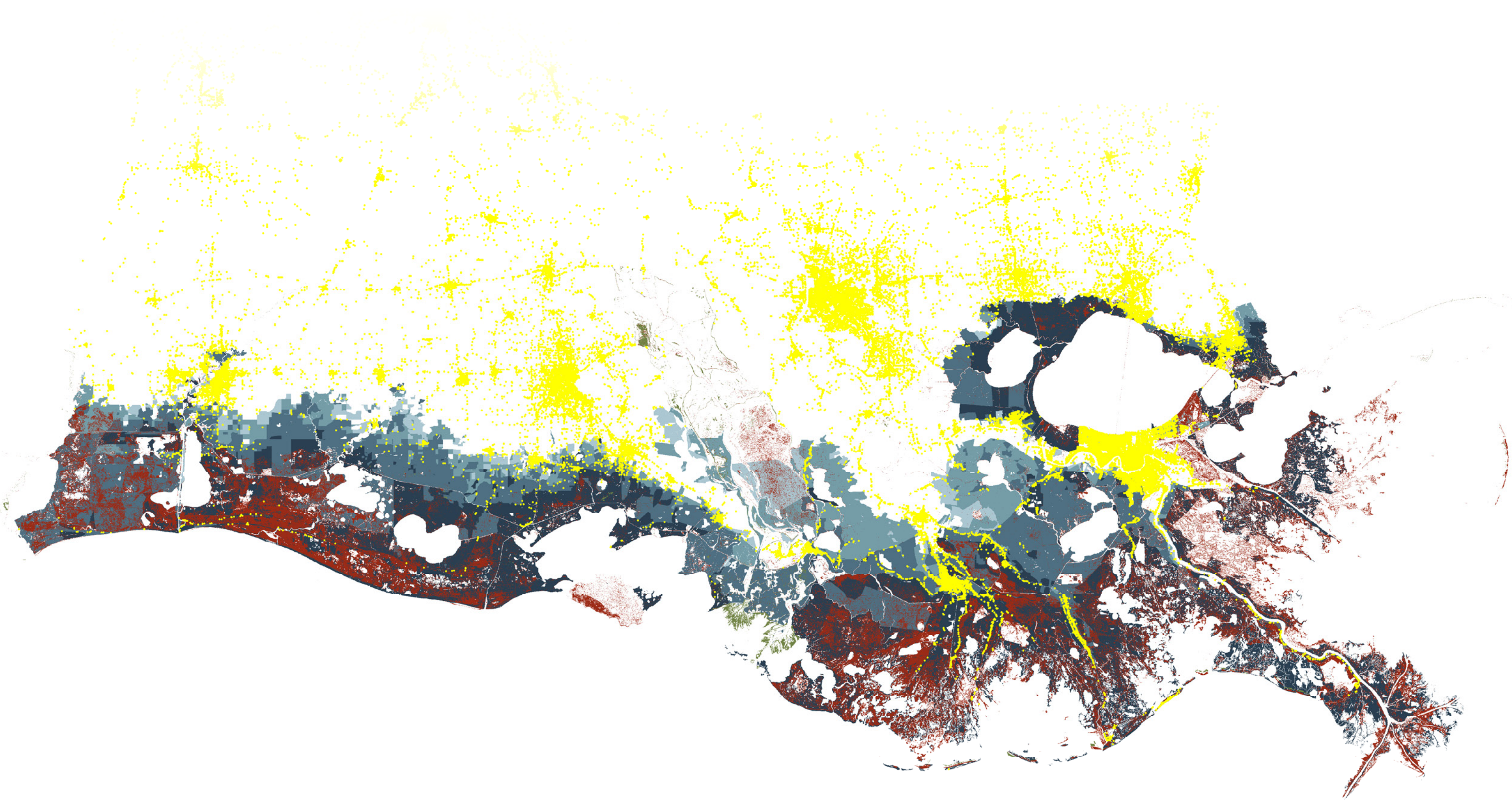
Economic Evaluation of

Coastal Land Loss in Louisiana



E. J. Ourso College of Business
Economics & Policy Research Group

RAND CORPORATION

Economic Evaluation of Coastal Land Loss in Louisiana

Stephen Barnes[1]*
Craig Bond[2]*
Nicholas Burger[2]
Kate Anania[2]
Aaron Strong[2]
Sarah Weilant[2]
Stephanie Virgets[1]

[1] Louisiana State University, Economics & Policy Research Group
[2] The RAND Corporation
* Corresponding authors

December 2015

Preface

Louisiana has experienced a rapid loss of land of approximately 1,880 square miles over the past eighty years. Projections suggest that in a future without action, the next fifty years could result in the loss of 1,750 additional square miles of land area. As land loss continues a large portion of the natural and man-made capital stocks of coastal Louisiana will be at greater risk of damage, either from land loss or from the associated loss of storm protection services. To help quantify the economic consequences of land loss in coastal Louisiana both locally and nationally, the Coastal Protection and Restoration Authority of Louisiana (CPRA) asked a team of researchers from Louisiana State University and the RAND Corporation to provide an empirical understanding of the economic damages caused by land loss in a future without action. This report presents findings from that research effort.

This research was sponsored by CPRA and conducted as a joint effort between Louisiana State University (LSU) and the RAND Corporation. Within LSU, the research was conducted within the Economics & Policy Research Group, an applied economics research group in the E.J. Ourso College of Business. The LSU co-principal investigators were Dr. Stephen Barnes and Dr. Dek Terrell. In RAND, the research was conducted within the RAND Environment, Energy, and Economic Development Program (Keith Crane, Director), located within RAND Justice, Infrastructure, and Environment. The RAND co-principal investigators were Dr. Nick Burger and Dr. Craig A. Bond.

Table of Contents

Figures

Tables

Acknowledgments

Charles Sutcliffe provided invaluable advice and guidance throughout the project. The authors also thank Coastal Protection and Restoration Authority of Louisiana (CPRA) staff and and members of the Steering Committee for their important contributions to the study scoping and feedback. We thank all those who provided data and expert opinion, including Jim Mitchell, Chris Fillastre, and Virginia Burton from Louisiana Department of Transportation and Development; David Dismukes and Greg Upton from the Louisiana State University Center for Energy Studies; Raymond Berthelot from the Louisiana Office of State Parks; Sean Duffy of the Big River Coalition; and CPRA staff working on the Mississippi River Hydrodynamic and Delta Management Study. The authors also thank David R. Johnson and Rachel Costello for their vital support and research assistance with RAND's CLARA model. The RAND team appreciates the support from Gary Cecchine and the RAND Gulf States Policy Institute throughout the project. The research staff of the LSU Economics & Policy Research Group also deserve special recognition for their work in this process. The team was instrumental in shaping and carrying out the analysis for this study. Finally, we thank our two reviewers for making this a better report.

Abbreviations

ACS	American Community Survey
AHS	American Housing Survey
API	American Petroleum Institute
BPD	Barrels Per Day
BTES	Barataria-Terrebonne Estuarine System
CBP	County Business Patterns
CLARA	Coastal Louisiana Risk Assessment
CMP	Model Coastal Master Plan
CPRA	Coastal Protection and Restoration Authority of Louisiana
CRC	Concrete Rising and Repair
CRT	Culture, Recreation, and Tourism
CTA	Center for Transportation Analysis
D&B	Dun and Bradstreet
DHH	Department of Health and Hospitals
DOTD	Department of Transportation and Development
EIA	Energy Information Administration
FAF	Freight Analysis Framework
FEMA	Federal Emergency Management Agency
FWS	Fish and Wildlife Service
GDP	Gross Domestic Product
GIS	Geographic Information System
HIS-SSM	Hoogwater Informatie Systeem – Schade en Slachtoffer Methode
JCP	Joint Plain Concrete
LADOTD	Louisiana Department of Transportation & Development
LDWF	Louisiana Department of Wildlife and Fisheries
LODES	LEHD Origin-Destination Employment Statistics
LOOP	Louisiana Offshore Oil Port
MRIO	Multiple Region Input-Output
NAICS	North American Industry Classification System
NASS	National Agricultural Statistics Service
NCHRP	National Cooperative Highway Research Program
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NRC	National Response Center
NTAD	National Transportation Atlas Database
ORNL	Oak Ridge National Laboratory
QCEW	Quarterly Census of Employment Wages
QCEW	Quarterly Census of Employment and Wages
RAM	Rhine Atlas Damage Model
RIL	Rental Income Losses
SPR	Strategic Petroleum Reserve
TLC	Temporary Location Costs
UNO	University of New Orleans
USGS	United States Geological Service
WMA	Wildlife Management Areas

Executive Summary

From 1932 to 2010, Louisiana lost approximately 1,880 square miles of land, and another 1,750 square miles are at risk of being lost by 2060 (U.S. Geological Survey, 2011; CPRA, 2012). Through the land loss process, wetland habitat becomes open water, the shoreline retreats, and dry upland areas subside. This process will impact infrastructure and economic activity connected to coastal Louisiana in the absence of private and public actions to guard against it. The economic impact of coastal land loss will be felt most severely in Louisiana, but these impacts will reverberate through the rest of the country and the world. This report presents the findings from joint research conducted by Louisiana State University and the RAND Corporation on the economic consequences of land loss to Louisiana and the rest of the nation, focusing on physical capital stock and economic activity at risk due to land loss in a future without action to protect and restore Louisiana's coast.

Coastal land loss directly affects some areas, but also increases storm damage to areas further inland, and this study considers both. Some land that currently holds valuable capital stock, such as homes and businesses, will be inundated over time and will diminish in value. In addition to those things directly threatened by a shifting coastline, Louisiana is losing its valuable coastal wetlands, which provide a natural buffer between storm surges and inland areas. As Louisiana's shoreline migrates inward and the remaining landscape degrades, more developed areas further inland will face greater risk of damage due to the loss of storm protection services currently provided by that land.

Land loss will affect or put at risk natural and manmade assets generating costs through damage to capital stock, disruption of economic activity, and changes in ecosystem services. The analysis in this report includes estimates of damage to physical capital stocks, including residential and non-residential structures and network infrastructure, such as roads, rail, waterways, and oil and gas transportation systems. We also estimate how land loss could affect economic activity, such as business operations or employment, and how these disruptions extend to commodity and trade flows linking coastal Louisiana to the rest of the country and the rest of the world. Finally, land loss may have important effects on ecosystem services, and although we do not calculate specific damages we classify the major categories and describe the regional economic activity in sectors directly related to ecosystem services, including fisheries and recreation.

Methodology

Land loss is a long term challenge; any analysis of coastal land loss and related storm damage effects must deal with uncertainty over the location, timing, and severity of land loss, as well as characteristics of future storms. There is a great deal of uncertainty inherent in efforts to model land loss over many years. As the basis of our analysis, we take as given estimates of land loss at 25 and 50 year time horizons from Louisiana's 2012 Coastal Master Plan. At each time horizon, we assess both "moderate" and "less optimistic" environmental scenarios from the Coastal Master Plan. Finally, to assess increased storm damage associated with land loss, we use estimates of increases in flooding with and without land loss for three hypothetical storm alternatives drawn from models used in the 2012 Coastal Master Plan, with each case illustrating distinct impacts on Louisiana's capital stock and economic activity.

The goal of this report is to provide methodologically sound estimates of the potential economic costs associated with anticipated coastal land loss, and the LSU-RAND team developed an analytical approach that achieved these goals while balancing scope and feasibility. The analysis has two main components and the methodology for each is related but distinct. The basis for this analysis is the economic landscape as it exists today and maps of land loss and storm surge projections from the 2012 Coastal Master Plan. To study direct land loss, we compiled data on capital stock and activities that currently rest on land that is predicted to be lost in a future without action. Those are "at risk" capital stock and activities. For storm damage effects, we combined current economic data with storm surge and flood data, using simulation models to calculate the *increase* in estimated storm damage after land loss relative to the expected damage from the same storm with today's coast. We did not simulate future changes in economic patterns of activity or population movement in Louisiana, given the level of uncertainty involved in making such predictions.

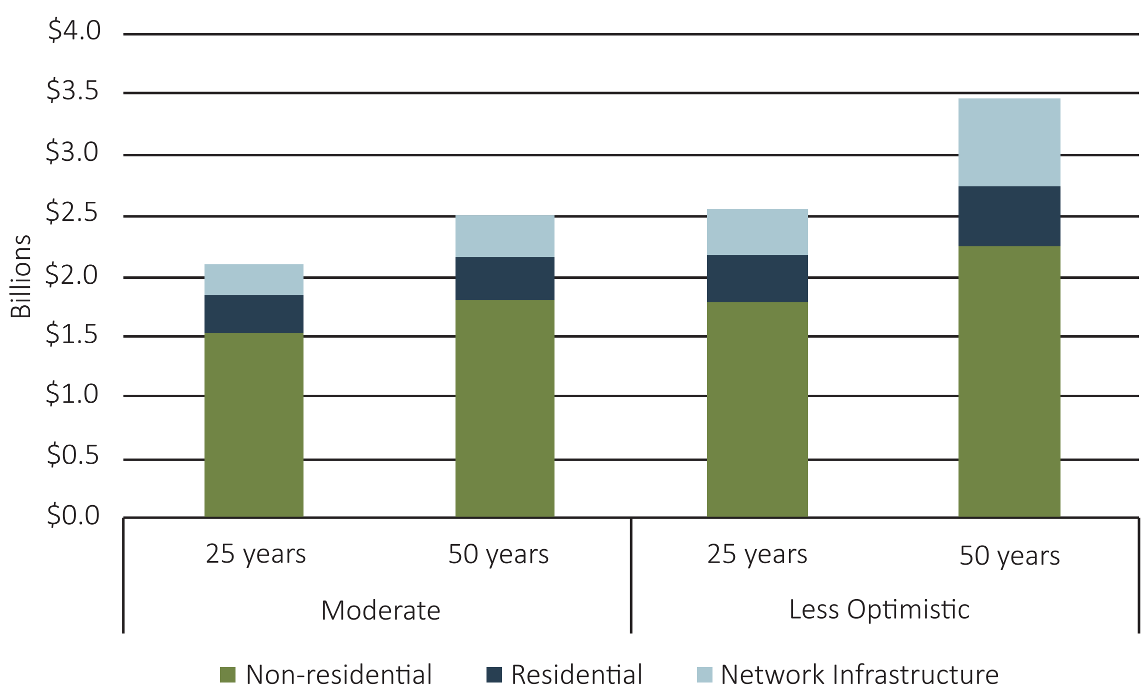
Disruptions to economic activity in coastal Louisiana can affect the economy throughout the rest of the state and the nation. We use IMPLAN, an input-output model, to document the economic contributions of businesses at risk from direct land loss and increased storm damage on the state of Louisiana and the rest of the country. We also analyze the effects of storm damage on gasoline prices, given Louisiana's important role in the production and distribution of refined petroleum products.

The result of this analysis is a set of estimates of the replacement cost of economic capital stock and value of activities that are "at risk" in a future without action from (1) land loss and (2) increased storm damage. We break down the results further by major categories, including residential and non-residential structures, network infrastructure, and economic activity. Where possible, we calculate the expected monetary costs. In some cases, it is not feasible to calculate monetary damages, and in those cases we report quantities or describe the potential land loss effects, depending on the information available. Because some costs cannot be added to others (e.g. lost wages and damage to roads) there is not a single damage figure associated with any combination of environmental scenario, time horizon, and storm track. Instead, we aggregate numbers to the extent possible and then report the resulting set of estimates that characterize damage in each case.

Results

The estimated replacement cost of capital stock directly at risk from land loss ranges from approximately $2.1 billion to $3.5 billion. Figure ES.1 illustrates the major components of capital stock damage associated with each combination of time horizon and environmental scenario. Between 60% and 75% of the costs are associated with non-residential structures, with approximately 1,200 structures at risk in the less optimistic 50 year case. Beyond these damage estimates, the report provides information on pipeline infrastructure potentially impacted through miles of infrastructure in land loss areas, because accurate cost estimates were not feasible. Estimated replacement costs are not annual but instead reflect the total replacement cost of capital stock at-risk. These values may differ from actual future costs to capital stock owners depending on actions taken by those owners in response to the threat.

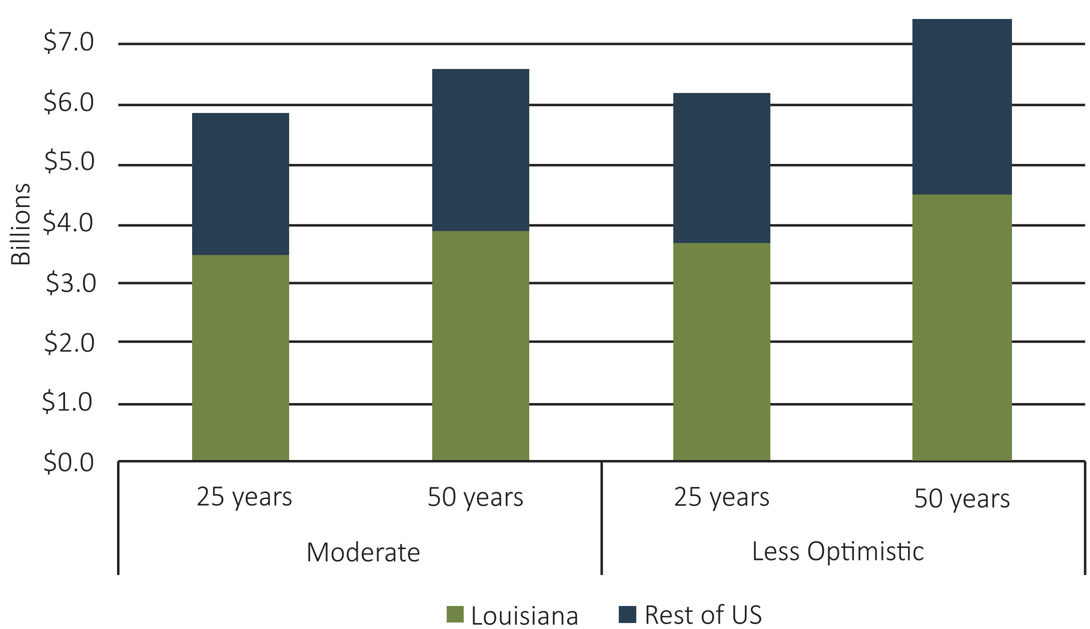
Figure ES.1: Total Replacement Costs Associated with Capital Stock at Risk from Land Loss



Note: Network infrastructure estimates include only road and rail infrastructure. All results presented in 2012 dollars.

Land loss also directly affects economic activity with estimated total activity at risk ranging from $5.8 billion to $7.4 billion in output. Louisiana is a major trade hub, and the coastal parishes import $160 billion and export $156 billion annually; petroleum and chemical products constitute a large share of this activity. Louisiana is connected to and services other states through an extensive transportation system, including waterways, roads, rail and pipelines. Including indirect and induced impacts to the rest of the state and the nation, total annualized output directly at risk from each land loss case is shown in Figure ES.2. This reduction in output is driven by land loss impacting between 800 and 1,200 establishments, depending on the specific land loss case. The at-risk establishments produce between $2.4 and $3.1 billion in annual sales, and their associated payroll is approximately $400 million to $575 million. These direct impacts are estimated to generate a total impact of between $3.4 and $4.5 billion in output in Louisiana and an additional $2.4 to $2.9 billion in output in the rest of the United States. In a future without action, some of the economic activity from at-risk establishments may be able to relocate, which could take more or less than the one-year time horizon of economic activity estimates provided in this report. These annual numbers provide context for the scale of current activity at-risk. For example, the establishments in coastal Louisiana that are at-risk in the 50 year, less optimistic case are roughly 0.7% of all establishments statewide and reflect a similar share of annual sales volume.

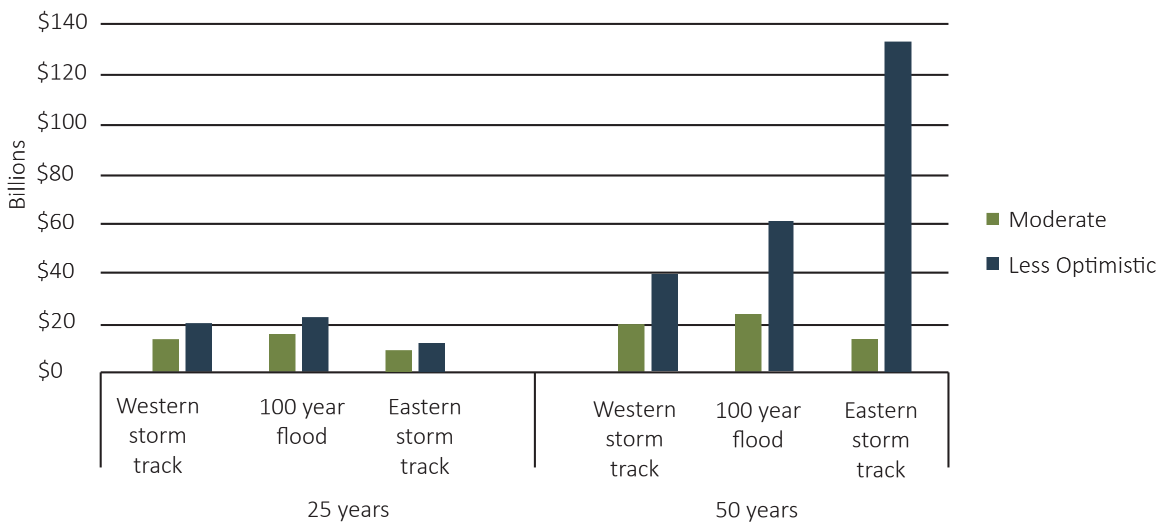
Figure ES.2. Total Annual Output at Risk from Land Loss



Note: All results presented in 2012 dollars.

Increases in storm damage to capital stock range from less than $10 billion to as much as $133 billion. These costs cannot simply be aggregated with the damages to at-risk capital stock because each storm event has only a limited probability of occurring within the context of a specific land loss case. The storm damage estimates are larger than the direct land loss estimates which reflects the location of capital stock across different parts of the Louisiana coast and the widespread impacts of flood damage further inland associated with severe storms. Figure ES.3 shows the increased storm damage to capital stock from each combination of land loss and storm event considered. Increases in damage range from approximately $9 billion for the eastern track storm in the moderate scenario at 25 years to over $130 billion for the less optimistic scenario at 50 years for the same storm track. This wide range of estimates for the eastern storm is driven by the enhanced storm protection built around New Orleans after Katrina that leads to less damage in the moderate scenario at 25 years and the predicted levee breaches in the less optimistic scenario at 50 years.

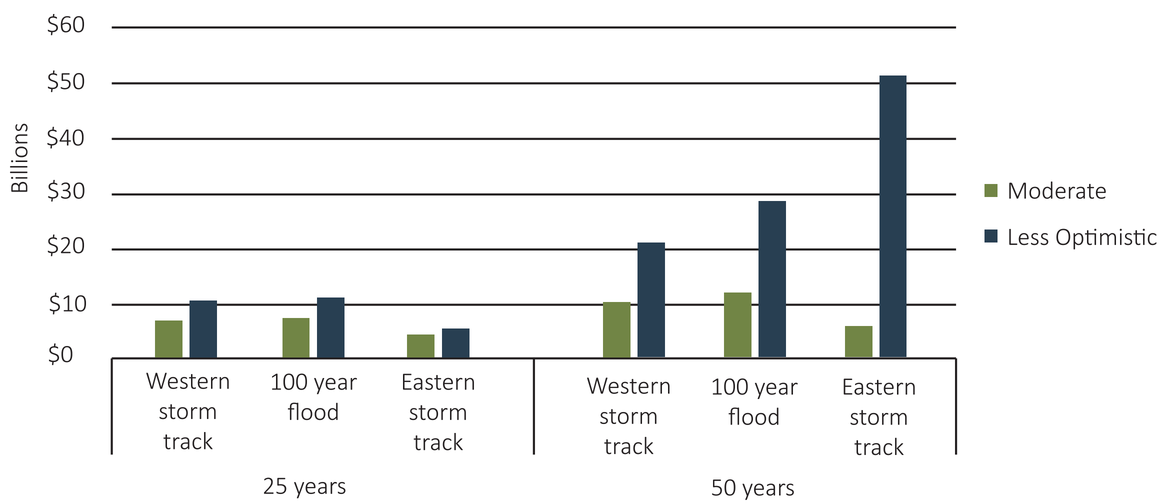
Figure ES.3. Increases in Storm Damage to Capital Stock



Note: Capital stock includes non-residential buildings, residential buildings, and network infrastructure. Network infrastructure estimates include only roads and rail. All results presented in 2012 dollars.

Increased storm damage caused by land loss also disrupts economic activity leading to an additional $5 billion to $51 billion in total lost output including indirect and induced effects. As with damage to capital stock, the estimates of business disruption are heavily influenced by whether or not levees are predicted to fail in the New Orleans area due to reduced natural storm protection caused by land loss. In the less optimistic scenario at 50 years, we estimate that the eastern track storm would affect an additional 26,000 establishments and 320,000 employees relative to a similar storm hitting the current coast. This type of disruption would directly generate between $140 million and $6.4 billion in lost wages and between $340 million and $23 billion in lost sales, depending on the land loss case, storm and model assumptions. Finally, because Louisiana serves as a hub for production and transportation of refined petroleum products, we analyze the effect of potential short term supply disruptions caused by major storms on national gasoline prices, which can add approximately $2.3 billion to $2.6 billion in additional costs to the nation.

Figure ES.4. Total Output Lost to Increased Storm Damage



Note: All results presented in 2012 dollars.

Ecosystem services offer significant value to Louisiana and the nation including their role in supporting a significant portion of the economic activity we document in the report. While we do not estimate a total monetary value of ecosystem service changes associated with land loss, we summarize the types of ecosystem services that exist in coastal Louisiana, describe their roles, and where possible, report the expected qualitative effects of land loss. Fisheries are an important source of economic activity that reflect a critical ecosystem service of coastal Louisiana. We expect fisheries catch to increase initially as marsh edge increases with land loss. But in the long run, catch rates may decrease as the amount of marsh edge ultimately falls due to coastal land loss. Land loss will also affect public lands, including state parks, and associated tourism and recreation activities. Depending on the land loss case, we estimate that between 1.5 and 13% of wildlife management areas, reserves, and parks are at risk from land loss. Due to a lack of data linking recreation demand with detailed geographic locations along the coast, we are not able to calculate quantitative impacts of land loss on these activities. However, we estimate that outdoor recreational activities in Louisiana provide approximately $4 billion of total value statewide with much of that activity concentrated in coastal areas. Finally, storm protection is a critical ecosystem service provided by Louisiana's coast. One way to value this ecosystem service is by quantifying the costs of increased storm damage brought on by land loss as is done in this study.

Study Limitations and Future Analysis

Our goal was to provide broad-based, informed estimates of the cost of land loss in coastal Louisiana, but we acknowledge a range of limitations in our analysis and final estimates. These limitations are both built into our approach and the natural consequence of data limitations encountered during our work. The reader should be aware of these limitations when interpreting our approach and results.

Economic systems are responsive, and we do not try to account for how the economy or individuals will respond to adverse conditions. Individuals or firms with capital stock or economic activity at risk from land loss may be able to reduce that risk through a variety of mitigating actions. For example, firms and individuals can relocate to other areas along the coast, other areas within Louisiana, or outside of the state. Rebuilding capital stock in any of these other areas would have costs that may be greater or less than the total value of the asset at-risk. For economic activities that can be relocated to other areas, the time needed to reestablish those activities elsewhere will vary and actual disruptions may be more than or less than the one-year estimates of economic activity provided in this report. In the same way, some firms that are indirectly impacted by activities at risk due to increased storm damage may be able to identify alternate customers, which would reduce the indirect costs associated with increased storm damage. Similarly, we do not account for changes in the scale of future economic activity. While a future without action could lead to long-run declines in investment and economic activity, this is far from certain. Similarly, a robust coastal protection and restoration effort could stimulate continued investment and growth, but failures could lead to longer-term declines. To achieve a stated goal of this analysis in informing those decisions, we avoid specific assumptions about economic growth or decline.

We provide guidance on the uncertainty inherent in our overall approach, but we do not explicitly treat uncertainty in all calculations. The variation in modeled time horizons, environmental scenarios, and storms provide a wide range of cost estimates, and for some parameters—such as how quickly establishments rebound after a hurricane—we offer alternative values and show the implications. But we do not take a comprehensive approach to assessing uncertainty, such as calculating confidence bands around estimates.

The results we report focus on the entire Louisiana coast and should not be interpreted to imply changes to or impacts on any specific piece of land, infrastructure asset, or industry. We use disaggregated data on population, the location of structures, and business activity, but the results should not be interpreted at that level of disaggregation. This is partially because the effects of land loss are uncertain, especially at a fine geographic scale. It is also because capital investments will vary over time, and industries will respond accordingly, so we cannot estimate the effect on any one industry.

The report covers a wide range of economic effects associated with land loss, but there are some categories of damages for which we did not try to calculate monetary damages. For example, although our analysis accounts for some broad-based ecosystem services, such as the storm buffering benefits of coastal marsh land, there are major categories of ecosystem services that were outside the scope of our analysis. Related to ecosystem services, we do not directly account for cultural or other "existence" values that individuals and groups may place on land that is lost under a future without action. These losses are difficult—although not impossible—to estimate, but doing so requires dedicated analysis of individual resources or classes of resources. We summarize some of the major types of cultural values and report total economic values, but we do not calculate the change in value due to coastal land loss.

Future analysis could address some of these limitations by expanding the analytic scope, conducting additional data collection, or carrying out case studies for specific sectors. Although using today's fixed economic landscape helped simplify and clarify the analysis, future work could account for changes in the location and scale of economic activity over time. Similarly, it would be beneficial to model how the economy is likely to respond through feedback mechanisms, which could be accomplished through a general equilibrium approach. Finally, there are some important damage categories, such as broad ecosystem services, that could be estimated in a more comprehensive way. These expansions would add complexity to the analysis and results, but they would provide additional information for policymakers and other stakeholders.

1 Introduction

From 1932 to 2010, Louisiana lost approximately 1,880 square miles of land, with another 1,750 square miles at risk of being lost by 2060 (U.S. Geological Survey, 2011; CPRA, 2012). Future coastal land loss includes the conversion of wetland habitat to open water, shoreline retreat, and subsidence of dry upland areas. This process is driven by a number of environmental changes, including global sea level rise and subsidence, coupled with dredging, channelization, industrial development, agricultural drainage, and oil and gas extraction (Turner, 1990). Due to geological factors along the coast, there is a northern limit on lands that can be converted to wetlands due to these processes; as such, it is expected that 80% of Louisiana's coastal wetlands will be lost by the turn of the century (Farber, 1996).

In recent years, there has been significant concern regarding the economic effects of land loss in coastal Louisiana. Land loss may deeply affect capital stocks and economic activity, as well as flows of goods, services, and people to, from, and through coastal Louisiana. Land loss will reduce the footprint of the state's coastal wetlands, which provide a number of ecosystem services (benefits from the natural system) to the region. In particular, these wetlands serve as a naturally-occurring buffer between storm surges and towns, cities, and other municipalities along the coast, and along with man-made protection structures, are often the first line of defense against storms in reducing damage to highly developed areas further inland. The widespread damage caused by Hurricanes Katrina and Rita in 2005 demonstrated the magnitude of devastation that can occur with the existing landscape and storm protection infrastructure as of August 2005. While the man-made storm protection system has been significantly enhanced since 2005, continued land loss and the resulting inward migration of the shoreline coupled with degradation of the remaining landscape will place a large portion of coastal Louisiana's natural and manmade capital stock at greater risk of damage directly from land loss or the associated loss of storm protection services.

To help quantify the economic consequences of land loss in coastal Louisiana both locally and nationally, the Coastal Protection and Restoration Authority of Louisiana (CPRA) asked researchers from Louisiana State University and the RAND Corporation to provide an empirical evaluation of the economic damages caused by land loss in a future without action. In this report, we identify assets (in the form of capital stocks) and economic activity (in the form of flows of goods or value) that are at risk due to land loss in a future without restoration and protection efforts to minimize or mitigate land loss (a "future without action").

This work builds on previous studies conducted by and with the Coastal Protection and Restoration Authority of Louisiana (CPRA), particularly for the 2012 Coastal Master Plan, including core outputs describing potential land loss in a future without action. The analysis also draws heavily on modeling done previously by RAND, particularly the Coastal Louisiana Risk Assessment (CLARA) model to estimate flood levels by census block (Fischbach, et al., 2012), though we use different estimates of establishments, economic activity, and capital stocks in the region. Finally, we use sector specific analyses of capital stock damage or economic impacts from sources such as the Federal Emergency Management Agency's (FEMA) HAZUS-MH methodology to validate or improve damage estimates.

Study Focus

The basis for this analysis is the economic landscape that exists today and maps of projected land loss and storm-related flooding from the 2012 Coastal Master Plan. We estimate the value of capital stock and economic activities directly at risk from land loss, as well as the increase in storm damage attributable to land loss, using information about the projected rate and distribution of land loss in coastal Louisiana over twenty-five and fifty year periods. To isolate the effects of these geophysical processes, the future economic conditions of the state are not forecasted; instead, we overlay the projected land maps over the current economic base, and assess the potential implications.

Our primary focus is on the *incremental* change in damages (for stocks) and disruptions (for flows of economic activity and ecosystem services) that result from land loss. We assume that capital stocks (such as residential and non-residential fixed capital stocks and infrastructure related to transportation) can be impacted either directly (e.g., when the asset is currently located in an area expected to be converted from land to water) or through increased flooding due to land loss and the resulting reduction in storm protection services. We assume that annual flows of economic activity (e.g., wage payments, employment, trade, etc.) and ecosystem services can similarly be impacted in these two ways by land loss. However, while the economic information available is sufficient to estimate the values affected by land loss, the change in non-protection ecosystem services generated by land loss is much more uncertain. As such, we identify the types of ecosystem services provided by coastal wetlands in Louisiana, and qualitatively describe the potential effects of land loss on them when possible.

Our study focuses on the risk to capital stocks (including both man-made and natural) and the economic activity that they support, with an approach that is essentially static in nature. We take the existing stocks, and their spatial structure, as the result of past decisions, and generally do not account for future adaptive dynamic behaviors of residents, firms, and governments in response to the land loss process. Any mitigation response, from hardening of infrastructure to relocation, is not considered, which is consistent with the notion of a "future without action." As such, one might consider the report to identify the "footprint" of economic activity at risk, rather than a forecast of the future.

Organization of this Report

In Chapter 2, we review our overall approach to estimating land loss impacts and the specific methodologies used to estimate monetary costs. Chapter 3 presents our main results, focusing on capital stock and activity at risk from direct land loss and increases in storm damage. There are important potential impacts for which quantitative analysis was outside the scope of our study—primarily ecosystem services. We describe these classes of impacts in Chapter 4. In Chapter 5, we take a broader economic view and assess how coastal land loss in Louisiana is linked to economic activity in the rest of the country. Finally, Chapter 6 summarizes the overall results and describes the implications and limitations of our work. To make results more clear, tables with general background were formatted in gray while tables summarizing land loss are red and tables summarizing increased storm damage are blue.

2 Study Approach and Methodology

The objective of this study is to estimate the incremental effects of land loss on the valuable economic stocks and flows (broadly defined) that are dependent on the existing coastal land base.[1] This broad-based goal made defining our terms early on in the study mandatory. We also needed to develop a study plan that would allow us to bring together diverse data and put different methodologies into practice.

Here, we present our use of key terms and factors such as land loss, coastal parishes, and economic activity. We then describe the land loss projections considered in the analysis and discuss the major economic concepts that are used in the analysis. Next, we describe how we estimate the values of capital stocks and economic activities at risk of land loss and increased storm damage. Because of the different natures of non-protection ecosystem services and links with the rest of the nation and the world, we defer discussion of those methodologies until Chapters 4 and 5. More detailed methodological aspects of the approach are presented in Appendix A.

Conceptual Framework

From a theoretical perspective, the cost of land loss in a future without action is the difference in total welfare from a world in which land loss does not happen and a world in which it does (and no actions are taken to stop it). Both of these paths are theoretical in nature, will depend on a very large number of assumptions about adaptive responses and future states of nature, and are unobservable from the present. In order to isolate the effects of land loss without confounding it with additional assumptions, the basis for this analysis is the existing economic landscape and maps of land loss and storm surge projections from the 2012 Coastal Master Plan. That is, we estimate the effects of projected land loss on current, rather than future, economic activity.

We chose this approach for several reasons. First, future economic development paths are highly uncertain. While a 50 year time horizon may not be especially long in geophysical terms, such an increment reaches beyond any widely accepted economic forecast, and many variables can contribute to the path of growth. Historically, the coastal Louisiana region has experienced a long-run trend of positive population and economic growth (most recently driven by large industrial expansions fueled by low-cost and abundant natural gas) and the

[1] By "broadly defined," we mean to include ecosystem services (and the natural capital stocks that provide them) as valuable components of the economic landscape.

state's long run employment forecast to 2022 shows such trends continuing for years to come. In the context of disaster management, a robust restoration and protection program would encourage additional individuals and firms to relocate to coastal Louisiana, drawn in part by the region's rich natural resources, competitive business environment, quality of life and culture.

However, a future without action in which individuals, firms, and governments invest little in mitigating action against potential threats from land loss, in conjunction with unpredictable storm events, could result in a very different development path for coastal Louisiana, possibly including depopulation and economic decline. For example, the 2005 hurricane season resulted in severe storm impacts and significant population decreases in many coastal Louisiana parishes (though the region as a whole has mostly recovered). Outside of land loss, a number of local, national, and international economic, political, and other developments will affect the Louisiana economy in meaningful yet unpredictable ways.

Second, even if one or more assumptions for future growth in the region could be agreed upon, the spatial and industry-level distribution of that growth across the region (including supporting infrastructure and patterns of trade) in the presence of land loss and random storm events would skew many of the results. To concentrate attention on the services provided by coastal land, we extrapolate away from future dynamics of the coastal region's economy.

Third, this approach minimizes the need for assumptions about adaptive behaviors on behalf of individual economic actors or the public sector. Rational households or firms will make mitigation or relocation decisions regarding responses to land loss on the basis of their own preferences, available opportunities, and their own constraints. We do not model this behavior, as ours is a static, rather than dynamic, approach. If households or firms are able to respond to environmental changes through mitigating actions at their current location, or moving to a new location, estimates of the costs of land loss would certainly change.

Finally, we believe that fixing the current economic system provides insight into the likely causal effects of land loss on damage and disruptions without confounding future economic conditions. By overlaying the current economic system, which is well-known, with the projected loss of land, we essentially keep "all else constant" in our analysis. This avoids confounding the damage associated with land loss with forecasts of future economic development. On a proportional basis, however, one can interpret our results as valid if one were to make the assumption that the coastal economy grows at a constant rate. Alternatively, one can think of these results representing the present value of future costs if the economy grows at a rate equal to the discount rate.

Within this context, we estimate the effects of land loss and resultant increase in flooding and storm damage on man-made capital stocks and the flows of economic activity that are supported by those stocks. We quantify the effects of land loss as the value of stocks or economic flows that are at risk of damage or disruption due to the conversion of land to water. Stocks or flows that are in close proximity to predicted land loss are assumed to be directly at risk. Calculated effects of increased storm damage are primarily focused on the change in flooding resulting from the degradation of storm protection services due to the loss of land.

Given the projections currently available, this damage is calculated from the increase in flooding in areas where fixed capital is currently located and the associated increase in disruptions to economic activity in future conditions compared to current conditions. From an economic perspective, this is a static approach to estimating the effects of land loss. While these estimates are indicative of the order of magnitudes of damage that the various land loss projections might entail, the analysis does not include every potential type of capital stock damage or economic flow disruption, nor does it consider any general equilibrium effects, such as reactions by individuals or firms to changes in the environment or economy.

In this report, we generally restrict our results to reporting the total value at risk from land loss for private economic activity. As such, our estimates provide a broad perspective on estimated capital stock and flows at risk from coastal land loss without focusing on impacts to specific subsectors of the economy or specific areas within coastal Louisiana. As a supplement to these values, we provide a number of appendices that add additional details for sectors of the economy or asset categories that may be of particular interest to some readers.

Defining Coastal Louisiana

For the purposes of this study, we define coastal Louisiana as the following parishes: Acadia, Ascension, Assumption, Calcasieu, Cameron, Iberia, Iberville, Jefferson, Jefferson Davis, Lafayette, Lafourche, Livingston, Orleans, Plaquemines, St. Bernard, St. Charles, St. James, St. John the Baptist, St. Martin, St. Mary, St. Tammany, Tangipahoa, Terrebonne, and Vermilion. These 24 parishes are projected to have at least some land loss in at least one of the environmental scenarios and time horizons considered in our analysis.

The major commodities produced and exported from the coastal parishes are refined petroleum products, petrochemicals, and plastics materials and resins. The region also serves as a transport hub for a variety of goods and services between the rest of the United States and international markets. This working coast supports a population of 2.56 million people (57% of the state of Louisiana). Average annual household income is approximately $65,300 in the coastal parishes compared to $58,500 in the rest of the state (ACS 2012). In March 2012, there were 1.06 million people working in the coastal region with a total quarterly payroll of $12.2 billion (QCEW 2012).

To place the size of the coastal Louisiana's economy within the context of the state and national economies, Table 2.1 reports the relative size of coastal and state economies with respect to the national economy.

Table 2.1

Relative Size of Coastal Louisiana and State of Louisiana Economies, 2012

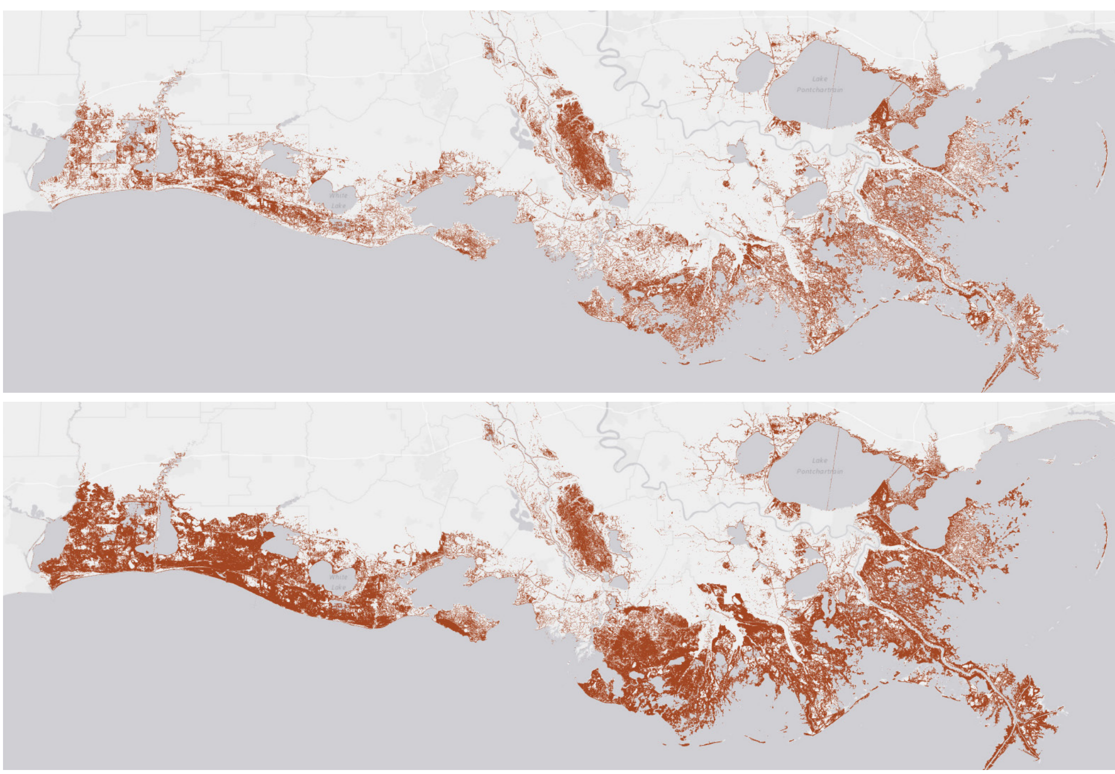
Regional Economy/Metric	Percent of Louisiana	Percent of USA
Coastal Louisiana		
Wages	61%	0.7%
Employment	57%	0.8%
Population	57%	0.8%
State of Louisiana		
Wages	100%	1.2%
Employment	100%	1.4%
Population	100%	1.4%

Land Loss Projections

This economic analysis is based on model results for land loss from four future without action projections developed for the 2012 Coastal Master Plan using 2010 as the base year (CPRA, 2012). The projections rely on environmental scenarios that are defined over two sets of environmental conditions representing scientific uncertainty over key parameters including sea level rise, rates of subsidence, storm intensity and frequency, Mississippi River discharge and nutrient concentration, evapotranspiration, and marsh collapse threshold. In the 2012 Coastal Master Plan, these two sets of environmental conditions are referred to as moderate, which corresponds to a set of conditions leading to relatively less land loss, and less optimistic, which corresponds to a set of conditions leading to relatively more land loss. The less optimistic scenario assumes higher rates of sea level rise and increased subsidence, higher storm intensity and frequency, and more susceptible marsh conditions. The other dimension under consideration is the span of time. Land loss is projected under each set of environmental conditions for 25 and 50 year time horizons. Given current understanding of geophysical processes, a longer time horizon is expected to result in greater land loss. Figure 2.1 shows the projected land loss for the moderate and less optimistic scenarios for the 25 year period concluding in 2035. Figure 2.2 shows the projected land loss for the two sets of environmental conditions for the 50 year horizon concluding in 2060.

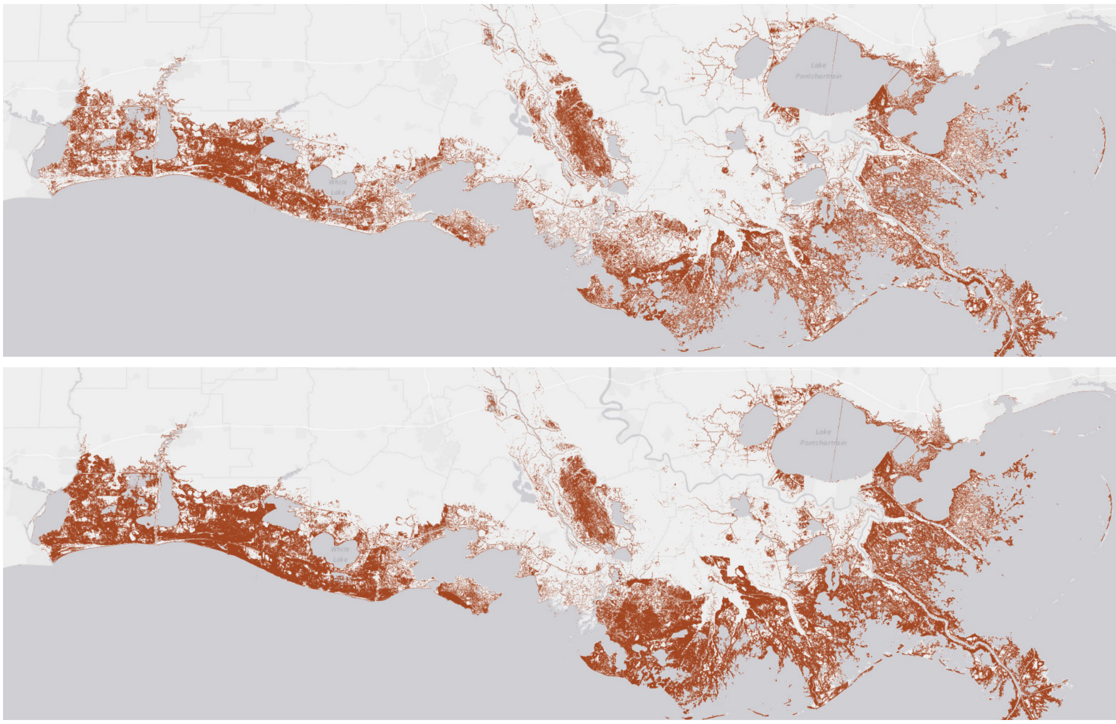
For more information on environmental modeling conditions, see the 2012 Coastal Master Plan Appendix C.

Figure 2.1. Land Loss at 25 Years with A) Moderate Scenario, B) Less Optimistic Scenario



Source: Authors based on 2012 Coastal Master Plan projections. Red pixels denote projected land loss.

Figure 2.2. Land Loss at 50 Years with A) Moderate Scenario, B) Less Optimistic Scenario



Source: Authors based on 2012 Coastal Master Plan projections. Red pixels denote projected land loss.

Economic Framework

We characterize the current economic system in a number of ways using various data sources, and calculate the implications of land loss on this system using methodologies tailored to accommodate the nuances of each data source. In particular, we group capital stocks and activities into the following categories:

Stocks of Physical Capital

- Non-residential structures and inventory
- Residential structures and contents
- Network Infrastructure (roads, rail, pipelines, and waterways)

Flows of Economic Activity

- Economic activity at risk of disruption directly through land loss
- Indirect impacts
- Commodity and trade flows

Ecosystem Services

- Provisioning Goods
- Regulating Services
- Cultural Goods and Services
- Supporting Services

This study examines the businesses, residences, and infrastructure impacted by land loss. It also evaluates the increase in storm damage in each of these categories as a result of predicted land loss. We also document the ecosystem services that may be affected by the land loss process. In associated appendices, we explore sector-level effects in greater detail.

Where sufficient data or modeling exist on the processes that relate land loss to economic effects, we report the economic effects. This is the case for most of the non-network infrastructure capital stocks and many of the economic flows. In other cases, such as network infrastructure, the linkages between land loss and economic effects are complicated by a lack of data, potential behavioral adaptation, or other factors. In these cases, we typically report either the physical drivers of damage or current levels of economic activity at risk, or qualitatively discuss the potential effects.

Direct Risk from Land Loss

The economic impacts of land loss are calculated for both the stocks of physical capital and the flows of economic activity. We estimate the total value of a stock or flow that is at-risk from being abandoned, damaged, disrupted, or destroyed by the loss of land, based on the land loss projections. For an at-risk stock, such as a residential building, we estimate the value of the structure. For an at-risk flow, such as employment or wages, we characterize disruptions by measuring the at-risk activity on an annual basis. There may be activities that could be replaced or relocated to other areas in less than a year while other activities may uniquely benefit from their current location and may take more than a year to become fully reestablished elsewhere, or the loss may be permanent.

The term "at risk" is used to alert the reader that there is considerable uncertainty as to the actual damage that might occur under each land loss projection. In addition to uncertainty over the exact location of land-to-water conversion, the behavioral responses to this threat are largely unknown as well.

The analysis of direct impacts of land loss follows four basic steps:

1. **Identify land loss.** Four spatially-explicit land loss maps depict the estimated land loss 25 or 50 years in the future. These maps were provided by CPRA and were developed for the 2012 Coastal Master Plan. Although it cannot be confidently stated that a certain point on the map or grid cell in the model is gained or lost, the model indicates land that is at high risk of loss in the future.
2. **Identify locations of physical capital stock and activity.** Business activity and capital stock is not distributed evenly across the coast but is concentrated along relatively high ridges of land. Therefore, we identify the most geographically granular and reliable source of geospatial data for each type of asset or activity. In general, point, path, or footprint level data are used rather than aggregated regions or blocks. The data and specificity for each group of capital stock or activity are discussed in detail in the appropriate subsections of Chapter 3.
3. **Determine which capital stock and activities are at risk.** The geospatial data is used in conjunction with the land loss maps prepared by CPRA to identify structures and activity at risk from land loss. For the purposes of measuring the direct effects of land loss, the capital stock and activities at risk are those located within the area of predicted future land loss identified

in maps from the 2012 Coastal Master Plan.

4. **Screen Results.** While the land loss maps imply dense clusters of loss in the most vulnerable areas, there are some areas further inland with only a few small, isolated areas of land loss (see Figures 2.1 and 2.2). To avoid overstating the effect of land loss on economic activity, we allow for a modest degree of private mitigating action. In cases where a business or capital asset is on land estimated to be lost, but the surrounding area is not significantly impacted, we assume that modest private mitigation actions will prevent losses.

Where the extent of potential damage to capital stock or disruption of activities attributable to land loss cannot be quantified, as in the case of river navigation, we report totals from the coastal region and offer only a qualitative discussion.

Increased Storm Risk from Land Loss

The second component of this analysis looks at incremental damage from the increased risk of flooding driven by land loss in a future without action. Much of the land that will be lost over the next 25 to 50 years is wetlands. A valuable characteristic of wetlands is their ability to slow down or reduce effects of storm surge (see, e.g., Kawabe and Oka, 1996; Tovilla-Hernandez et al., 2001, Johnston, et al. 2002; Wilson and Farber, undated; Costanza, et al. 2008). As such, the storm protection services from coastal land are a predominant ecosystem service with relatively well-defined links to the rest of the economic system.

Increased storm damage in a future without action is also calculated for both stocks and flows for each land loss projection and three particular storms chosen as illustrative examples. The incremental flooding that is assumed to drive the damage was not estimated particularly for this study, but rather as part of the 2012 Coastal Master Plan. We discuss storm selection, flood modeling, and damage estimation in the subsections that follow.

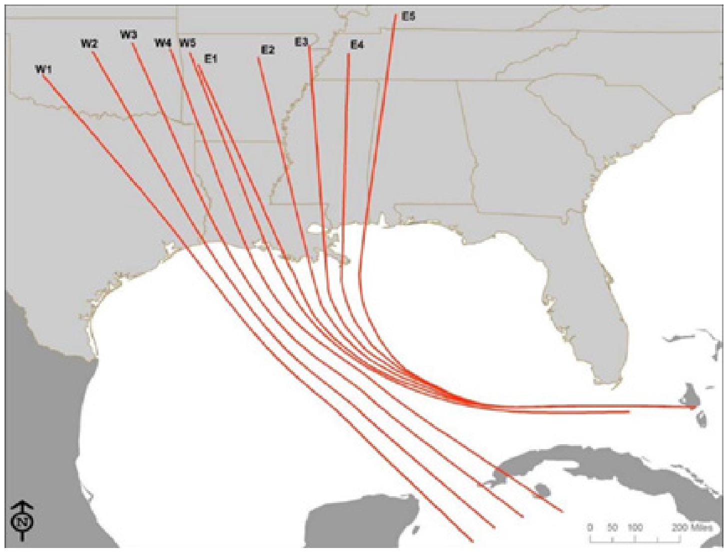
Case-Study Storms

As part of the 2012 Coastal Master Plan analysis, ARCADIS modeled coastal flooding on 40 individual storms following the ten tracks shown in Figure 2.3 under baseline, moderate, and less optimistic scenario conditions (2012 Coastal Master Plan, Appendix D-24, 2012). Four storms per track were modeled which varied by wind and pressure field, resulting in maximum values for storm surge, wave height, and wave period, as well as hydrographs that describe the evolution of the storm surge process (2012 Coastal Master Plan, Appendix D-24, 2012).

To illustrate the potential impacts of degraded storm protection on flooding in Louisiana, the current study team chose two representative storms in conjunction with input from CPRA from these forty to analyze. We chose one eastern track (E2) and one western track (W2) storm to illustrate the differences in damage due to differing storm tracks. The chosen storms had the third-highest wind speed and third-lowest pressure of the storms along each track.

In addition, we modeled the impacts of the "100 year" flood depths, which correspond to the flood depth levels associated with a 1% chance of being reached each year. Given the evolution of the land loss process, the flood depths associated with this probability are scenario-dependent for each time horizon, and found via probabilistic simulation of possible storms over a representative set (see the "Flood Modeling" subsection). Unlike the other two case studies, this case does not fix a particular storm's track and intensity over the land loss projections, but rather fixes the 1% probability and varies the flood depths in accordance with the land loss projections. However, for the sake of exposition, we refer to this case as the "100-year storm."

Figure 2.3. Storm Tracks Used in the 2012 Coastal Master Plan Modeling



Source: 2012 Coastal Master Plan Appendix D-24: Storm Surge/Wave Model (ADCIRC) Technical Report

The chosen storms along each track have wind speed of 57.8 meters per second (or approximately 130 miles per hour), pressure of 900 millibars, landfall winds of 46.7 meters per second (or approximately 105 miles per hour), landfall pressure of 918 millibars, pressure scale radius of 21.8 nautical miles, and forward velocity of 11 knots (see Table 3 in 2012 Coastal Master Plan Appendix D-24, p. 15).

The three case-study storm events are thus defined by:

1. **Storm 18 (Eastern Track Storm):** This case-study storm has an eastern (E2) track. Storm parameters are fixed with respect to land loss projections.
2. **Storm 218 (Western Track Storm):** This case-study storm has a western (W2) track. Storm parameters are fixed with respect to land loss projections.
3. **The 100-year storm:** Estimate of flooding expected to recur with a 1% probability each year, commonly referred to as the 100-year flood. Storm is not fixed with respect to land loss projections; rather, probability of flooding is fixed at 1%.

Flood Modeling

The Coastal Louisiana Risk Assessment (CLARA) Model, originally developed by the RAND Corporation for the 2012 Coastal Master Plan (Fischbach, et al., 2012; Coastal Master Plan Appendix D25, 2012), can be used to translate the ADCIRC storm modeling developed by Arcadis into maximum flood depths.[2] CLARA uses the ADCIRC results and statistical techniques to generate a suite of "synthetic storms" and uses these in conjunction with probability distributions over the suite to model the expected annual damage of storm activity in each modeled land-loss projection. These projections take man-made infrastructure for storm surge protection (e.g., ring levees) into account and models flooding via a "bathtub" model at the census block level.[3,4] Because CLARA models surge protection infrastructure failures as a stochastic process, we assume flooding from each storm is equal to the median flood depth across a full Monte Carlo simulation of protective infrastructure failures based on default CLARA assumptions. For more information on the CLARA model, see 2012 Coastal Master Plan Appendix D-25: Risk Assessment (CLARA) Model Technical Report, or Fischbach, et al. (2012).

Figures 2.4 through 2.7 show the results of flood modeling for the three storms under each combination of environmental scenario and time horizon. Note that significant portions of New Orleans are assumed to flood only in the less optimistic scenario at 50 years due to infrastructure failure.

---

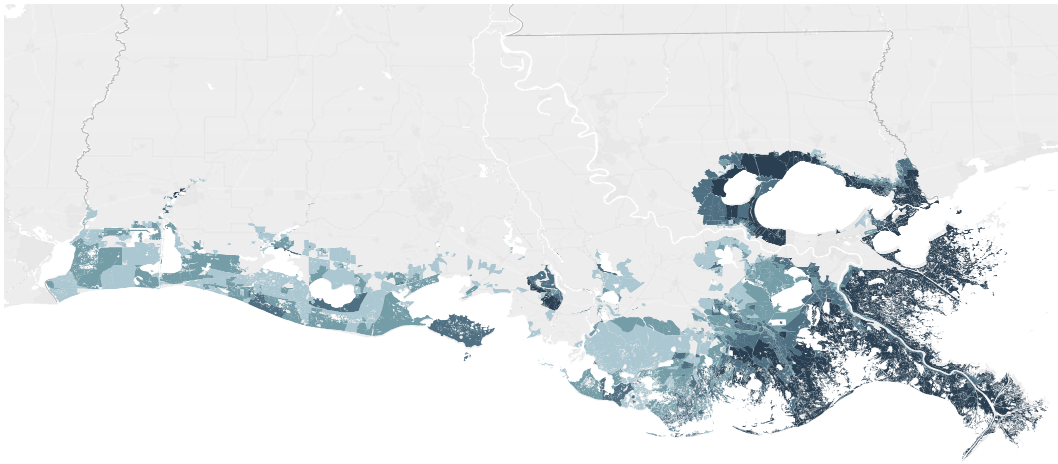
[2] CLARA is a constantly-evolving modeling tool incorporating new techniques and data as they become available. CPRA requested that the study team use the version of the CLARA model used for the 2012 Coastal Master Plan effort.

[3] The study area contains 35,556 census blocks overall.

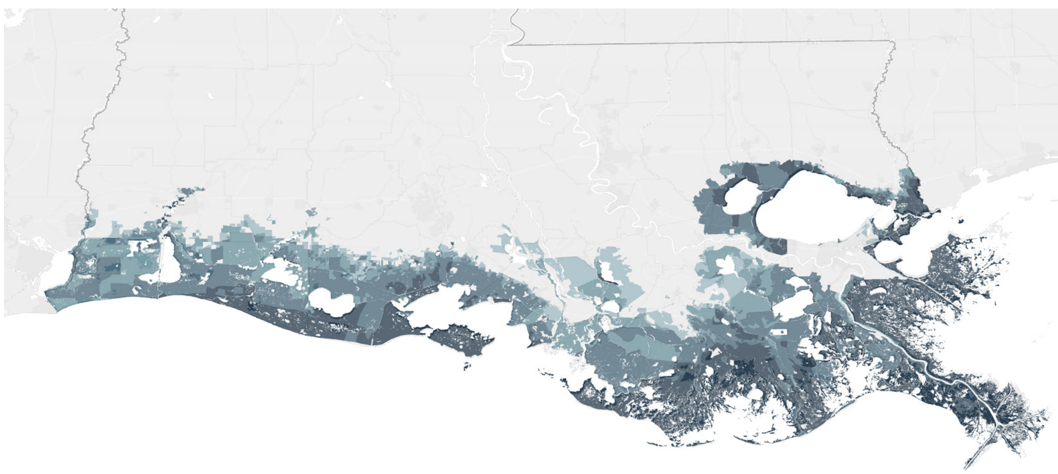
[4] The baseline storm protection systems were those in place as of 2012 in accordance with CLARA current condition assumptions (Fischbach, et al., 2012). In CLARA, protection infrastructure failure is probabilistic; for simplicity in this report, failure rates are assumed at the median for each scenario.

Figure 2.4: Storms in Moderate Environmental Scenario, 25 Year Time Horizon

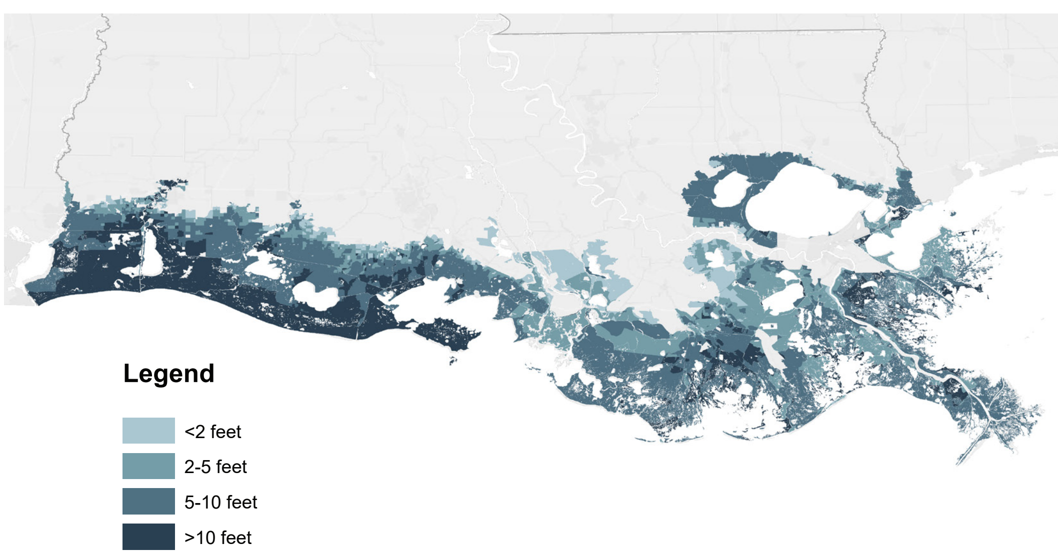
Eastern Storm



100 Year Flood



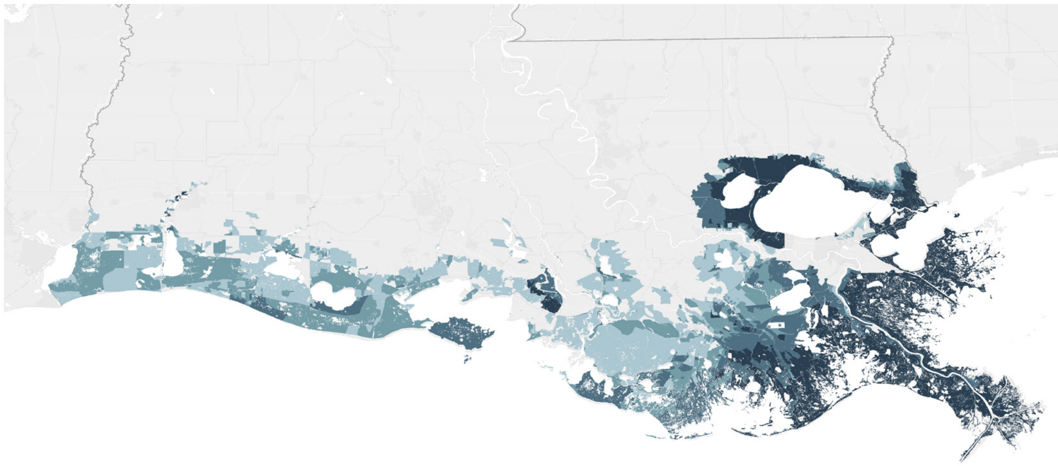
Western Storm



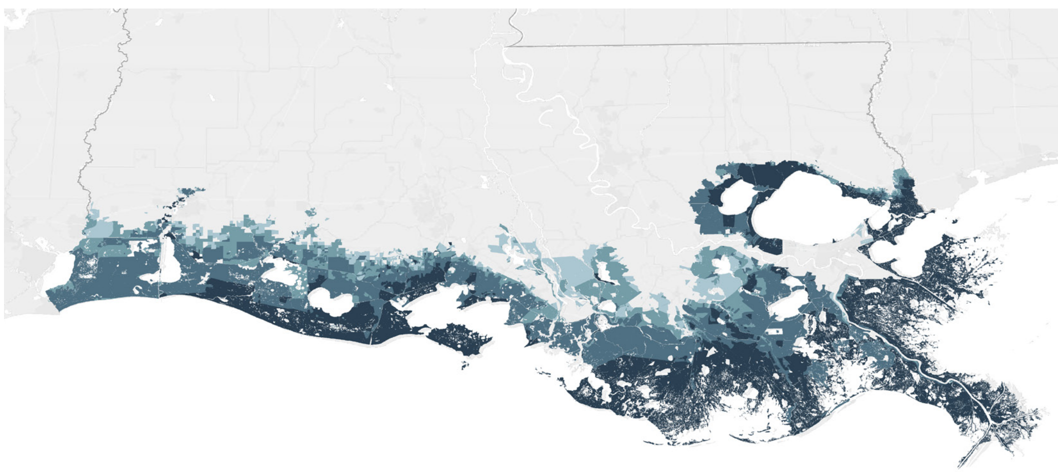
Source: CLARA model output mapped to GIS by authors

Figure 2.5: Storms in Moderate Environmental Scenario, 50 Year Time Horizon

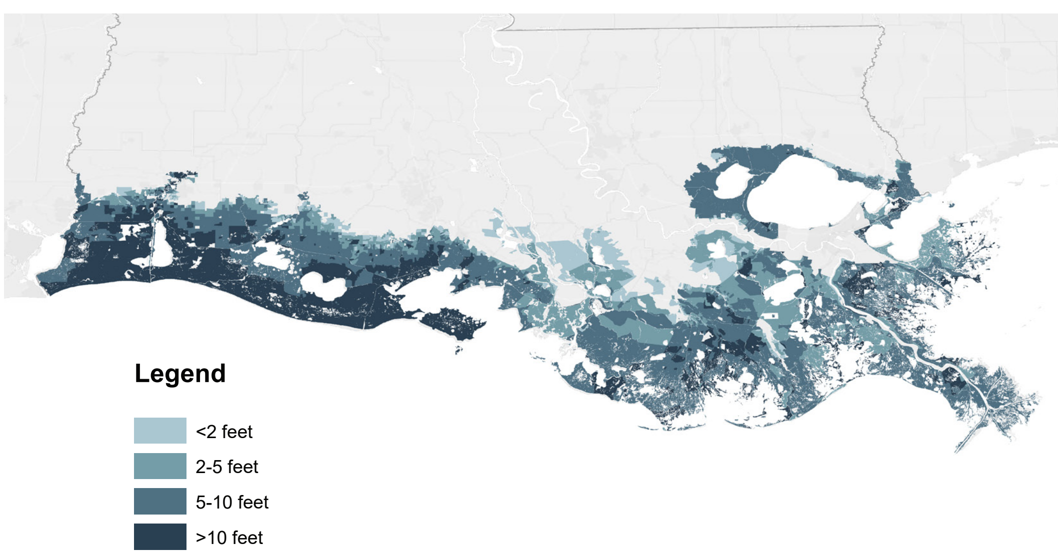
Eastern Storm



100 Year Flood



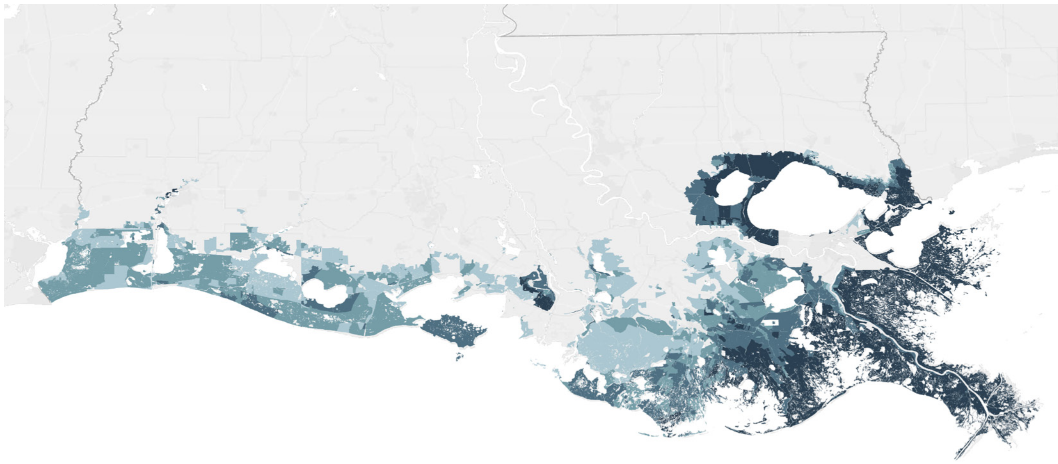
Western Storm



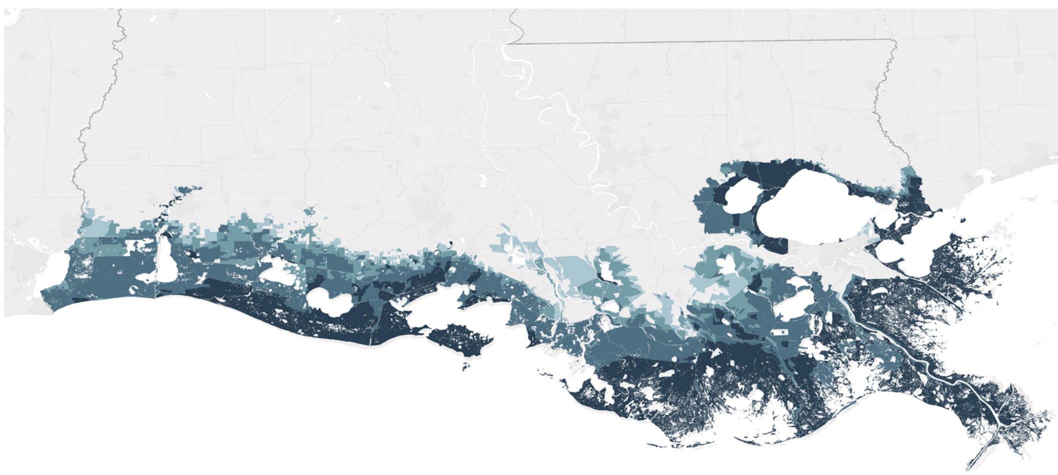
Source: CLARA model output mapped to GIS by authors

Figure 2.6: Storms in Less Optimistic Environmental Scenario, 25 Year Time Horizon

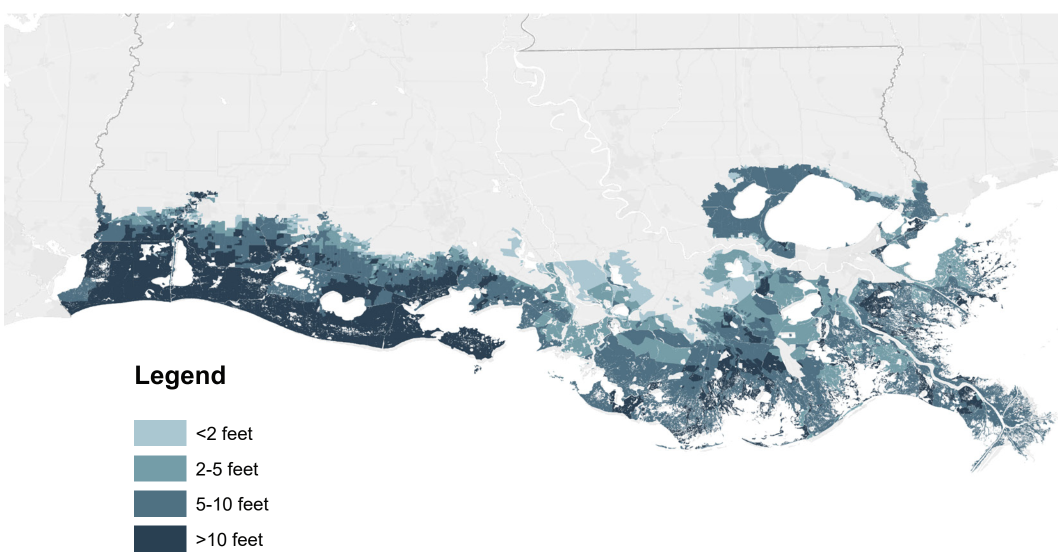
Eastern Storm



100 Year Flood



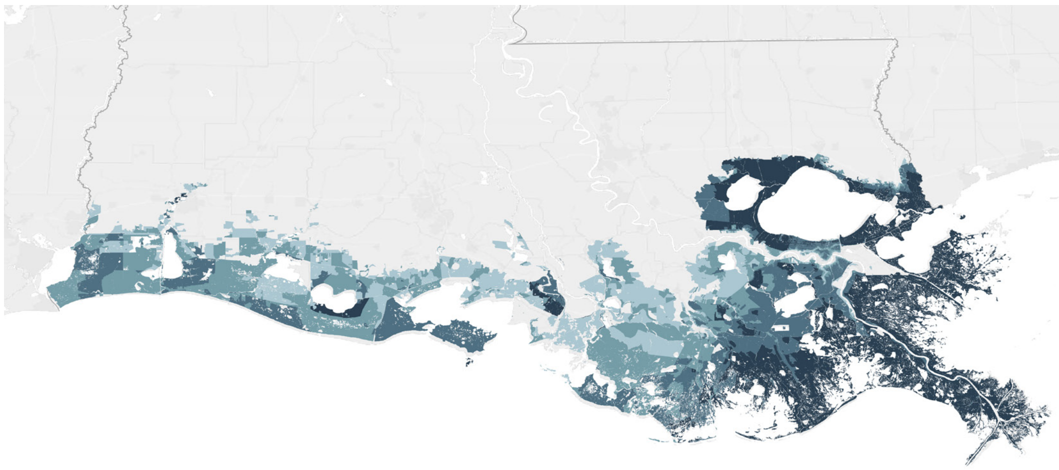
Western Storm



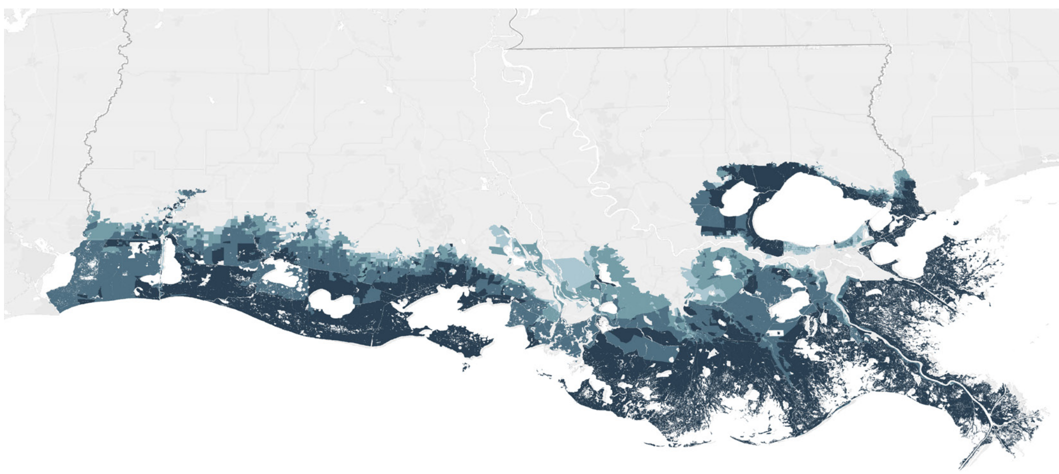
Source: CLARA model output mapped to GIS by authors

Figure 2.7: Storms in Less Optimistic Environmental Scenario, 50 Year Time Horizon

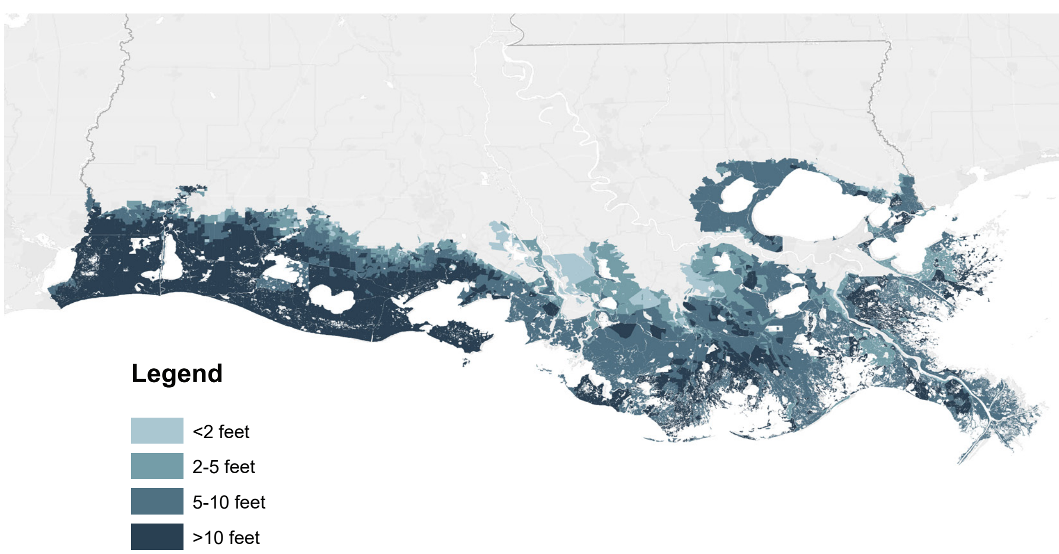
Eastern Storm



100 Year Flood



Western Storm

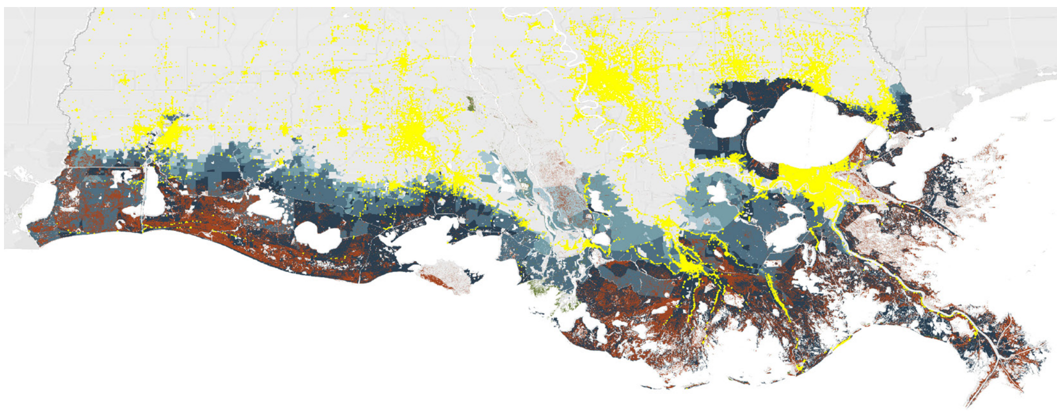


Source: CLARA model output mapped to GIS by authors

Capital Stock Location Relative to Land Loss and Flooding

Figure 2.8 shows the relative location of non-residential capital stock across the coast overlaid on a representative land loss model (the less optimistic scenario at 50 years) and flooding output (100-year storm in the less optimistic scenario at 50 years). As can be seen in the map, the capital stock is not evenly distributed across the coast, but clustered in relatively protected urban areas like Houma-Thibodaux and New Orleans, and along major highways.

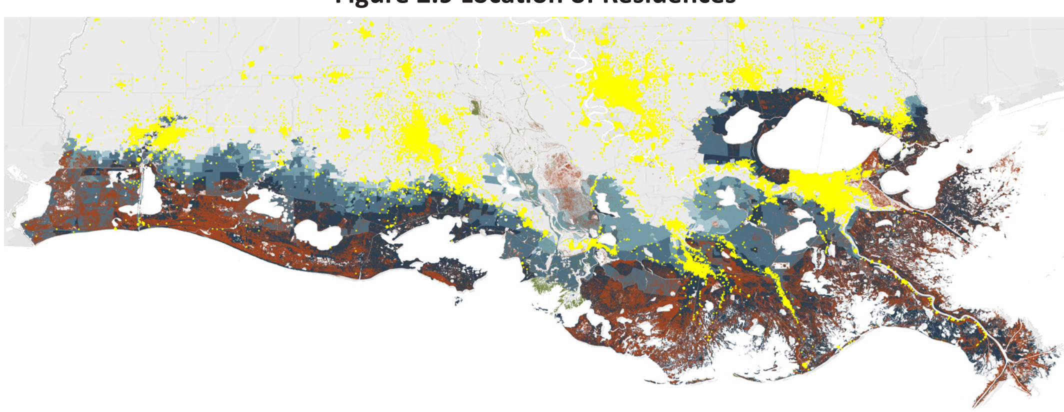
Figure 2.8 Location of Non-residential Capital Stock



Source: InfoUSA establishments (yellow), CLARA model flooding (blue), and CPRA land loss model (red) mapped to GIS by authors.

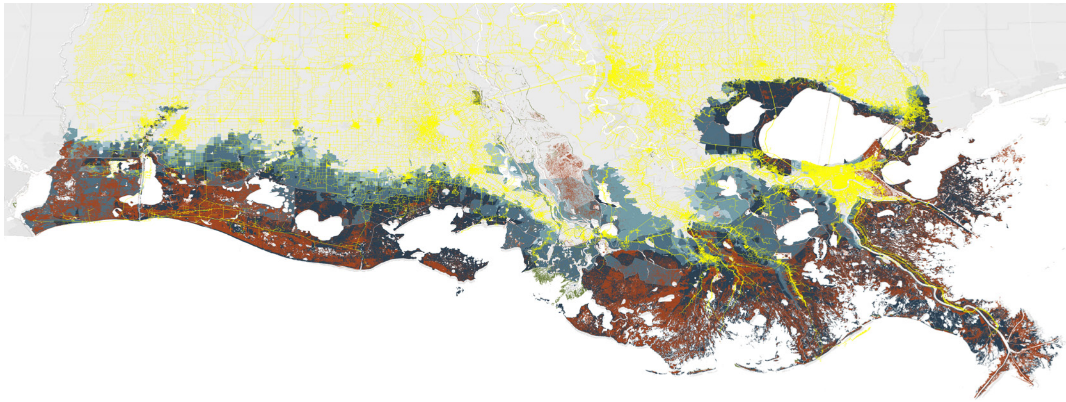
We assume that the location of residential buildings is tied to nighttime population as given by LANDscan data. Nighttime population is shown in Figure 2.9 over the representative land loss and flooding map. Residences follow the same pattern of non-residential capital stock, with clusters in urban areas and along highways.

Figure 2.9 Location of Residences



Source: LANDscan population (yellow), CLARA model flooding (blue), and CPRA land loss model (red) mapped to GIS by authors.

Figure 2.10 Location of Network Infrastructure



Source: LADOTD roads (yellow), CLARA model flooding (blue), and CPRA land loss model (red) mapped to GIS by authors.

The network of roads and highways is shown in Figure 2.10 over the representative land loss and flooding map.

Storm Damage Estimation

Increased storm damage from land loss in a future without action is calculated for both stocks and flows on the basis of the predicted flood depths and timing of economic disruptions, both of which are outputs of the CLARA model. For capital stocks, we use default, structure-specific depth-damage curves in CLARA (unless otherwise indicated) to compute proportional damage to the stock and associated replacement costs. For economic flows, disruption times are used to estimate lost sales and wages.

The analysis of the increased storm damage follows the following steps:

1. **Estimate Flood Depths.** This process is described in the previous subsection.

2. **Identify locations of capital stock and activity.** The census block of each stock or flow is calculated in order to remain consistent with the flooding output. The data used for each group of capital stock or activity is discussed in detail in the appropriate subsections of Chapter 3.

3. **Calculate damage or value of disruption.** Conditional on estimated flood depth at the location of each stock or flow, the depth-damage curves or disruption times are used to estimate the effect of flooding.

Because our focus is on the economic consequences of environmental changes, we report the increase in storm damage relative to expected baseline flooding under current conditions. Therefore, all results presented in storm damage sections represent the damage in a future without action minus damage from an identical storm using current land conditions.

These estimates represent potential short-term losses. Capital stock and activities affected may not close permanently, but may need repairs or experience temporary business interruptions. Economic activity generally picks up again after a brief interruption implying that the major effects of a storm are temporary. However, storm damage can also cause more lasting, or even permanent losses if damage or disruption is severe enough to cause some businesses to fail to reopen.

We use these methods in Chapter 3 to estimate the capital stocks and economic activity at risk from land loss and assicated incremental storm damage.

3 Capital Stock and Economic Activity at Risk

In this chapter, we document the direct and storm-protection effects of land loss on capital stocks (assets) and economic activity (flows) in the state of Louisiana. In the first section, we define key terms and document the data and class-specific methodology we use for estimating the effects of land loss on each capital stock type and on the economic activity of business establishments. We then report estimates of the capital stock and economic activity at risk from land loss and estimates of the increased storm damage costs to residences, establishments, and network infrastructure as a result of the predicted changes in coastal land.

The contributions of at-risk establishments to the state and national economies and the impact of economic disruptions due to the storm events on state and local economies are reported in Chapter 5. All estimates of value at-risk are in real 2012 dollars.

Defining Assets (Physical Capital Stocks) and the Movement (Flows) of Commodities

Some of the land predicted to be lost accommodates physical assets. We identify *assets* as *physical capital stocks*. These include residential and non-residential buildings and network infrastructure. The economic activity supported by these assets is identified as economic flows. Over a timeline of 25 to 50 years, governments and private economic actors may adapt through mitigating behaviors, such as relocating further inland, making it inappropriate to assume land loss would result in the elimination of all assets and activity on that land. Therefore, this study only quantifies the assets and major economic flows that are “at risk” from land loss. The estimates presented in the study should be interpreted as the maximum annual potential damage from land loss (not including storm damage), though it is most likely that only a fraction of these costs will be incurred in the future.

Network infrastructure also supports economic activity through the flows of goods and services that are enabled by these stocks. In particular, intra and inter- state trade is enabled by these networks, with well-functioning non-congested infrastructure allowing for the movement of goods and services at a lower cost than degraded, congested networks. Land loss and the loss of storm protection services will undoubtedly affect future commodity and service flows (and thus supply chains); however, the nature of these changes is complex and depends on a number of different factors. The Transportation Research Board of the National Academies suggests the following steps in best-practice estimation of the economic effects of network system disruptions (NCHRP, 2012, p. 10):

> 1. Gather as much data as possible about flows across the network, disaggregated by mode, industry, and commodity.
>
> 2. Compute short-term direct effects based on analysis of route and mode diversions; Direct effects include transport and inventory costs from longer and slower routes and differences in costs by mode.
>
> 3. Compute additional direct effects for additional shutdowns and disruptions.
>
> 4. Calculate indirect effects through input-output or other relevant economic models.
>
> 5. If possible, provide a more in-depth analysis based on more detailed dynamic behavioral responses.

We opted not to speculate on specific rerouting behavior in our analysis of land loss and increased storm damage effects. There is substantial uncertainty about future mitigation behavior with respect to network infrastructure and land loss. . This includes uncertainty related to short-term substitution behavior of Louisiana and rest-of-world transporters with respect to both direct land loss and storm disruptions; it also includes the extent of damage to the non-residential structural stocks in Louisiana, which would disrupt business activity and possibly lead to double-counting of the damage from storms. For these reasons, we chose not to try to predict how economic actors would change or adapt their route choices.

Rather, in Chapter 5, we report information about the movement of commodities by mode and data on trade between Louisiana, the rest of the country, and the rest of the world. Given potential changes in either a) costs associated with maintaining navigability in the waterways; or b) costs borne by shippers for using altered routes, at least some trade flows would be indirectly influenced by the land loss process. The extent of these changes will depend on the overall cost changes associated with transport by water relative to other modes, which we do not forecast. In addition, we use input-output analysis to model the indirect and induced effects of the complete loss of at-risk businesses as well as the impacts of storm disruptions on the rest of the country. To the extent that disruptions in network infrastructure would result in additional general equilibrium effects in Louisiana or affect businesses not directly impacted by storm disruptions, the latter may be underestimated.

Land Loss: Data and Methodology

We first estimate the economic assets and activity that reside on land that may be lost in a future without action. In this section we describe the data sources we draw on for these estimates and the approach to calculating the potential assets and activity at-risk. Land loss along the coast will result in the potential loss of land upon which residential, non-residential, and network infrastructure, as well as buildings and capital stock owned by the public.

Non-residential Capital Stock

To analyze non-residential structures, we evaluated and compared several datasets for locations of businesses and other sources of economic activity to assess the accuracy of the data as well as the usefulness for this effort given the degree of geographic detail available.[5] While data sources based on state and federal administrative employment tax records provide some of the highest quality measures of economic activity, each has a slightly different scope of coverage and confidentiality restriction which limits the degree of geographic detail that is readily available. Among sources with finer geographic detail, we determined that the Info-USA database provides the most accurate data on business activity. These data includes information on the location of private businesses, government agencies, and the self-employed. For each record, these dataset contains a latitude and longitude of the establishment geocoded by its physical address to a location on a street. It also includes information on a number of employees, annual sales volume, and square footage of the facility. For more information on other data sources considered, see Appendix A.

Because the geocoded addresses are one-dimensional points located on a road, we had to approximate the location of the facility in relation to the road. We define an approximate establishment area as the land surrounding the geocoded address within 90 meters of the road and on the same side of the road as the address.[6] We consider establishments to be directly at risk from land loss if the approximate establishment area intersects with the land loss map so that at least a portion of the establishment area lies within the area of predicted land loss.

One final step screens out potential establishments that overlap with a low-density area of loss or may be only marginally affected. Specifically, for establishments whose locations overlap the land loss map, we assume that private mitigating actions will prevent losses if less than 5% of the area within a quarter mile of that establishment is lost.

Replacement costs were taken from the Federal Emergency Management Agency's HAZUS-MH model documentation (Table 14.1), which provides cost estimates per square foot by class of structure and updated to 2012 dollars using the GDP price deflator. HAZUS-MH is a multi-hazard loss estimation methodology and tool used to predict damage for earthquakes and floods.

Residential Capital Stock

There is no readily available, coast-wide geo-referenced database available for the analysis of residential structures at risk. In addition, the residential structure estimates contained in the CLARA model used to support the 2012 Coastal Master Plan are based on older, pre-Katrina stock levels. These issues necessitate a different approach to identifying residential capital stock at-risk compared to non-residential forms of capital.

To estimate a spatial inventory of residential stocks, we use a methodology based on combining two data sources: the 2010 American Community Survey (ACS) five-year housing structure estimates from the U.S. Census Bureau, and the 2012 LANDscan population estimates. The former provides census-tract level estimates of housing stocks by building

[5] Data sources reviewed include County Business Patterns (U.S. Census Bureau), Quarterly Census of Employment and Wages (Louisiana Workforce Commission), OnTheMap (U.S. Census Bureau/state administrative data), HAZUS-MH (FEMA), Dun & Bradstreet (commercial dataset), and Info-USA (commercial dataset).

[6] As a sensitivity test, 30 meters and 60 meters were considered as well. Visual inspection in select areas of the number of buildings captured within each of these radii led us to select 90 meters as a preferred range that captured most businesses without adding a significant amount of erroneous overlap with the land loss map. Meters are the standard unit of distance in GIS software applications.

type and occupancy status, as well as average occupancy rates. The latter provides geospatial estimates of population distribution at a sub-tract level (more specifically, in cells of 100x100 meters), which can then be used to aggregate into sub-tract geographies.

To estimate spatially-specific residential housing stock estimates, we calculate the average value of stocks per person by census tract from the ACS data using Census estimates of occupancy, owner-occupied housing value, average rents (for rented property), and estimated vacancy. These tract-level estimates are then multiplied by estimated population from the LANDscan data to obtain 100x100 meter estimates of the value of housing stock in the study region.

To obtain estimates of the value of residential stocks at risk from direct land loss, the land loss maps provided by CPRA are overlaid onto the LANDscan data to identify cells predicted to be affected by the land loss process. For each affected cell, the proportion of cell lost is calculated, and this proportion is multiplied by the estimated residential stock value for that cell to obtain the estimate of the residential housing stock at risk. Values were updated to 2012 using the GDP price deflator. [7]

This methodology implicitly assumes a uniform distribution of housing within each LANDscan cell. If, as expected, land loss is negatively correlated with elevation, and the value of residential housing stocks is positively correlated with elevation (i.e., housing stocks tend to be on higher ground), then the measure of housing structures at risk will be overestimated. However, it should offer an improvement over assuming a uniform distribution of structures within an entire census block or tract via the inclusion of spatially-explicit population information. It also uses updated information on estimated housing stock values post-Katrina.

Network Infrastructure

For network infrastructure, we calculate the miles of infrastructure in the predicted area of land loss for each projection for roads, rail, and pipelines. For roads and rail, we also estimate replacement costs. For more detail on data and methodology for these topics, see Appendix A: Network Stocks and Flows.

For pipelines, it is less obvious what the exact effect of land loss will be. Although we can calculate the miles of pipelines newly exposed to the elements and more vulnerable to cracking and maintenance problems, there is a lack of literature on expected damage caused by exposed pipelines. Therefore, we cannot estimate what these additional costs will be. We thus, only display miles of pipeline exposed and do not quantify future costs. Discussion of the value of pipelines to Louisiana and the nation and how they are affected by land loss can be found in Appendices C and D and in Chapter 5.

Finally, we do not specifically articulate damage to communications infrastructure (such as telephone or cable lines) given significant uncertainty about the degree to which land loss will directly or indirectly affect these capital stock. However, as many of these lines will likely

[7] A second method in which buffer areas around roads were calculated for each Census Block used by the CLARA model, and all housing was assumed to lie within these buffers, was tested by the study team. This methodology also assumes a uniform distribution of housing stocks within the buffer zones. For 30 meter and 90 meter buffer zones, the total calculated at-risk stock percentages were 0.32% and 0.52% for the less optimistic scenario at 50 years. The method using the LANDscan data resulted in an estimate of 0.29% of total estimated stock in affected regions. Given a lack of empirical data on the proper width of the buffer zone and the specificity of the spatial distribution of the estimates, we chose to use the LANDscan methodology.

follow the rights-of-way associated with roads and rail, the estimates of miles affected presented for these capital stock may provide a proxy estimate for the extent of this type of infrastructure that is at risk.

Economic Activity

Using data from Info-USA and the selection method described for selecting non-residential structures at risk, we report the employment and sales volume of all establishments affected by land loss to estimate total employment and sales at risk directly from land loss under the four land loss projections. A second source of data, County Business Patterns (CBP), is used to estimate wages for lost jobs in this area. The average annual salary by parish from CBP is multiplied by total employment affected by land loss in that parish to estimate at-risk wages in the affected area.

Land Loss: Results

Non-residential Structures Results

Table 3.1 shows that total replacement costs for non-residential structures for establishments at risk lay between $1.5 billion and $2.2 billion, depending on the scenario and time horizon. Furthermore, between 800 and 1,200 establishments are directly at risk due to land loss. In terms of both number of establishments and total replacement costs under both scenarios, the effect over time is non-linear, in that the number/cost for the first 25 years of the planning horizon is greater than the additional number/cost for the second 25 years.

The largest industries in the affected area include Retail Trade, Construction, Transportation and Warehousing, Accommodation and Food Services, and Other Services. Compared to the entire coastal region, this area has a relatively larger number of businesses in the Construction, Transportation and Warehousing industries and a relatively smaller number of businesses in the Professional, Scientific, and Technical Services and Health Care and Social Assistance industries. Most of these businesses are small, with an average of 10 employees.

Table 3.1

Non-Residential Structures at Risk from Land Loss

Environmental Scenario	Time Horizon	Establishments	Total Replacement Costs ($ millions)
Moderate	25 year	810	$1,500
Moderate	50 year	960	$1,800
Less Optimistic	25 year	970	$1,800
Less Optimistic	50 year	1,200	$2,200

Source: Uses HAZUS-MH square footage by business class unless it contradicts InfoUSA square footage data, in which case endpoints of InfoUSA square footage class most consistent with HAZUS-MH square footage is used. Replacement costs from HAZUS-MH documentation (Table 14.1) and updated to 2012 using the GDP price deflator from BEA. Note: All monetary values presented in 2012 dollars.

Table 3.2

Residential Structures at Risk from Land Loss			
Environmental Scenario	Time Horizon	Number of Structures	Total Replacement Costs ($ millions)
Moderate	25 year	2,100	$310
Moderate	50 year	2,500	$360
Less Optimistic	25 year	2,700	$380
Less Optimistic	50 year	3,700	$510

Source: Authors' calculation based on per-person estimates of residential housing stock values from the U.S. Census American Community Survey and spatial distribution of nighttime population levels from LANDscan. Note: All results presented in 2012 dollars.

Residential Structures Results

Table 3.2 shows that total replacement costs for residential structures at risk are between $310 million and $510 million. Total estimated baseline residential stocks for the state of Louisiana are approximately $260 billion (approximately 1.9 million housing units), suggesting that between 0.1 and 0.2% of the value of the state's fixed residential structures are at-risk from land loss.[8] As with non-residential structures, most of the at-risk housing stock is threatened in the first 25 years for each environmental scenario. Comparing these results with non-residential structures, the value of establishment structures directly at risk are estimated to be approximately 4.5 to 5 times that of housing structures.

Network Infrastructure Results

The results in this subsection focus on the value of the stock of at-risk network infrastructure directly resulting from the loss of land. In general, we take the current inventory of infrastructure and estimate the dollar value that is at-risk of damage or destruction from the conversion of land to water absent any additional mitigating behavior. Information about the economic flows that are enabled by network infrastructure is discussed in Chapter 5.

Roads and Highways

Miles lost and replacement cost for roads and highways are presented in Table 3.3, based on data from the Louisiana Department of Transportation & Development (LADOTD). At the low end, nearly 200 miles are at risk under the moderate scenario at the end of 25 years with an estimated replacement cost of $220 million. At the high end, approximately 600 miles are at risk under the less optimistic scenario at 50 - years with an estimated replacement cost of $700 million. We use replacement cost to value these roads; however, some of these losses are permanent losses, or may require a bridge or elevated highway to repair the roadway completely, which may involve a greater cost than replacing a ground-level highway. As such, these replacement costs should be considered a lower bound.

[8] Due to the lack of geospatial residential structure information, the estimated number of structures is based on average housing stock per resident at the Census Block level and the number of structures reported in the American Community Survey. If there are differences in average values for those properties at-risk due to land loss relative to the rest of the census block, then the structure count will be biased.

Table 3.3

Roads at Risk from Land Loss			
Environmental Scenario	Time Horizon	Miles Lost	Total Replacement Costs ($ millions)
Moderate	25 year	190	$220
Moderate	50 year	280	$320
Less Optimistic	25 year	300	$340
Less Optimistic	50 year	580	$700

Source: Based on road distribution type and repair/replacement cost information obtained from LADOTD.
Note: All monetary values presented in 2012 dollars.

There are two areas of land loss near heavily traveled and strategic highways that we highlight specifically: Louisiana Highway 1 between Golden Meadow and Leeville, and I-10 near New Orleans before the Twin Spans over Lake Pontchartrain. These roads will be particularly vulnerable to land loss over the next 25 to 50 years. For more information on data, methodology, and these two highways, see Appendix A: Networks Stocks and Flows.

Rail

Data on rail infrastructure was sourced from the National Transportation Atlas Database (NTAD) 2014, published by the U.S. Department of Transportation's Bureau of Transportation Statistics. Replacement costs were sourced from HAZUS-MH.

Rail losses are much smaller than road losses because there are fewer miles of railway track in the state. Table 3.4 displays miles of track lost and replacement value of the track. The replacement cost of rail infrastructure at risk from land loss is between $28 million and $48 million depending on the land loss projection.

Table 3.4

Rail at Risk from Land Loss			
Environmental Scenario	Time Horizon	Miles of Track	Total Replacement Costs ($ millions)
Moderate	25 year	11	$28
Moderate	50 year	14	$33
Less Optimistic	25 year	15	$36
Less Optimistic	50 year	20	$48

Source: Based on infrastructure inventory data from NTAD2014 and replacement estimates from HAZUS-MH.
Note: All monetary values presented in 2012 dollars.

Pipelines

Louisiana's coast has a vast network of pipelines, almost entirely privately owned, that have been built over many decades to support offshore oil and gas activity as well as the Louisiana Offshore Oil Port (LOOP). In a future without action, some pipelines not designed to be in open water will become exposed. These pipelines will be more vulnerable to damage from vessels and scouring by wave action, which will create a need for more maintenance, repair or replacement. Damage to these pipelines could not only result in environmental damage, but also create disruptions to the oil and gas-related businesses that rely on this critical infrastructure.

Reliable studies that quantify the increased vulnerability from exposure could not be found. However, to provide a sense of how widespread this potential risk may be, we measure the number of miles of pipeline that will be exposed in a future without action and present those results in Table 3.5. The number of miles of pipeline exposed by land loss is detailed by pipeline commodity and by pipeline size; the larger the pipeline, the greater the flow of commodities through it. For comparison, there are approximately 46,500 miles of pipeline in Louisiana, so the estimates in Table 3.5 range from 1% to 3.5% of total pipeline mileage in the state.

Table 3.5

Miles of Pipeline Exposed by Coastal Land Loss

	Moderate, 25 Year	Moderate, 50 Year	Less Optimistic, 25 Year	Less Optimistic, 50 Year
Commodity				
Natural Gas	360	570	570	1,100
Crude Oil	140	240	200	360
LPG/NGL	87	120	110	170
Petrochemical	14	17	19	43
Refined Products	12	18	14	24
Other	2	3	2	3
Diameter (inches)				
Less than 20	400	630	600	1,100
20-36	210	320	310	600
More than 40	6	9	9	25
Total Miles of Pipeline	610	960	910	1,700

Source: Based on infrastructure inventory data from the LSU Center for Energy Studies and valuation data from the Center for Energy Studies.

To further characterize the potential damage associated with increased pipeline exposure, we investigated oil spill notifications from the U.S. Coast Guard's National Response Center (NRC). Between 1990 and 2012, there were 1,870 pipeline-related oil spill notifications generated by Louisiana. Of that total, 1,565 spill notifications were in the 24 coastal parishes that are the focus of this study. When reported to the NRC, many of these incidents are identified as being caused by corrosion, a result of aging infrastructure reaching the end of its useful life. However, there were 58 spill notifications between 1990 and 2012 that were attributed to exposure or a storm-related event. Specific causes for these pipeline-related spill notifications include vessels hitting a pipeline or pipe movement caused by a storm, including eleven notifications associated with Hurricane Katrina damage. In a future without action, the existing pipeline network will become increasingly exposed and pipeline-related spills are likely to increase.

On average, the 58 storm-related spill notifications reported less than a barrel of oil spilled, the largest being an estimated 1,000 barrels from a pipeline damaged by Hurricane Gustav. The NRC data suggest that pipeline spills are sometimes not detected until much later than the event that caused the spill. In the case of a small leak or a leak that was reported significantly after the spill began, reported volumes may not accurately reflect the actual amount spilled. However, historical data suggest that the volumes spilled from pipelines are relatively low. If a spill is contained quickly, it is still possible for an exposure-related event to create larger impacts if commodity flows are disrupted for extended periods of time. The high value of commodities flowing through these pipelines (which is discussed in detail in Appendix D) elevates the importance of this increase in vulnerability. However, the lack of data quantifying the probability of such a disruption prevents us from formally estimating these effects.

Economic Activity

Info-USA data include estimates of the number of employees and sales volume at each establishment in the database. We use these data in conjunction with the at-risk businesses identified for each land loss projection to determine the employment and sales volume directly at risk from coastal land loss. Should all or a portion of these businesses relocate out of the region or state due to the threat of land loss, these losses can be interpreted as permanent, because the jobs and output are permanently removed from the regional economy.[9] Government establishments and public institutions are not included in the data. Disruptions to trade flows are discussed in Chapter 5.

Table 3.6 shows total establishments, direct employment, and sales volume in the state and in the coastal parishes as a baseline according to Info-USA data. Of the approximately 170,000 establishments in the state of Louisiana, approximately 57% are located in coastal parishes. These coastal businesses constitute 57% of employment in the state and 63% of sales.

[9] The decision to mitigate or relocate a business due to the threat of land loss is a micro-level decision that will depend on individual preferences, the extent of the threat, and other financial, economic, and environmental factors. The count of business establishments identified as "at risk," as well as their employment and sales, is an upper bound on the direct losses that could be attributable to the land loss process.

Table 3.6

Total Establishments, Direct Employment, and Annual Sales Volume in State and Coastal Parishes

Area	Establishments	Employment (millions)	Sales Volume ($ billions)
Louisiana, Statewide	172,000	2.0	$430
Coastal Parishes Only	98,000	1.2	$270

Source: Based on Info-USA data for business establishments. Government institutions are not included in sales figures. Note: All monetary values presented in 2012 dollars

Table 3.7 summarizes total establishments, employment, and sales volume of the businesses on land that is expected to be lost, as described in methodology. The range of total employment directly at risk from land loss is between 0.8% and 1.1% of total coastal employment, with between $2.4 billion and $3.1 billion of sales (approximately 1% of total coastal sales) at risk.

Table 3.7

Economic Activity at Risk: Establishments and Sales Volume

Environmental Scenario	Time Horizon	Establishments	Total Replacement Costs ($ billions)
Moderate	25 year	810	$2.4
Moderate	50 year	960	$2.6
Less Optimistic	25 year	970	$2.6
Less Optimistic	50 year	1,200	$3.1

Source: Based on Info-USA data for business establishments. Sales volume is defines as the total value of output from establishments. Government institutions are not included in sales figures. Note: All monetary values presented in 2012 dollars.

Table 3.8 displays estimates of wages from lost jobs, in terms of annual payroll. Between $410 million and $580 million of annual payroll is directly at risk from coastal land loss.

Table 3.8

Economic Activity at Risk: Employment and Annual Payroll

Environmental Scenario	Time Horizon	Employment	Total Payroll ($ millions)
Moderate	25 year	8,800	$410
Moderate	50 year	9,700	$450
Less Optimistic	25 year	9,800	$460
Less Optimistic	50 year	12,200	$580

Source: Based on Info-USA data for business establishments and County Business Patterns for wages. Government institutions are not included in sales figures. Note: All monetary values presented in 2012 dollars.

Storm Damage: Data and Methodology

In the following subsections, we review the methods used to estimate increased damage related to the capital stock and disruption to economic activity .as a result of increased flooding for the case study storms. The basic categorization of damage into those related to capital stock and those related to economic activity is similar to the land loss analysis. However, disruptions to economic activity can be significantly reduced with some additional capital-related expenditures to allow businesses to operate at a temporary location while the primary location is being repaired or rebuilt. Because of the interdependency of capital-related costs and activity-related costs of storms, we discuss the two types of damage together in laying out the methodology for estimating costs. Flood model data is drawn from the CLARA model. For more information about the CLARA model, see Fischbach, et al. (2012) and Coastal Master Plan Appendix D25 (2012).

Capital-related Costs and Disruptions to Economic Activity

The general methodology followed in calculating storm damage follows an adjusted HAZUS-MH methodology. HAZUS-MH measures "direct economic losses" – the cost of repair and replacement of damaged and destroyed buildings, the cost of damage to building contents, and losses of building inventories. HAZUS-MH also estimates "indirect economic costs," which are losses related to the length of time the facility is non-operational. The four indirect economic costs calculated by HAZUS-MH are business disruption losses (a measure of the loss of services or sales), wage loss, relocation expense (the cost to move operations to a temporary location while the usual building is being repaired, which we will henceforth term "temporary location cost"), and rental income loss to business owners. Post-storm clean-up costs can also be estimated using the HAZUS-MH methodology. We supplement HAZUS-MH with Louisiana-specific data, which allows us to select only the most reliable estimates of damage from HAZUS-MH and minimize the potential for double counting while providing the most complete picture of potential damage possible as described in this section.

The value of non-residential structures is estimated from the square footage of businesses in the Info-USA database and the HAZUS-MH estimates of degree of damage associated with a given flood depth for each business. The value of residential structures by census block was estimated using information from the 2010 ACS and 2012 LANDScan population data as described in the data and methods section earlier in this chapter. We use this information in conjunction with depth-damage curves and distributions of structure and foundation types in the CLARA model, as well as estimates on residence contents, to estimate flood damage from each of the three storms under the four land-loss projections (see Fischbach, et al. 2012 for more details on CLARA assumptions).[10]

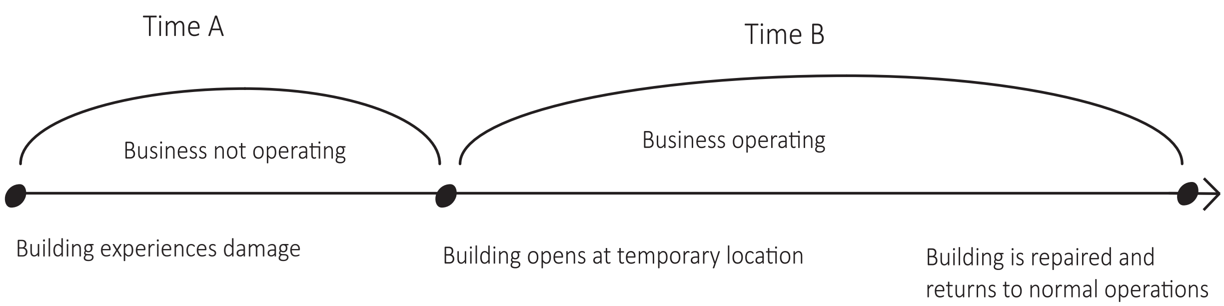
For network infrastructure, we estimate damage and replacement costs from flooding of roads and rail. For more detail on damage curves or methodology for these topics, see Appendix A: Rail and Road Depth-Damage Curves. Like direct land loss, the exact cost of flooding on pipelines is not measured, though the length of pipelines flooded is calculated. Discussion of value of pipelines and the effect

[10] The storm damage estimates are based on improved levee and other infrastructure, as described in Fischbach et al. (2012), but the model allows for infrastructure failure.

of storms on pipelines and the oil and gas industry can be found in Appendices B, C, and in Chapter 4: Gasoline Prices after a Storm.

Storm damage typically leads to disruptions in business activity, which can range from short-term closures to business failure. Losses associated with business interruption depend on the length of time a facility takes to repair. Some of these losses may be offset by private insurance for business interruption claims, which is not explored in this report. To calculate business interruption losses, we use information from FEMA's HAZUS-MH modeling methodology and tool, embedded within the CLARA model, to identify repair time based on industry type and amount of damage as the "loss of function" time – the amount of time it takes a business to assess damage, make decisions, find alternate locations for temporary operations while the business is repaired, and restart operations in a temporary location. We call this period of time while the business is non-operational "Time A" in the schematic in Figure 3.1. For the rest of the time the building is being repaired – "Time B" – it is assumed that the business operates in a temporary location.

Figure 3.1: Schematic Representation of Business Recovery after a Storm



To calculate income losses in both sales and wages, we assume the business earns 0 sales/wages during Time A and 100% of sales/wages, plus a recapture factor, during Time B. The recapture factor represents a percentage of sales during the period of loss that can be made up by working overtime or extra shifts once full operation is resumed in Time B. The default recapture factor varies by industry, ranging from 51% to 98%. For example, retail trade has a recapture factor of 87% while heavy industrial has a recapture factor of 98%. However, the additional costs of paying employees overtime, or accelerated depreciation from running equipment at higher than normal rates is not considered, suggesting that the true costs of disruptions would be understated when using the default recapture factors.

For a short disruption, such as one week, a large recapture factor is reasonable. Over longer periods of time, the ability to recapture lost activity without significant additional costs breaks down. We extract estimates of Time A for each business class from HAZUS-MH. According to the technical manual, default HAZUS-MH recapture factors are only applicable for approximately 3 months. Since the median length of Time A for all damaged businesses in all cases is 5.4 months due to the severity of damage in the three storm cases, we present a range for sales and income losses that assumes on the low end that default recapture factors apply across all of Time A and on the high end that recapture factors are 0. Considering the length of time it will take most businesses to reopen, we believe that actual recapture factors will be minimal.

Estimated lost sales and wages for each damaged establishment are calculated as the sales (wages) lost during Time A minus any recapture. Analysis of the agricultural sector showed that sales were underrepresented in InfoUSA, so agricultural sales were supplemented with crop data from the National Agricultural Statistical Service (NASS). See Appendix A: Non-Residential Stocks and Flows for a more detailed explanation of this procedure for agriculture, and for the mathematical structure of the lost sales and wage estimates.

To reduce lost economic activity, many businesses facing extended repair or rebuilding times will likely attempt to find a temporary location and incur additional capital-related costs to secure that location. Temporary location costs are the costs incurred by moving businesses into a temporary location during Time B. HAZUS-MH assumes that it will be possible for businesses to operate at a rented temporary location while original buildings are being repaired. We use the default parameters for disruption costs, the cost of moving to a temporary location and operating there, and rental costs per square foot for the temporary location. It is assumed that temporary location costs will be higher for businesses which own their own buildings, that owner-occupied businesses must pay rent at the new location, and that non-owner-occupied businesses only switch from paying rent at previous location to paying rent at new location. These parameters are taken from HAZUS-MH (per square foot) for different occupancy classes, and multiplied by the floor area measures contained in the InfoUSA data.

Rental income losses are only incurred during Time B by building owners that rent to other businesses. When the building used by a non-owner-occupied business is damaged, the business stops paying rent to the building owners during the period of time that the business is being repaired. Rental income losses are calculated based on the average percentage of non-owner-occupied businesses in the HAZUS-MH inventory, average rental costs per square foot by industry, calculated default formulas for temporary location costs and disruption costs by industry, and the calculated Time B. However, the appropriate formulas are applied to the inventory in Info-USA. Appendix A: Non-Residential Stocks and Flows provides additional details.

In potentially catastrophic events like the case-study storms with widespread damage over a large area, it may not be possible for every business to find a temporary location. In particular, the manufacturing sector may have difficulty finding temporary locations due to large equipment and training costs. There may also be a crowding effect that will extend time A or B or both. Some establishments may leave the area, moving to neighboring cities and states. There will likely be delays in the reconstruction and repair of buildings. Finally, as a result of the loss of their facilities and displacement of customers, workers and suppliers, some businesses may face additional challenges in reopening after a storm. This possibility is explored further in the section on business survival. Given these additional considerations, the primary results presented here should be considered conservative estimates of business interruption costs.

Business Survival

After a catastrophic storm event like the three storms used in this analysis, some businesses and organizations impacted by the storm may not reopen. In past natural disasters, the federal government has spent billions of dollars to assist in rebuilding and implemented programs to minimize business failures. While storms can affect businesses in many ways, the hypothetical storms considered in this study can be used to investigate how increased flooding in a future without action would impact the probability of business failure after a storm.

Two recent studies examined flooding and business failure associated with Hurricanes Katrina and Rita. A 2012 study by Lam, Arenas, Pace, LeSage, and Campanella focuses on businesses located in Orleans Parish before Hurricanes Katrina and Rita and conducted a follow-up survey roughly two years after the storms to determine whether they had reopened after the hurricanes hit. Based on the follow-up survey, Lam et al. (2012) found that approximately 12.4% of firms had not reopened within the first 26 months following the storm. A working paper by Craioveanu and Terrell (2010) uses state administrative data from the unemployment insurance tax system to investigate business failure and found 38.5% of Orleans Parish businesses had not reopened within two years of the storm, indicating impacts that are potentially much larger than those found by Lam et al. (2010).

The more conservative estimates based on the work of Lam et al. (2010) are used to examine the effects of increased storm damage in a future without action. The study used a Bayesian spatial probit model to assess the effects of a number of factors on firm survival, including whether or not a business flooded, the degree of flooding, flooding of nearby businesses, industry, and the size of the business. Flood depth was the most important factor in predicting reopening probabilities. Other important predictors suggest that flooding of nearby businesses reduces probability of reopening, and smaller businesses had lower reopening probabilities than larger ones. In this report, we use the marginal effects of flooding on the probability of reopening after a storm from Lam et al. (2010) to estimate the number of establishments that would remain closed two years after each of the storm cases considered.

Storm Damage: Results

This section reports the increased damage in a future without action across multiple storms and land loss projections. In other words, the reported damage captures the net, or increased, effect that land loss has on overall regional storm damage.

The results for the eastern track storm under the less optimistic scenario show a substantial amount of additional storm-related damage to the capital stock compared to other land loss and storm track combinations. The estimated damages from the eastern track storm under the less optimistic scenario are much higher for the 50 year time horizon than for the 25 year horizon. The explanation is that unlike most of the other cases, storm protection infrastructure failures are predicted around New Orleans in this case due to increased pressure from greater storm surge associated with long-term land loss. Given the density of the fixed capital stock and economic activity in that city, substantially more structures and businesses are affected.

Non-Residential Structures

Table 3.9 reports the increased cost of storm damage to businesses under each of the land loss projections. Depending on the storm and land loss projection, increased damage to private and public establishment buildings and inventory at the 50 year time horizon ranges from about $7 billion for the moderate land loss eastern track storm to $71 billion for the less optimistic eastern track storm. Commercial damages make up between 64 to 74% of the baseline costs from which this damage is estimated, while industrial business costs make up between 22 and 31% of the baseline. The remainder is from public and agricultural structure and inventory losses due to storm damage. These results show that storm damage protection is a valuable ecosystem service provided by coastal land, though the realized value is storm-dependent.

Table 3.9

Increased Storm Damage to Non-Residential Structures			
Storm	Environmental Scenario	Time Horizon	Damage to Establishments ($ billions)
Eastern	Moderate	25 year	$4.7
	Moderate	50 year	$7.2
	Less Optimistic	25 year	$6.4
	Less Optimistic	50 year	$71.0
100 Year	Moderate	25 year	$9.2
	Moderate	50 year	$14.0
	Less Optimistic	25 year	$13.0
	Less Optimistic	50 year	$33.0
Western	Moderate	25 year	$8.2
	Moderate	50 year	$13.0
	Less Optimistic	25 year	$12.0
	Less Optimistic	50 year	$26.0

Source: Authors' calculations from CLARA flood modeling and InfoUSA establishment database. Note: All results presented in 2012 dollars.

Residential Structures

As shown in Table 3.10, our estimates for increased storm damage for residential structures follows a pattern of damage across storms, environmental scenarios and time horizons that similar to the non-residential structures estimates. For example, under current conditions, the western track storm causes approximately $6.4 billion in damage, the storm associated with 100-year flooding causes $7.8 billion, and the eastern track storm causes $7.5 billion (baseline not shown in the figure). Increased storm damage at 25 years ranges from $4 billion to $9 billion depending on the storm and land loss projection. Extending the simulation to 50 years increases the expected damage under both environmental scenarios for each storm, but it does so much more for the 100-year storm and eastern track storm under the less optimistic scenario. This non-linearity is due primarily to predicted failures in flood protection systems, especially around the New Orleans area. The eastern track, less optimistic scenario in 50 years produces residential structure and contents damage that is over nine times the damage under current land conditions (nearly $62 billion). The total damage under this scenario is 42.4% of the total value of the study area's fixed structures and their contents.

Table 3.10

Increased Storm Damage to Residential Structures

Storm	Environmental Scenario	Time Horizon	Damage to Residences ($ billions)
Eastern	Moderate	25 year	$3.9
	Moderate	50 year	$6.0
	Less Optimistic	25 year	$5.1
	Less Optimistic	50 year	$61.0
100 Year	Moderate	25 year	$6.1
	Moderate	50 year	$9.0
	Less Optimistic	25 year	$8.5
	Less Optimistic	50 year	$27.0
Western	Moderate	25 year	$4.8
	Moderate	50 year	$7.5
	Less Optimistic	25 year	$7.5
	Less Optimistic	50 year	$13.0

Source: Authors' calculation based on CLARA flood modeling, per-person estimates of residential housing stock values from the U.S. Census American Community Survey and spatial distribution of nighttime population levels from LANDscan. Note: All results presented in 2012 dollars.

Network Infrastructure

Road and Rail

Results showing replacement costs to damaged roads and rail relative to current conditions are shown in Table 3.11. Damage to road and rail infrastructure is a relatively small fraction of total overall damage to non-residential or residential structures and inventories/contents, with increased rail damage from the eastern track storm in the less optimistic scenario at 50 years estimated to be approximately $140 million and road damage estimated at just under $500 million, as compared to total structure, inventory and contents damage of over $130 billion. Patterns of damage are generally consistent with the structural estimates across storms, although the infrastructure failures that lead to the flooding of New Orleans in the worst case considered does not affect network infrastructure to the same degree, due to a lack of density of infrastructure type in the city.

Table 3.11

Increased Storm Damage to Roads and Rail

Storm	Environmental Scenario	Time Horizon	Damage to Rail ($ millions)	Damage to Roads ($ millions)
Eastern	Moderate	25 year	$40	$100
	Moderate	50 year	$40	$150
	Less Optimistic	25 year	$40	$140
	Less Optimistic	50 year	$140	$500
100 Year	Moderate	25 year	$40	$140
	Moderate	50 year	$60	$210
	Less Optimistic	25 year	$60	$200
	Less Optimistic	50 year	$130	$380
Western	Moderate	25 year	$30	$110
	Moderate	50 year	$50	$170
	Less Optimistic	25 year	$50	$170
	Less Optimistic	50 year	$110	$310

Source: Authors' calculations. Note: All results are presented in 2012 dollars.

Pipelines

Like exposed pipelines, pipelines experiencing flooding are more vulnerable to cracks and ruptures. Exactly to what degree they are affected cannot be determined, but the length of potential flooded pipeline is detailed in Table 3.12

Some of the most important pipelines in Louisiana are those carrying crude oil or natural gas to refineries and processing centers and refined products like gasoline to other parts of the nation. After a major storm, it is common for major pipelines to shut down or reduce capacity for days or even weeks. A discussion of the effect of disruptions in the trade of energy products and the effect of pipeline shutdowns on gasoline prices after a storm is provided in Chapter 5.

Table 3.12

Increased Storm Flooding to Pipelines

Storm	Environmental Scenario	Time Horizon	Length Flooded (Miles)
Eastern	Moderate	25 year	470
	Moderate	50 year	1,500
	Less Optimistic	25 year	1,100
	Less Optimistic	50 year	2,300
100 Year	Moderate	25 year	770
	Moderate	50 year	1,200
	Less Optimistic	25 year	1,200
	Less Optimistic	50 year	1,900
Western	Moderate	25 year	590
	Moderate	50 year	920
	Less Optimistic	25 year	950
	Less Optimistic	50 year	1,600

Source: Based on infrastructure inventory data and valuation data from the LSU Center for Energy Studies.

Temporary Location Costs

Table 3.13 reports the temporary relocation costs in each case. These figures capture the fact that many businesses whose primary locations experienced significant damage would likely incur additional capital-related costs to resume operations as quickly as possible. Additional temporary location costs are relatively small compared to the primary damage to capital stock estimates, but they still range from $260 million for the eastern track storm under moderate conditions at 25 years to $3.9 billion for the same storm under less optimistic conditions at 50 years. While these costs represent real costs businesses would incur after a storm, it should be noted that rental rates can fluctuate dramatically after a storm in areas within close proximity to the impacted area and we do not attempt to model changes to the rental market. Moreover, while these costs are directly related to a firm's ability to reduce businesses activity losses, we do not include these figures in total capital-related costs from increased storm damage to ensure that our preferred estimate of activity losses with zero recapture do not overstate total costs.

Table 3.13

Temporary Location Costs from Increased Storm Damage

Storm	Environmental Scenario	Time Horizon	Temporary Location Costs ($ millions)
Eastern	Moderate	25 year	$260
	Moderate	50 year	$380
	Less Optimistic	25 year	$350
	Less Optimistic	50 year	$3,910
100 Year	Moderate	25 year	$470
	Moderate	50 year	$700
	Less Optimistic	25 year	$660
	Less Optimistic	50 year	$2,800
Western	Moderate	25 year	$400
	Moderate	50 year	$620
	Less Optimistic	25 year	$620
	Less Optimistic	50 year	$1,280

Source: Based on Info-USA data for business establishments and HAZUS-MH rental costs.
Note: All results presented in 2012 dollars.

Economic Activity

Table 3.14 reports the incremental number of damaged establishments and the incremental number of workers that are employed at these damaged establishments given each storm and land loss case. As in the previous subsections on damages to capital stock, there are fairly large differences across storms and land loss scenarios. For example, less optimistic environmental conditions result in 8,000 additional establishments flooded and nearly 90,000 additional employees affected at the 100-year flood level relative to the moderate scenario in fifty years, while the flooding of New Orleans with the eastern storm increases the number of impacted establishments by 24,000 and workers by just over 290,000 in the less optimistic scenario. Differences are less dramatic for the western track storm due to both density and elevation considerations.

Table 3.14

Establishments and Workers Affected by Increased Storm Damage

Storm	Environmental Scenario	Time Horizon	Establishments	Workers
Eastern	Moderate	25 year	1,600	20,000
	Moderate	50 year	2,400	29,000
	Less Optimistic	25 year	2,100	27,000
	Less Optimistic	50 year	26,000	320,000
100 Year	Moderate	25 year	3,100	32,000
	Moderate	50 year	4,800	51,000
	Less Optimistic	25 year	4,500	46,000
	Less Optimistic	50 year	13,000	140,000
Western	Moderate	25 year	2,500	30,000
	Moderate	50 year	4,200	49,000
	Less Optimistic	25 year	4,000	49,000
	Less Optimistic	50 year	9,000	100,000

Source: Based on Info-USA data for business establishments. Government institutions are not included in sales figures. All monetary values presented in 2012 dollars.

As discussed in the methodology subsection, the duration of impacts must be carefully considered. For smaller scale events, a certain portion of the loss can be recaptured over time through overtime, for example. However, longer periods of disruption like those likely to occur with the type of storms considered in this study generate losses that are more difficult to recapture. Table 3.15 reports a range of lost wages and sales using default HAZUS-MH recapture factors for a "low-end" damage estimate and a 0% recapture factor at the high-end of the damage estimates, which is our preferred approach because of the extended length of time most businesses will be non-operational.

With no recapture, the eastern track storm under less optimistic environmental conditions at 50 years is expected to result in a loss of an additional $23 billion in sales and $6.4 billion in lost wages to workers relative to the baseline current condition case. Again, given the distribution of economic activity across the state, the western track storm under less optimistic environmental conditions results in a $9.1 billion loss of sales and $2.5 billion of lost wages overall. However, it should be noted that lost wages and sales may be larger if businesses are delayed finding temporary locations or in repairing building damage due to shortages generated by widespread damage.

Table 3.15

Lost Economic Activity from Increased Storm Damage

Storm	Environmental Scenario	Time Horizon	Lost Wages ($ millions)		Lost Sales ($ millions)	
			Default Recapture Factor	Zero Recapture Factor	Default Recapture Factor	Zero Recapture Factor
Eastern	Moderate	25 year	$140	$530	$340	$1,900
	Moderate	50 year	$210	$740	$510	$2,600
	Less Optimistic	25 year	$190	$690	$450	$2,400
	Less Optimistic	50 year	$1,800	$6,400	$4,600	$23,000
100 Year	Moderate	25 year	$200	$920	$510	$3,200
	Moderate	50 year	$360	$1,500	$920	$5,300
	Less Optimistic	25 year	$320	$1,300	$820	$4,900
	Less Optimistic	50 year	$900	$3,300	$2,400	$12,00
Western	Moderate	25 year	$140	$710	$430	$3,100
	Moderate	50 year	$250	$1,100	$730	$4,500
	Less Optimistic	25 year	$250	$1,200	$700	$4,600
	Less Optimistic	50 year	$650	$2,500	$1,700	$9,100

Source: Based on Info-USA data for business establishments, County Business Pattern Wages, and HAZUS-MH recapture factors. Government institutions are not included in sales figures.
Note: All monetary values presented in 2012 dollars.

Lost Rental Income

Table 3.16 reports the lost rental income in each case. Rental income losses may be larger than given estimates if property owners are delayed in securing contracts to repair building damage or locating new tenants after periods of extended disruptions. Lost rental income is relatively small compared to the primary business disruption costs, but they still range from $100 million for the eastern track storm under moderate conditions at 25 years to $1.9 billion for the same storm under less optimistic conditions at 50 years. However, rental rates can fluctuate dramatically after a storm. Because we do not attempt to model changes to the rental market, we present these estimates for reference, but do not include them in totals for disruptions to economic activity.

Table 3.16

Lost Rental Income from Increased Storm Damage

Storm	Environmental Scenario	Time Horizon	Rental Income Lost ($ millions)
Eastern	Moderate	25 year	$100
	Moderate	50 year	$160
	Less Optimistic	25 year	$140
	Less Optimistic	50 year	$1,900
100 Year	Moderate	25 year	$200
	Moderate	50 year	$320
	Less Optimistic	25 year	$300
	Less Optimistic	50 year	$880
Western	Moderate	25 year	$170
	Moderate	50 year	$290
	Less Optimistic	25 year	$280
	Less Optimistic	50 year	$600

Source: Based on Info-USA data for business establishments and HAZUS-MH rental costs. Note: All results presented in 2012 dollars.

Business Survival

The marginal effects of flooding on the probability a firm would reopen after a storm are used to estimate the number of establishments that would remain closed two years after the flooding associated with each case considered in this analysis. Results depicting increased storm damage for each case are provided in Table 3.17. The number of establishments estimated to remain closed two years after a major storm ranges from 280 establishments in the eastern storm with the moderate environmental scenario at 25 years to 3,400 establishments in the eastern storm with the less optimistic environmental scenario at 50 years. These estimates correspond with approximately 3,000 to 39,000 jobs. Because the long-run dynamics of changes to the economy are outside of the scope of our analysis, these potential long-term impacts are not included in totals for disruptions to economic activity.

Table 3.17

Increase in Establishments Remaining Closed Two Years After Major Storm

Storm	Environmental Scenario	Time Horizon	Number of Establishments
Eastern	Moderate	25 year	280
	Moderate	50 year	410
	Less Optimistic	25 year	360
	Less Optimistic	50 year	3,400
100 Year	Moderate	25 year	440
	Moderate	50 year	670
	Less Optimistic	25 year	690
	Less Optimistic	50 year	1,500
Western	Moderate	25 year	300
	Moderate	50 year	480
	Less Optimistic	25 year	480
	Less Optimistic	50 year	1,000

Source: Based on Info-USA data for business establishments and HAZUS-MH rental costs. Note: All results presented in 2012 dollars.

Summary

The estimated replacement cost of capital stock directly at risk from land loss ranges from approximately $2.1 billion to $3.5 billion, with between 60% and 75% of the costs attributable to non-residential structures. In addition, pipeline infrastructure may also be at risk, although available data, while limited, does not suggest those risks are substantial. Land loss also directly affects economic activity with estimated total activity at risk ranging from $5.8 billion to $7.4 billion in output. The establishments in coastal Louisiana that are at-risk in the 50 year, less optimistic case are roughly 0.7% of all establishments statewide and reflect a similar share of annual sales volume.

Increases in storm damage to capital stocks for select storms range from less than $10 billion to as much as $133 billion, depending on the assumed storm track and land loss scenario. The worst damage occurs in the 50-year, less optimistic scenario for the eastern track storm, where the current protection system around the New Orleans area is projected to be breached. Storm damage estimates are larger than the direct land loss estimates which reflects the location of capital stock across different parts of the Louisiana coast and the widespread impacts of flood damage further inland associated with severe storms. However, these costs should not be aggregated with the damages to at-risk capital stock because each storm event has only a limited probability of occurring within the context of a specific land loss case.

4 Economic Links to the Nation and World

This chapter documents the economic links between Louisiana and the rest of the country. We first detail the economic activity of coastal Louisiana, including exports to the rest of the country and imports into the region. We then present data on the commodity flows to and from Louisiana by transportation mode, including roads, waterways, rail, air, and pipeline. Finally, we create a multiple region input-output (MRIO) model using IMPLAN to document the economic contributions of business activity at risk from direct land loss and increased storm damage on the state of Louisiana and the rest of the country. Given the nation's reliance on Louisiana's oil refineries and pipeline transportation network for gasoline supplies, we also analyze the effects of changes in gasoline prices following a storm.

Regional Exports and Imports

The IMPLAN data estimates that Louisiana's working coast exports over $120 billion of goods and services annually to the rest of the United States, with nearly 40% of those exports consisting of refined petroleum products. This is consistent with the Gulf Coast region being "the epicenter of the U.S. petrochemical industry" (NRC, 2008, p. 105). An additional $36.2 billion is exported internationally. Table 4.1 reports the top five industries for domestic export for coastal Louisiana, ranked in terms of value.

Table 4.1

Domestic and Foreign Exports by Industry, Coastal Parishes		
Industry Sector	Domestic Export Value ($ billions)	Foreign Export Value ($ billions)
Petroleum refineries	$50.0	$12.0
Petrochemical manufacturing	$17.0	$6.4
Mining and oil gas field machinery manufacturing	$3.2	$1.6
Transport by water	$3.2	$2.3
Commercial and industrial machinery and equipment rental and leasing	$2.3	$0.4

Source: IMPLAN 2012 data. Note: All results presented in 2012 dollars

As implied by the table, the production and export of refined petroleum products and petrochemicals provides a major link to the rest of the country, in addition to accounting for over one-quarter of the value of production in the region. Of the $747 billion in national refined petroleum production, $71 billion (9.5% of all national production) is attributable to coastal Louisiana.

The Louisiana coastal parishes import just over $160 billion of goods and services annually. Estimating sales from the rest of the country to coastal Louisiana is less straightforward in IMPLAN, as imports are not divided into domestic and foreign.[11] However, our calculations indicate that the region imports approximately $91.3 billion of commodities from the rest of the country, or about 57% of all regional imports. The top twenty industries and estimated shares of domestic imports for coastal Louisiana are reported in Table 4.2.

[11] To obtain domestic imports, we subtracted the sum of total imports for a model of coastal LA and total imports from a rest-of-country model from the total imports from a national model. This yields estimated sum of total domestic imports for each region. We then used the shares of total domestic exports across the regions to allocate domestic imports between the sub-national regions.

Table 4.2

Coastal Louisiana Domestic Imports by Commodity		
Sector	Non-Foreign Imports ($ billions)	Percent of Non-Foreign Imports
Management of companies and enterprises	$21.0	7.4%
Oil and natural gas	$16.0	5.5%
Architectural, engineering, and related services	$13.0	4.6%
Nondepository credit intermediation and related services	$11.0	3.8%
Flavoring syrups and concentrates	$11.0	3.7%
Wholesale trade distribution services	$9.9	3.4%
Semiconductor and related devices	$9.6	3.3%
Electricity and distribution services	$7.5	2.6%
Scientific research and development services	$7.1	2.4%
Other concrete products	$6.7	2.3%
Synthetic dyes and pigments	$5.8	2.0%
Natural gas and distribution services	$5.7	2.0%
Petrochemicals	$5.3	1.8%
Ornamental and architectural metal products	$5.3	1.8%
Lime and gypsum products	$5.2	1.8%
Telecommunications	$4.8	1.7%
Ready-mix concrete	$4.5	1.6%
Rail transportation services	$4.0	1.4%
Machined products	$3.5	1.2%
Paperboard containers	$3.3	1.1%

Source: Authors' calculations based on IMPLAN 2012 data.
Note: All monetary values presented in 2012 dollars

State-Level Imports and Exports

Not only is Louisiana an important hub for domestic trade, it is also an important location for international imports and exports. In 2012, Louisiana imported $74 billion worth of goods from international sources, of which $32 billion was distributed amongst other U.S. states, mostly by water, pipeline and truck (Freight Analysis Framework (FAF) 2015). Most imports by value were from Africa, Asia and North and South America (FAF 2015).

Over $44 billion worth of goods were exported internationally from the state of Louisiana in 2012 (FAF 2015). Over 99% of these exports were transported by water, unsurprising given Louisiana's strategic location between the Mississippi River and the Gulf of Mexico.

The Origin of Movement series of the United States Census Bureau foreign trade statistics provides detailed information on exports by state. This series reports exports from the place from which the goods begin their movement to the appropriate port for all international destinations. Reporting for all such exports is mandatory under law. Commodities are defined by the Harmonized Commodity Description and Coding System.

Table 4.3 reports the top ten commodity exports by value share to international destinations and the state total, sorted by 2014 value.

Table 4.3

Top Ten International Export Commodities from Louisiana, 2013-2014

Rank	Commodity Description	2013 Value ($ millions)	2014 Value ($ millions)	2013 Share of Total	2014 Share of Total
	Total Louisiana Exports and Percent Share of U.S. Total	$63,000	$65,000	4.0%	4.0%
1	Petrol oil bitum mineral (NT crud) etc NT bio	$21,000	$20,000	33.4%	31.3%
2	Soybeans	$9,500	$11,000	15.0%	16.4%
3	Corn (maize), other than seed corn	$3,300	$5,400	5.2%	8.3%
4	LT OILS, PREPS GT=70 percent PETROLEUM/ BITUM NT BIOD	$3,200	$3,900	5.0%	6.0%
5	Soybean oilcake & oth solid residue	$2,000	$1,900	3.2%	3.0%
6	Wheat and meslin	$2,100	$820	3.3%	1.3%
7	Parts for boring or sinking machinery	$940	$780	1.5%	1.2%
8	Polyvinyl chloride, not mixed	$690	$760	1.1%	1.2%
9	Brewing or distilling dregs and waste	$540	$695	0.9%	1.1%

Source: U.S. Bureau of the Census, Total U.S. Exports (Origin of Movement) from Louisiana with commodity descriptions and coding system harmonized by authors.
Note: All monetary values presented in 2012 dollars.

Nearly one-third of state level international exports are crude oil, with soybeans and corn constituting an additional 20-24%. Other petroleum and agricultural products make up the remainder of the top ten. Exports originated in Louisiana account for approximately 4% of the U.S. international total. The Census data from the Origin of Movement series captures trade that passes through Louisiana including goods that were originally produced elsewhere, but were shipped internationally from a Louisiana port. The IMPLAN data in Table 4.1 provides a better picture of what is actually produced in coastal Louisiana and then exported since IMPLAN is a production model rather than simply a flow of goods. Large amounts of lower valued, heavy goods typically transported by barge such as soybeans and corn pass through Louisiana due to its location on the Mississippi River and the Gulf of Mexico.

Commodity Flows by Transportation Mode and Location

In this subsection, we present data related to transportation flows by mode in the state of Louisiana. Given its Gulf Coast location and access to the Mississippi River, the state is especially attractive to international shippers transporting goods into and out of the country as a whole (NRC, 2008). In addition to waterborne transportation, Louisiana boasts a number of additional transportation modes including pipeline, road, and rail (NRC, 2008). This network infrastructure not only supports the economic activity highlighted in the previous subsection, but also serves as a link between Louisiana and the rest of the country.

We make no representation here that direct land loss or storm damage would disrupt 100% of these transportation flows, as shippers have various transport options and can plan in advance of events. However, any individual event or series of events could disrupt a portion of the flows until such time as the infrastructure can be repaired, which could last from weeks to months, potentially increasing costs of goods and services to final end users. In addition, waterways currently being used presumably offer the lowest cost alternative for shippers so even a switch to an alternate route would likely result in some degree of lasting cost. For example, in the context of waterways, it is possible that portions of the Gulf Intracoastal Waterway would convert to open water through the land loss process, which may end barge traffic along some portions of the Gulf Intracoastal Waterway (NRC, 2008). Without additional water-based transportation options, this could increase rail and highway congestion (and thus costs of goods transported) across the nation (NRC, 2008). Similarly, future saltwater intrusion may change patterns of sedimentation, which could increase or decrease channel navigability, and relative sea level rise may hamper some bridge clearances (Titus, 2002). On the other hand, net increases in the depth of some channels may enable larger vessels to navigate those channels (Titus, 2002).

Data included in this section include, in theory, the inter- and intra- country imports and exports reported in the previous section.

Data

The primary data source for transportation and related network flows is the Freight Analysis Framework (FAF), which is produced by the Center for Transportation Analysis (CTA) in the Oak Ridge National Laboratory (ORNL) for the U.S. Department of Transportation.

The most recent FAF data is from 2012 and includes information on the commodities listed in Table 4.4:

Table 4.4

Commodities List
Agricultural products (grains, feed, other foodstuffs)
Perishable agricultural products (meat/seafood)
Fuel (crude petroleum, fuel oils, gasoline, coal)
Chemicals (chemicals, fertilizers, chemical products)
Forest products (Wood products, paper articles, newsprint/paper, logs, furniture, printed products)
Stone products (Nonmetallic minerals, nonmetallic mineral products, gravel, natural sands, building stone)
Metal products (Base metals, metallic ores, articles-base metal)
Equipment (transportation equipment, electronics, machinery, motorized vehicles, precision instruments)
Waste/scrap
Misc. (Alcoholic beverages, textiles/leather, pharmaceuticals, misc. products, unknown, mixed freight, plastics/rubber)

Source: FAF 2012.

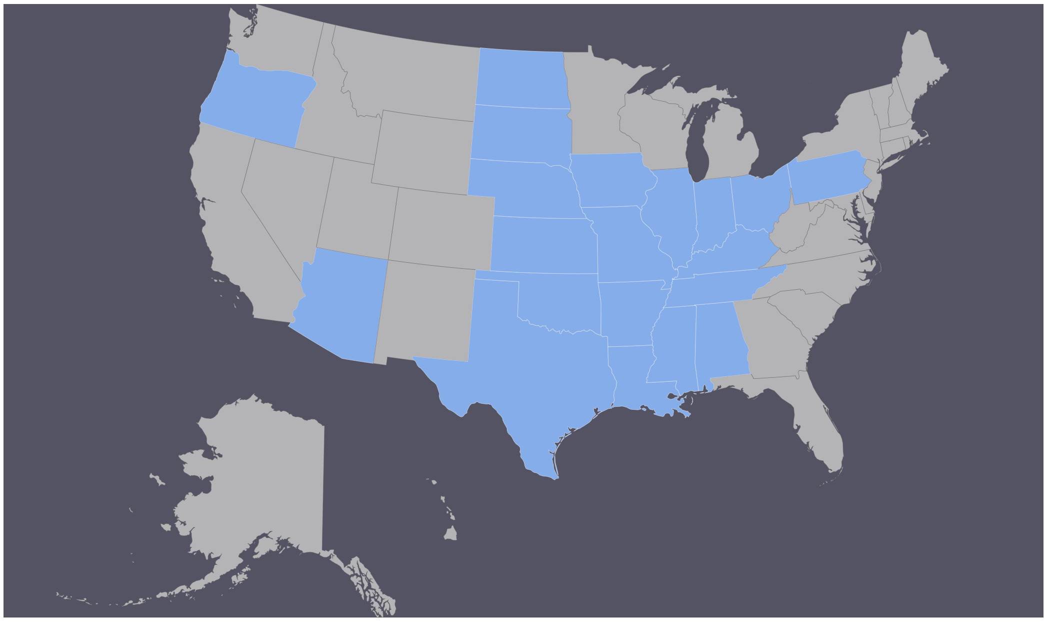
Commodities are measured in thousands of tons, millions of ton-miles and values in millions of 2012 dollars. We did not compute value information from prices and quantities; rather, we report values as reported in the FAF. Freight flows are divided by mode, which include truck, rail, water, air and pipeline.

FAF data are available between states and major metropolitan areas. International imports are tallied as originating at the zone or state of entry, while international exports are counted for the zone that is the last domestic destination.

Methods

We considered the flows traveling to and from the states bordering Louisiana (Mississippi, Texas and Arkansas), the states bordering the Mississippi River (Tennessee, Kentucky, Missouri, Illinois, Iowa, Minnesota, Wisconsin), the states one removed from the Mississippi River (Oklahoma, Indiana, Nebraska, Alabama, Kansas, North Dakota, South Dakota), states along the Ohio River (Ohio, Pennsylvania), and two states (Arizona, Oregon) chosen randomly to serve as proxies for the rest of the continental United States with no direct waterway or border connection to Louisiana and relatively similar gross state products. The FAF data tabulation tool also allowed combined totals to and from all the states. Figure 4.1 shows the states under consideration.

Figure 4.1: Freight Analysis Framework State Flows



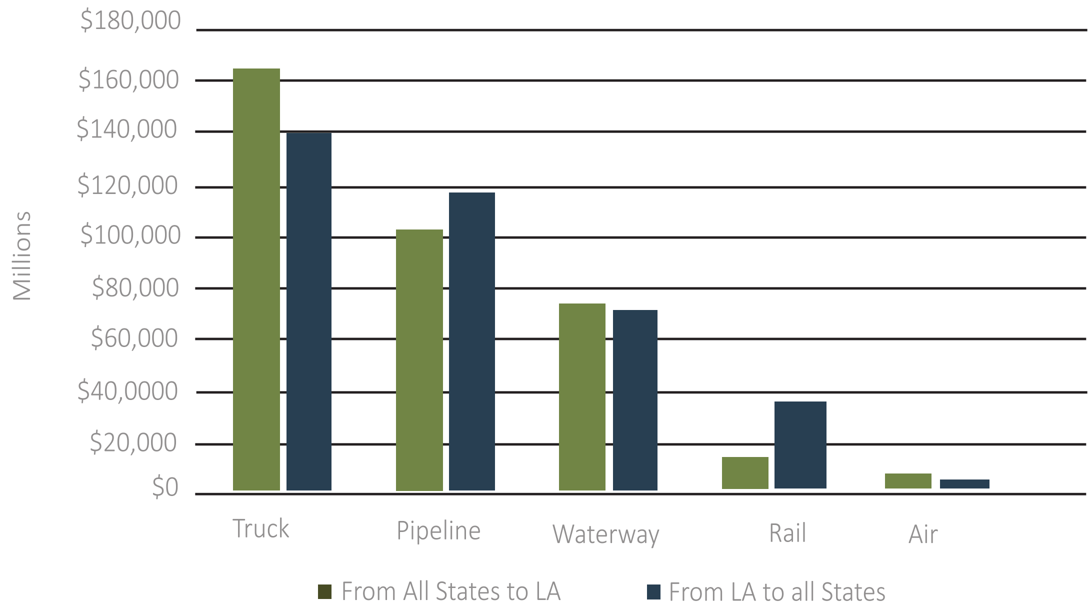
Source: Authors' design. Note: Blue state commodity flows to and from Louisiana were considered in this analysis.

Data was collected for five different cargo transport modes: truck, rail, water, air and pipeline. For more complete data about commodity flows for each individual state and transportation mode, please refer to Appendix D. The flows from all states to Louisiana represent goods consumed in Louisiana as well as goods that were exported internationally with Louisiana as their last domestic stop.

Commodity Flows by Mode

The data presented in Figure 4.2 below show that Louisiana is an economically important transportation hub for the rest of the nation. The three most important modes of transportation into and out of Louisiana include truck, pipeline and waterway. Flows from the state (regional domestic production plus international shipments) are greater for pipeline and rail, while flows to the state (domestic imports for Louisiana plus country-level exports) are larger for truck, waterway, and air. It is likely that the former is a result of the energy resources in the Gulf, while much of the waterway import into Louisiana is likely due to agricultural production of the Midwest.

Figure 4.2: Value of Goods Shipped to and From Louisiana by Mode



Source: FAF, 2012. Note: All results presented in 2012 dollars.

The database shows that the three largest modes of transportation, both in volume and by value, are truck, pipeline and water. Rail and air transport are relatively small compared with other modes for both import and export goods. Trucks transport the most valuable portion of imports and exports to and from Louisiana. Because of this, it may be more prudent to prioritize mitigation of the effect that land loss has on roads and highways that are most affected by potential land loss.

The data presented in Table 4.5 show the top two commodities by percentage of value and weight for each mode to Louisiana. Equipment, fuel, chemical products and agricultural products are the most valuable commodities sent to Louisiana. Agricultural products and fuel are the largest flows to Louisiana by weight.

Table 4.5

Percent Value and Weight of Flows to Louisiana by Mode and Commodity				
Shipments to Louisiana by Mode	**Top Commodity by Value**	**Percent Value**	**Second Top Commodity by Value**	**Percent Value**
Truck Commodities	Equipment	25%	Misc	20%
Waterways	Fuel	60%	Agricultural Prodcuts	29%
Rail	Chemicals	32%	Agricultural Products	20%
Air	Equipment	86%	Misc	5%
Pipeline	Fuel	96%	Chemicals	4%
	Top Commodity by Weight	**Percent Weight**	**Second Top Commodity by Weight**	**Percent Weight**
Truck Commodities	Stone Products	26%	Fuel	19%
Waterways	Agricultural Products	47%	Fuel	43%
Rail	Agricultural Products	34%	Fuel	27%
Air	Equipment	50%	Metal Products	13%
Pipeline	Fuel	96%	Chemicals	4%

Source: FAF 2012.

The values above may be consumed in Louisiana or may be shipped internationally, with Louisiana as the last domestic stop.

Table 4.6 shows the top two percentages of value and weight for each mode exported from Louisiana.

Table 4.6

Percent Value and Weight of Flows From Louisiana by Mode and Commodity				
Shipments from Louisiana by Mode	**Top Commodity by Value**	**Percent Value**	**Second Top Commodity by Value**	**Percent Value**
Truck Commodities	Equipment	19%	Misc	17%
Waterways	Fuel	75%	Agricultural Prodcuts	16%
Rail	Chemicals	47%	Agricultural Products	16%
Air	Equipment	61%	Misc	20%
Pipeline	Fuel	97%	Chemicals	3%
	Top Commodity by Weight	**Percent Weight**	**Second Top Commodity by Weight**	**Percent Weight**
Truck Commodities	Stone Products	26%	Fuel	18%
Waterways	Agricultural Products	73%	Fuel	14%
Rail	Agricultural Products	46%	Fuel	16%
Air	Equipment	51%	Metal Products	13%
Pipeline	Fuel	97%	Chemicals	3%

Source: FAF 2012.

This table includes both exports from Louisiana to other states as well as international exports. The most valuable exports from Louisiana include fuel, chemical products and agricultural products. Agricultural products and fuel are the heaviest, by tonnage, exports from Louisiana.

Total Commodity Flows by Location

2012 data for the top ten most valuable flows from the state of Louisiana to the other states are presented in Table 4.7

Table 4.7

Commodity Flows From Louisiana to Louisiana and Other States 2012

State of Origin	Destination State	Total weight (thousand tons)	Total value ($ millions)
Louisiana	Louiaiana	550,000	$250,000
Louisiana	Texas	64,000	$40,000
Louisiana	Mississippi	28,000	$14,000
Louisiana	Florida	16,000	$10,000
Louisiana	Tennessee	7,800	$9,300
Louisiana	California	11,000	$8,600
Louisiana	New Jersey	6,800	$7,700
Louisiana	Illinois	16,000	$7,300
Louisiana	Ohio	10,000	$5,800
Louisiana	Pennsylvania	5,300	$5,700
Louisiana	**Total**	**800,000**	**$470,000**

Source: FAF 2012. Note: All monetary values presented in 2012 dollars

The neighboring states of Texas and Mississippi import the most goods (by value) from Louisiana, but Louisiana provides billions of dollars of goods to states on the West Coast, Midwest and in the Northeast as well.

2012 data for the top ten most valuable flows to the state of Louisiana from the other US states is shown in Table 4.8.

Table 4.8

Commodity Flows to Louisiana From Louisiana and Other States 2012

State of Origin	Destination State	Total weight (thousand tons)	Total value ($ millions)
Louisiana	Louisiana	550,000	$250,000
Texas	Louisiana	42,000	$55,000
Illinois	Louisiana	69,000	$14,000
Mississippi	Louisiana	16,000	$9,000
Missouri	Louisiana	39,000	$8,000
California	Louisiana	3,200	$6,700
Tennessee	Louisiana	8,800	$5,800
Minnesota	Louisiana	25,000	$4,900
Florida	Louisiana	13,000	$4,500
Georgia	Louisiana	2,400	$4,300
Total	**Louisiana**	**875,000**	**$450,000**

Source: FAF 2012 Note: All monetary values presented in 2012 dollars

The state of Louisiana also serves as an important consumer and hub for export of large values of goods from the rest of the United States. Texas alone provides over $55 billion worth of commodities to be consumed in Louisiana or to be exported internationally through Louisiana's transport systems.

Ports

One of Louisiana's most important contributions to the national economy is its location at the mouth of the Mississippi River. This strategic location makes Louisiana an important hub, especially for exports leaving the United States through the port system that is maintained in the state waterways.

There are several data sources on port activity at the Federal level. The U.S. Army Corps of Engineers collects data on foreign and domestic cargo by commodity and port for the United States. The FAF also collects similar data which also includes economic values. The U.S. Maritime Administration collects data on port calls and capacity (deadweight tonnage time calls) by vessel type by year for vessels over 1,000 gross register tons. A major study commissioned by the Ports Association of Louisiana on the economic impact of ports was completed in 2012 (Richardson, 2012). The data presented below comes from these sources.

As of 2012, there were 28 active ports in the state of Louisiana, with an additional five in various stages of development (Richardson, 2012). Thirteen are shallow-draft inland ports along various navigable waterways, nine are shallow-draft coastal ports which primarily service the fisheries and oil and gas industries, and six are deep-draft ports which serve as the origin and destination points for imported and exported commodities (Richardson, 2012). Five of the deep draft ports (Baton Rouge, South Louisiana, New Orleans, St. Bernard, and Plaquemines) are located along the Mississippi River, while the sixth (Lake Charles) is located on the Calcasieu River (Richardson, 2012). Coastal ports include Port Fourchon, which services almost 90% of deep-water offshore drilling equipment in the Gulf of Mexico and half of those operating in shallow water (Richardson, 2012).

Direct employment by the ports in Louisiana totals approximately 600, with 75% of direct spending by deep-water ports, 14% of direct spending by coastal ports, and the remainder by inland ports (Richardson, 2012). In addition, there are numerous businesses in Louisiana that have developed or located in the state due to the presence of port activities.

The following tables (Table 4.9 and 4.10) report calls and capacity at deep-water ports for 2012 for the State of Louisiana.

Table 4.9

Overall Calls and Capacity at Louisiana Ports and Lightering Areas, Vessels Over 1,000 Gross Register Tons, 2012

Port	Calls	Capacity (deadweight tonnage X calls, millions)
South Louisiana	2,300	120
Greater Baton Rouge	840	39
New Orleans	2,100	95
Lake Charles	810	51
Louiaiana Offshore Oil Port (LOOP)	300	74
Soutwest Pass Lightering Area	280	37

Source: U.S. Department of Transportation Maritime Administration Maritime Statistics, 2012 data. Port of South Louisiana includes Convent, Destrehan, Garyville, Good Hope, Gramercy, La Place, Norco, Paulina, Reserve, St. James, St. Rose, and Taft. Port of Greater Baton Rouge includes Baton Rouge, Burnside, Darrow, Donaldsonville, Geismar, St. Gabriel, and Sunshine.

Table 4.10

Calls and Capacity at Louisiana Ports and Lightering Areas by Vessel Type, Vessels Over 1,000 Gross Register Tons, 2012						
	Tankers		Containers		Gas (LNG/LPG)	
Port	**Calls**	**Capacity (deadweight tonnage X calls, millions)**	**Calls**	**Deadweight Tonnage (millions)**	**Calls**	**Deadweight Tonnage (millions)**
South Louisiana	960	56	1	.009	39	1.4
Greater Baton Rouge	590	29	-	-	28	.09
New Orleans	410	19	440	22	21	.62
Lake Charles	580	43	-	-	20	.23
Louisiana Offshore Oil Port (LOOP)	300	74	-	-	-	-
Southwest Pass Lightering Area	280	37	-	-	-	-
	Roll On / Roll Off		**Bulk**		**General Cargo**	
Port	**Calls**	**Capacity (deadweight tonnage X calls, millions)**	**Calls**	**Deadweight Tonnage**	**Calls**	**Deadweight Tonnage**
South Louisiana	1	.008	1,200	68	94	2.0
Greater Baton Rouge	-	-	160	7.9	64	.97
New Orleans	17	.343	880	47	330	5.8
Lake Charles	-	-	110	5.6	100	1.4
Louisiana Offshore Oil Port (LOOP)	-	-	-	-	-	-
Southwest Pass Lightering Area	-	-	-	-	-	-

Source: U.S. Department of Transportation Maritime Administration Maritime Statistics, 2012 data. Port of South Louisiana includes Convent, Destrehan, Garyville, Good Hope, Gramercy, La Place, Norco, Paulina, Reserve, St. James, St. Rose, and Taft. Port of Greater Baton Rouge includes Baton Rouge, Burnside, Darrow, Donaldsonville, Geismar, St. Gabriel, and Sunshine. Note: All results presented in 2012 dollars.

Louisiana's strategic location at the mouth of the Mississippi River provides it an important role in the overall US economy. Although there exist alternative routes to ship goods into and out of the US and across the US, Louisiana's central location makes it an attractive location to aggregate goods for shipment abroad especially heavy, lower valued goods that typically travel by barge. The potential for disruptions due directly to land loss and indirectly through storm surge are important considerations for not only coastal Louisiana but the rest of the country.

Economic Contribution of Business Activity at Risk from Direct Land Loss

The data presented earlier in this chapter suggests significant linkages between coastal Louisiana, the rest of Louisiana, and the rest of the United States in terms of the movement of goods from the coast to inland areas. In this subsection, we use input-output modeling to estimate the economic activity generated by businesses directly at risk from land loss on Coastal Louisiana, the rest of Louisiana and the rest of the United States. We use a multi-regional input-output model (IMPLAN) comprised of three regions: coastal Louisiana, Louisiana without the coastal Parishes, and the rest of the country, which allows for estimation of the trade flow effects between parts of the country as a result of differing changes in economic activity in coastal Louisiana.

Data and Methods

We treat the previously reported business activity at risk as the potential direct effects of land loss on the coastal Louisiana region. We are highlighting the economic activity, both within the state and in the rest of the country, which is supported by the at-risk businesses on an annual basis. Default trade-flow relationships within IMPLAN are used to model the relationship between regions.

Using the North American Industry Classification System (NAICS) code identified for each at-risk business, businesses were linked to IMPLAN sectors using the crosswalk provided by IMPLAN. For each IMPLAN sector, at-risk businesses whose primary output falls in that sector were aggregated by employment for each of the two future environmental scenarios at 50 years using the InfoUSA establishment dataset.

Using the default IMPLAN production function for each sector in coastal Louisiana, sector-level output was generated for at-risk businesses from the aggregated employment data for each case.[12] By using the IMPLAN production functions for each sector, small differences between the Info-USA data used in Chapter 3 will be introduced. As these are order of magnitude estimates for the economic impact, we are more comfortable using estimates of employment rather than sales to estimate the impact of future land loss.

These sector-level outputs were used as reductions in output for each sector in the multi-region input-output model. Results are reported as direct, indirect, induced, and total contributions of at-risk businesses in terms of industry output, employment, and wages. Direct contributions are the value of economic activity assumed removed from the region. Indirect contributions trace through the economic activity assumed lost due to the inter-industry linkages between regional economies; that is, it is a measure of the disruption to suppliers of directly affected industries, the suppliers of the suppliers, and so on. Induced contributions trace through the lost personal and proprietors' income due the lost economic activity. Results are presented by IMPLAN industry sector for the top ten industries in terms of total contribution, plus the total contribution to each region.

[13] The default production functinos are the inputs needed to create a unit of output; that is, it is the "recipe" for producing sector-level output.

Results

Moderate Scenario - 50 years

Businesses at risk from the moderate scenario at 50 years contribute approximately 9,600 jobs across 122 sectors within the State of Louisiana. Through the IMPLAN production functions, at-risk businesses translates into approximately $2.5 billion in output that could be affected or approximately 1% of total coastal Louisiana output in 2012; resulting in a total effect on the economy of coastal Louisiana of approximately $3.7 billion once all the linkages within Coastal Louisiana are considered. In terms of employment within coastal Louisiana, there is a total impact of approximately 18,000 jobs with nearly $1 billion in wages. The top 10 sectors most affected in terms of output by land loss in the moderate scenario at 50 years are given in Table 4.11. Tables for employment and wages appear in Appendix G.

Table 4.11

Economic Impact on Output in Coastal Louisiana From Land Loss (Moderate, 50 years), Top 10 Sectors

Sector	Direct ($ millions)	Indirect ($ millions)	Induced ($ millions)	Total ($ millions)
Petroleum refineries	$1,100	$120	$15	$1,300
Construction of new residential permanent site single- and multi-family structures	$160	$0	$0	$160
Wholesale trade businesses	$75	$37	$25	$140
Insurance agencies, brokerages, and related activities	$91	$23	$4	$120
Extraction of oil and natural gas	$20	$95	$1	$120
Cable and other subscription programming	$85	$20	$1	$100
Construction and other new non-residential structures	$76	$0	$0	$76
Food services and drinking places	$33	$10	$31	$74
Imputed rental activity for owner-occupied dwellings	$0	$0	$71	$71
Monetary Authorities and depository credit intermediation activities	$27	$24	$19	$71
Total	$2,500	$740	$500	$3,700

Source: IMPLAN 2012 data output from MRIO model. Row sums do not equal total, as only top 10 industries displayed. Direct impact estimates are based on employment and not sales and should be treated as order of magnitude estimates. Note: All results presented in 2012 dollars.

There are no direct impacts to the rest of Louisiana since it is not directly affected by land loss. The total contributions to the rest of the Louisiana from land loss are based on indirect and induced economic flows from the coastal area and are estimated to be an additional $150 million and more than 520 jobs and wages of approximately $34 million. Table 4.12 shows output for the top 10 sectors in the rest of the Louisiana supported by at-risk businesses in the moderate scenario at 50 years. Tables of employment and wages appear in Appendix G.

Table 4.12

Economic Impact on Output in Rest of Louisiana From Land Loss (Moderate, 50 years), Top 10 Sectors

Sector	Indirect ($ millions)	Induced ($ millions)	Total ($ millions)
Extraction of oil and natural gas	$40	$1	$41
Petroleum refineries	$18	$1	$19
Maintenance and repair construction of non residential structures	$7	$1	$8
Electric power generation, transmission, and distribution	$4	$1	$5
Wholesale trade businesses	$3	$1	$4
Management of companies and enterprises	$3	$1	$4
Cable and other subscription programming	$4	$0	$4
Architectural, engineering, and related services	$3	$0	$3
Imputed rental activity for owner-occupied dwellings	$0	$3	$3
Petrochemical manufacturing	$3	$0	$3
Total	**$120**	**$27**	**$150**

Source: IMPLAN 2012 data from MRIO model. Row sums do not equal total, as only top 10 industries displayed.
Note: All results presented in 2012 dollars.

The total contributions of these businesses to the rest of the United States are estimated to be an additional $2.7 billion in output, over 12,000 jobs and wages of approximately $800 million. Table 4.13 shows output for the top 10 sectors in the rest of the United States supported by at-risk businesses in the moderate scenario at 50 years. Tables for employment and wages are available in Appendix G.

Table 4.13

Economic Impact on Output in Rest of US From Land Loss (Moderate, 50 years), Top 10 Sectors			
Sector	Indirect ($ millions)	Induced ($ millions)	Total ($millions)
Extraction of oil and natural gas	$690	$20	$710
Maintenance and repair construction of non-residential structures	$90	$10	$100
Wholesale trade businesses	$40	$30	$70
Lessors of nonfinancial intangible assets	$60	$0	$60
Monetary authorities and depository credit intermediation activities	$30	$30	$60
Management of companies and enterprises	$50	$10	$60
Real estate establishments	$20	$40	$60
Securities, commodity contracts, investments, and related activities	$30	$30	$60
Imputed rental activity for owner-occupied dwellings	$0	$60	$60
Petroleum refineries	$30	$20	$50
Total	**$1,800**	**$900**	**$2,700**

Source: IMPLAN 2012 data output from MRIO model. Row sums do not equal total, as only top 10 industries displayed.
Note: All results presented in 2012 dollars.

Less Optimistic Scenario - 50 years

Businesses at risk in the less optimistic scenario at 50 years directly contribute 12,200 jobs across 122 sectors within the state of Louisiana. Considering indirect and induced impacts, we estimate that at-risk businesses support approximately $2.8 billion in output. This results in total contributions to the Louisiana economy of approximately $4.3 billion in output, nearly 23,000 jobs with wages of approximately $1.2 billion once all the linkages within Coastal Louisiana are considered. Table 4.14 shows output for the top 10 sectors in Coastal Louisiana most affected by businesses at risk in the less optimistic scenario at 50 years. Tables for employment and wages appear in Appendix G.

Table 4.14

Economic Impact on Output in Coastal Louisiana From Land Loss (Less Optimistic, 50 years), Top 10 Sectors				
Sector	Direct ($ millions)	Indirect ($ millions)	Induced ($ millions)	Total ($ millions)
Petroleum refineries	$1,100	$130	$19	$1,300
Construction of other new non-residential structures	$170	$0	$0	$180
Construction of new residential permanent site single- and multi-family structures	$170	$0	$0	$170
Wholesale trade businesses	$88	$43	$30	$160
Extraction of oil and natural gas	$22	$100	$2	$120
Insurance agencies, brokerages, and related activities	$91	$24	$4	$120
Cable and other subscription programming	$85	$21	$1	$110
Monetary authorities and depository credit intermediation activities	$46	$30	$24	$100
Scenic and sightseeing transportation and support activities for transportation	$88	$7	$2	$96
Imputed rental activity for owner-occupied dwellings	$0	$0	$88	$88
Total	**$2,800**	**$850**	**$630**	**$4,300**

Source: IMPLAN 2012 data from MRIO model. Row sums do not equal total, as only top 10 industries displayed. Direct impact estimates are based on employment and not sales and should be treated as order of magnitude estimates.
Note: All results presented in 2012 dollars.

Once the linkages to the rest of the Louisiana are taken into account, the total contribution to the rest of the Louisiana is estimated to be an additional $160 million in output and nearly 800 jobs with wages totaling $39 million. Table 4.15 shows output for the top 10 sectors in the rest of the Louisiana that are most affected by at-risk businesses in the less optimistic scenario at 50 years. Tables for employment and wages appear in Appendix G.

Table 4.15

Economic Impact on Output in Rest of Louisiana From Land Loss (Less Optimistic, 50 years), Top 10 Sectors			
Sector	Indirect ($ millions)	Induced ($ millions)	Total ($ millions)
Extraction of oil and natural gas	$40	$1	$41
Petroleum refineries	$20	$1	$21
Maintenance and repair construction of non-residential structures	$7	$1	$8
Electric power generation, transmission, and distribution	$4	$1	$5
Wholesale trade businesses	$3	$1	$4
Architectural, engineering, and related services	$3	$0	$3
Management of companies and enterprises	$3	$0	$3
Imputed rental activity for owner-occupied dwellings	$0	$2	$2
Cable and other subscription programming	$2	$0	$2
Petrochemical manufacturing	$2	$0	$2
Total	**$130**	**$31**	**$160**

Source: IMPLAN 2012 data from MRIO model. Row sums do not equal total, as only top 10 industries displayed.
Note: All results presented in 2012 dollars.

The total contribution onto the rest of the United States is estimated to be an additional $2.9 billion in output and 14,000 jobs with wages of approximately $860 million. Table 4.16 shows output for the top 10 sectors in the rest of the United States that are most affected by at-risk businesses in the less optimistic scenario at 50 years. Tables of employment and wages appear in Appendix G.

Table 4.16

Economic Impact on Output in Rest of US From Land Loss (Less Optimistic, 50 years), Top 10 Sectors			
Sector	Indirect ($ millions)	Induced ($ millions)	Total ($ millions)
Extraction of oil and natural gas	$700	$20	$720
Maintenance and repair construction of non residential structures	$90	$10	$100
Wholesale trade business	$40	$40	$80
Monetary authorities and depository credit intermediation activities	$40	$40	$80
Securities, commodity contracts. investments, and related activities	$40	$40	$80
Real estate establishments	$30	$40	$70
Management of companies and enterprises	$50	$20	$70
Lessors of nonfinancial in-tangible assets	$60	$0	$60
Imputed rental activity for owner-occupied dwellings	$0	$60	$60
Petroleum refineries	$30	$20	$50
Total	**$1,940**	**$980**	**$2,920**

Source: IMPLAN 2012 data from MRIO model. Row sums do not equal total, as only top 10 industries displayed.
Note: All results presented in 2012 dollars.

In addition to the analysis with a 50 year time horizon, we have also mirrored the analysis with a 25 year horizon. The summary of the results from all the analyses of the economic activity from business at risk appears in Tables 4.17 to 4.19. Table 4.17 displays the results for coastal Louisiana, Table 4.18 displays the results for the rest of Louisiana, and Table 4.19 displays the results for the rest of the US.

Table 4.17

Total Impact in Coastal Louisiana of Businesses at Risk

Output ($ millions)				
Land Loss Scenario	**Moderate Scenario**		**Less Optimistic**	
Year	**25**	**50**	**25**	**50**
Direct Impact	2,200	2,500	2,300	2,800
Indirect Impact	700	700	700	850
Induced Impact	400	500	500	620
Total Impact	3,300	3,700	3,500	4,300

Employment				
Land Loss Scenario	**Moderate Scenario**		**Less Optimistic**	
Year	**25**	**50**	**25**	**50**
Direct Impact	8,800	9,600	9,800	12,200
Indirect Impact	3,800	4,300	4,100	5,100
Induced Impact	3,900	4,500	7,300	5,500
Total Impact	16,500	18,400	18,200	22,800

Wages ($ millions)				
Land Loss Scenario	**Moderate Scenario**		**Less Optimistic**	
Year	**25**	**50**	**25**	**50**
Direct Impact	480	560	530	700
Indirect Impact	200	230	220	300
Induced Impact	150	170	170	200
Total Impact	830	960	920	1,200

Source: IMPLAN 2012 data output from MRIO model.
Note: All results presented in 2012 dollars.

Table 4.18

Total Impact in Rest of Louisiana of Businesses at Risk

Output ($ millions)				
Land Loss Scenario	**Moderate Scenario**		**Less Optimistic**	
Year	**25**	**50**	**25**	**50**
Direct Impact	0	0	0	0
Indirect Impact	100	120	110	130
Induced Impact	20	30	20	30
Total Impact	130	150	130	160

Employment				
Land Loss Scenario	**Moderate Scenario**		**Less Optimistic**	
Year	**25**	**50**	**25**	**50**
Direct Impact	0	0	0	0
Indirect Impact	430	490	450	550
Induced Impact	190	210	200	250
Total Impact	620	700	650	800

Wages ($ millions)				
Land Loss Scenario	**Moderate Scenario**		**Less Optimistic**	
Year	**25**	**50**	**25**	**50**
Direct Impact	0	0	0	0
Indirect Impact	20	30	20	30
Induced Impact	10	10	10	10
Total Impact	30	40	30	40

Source: IMPLAN 2012 data output from MRIO model.
Note: All results presented in 2012 dollars.

Table 4.19

Total Impact in Rest of US of Businesses at Risk

Output ($ millions)				
Land Loss Scenario	**Moderate Scenario**		**Less Optimistic**	
Year	**25**	**50**	**25**	**50**
Direct Impact	0	0	0	0
Indirect Impact	1,600	1,800	1,600	1,900
Induced Impact	800	900	800	1,000
Total Impact	2,400	2,700	2,500	2,900

Employment				
Land Loss Scenario	**Moderate Scenario**		**Less Optimistic**	
Year	**25**	**50**	**25**	**50**
Direct Impact	0	0	0	0
Indirect Impact	6,000	6,800	6,300	7,500
Induced Impact	5,000	5,600	5,200	6,300
Total Impact	11,000	12,400	11,500	13,800

Wages ($ millions)				
Land Loss Scenario	**Moderate Scenario**		**Less Optimistic**	
Year	**25**	**50**	**25**	**50**
Direct Impact	0	0	0	0
Indirect Impact	440	500	450	540
Induced Impact	250	300	260	320
Total Impact	690	800	710	860

Source: IMPLAN 2012 data output from MRIO model.
Note: All results presented in 2012 dollars.

Including direct, indirect and induced economic impacts, the economic activity at risk from land loss ranges from $5.8 billion to $7.4 billion in output across the entire US. This reduction in output is driven by land loss impacting between 800 and 1,200 establishments, depending on the specific land loss case. The at-risk establishments produce between $2.4 and $3.1 billion in annual sales, and their associated payroll is approximately $400 million to $575 million. These direct impacts are estimated to generate a total impact of between $3.4 and $4.5 billion in output in Louisiana and an additional $2.4 to $2.9 billion in output in the rest of the United States. In a future without action, some of the economic activity from at-risk establishments may be able to relocate, which could take more or less than the one-year time horizon of economic activity estimates provided in this report. These annual numbers provide context for the scale of current activity at-risk. For example, the establishments in coastal Louisiana that are at-risk in the 50 year, less optimistic case are roughly 0.7% of all establishments statewide and reflect approximately 0.9% of gross state product of a baseline of $497 billion. This does not take into account the potential losses due to increases in storm damage as a result of land loss or behavioral responses that may occur.

Economic Effects of Business Activity at Risk from Storm Damage

The effect of direct disruptions on business activity in Coastal Louisiana from storms is linked to business activity in Coastal Louisiana as well as the rest of Louisiana and the United States. Since business disruptions from storms directly affect output, lost sales were used for calibration of the analysis as opposed to employment statistics used in the previous section. The analysis also assumes that there is zero recapture in order to be consistent with an upper bound estimate of the potential impacts. As in the analysis of economic activity in Louisiana, we consider the three hypothetical events over three time periods (present, 25 years, and 50 years) for two environmental scenarios (moderate and less optimistic). The results show the increase in impacts from the present land conditions to the future land conditions for each of the hypothetical events and land loss projections to match the analysis in Chapter 3. The analysis assumes that the location of business activity and domestic trade patterns are fixed in coastal Louisiana across time but that the geography changes through the land loss process. The results for Coastal Louisiana for output appear in Table 4.20. Tables for employment and wages appear in Appendix G.

Similarly, there exist economic linkages between Coastal Louisiana and the rest of state, and the U.S. The effects on the rest of Louisiana appear in Table 4.21 and for the United States in Table 4.22.There is no direct effect on the rest of Louisiana and the United States since they are not affected directly by land loss and storms but indirectly though forward and backward linkages within the economy.

The potential losses from storm damage are an order of magnitude higher than simply for land loss. An eastern storm or a 100-year flooding event combined with the less optimistic environmental scenario, would impose significant costs to coastal Louisiana. These estimates are for the business disruptions and are in addition to the damages to housing and capital stocks.

Table 4.20

Economic Impact on Output in Costal Louisana From Increased Storm Damage					
Storm	Environmental Scenario	Time Horizon	Direct Impact ($ billions)	Indirect/Induced Impact ($ bilions)	Total Impact ($ billions)
Eastern	Moderate	25 year	$1.9	$1.3	$3.1
	Moderate	50 year	$2.6	$1.7	$4.2
	Less Optimistic	25 year	$2.4	$1.6	$3.9
	Less Optimistic	50 year	$22.0	$14.0	$36.0
100 Year	Moderate	25 year	$3.0	$1.9	$5.1
	Moderate	50 year	$5.0	$3.1	$8.1
	Less Optimistic	25 year	$4.6	$2.9	$7.5
	Less Optimistic	50 year	$12.0	$7.4	$20.0
Western	Moderate	25 year	$3.0	$1.8	$4.8
	Moderate	50 year	$4.4	$2.6	$7.1
	Less Optimistic	25 year	$4.5	$2.7	$7.2
	Less Optimistic	50 year	$9.0	$5.5	$14.0

Source: Authors' calculations using 2012 IMPLAN data model inputs.
Note: All monetary values presented in 2012 dollars.

Table 4.21

Economic Impact in Rest of Louisiana From Increased Storm Damage

Storm	Environmental Scenario	Time Horizon	Total Output Impact ($ billion)	Total Employment Impact (thousands)	Total Wages Impact ($ billion)
Eastern	Moderate	25 year	$0.1	0.4	$0.02
	Moderate	50 year	$0.1	0.6	$0.03
	Less Optimistic	25 year	$0.1	0.5	$0.02
	Less Optimistic	50 year	$0.8	4.4	$0.16
100 Year	Moderate	25 year	$0.1	0.8	$0.03
	Moderate	50 year	$0.2	1.2	$0.05
	Less Optimistic	25 year	$0.2	1.1	$0.05
	Less Optimistic	50 year	$0.4	2.6	$0.15
Western	Moderate	25 year	$0.1	0.7	$0.04
	Moderate	50 year	$0.2	1	$0.05
	Less Optimistic	25 year	$0.2	1	$0.05
	Less Optimistic	50 year	$0.3	1.9	$0.05

Source: Authors’ calculations using 2012 IMPLAN data model inputs.
Note: All monetary values presented in 2012 dollars.

Table 4.22

Economic Impact in Rest of US From Increased Storm Damage					
Storm	Environmental Scenario	Time Horizon	Total Output Impact ($ billions)	Total Employment Impact (thousands)	Total Wages Impact ($ billion)
Eastern	Moderate	25 year	$1.4	7	$0.4
	Moderate	50 year	$1.8	10	$0.6
	Less Optimistic	25 year	$1.7	9	$0.6
	Less Optimistic	50 year	$14.7	78	$4.6
100 Year	Moderate	25 year	$2.4	13	$0.7
	Moderate	50 year	$3.9	20	$1.2
	Less Optimistic	25 year	$3.6	19	$1.1
	Less Optimistic	50 year	$8.7	45	$2.6
Western	Moderate	25 year	$2.2	11	$0.7
	Moderate	50 year	$3.2	16	$1.0
	Less Optimistic	25 year	$3.4	17	$1.0
	Less Optimistic	50 year	$6.5	33	$2.0

Source: Authors' calculations using 2012 IMPLAN data model inputs.
Note: All monetary values presented in 2012 dollars.

Gasoline Prices after a Storm

This section describes the effect of storms on national gasoline prices. Storms hitting the Louisiana coast can cause significant disruptions in the supply and distribution of crude oil and finished gasoline across the nation because of the large amount of oil and gas production, refining and network infrastructure in coastal Louisiana. For more information about oil and gas in general and specific infrastructure like the Louisiana Offshore Oil Platform (LOOP) or Strategic Petroleum Reserves, see Appendix C.

During a major storm, several things happen to restrict gasoline production and distribution in the United States and especially the Gulf Coast region. The following description of storm impacts draws on information from a 2009 study by the U.S. Department of Energy on the 2005 and 2008 hurricane seasons, and input from David Dismukes of the LSU Center for Energy Studies.

The first effect of a storm is on crude oil supply. During a storm, most or all platforms in the Gulf of Mexico are shut-in and evacuated, halting a portion of U.S. crude oil production. Afterward, some platforms are left destroyed or damaged and remain shut-in for some time. Waterborne imports are temporarily restricted, and LOOP may be shut down or operated at a reduced rate. However, imports and LOOP are only curtailed for a short period of time; historically, a few days to perhaps two weeks. Imports can be increased after this time to make up for the reduced production in the Gulf of Mexico, so the reduction in crude oil supply lasts no longer than the restricted imports. If crude oil supply runs short before imports and LOOP return to normal, refiners can draw from the Strategic Petroleum Reserve (SPR). During both the 2005 and 2008 hurricane seasons, refineries did draw from the SPR in the immediate aftermath of the storms. Aside from a small amount of onshore oil production, this type of storm impact is not likely to be significantly influenced by land loss.

The second effect of a storm is on the Gulf Coast refineries, particularly in Louisiana and Texas. These refineries are mostly affected by power losses, crude supply disruptions, and workforce disruptions rather than damage caused by flooding of facilities. After a storm, many refineries operate at reduced capacity for a period of time. During the 2005 and 2008 hurricane seasons, refineries were operating at normal capacity within a few days to a few weeks after the storms. Refineries also have large reserves of refined products like gasoline that can be drawn down when the refinery is operated far below capacity, so there is little to no disruption in the supply of refined product. However, it is difficult to make up for the time the refinery is shut down or reduced. There is very little excess refinery capacity in the United States. Refineries operated at approximately a 92% utilization rate in 2014 (EIA Refinery Utilization and Capacity).

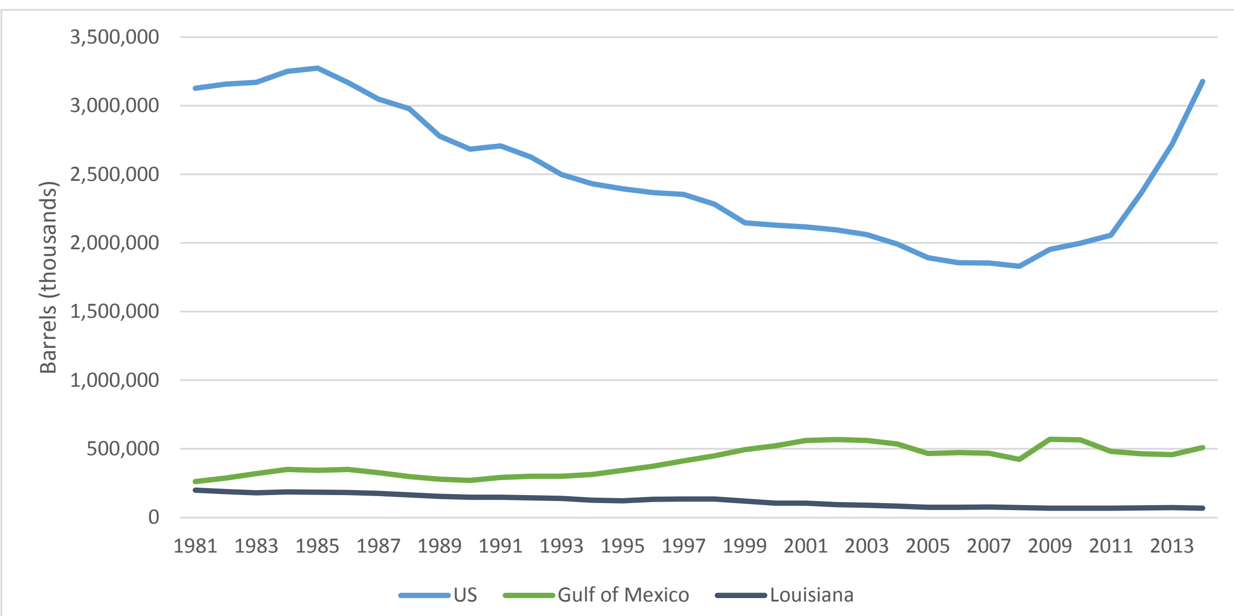
Storms can also cause disruptions in the distribution of refined oil products. Gasoline and petroleum products are transported by truck (58%), pipeline (34%), water (5%), and rail (1%) (Freight Analysis Framework). Several major product pipelines have been shut down or operated at reduced capacity after storms. To a smaller extent, parts of the Gulf Intracoastal Waterway and other important shipping routes have been closed after storms. Trucks and alternate means of transportation have only a limited ability to compensate. Truck deliveries are limited by fleet size and driver hours, among other problems. Because gas stations have relatively small storage capacity, they quickly run out of gasoline when there are disruptions in distribution. Additionally, gas stations may lose power and not have backup generators to operate. Consequently, there are spot outages at some gas stations and long lines at others.

The last two of these effects, disruptions in refineries and the distribution of refined oil product are the most vulnerable to storms. There are a few offsetting factors that can reduce the effect of these disruptions. Most important is the brevity of these disruptions – the largest disruptions, such as complete shutdowns of pipelines and refineries, only last for a few days, while capacity is only reduced for a few weeks. Temporary emergency measures can be adopted, such as EPA fuel waivers, allowing the sale of easier-to-refine gasoline specifications, the legal extension of maximum driver hours for fuel delivery, or the use of backup generators for power supply. Louisiana and many other states have passed laws that prohibit price gouging during emergencies, keeping prices of gasoline relatively stable despite some difficulties in supply.

While there has been little research into the potential impacts of storm-related disruptions, one notable study estimated the price effect on national gasoline and natural gas prices based on three hypothetical crude supply disruptions (Waldemar S. Nelson Company, 2003). One of these was a hypothetical three to five week disruption in supply of crude oil of 675,000 barrels per day (BPD) from the Houma region and Port Fourchon. The Nelson study estimated this supply disruption would increase the price of gasoline by 21.6 cents/gallon, or a total cost to the nation of $1.74 billion to $2.91 billion.

Since the Nelson study, two significant hurricane seasons that affected Louisiana and Texas pipelines and refineries (2005 with Hurricane Katrina and Hurricane Rita and 2008 with Hurricane Gustav and Hurricane Ike) have occurred and provide real-world examples of how the industry can be affected by storm events. While the general order of magnitude of the impact estimated by the Nelson study was similar to the price changes seen during the 2005 storm season, the mechanism causing the disruptions differed from their focus on crude oil supplies. Moreover, non-Louisiana domestic oil production has also increased significantly in the last decade, making a shutdown of Louisiana and Gulf of Mexico crude production during a storm event less significant at the national level – see Figure 4.3 below.

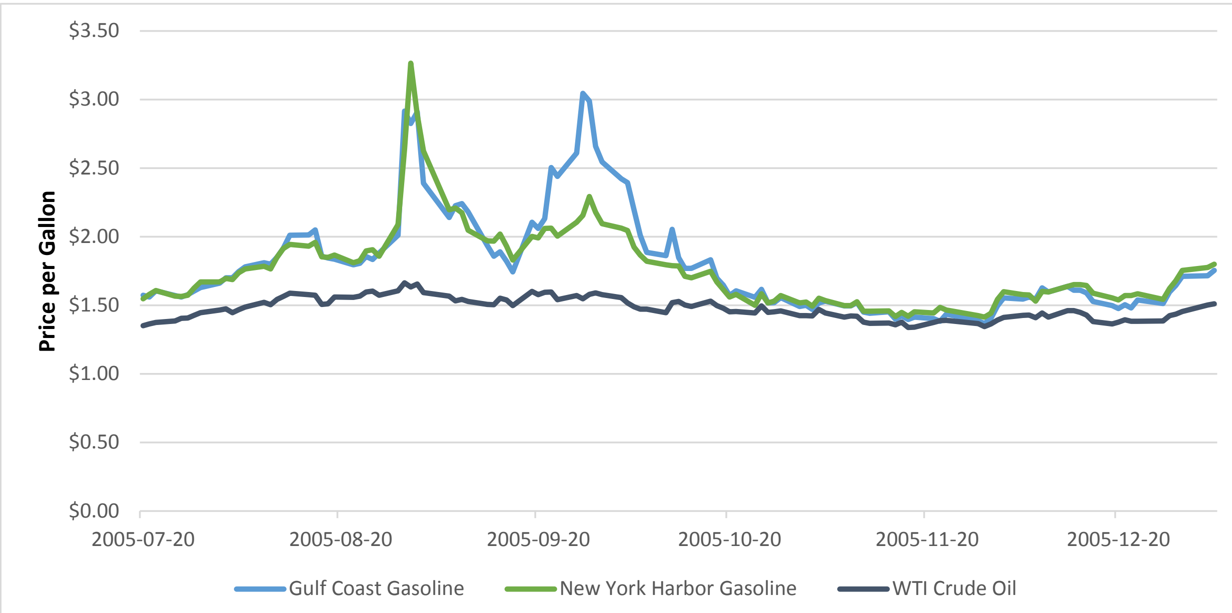
Figure 4.3: Oil Production in the US, Gulf of Mexico and Louisiana From 1981-2013



Source: U.S. Energy Information Administration.

We use the 2005 hurricane season as a case study to characterize the effect of hurricane-related supply disruptions on gasoline prices. Figure 4.4 shows wholesale spot prices per gallon for conventional gasoline along the Gulf Coast and at New York Harbor and for crude oil using West Texas Intermediate prices for the 2005 hurricane season. Hurricane Katrina made landfall on August 28, just before the first price increase. Hurricane Rita made landfall in west Texas on September 24. The price increase began 3 days in anticipation of Rita. Throughout this time period, crude prices remain stable while gasoline prices exhibit a considerable spike suggesting that market disruptions are more closely related to production and distribution than to crude oil supply.

Figure 4.4: Gasoline and Crude Oil Spot Prices During 2005 Hurricane Season



Source: U.S. Energy Information Administration.

Retail gasoline prices are available on a weekly basis in 2005 from U.S. Energy Information Administration (EIA) Weekly U.S. All Grades All Formulations Retail Gasoline Prices series. These data show that retail prices also increased for several weeks after Hurricanes Katrina and Rita. Because these hurricanes occurred only weeks from one another, it is difficult to fully separate the retail price effects between the two. Table 4.23 shows retail prices in the weeks following Hurricanes Katrina and Rita and the difference in prices from week zero, before Katrina's impact took effect.

Table 4.23

Difference in Retail Gasoline Prices Following Hurricanes Katrina and Rita			
Date	Week	Price ($/gallon)	Price Difference from week 0 baseline ($/gallon)
8/29	Katrina + 0	$2.653	
9/05	Katrina + 1	$3.117	$0.464
9/12	Katrina + 2	$3.002	$0.349
9/19	Katrina + 3	$2.835	$0.182
9/26	Rita + 0	$2.851	$0.198
10/03	Rita + 1	$2.975	$0.322
10/10	Rita + 2	$2.896	$0.243
10/17	Rita + 4	$2.775	$0.122

Source: EIA and authors' calculations
Note: All monetary values presented in 2012 dollars

To simplify, we assume that price differences between September 5 and September 19 can be attributed to Katrina, and price differences between September 26 and October 17 can be attributed to Rita. By October 24, prices had returned to pre-Katrina prices despite widespread damage created by these two storms. The data suggest that increases in gasoline prices from storms tend to be very short-lived.

Consumption of finished motor gasoline is approximated by the EIA with the product supplied of finished motor gasoline series. Product supplied is computed as follows: field production, plus renewable fuels and oxygenate plant net production, plus refinery and blender net production, plus imports, plus net receipts, plus adjustments, minus stock change, minus refinery and blender net inputs, minus exports. In September 2014, the most active month of hurricane season, there were approximately 369 million gallons of gasoline consumed daily.

Using these consumption numbers and price effects, we find that the total cost of increased gasoline prices are $2.6 billion from a Katrina-like storm and $2.3 billion from Rita-like storm. In a future without action, one can expect storm damage to increase, but the actual impact on gasoline prices from future storms remains uncertain. Many factors go into determining whether the cost of this type of disruption is likely to increase or decrease in the future, including the changing coastal landscape and industry flood control measures and policies. Future losses will vary depending on gasoline consumption patterns, the amount of damage to network infrastructure and distribution systems, and swiftness of industry response.

Summary

Louisiana is a major trade hub, with coastal parishes importing $160 billion and exporting $156 billion annually, with petroleum and chemical products constitute a large share of this activity. Louisiana is connected to and services other states through an extensive transportation system, including waterways, roads, rail and pipelines. Establishments directly at risk from land loss produce between $2.4 and $3.1 billion in annual sales, and their associated payroll is approximately $400 million to $575 million. These direct impacts are estimated to generate a total impact of between $3.4 and $4.5 billion in output in Louisiana and an additional $2.4 to $2.9 billion in output in the rest of the United States. In a future without action, some of the economic activity from at-risk establishments may be able to relocate, which could take more or less than the one-year time horizon of economic activity estimates provided in this report.

Increased storm damage caused by land loss also disrupts economic activity leading to an additional $5 billion to $51 billion in total lost output including indirect and induced effects. As with damage to capital stock, the estimates of business disruption are heavily influenced by whether or not levees are predicted to fail in the New Orleans area due to reduced natural storm protection caused by land loss. In the less optimistic scenario at 50 years, we estimate that the eastern track storm would affect an additional 26,000 establishments and 320,000 employees relative to a similar storm hitting the current coast. This type of disruption would directly generate between $140 million and $6.4 billion in lost wages and between $340 million and $23 billion in lost sales, depending on the land loss case, storm and model assumptions. Finally, because Louisiana serves as a hub for production and transportation of refined petroleum products, we analyze the effect of potential short term supply disruptions caused by major storms on national gasoline prices, which can add approximately $2.3 billion to $2.6 billion in additional costs to the nation.

5 Ecosystem Services

The previous Chapter documented many of the major effects of land loss on establishments and man-made capital stocks, both directly from land loss and from increased storm surge caused by land loss. These are but two of the services provided by coastal wetlands that are of value to the economy. In this chapter, we briefly review some of the additional non-protection ecosystem services that are of value in the region, and provide some details on a few (such as fisheries and recreation and tourism) that are typically measured in aggregate economic statistics. We also provide some qualitative information about additional ecosystem services that are largely ignored in regional economic statistics, but nevertheless have value. A major complication in the valuation of ecosystem services in this context is a lack of information about the relationship between land loss and each individual ecosystem service. As such, we document a few results from the literature that estimate per acre benefits of wetlands, and place these values in the context of the costs of stopping the process.

Definition and Categorization of Ecosystem Services

An ecosystem service is "…an activity or function of an ecosystem that provides benefit (or occasionally disbenefit) to humans" (Mace et al., 2012, p. 19). Ecosystem services can be classified as "final ecosystem goods and services", or ecological endpoints, that provide direct benefits in terms of utility to individuals or profits to firms, or indirect ecosystem goods and services that provide inputs into systems that support the endpoints (Ringold, et al., 2013; Boyd and Krupnick, 2013). Final ecosystem services can be further categorized as follows (Millennium Ecosystem Assessment, 2003):

- Provisioning Goods – goods produced or provided by ecosystems, such as food, water, and fuel;
- Regulating Services – services that regulate ecosystem process, such as storm and flood protection and disease regulation; and
- Cultural Goods and Services – typically non-market goods and services provided by ecosystems, including spiritual, recreational, and aesthetic services.

Services that support the production of final ecosystem services but do not directly provide benefits to humans are classified as supporting services.

We focus on ecosystem services provided by estuaries and wetlands in this report. Estuaries are bodies of water where oceans and rivers meet (Wilson and Farber, undated). They provide a number of provisioning, regulating, cultural, and supporting services. Table 5.1 provides a (partial) list of ecosystem services supported by estuaries and wetlands on the coast of Louisiana.

Table 5.1

Ecosystem Services Supported by Wetlands and Estuaries in Louisiana

Provisioning Goods	Regulating Services	Cultural Goods and Services	Supporting Services
Water Supply (consumption and transport)	Storm Protection Services	Recreation	Nutrient Cycling
Food (e.g., fish)	Gas Regulation	Aesthetic	Soil Formation
Raw Materials	Climate Regulation	Science and Education	Biological Regulation and Biodiversity
Genetic Resources	Disturbance Regulation	Spiritual and Historic	Habitat
Medicinal and Plant Resources	Soil Retention		Hydrological Cycle
Ornamental Resources	Waste Assimilation		

Source: Wilson and Farber, undated, based on modification of Millennium Ecosystem Assessment (2003). Gas regulation refers to the chemical composition of the atmosphere and oceans. Climate regulation refers to biologically mediated climate processes. Soil retention includes erosion control and sediment retention. Waste assimilation includes the detoxification of pollution and water quality benefits.

From Table 5.1, it can be seen that most marketable goods related to wetlands and estuaries fall in the provisioning goods category, including natural resource-based industries and water provision. One possible exception is recreation, which is classified in cultural goods and services and is an activity that may be supported by a number of economic sectors. Furthermore, storm damage protection is a regulating service (disturbance regulation) whose value to Louisiana for select events was estimated in Chapter 3.

However, there are a number of other services that are of value to society yet are not traded in markets. Estimation of the effect of land loss on each of these services is complex and fraught with scientific uncertainty, as are the measures of the value of each type of service. However, this does not imply that such services are unimportant, nor does it imply that techniques to estimate such value do not exist.

In this report, we briefly discuss each general category of ecosystem service, and provide details on two of the major sectors that might be affected by land loss: recreation and tourism, and the fisheries sector. We also provide a description of the habitat and other models developed for the 2012 Coastal Master Plan, and a brief background on the order of magnitude estimate associated with a subset of these services. In principle, the cost of any land loss in a future without action for the ecosystem services described in this chapter is the change in the net present value of all of the services supported by that land, as compared to a world in which those services are not lost (Fenichel and Abbott, 2014; Bond, 2015). Future research should be undertaken to more fully investigate these values.

Provisioning Goods

The major provisioning goods potentially at-risk from land loss in Louisiana are water supply (consumption and transport), food (especially fisheries, but also hunting, aquaculture, agriculture, and animals), raw materials, genetic resources (especially fish), medicinal and plant resources, and ornamental resources (e.g., shells and grasses used in the production of other goods) (Wilson and Farber, undated). For the most part, these goods are either directly traded in markets or are associated with related markets, and thus their market values are incorporated into the previous analysis of the economic activity in the region. One exception is the valuation of genetic resources, which contains a non-market concept known as "option value", which is the value derived from future use of a resource.

The analysis of Chapter 3 includes firms that provide provisioning services. However, given their direct relationship between the fisheries sector and the coastal environment, we detail the economic activity of the fishing sector below to highlight provisioning services of coastal Louisiana.

Fish Landings

Louisiana's coast provides the state with significant economic resources, and fisheries are a notable resource supported by the coastal marine ecosystem, including the coastal and estuarine environments (Chesney, et al., 2000). The five most economically important fisheries in Louisiana are white shrimp, menhaden (an oily fish commonly used in supplements and fish meal but not generally eaten), oysters, blue crabs and brown shrimp.

Louisiana fisheries produce approximately $300 million in revenue each year, and are a main contributor to the nation's seafood supply. Louisiana landed approximately 10% of the nation's fishery catch in 2012. Data from the National Marine Fisheries Service (NMFS) describes the total fisheries landings from both state and Federal waters for 2012. Data is available in aggregate and broken down by species from the years 1950 through 2012. This dataset includes both freshwater and saltwater landings. The most valuable species caught in 2012 in Louisiana are shown below in Table 5.2 (additional details can be found in Appendix E):

Table 5.2

The Most Valuable Species Caught in 2012 in Louisiana			
Species Name	Pounds (millions)	Dollars ($ millions)	Price/Pound
Shrimp, White	70	$110	$1.58
Menhaden	670	$40	$0.07
Oyster, Eastern	11	$40	$3.69
Crab, Blue	40	$40	$0.95
Shrimp, Brown	30	$30	$1.14
Totals	850	$300	

Source: NOAA. Note: All monetary values presented in 2012 dollars.

Table 5.3 shows the total fisheries catch in the state of Louisiana from 2002 through 2012. Total value has been more stable over time than total pounds as prices partially offset the effect of increases and decreases in supply.

Table 5.3

Total Fisheries Catch in Louisiana by Year		
Year	Pounds (millions)	Dollar value ($ millions)
2002	1,310	$280
2003	1,180	$270
2004	1,100	$270
2005	850	$250
2006	920	$280
2007	1,000	$290
2008	920	$280
2009	1,000	$290
2010	790	$230
2011	1,310	$320
2012	850	$300
TOTALS:	11,240	$3,070

Source: NOAA. Note: All monetary values presented in 2012 dollars.

Relationship between Wetlands and Estuaries and Fish Stocks

Fisheries stocks are closely tied to the habitats required for different stages of fish life cycles. Wetlands and estuaries are used as breeding, spawning, feeding, and nursery habitat for many species. It is estimated that over 75% of the commercially harvested fish species in Louisiana utilize wetlands for at least one life stage (Louisiana Coastal Wetland Functions and Values, 1997). Therefore, as land loss in Louisiana progresses, one might expect negative effects on Louisiana's total catch. However, despite decades of land loss and other habitat alterations, most Louisiana coastal fisheries have shown themselves to be resilient to change, with many populations (and catch) either constant or increasing (Chesney, et al., 2000).

Some research hypothesizes that there is a relationship between fishery biomass and marsh edge. Browder et al. (1985) suggests that as the land loss process progresses, there is first an increasing, then a decreasing relationship (after about the 50% loss point) between the length of the land-water interface and the amount of loss. Haas et al. (2004) found that brown shrimp have higher survival rates in locations with more marsh edges. This is because more marsh edge leads to lower movement-related mortality as the shrimp have direct access to vegetation (Haas et al. 2004). Additionally, more habitat reduces density-dependent growth limitations (Haas et al. 2004). Boesch and Turner (1984) did complimentary research tying commercially important species (including shrimp) to increased juvenile survivorship in vegetated habitat. They go on to state that there are regional trends of increased fisheries yield in areas with larger areas of salt marsh edge (Boesch and Turner, 1984). Alternative hypotheses for the positive relationship between wetland loss and increased populations include increased access to flooded marshlands, or submerged aquatic vegetation (Chesney, et al., 2000).

If the postulated relationship between marsh edge and some fishery stocks holds, and if the land loss process progresses towards a total loss of land along the coast, then fisheries yield can be expected to decrease. To date, as the land loss process has progressed, there is little evidence that overall fishery production has declined; however, this may not be indicative of future environmental conditions. Changes in the number and species distribution of fish are possible, and would likely have (unknown) economic consequences.

It should be noted that wetlands provide additional services to fisheries beyond habitat. Wetlands act as a filter between land runoff and the open ocean, and it can be expected that as wetland loss continues there will also be a decrease in water quality in the near shore Gulf of Mexico due to pollutants entering the open ocean without the wetlands acting as a filter (Reed 1991; Kadlec and Knight 1996; Kazmierczak, 2001). Decreased water quality (which may exacerbate the hypoxic[13] "dead zone" already plaguing the area) may cause significant harm to fisheries stocks. Therefore, even if wetland edge area temporarily increases as coastal land is lost, the associated decrease in water quality and other supporting services may have a negative effect on fisheries overall. Capturing the overall effect of land loss on fisheries would require detailed bio-economic modeling efforts that take into account

[13] Hypoxia refers to a condition of depleted oxygen in the water such that life is not supported.

the direct effect of land loss on fish stocks, the effect of supporting services on fish population dynamics, and the behavioral effects of changes in fisheries stocks and other changes.

Regulating Services

The major regulating services potentially at risk from land loss in Louisiana are gas and climate regulation (including carbon sequestration and regulation of the chemical compositions of air and water as well as local climate effects), soil retention and erosion control, waste assimilation (pollution control), and disturbance regulation in terms of storm and flood protection (Wilson and Farber, undated). Chapter 3 provides a case study of the economics of land loss and storm protection.

Although several studies in the literature investigate at least the biological implications of each category on humans (see, e.g., Kawabe and Oka, 1996; Tovilla-Hernandez et al., 2001, Johnston, et al. 2002), the physical relationships between land loss and non-protection services are not especially clear. As such, we do not discuss gas and climate regulation, and soil retention and erosion control are related to storm protection services.

There is a small literature that has tried to estimate the water quality benefits of coastal wetlands, though they tend to differ widely across space, measures, and techniques (Kazmierczak, 2001). In a review of the literature, Kazmierczak (2001) finds that the value of water quality services provided by coastal zone wetlands ranged from $3.66/acre/year to $7,291/acre/year (in 2012 dollars), with measures of central tendency of several hundred dollars/acre/year.

It should be noted that in some cases, water quality benefits may be entangled with other supporting ecosystem services (such as the aforementioned water quality impacts on fisheries). As such, care should be taken not to double-count ecosystem service values when making benefit-cost comparisons.

Cultural Goods and Services

The major cultural goods and services potentially at-risk from land loss in Louisiana involve outdoor recreation, use and non-use values related to aesthetic qualities of the coast, the value of current and future knowledge that could be lost (or gained) about estuaries and their processes, and other use or non-use values of the coast as it stands today (i.e., existence, option, and bequest values) (Wilson and Farber, undated).[14] Below, we document some of the effects of land loss related to use of coastal ecosystems for recreation. Non-use values are more difficult to measure, but could, in theory, be estimated using various non-market valuation techniques in the literature.

Recreation

In this section we consider risk of land loss to national and state parks as a proxy for recreational activities in Louisiana We are unaware of any general model that directly links recreational behavior (and thus associated expenditures) to land loss. In theory, however, if an explicit link between quality and other changes to recreational sites and land loss were available, various recreation demand models could be used to estimate the marginal effects of land loss on recreation expenditures and overall consumer surplus values.

[14] This categorization of non-market values is typical in the environmental economics literature. Use values come from directly consuming or enjoying a resource, while non-use values do not require direct interaction. Option value arises from the possibility of use in the future. Bequest value arises from the possibility of preserving an asset across generations. Existence value represents all other non-use values.

Instead, we document the direct effects of land loss on some of the public land areas in coastal Louisiana, document the extent of recreation spending across the state, and provide estimates of the overall value of a few categories of resources. In this sense, the discussion mirrors our treatment of structures and capital stock directly at risk, in that we are identifying natural capital stocks that may be affected by land loss, but we are unable to directly link the land loss processes to changes in value.

The expenditures themselves are largely captured in the estimates of all economic activity discussed in Chapter 3, but some values of recreation cannot be expressed fully in these dollars. Use values are estimated in this section to capture the economic value of these extra benefits.

Recreation Data and Methodology

Data for this section was collected from several state and national agencies as well as LSU. Geospatial data publicly available on Atlas: Louisiana's Statewide Geographic Information System included a Wildlife Management Area shapefile created by the Louisiana Department of Wildlife and Fisheries (LDWF) and a National Wildlife Refuges file from the U.S. Fish and Wildlife Service (FWS). We used a National Hydrography Dataset map created by the U.S. Geological Survey and revised in 2013 to determine land area in parks and wildlife management areas and refuges. Finally, LSU created a shapefile of state park boundaries from location and size data from Louisiana DOTD and Google Maps.

Many state parks and wildlife management areas and refuges include large masses of water within their borders. To determine the degree of land loss in recreation areas, we first calculate the current land area within the borders of recreational areas using the USGS hydrography maps to determine land versus water. Then, we measure future land area in each of the land loss projections to determine what percentage of the land of the park will be lost.

Data on recreational activity and spending is provided by a variety of sources. The Louisiana Office of Culture, Recreation, and Tourism (CRT) provided total revenues collected from users of state and federal parks for 2013. CRT also provided a comprehensive list of cultural festivals with attendance numbers and a listing of designated historical sites. FWS provides survey data for total days of various recreation activities in the state, and total dollars spent by each type of activity. Data on recreational saltwater fishing activity is provided by the NOAA Marine Recreational Information Program. LDWF provides surveys with data on the activities of recreational boaters, and makes statistics on the number of recreational and commercial licenses issued annually publicly available on the LDWF website. The Louisiana CRT office provided information on museum visits.

The first step in making a valuation for these sites and activities is to measure total spending for maintenance in-use. As described above, state and federal agencies report a great deal of information on money spent at these sites, including fees for entry and numbers of recreational licenses. In addition to entrance fees and licenses, money is spent on equipment, food, fuel, and lodging – estimated by the FWS survey data and NOAA – and the public spends money to maintain and protect these areas – also estimated by FWS.

The second step in total valuation is utilizing benefit transfers in order to estimate use value. Benefit transfer is the name given to the process of determining the most appropriate use value, or estimates of the value in excess of what is spent to participate in an activity, and is represented in dollars per activity-day. Estimates from relevant studies in the Oregon State University Recreational Use Values Database (which collects data from a number of recreational studies around the United States) are considered. Where there are a range of relevant studies to choose from, the mean of the previously estimated use value is directly applied to the activity of interest. If there is only a single relevant study available, this estimated use value is applied directly. Estimated use values are then applied to total days of participation for each activity.

The total valuation for each activity will therefore represent total spending plus total use value. Where possible, we show what recreational activities will be limited by land losses in our coastal areas.

Finally, we characterize general tourism, usually located in more urban areas that see less land loss, using data from Louisiana CRT and discuss how this tourism may be affected by increased storm damage in the future.

Recreation Results

Thirteen of Louisiana's 23 state parks and three of its 20 CRT-designated historical sites are threatened by land loss. Additionally, two national parks sited in Louisiana are threatened. Table 5.4 reports the most recent figures for visitors and self-generated revenues aggregated for these sites. In Table 5.5, aggregated estimates of future land loss in all recreation areas are presented. We note that changes in visitation will not necessarily be proportional to changes in land loss. For site-specific estimates, see Appendix F.

Table 5.4

State Park and Historic Sites Visitors and Revenue

	Visitors	Self-Generated Revenue
Coastal Area	1.2 million	$29 million
Total Statewide	2.2 million	$41 million

Source: Based on data from Raymond Berthelot of the Office of State Parks.
Note: All results are presented in 2012 dollars.

Table 5.5

Land Loss as a Percentage of Recreational Land by Category in Coastal Parishes

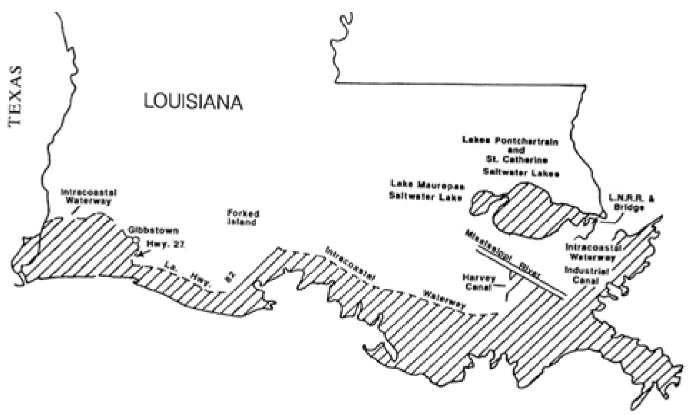
Environmental Scenario	Time Horizon	Wildlife Management Areas	Wildlife Reserves	Parks & Historical Sites
Moderate	25 year	6.5%	7.7%	1.4%
Moderate	50 year	9.4%	10.0%	2.7%
Less Optimistic	25 year	10.0%	13.0%	1.9%
Less Optimistic	50 year	20.0%	26.0%	3.4%

Source: Calculations from land loss models, park and wildlife maps, and National Hydrography Dataset.

To the extent possible, we assign various recreational activities to different coastal areas or ecosystem types. In Louisiana, there are some valuable activities that take place in the coastal marshes and other areas most severely affected by land loss. Chief among these are saltwater fishing, waterfowl hunting, and wildlife viewing, all of which are largely driven by coastal marshes or easy access to the Gulf.

Figure 5.1 shows all locations where saltwater recreational activity is available in Louisiana. We assume that 100% of recreational saltwater fishing activity is driven by the coastal region.

Figure 5.1: Saltwater-Freshwater Line



Source: Louisiana Wildlife and Fisheries.
Note: Saltwater areas shaded

According to the US Geological Survey, Louisiana contains 40 to 45% of all coastal marsh within the United States. The concentration of birds and species diversity offers opportunities for both birding and waterfowl/migratory bird hunting, compared to nearby areas that are dominated by forests and fields. Therefore, the coastal region also largely drives waterfowl hunting and wildlife watching activities within the state.

Of the seven parishes with the most frequent waterfowl hunting activity, six are coastal parishes, Approximately 75% of the sites reported as most hunted in surveys are in coastal parishes. We therefore conservatively estimate that 70% of waterfowl hunting activity is driven by coastal parishes.

According to FWS surveys, birding alone accounts for 52% of total wildlife viewing activity-days. Eighty four percent of Louisiana wildlife watchers have indicated that they seek out waterfowl and migratory birds, and we have already noted that the types of birds that these avid viewers seek are most successfully sighted in coastal parishes. Additionally, coastal regions host a unique concentration of amphibians and reptiles, which are also specifically sought by 49% of wildlife viewers. We therefore conservatively estimate that 60% of wildlife viewing activity is driven by the coastal region.

Table 5.6 reports the most recent estimates for activity and spending on recreational activities occurring in the coastal regions only and estimate their use values.

Table 5.6

Coastal Recreation, Selected Activities

Activity	Total Expenditure ($ millions)	Total days (millions)	Daily Use Value	Total Use Value ($ millions)
Saltwater Fishing	$870	4.7	$56.36	$260
Waterfowl Hunting (estimated)	$77	0.8	$42.53	$33
Wildlife Viewing (estimated)	$340	2.9	$36.86	$110
Coastal Subtotal (estimated)	$1,300	8.4	-	$400

Source: Authors' calculations and LDWF data. Note: All results presented in 2012 dollars.

Table 5.7 reports the most recent estimates for activity and spending on total recreational activities statewide, and estimates for their use values.

Table 5.7

Statewide Recreation, Selected Activities

Activity	Total Expenditure ($ millions)	Total Days (thousands)	Daily Use Value	Total Use Value ($ millions)
Saltwater Fishing	$870	4,700	$56.36	$260
Waterfowl Hunting	$110	1,100	$42.53	$47
Wildlife Viewing	$570	4,900	$36.86	$180
Freshwater Fishing	$530	16,700	$48.67	$810
Small Game Hunting	$30	1,000	$31.13	$31
Big Game Hunting	$260	3,700	$67.11	$250
Motor Boating	$1.0	30	$11.85	$0.4
Historical Sightseeing	$5.4	1,000	$29.73	$31
Museum Sightseeing	$0.6	350	$5.28	$1.9

Source: Authors' calculations, FWS, CRT, LDWF, NOAA. Note: All results presented in 2012 dollars.

It is important to note that there are several activities for which participation is not surveyed or estimated (e.g. off-road vehicle driving). However, the types of activities that tend to be monitored most closely also tend to be the activities that have the largest use value to consumers, and for which there is also the most direct spending, such as big-game hunting or saltwater fishing. Missing from these estimates is the highly subjective question of how to value these activities as a piece of Louisiana's cultural heritage. While the choice of a specific valuation method is unclear, there is no doubt that this quality has some value suggesting that the estimates presented in this report are somewhat conservative overall.

As seen in Table 5.8, the total recreational valuation for the state of Louisiana is $4.2 billion annually. This includes an estimated $2.4 billion in recreational spending, and additional $1.6 billion in surplus value enjoyed from all the activities the state has to offer.

Table 5.8

Total Annual Valuation of Recreational Activities

Component	Total Spending/ Revenue ($ millions)	Surplus Value ($ millions)	Total Valuation ($ millions)
Parks, Historical Sites, Wildlife Areas, Museums	$100	-	$100
Recreational Activities	$2,400	$1,600	$4,100
Total Recreational Licenses Issued (~780K)	$5	-	$5
Total Recreational Valuation	$2,500	-	$4,200

Source: Authors' calculations from FWS, CRT, LDWF, NOAA. Note: All results presented in 2012 dollars.

It is noteworthy that approximately 54% of total recreational expenditures in Louisiana (over $1.3 billion) are for activities in the coastal region alone, and that coastal activities contribute over $400 million in additional use value to the state's economy as well. In total, recreational activities in the coastal region contribute approximately $1.7 billion in direct recreational spending and surplus use value annually.

Supporting Services

Supporting ecosystem services are not directly valued by humans, but rather act as inputs into final demand goods and services, or ecological endpoints, that are used by individuals and groups. The major supporting services potentially at-risk from land loss in Louisiana are nutrient cycling that supports net primary productivity, biological support services including pest control and pollination, hydrological services that support groundwater and salinity gradients, and habitat for fish and wildlife (Wilson and Farber, undated). These are complex geophysical and biological processes that have the potential to be disrupted by the loss of land, and most certainly have value to the human system. We previously mentioned the habitat services for fisheries provided by coastal wetlands; additional categories of habitat measured in the 2012 Coastal Master Plan are given in the next section.

Ecosystem Services in the 2012 Coastal Master Plan

The 2012 Coastal Master Plan evaluated the impact of various restoration projects on 14 individual ecosystem services over a fifty-year period (CPRA, 2012). The quantification approach for each is described in Table 5.9.

Table 5.9

Quantification Methods of Ecosystem Services in 2012 Coastal Master Plan		
Ecosystem Service	Category	Quantification Method
Alligator habitat	Supporting services	Estimated habitat suitability index based on how different combinations of water, vegetation and land characteristics support alligator habitat
Crawfish (wild caught) habitat	Supporting services	Estimated habitat suitability index based on how different combinations of water, vegetation and land characteristics support crawfish habitat
Oyster habitat	Supporting services	Changes in oyster habitat were predicted through a habitat suitability model that accounted for land change, water, and bottom characteristics.
Shrimp (white and brown) habitat	Supporting services	Habitat suitability models were developed for juvenile brown shrimp and juvenile white shrimp to predict changes in habitat based on water and vegetation characteristics.
Saltwater fishery habitat	Supporting services	A habitat suitability model for juvenile speckled trout was used to reflect changes to saltwater fisheries, based on water and vegetation characteristics.
Freshwater fishery habitat	Supporting services	A habitat suitability model for largemouth bass was developed, which incorporated changes in water and submerged aquatic vegetation characteristics.
Waterfowl habitat	Supporting services	A combination of habitat suitability models for mottled duck, gadwall, and green winged teal was used to estimate waterfowl habitat changes based on predicted changes to water, vegetation and land characteristics.
Other coastal wildlife habitat	Supporting services	Habitat suitability models for muskrat, river otter, and roseate spoonbill were developed based on water, vegetation, and land characteristics.
Nature-based tourism	Cultural Goods and Services	A model was developed to estimate the potential for nature-based tourism, which measured human access to high quality habitats for wildlife near coastal tourism centers, such as barrier islands and wildlife management areas. The species used to describe this service included: alligator, roseate spoonbill, river otter, muskrat, neotropical migrants, and waterfowl.
Support for agriculture and aquaculture	Regulating Services	A model was developed that evaluated salinity characteristics and frequency of flooding in upland areas. This index includes lands that are in production for rice, sugarcane, cattle, farmed crawfish, and other agricultural and aquaculture activities.
Nutrient uptake	Supporting Services	A model was developed to predict effects on nitrogen removal in open water, sediment, and wetlands.
Carbon sequestration	Regulating Services	A wetland morphology model was used to estimate effects on carbon storage potential, which allows for variation in carbon storage with the type of wetland, the acreage, and the annual vertical accretion of soil.
Freshwater availability	Provisioning Goods	A suitability model was developed to evaluate salinities in close proximity to strategic assets or populated areas.
Storm surge/ wave Attenuation	Regulating Services	Estimated the effects of storm surge and waves on coastal communities, based on the location and amount of land in proximity to population centers, type of vegetation, and land elevation.

Source: Adapted from Barbier (2013), Table 2. “Category” column added by the authors.

As can be seen in the table, the 2012 Coastal Master Plan focused primarily on supporting services, including wildlife habitat for a number of species and nutrient uptake, though it also included models for storm surge/wage attenuation, carbon sequestration, and flooding services for agriculture, which are regulating services. Models related to use values included nature-based tourism (based on cultural goods) and freshwater availability (a provisioning good).

These effects were not monetized, but rather expressed in non-monetary terms (e.g., suitability, nitrogen removal). This is standard practice for restoration and other studies, but does not provide estimates suitable for benefit-cost and other types of economic analysis (Caffey, et al., 2014).

Estimated Values of Ecosystem Services

Given the complexity of ecological systems, including the human relationships involved, full accounting of the value of ecosystem services is rare. Instead, the value of some subset of services is often reported. In the case of coastal wetland restoration, dollar values are often estimated for habitat provision, nutrient management, and storm surge attenuation (see Caffey, et al., 2014 and citations therein). One of the primary focuses of the current report is on the effects of land loss on capital stock damage and economic flow disruptions in the context of major storm events, as reported in Chapter 3.

The constantly-evolving economic valuation literature provides a wealth of studies that estimate the value of certain non-protection ecosystem services within a particular context relative to a particular baseline. As an example, the Barataria-Terrebonne Estuarine System (BTES) lies on the southern coast of Louisiana between the Mississippi and Atchafalaya Rivers, comprising approximately 4.2 million acres of low-lying land, wetlands, and water (Wilson and Farber, undated). The marginal values of select ecosystem services have been estimated for BTES, and are provided, along with the appropriate source, in Table 5.10.

Table 5.10

Values of Selected Ecosystem Services in Barataria-Terrebonne Estuartine System

Ecosystem Service	Value per acre ($)	Source
Wetland Habitat Provision for Commercial Species	$84.00	Farber and Costanza, 1987
Shrimp	$24.00	Farber and Costanza, 1987
Blue Crab	$21.50	Farber and Costanza, 1987
Oysters	$18.00	Farber and Costanza, 1987
Menhaden	$13.00	Farber and Costanza, 1987
Muskrat	$27.00	Farber and Costanza, 1987
Storm Protection	$20 – $70.00	Farber, 1987; Farber and Costanza, 1987
Wetland Municipal Wastewater Treatment	$112.00	Breaux, et al. 1995; Industrial Economics, 1996
Wetland Manufacturing Wastewater Treatment	$6,300	Breaux, et al. 1995; Industrial Economics, 1996

Source: Wilson and Farber (undated). Note: All results presented in 2012 dollars

More generally, Woodward and Wui (2001) performed a meta-analysis on 39 wetland valuation studies that provided estimates of per-acre consumer surplus values for a number of (potentially overlapping) services. The empirically estimate a model that explains the variation in average per-acre wetland value when that wetland includes a particular ecosystem service. Values for hypothetical single-service wetlands, converted to 2012 dollars, are reported in Table 5.11. These values should not be summed to obtain total values due to the potential for double-counting.

Table 5.11

Estimated Per-Acre Single-Service Wetland Values			
	Lower	Mean	Upper
Reduced Storm Damage	$140	$619	$2,753
Water Quality	$199	$657	$2,171
Water Quantity	$9	$200	$4,051
Recreational Fishery	$150	$563	$2,115
Commercial Fishery	$170	$1226	$8,852
Bird Hunting	$39	$110	$310
Bird Watching	$832	$1910	$4,383
Amenity Values	$2	$5	$22
Habitat (Non-Use Values)	$150	$482	$1,546
Erosion Reduction	$17	$373	$8,102

Source: Woodward and Wie (2001). Note: All results presented in 2012 dollars. Lower and Upper refer to bounds of 90% confidence interval. Values are for single-service wetlands per acre, and are not additive.

The two important takeaways from these estimates are that a) there is a great deal of difference between the estimated net present value of each type of service (as revealed in the per-acre benefits); and b) the confidence intervals around each are very wide, suggesting additional differences over primarily methods and space. It is also notable that habitat values for commercial fisheries and birds are two to three times the estimates from the estimated value of capital from reduced storm damage, suggesting that ecosystem service values are far from trivial.

Finally, in Table 5.12, we report the range of values of wetlands specifically for Louisiana. Each estimate includes a certain subset of ecosystem services that are converted to net present value terms.[15] Unlike the values in Table 5.11, they include multiple ecosystem services. Each includes estimates of annual storm damage, but vary in terms of other coverage. They are ordered from least to most inclusive in terms of the services that are included.

Table 5.12

Implied Values per Acre for Louisiana Wetlands	
Source	Range
Farber (1996)	$17,000 - $19,000
Kim and Petrolia (2013)	$15,000 - $23,000
Batker, et al. (2010)	$29,000 - $113,000

Source: Results from Kim and Petrolia (2013) and Batker, et al. (2010) were not originally presented in values per acre. Values for Kim and Petrolia (2013) are based on a 10 year time horizon due to methods used in the analysis, while Farber (1996) and Batker, et al. (2010) are on the order of 100 years. Note: All results presented in 2012 dollars. All ranges assume a 5% discount rate.

[15] Farber (1996) and Batker, et al. (2010) estimate the value of separate services and then sum to create the total. Petorlia and Kim (2013) use a contingent valuation survey to estimate aggregate willingness to pay for a wetlands protection project.

As with individual services, the estimated per-acre values have a fairly wide range both within and between studies, likely due to methodological differences.

Future Research on the Link between Ecosystem Services and Land Loss

Comprehensive and theoretically-sound valuation of ecosystem services in complex, uncertain, and non-linear coupled systems is characterized by a number of difficulties, including, but not necessarily limited to:

- Scientific uncertainty as to the relationships between supporting services and final ecosystem goods and sevices;
- The potential for double-counting benefits;
- Economic uncertainty over the marginal values of final ecosystem goods and services, especially those that are of a non-market nature; and
- Context-dependence of marginal valuations, including the role of substitutes.

If a relationship between land loss and each type of service could be specified or estimated, and it was determined that past estimates of the marginal values associated with each were appropriate for coastal Louisiana, then bio-economic methods such as those described in Abbott and Fenichel (2014) and Bond (2015) could be used to develop theoretically-consistent values of ecosystem services that could take into account non-linearities and any number of assumed economic behaviors.

Existing estimates for the value of coastal wetlands, and the services they provide, vary greatly across studies of value. Nevertheless, we can place the estimates in context. As reported in Petrolia and Kim (2011), through 2006, an es-timate 32,345 acres of land was re-established under the Coastal Wetlands Planning, Protection, and Restoration Act of 1990 (also known as the Breaux Act) at a cost of approximately $624.5 million.[16] Using these figures, the break-even per acre benefits of wetlands would need to be just over $19,000 to justify the costs, which is in the range of the estimates presented in Table 4.12. Similarly, although based on much older estimates, Farber (1996) estimated that in 1990, expenditures of $3 billion over twenty years could arrest the land loss process; when converted to 2012 dollars, the break-even point is around $9,000 per acre assuming 25,500 acres lost per year.

The evidence presented here suggests that when ecosystem service values are taken into account, it is possible that the benefits of arresting the land loss process will outweigh the costs. Of course, given the differential in estimated values across services, sites, and methods, as well as the expenditure uncertainties associated with large-scale public work projects, this conclusion cannot be taken for granted. Rather, project-specific evaluation of the projected change in ecosystem service values should be undertaken to promote efficiency in public resource allocations.

[16] It is not clear from the article if these are real or nominal dollars; as such, we simply divide this figure by the acreage.

6 Summary and Conclusions

This report presents an economic evaluation of assets and activities at risk from land loss and associated storm damage in coastal Louisiana. The results show a significant level of risk to economic assets and activity in Louisiana, and that the potential disruptions along the coast can have significant implications beyond the immediate region.

In summary, we estimate that replacement costs associated with capital stock at risk from direct land loss range from approximately $2.1 billion to $3.5 billion under the environmental scenarios and time horizons considered. The economic activity directly at risk in coastal Louisiana ranges from $2.4 billion to $3.1 billion in annual output. At-risk establishments in the less optimistic scenario at the end of 50 years are roughly 0.7 percent of all establishments statewide and reflect a similar share of economic output.

We estimate that increased storm damage to capital stocks ranges from $8.7 to $132 billion across our storm case studies. Increased damage to non-residential structures ranges from approximately $5 billion for the eastern track storm in the moderate scenario at 25 years to over $70 billion for the same storm track in the less optimistic scenario at 50 years. Damage estimates for residential structures range from $4 billion to $61 billion for the same storm cases, with network infrastructure costs ranging from $140 million to $640 million. Economic activity will also face more substantial disruptions by storms in a future without action. Our preferred estimates imply that lost activity from businesses directly facing additional damage ranges from $1.9 billion to $23 billion in lost sales across the storm case studies; for example, the eastern track storm in the less optimistic scenario at 50 years is estimated to increase damage for approximately 26,000 establishments employing 320,000 workers, resulting in $6.4 billion of lost wages and $23 billion of lost sales. The estimated number of businesses potentially facing long term closure due to increased storm damage ranges from about 250 to 3,500 across the storm case studies.

Coastal Louisiana has strong ties to the rest of the country and provides a number of gateways, primarily water-based, for commodity flows to the rest of the world. When considering the indirect and induced impacts of losses in coastal Louisiana to the rest of the state and the nation, we estimate that a total of between $5.8 and $7.4 billion in annual output is at risk from the direct loss of land along Louisiana's coast. Similarly, we estimate that increased storm damage will have a total impact on the nation of between $8.7 and $51.5 billion across the storm case studies. These estimates of impacts to economic activity should be considered alongside the estimates of capital assets at risk; they range from $2.1 billion to $3.5 billion for direct land loss, and $8.7 billion to $132 billion for increased storm damage. While several critical elements such as pipeline infrastructure, Mississippi River navigation and Gulf Intracoastal Waterway navigation were not quantified in the study, it should be remembered that each play a major role in the state and national economy. Additional substantial costs would be generated by damage and other negative impacts by land loss.

Finally, in addition to storm protection services, coastal Louisiana is characterized by a number of other valuable ecosystem services. In particular, fisheries, tourism, and recreation are major sources of economic activity that are directly attributable to provisioning and cultural services. All are expected to be impacted either directly by land loss or by increasing storm damage driven by land loss.

To place these estimates into context, we note that past estimates of the costs of protecting wetlands have ranged between $9,000 and $19,000 per acre in 2012 dollars (Petrolia and Kim, 2011; Farber, 1996).[17] Furthermore, the 2012 Coastal Master Plan approved by the Louisiana legislature proposed protection and restoration expenditures of approximately $50 billion over a 50 year time horizon, though that suite of projects was not intended solely to protect coastal land, but rather to balance a number of objectives towards supporting a sustainable coast. Because estimates provided in this report are not forecasts of damage from land lost nor do they predict the benefits from a portfolio of potential projects, they should not be directly incorporated into a benefit-cost framework. Rather, they provide a baseline understanding of assets and activities that are currently at risk in a future without action and for several possible storm incidents. That said, conditional on the realization of an eastern-track storm similar to the one assumed here and a less-optimistic land loss scenario, our results suggest that the benefits provided by coastal land can be substantial.

Study Limitations

Our goal was to provide comprehensive, accurate estimates of the cost of coastal land loss in Louisiana, but we acknowledge a range of limitations to our analysis and final estimates. While the results are suggestive of the magnitude of the potential damage that could result from future land loss, there are a number limitations and caveats to our analysis that can provide opportunities for future research.

First, we do not attempt to project how the distribution of economic assets and activity in Louisiana would change over the 25- and 50-year horizons of our study period, although we know that current conditions will not persist into the future. We make the assumption of *no change in capital stock* in order to avoid the large degree of uncertainty in the level and distribution of future economic development across coastal Louisiana, and to abstract away from the likely feedbacks between land loss and economic development. We believe that by assuming economic assets and activities remain fixed at current conditions, we are able to more fully isolate and illustrate the differential impact of land loss on the economy.

[17] Note that these costs are in terms of restoration of wetlands acreage, and do not necessarily imply a cost-minimizing approach to coastal protection of economic assets.

Second, our methodology uses static models to estimate the effects of land loss on major categories of economic assets and activity. This approach has the advantages of being both tractable and easily understood. Yet like all models, it greatly simplifies reality by not taking into account dynamic economic processes and behaviors, including feedback between the geophysical process of land loss and the economic system. At each stage in our analysis, we make assumptions that eliminated the possibility of individual economic actors taking actions to reduce damage due to land loss. For example, individual homeowners can take action to harden their homes. Businesses at direct risk from land loss can choose to relocate further inland or invest to protect critical asset. Government organizations can opt to undertake projects to further protect areas viewed as particularly at risk (See the 2012 Coastal Master Plan for an evaluation of the benefits of particular suites of such protection projects). We interpret a "future without action" as one in which such behaviors are generally assumed away, though it seems unlikely that this assumption is predictively accurate.

That being said, the estimates of potential costs presented in this report are limited to three categories of effects: 1) the capital stock and activity at risk of land loss; 2) the expected increase in storm damage from a loss of storm surge protection; and 3) the impact of those potential disruptions on the rest of the economy. While we believe that these categories are likely the largest components of the overall costs of land loss, they are not comprehensive in nature. There are a number of potential effects of land loss that will affect economic activity that are not explicitly valued in this report (e.g. non-protective ecosystem services and navigability of the Mississippi River). The major characteristics of these excluded effects are that either a) there is great uncertainty in the physical relationship between land loss and the asset or service being valued; b) there is uncertainty about the marginal values associated with the asset or service being valued; or c) both. Many of these values may be non-market in nature. For example, the value of supporting ecosystem services is derived from a suite of potentially market and non-market final ecosystem services. Furthermore, there may be existence, option, and bequest values associated with coastal Louisiana as a unique cultural place in the American landscape. Future research into these characteristics would help clarify the potential effects of land loss by reducing the uncertainty over these elements. Their exclusion here will result in an underestimation of the costs of land loss (assuming that, on balance, the excluded effects tend to increase damage). Relatedly, in some cases we underestimate the capital stock at risk of damage or loss due to data or methodological limitations. For example, we estimate increased damage to roads and rail infrastructure, but did not calculate the monetary costs for bridges and pipelines. In the former, significant bridge damage could occur because of collisions with vessels or debris propelled by storm surge, but there does not appear to be a practical way of attributing a differential in this risk to the process of land loss. In the latter, the relationships are not sufficiently well-known to provide informed estimates.

This uncertainty extends to relationships between economic actors and their aggregate behaviors both within and outside of Louisiana. While our methodology does account for sector-specific impacts in some cases, it does not account for the incremental effects on industry-specific transportation routes or modes, supply chains, or other general equilibrium effects that might be attributable to land loss. Rather, we assume that the average relationships under current conditions persist into the future. This assumption is appropriate for estimating the effects of land loss in aggregate, but may not reveal industry-specific nuances of the land loss process.

Finally, we consider uncertainty in this analysis through the variations implicit in the land loss scenarios and time horizons, and through three representative storm events and resulting damage. In some cases, we also provide estimates over a varying parameter space. While this representation of uncertainty can provide some indication of the differences in costs of land loss across various futures, it is not a complete representation of the uncertainty associated with the future. Rather, we intend this treatment as a compromise that helps illustrate the variation in potential magnitudes across certain futures and events. We remind readers that there will surely be some future years in which no major storm events impact coastal Louisiana, but there may also be years with multiple severe events like the 2005 hurricane season.

Conclusion

In this report we have sought to provide informed, practical estimates of the economic effects associated with a changing coastline in Louisiana by calculating the direct and indirect costs of projected coast land loss in a future without action. The results show that land loss threatens the capital stock and economic activity of coastal Louisiana and disrupts its economic relationships with the rest of the country and the world. As such, beneficial projects that help reduce future damage from theconversion of land to wetlands or open water (such as those in the 2012 Coastal Master Plan) will likely induce benefits to those outside of the immediate coastal region through the maintenance of commodity flow and trade relationships that capitalize on Louisiana's comparative and absolute advantages. However, the cost of a specific project or suite of projects should be weighed against the project benefits, which will require additional research. This study provides a baseline measure of the consequences of no action and has identified and refined a set of methods and data that can be used in future work to investigate the potential benefits of specific protection and restoration plans.

Future research could improve the estimates of these benefits by expanding the analytic scope, conducting additional data collection, or carrying out case studies for specific sectors. In particular, future work could account for changes in the location and scale of economic activity over time, including how the economy is likely to respond through feedback mechanisms, thus incorporating likely mitigating behaviors. Industry-specific case studies, especially focused on substitutability in supply chains and transportation modes, could lend additional insight into the likely effects of land loss on specific sectors. Finally, there are some important damage categories, such as broad ecosystem services and other non-market costs of land loss, which could be estimated in a more comprehensive way if primary data could be collected. These expansions would add complexity to the analysis and results, but the additional nuance could provide valuable information for policymakers and other stakeholders.

References

AHA Annual Survey Health Forum, L.L.C., 2013. http://www.ihaonline.org/imis15/Images/IHAWebPageDocs/infoservices/2013%20AHA-IHA%20Iowa%20Licensure%20Survey.pdf

ARCADIS, Louisiana's Comprehensive Master Plan for a Sustainable Coast, Appendix D-24 Storm Surge / Wave Model (ADCIRC) Technical Report, 2012. As of July 24, 2015: http://coastal.la.gov/a-common-vision/2012-coastal-master-plan/cmp-appendices/

Amlin, J., R. Levesque, and G. Backus. 2003. Economic Impact of a Pacific Northwest Port Shutdown. Prepared for: Sandia National Laboratories. Accessed 09/18/14 at http://www.remi.com/the-remi-model/topic-areas/economic-development/economic-development-research.

Barbier, E.B. 2013. Valuing Ecosystem Services for Coastal Wetland Protection and Restoration: Progress and Challenges. Resources 2: 213-230.

Barras, John A. 2006.Land Area Change in Coastal Louisiana after the 2005 Hurricanes—A Series of Three Maps: U.S. Geological Survey Open-File Report 06-1274.

Batker, D., de la Torre, I., Costanza, R., Swedeen, P., Day, J., Boumans, R., & Bagstad, K. (2010). Gaining Ground: Wetlands, Hurricanes, and the Economy: The Value of Restoring the Mississippi River Delta. Earth Economics Project Report.

Bingham, P. 2013. The Impacts of Temporary U.S. Port Closures on International Supply Chains. FHWA Talking Freight Webinar, January 23, 2013, accessed 09/19/14 at http://www.fhwa.dot.gov/planning/freight_planning/talking_freight/january_2013/talkingfreight01_23_2013pb.pptx.

Boesch, Donald F., and R. Eugene Turner, "Dependence of Fishery Species on Salt Marshes: The Role of Food and Refuge," Estuaries, Vol. 7, No. 4A, December 1984, pp. 460-468. As of December 15, 2014: https://marine.rutgers.edu/pubsclassics/private/Estuaries%20vol7Z%20p460-468.pdf

Boyd, J. and A. Krupnick. 2013. Using Ecological Production to Define and Select Environmental Commodities for Nonmarket Valuation. Agricultural and Resource Economics Review 42(1): 1-31.

Breaux, A., Farber, S., Day, J. 1995. Using Natural Coastal Wetlands Systems for Wastewater Treatment-an Economic Benefit Analysis. Journal of Environmental Management 44: 285-91.

Browder, Joan A., Henry A. Bartley and Kevin S. Davis, "A Probabilistic Model of the Relationship Between Marshland-Water Interface and Marsh Disintegration," Ecological Modeling, Vol. 29, No. 1-4, 1985, pp. 245-260. As of December 15, 2014: http://phdtree.org/pdf/32181851-a-probabilistic-model-of-the-relationship-between-marshland-water-interface-and-marsh-disintegration/

Burkett, V. 2002. Potential Impacts of Climate Change and Variability on Transportation in the Gulf Coast/Mississippi Delta Region. In The Potential Impacts of Climate Change on Transportation, Summary and Discussion Papers, Federal Research Partnership Workshop, Brookings Institution, Washington, D.C., Oct. 1–2, pp. 103–113.

Caffey, R.H., H. Wang, and D.R. Petrolia. Trajectory Economics: Assessing the Flow of Ecosystem Services from Coastal Restoration. Ecological Economics 100:74-84.

Chesney, E.J., D.M. Baltz, and R. G. Thomas. 2000. Louisiana Estuarine and Coastal Fisheries and Habitats: Perspectives from a Fish's Eye View. Ecological Applications 10(2): 350-366.

Coastal Protection & Restoration Authority (CPRA) of Louisiana. 2012. Louisiana's Comprehensive Master Plan for a Sustainable Coast; Office of Coastal Protection and Restoration: Baton Rouge, LA, USA.

Congressional Budget Office. 2006. The Economic Costs of Disruptions in Container Shipments. Washington, D.C. Accessed 09/18/14 at http://www.cbo.gov/sites/default/files/cbofiles/ftpdocs/71xx/doc7106/03-29-container_shipments.pdf.

Costanza, R., O. Perez-Maqueo, M.L. Martinez, P. Sutton, S.J. Anderson, and K. Mulder. 2008. The Value of Coastal Wetlands for Hurricane Protection. Ambio 37(4): 241-248.

Craioveanu & Terrell. 2010. The impact of storms on firm survival: a Bayesian spatial econometric model for firm survival.
Dingerson, L. 2005. Predicting Future Shoreline Condition Based on Land Use Trends, Logistic Regression, and Fuzzy Logic. Thesis. Virginia Institute of Marine Science, College of William and Mary, Gloucester, VA.
Dismukes, D.E., M.L. Barnett, and K.A.R. Darby. Undated. Determining the Economic Value of Coastal Preservation and Restoration on Critical Energy Infrastructure. In The Economic and Market Value of Coasts and Estuaries: What's At Stake, Pendleton, L.H. (ed.), Washington, D.C.: Restore America's Estuaries, pp. 82-96.
Douglass, S. L., J. M. Richards, J. Lindstrom, and J. Shaw. 2005. An Estimate of the Extent of U.S. Coastal Highways. Presented at 84th Annual Meeting of the Transportation Research Board to the Committee on Hydraulics, Hydrology, and Water Quality, Washington, D.C., Jan. 10.
Farber, S. 1996. A Welfare Loss of Wetlands Disintegration: A Louisiana Study. Contemporary Economic Policy XIV, 92-106.
Farber, S. 1987. The value of coastal wetlands for the protection of property against hurricane wind damage. Journal of Environmental Economics and Management 14: 143-51.
Farber, S. and R. Costanza. 1987. The Economic Value of Wetlands Systems. Journal of Environmental Management 24: 41-51.
Fenichel. E.P. and J.K. Abbott. 2014. Natural Capital: From Metaphor to Measurement. Journal of the Association of Environmental and Resource Economists 1(1/2): 1-27.
Fischbach, Jordan R., David R. Johnson, David S. Ortiz, Benjamin P. Bryant, Matthew Hoover and Jordan Ostwald. Coastal Louisiana Risk Assessment Model: Technical Description and 2012 Coastal Master Plan Analysis Results. Santa Monica, CA: RAND Corporation, 2012. http://www.rand.org/pubs/technical_reports/TR1259.
Grenzeback, L.R. and A.T. Lukmann. 2007. Case Study of the Transportation Sector's Response to and Recovery from Hurricanes Katrina and Rita. Cambridge Systematics, Inc., Cambridge, MA.
Haas, H.L., K.A. Rose, B. Fry, T.J. Minello, and L.P. Rozas. 2004. Brown Shrimp on the Edge: Linking Habitat to Survival Using an Individual-Based Simulation Model. Ecological Applications 14(4): 1232-1247.
Inforum. 2014. The National impact of a West Coast Port Stoppage. Inforum Report Commissioned by the National Association of Manufactures and the National Retail Federation, June, 2014, accessed 09/19/14 at https://nrf.com/sites/default/files/Port%20Closure%20Full%20Report.pdf.
Industrial Economics. 1996. Economic Value Assessment for the Barataria-Terrebone Estuarine System. Rep. BTNEP Publication #6. pp.Johnston, R. J., Grigalunas, T. A., Opaluch, J. J., Mazzotta, M., Diamantedes, J. 2002. Valuing estuarine resource services using economic and ecological models: the Peconic Estuary System study. Coastal Management 30: 47-65.
Isaacs, Jack C. and Lavergne, David R. 2010. Survey of Louisiana Recreational Boaters. Prepared for: Louisiana Department of Wildlife & Fisheries. Accessed 11/10/2014 at http://www.wlf.louisiana.gov/publication/survey-louisiana-recreational-boaters
Isaacs, Jack C. 2010. Louisiana Bird Watchers: A Further Examination of Past Research. Prepared for: Louisiana Department of Wildlife & Fisheries. Accessed 11/10/2014 at http://www.wlf.louisiana.gov/sites/default/files/pdf/document/33317-louisiana-bird-watchers-further-examination-past-research/louisiana-birders-further-examination.pdf
Johnston, R.J., T.A. Grigalunas, and J.H. Opaluch. 2002. Valuing Estuarine Resource Services Using Economic and Ecological Models: The Peconic Estuary System Study. Coastal Management 30:47-65.
Kawabe, M., Oka, T. 1996. Benefit from improvement of organic contamination of Tokyo Bay. Marine Pollution Bulletin 32: 788-93.
Kadlec, R.H. and R.L. Knight. 1996. Treatment Wetlands. Lewis Publishing, New York.
Kazmierczak, Richard, (2001), Economic Linkages Between Coastal Wetlands and Water Quality: A Review of Value Estimates Reported in the Published Literature, No 31685, Staff Papers, Louisiana State University, Department of Agricultural Economics and Agribusiness, http://EconPapers.repec.org/RePEc:ags:lsustp:31685.

Kim, T. and D.R. Petrolia. 2013. Public Perceptions of Wetland Restoration Benefits in Louisiana. ICES Journal of Marine Science, 70(5): 1045-1054.

LACoast.gov, Louisiana Coastal Wetland Functions and Values, 1997. As of December 15, 2014: https://lacoast.gov/reports/rtc/1997/4.htm

Laborde, Luke and Rohwer, Frank C. 2010. 2010 Survey of Louisiana Waterfowl Hunters. Accessed 11/10/2014 at http://www.wlf.louisiana.gov/sites/default/files/pdf/page/32574-research-projects/ldwffinalreport03-2011a.pdf

Lam, Arenas, Pace, LeSage, & Campanella. (2012). Predictors of Business Return in New Orleans after Hurricane Katrina. Retrieved from http://www.plosone.org/article/fetchObject.action?uri=info:doi/10.1371/journal.pone.0047935&representation=PDF

Louisiana Department of Wildlife & Fisheries. 2014. Recreational License Sales Summary, 1972-2013. Accessed 11/10/2014 at http://www.wlf.louisiana.gov/publication/survey-louisiana-recreational-boaters

Louisiana Department of Wildlife & Fisheries. 2014. Saltwater – Freshwater Line. Accessed 11/10/2014 at http://www.wlf.louisiana.gov/fishing/saltwater-freshwater-line-0

Mace, G.M., K. Norris, and A.H. Fitter. (2012). Biodiversity and ecosystem services: a multilayered relationship. Trends in Ecology and Evolution, 27(1), 19-25.

Marcell, Marianne Hawkins, et al. 2006. Louisiana State Museum. Prepared for: Louisiana Department of Culture, Recreation, and Tourism. Accessed 11/10/2014 at http://www.crt.state.la.us/Assets/documentarchive/impact-report/Museum.pdf

McKinnon, A. and A. Kreie. Adaptive Logistics: Preparing Logistical Systems for Climate Change. Working Paper, 2010, accessed 09/19/14 at http://www.greenlogistics.org/SiteResources/15thLRN/McKinnon%20and%20Kreie%20Adaptive%20Logistics.pdf.

Millennium Ecosystem Assessment. 2003. Ecosystems and Human Well-Being: A Framework for Assessment. Island Press. Washington DC.

National Cooperative Highway Research Program (NCHRP). 2012. Methodologies to Estimate the Economic Impacts of Disruptions to the Goods Movement System. Transportation Research Board of the National Academies, NCHRP Report 732, Washington, D.C.

National Oceanic and Atmospheric Administration (NOAA). 2013. Underwater: Land Loss in Coastal Louisiana since 1932. Webpage, accessed 09/18/14 at https://www.climate.gov/news-features/featured-images/underwater-land-loss-coastal-louisiana-1932.

National Research Council (NRC), (U.S.) Committee on Climate Change and U.S. Transportation. 2008. Potential Impacts of Climate Change on U.S. Transportation. Transportation Research Board Special Report 290, Washington, D.C.

National Park Service. 2014. Working with Louisiana: By the Numbers [Fact Sheet]. Accessed 11/10/2014 at http://www.nps.gov/state/customcf/bythenumbers/la.pdf

Nelson, Waldemar. 2003. Economic Impact Assessment Louisiana Coastal Area Comprehensive Coastwide Ecosystem Restoration Study. Report prepared for United States Army Corps of Engineers and Louisiana Department of Natural Resources. Nelson Project Number 20030009.

Petrolia, D.R. and T. Kim. Preventing Land Loss in Coastal Louisiana: Estimates of WTP and WTA. Journal of Environmental Management 92: 859-865.

Reed, S.C. 1991. Constructed Wetlands for Wastewater Treatment. Biocycle 44-49.

Richardson, J.A. 2012. The Economic Impact of the Ports of Louisiana. Prepared for the Ports Association of Louisiana, March, 2012.

Ringold, P., J. Boyd, D. Landers, and M. Weber. 2013. What Data Should We Collect? A Framework for Identifying Indicators of Ecosystem Contributions to Human Wellbeing. Frontiers in Ecology and the Environment 11(2): 98-105.

Rose, A.Z. 2009. A Framework for Analyzing the Total Economic Impacts of Terrorist Attacks and Natural Disasters. Journal of Homeland Security and Emergency Management 6(1):1-27.

Rosenberger, Randall S. and Loomis, John B. 2001. Benefit Transfer of outdoor recreation use values: A technical document supporting the Forest Service Strategic Plan (2000 revision). Accessed 11/10/2014 at http://www.fs.fed.us/rm/pubs/rmrs_gtr072.pdf

Scott, Loren C. & Associates. 2004. The Economic Impact of Recreational Saltwater Fishing on the Louisiana Economy. Prepared for: The Coastal Conservation Association of Louisiana. Accessed 11/10/2014 at http://www.lorenscottassociates.com/Reports/ImpactofSaltwaterFishing.pdf

South Cameron Memorial Hospital Project Case Study, http://www.willscot.com/case-studies/080248_SouthCameron_CS_WEB.pdf

"South Cameron Memorial Hospital- A case study in building Safter, Smarter and Stronger" Louisiana Recovery Authority, http://lra.louisiana.gov/index.cfm?md=photogallery&tmp=album_html&catID=5&ssid=0

"South Cameron Memorial Hospital Comes Back after Rita", Louisiana Medical News http://www.louisianamedicalnews.com/south-cameron-memorial-hospital-comes-back-after-rita-cms-1119

Titus, J. 2002. Does Sea Level Rise Matter to Transportation Along the Atlantic Coast? In The Potential Impacts of Climate Change on Transportation, Summary and Discussion Papers, Federal Research Partnership Workshop, Brookings Institution, Washington, D.C., Oct. 1–2, pp. 135–150.

Tovilla-Hernandez, C., de la Lanza, G. E., Orihuela-Belmonte, D. E. 2001. Impact of logging on a mangrove swamp in South Mexico: Cost/benefit analysis. Revista De Biologia Tropical 49: 571-80.

Turner, R.E. 1990. Landscape Development and Coastal Wetland Losses in the Northern Gulf of Mexico. American Zoologist 30(1): 89-105.

United States Corps of Engineers Navigation Data Center. Waterborne Commerce of the United States. Accessed 09/18/14 at http://www.navigationdatacenter.us/data/datawcus.htm.

United States Department of Energy. 2009. Comparing the Impacts of the 2005 and 2008 Hurricanes on U.S. Energy Infrastructure. Retrieved from https://www.oe.netl.doe.gov/docs/HurricaneComp0508r2.pdf

United States Fish & Wildlife Service. 2011. Birding in the United States: A Demographic and Economic Analysis. Accessed 11/10/2014 at http://www.wlf.louisiana.gov/sites/default/files/pdf/page/32574-research-projects/ldwffinalreport03-2011a.pdf

United States Fish & Wildlife Service. 2013. 2011 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation. Accessed 11/10/2014 at http://www.census.gov/prod/www/fishing.html

United States Geological Survey. 2014. Louisiana Coastal Wetlands: A Resource at Risk [Fact Sheet]. Accessed 11/10/2014 at http://pubs.usgs.gov/fs/la-wetlands/

U.S. Department of Energy, Oak Ridge National Laboratory, LandScan data, 2012. As of July 24, 2015: http://web.ornl.gov/sci/landscan/index.shtml

Wilson, M.A. and S. Farber. Undated. "Accounting for Ecosystem Goods and Services in Coastal Estuaries." In The Economic and Market Value of Coasts and Estuaries: What's At Stake, Pendleton, L.H. (ed.), Washington, D.C.: Restore America's Estuaries.

"Williams Scotsman Completes Modular Building Reconstrcution Effort in Louisiana", Williams Scotsman, http://www.willscot.com/news/modular-building-reconstruction-effort-in-louisiana-hospital.php

Data & Database References

AHA DataViewer, American Hospital Association

Berthelot, Raymond, Louisiana Office of State Parks, Chief of Interpretive Services, Louisana Park Entry and Festival Attendance Data, provided by email: June 19, 2014.

Directory, Department of Health & Hospitals, http://www.dhh.state.la.us/index.cfm/directory/category/169

Directory, Louisiana Department of Culture, Recreation, and Tourism, http://www.crt.state.la.us/louisiana-state-parks/maps/inde

ESRI (Environmental Systems Resource Institute). 2012. ArcMap 10.1. ESRI, Redlands, California.

FAF – see U.S. Department of Transportation Federal Highway Administration. Freight Analysis Framework (FAF)

Federal Emergency Management Agency, HAZUS-MH database version 2.1 data years 2000 and forward.

Federal Reserve Bank Economic Research, Economic Data (FRED), Gross Domestic Product: Implicit Price Deflator. As of July24, 2015: https://research.stlouisfed.org/fred2/series/GDPDEF/downloaddata

IMPLAN Group, LLC, IMPLAN System (data and software), IMPLAN Data 2012, Huntersville, NC. As of July 24, 2015: www.implan.com.

Infogroup and ESRI Business Analyst, Info-USA Business Geodatabase Version 10.1. U.S.

Jordan R. Fischbach, David R. Johnson, David S. Ortiz, Benjamin Bryant, Matthew Hoover, Jordan Ostwald. Louisiana's Comprehensive Master Plan for a Sustainable Coast, Appendix D-25 Risk Assessment (CLARA) Model Technical Report, 2012. As of July 24, 2015: http://coastal.la.gov/a-common-vision/2012-coastal-master-plan/cmp-appendices/

Louisiana State University CADGIS Research Laboratory. (n.d.) Atlas: The Louisiana Statewide GIS. Accessed 11/10/2014 at http://www.atlas.lsu.edu/search/

Louisiana State University Center for Energy Studies. 2014. Energy Geodatabases.

Louisiana Department of Transportation and Development (2013). Base Map Road Feature (10_0) [Geodatabase]. Retrieved from http://www.dotd.la.gov.

Louisiana, Department of Transportation and Development, Geodatabase, 2013. As of July 24, 2015: http://wwwsp.dotd.la.gov/Business/Pages/GIS_Maps.aspx

Louisiana, Department of Wildlife and Fisheries. 2006. Wildlife Management Areas and Refuges [Geodatabase]. Retrieved from LSU Atlas http://atlas.lsu.edu/.

National Oceanic and Atmospheric Administration (NOAA). 2012. Annual Commercial Landing Statistics. Webpage accessed 6/27/15 at http://www.st.nmfs.noaa.gov/commercial-fisheries/commercial-landings/annual-landings/index.

National Oceanic and Atmospheric Administration. 2014. Marine Recreational Information Program, Recreational Fisheries Statistics [Database]. Accessed 11/10/2014 at http://www.st.nmfs.noaa.gov/recreational-fisheries/access-data/run-a-data-query/queries/index

National Oceanic and Atmospheric Administration Office of Science and Technology, Commercial Fisheries Statistics, 2007. As of December 15, 2014: http://www.st.nmfs.noaa.gov/commercial-fisheries/commercial-landings/annual-landings-with-group-subtotals/index

---, Annual Commercial Landing Statistics, 2014. As of December 15, 2014: http://www.st.nmfs.noaa.gov/commercial-fisheries/commercial-landings/annual-landings/index

Oregon State University College of Forestry. 2014. Recreation Use Values Database [Database]. Accessed 11/10/2014 at http://recvaluation.forestry.oregonstate.edu/database

Pipeline Construction Costs. September 2014. Oil & Gas Journal. Compiled by LSU Center for Energy Studies.

U.S. Census Bureau, American Community Survey (ACS) data, 2010. As of July 24, 2015: http://www.census.gov/acs/www/data/data-tables-and-tools/index.php

U.S. Census Bureau, American Community Survey (ACS) data, 2012. As of July 24, 2015: http://www.census.gov/acs/www/data/data-tables-and-tools/index.php

U.S. Census Bureau, Foreign Trade Statistics, 2013-2014. As of July 24, 2015: https://www.census.gov/foreign-trade/statistics/state/data/la.html

U.S. Census Bureau, North American Industry Classification System (NAICS) 2012. As of July 24, 2015: http://www.census.gov/eos/www/naics/

U.S. Census Bureau. 2011. County Business Patterns

U.S. Coast Guard, National Response Center. 2012

Department of Energy, Oak Ridge National Laboratory, LandScan data, 2012. As of July 24, 2015: http://web.ornl.gov/sci/landscan/index.shtml

U.S. Department of the Interior, U.S. Geological Survey (2013). National Hydrography Dataset [Geodatabase]. Retrieved from http://wwwsp.dotd.la.gov/Business/Pages/GIS_Maps.aspx

U.S. Department of Labor, Bureau of Labor Statistics. QCEW (Quarterly Census of Employment and Wages). 2012. As of September 2015: http://www.bls.gov/data/

U.S. Department of Transportation, Federal Highway Administration. Freight Analysis Framework (FAF). As of July 31, 2015: http://ops.fhwa.dot.gov/Freight/freight_analysis/faf/index.htm

U.S. Department of Transportation, Maritime Administration. Maritime Statistics. As of July 24, 2015: http://www.marad.dot.gov/resources/data-statistics/

U.S. Department of Transportation. National Transportation Atlas Database. 2014. Retrieved from http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/national_transportation_atlas_database/index.html

U.S. Energy Information Administration, Annual Crude Oil Production. As of July 24, 2015, http://www.eia.gov/dnav/pet/pet_crd_crpdn_adc_mbbl_a.htm

U.S. Energy Information Administration. 2014. Refinery Utilization and Capacity. Retrieved from http://www.eia.gov/dnav/pet/pet_pnp_unc_dcu_nus_m.htm

U.S. Energy Information Administration. 2014. Weekly Retail Gasoline and Diesel Prices. Retrieved from http://www.eia.gov/dnav/pet/pet_pri_gnd_dcus_nus_w.htm

U.S. Energy Information Administration. 2014. Product Supplied Finished Motor Gasoline. Retrieved from http://www.eia.gov/dnav/pet/pet_cons_psup_dc_nus_mbbl_a.htm

U.S. Energy Information Administration, Crude Oil Prices: West Texas Intermediate (WTI)- Cushing, Oklahoma [DCOILWTICO], retrieved from FRED, Federal Reserve Bank of St. Louis as of July 23, 2015: https://research.stlouisfed.org/fred2/series/DCOILWTICO/

US. Energy Information Administration, Conventional Gasoline Prices: New York Harbor, Regular [DGASNYH], retrieved from FRED, Federal Reserve Bank of St. Louis As of July 23, 2015: https://research.stlouisfed.org/fred2/series/DGASNYH/

U.S. Energy Information Administration, Conventional Gasoline Prices: U.S. Gulf Coast, Regular [WGASUSGULF], retrieved from FRED, Federal Reserve Bank of St. Louis As of July 24, 2015: https://research.stlouisfed.org/fred2/series/WGASUSGULF/

U.S. Fish and Wildlife Service. 2001. National Wildlife Refuges [Geodatabase]. Retrieved from LSU Atlas http://atlas.lsu.edu/.

U.S. Geological Survey, National Wetlands Research Center. 2011. Land Area Change in Coastal Louisiana from 1932 to 2010. Retrieved from http://www.nwrc.usgs.gov/topics/landloss.htm.