Bank Erosion of Navigation Canals in the Western and Central Gulf of Mexico

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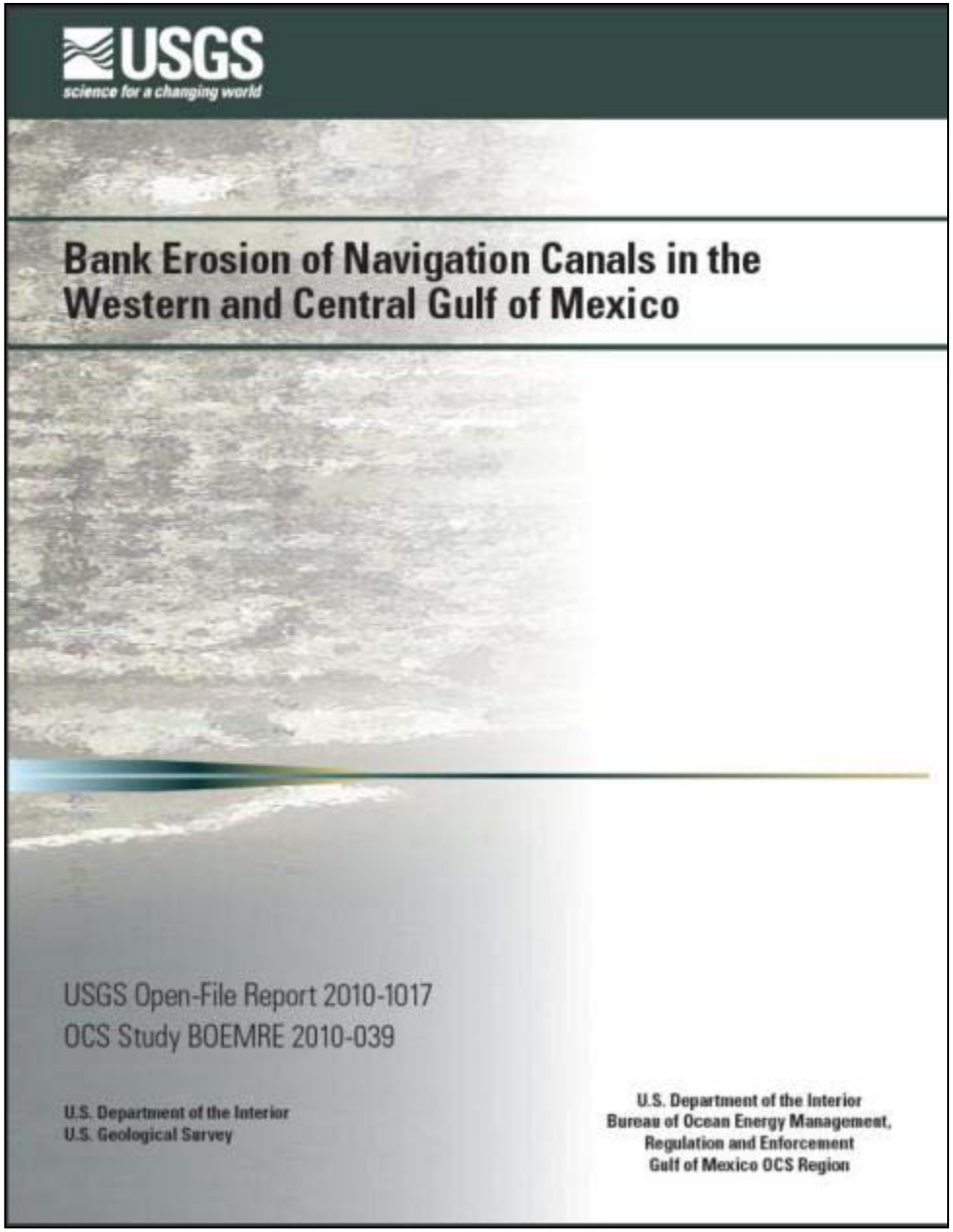
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Gulf of Mexico OCS Region

Introduction

Erosion of navigation canal banks is a direct cause of land loss, but there has been little quantitative analysis to determine why certain major canals exhibit faster widening rates (indicative of erosion) than others in the coastal zones of Texas, Louisiana, Mississippi, and Alabama. In this study we hypothesized that navigation canals exhibit varying rates of erosion based on soil properties of the embankment substrate, vegetation type, geologic region, and the presence or absence of canal bank armaments (that is, rock rip-rap, concrete bulkheads, or other shoreline protection structures).

Study Area

The study area is within the BOEMRE-designated western and central planning areas of the Outer Continental Shelf (OCS) region, which includes the coastal zones of Texas, Louisiana, Mississippi, and Alabama. The canals in the study, the largest or most important for navigation within the two planning regions, vary in length from approximately 4 km (Theodore Ship Channel, AL) up to 59 km (Freshwater Bayou Channel, LA). In total, approximately 356 linear kilometers of navigation canals were included in the study area.

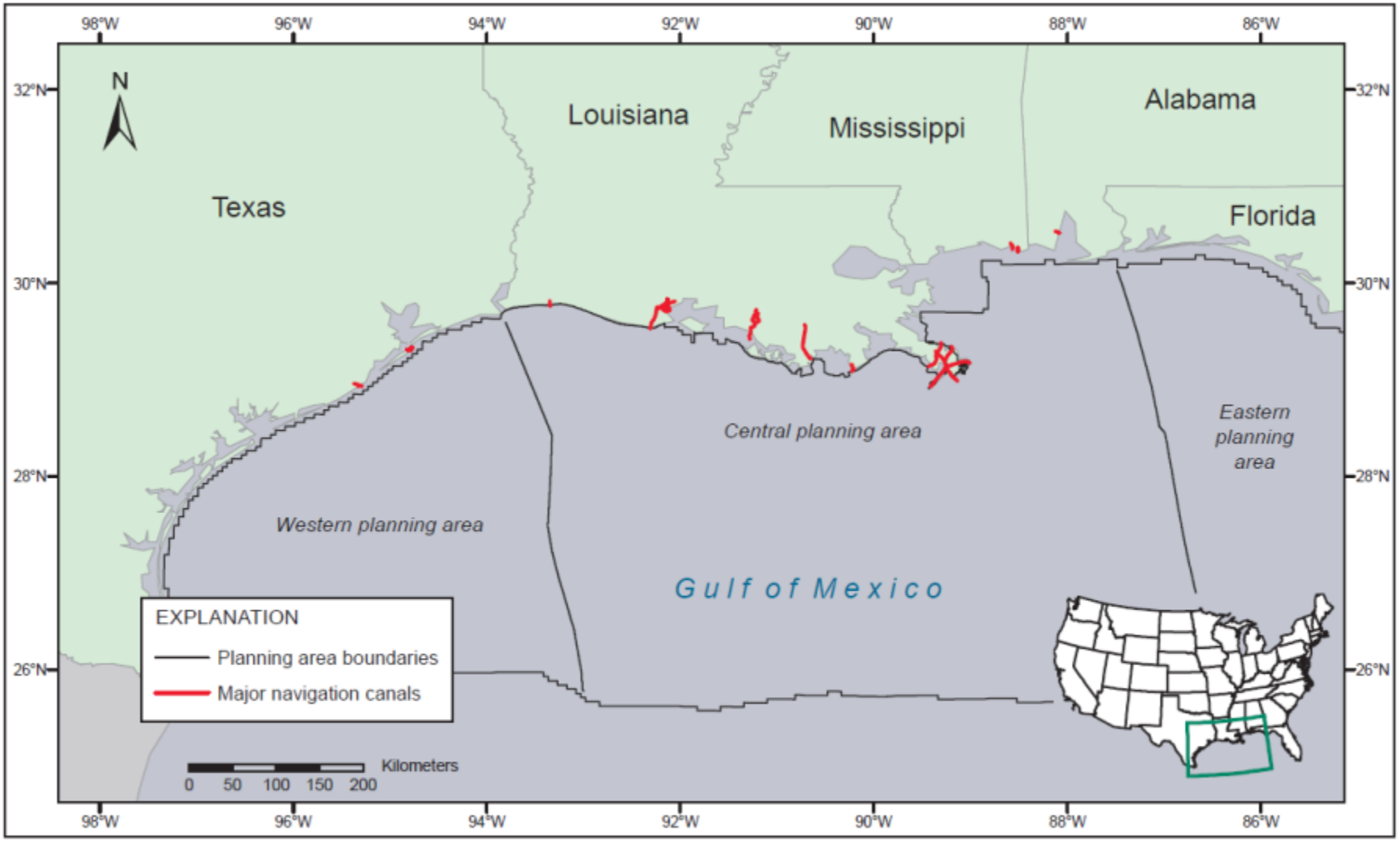


Figure 1. Map of Bureau of Ocean Energy Management, Regulation and Enforcement-designated planning areas in the Gulf of Mexico and Outer Continental Shelf-related navigation canals.

Objectives

- The first objective of this project was to map the shoreline position and substrate along both banks of the navigation canals, which were digitized from three different time periods of aerial photography spanning the years of 1978/79 to 2005/06.
- The second objective was to quantify the erosion rates of the navigation canals in the study area and to determine whether differences in erosion rates are related to embankment substrate, vegetation type, geologic region, or soil type.

Methods

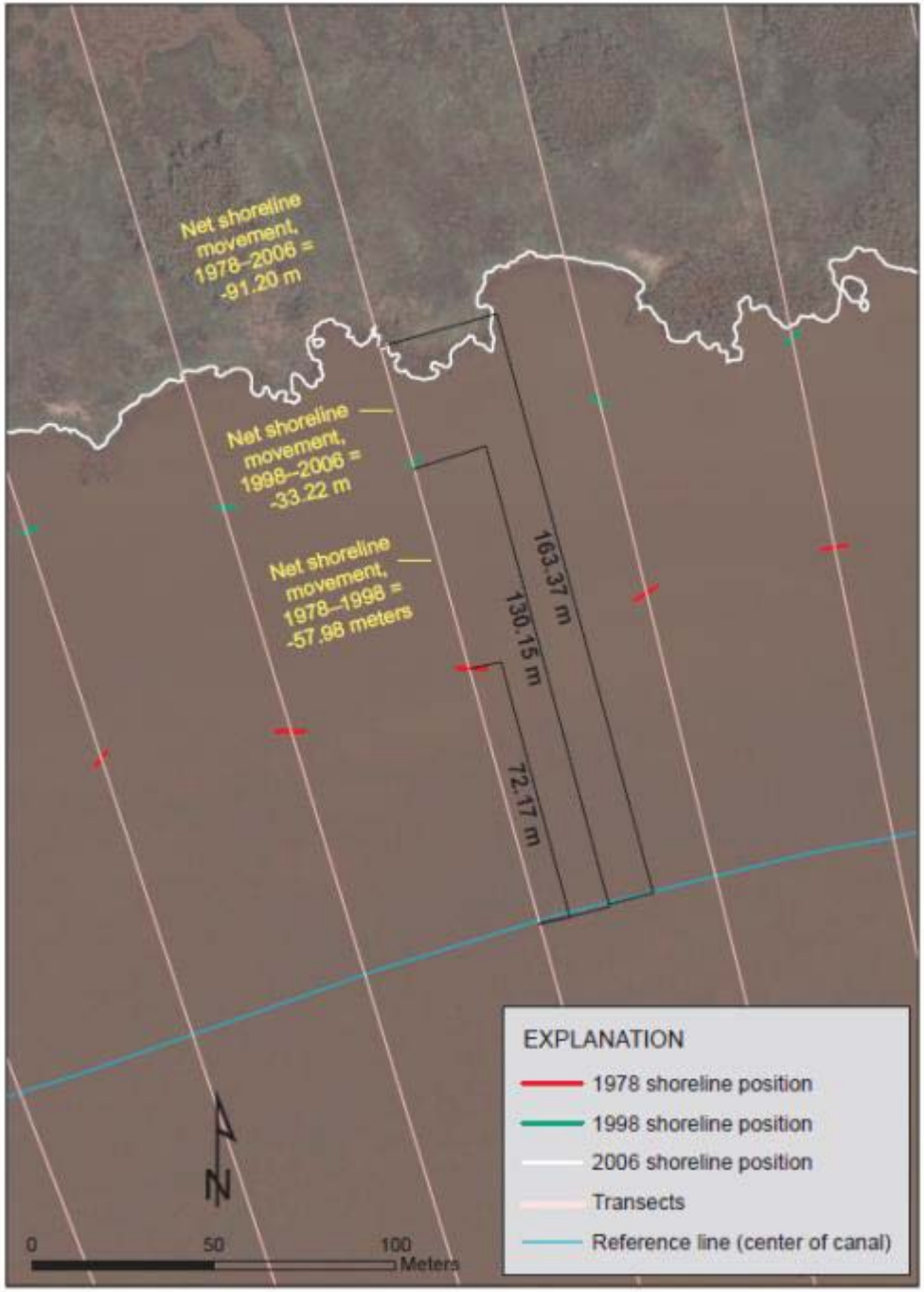
General Approach

The methods and transect spacing for this study were derived from the U.S. Geological Survey's (USGS) National Assessment of Shoreline Change Project, which provides a national standard for measuring shoreline change (Morton et al. 2004). Historical canal bank positions were digitized from 1978/79 and 1996/98 aerial photography, and the most recent canal bank locations were digitized from 2005/06 aerial photography. To measure changes in shoreline position over time, transects intersecting the canal bank were spaced at 50-m (164-ft) intervals. The shoreline position was determined for all three time periods at transect locations and was used to calculate an annual rate of change for each transect.

Methods

Shoreline Position

Aerial photography was acquired for three different time periods to map the position of navigation canal banks. High-resolution, color, aerial photography with a 0.15-m (6-ft) pixel resolution from 2006 and 1-m (3.3-ft) resolution photography from 2005 was used to digitize the canal banks, to determine the length of the navigation canals, and to identify the bank substrate type. Canal banks were also digitized based on 1996, 1997, or 1998 digital aerial photos with a pixel resolution of 1-m (3.3-ft). To represent a third time period, canal banks were digitized from analog aerial photographs that were scanned and registered for 1978 in Louisiana, 1979 in Texas, 1979 in Mississippi, and 1979 in Alabama; photographs were of varying resolutions (2.11–2.97 m [6.9–9.7 ft]).


Net shoreline movement, 1978–2006 = -91.20 m
Net shoreline movement, 1998–2006 = -33.22 m
Net shoreline movement, 1978–1998 = -57.98 meters
163.37 m
130.15 m
72.17 m
N
0
50
100
Meters
EXPLANATION
1978 shoreline position
1998 shoreline position
2006 shoreline position
Transects
Reference line (center of canal)

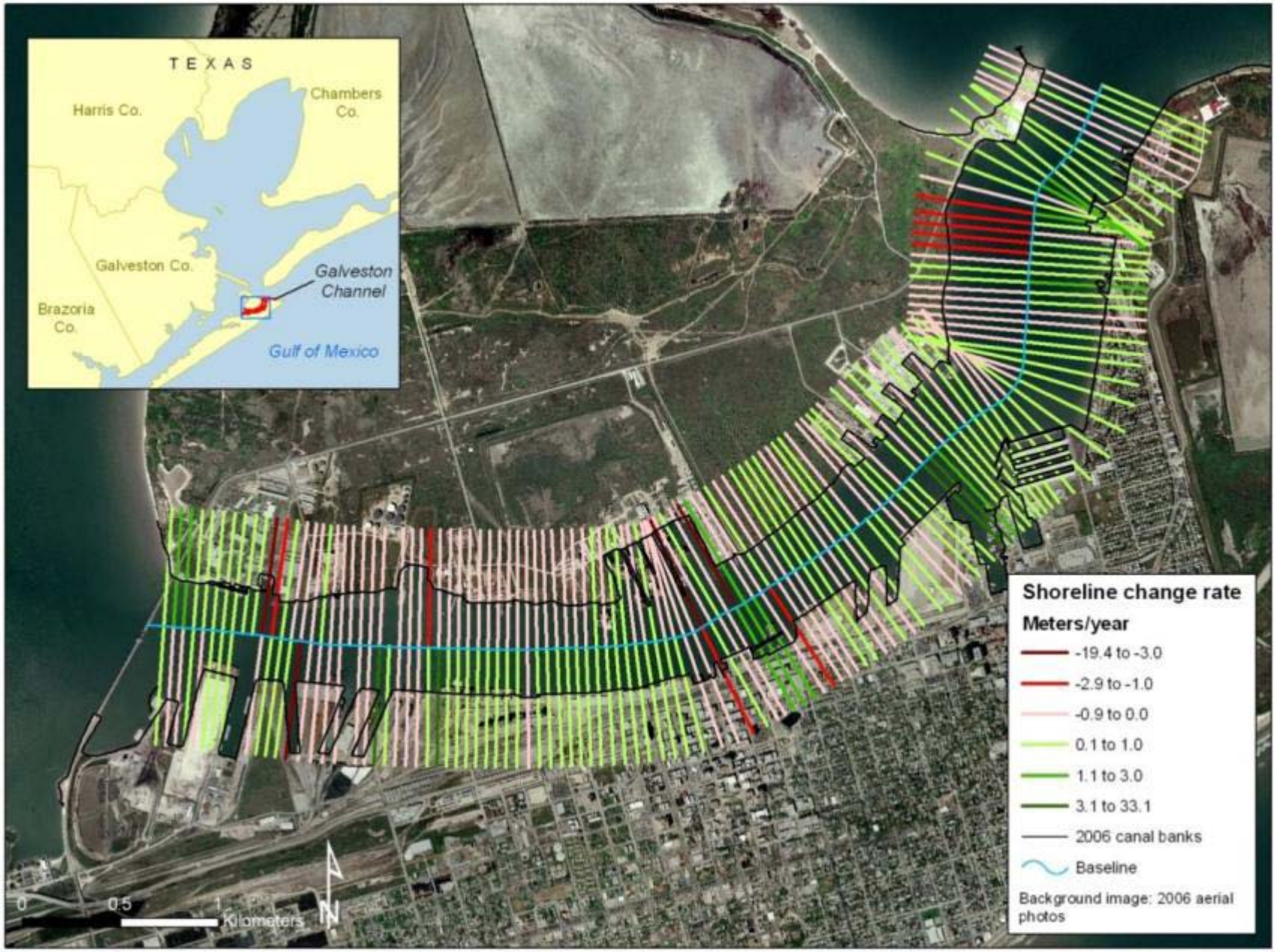
Methods

GIS Methods to Develop Transects

A line digitized along the center of the navigation canals was used as a reference point for measuring erosion from three different time periods. We used Digital Shoreline Analysis System (DSAS) software, which was developed by USGS for use with ArcGIS (ESRI, Redlands, CA) as part of the National Assessment of Shoreline Change Project (Morton et al. 2004), to automate the production of transects (Thieler et al. 2005). Transects were generated at 50-m (164-ft) intervals, perpendicular to the center of the canal, and were greater than 300 m (984 ft) in length to ensure that each transect intersected both canal bank positions for all three time periods. A total of more than 11,000 transects were generated for use in the erosion analysis. Transects were manually deleted to avoid sampling in areas where canal banks were absent for any of the three time periods.

[OCS=Outer Continental Shelf; Y=yes; N=no]

Name of Canal	OCS	Service Base	Length (km)	Number of transects (50 m spacing)
Atchafalaya River, LA	Y	Morgan City	57	1,947
Baptiste Collette Bayou Channel, LA	Y	Venice	13	391
Bayou Lafourche Cutoff, LA	Y	Fourchon	9	351
Calcasieu Ship Channel, LA	Y	Cameron	7	241
Freeport Harbor Channel, TX	Y	Freeport	12	391
Freshwater Bayou Channnel, LA	Y	Intracoastal City	59	2,318
Galveston Ship Channel, TX	N	Galveston	6	247
Houma Navigation Canal, LA	Y	Houma	42	1,575
Main Pass Channel, LA	Y	Venice	19	640
Mississippi River Mouth Pass, LA	Y	Venice	20	676
Pascagoula Channel, Miss. (large channel)	N	Pascagoula	9	284
Pascagoula Channel, Miss. (small channel)	N	Pascagoula	4	132
Pass a Loutre Channel, LA	Y	Venice	26	747
South Pass Channel, LA	Y	Venice	22	774
Southwest Pass channel, LA	Y	Venice	30	667
Theodore Ship Channel, AL	N	Theodore	4	128
Tiger Pass Channel, LA	N	Venice	20	443


TEXAS
Harris Co.
Chambers Co.
Galveston Co.
Galveston Channel
Brazoria Co.
Gulf of Mexico
Shoreline change rate
Meters/year
-19.4 to -3.0
-2.9 to -1.0
-0.9 to 0.0
0.1 to 1.0
1.1 to 3.0
3.1 to 33.1
2006 canal banks
Baseline
Background image: 2006 aerial photos
0
0.5
1
Kilometers
N

	Natural/ Vegetated	Rock wall	Shell	Sand	Bulkhead	Dredge spoil	Other	Degraded rock wall	Total shoreline length
Atchafalaya River, LA	160,225	5,491	0	312	9,324	666	4	0	176,022
Baptiste Collette Bayou Channel, LA	52,207	5,729	0	97	0	0	354	65	58,452
Bayou Lafourche Cutoff, LA	13,057	5,397	342	2,275	4,174	0	0	2,177	27,422
Calcasieu Ship Channel, LA	8,576	6,444	0	577	2,775	0	0	0	18,372
Freeport Harbor Channel, TX	1,941	21,179	0	1,816	8,436	0	0	0	33,372
Freshwater Bayou Channnel, LA	138,448	21,277	0	1,024	14,045	4,524	6,886	5,024	191,228
Galveston Ship Channel, TX	1,696	5,410	0	2,471	25,737	0	140	0	35,454
Houma Navigation Canal, LA	128,228	12,433	909	84	18,697	0	747	127	161,225
Main Pass Channel, LA	56,211	601	0	274	827	0	176	0	58,089
Mississippi River Mouth Pass, LA	14,395	25,234	0	131	2,422	0	1,031	4,553	47,766
Pascagoula Channel, MS (large channel)	13,697	7,227	0	4,689	5,196	1,656	0	0	32,465
Pascagoula Channel, MS (small channel)	3,049	1,733	140	3,268	5,082	0	130	0	13,402
Pass a Loutre Channel, LA	74,116	588	0	0	701	0	1,890	0	77,295
South Pass Channel, LA	56,663	1,012	0	0	118	0	474	91	58,358
Southwest Pass Channel, LA	10,619	36,206	0	187	24	0	75	26,365	73,476
Theodore Ship Channel, AL	5,842	878	0	814	4,440	0	0	0	11,974
Tiger Pass Channel, LA	51,276	2,403	0	153	6,347	0	888	227	61,294

Table 4. Linear length of canals by substrate type, measured in 50-m increments from the canal center line within navigation canals in the northern Gulf of Mexico in 2005–06.

	Side	Natural/ Vegetated	Rock rip-rap	Shell	Sand	Bulkhead	Dredge spoil	Water	Other	Degraded rock rip-rap	Total length
Atchafalaya River, La.	East	48,350	1,300	0	100	3,650	150	1,100	0	0	54,650
Atchafalaya River, La.	West	47,450	2,700	0	0	3,400	0	1,000	0	0	54,550
Baptiste Collette Bayou, La.	East	9,950	1,750	0	0	0	0	950	0	0	12,650
Baptiste Collette Bayou, La.	West	8,950	2,800	0	50	0	0	800	0	50	12,650
Bayou Lafourche Cutoff, La.	East	4,650	50	100	1,850	2,450	0	400	0	0	9,500
Bayou Lafourche Cutoff, La.	West	3,900	5,100	0	100	0	0	250	0	150	9,500
Calcasieu Ship Channel, La.	East	3,350	1,900	0	100	1,000	0	350	0	0	6,700
Calcasieu Ship Channel, La.	West	2,550	3,150	0	50	950	0	0	0	0	6,700
Freeport Harbor Channel, Tex.	North	0	9,700	0	550	1,450	0	0	0	0	11,700
Freeport Harbor Channel, Tex.	South	350	8,000	0	750	2,450	0	150	0	0	11,700
Freshwater Bayou Channel, La.	N & S	49,550	7,950	0	700	4,850	350	900	50	700	65,050
Freshwater Bayou Channel, La.	N & S	47,300	10,950	0	0	600	150	750	1,200	4,300	65,250
Galveston Ship Channel, Tex.	North	0	850	0	100	5,400	0	0	50	0	6,400
Galveston Ship Channel, Tex.	South	1,700	1,150	1,250	0	2,100	0	0	0	0	6,200
Houma Navigation Canal, La.	West	31,550	7,700	0	0	1,750	0	1,150	50	0	42,200
Houma Navigation Canal, La.	East	35,200	1,900	0	0	2,700	0	1,050	50	0	40,900
Main Pass channel, La.	East	17,900	0	0	250	0	0	1,050	0	0	19,200
Main Pass channel, La.	West	17,150	550	0	0	0	0	1,350	0	0	19,050
Mississippi River Mouth Pass La.	East	4,750	11,250	0	0	1,000	0	1,350	0	400	18,750
Mississippi River Mouth Pass, La.	West	150	12,700	0	0	2,350	0	300	100	3,300	18,900
Pascagoula Channel, Miss. (large)	East	4,100	2,300	0	500	650	800	550	0	0	8,900
Pascagoula Channel, Miss. (large)	West	3,200	1,150	0	1,600	2,500	0	250	0	0	8,700
Pascagoula Channel, Miss. (small)	East	1,400	150	0	550	1,650	0	50	0	0	3,800
Pascagoula Channel, Miss. (small)	West	400	50	150	1,150	1,800	0	0	0	0	3,550
Pass a Loutre channel, La.	North	19,600	50	0	0	50	0	1,750	450	0	21,900
Pass a Loutre channel, La.	South	18,700	500	0	0	0	0	1,100	600	0	20,900
South Pass channel, La.	East	17,900	400	0	0	0	0	2,950	0	100	21,350
South Pass channel, La.	West	19,350	450	0	0	0	0	1,050	250	0	21,100
Southwest Pass channel, La.	East	1,250	17,850	0	150	50	0	750	50	9,600	29,700
Southwest Pass channel, La.	West	2,100	17,550	0	0	0	0	150	0	10,200	30,000
Theodore Ship Channel, Ala.	North	900	600	0	300	1,600	0	0	0	0	3,400
Theodore Ship Channel, Ala.	South	1,100	0	0	200	1,500	0	0	0	0	2,800
Tiger Pass channel, La.	East	9,200	650	0	0	0	0	5,600	150	0	15,600
Tiger Pass channel, La.	West	11,050	500	0	100	2,450	0	1,750	50	250	16,150

Methods

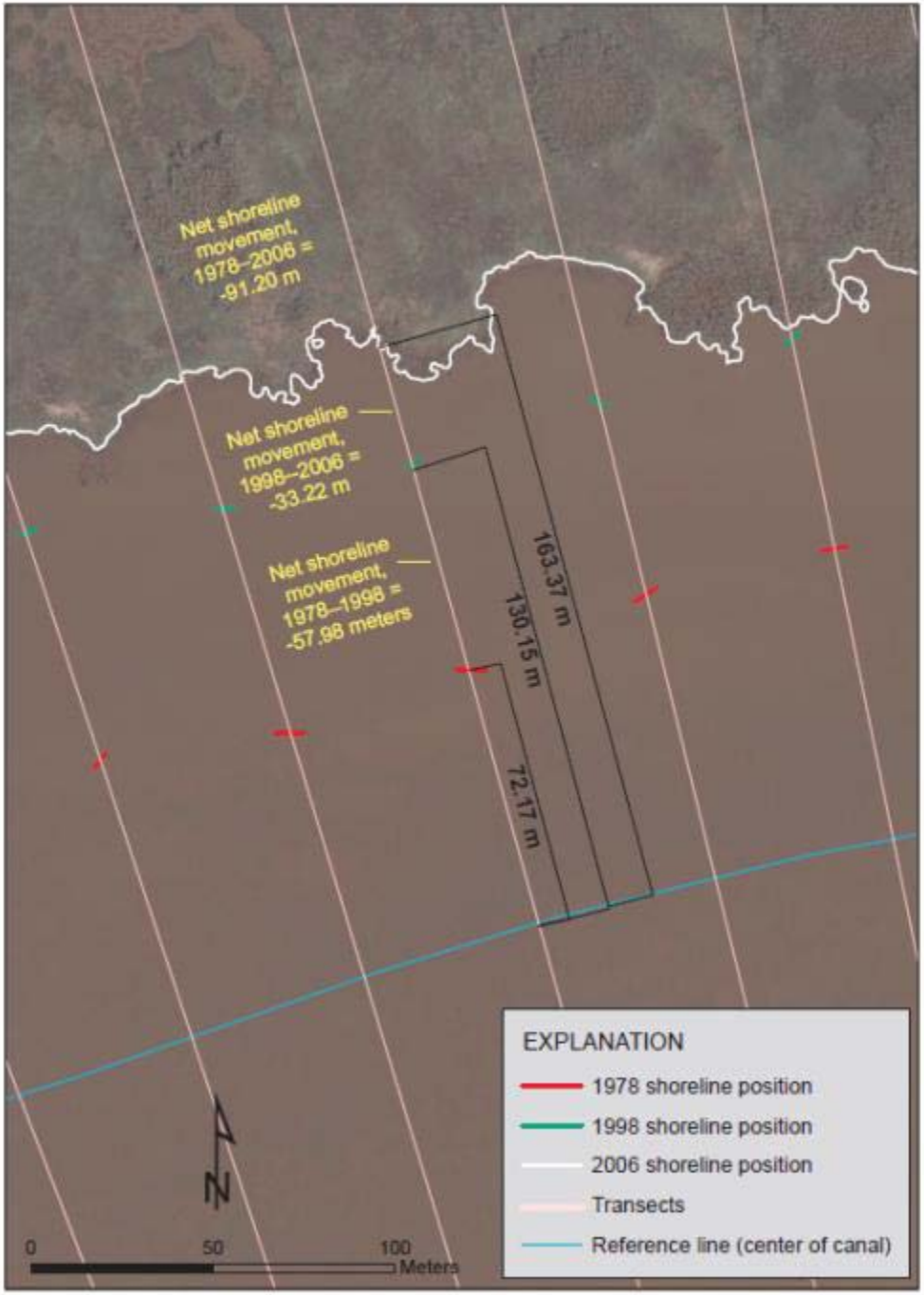
Canal Bank Substrate

Canal bank substrate was identified based on aerial photography from 1978/79, 1996/97, and 2005/06; that information was added to the table of attributes associated with the digitized canal banks. Categories of canal bank substrate included natural/vegetated, rock rip-rap, degraded rock rip-rap, shell, sand, concrete bulkhead, dredge spoil, and other/unidentified. Airborne video images of the canals were taken at an oblique angle in 2008 and were used to determine canal bank substrate where necessary. Approximately 15,000 images were acquired at an altitude of 500 to 2,000 ft, (*http://nwrcwebapps.cr.usgs.gov/canals/*). A field survey was conducted of the Houma Navigation Canal, LA, by boat from the city of Houma to the Gulf of Mexico to verify the substrate type of the canal bank. That particular canal was chosen for the field survey because overhanging trees along parts of the canal obscured the canal banks in the aerial photographs, making it more difficult to determine bank substrate.

Methods

Annual Erosion Rates

The transect length between the reference (the center of the navigation canal) and the canal bank was calculated for each time period. Differences in transect length were used to determine net canal bank movement (that is, the distance between the 1978/79 and 1996/98 canal bank position, the 1996/98 and 2005/06 canal bank position, and the 1978/79 and 2005/06 canal bank position). Long-term erosion rates were derived by using simple linear regression.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130.15 m
72.17 m
N
0
50
100
Meters
EXPLANATION
1978 shoreline position
1998 shoreline position
2006 shoreline position
Transects
Reference line (center of canal)

Methods

Statistical Analysis

To report mean annual change rates for canal bank movement, we calculated the mean change in shoreline position for the left and right side of each canal separately and added the two means together. Thus, the reported mean value represents a total rate per year of canal widening (or narrowing). A negative value indicates that a canal has widened because of erosion or land loss, while a positive value indicates that a canal has narrowed because of land gain and shoreline advancement.

Results

Canal Bank Substrate

The total length (m) of canal banks by substrate type was measured for selected navigation canals in the northern Gulf of Mexico study area, based on 2005–06 aerial photography. The shoreline length by substrate was also measured as a straight line along the canal bank, parallel to the canal center line, based on the same photography. This measurement of shoreline length ignores small bends or inlets along the canal banks and thus provides a better characterization of the substrate composition of the navigation canals. This length measurement was then used to calculate the percentage of canal bank length within each substrate type. Combining all canals, we found that almost 64% of the navigation canal banks had a vegetated substrate, 19% were armored with rock rip-rap, 7% were armored with bulkheads (typically concrete), 4% were armored with visibly degraded rock rip-rap, 4% was open water, and the remaining 2% of the canal banks consisted of dredge spoil, sand, and shell.

Results

Shoreline Change Rates

Results from the linear regression method were that mean annual rates of shoreline change ranged from 1.75 m/year (5.74 ft/year) on the west side of the Atchafalaya River, LA, where there was shoreline advancement or canal narrowing, to -3.29 m/year (-10.79 ft/year) on the south side of the Theodore Ship Channel, AL, where there was shoreline retreat or erosion. Note that in the shoreline change measurements, a negative number indicates erosion (shoreline retreat), while a positive number indicates land gain (shoreline advance). Canal widening or narrowing rates were calculated by adding shoreline change for each side of the canal together. The mean annual rates of total canal widening or narrowing ranged from -6.47 m/year (-21.23 ft/year) (measured as shoreline retreat) for the Theodore Ship Channel, AL, to 2.58 m/year (8.46 ft/year) for the Atchafalaya River, LA (measured as shoreline advancement).

Table 7. Mean annual change in canal width (meters per year) for nonarmored portions of navigation canals in the northern Gulf of Mexico, 1978–2006, based on linear regression calculations. Negative values refer to shoreline retreat (erosion or canal widening), while positive values refer to shoreline advance (canal narrowing).

[SE, standard error]

me	Mean	SE
Atchafalaya River, La.	2.58	0.21
Baptiste Collette Bayou channel, La.	-6.34	0.10
Calcasieu Ship Channel, La.	-2.24	0.11
Freeport Harbor Channel, Tex.	0.20	0.13
Freshwater Bayou Channel, La.	-2.69	0.06
Galveston Ship Channel, Tex.	0.85	0.36
Houma Navigation Canal, La.	-2.97	0.06
Bayou Lafourche Cutoff, La.	-2.48	0.12
Main Pass channel, La.	1.62	0.07
Mississippi River Mouth Pass, La.	-2.72	0.35
Pascagoula Channel, Miss. (large channel)	-0.76	0.08
Pascagoula Channel, Miss. (small channel)	-0.88	0.28
Pass a Loutre channel, La.	1.75	0.12
South Pass channel, La.	-0.01	0.06
Southwest Pass channel, La.	.	.
Theodore Ship Channel, Ala.	-6.47	0.56
Tiger Pass channel, La.	-4.30	0.15

Table 8. Mean annual change in canal width (meters per year) for nonarmored portions of navigation canals in the northern Gulf of Mexico, 1978–2006, based on geologic region.

[N, number of transects in sample; SE, standard error]

Geology type	N	Mean	SE	Minimum	Maximum
Alluvium	47	0.27	1.03	-8.99	24.76
Chenier plain	44	-3.46	0.41	-8.51	-0.32
Deltaic plain	164	-0.82	0.43	-10.91	24.50
Natural levees	10	-1.20	0.45	-2.57	0.37

Table 9. Mean annual change in canal width (meters per year) for nonarmored portions of navigation canals in the northern Gulf of Mexico, 1978/79–1996/98, based on vegetation type.

[N, number of transects in sample; SE, standard error]

Vegetation type	N	Mean	SE	Minimum	Maximum
Fresh marsh	123	0.57	0.73	-11.9	39.73
Intermediate marsh	66	-2.56	0.41	-9.52	2.25
Brackish marsh	14	-5.19	0.76	-12.224	-2.35
Salt marsh	20	-4.11	0.57	-7.47	-1.77
Other	43	-1.29	0.17	-2.61	0.66

Table 10. Mean annual change in canal width (meters per year) for nonarmored portions of navigation canals in the northern Gulf of Mexico, 1996/98–2005/06, based on vegetation type.

[N, number of transects in sample; SE, standard error]

Vegetation type	N	Mean	SE	Minimum	Maximum
Swamp	27	0.08	0.46	-2.23	4.99
Fresh marsh	94	3.83	1.88	-53.08	80.71
Intermediate marsh	84	-1.7	0.48	-22.6	4.74
Brackish marsh	20	-2.94	0.49	-6.22	-0.44
Salt marsh	25	-3.16	0.73	-13.93	0.62
Other	21	-0.8	0.48	-4.2	1.1

Table 11. Mean annual change in canal width (meters per year) for nonarmored portions of navigation canals in the northern Gulf of Mexico, 1978–2006, based on substrate type.

[N, number of transects in sample; SE, standard error]

Substrate	N	Mean	SE	Minimum	Maximum
Vegetated	247	-1.03	0.35	-11.11	24.76
Shell	1	-1.07	.	-1.07	-1.07
Sand	10	-4.53	1.12	-9.29	-1.56
Other	9	-1.03	1.10	-5.43	5.22

Conclusions

If the goal in managing navigation canals is to reduce erosion at the land-water interface, then constructing armaments such as rock walls and concrete bulkheads may be an effective strategy. Approximately 70% of the navigation canal banks in the study area were nonarmored in 2005 or 2006. The highest erosion rates occurred in navigation canal segments located in salt marshes, in the chenier plain geologic region, and in areas with a higher percent organic content in soils. The results of this study could be used to help direct the construction of shoreline armaments to areas with the highest erosion rates; however, additional investigation is needed to determine how the construction of canal bank armaments could affect interior marshes. For example, the addition of structures such as rock walls could affect the movement of water, sediments, and nutrients between canals and nearby marshes. In addition, obtaining vessel traffic data to include in the analysis would further help explain why some sections of canals erode faster than others and could be used to help refine estimates of future erosion rates for individual canals. This information could help predict the potential increase in erosion rates associated with any increase in the number of vessels creating wakes.

References

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