Recent and Local CVI Assessment for Lake Borgne, LA

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Introduction

“The erosional impact caused by the passage of Hurricane Katrina in 2005 is unprecedented. Between 2004 and 2005, the shoreline of the northern Chandeleur Islands moved by -201.5 m/yr, compared with an average rate of erosion of -38.4 m/yr between 1922 and 2004” (Fearnley et. al., 2009). It is this massive effect of storms like Hurricane Katrina and subsequent “natural” shoreline erosion due to sea level rise that has turned the historical Lake Borgne, Louisiana from a lake into a lagoon leading into the Gulf of Mexico (Fearnley et. al., 2009). The United States Geological Survey (USGS) considers the coastal region of Louisiana, the most fragile of the entire United States and therefore “its infrastructure, ecosystems, and natural resources a primary concern for coastal managers.” (Thieler and Hammar-Klose, 2000). This project aims to understand the physical and social vulnerability of the Louisiana coast now 15 years removed from Hurricane Katrina and in light of the recent research regarding sea level rise. To best fit within the limited scope of this project, the small region of Lake Borgne was chosen as the study area. USGS published an assessment at the national scale of the “relative susceptibility of the Nation's coast to sea- level rise through the use of a coastal vulnerability index (CVI)”, as well as a report extrapolating on this national CVI assessment for the Northern Gulf of Mexico (Pendleton et. al., 2010). Although published in 2010, the data used in this assessment ranges from 1990 to 2009 and many datasets were very low resolution. It is this precedent that sets the stage for this project. The research question driving this study is, in light of the National CVI Assessment, what is the post- Hurricane Katrina (2005 to present) local Coastal Vulnerability Index of the shoreline area surrounding Lake Borgne, LA? In conjunction with the local CVI calculated in this study, we will be surveying how Hurricane Katrina and the subsequent social, economic, and political factors that contribute to this area's social vulnerability.

Coastal Vulnerability Index (CVI)

> "Coastal vulnerability index assessments can provide insight into the relative potential of coastal change due to future sea-level rise... CVI data can be used in at least two ways: (1) as a way of identifying areas where physical changes are most likely to occur as sea-level rises and (2) as a planning tool for managing and protecting resources along the Northern Gulf of Mexico… Coastal Louisiana may be the most vulnerable to the effects of future sea-level rise and coastal change in this region, due to the high rates of relative sea-level rise, shoreline change, and land-area change.." (Thieler and Hammar-Klose, 2000, Pendleton et. al., 2010)

It is with this type of assessment that provides an explanation of coastal system change in conjunction with storm vulnerability that is essential to hazard mitigation (Pendleton et. al., 2010). Six variables are used in calculating CVI: A) geomorphology, B) coastal slope, C) relative sea-level rise rate, D) shoreline erosion/accretion rate, E) mean tide range, and F) mean wave height. These variables are assigned a numerical value of 1-5, where a 1 is considered very low risk and a 5 is considered very high risk. Our project mimicked the same general methodology as the USGS national assessment, calculating the square root of the mean of the six variables, which is based off of the method published by Gornitz et al. (1994) (Pendleton et. al., 2010).

$$CVI=\sqrt{(a\times b\times c\times d\times e\times f)/6}$$

Methods

Because of the range of variables calculated in the CVI, we used a variety of data types but these were primarily sourced from U.S Geological Survey and National Oceanic and

Atmospheric Administration (NOAA). While a detailed source document is included at the end of this report, a summary of these data types and sources are as follows:

A. Geomorphology:

A USGS vector dataset of the Geomorphology of the Lower Mississippi River Valley in Missouri, Kentucky, Arkansas, Tennessee, Louisiana, and Mississippi from 2017-2018. This file was not manipulated in anyway, we simply identified the geomorphology type of the Lake Borgne shoreline and added it to the CVI table.

B. Coastal slope:

The slope was calculated using two different raster tiles (to cover the footprint of the Lake Borgne area) of the USGS 3D Elevation Program (3DEP) NED at 1/3 arc-second resolution from 2018. Chose Spatial Analyst tools → surface → slope. Input raster was the DEM, chose name for the output slope raster, chose percent rise for the output measurement, and left the rest of the default parameters. Once loaded, the resulting slope raster layer (a .tif) was saved as a separate file. From here the percent slope rise was reclassified using the CVI breakpoints (>20% = very low, 20-7% = low, 7-4% = moderate, 4-2.5% = high, <2.5% = very high). From here, the shoreline of Lake Borgne could easily be identified and inputted into our table.

C. Relative sea level change:

This data was derived from NOAA's Sea Level Trends webpage. The Center for Operational Oceanographic Products and Services has been measuring sea level for over 150 years, with tide stations of the National Water Level Observation Network operating on all U.S. coasts, this Sea Level Trends work is funded in partnership with the NOAA OAR Climate Observation Division. The sea level trends measured by tide gauges that are presented on this site are local relative sea level (RSL) trends as opposed to the global sea level trend and is a combination of the sea level rise and the local vertical land motion. These tide gauge measurements are made with respect to a local fixed reference on land, the closest station to our local study area is the New Canal, about 25km West, which was used as a proxy (in replacement of the two datum stations used for Mean Tide Range and Mean Wave Height, Shell Beach and Martello Castle).

D. Shoreline erosion/accretion:

All of the federally produced shoreline change studies and vector datasets have the shoreline set at the Chandeleur Islands (East of our local study area) so those were useless for this study. The industry preferred method of calculating shoreline change is using the Digital Shoreline Analysis System (DSAS). It is a free ArcGIS desktop extension (that was downloaded as an attempt for use) but requires vector shoreline files, shoreline transect points, as well as imagery. Because of these input requirements, this method was considered not feasible for this project. In an effort to calculate shoreline change with more accuracy than conducted in this class's lab assignment, shoreline change was instead measured manually using imagery from 2004 and 2014. The 2004 imagery used is composed of 13 digital orthophoto quarter quadrangle (DOQQ) color infrared imagery of Louisiana taken in 2004 at 1-meter resolution. To have the flexibility to treat all these MrSID tiles as one image so a "mosaic dataset" was created within the project geodatabase. The parameters required were the coordinate system used in the images, the pixel properties (number of bands and pixel type) which can be found in the metadata for the images. Once this was created, the MrSID files (imagery tiles) were added. Now a footprint of each tile was provided as well as a boundary, but all of them were treated by ArcGIS as one imagery layer which allows for simpler analysis and map creation. The 2014 imagery used was a pan-sharpened mosaic of fourteen Landsat 8 OLI satellite scenes acquired during the winter of 2013-2014 with a resolution of 15 meters. This GeoTIFF was easily downloaded and imported into ArcGIS. Originally, all measurements were planned to be conducted within ArcGIS but we were unable to get a question answered in enough time before we had to move on. Instead, the December 2004 shoreline was traced in Google Earth Pro then seven equidistant points were selected along the shoreline to be used as measurement markers. Then February 2017 composite imagery was used to measure the difference between this recent shoreline and the December 2004 traced polyline shoreline. The traced 2004 shoreline KML and seven measured points KML were then imported into ArcGIS using the "KML to Layer" conversion tool. An average of erosion (per year) in meters from those seven points was inputted into the CVI table.

E. Mean tide range:

Mean Tide range and mean wave height were both obtained by connecting to the NOAA GIS Server via ArcMap. To connect to this server we clicked, "Add Data", selected "Add GIS Server", then selected "Add ArcGIS Server". Then we used the web map service URL from the NOAA web page, no "username" or "password" was required. Once connected, the "observed_stations " datum layers were added to a blank map document where the selected datum points of the Lake Borgne area were exported and inputted them to a new file geodatabase. The datum stations used for our local study area were Shell Beach and Martello Castle. The MN (Mean Tide Range) was selected from stations' the attribute table, a point vector layer, and exported into a new feature class. The average of the values from both Shell Beach and Martello Castle was calculated and converted units from feet to meters and then added to the CVI table. (Note, the mean tide range and mean wave height were both extracted from the same server database connection).

E. Mean wave height: In the attribute table of the same datum stations named above were values for MHHW (Mean Higher-High Water), and MLLW (Mean Lower-Low Water). The mean wave height was calculated by simply subtracting the MHHW by the MLLW of both the Shell Beach and Martello Castle datum stations. Then the mean of the two values was calculated, converted the units from feet to meters, then inputted into our CVI table.

Findings/Results

The results table (see appendix) displays the values derived for each CVI variable, while these are simply interpreted a few are worth further discussion. Although geomorphology and coastal slope were derived for our specific study area, these variables are relatively static and vary little from the national assessment. Saline marshes, like those that make up the majority of the Northern Gulf of Mexico region, are considered the most vulnerable to sea level rise. Additionally, "coastal slope is an indication of vulnerability to inundation and the potential rapidity of shoreline retreat because low-sloping coastal regions should retreat faster than steeper regions" (Pendleton et. al., 2010). For example, the coastal slope used in the USGS national assessment was from 2009, versus our 2018 data, where 86% of the Northern Gulf of Mexico coastline fell within the very high vulnerability category (Pendleton et. al., 2010). Nine years later the assessment is the same. Furthermore, though the mean of seven different measured points along Lake Borgne's shoreline equated to a loss of approximately 68 meters from 2004 to 2017, some areas had a loss of close to 220 meters in contrast to others where there was only approximately 16 meters. This wide range of shoreline erosion is partly due to unevenly distributed coastal armoring efforts in this region as well as the inherent difficulty in measuring "shoreline erosion" in marshland. Additionally, because Lake Borgne is now more of a lagoon leading to the Gulf of Mexico, it does receive partial protection from sea waves, thus the mean wave height was expected to be low for this area.

The CVI generated for this project is 22.82, which expresses that the Lake Borgne area is classified as very high risk (Thieler and Hammar-Klose, 2000, Pendleton et. al., 2010).

This local area CVI study differed from the national CVI assessment in three main ways. The first, of the national assessment conducted by USGS, they published a report specifically for the Northern Gulf of Mexico coastline, which consisted of the area from Panama City, FL, to Galveston, TX (Pendleton et. al., 2010). Though this study is older and includes lower resolution data for some variables, more areas of study require more data collection points which would lend itself to a more accurate CVI calculation, in contrast to this project's study area which only had two datum station collection points. Secondly, the Lake Borgne shoreline in the national assessment received a "high" risk ranking for the geomorphology variable and this project ranked Lake Borgne as "very high" risk. This is due to a difference in the geomorphology dataset. The geomorphology dataset used in the national assessment appears to be dated from 2004-2007 and classified the Lake Borgne area as an "estuary" or "lagoon" which is a "high" ranking (Pendleton et. al., 2010). The 2017-2018 dataset used for this project classified Lake Borgne as "interdistributary deposits, represents brackish to saline marsh environments" which is a "very high" ranking. Thirdly, the shoreline erosion calculation methods used in this project were very rudimentary in contrast to those used in the national assessment. As stated in the USGS national assessment for the Gulf of Mexico,

> "Large wetland areas cannot be quantified with regard to shoreline erosion and accretion through the use of traditional mean high water line delineation and linear regression techniques. In order to investigate vulnerability for the vast wetland stretches of Louisiana, the traditional CVI methodology (Theiler and Hammar-Klose, 2000b) is modified to include land-loss data produced by Barras and others (2008). These data represent inland and coastal wetland loss from 1956 to 2008 (*fig. 5D*). These data are incorporated into the CVI in much the same way as the historical shoreline change studies are included. The main difference is that land loss data are measured in terms of area change rather than length. The Barras and others (2008) land-area change dataset provides a quantitative and novel approach to delineating land loss rates in Louisiana wetland areas, where traditional shoreline change determinations cannot be made. These data provide a long-term record (1956-2008) of land-area change that can be incorporated into the CVI" (Pendleton et. al., 2010).

Nevertheless, considering that our data was extracted from the specific shoreline area along Lake Borgne and the oldest data used for this project ranged from 2008-2012, this project's simple coastal vulnerability assessment can be considered a valid and recent local area study.

Limitations/Unresolved Issues

One major limitation addressed by USGS is that CVI

> "assessments are still limited by the omission of coastal storm information, and the episodic and nonlinear nature of storms makes them difficult to incorporate into the CVI framework. The CVI results presented in [the USGS national assessment] report are an indication of vulnerability based on coastal processes and geologic qualities that are ever-

present and predictable and should be used in conjunction with storm vulnerability studies within the region" (Pendleton et. al., 2010).

It is for this reason that a discussion involving variables of vulnerability/resilience to coastal issues *must* incorporate social, political, economic, and infrastructure variables to truly understand the larger picture of an area's vulnerability. Due to the limited scope of this report, this discussion of "non-physical" variables is very brief and more of a survey of the effects of Katrina on the New Orleans area on coastal vulnerability and resilience.

Socio-Economic Factors

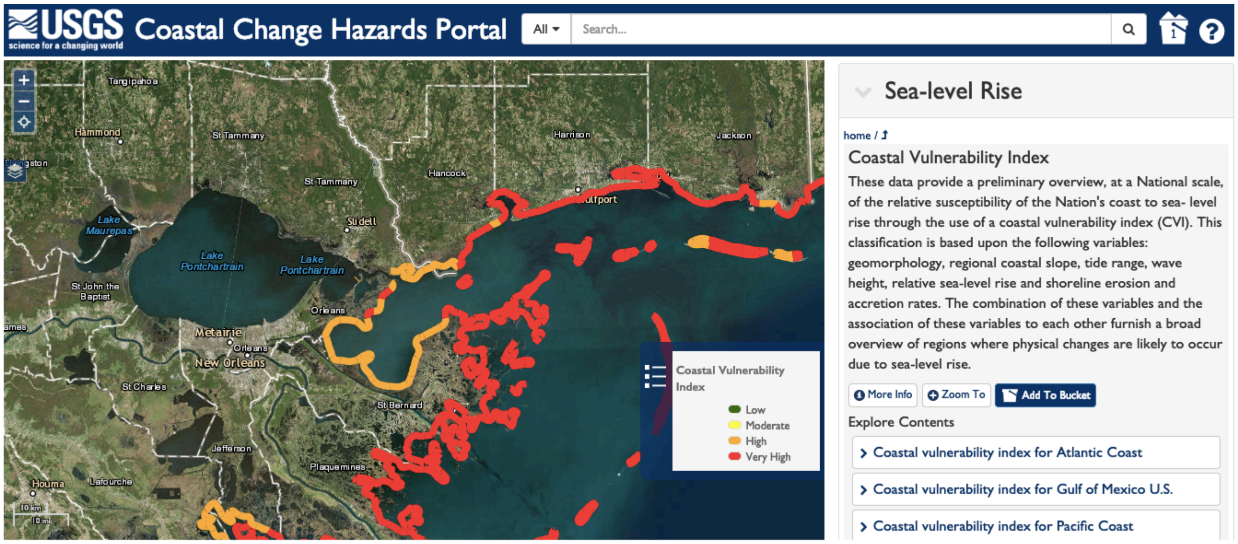
Now the CVI results provides only the physical vulnerability after Hurricane Katrina, it does not include the socio-economic effects. This is important to note since the storm exploited the social and economic vulnerabilities that the CVI did not show, but provided evidence of. In the article Social Vulnerability to Environmental Hazards, social vulnerability is described as the "measure of both the sensitivity of a population to natural hazards and its ability to respond and recover from the impacts of hazards", (Cutter SL, Boruff BJ, Shirley WL, 2003). The article "Measuring Capacity for Resilience among Coastal Counties of the US Northern Gulf of Mexico Region" also further clarifies that social vulnerability may have several factors that contribute to it, such as neglected stakeholders in public policy making, or the misunderstanding of ecological processes that can contribute to potential natural disasters along with incorrect planning of them. One example of the first factor, being the low-income population living in areas higher at risks for flooding (Reams, Lam, Baker, 2012). The article "A Preliminary Assessment of Social and Economic Impacts Associated with Hurricane Katrina" (Petterson, Stanley, Glazier, Philipp, 2006), discusses the social effects of residents being displaced and having no homes. The loss of homes also came with the loss of labor and businesses then hurting the economy. Since workers had no homes they could not work and businesses (particularly small ones) could not survive.

Also, business properties were destroyed which left those without a job. Cutter and his colleagues created a Resilience-Capacity Index that takes the highest loading variable on each of the first 6 factors was selected for the Rotated Factor Matrix that they first constructed. The factors being: Expenditures for education, Median income of the parish (county), Percent of the workforce that is female, Mean elevation of the parish, Percent of the population below 5 years old, Percent of the population that voted in the last presidential election. The index provides a score from 0-1, 0 being weakest and 1 being strongest to the area. The CVI may not have all the information to display the vulnerability/resilience of a coastal area, but it is an important companion piece to other research methods that consider all factors like the Resilience-Capacity Index in finding the level of readiness especially after a major natural disaster like Hurricane Katrina.

Conclusion/Recommendation

The CVI can provide insight into areas that are suffering/will suffer the due to sea-level rise and also as a "planning tool for managing and protecting resources along the Northern Gulf of Mexico." (Thieler and Hammar-Klose, 2000, Pendleton et. al., 2010). The 2018-2019 local, high resolution scale CVI calculated in this report expresses that the Lake Borgne region of Louisiana is very vulnerable to coastal change. We suggest that local level assessments continue to be conducted alongside additional research into what enables a community to be resilient to sea level rise and storms when geographically, they are facing those immediate threats. One method being the Resilience Capacity Index that covers a wider variety of factors that contribute to an area's resilience. Another recommendation particularly for local governments in the area is to have a firm understanding of the analysis made and use it to make better policy making decisions that will not endanger residents, and increase the level of readiness, along with more transparency to them

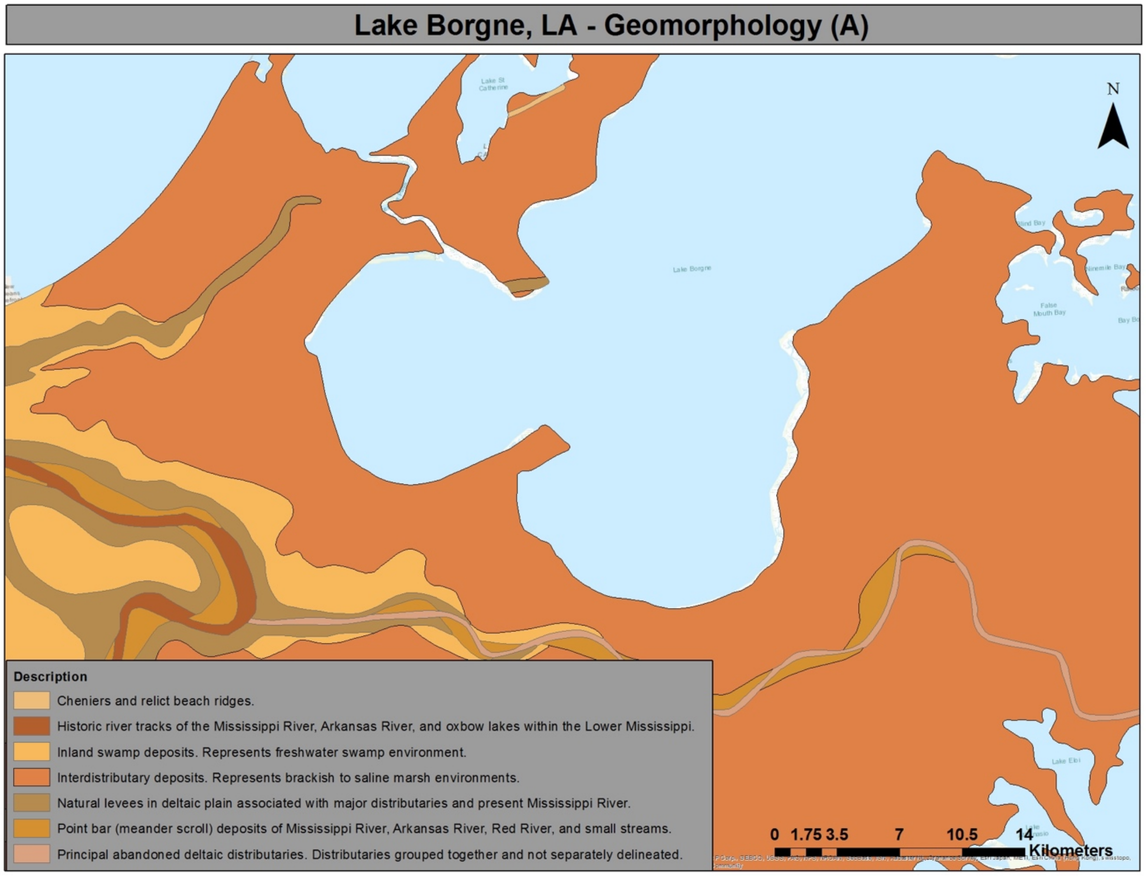
Appendix



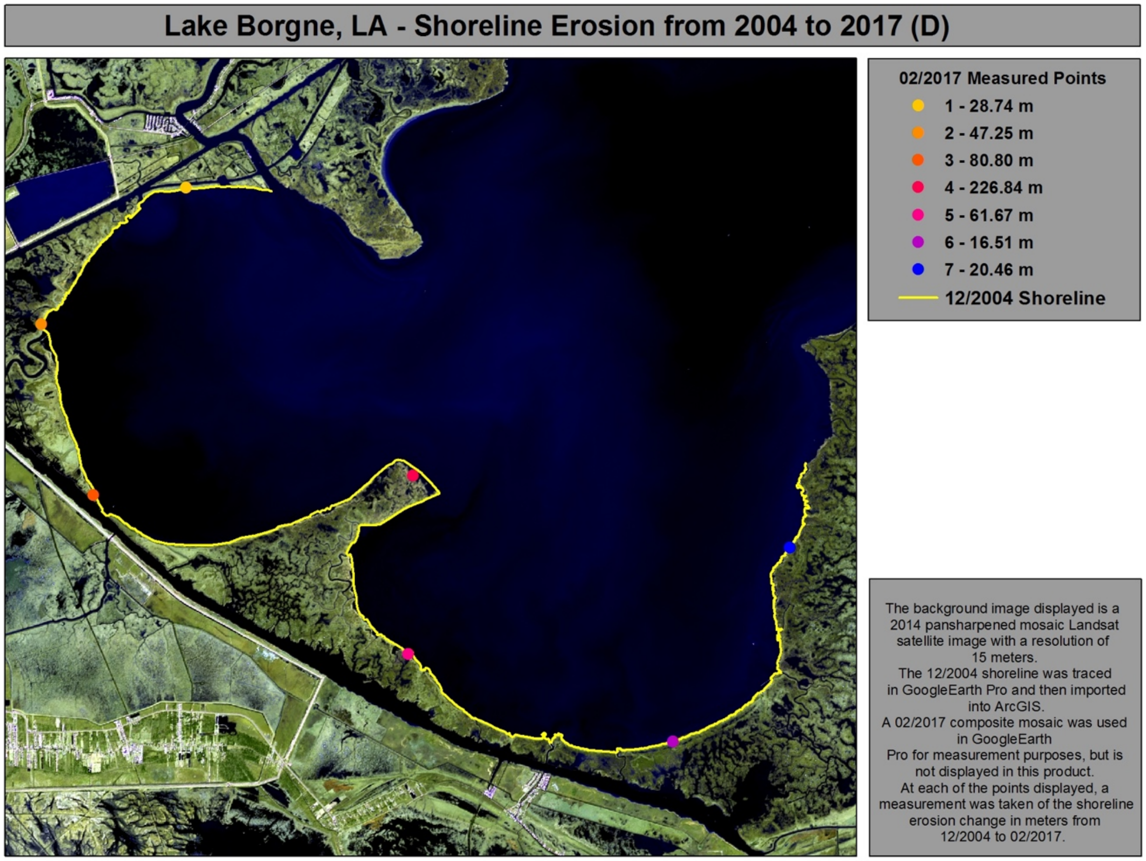
National CVI Assessment for the Gulf of Mexico, USGS Coastal Change Hazards Portal

	Ranking of coastal vulnerability index				
	Very low	Low	Moderate	High	Very high
VARIABLE	1	2	3	4	5
Geomorphology	Rocky, cliffed coasts Fiords Fiards	Medium cliffs Indented coasts	Low cliffs Glacial drift Alluvial plains	Cobble beaches Estuary Lagoon	Barrier beaches Sand Beaches Salt marsh Mud flats Deltas Mangrove Coral reefs
Coastal Slope (%)	> .2	.2 – .07	.07 – .04	.04 – .025	< .025
Relative sea-level change (mm/yr)	< 1.8	1.8 – 2.5	2.5 – 2.95	2.95 – 3.16	> 3.16
Shoreline erosion/ accretion (m/yr)	>2.0 Accretion	1.0 – 2.0	-1.0 – +1.0 Stable	-1.1– -2.0	< - 2.0 Erosion
Mean tide range (m)	> 6.0	4.1 – 6.0	2.0 – 4.0	1.0 – 1.9	< 1.0
Mean wave height (m)	<.55	.55 – .85	.85 – 1.05	1.05 – 1.25	>1.25

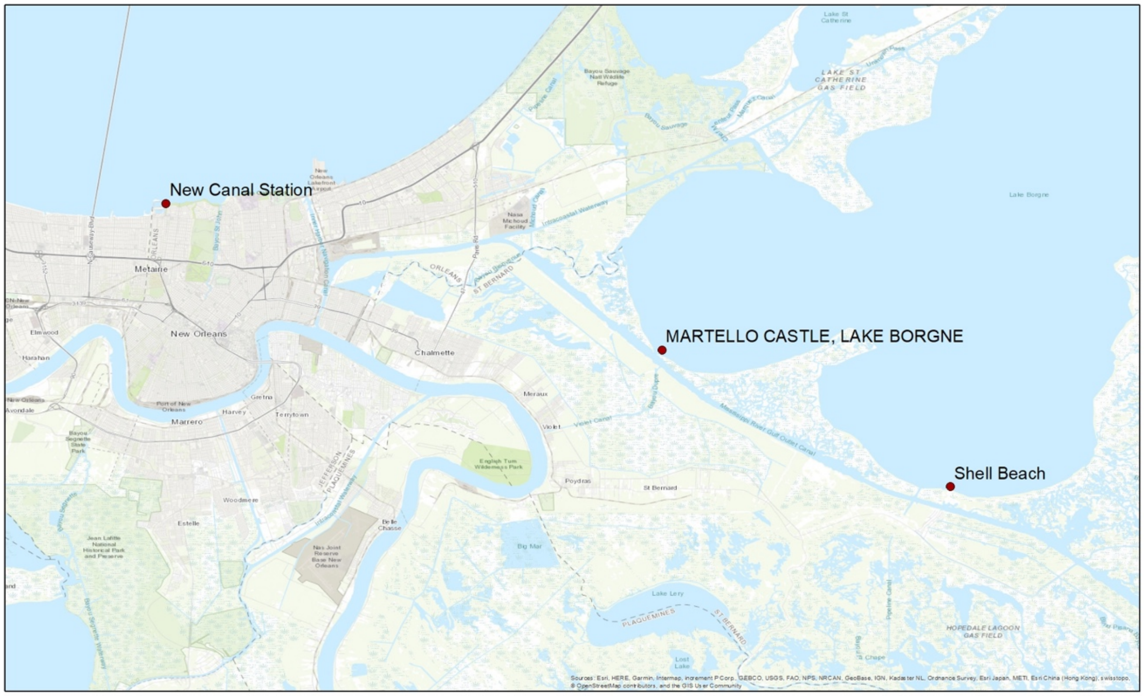
USGS, CVI


Lake Borgne, LA - Geomorphology (A)
N
Description
Cheniers and relict beach ridges.
Historic river tracks of the Mississippi River, Arkansas River, and oxbow lakes within the Lower Mississippi.
Inland swamp deposits. Represents freshwater swamp environment.
Interdistributary deposits. Represents brackish to saline marsh environments.
Natural levees in deltaic plain associated with major distributaries and present Mississippi River.
Point bar (meander scroll) deposits of Mississippi River, Arkansas River, Red River, and small streams.
Principal abandoned deltaic distributaries. Distributaries grouped together and not separately delineated.
0 1.75 3.5 7 10.5 14
Kilometers


Lake Borgne, LA - Slope (B)
Slope (Percent Rise)
0 - 2.5 %
2.6 - 4 %
4.1 - 7 %
7.1 - 20 %
20.1 - 89.8 %
World Terrain Base


Lake Borgne, LA - Shoreline Erosion from 2004 to 2017 (D)
02/2017 Measured Points
1 - 28.74 m
2 - 47.25 m
3 - 80.80 m
4 - 226.84 m
5 - 61.67 m
6 - 16.51 m
7 - 20.46 m
12/2004 Shoreline
The background image displayed is a 2014 pansharpened mosaic Landsat satellite image with a resolution of 15 meters.
The 12/2004 shoreline was traced in GoogleEarth Pro and then imported into ArcGIS.
A 02/2017 composite mosaic was used in GoogleEarth Pro for measurement purposes, but is not displayed in this product.
At each of the points displayed, a measurement was taken of the shoreline erosion change in meters from 12/2004 to 02/2017.

Datum Stations of Lake Borgne, LA



Relative Sea level change (C) data collected from New Canal Datum Sation.
Mean Tide Range (E) and Mean Wave Height(F) were collected from the Martello Castle and Shell Beach Stations.

VARIABLE	Actual Value	CVI Rank : Very low (1) - Very high (5)	Important Notes:
A. geomorphology	FID24 - "Interdistributary deposits, represents brackish to saline marsh environments", 2017-2018	5	
B. coastal slope (%)	Primarily <2.5%, 2018	5	
C. relative sea-level change (mm/yr)	5.35m, 1982 - 2018	5	Proxy datum station, New Canal, used
D. shoreline erosion/accretion (m/y)	-68.88m/13yr, 2004-2017	5	Some areas the erosion was as high as 220m, others as low as 16m
E. mean tide range (m)	0.38, 2008-2012	5	Mean of both Martello and Shell
F. mean wave height (m)	0.43, 2008-2012	1	*Martello Castle is higher than Shell Beach.(Mean of both)
	CVI: 22.82 = Very High Vulnerability		

CVI Study Results

References

Data

A. Geomorphology:

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C. Relative Sea Level Change:

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https://atlas.ga.lsu.edu/datasets/landsat2014/

E. Mean Tide Range:

National Oceanic and Atmospheric Administration (NOAA) National (NOS) Center for Operational Oceanographic Products and Services (CO-OPS): NOAA NOS CO-OPS Product.
https://idpgis.ncep.noaa.gov/arcgis/rest/services/NOS_Observations/CO_OPS_Products/MapServer

F. Mean Wave Height:

NOAA NOS Center for Operational Oceanographic Products and Services (CO-OPS): NOAA NOS CO-OPS Product.
https://idpgis.ncep.noaa.gov/arcgis/rest/services/NOS_Observations/CO_OPS_Products/MapServer

Academic

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