sp.*).

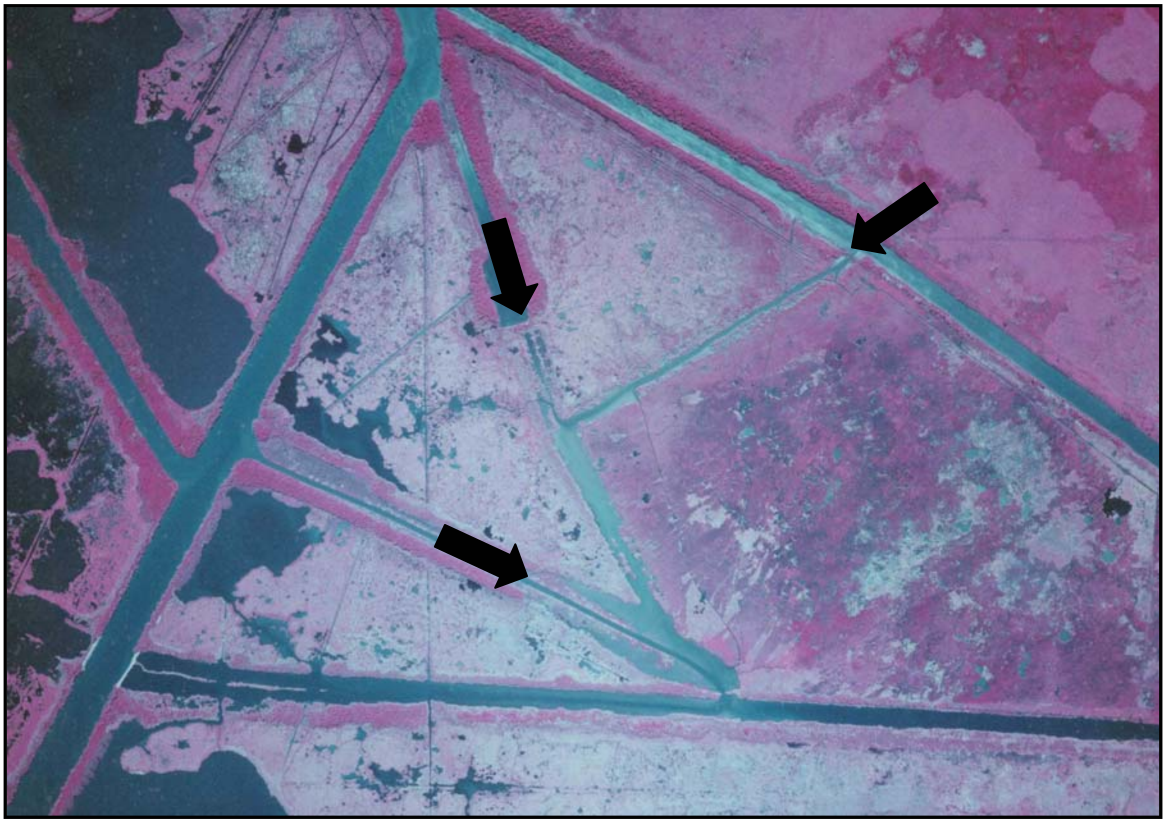

Figure 40. An infrared image of the Pecan Island West backfilled canal taken in 2000. Note the three separate backfilled canals identified by the arrows.

Figure 41. The Pecan Island West backfilled site in April 2004.

17 – Lafitte

Coastal Use Permit Number: Not issued
U.S. Army Corps of Engineers Permit Number: Jefferson Parish Wetlands 77
Applicant: Texaco Incorporated
Landowner: Lucien D. Adams
Well Name: Lucien D. Adams Number 10
Location: 29°36’53” North, 90°02’46” West
Length: 152 m
Area Disturbed: Canal – 0.7 ha, Spoil Banks – 1.0 ha
Vegetation Type: Brackish
Date Canal Dredged: April 1974
Date Canal Backfilled: September 1982
Aerial Inspection: 5 October 2004
Ground Inspection: 24 May 2004
Percent of Spoil Bank Returned to Marsh Elevation: 15%
Average Canal Depth After Backfilling: 1.2 m
Cover on Backfilled Spoil Banks: Marsh – 15%, Spoil – 75%, Water – 10%

Site Characteristics

The original evaluation of this canal in 1984 noted that the site had no appearance of ever being backfilled. The site occurred in the Lafitte Oil Field, an area highly impacted by oil and gas activities, with nearly all marsh between canals being turned to open water. The only emergent vegetation immediately surrounding this canal was on spoil banks.

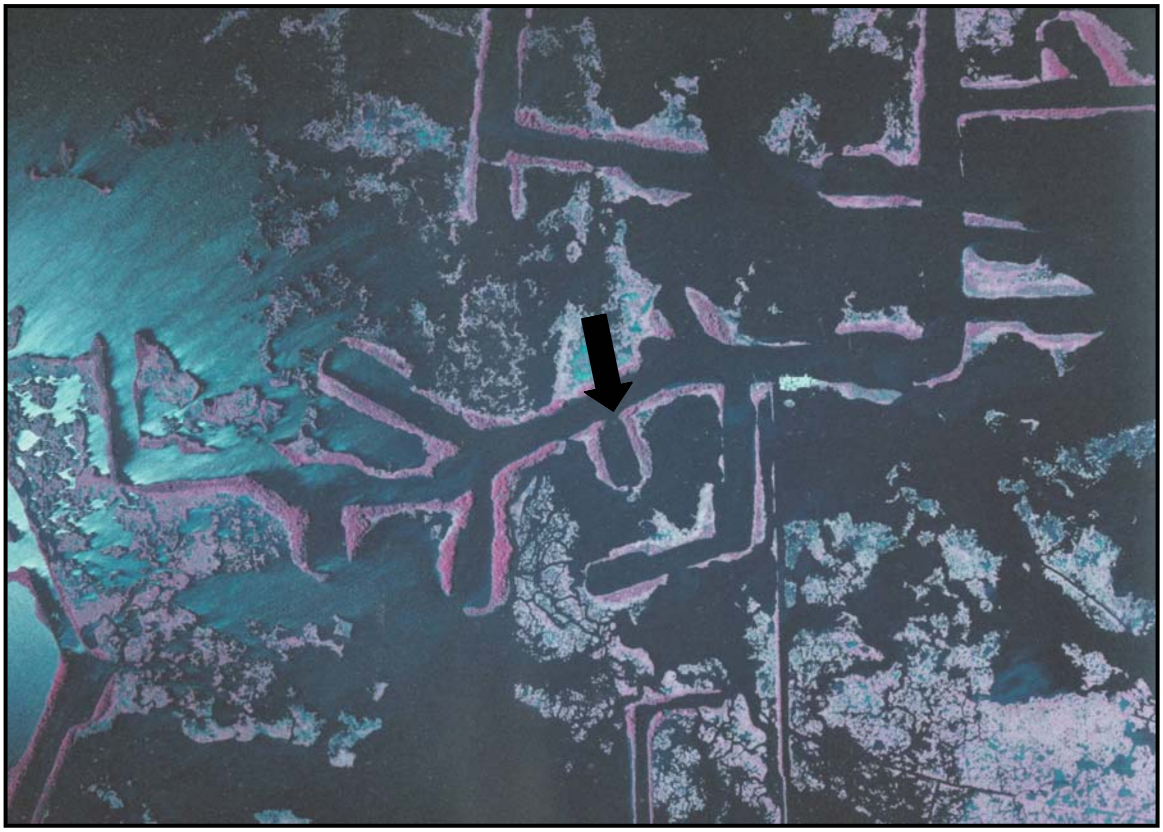
Figure 42. An infrared image of the Lafitte backfilled canal, noted by the arrow, taken in 2000.


Figure 43. The Lafitte backfilled site in October 2004.

18 – Dupree Cut

Coastal Use Permit Number: Not issued
U.S. Army Corps of Engineers Permit Number: Jefferson Parish Wetlands 77
Applicant: Texaco Incorporated
Landowner: John C. Christian Jr. et al.
Well Name: John C. Christian Jr. et al B Number 1
Location: 29°35'59" North, 90°04'24" West
Length: 152 m
Area Disturbed: Canal – 0.7 ha, Spoil Banks – 1.5 ha
Vegetation Type: Brackish
Date Canal Dredged: June 1978
Date Canal Backfilled: September 1982
Aerial Inspection: 5 October 2004
Ground Inspection: 24 May 2004
Percent of Spoil Bank Returned to Marsh Elevation: 15 m
Average Canal Depth After Backfilling: 0 m
Cover on Backfilled Spoil Banks: Marsh – 15%, Spoil – 85%, Water – 0%

Site Characteristics

Canal. This canal was dredged off of the Barataria Waterway on the levee ridge of the former Bayou Barataria. There was emergent marsh vegetation growing in the canal with about 100% plant cover. This canal may have been filled with sediments from an adjacent canal, leaving most of its spoil banks intact.

Spoil Banks. The spoil banks remained elevated higher than marsh elevation in a nearly complete ridge around the canal. The spoil bank on the north side of the canal was higher than the south spoil; near the Barataria Waterway, the spoil was over 4 m high. The plant species on the spoil surrounding the canal included: Groundselbush (*Baccharis halimifolia*), Goldenrod (*Solidago* sp.), Marshhay Cordgrass (*Spartina patens*), Marsh Elder (*Iva frutescens*), Smartweed (*Polygonum* sp.), and Pennywort (*Hydrocotly umbellata*).

Marsh. The marsh surrounding the canal is an intact salt to brackish marsh and includes portions of the former Bayou Barataria levee ridge. A large open water area exists where the former bayou channel once was. The dominate vegetation is as follows: 55% Smooth Cordgrass (*Spartina alterniflora*), 19% Saltgrass (*Distichlis spicata*), 3% of both Spikerush (*Eleocharis* sp.) and Salt Marsh Loosestrife (*Lythrum lineare*), and traces of Marsh Elder (*Iva frutescens*), Smartweed (*Polygonum* sp.), Marsh Morning Glory (*Ipomoea sagittata*). A small pipeline had recently been buried in the marsh immediately south of the canal.

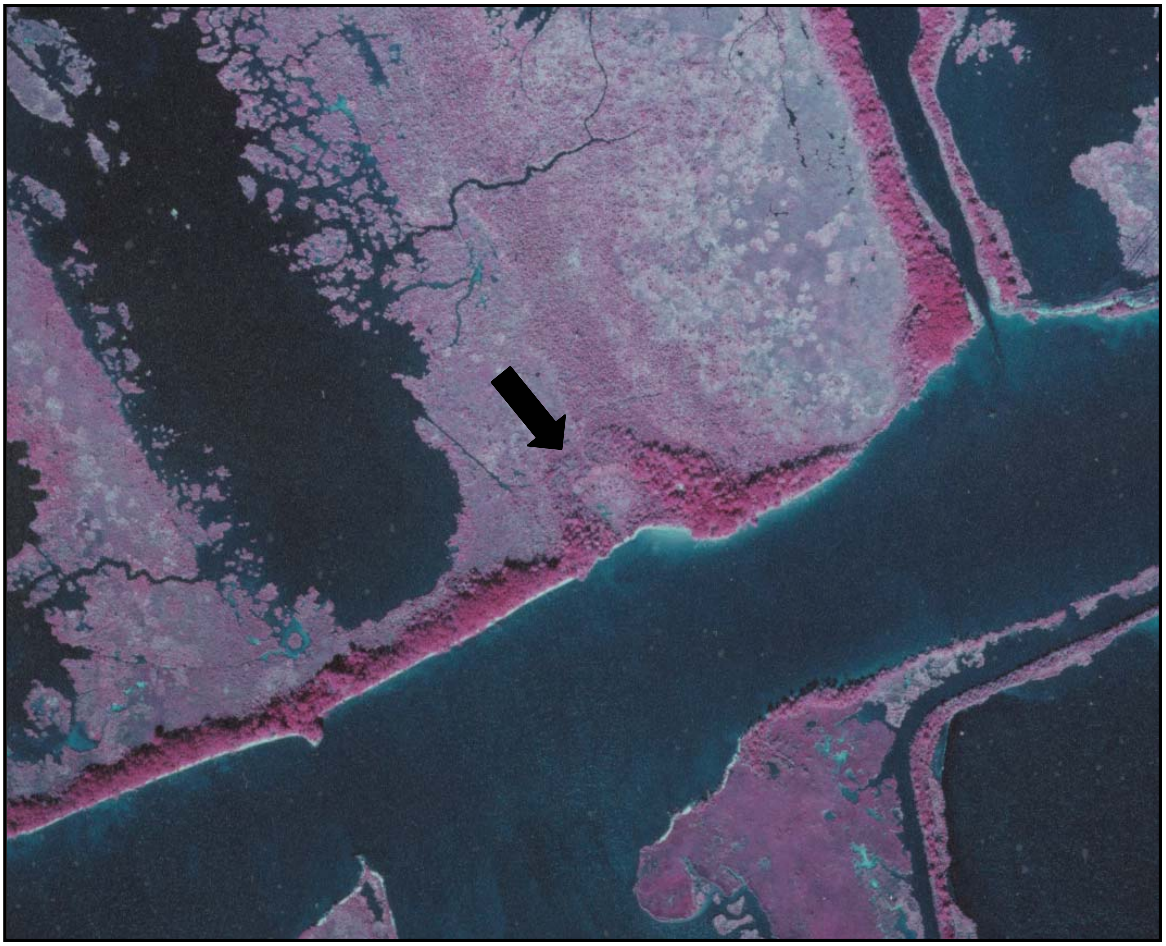

Figure 44. An infrared image of the Dupree Cut backfilled canal, noted by the arrow, taken in 2000.

Figure 45. The Dupree backfilled site in October 2004.

19 – Buckskin Bayou

Coastal Use Permit Number: P810107
U.S. Army Corps of Engineers Permit Number: Buckskin Bayou 2
Applicant: James A. Whitson Jr.
Landowner: Louisiana Land and Exploration
Well Name: LL&E Number 1
Location: 29°16’49” North, 91°02’12” West
Length: 610 m
Area Disturbed: Canal – 1.4 ha, Spoil Banks – 3.2 ha
Vegetation Type: Brackish
Date Canal Dredged: April 1981
Date Canal Backfilled: June 1981
Aerial Inspection: 25 October 2004
Ground Inspection: 29 June 2004
Percent of Spoil Bank Returned to Marsh Elevation: 75 m
Average Canal Depth After Backfilling: 1.4 m
Cover on Backfilled Spoil Banks: Marsh – 90%, Spoil – 5%, Water – 5%

Site Characteristics

Canal. The canal ranged in depth from 0.7 to 1.8 m and had an average depth of 1.4 m. There was an intact plug nearly 1 m above marsh elevation which completely restricted water exchange between the canal and the bayou. There was no emergent vegetation in the canal, but there was submerged vegetation (*Ruppia maritima*) present.

Spoil Banks. The spoil banks were effectively leveled to marsh elevation over 90% of their area, with elevated spoil remaining along the sides of the plug. A slightly elevated portion of spoil remained around the turning basin, and was colonized by Marsh Elder (*Iva frutescens*), and Sea Ox-eye (*Borrichia frutescens*). The portions of the spoil bank that were at marsh elevation contained 75% Saltgrass (*Distichlis spicata*), with Smooth Cordgrass (*Spartina alterniflora*), Salt Marsh Bulrush (*Schoenoplectus robustus*), and Marsh Morning Glory (*Ipomoea sagittata*).

Marsh. This canal was in an area of brackish marsh with many small ponds and very little oil and gas activity. The marsh was dominated by 50% Marshhay Cordgrass (*Spartina patens*), 18% Saltgrass (*Distichlis spicata*), 12% Smooth Cordgrass (*Spartina alterniflora*), 7% Salt Marsh Bulrush (*Schoenoplectus robustus*), 7% Soft-stemmed Bulrush (*Schoenoplectus tabernaemontani*), and 5% Common Three-square (*Schoenoplectus americanus*).

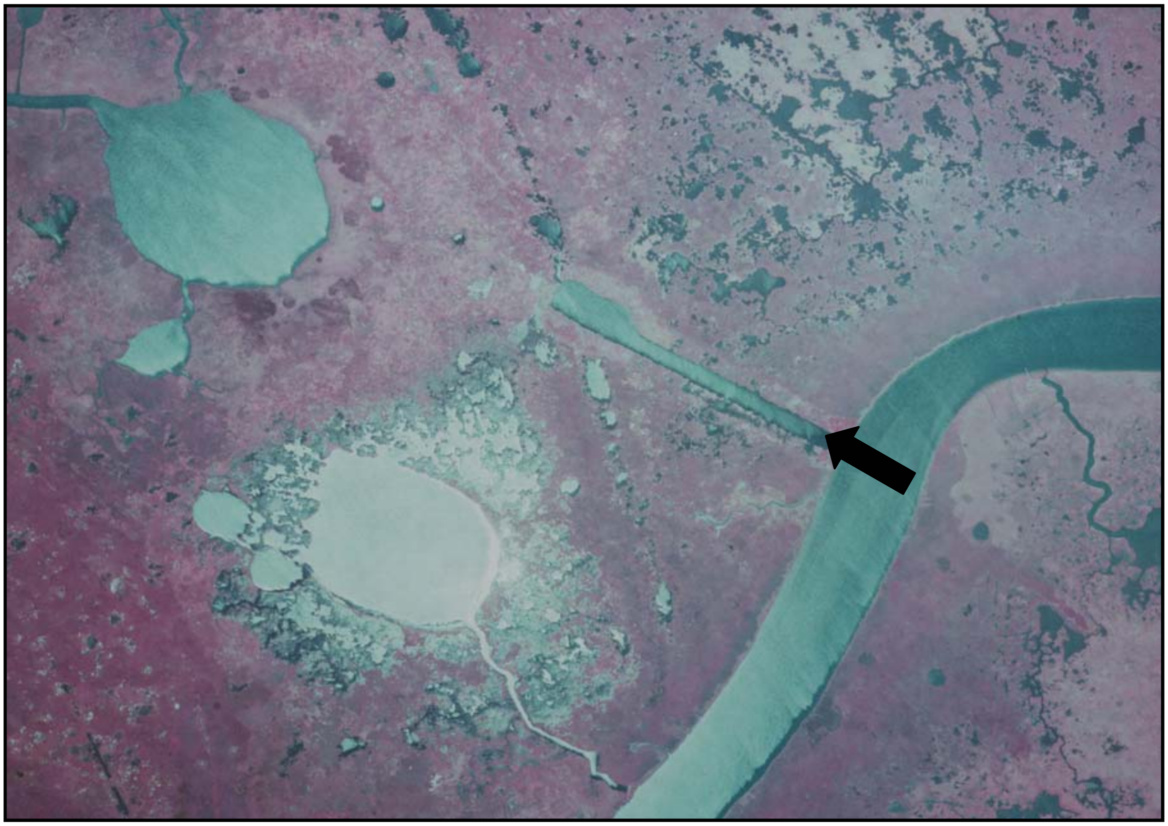

Figure 46. An infrared image of the Buckskin Bayou backfilled canal, noted by the arrow, taken in 2000.

Figure 47. The Buckskin Bayou backfilled site in April 2004.

20 – Lake DeCade

<u>Coastal Use Permit Number</u>: Not issued
<u>U.S. Army Corps of Engineers Permit Number</u>: Turtle Bayou 36
<u>Applicant</u>: Tenneco Oil Company
<u>Landowner</u>: LaTerre Petroleum Corporation
<u>Well Name</u>: LaTerre Petroleum Corporation F-2
<u>Location</u>: 29°24’00” North, 91°49’30” West
<u>Length</u>: 314 m
<u>Area Disturbed</u>: Canal – 1.1 ha, Spoil Banks – 2.1 ha
<u>Vegetation Type</u>: Intermediate
<u>Date Canal Dredged</u>: March 1973
<u>Date Canal Backfilled</u>: January 1980
<u>Aerial Inspection</u>: 19 November 2003
<u>Ground Inspection</u>: 10 June 2004
<u>Percent of Spoil Bank Returned to Marsh Elevation</u>: NA
<u>Average Canal Depth After Backfilling</u>: NA
<u>Cover on Backfilled Spoil Banks</u>: NA

Site Characteristics

The backfilled canal at Lake DeCade had its plug removed and was swept out to allow for barges to bring in the drilling equipment which is now present in the canal. There was no sampling done at this site because there was active drilling in the canal.

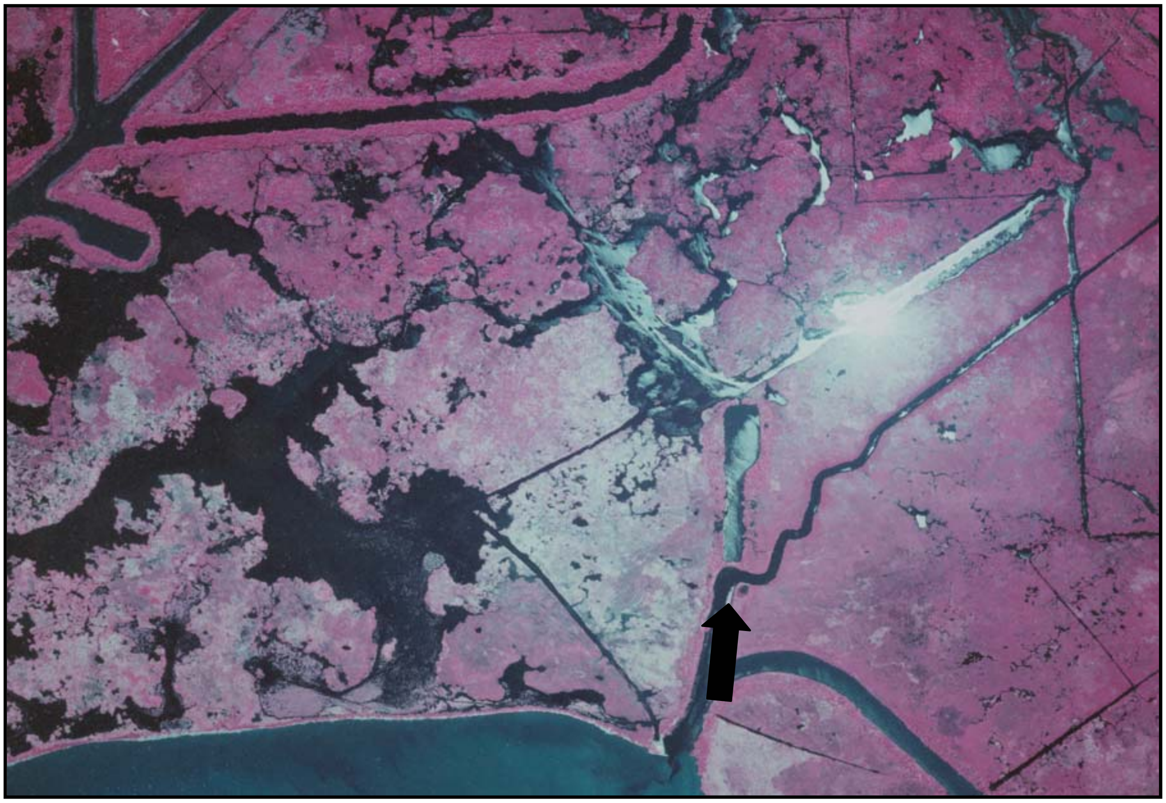

Figure 48. An infrared image of the Lake DeCade backfilled canal, noted by the arrow, taken in 2000.

Figure 49. The Lake DeCade backfilled site in November 2003 after it was reopened for drilling.

21 – Falgout Canal

Coastal Use Permit Number: Not issued
U.S. Army Corps of Engineers Permit Number: Terrebonne Parish Wetlands 324
Applicant: Tenneco Oil Company
Landowner: LaTerre Petroleum Corporation
Well Name: LaTerre Petroleum Corporation Number 4
Location: 29°26’30” North, 91°49’00” West
Length: 401 m
Area Disturbed: Canal – 1.2 ha, Spoil Banks – 2.6 ha
Vegetation Type: Intermediate
Date Canal Dredged: April 1972
Date Canal Backfilled: August 1980
Aerial Inspection: 8 November 2004
Ground Inspection: 10 June 2004
Percent of Spoil Bank Returned to Marsh Elevation: 83 m
Average Canal Depth After Backfilling: 1.2 m
Cover on Backfilled Spoil Banks: Marsh – 83%, Spoil – 2%, Water – 15%

Site Characteristics

Canal. The canal ranged in depth from 0.7 to 1.7 m and had an average depth of 1.2 m. There were many submerged aquatic species in the canal including Coontail (*Ceratophyllum demersum*), and Eurasian Water-milfoil (*Myriophyllum spicatum*).

Spoil Banks. The spoil banks were effectively leveled to marsh elevation over 83% of their area. The plant species present in the portions of the spoil bank that were at marsh elevation included: Groundsel Bush (*Baccharis halimIfolia*), Bull-tongue (*Sagittaria lancifoloia*), Spikerush (*Eleocharis* sp.), Smartweed (Polygonum sp.), Marshhay Cordgrass (*Spartina patens*), and Alligatorweed (*Alternanthera philoxeroides*).

Marsh. The canal was in an area of badly degraded floating intermediate marsh. The dominate species were: 39% Marshhay Cordgrass (*Spartina patens*), 21% Spikerush (*Eleocharis* sp.), 15% Smartweed (Polygonum sp.), 14% Common Three-square (*Schoenoplectus americanus*), with traces of Joint Paspalum (*Paspalum distichum*), Pennywort (*Hydrocotly umbellata*), Marsh Morning Glory (*Ipomoea sagittata*), and Marsh Fern (*Thelypteris thelypteroides*).

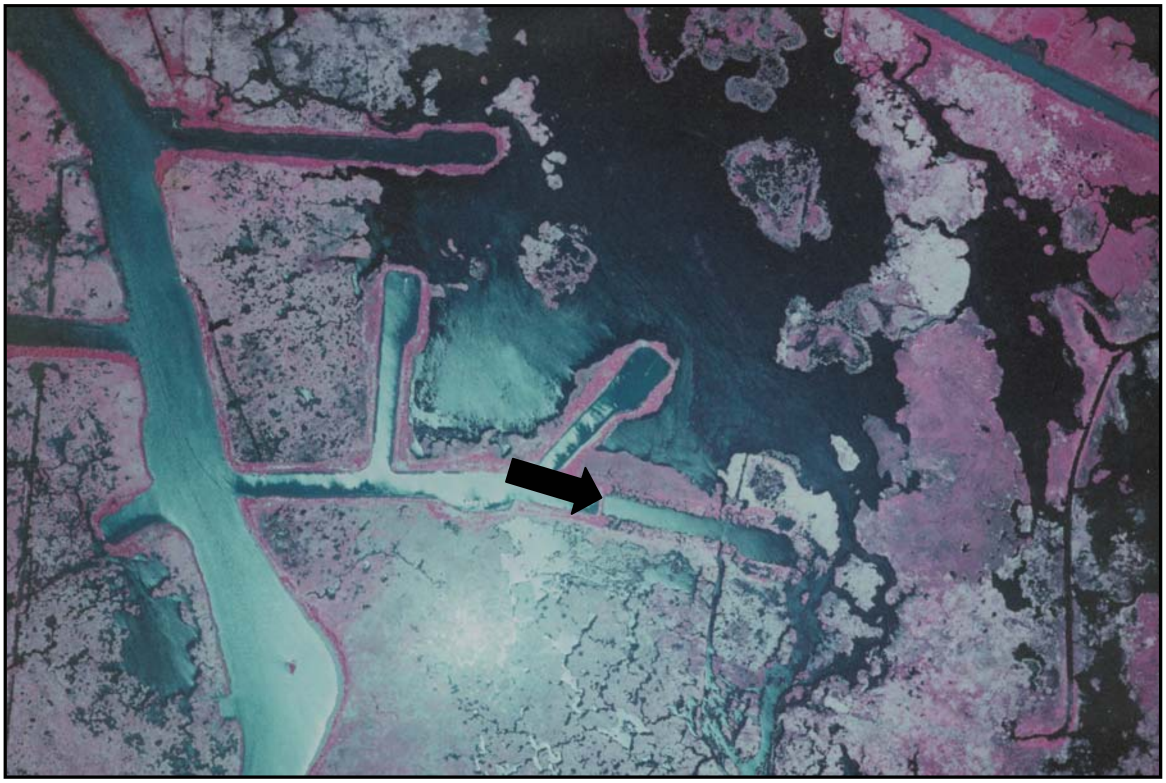

Figure 50. An infrared image of the Falgout Canal backfilled canal, noted by the arrow, taken in 2000.

Figure 51. The Falgout Canal backfilled site in October 2004.

22 – Catfish Lake

Coastal Use Permit Number: Not issued
U.S. Army Corps of Engineers Permit Number: Catfish Lake 1-14-T
Applicant: Texaco Incorporated
Landowner: Louisiana Land and Exploration Company
Well Name: LL&E Golden Meadow Number 205
Location: 29°23’41” North, 90°20’36” West
Length: 457 m
Area Disturbed: Canal – 1.3 ha, Spoil Banks – 2.1 ha
Vegetation Type: Salt
Date Canal Dredged: July 1978
Date Canal Backfilled: May 1981
Aerial Inspection: 5 October 2004
Ground Inspection: 9 June 2004
Percent of Spoil Bank Returned to Marsh Elevation: 50%
Average Canal Depth After Backfilling: 0.8 m
Cover on Backfilled Spoil Banks: Marsh – 50%, Spoil – 25%, Water – 25%

Site Characteristics

Canal. The canal ranged in depth from 0.5 to 1.2 m and had an average depth of 0.8 m. There was no emergent vegetation growing in the canal.

Spoil Banks. The spoil banks were returned to marsh elevation over approximately 50% of their area. The elevated portions of the spoil bank contained Marsh Elder (*Iva frutescens*), Sea Ox-eye (*Borrichia frutescens*), and Smooth Cordgrass (*Spartina alterniflora*). The portions of the spoil bank that were at marsh elevation had a similar species composition as the surrounding marsh, and included: Marshhay Cordgrass (*Spartina patens*), Saltgrass (*Distichlis spicata*), and Smooth Cordgrass (*Spartina alterniflora*).

Marsh. The canal was in an area of highly degraded salt marsh with heavy oil and gas activity. The dominate plant species included: 58% Marshhay Cordgrass (*Spartina patens*), 19% Saltgrass (*Distichlis spicata*), 15% Smooth Cordgrass (*Spartina alterniflora*), 5% Black Needlerush (*Juncus Roemerianus*), and traces of Marsh Morning Glory (*Ipomoea sagittata*).

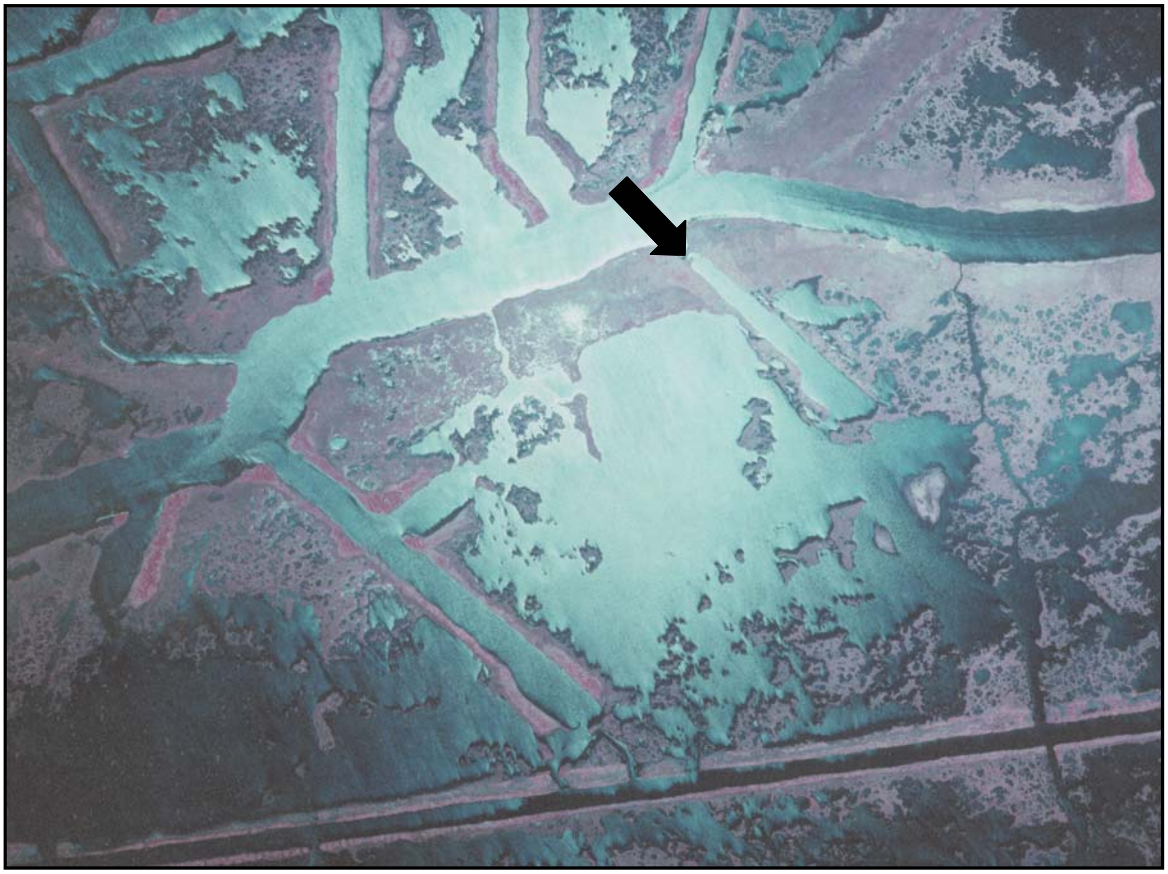

Figure 52. An infrared image of the Catfish Lake backfilled canal, noted by the arrow, taken in 2000.

Figure 53. The Catfish Lake backfilled site in October 2004.

23 – Four League Bay

<u>Coastal Use Permit Number</u>: Not issued
<u>U.S. Army Corps of Engineers Permit Number</u>: Fourleague Bay 60
<u>Applicant</u>: Eason Oil Company
<u>Landowner</u>: Mary Smythe Nelson Estate
<u>Well Name</u>: Mary Smythe Nelson Estate Number 3
<u>Location</u>: 29°20'00" North, 91°11'00" West
<u>Length</u>: 305 m
<u>Area Disturbed</u>: Canal – 1.0 ha, Spoil Banks – 1.5 ha
<u>Vegetation Type</u>: Brackish
<u>Date Canal Dredged</u>: December 1957
<u>Date Canal Backfilled</u>: November 1979
<u>Aerial Inspection</u>: 25 October 2004
<u>Ground Inspection</u>: 30 June 2004
<u>Percent of Spoil Bank Returned to Marsh Elevation</u>: 95%
<u>Average Canal Depth After Backfilling</u>: 0.6
<u>Cover on Backfilled Spoil Banks</u>: Marsh – 95%, Spoil – 0%, Water – 5%

Site Characteristics

<u>Canal</u>. The canal was shallow, ranging in depth from 0.4 to 0.8 m with an average depth of 0.6 m. There were submerged aquatic species such as Coontail (*Ceratophyllum demersum*) present in the canal. The north end of the canal, which is connected to Four League Bay, has been eroding landward and widening.

<u>Spoil Banks</u>. The spoil banks were completely leveled to marsh elevation over 95% of the spoil area. The spoil banks consisted of similar species as the marsh including: Common Three-square (*Schoenoplectus americanus*), Saltgrass (*Distichlis spicata*), Marshhay Cordgrass (*Spartina patens*), Salt Marsh Bulrush (*Schoenoplectus robustus*), Goldenrod (*Solidago* sp.), and Marsh Morning Glory (*Ipomoea sagittata*).

<u>Marsh</u>. The canal is in an area of intact brackish marsh with few small ponds and minimal oil and gas activity. The dominate species 40% Common Three-square (*Schoenoplectus americanus*), 29% Saltgrass (*Distichlis spicata*), 20% Marshhay Cordgrass (*Spartina patens*), and 10% Salt Marsh Bulrush (*Schoenoplectus robustus*).

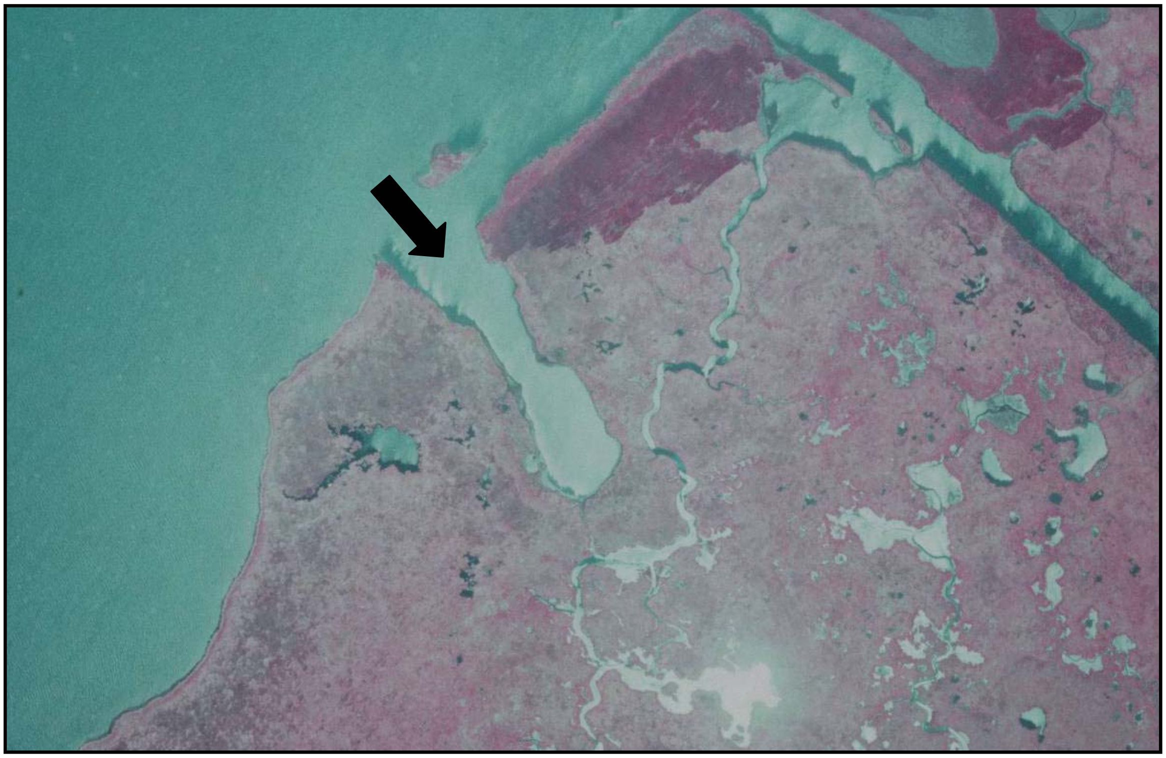

Figure 54. An infrared image of the Four League Bay backfilled canal, noted by the arrow, taken in 2000.

Figure 55. The Four League Bay backfilled site in October 2004

24 – Oaks Canal

Coastal Use Permit Number: Not issued
U.S. Army Corps of Engineers Permit Number: L.T.A.V 156
Applicant: Quintana Petroleum Corporation
Landowner: A. Broussard
Well Name: A. Broussard
Location: 29°49’51” North, 91°58’47” West
Length: 399 m
Area Disturbed: Canal – 1.3 ha, Spoil Banks – 3.0 ha
Vegetation Type: Brackish
Date Canal Dredged: August 1980
Date Canal Backfilled: February 1982
Aerial Inspection: 25 April 2004
Ground Inspection: 14 June 2004
Percent of Spoil Bank Returned to Marsh Elevation: 90%
Average Canal Depth After Backfilling: 0.5 m
Cover on Backfilled Spoil Banks: Marsh – 90%, Spoil – 10%, Water – 0%

Site Characteristics

Canal. An estimated 45% of the canal contained emergent marsh vegetation similar to that of the surrounding marsh. The turning basin was shallow open water ranging from 0 to 1.3 m in depth. There were narrow channels, 2 m wide or less, that connected a small pond in the canal to the turning basin. Submerged aquatic vegetation was present in the canal.

Spoil Banks. The spoil banks were leveled effectively to marsh elevation over 90% of their area. Elevated spoil remained in a few spots on the outer edges of the spoil bank and consisted of Marsh Elder (*Iva frutescens*), Goldenrod (*Solidago* sp.), Groundsel Bush (*Baccharis* halimifolia), Roseau Cane (*Phragmites australis*) and a few Chinese Tallow Trees (*Sapium sebiferum*). The portions of spoil bank that were at marsh elevation consisted of similar species as the marsh and included: Cattails (*Typha* sp.), Marshhay Cordgrass (*Spartina patens*), Common Three-square (*Schoenoplectus americanus*), Sedges (*Cyperus* sp.), and Joint Paspalum (*Paspalum distichum*).

Marsh. The canal was dredged directly from the Intracoastal Waterway and was in an area of intact intermediate to brackish marsh broken by a large pond nearby. The marsh was dominated by 38% Cattails (*Typha* sp.), 33% Marshhay Cordgrass (*Spartina patens*), 16% Common Three-square (*Schoenoplectus americanus*), 10% Sedges (*Cyperus* sp.), and traces of Joint Paspalum (*Paspalum distichum*)

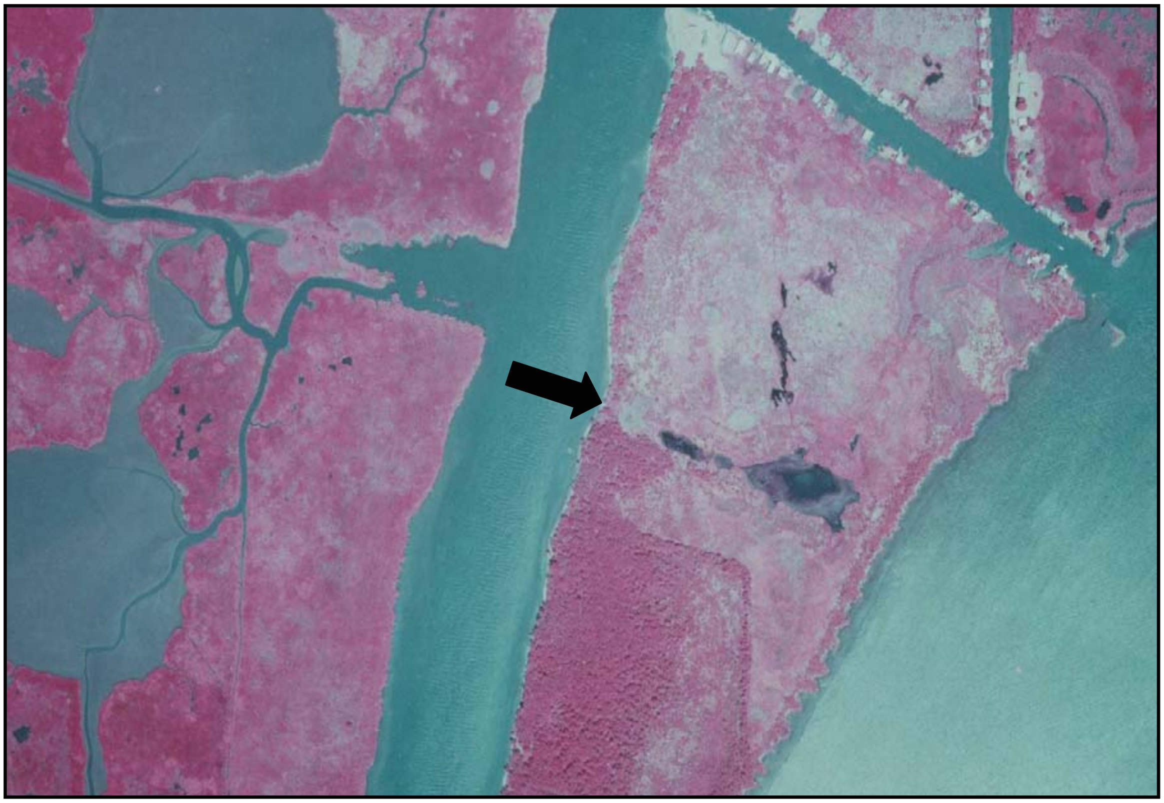
Figure 56. An infrared image of the Oaks Canal backfilled site, noted by the arrow, taken in 2000


Figure 57. The Oaks Canal backfilled site in April 2004

25 – Lower Mud Lake

Coastal Use Permit Number: P820906
U.S. Army Corps of Engineers Permit Number: Lower Mud Lake 11
Applicant: Sam Myers
Landowner: Dr. S. O. Carter Estate
Well Name: Dr. S. O. Carter Estate Number 2
Location: 29°45’04” North, 93°02’32” West
Length: 120 m
Area Disturbed: Canal – 1.2 ha, Spoil Banks – 3.3 ha
Vegetation Type: Salt
Date Canal Dredged: February 1983
Date Canal Backfilled: December 1983
Aerial Inspection: 25 April 2004
Ground Inspection: 2 July 2004
Percent of Spoil Bank Returned to Marsh Elevation: 75%
Average Canal Depth After Backfilling: 0.0 m
Cover on Backfilled Spoil Banks: Marsh – 75%, Spoil – 20%, Water – 5%

Site Characteristics

Canal. The canal was vegetated by Smooth Cordgrass (*Spartina alterniflora*) over 80% of its area. The only portions of the canal not colonized by emergent vegetation were open water in the form of a natural drainage channel that had developed. No submerged aquatic species were present.

Spoil Banks. The spoil banks were leveled to marsh elevation over 75% of their area, with a narrow ridge of unfilled spoil on both the east and west sides of the canal. The vegetation on the ridges was different than the rest of the spoil bank and consisted of Groundselbush (*Baccharis halimifolia*), Marshhay Cordgrass (*Spartina patens*), and Sea Ox-eye (*Borrichia frutescens*). The portions of spoil bank that were at marsh elevation consisted of Smooth Cordgrass (*Spartina alterniflora*), Saltgrass (*Distichlis spicata*), Salt Marsh Bulrush (*Schoenoplectus robustus*), and Salt Marsh Aster (*Aster* sp.)

Marsh. The canal occurred in an area of intact salt marsh on the south side of Lower Mud Lake. The marsh was dominated by 65% Saltgrass (*Distichlis spicata*), 24% Salt Marsh Bulrush (*Schoenoplectus robustus*), and 11% Smooth Cordgrass (*Spartina alterniflora*)

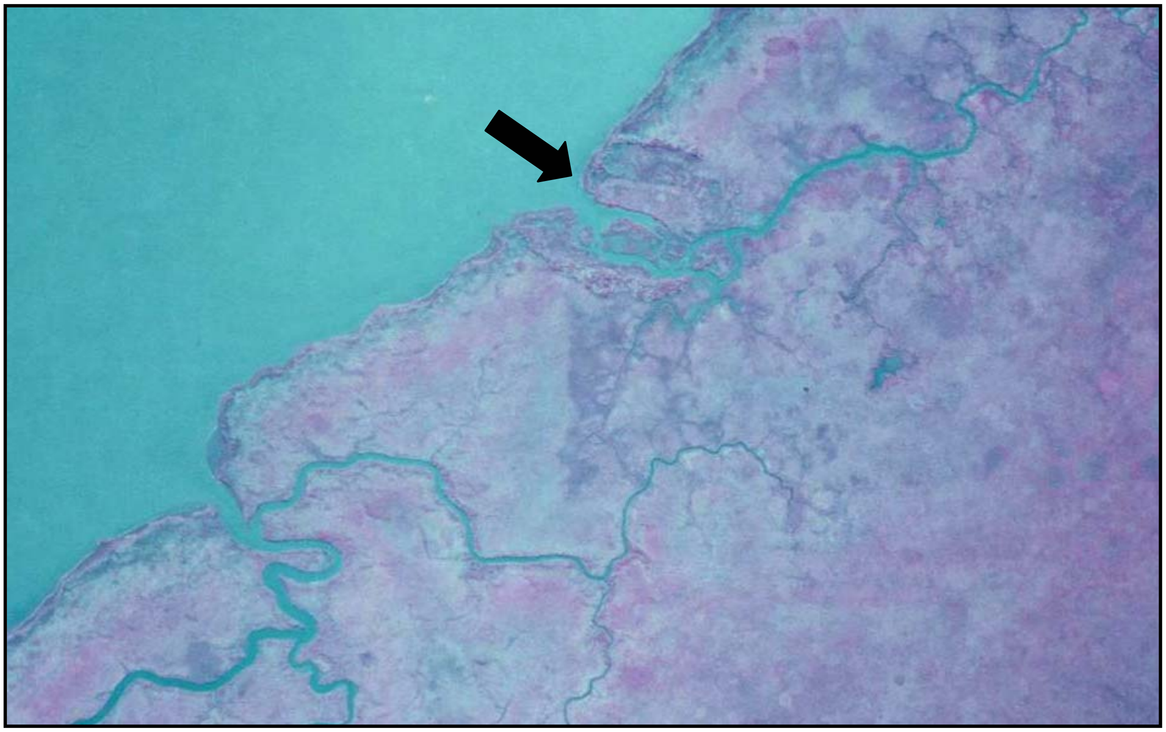

Figure 58. An infrared image of the Lower Mud Lake backfilled canal, noted by the arrow, taken in 2000

Figure 59. The Lower Mud Lake backfilled site in April 2004.

26 – Boston Bayou South

Coastal Use Permit Number: Not issued
U.S. Army Corps of Engineers Permit Number: Vermilion Parish Wetlands 114-A
Applicant: Lyons Petroleum Incorporated
Landowner: John Nugier et al.
Well Name: John Nugier et al. Number 2
Location: 29°45'04" North, 92°03'10" West
Length: 610 m
Area Disturbed: Canal – 1.6 ha, Spoil – 4.1 ha
Vegetation Type: Brackish
Date Canal Dredged: June 1962
Date Canal Backfilled: January 1981
Aerial Inspection: 25 April 2004
Ground Inspection: 2 June 2004
Percent of Spoil Bank Returned to Marsh Elevation: 50%
Average Canal Depth After Backfilling: 0.6 m
Cover on Backfilled Spoil Banks: Marsh – 50%, Spoil – 35%, Water – 15%

Site Characteristics

Canal. The canal was shallow, ranging in depth from 0.5 to 0.9 m with an average depth of 0.6 m. There was a variety of submerged aquatic species present in the canal. There were small amounts of emergent marsh vegetation growing along the edges of the canal.

Spoil Banks. The spoil banks were a mix of marsh vegetation, spoil vegetation and open water. There was an elevated spoil ridge, nearly continuous, around the back edge of the spoil bank. The vegetation on the portions of former spoil bank that were at marsh vegetation was diverse and included: Alligatorweed (*Alternanthera philoxeroides*), Bull-tongue (*Sagittaria lancifolia*), Common Three-square (*Schoenoplectus americanus*), *Panicum* sp., Mock Bishopweed (*Ptilimnium capillaceum*), and California Bulrush (*Schoenoplectus californicus*). The elevated spoil contained Chinese Tallow (*Sapium sebiferum*), Wax Myrtle (*Myrica cerifera*), Goldenrod (*Solidago* sp.), Hackberry (*Celtis Laevigata*), Honeysuckle (*Viburnum dentatum*), Yaupon (*Ilex vomitoria*), and Live Oak (*Quercus virginiana*).

Marsh. The canal was in an area of brackish marsh with locally heavy oil and gas activity. The marsh north and east of the canal was filled with many large ponds and marsh fragments. The marsh was made up of 32% Alligatorweed (*Alternanthera philoxeroides*), 32% Bull-tongue (*Sagittaria lancifolia*), 8% Common Three-square (*Schoenoplectus americanus*), 6% Spikerush (*Eleocharis* sp.), 4% *Carex* sp., with traces of Cattails (*Typha* sp.) and Mock Bishopweed (*Ptilimnium capillaceum*). The marsh south of the canal was similar in compostion, but had patches of Roseau Cane (*Phragmites australis*) which grew along an abandoned stream channel.

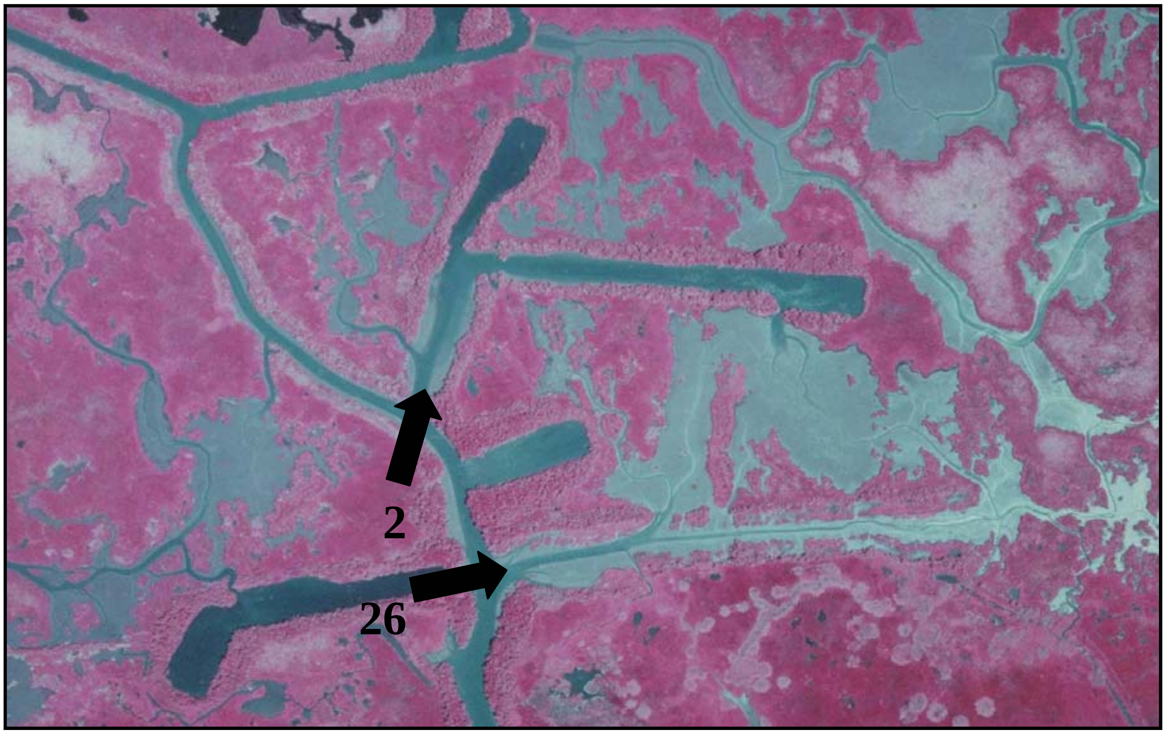

Figure 60. An infrared image of the Boston Bayou South, site 26, backfilled canal taken in 2000. The backfilled canal Boston Bayou North, site 2, can also be seen, along with numerous un-filled canals.


Figure 61. The Boston Bayou South backfilled site in April 2004.

27 – Iberia Canal

<u>Coastal Use Permit Number</u>: P810610
<u>U.S. Army Corps of Engineers Permit Number</u>: Iberia Parish Wetlands 63-A
<u>Applicant</u>: C & K Petroleum Incorporated
<u>Landowner</u>: McIlhenny Estate
<u>Well Name</u>: McIlhenny Estate Number 1
<u>Location</u>: 29°52'09" North, 91°51'53" West
<u>Length</u>: 1219 m
<u>Area Disturbed</u>: Canal – 2.9 ha, Spoil – 8.2 ha
<u>Vegetation Type</u>: Intermediate
<u>Date Canal Dredged</u>: October 1981
<u>Date Canal Backfilled</u>: December 1983
<u>Aerial Inspection</u>: 25 April 2004
<u>Ground Inspection</u>: 15 June 2004
<u>Percent of Spoil Bank Returned to Marsh Elevation</u>: 30%
<u>Average Canal Depth After Backfilling</u>: 1.2 m
<u>Cover on Backfilled Spoil Banks</u>: Marsh – 30%, Spoil – 70%, Water – 0%

Site Characteristics

<u>Canal</u>. This canal was originally backfilled along its entire 1219 m length, but between 1984 and 1990 around 500 m of the canal was re-dredged to access a new canal and well. The portion of the canal not re-dredged was surveyed and ranged in depth from 0.5 to 2.2 m with an average depth of 1.2 m. There was submerged aquatic vegetation in the canal.

<u>Spoil Banks</u>. The spoil bank on the southeast side of the canal were taken down to marsh elevation over most of its area, but the northwest side of the canal and the turning basin had elevated spoil that harbored spoil vegetation and trees. The elevated portions of spoil contained species such as: Black Willow (*Salix Nigra*), Chinese Tallow (*Sapium sebiferum*), Groundsel Bush (*Baccharis halimifolia*), Palmetto (*Sabal minor*), and Brambles (*Rubus sp*.). The lower elevation spoil area contained species similar to the marsh such as: Alligatorweed (*Alternanthera philoxeroides*), Bull-tongue (*Sagittaria lancifolia*), Common Three-square (*Schoenoplectus americanus*), Sawgrass (*Cladium jamaicense*), Marshhay Cordgrass (*Spartina patens*), and Marsh Morning Glory (*Ipomoea sagittata*).

<u>Marsh</u>. The canal was in an area of intact intermediate marsh with many small ponds in the vicinity. The dominate plant species were Marshhay Cordgrass (*Spartina patens*), Black Needlerush (*Juncus roemerianus*), Spikerush (*Eleocharis sp.*), Sawgrass (*Cladium jamaicense*), Common Three-square (*Schoenoplectus americanus*), Bull-tongue (*Sagittaria lancifolia*), Smartweed (*Polygonum sp.*), and Marsh Morning Glory (*Ipomoea sagittata*).

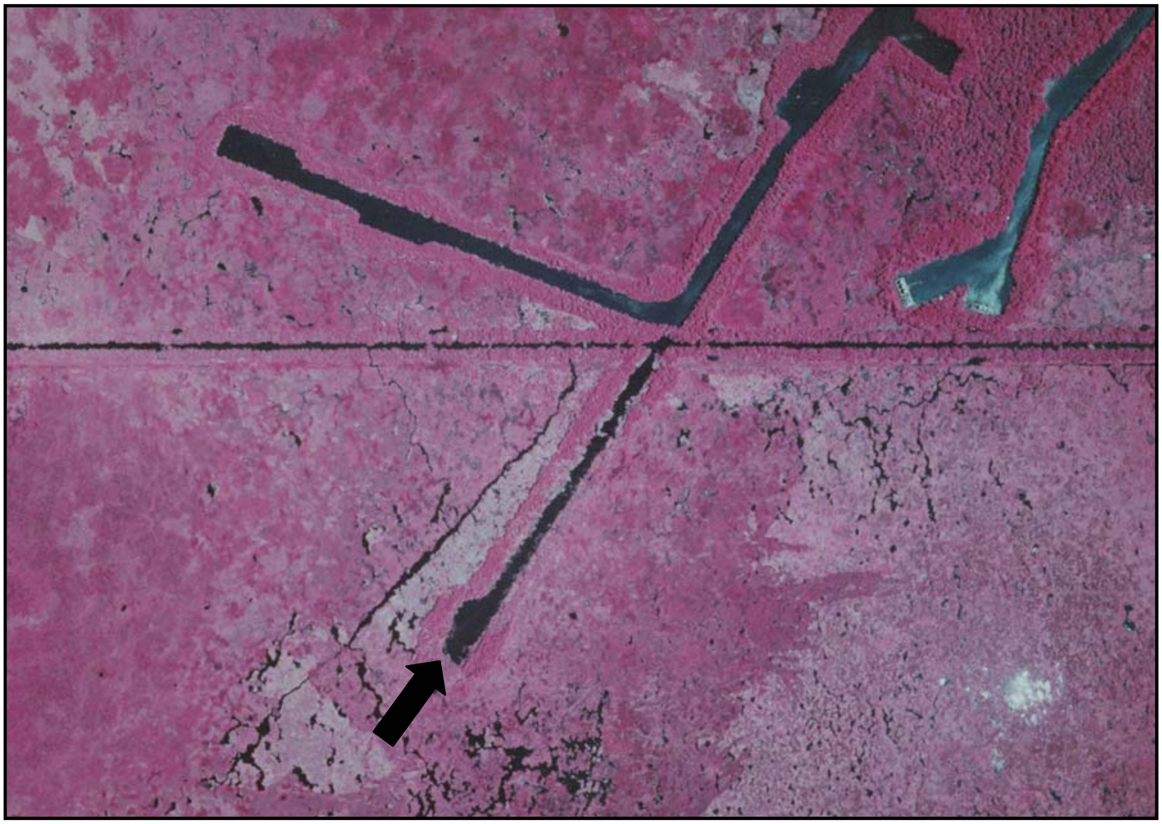

Figure 62. An infrared image of the Iberia Canal backfilled canal, noted by the arrow, taken in 2000.

Figure 63. The Iberia Canal backfilled site in April 2004.

28 – Delta Farms

Coastal Use Permit Number: P811832
U.S. Army Corps of Engineers Permit Number: Lafourche Parish Wetlands 420
Applicant: Halbouty Energy Corporation
Landowner: Hugh Hawthorne
Well Name: Hawtorne Number 1
Location: 29°36'56" North, 90°17'57" West
Length: 434 m
Area Disturbed: Canal – 1.4 ha, Spoil 2.8 ha
Vegetation Type: Fresh
Date Canal Dredged: September 1982
Date Canal Backfilled: February 1984
Aerial Inspection: 19 November 2003, 5 October 2004
Ground Inspection: None
Percent of Spoil Bank Returned to Marsh Elevation: 5%
Average Canal Depth After Backfilling: NA
Cover on Backfilled Spoil Banks: Marsh – 5%, Spoil – 95%, Water – 0%

Site Characteristics

No ground evaluation was conducted at this site because of restricted access, and private hunting leases. From the air, this site appears to never have been backfilled. Trees line the entire spoil bank, except for at the extreme northern end of the turning basin. The canal is located in a failed agricultural area that has since returned to marsh, but the original agricultural drainage canals are visible.

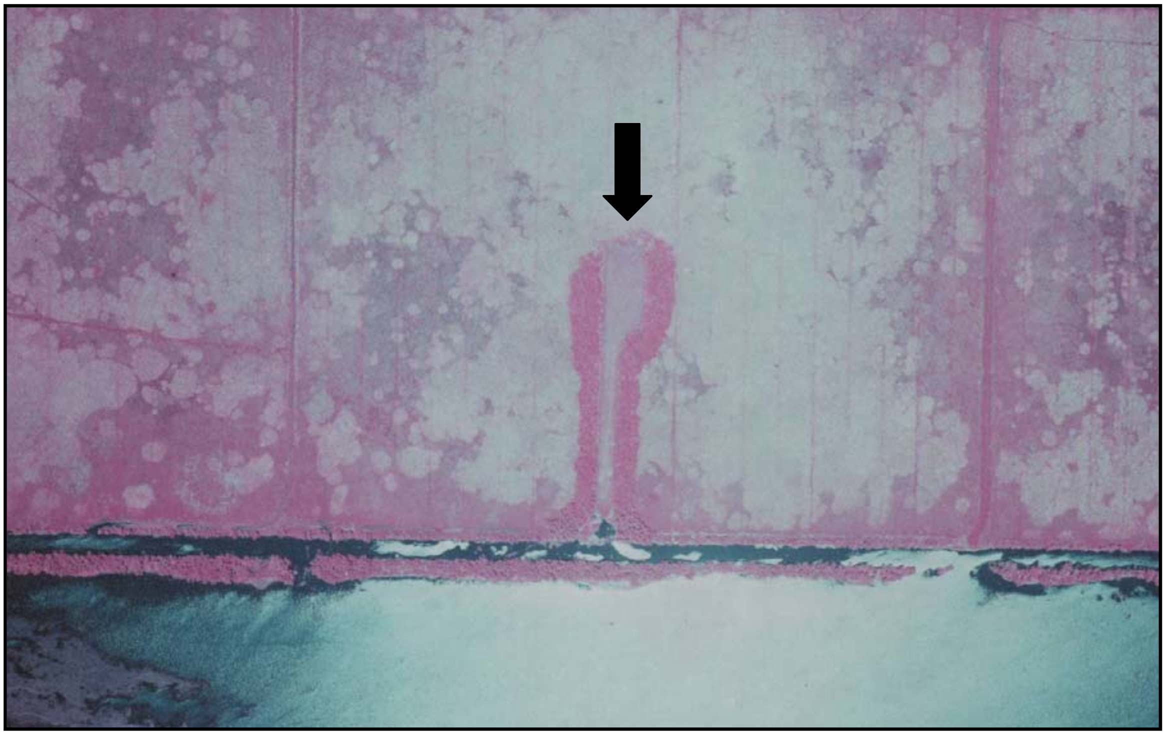

Figure 64. An infrared image of the Delta Farms backfilled canal, noted by the arrow, taken in 2000. The canal is filled with floating vegetation such as Water Hyacinth (*Eichhornia crassipes*).

Figure 65. The Delta Farms backfilled site in October 2004.

29 – Rainey Refuge

Coastal Use Permit Number: P810635
U.S. Army Corps of Engineers Permit Number: Vermilion Parish Wetlands 131
Applicant: Brock Petroleum Corporation
Landowner: National Audubon Society
Well Name: National Audubon Society Number 1
Location: 29°38’39” North, 92°14’04” West
Length: 174 m
Area Disturbed: Canal – 0.7 ha, Spoil Banks – 1.4 ha
Vegetation Type: Brackish
Date Canal Dredged: August 1981
Date Canal Backfilled: August 1983
Aerial Inspection: 21 April 2004
Ground Inspection: 1 June 2004
Percent of Spoil Bank Returned to Marsh Elevation: 55%
Average Canal Depth After Backfilling: 1.1 m
Cover on Backfilled Spoil Banks: Marsh – 55%, Spoil – 20%, Water – 25%

Site Characteristics

Canal. The canal was plugged with an earthen plug which completely restricted water exchange. The depth ranged from 0.6 to 1.7 m with an average depth of 1.1 m. The canal contained submerged aquatic vegetation. A limited area of the canal also contained emergent marsh vegetation.

Spoil Banks. The spoil banks were a combination of marsh vegetation, elevated spoil and shallow water. The elevated spoil occurred on the north and south spoil banks along the outside of the former spoil areas. The vegetation on the elevated portions contained Chinese Tallow (*Sapium sebiferum*), Roseau Cane (*Phragmites australis*), Groundsel Bush (*Baccharis halimifolia*), and Brambles (*Rubus sp.*). There was open water on the northern spoil bank and it contained submerged aquatic species similar to the canal. The portions of the canal leveled to marsh elevation were covered with emergent marsh vegetation, predominately Marshhay Cordgrass (*Spartina patens*), Giant Cutgrass (*Zizaniopsis miliacea*), and Roseau Cane (*Phragmites australis*).

Marsh. The canal was in an area of brackish marsh with moderate oil and gas activity in the Paul J. Rainey Wildlife Refuge. Immediately to the east of the canal was a pond that nearly equaled the area of the canal, and the rest of the canal was surrounded by nearly 100% cover of Marshhay Cordgrass (*Spartina patens*).

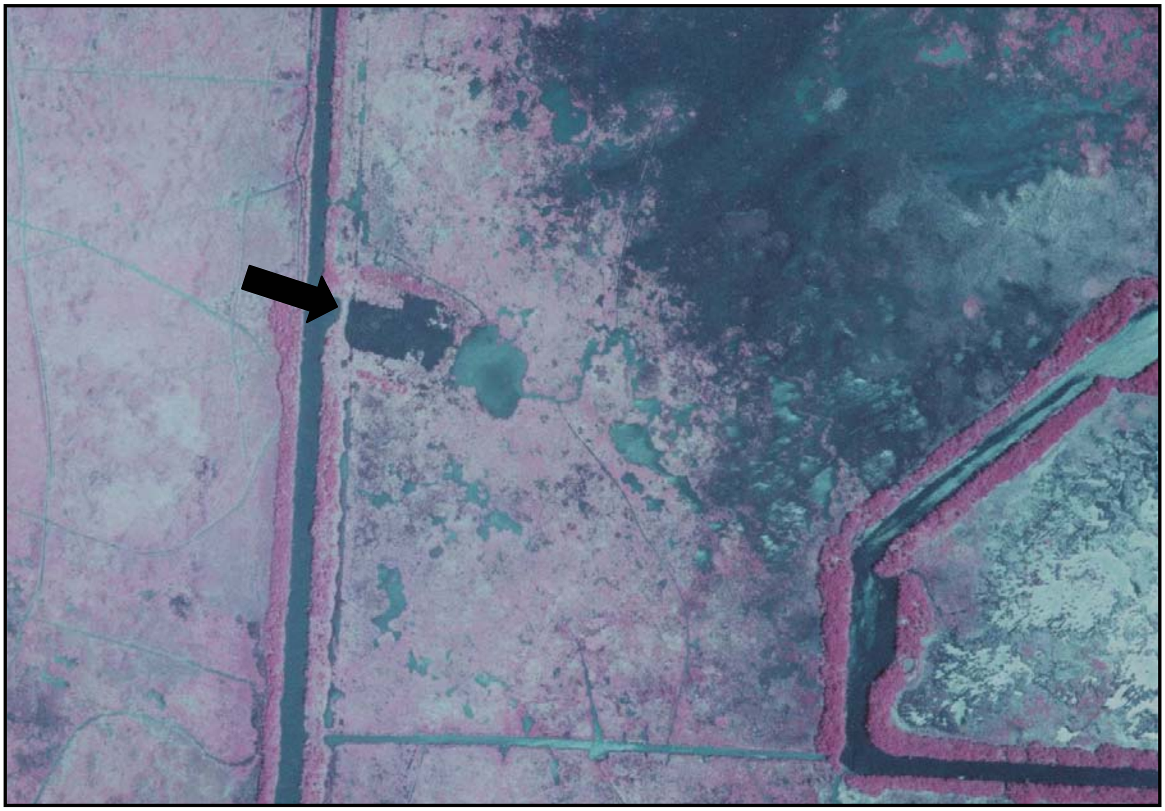

Figure 66. An infrared image of the Rainey Refuge backfilled canal, noted by the arrow, taken in 2000.

Figure 67. The Rainey Refuge backfilled site in April 2004.

30 – Pecan Island East

Coastal Use Permit Number: P840252
U.S. Army Corps of Engineers Permit Number: Vermilion Parish Wetlands 195
Applicant: Exxon Corporation
Landowner: Exxon Corporation
Well Name: Louisiana Furs Incorporated Number 4 and Number 8
Location: 29°35’30” North, 92°21’30” West
Length: 827 m
Area Disturbed: Canal – 1.8 ha, Spoil Banks – 3.6 ha
Vegetation Type: Brackish
Date Canal Dredged: 1944
Date Canal Backfilled: July 1984
Aerial Inspection: 21 April 2004
Ground Inspection: None
Percent of Spoil Bank Returned to Marsh Elevation: 5%
Average Canal Depth After Backfilling: ND
Cover on Backfilled Spoil Banks: Marsh – 5%, Spoil – 0%, Water – 95%

Site Characteristics

This site was only visually inspected, and no soil cores vegetation surveys, or depth profiles were taken. The spoil banks along the canal were backfilled to below marsh elevation, and remained shallow water. The canal contained submerged aquatic vegetation.

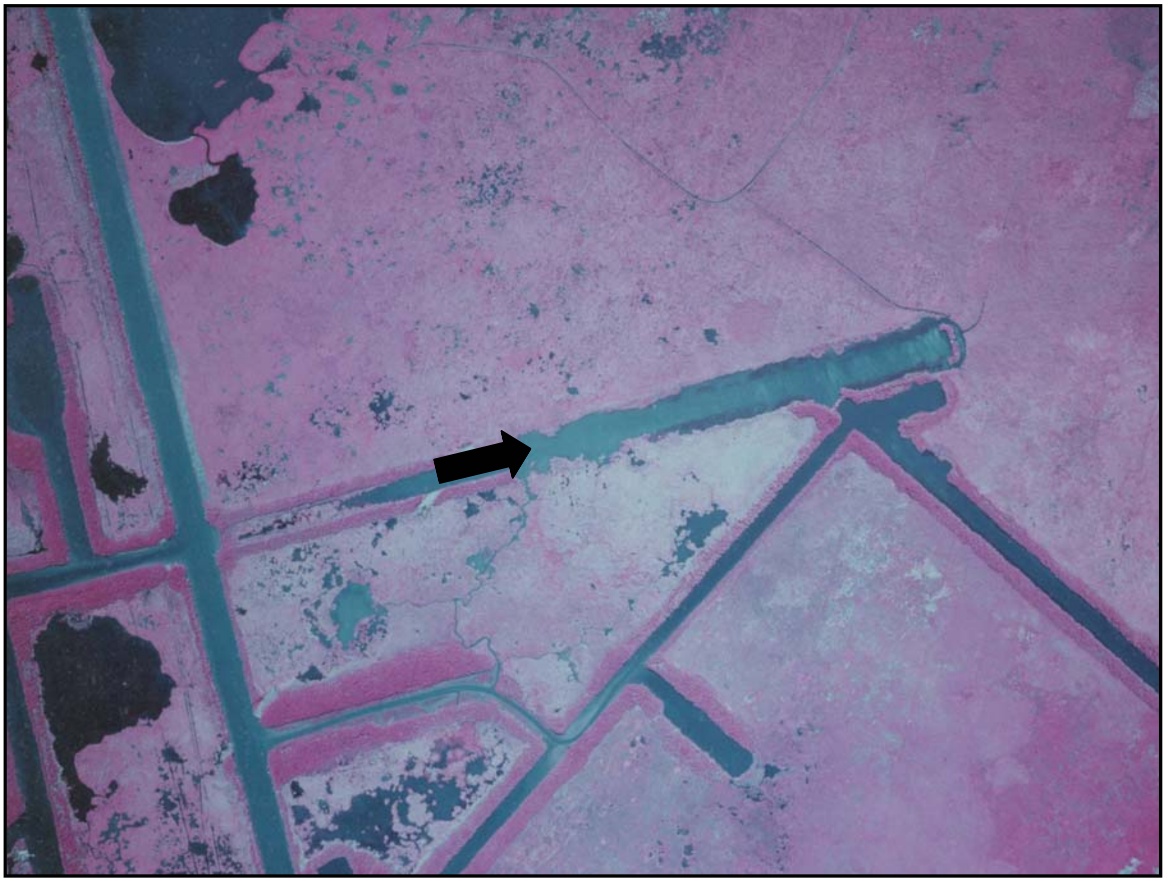

Figure 68. An infrared image of the Pecan Island East backfilled canal, noted by the arrow, taken in 2000.

Figure 69. The Pecan Island East backfilled site in April 2004.

31 – Superior Canal

Coastal Use Permit Number: NA
U.S. Army Corps of Engineers Permit Number: NA
Applicant: NA
Landowner: Miami Corporation
Well Name: NA
Location: NA
Length: 457 m
Area Disturbed: Canal 1.3 ha, Spoil Banks – 4.6 ha
Vegetation Type: Intermediate
Date Canal Dredged: NA
Date Canal Backfilled: NA
Aerial Inspection: 21 April 2004
Ground Inspection: 13 July 2004
Percent of Spoil Bank Returned to Marsh Elevation: 78%
Average Canal Depth After Backfilling: 1.4 m
Cover on Backfilled Spoil Banks: Marsh – 78%, Spoil – 20%, Water – 2%

Site Characteristics

Canal. The canal had emergent vegetation growing in from the edges, and portions of the canal were less than 10 m across. The open water portions of the canal remained deep with an average depth of 1.4 m. There were numerous species of submerged aquatic vegetation present.

Spoil Banks. The back edge of the spoil bank was incompletely filled, and elevated spoil remained. The elevated spoil harbored species such as Chinese Tallow (*Sapium sebiferum*), Groundsel Bush (*Baccharis halimifolia*), Black Willow (*Salix nigra*), and Marsh Elder (*Iva frutescens*).The inner portions of the spoil bank were effectively leveled to marsh elevation and harbored emergent marsh vegetation. The dominate species were Marshhay Cordgrass (*Spartina patens*), Common Three-square (*Schoenoplectus americanus*), with traces of Bulrush (*Schoenoplectus californicus*), Cattails (*Typha* sp.), Roseau Cane (*Phragmites australis*), Giant Cutgrass (*Zizaniopsis miliacea*).

Marsh. The canal was in an area of fresh to intermediate marsh with few ponds, moderate oil and gas activity, and a variety of vegetation. The marsh consisted of 50% Marshhay Cordgrass (*Spartina patens*), 40% Common Three-square (*Schoenoplectus americanus*), and 10% Cattails (*Typha* sp.), with traces of Smartweed (*Polygonum* sp.), and Bulrush (*Schoenoplectus californicus*).

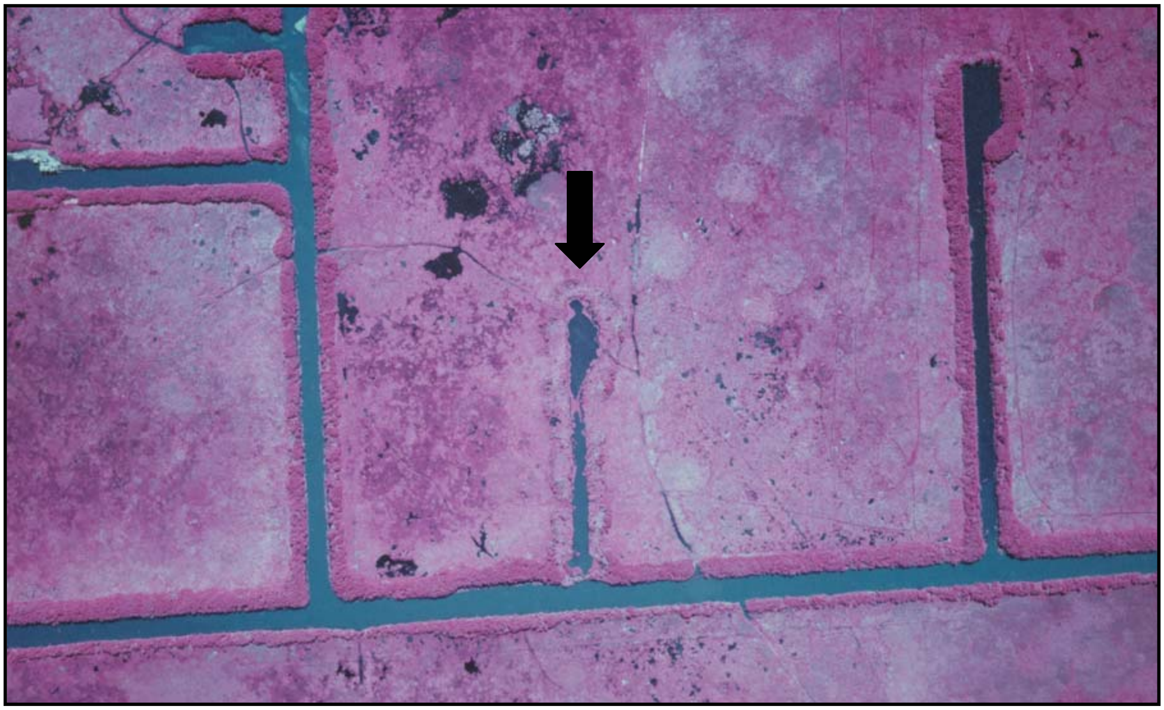
Figure 70. An infrared image of the Superior Canal backfilled site, noted by the arrow, taken in 2000.


Figure 71. The Superior Canal backfilled site in April 2004.

32 – Long Island

Coastal Use Permit Number: NA
U.S. Army Corps of Engineers Permit Number: NA
Applicant: NA
Landowner: Miami Corporation
Well Name: NA
Location: NA
Length: 457 m
Area Disturbed: Canal – 1.3 ha, Spoil Banks – 2.5 ha
Vegetation Type: Fresh
Date Canal Dredged: NA
Date Canal Backfilled: NA
Aerial Inspection: 21 April 2004
Ground Inspection: 14 July 2004
Percent of Spoil Bank Returned to Marsh Elevation: 50%
Average Canal Depth After Backfilling: NA
Cover on Backfilled Spoil Banks: Marsh – 50%, Spoil – 50%, Water – 0%

Site Characteristics

Canal. The canal was covered by emergent marsh and floating vegetation over approximately 80% of its area. The emergent species included Giant Cutgrass (*Zizaniopsis miliacea*), Marsh Purslane (*Ludwigia palustris*.), Alligatorweed (*Alternanthera philoxeroides*), and a Sedge species (*Cyperus* sp.). The emergent vegetation was not present in 2000, but has begun forming a mat over the past two years. There was also Water Hyacinth (*Eichhornia crassipes*) and Salvinia (*Salvinia sp.*) present.

Spoil Banks. The spoil banks contained roughly equal areas of elevated spoil and marsh. The marsh has formed in areas that were originally dredged too deep and were left as open water. The elevated spoil areas were covered almost exclusively by Black Willow (*Salix nigra*).

Marsh. The canal was in an area of fresh marsh dominated by Cattails (*Typha sp.*), Bull-tongue (*Sagittaria lancifolia*), Marshhay Cordgrass (*Spartina patens*), and Smartweed (*Polygonum*).

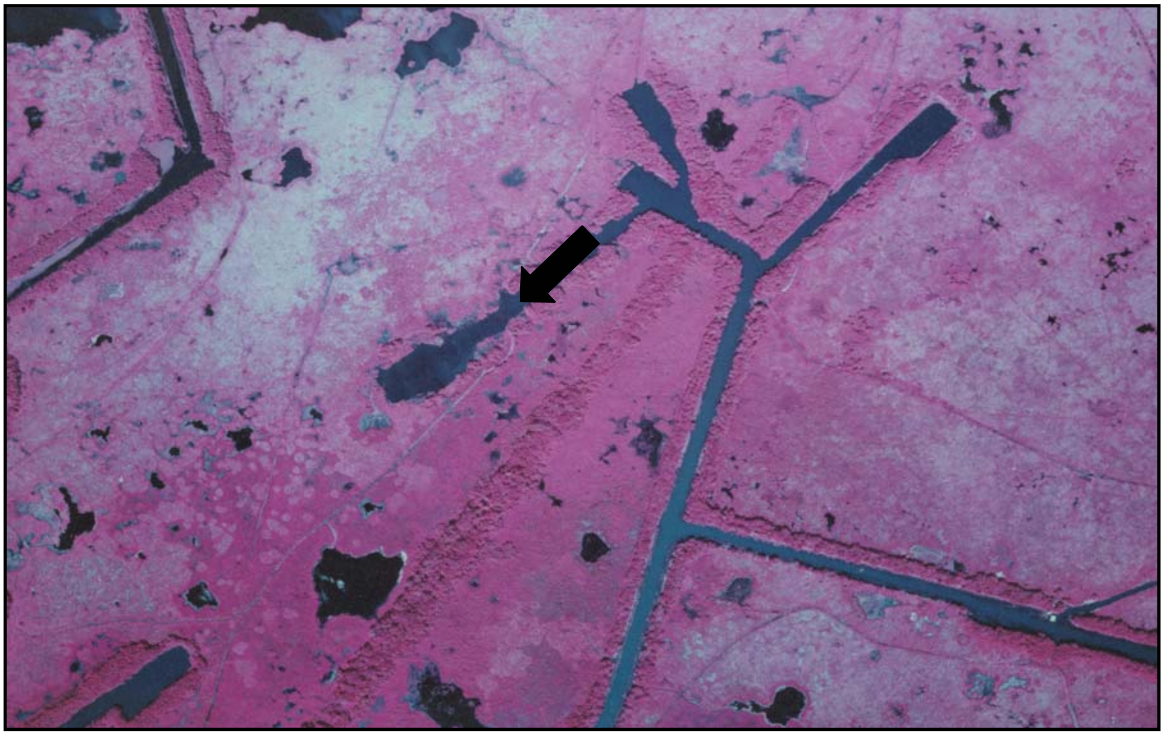

Figure 72. An infrared image of the Long Island backfilled canal, noted by the arrow, taken in 2000.

Figure 73. The Long Island backfilled site in April 2004.

33 – Point à la Hache

Coastal Use Permit Number: Not issued
U.S. Army Corps of Engineers Permit Number: Plaquemines Parish Wetland 181
Applicant: Campbell Energy Corporation
Landowner: Benedict C. Gravolet
Well Name: Benedict C. Gravolet
Location: 28°37’04” North, 89°49’45” West
Length: 664 m
Area Disturbed: Canal – 1.7 ha, Spoil Banks – 4.0 ha
Vegetation Type: Brackish
Date Canal Dredged: August 1981
Date Canal Backfilled: August 1981
Aerial Inspection: 19 November 2003
Ground Inspection: 4 June 2004
Percent of Spoil Bank Returned to Marsh Elevation: 50%
Average Canal Depth After Backfilling: 0.7 m
Cover on Backfilled Spoil Banks: Marsh – 50%, Spoil – 25%, Water – 25%

Site Characteristics

Canal. The canal ranged in depth from 0.4 to 1.2 m with an average depth of 0.7 m. Portions of the canal supported emergent vegetation, and other portions contained submerged aquatic species.

Spoil Banks. The spoil banks were leveled to marsh elevation along 50% of their area, and remained elevated spoil along 25% of their area. Twenty-five percent of the spoil area was dug deeper than marsh elevation and remained as shallow water less than 30 cm. The elevated portion of the spoil bank was entirely on the northern spoil bank, and was populated by spoil vegetation including Goldenrod (*Solidago sp.*), and Marsh Elder (*Iva frutescens*). The portions of the spoil bank at marsh elevation were populated by Marshhay Cordgrass (*Spartina patens*), Salt Marsh Loosestrife (*Lythrum lineare*), Common Three-square (*Schoenoplectus americanus*), Smartweed (*Polygonum* sp.), and Mock Bishopweed (*Ptilimnium capillaceum*).

Marsh. The canal was in an area of brackish marsh with many small ponds. The marsh was dominated by 70% Marshhay Cordgrass (*Spartina patens*), with 20% Salt Marsh Loosestrife (*Lythrum lineare*), and traces of Common Three-square (*Schoenoplectus americanus*).

Figure 74. The Point à la Hache backfilled site in November 2003.

Vita

Joseph Baustian was born in Davenport, Iowa, in 1980. He attended Iowa State University beginning in the fall of 1999, and received a Bachelor of Science degree in environmental science in the spring of 2003. He then moved to Baton Rouge, Louisiana, where he entered Louisiana State University in the fall of 2003 and began work on a Master of Science degree from the Department of Oceanography and Coastal Sciences.