COMPARATIVE ANALYSIS OF DELTA URBANISM CONCEPTS: SAVANNAH AND NEW ORLEANS

by

STEPHEN JAMES MORGAN

(Under the Direction of Stephen Ramos)

ABSTRACT

The aim of this thesis is to explore deltaic and estuarine cities, the nexus between the natural and built environment, and how concepts of delta urbanism can be applied to study these complex deltaic systems. Specifically, the aim of this thesis is to study the estuarine city of Savannah, Georgia through concepts of delta urbanism and to contribute to the comparative analysis recently proposed in delta urbanism literature. However, there has been little research on the concepts and frameworks found in delta urbanism literature. This thesis intends to research, compile, and outline concepts and frameworks found within delta urbanism literature, and then apply those concepts and frameworks to study the estuarine city of Savannah, Georgia. Through literature review, mapping, and historical analysis, the various failures, successes, similarities, and differences between urbanized deltas can be highlighted. This thesis intends to contribute to this discussion.

INDEX WORDS: Delta Urbanism, Comparative Analysis, Savannah, New Orleans, Resiliency, Urban Planning, Coastal Cities, Hazards, GIS
COMPARATIVE ANALYSIS OF DELTA URBANISM CONCEPTS: SAVANNAH AND NEW ORLEANS

by

STEPHEN JAMES MORGAN

B.S., The University of Georgia, 2010

A Thesis Submitted to the Graduate Faculty of The University of Georgia in Partial Fulfillment of the Requirements for the Degree

MASTER OF ENVIRONMENTAL PLANNING & DESIGN

ATHENS, GEORGIA

2015
DEDICATION

This thesis is dedicated to my wife, Anjali, whom without this thesis would not be possible. Her unwavering support and continuous encouragement were invaluable and vital during the completion of this thesis.
ACKNOWLEDGEMENTS

I would like to thank all of the Environmental Planning and Design professors at the College of Environment and Design for their encouraging and challenging work, which helped foster the evolution of my professionalism, outlook, and experience as a planner. I would like to give special thanks to my major professor, Stephen Ramos, for his stimulating lectures, constant encouragement, and invaluable feedback. I would like to also thank committee member Jackie Jackson for contributing her thoughts, feedback, and insights to this thesis.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>ACKNOWLEDGEMENTS</th>
<th>LIST OF FIGURES</th>
<th>LIST OF TABLES</th>
</tr>
</thead>
<tbody>
<tr>
<td>v</td>
<td>ix</td>
<td>xii</td>
</tr>
</tbody>
</table>

## CHAPTER

<table>
<thead>
<tr>
<th>ONE INTRODUCTION</th>
<th>TWO UNITED STATES ARMY CORPS OF ENGINEERS</th>
<th>THREE DELTA URBANISM</th>
<th>FOUR DELTA URBANISM: NEW ORLEANS, LOUISIANA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>13</td>
<td>22</td>
<td>46</td>
</tr>
<tr>
<td>Justification of Study</td>
<td>4</td>
<td>Urbanization</td>
<td></td>
</tr>
<tr>
<td>Methodology</td>
<td>5</td>
<td>Delta Urbanism Typologies</td>
<td></td>
</tr>
<tr>
<td>Outline</td>
<td>10</td>
<td>Resilience and Complex Adaptive Systems</td>
<td></td>
</tr>
<tr>
<td>Conclusion</td>
<td>12</td>
<td>Mapping and Comparative Historical Analysis</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Conclusion</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chapter</td>
<td>Title</td>
<td>Pages</td>
<td></td>
</tr>
<tr>
<td>---------</td>
<td>----------------------------------------------------------------------</td>
<td>-------</td>
<td></td>
</tr>
<tr>
<td></td>
<td>The Mississippi Delta</td>
<td>47</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Early Settlement and Transformation</td>
<td>52</td>
<td></td>
</tr>
<tr>
<td></td>
<td>18th Century Urbanization and Water Management</td>
<td>52</td>
<td></td>
</tr>
<tr>
<td></td>
<td>19th Century Urbanization and Water Management</td>
<td>55</td>
<td></td>
</tr>
<tr>
<td></td>
<td>20th and 21st Century Urbanization and Water Management</td>
<td>59</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Conclusion</td>
<td>63</td>
<td></td>
</tr>
<tr>
<td></td>
<td>FIVE DELTA URBANISM: SAVANNAH, GEORGIA</td>
<td>66</td>
<td></td>
</tr>
<tr>
<td></td>
<td>The Savannah Estuary</td>
<td>68</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Early Settlement and Transformation</td>
<td>76</td>
<td></td>
</tr>
<tr>
<td></td>
<td>18th Century Urbanization and Water Management</td>
<td>79</td>
<td></td>
</tr>
<tr>
<td></td>
<td>19th Century Urbanization and Water Management</td>
<td>86</td>
<td></td>
</tr>
<tr>
<td></td>
<td>20th Century Urbanization and Water Management</td>
<td>92</td>
<td></td>
</tr>
<tr>
<td></td>
<td>21st Century Urbanization and Water Management</td>
<td>98</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Conclusion</td>
<td>103</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SIX MAPPING &amp; COMPARATIVE HISTORICAL ANALYSIS</td>
<td>107</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mapping Analysis</td>
<td>107</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Comparative Historical Analysis</td>
<td>128</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Conclusion</td>
<td>136</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SEVEN CONCLUSION</td>
<td>140</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lessons Learned</td>
<td>142</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Recommendations</td>
<td>145</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Future Research</td>
<td>149</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Conclusion</td>
<td>151</td>
<td></td>
</tr>
</tbody>
</table>
# LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Diagram of deltas as complex adaptive systems</td>
<td>8</td>
</tr>
<tr>
<td>2</td>
<td>Types of deltas</td>
<td>30</td>
</tr>
<tr>
<td>3</td>
<td>Comparative mapping layers used for the Mississippi Delta</td>
<td>41</td>
</tr>
<tr>
<td>4</td>
<td>Context map of New Orleans</td>
<td>48</td>
</tr>
<tr>
<td>5</td>
<td>River Dominated Delta</td>
<td>50</td>
</tr>
<tr>
<td>6</td>
<td>Natural levee formation</td>
<td>51</td>
</tr>
<tr>
<td>7</td>
<td>Plan de la Ville La Nouvelle Orleans, 1755</td>
<td>54</td>
</tr>
<tr>
<td>8</td>
<td>Plan of the City and Suburbs of New Orleans, 1816</td>
<td>57</td>
</tr>
<tr>
<td>9</td>
<td>Map showing flooded district, 1849</td>
<td>59</td>
</tr>
<tr>
<td>10</td>
<td>The Lower Ninth Ward is shown here on August 30, 2005, after Katrina</td>
<td>63</td>
</tr>
<tr>
<td>11</td>
<td>Context map of Savannah</td>
<td>67</td>
</tr>
<tr>
<td>12</td>
<td>Five physiographic regions of Georgia</td>
<td>69</td>
</tr>
<tr>
<td>13</td>
<td>Ancient barrier island sequence</td>
<td>71</td>
</tr>
<tr>
<td>14</td>
<td>Ancient shorelines</td>
<td>72</td>
</tr>
<tr>
<td>15</td>
<td>Savannah River Basin</td>
<td>73</td>
</tr>
<tr>
<td>16</td>
<td>Map of Georgia, 1745</td>
<td>78</td>
</tr>
<tr>
<td>17</td>
<td>Ward design specifications</td>
<td>81</td>
</tr>
<tr>
<td>18</td>
<td>Six ward plan of Savannah in 1770</td>
<td>81</td>
</tr>
<tr>
<td>19</td>
<td>Conceptual regional plan of Savannah by Thomas Wilson</td>
<td>82</td>
</tr>
</tbody>
</table>
Figure 20: Copy of the John McKinnon map, 1798 ........................................82
Figure 21: Evolution of wards, 1733-1856 .................................................87
Figure 22: Map of Savannah, 1812 .......................................................87
Figure 23: Map of Savannah, 1856 .......................................................88
Figure 24: Map of Tybee Island, 1890 .....................................................89
Figure 25: Map of Georgia, 1817 ..........................................................90
Figure 26: Birds eye view of Savannah, 1891 ..........................................93
Figure 27: The Savannah area in 1910 ...................................................94
Figure 28: Union Bag and Paper Company, 1942 ..................................97
Figure 29: The port of Savannah, 2015 ..................................................100
Figure 30: The Jimmy DeLoach “Loop”, 2015 ........................................101
Figure 31: Urban Settlements in the Savannah Area .............................109
Figure 32: Urban settlements (red) of the Mississippi Delta area ..........110
Figure 33: Substratum in the Savannah Area .........................................112
Figure 34: The substratum of the Mississippi Delta ...............................113
Figure 35: Savannah Substratum ..........................................................114
Figure 36: Percentage of coastal plain ..................................................114
Figure 37: Climate (1) in the Savannah Area ........................................116
Figure 38: Climate (2) in the Savannah Area ........................................117
Figure 39: Climate in the Mississippi Delta area .....................................118
Figure 40: Comparison of average precipitation ...................................119
Figure 41: Comparison of average temperature .....................................119
Figure 42: Transportation Network in the Savannah Area ....................121
Figure 43: Transportation Network in the Mississippi Delta area........................................122

Figure 44: Land use in the Savannah Area. .......................................................................124

Figure 45: Land uses in the Mississippi Delta area ............................................................125

Figure 46: Percentages of land uses within the Coastal Plain of the Savannah area ......127
LIST OF TABLES

Table 1: Typologies of urbanized deltas .................................................................33
Table 2: Comparative land uses for the Mississippi Delta ........................................41
Table 3: Total square kilometers for each land use in the Savannah Estuary...........128
Table 4: Urbanization characteristics ......................................................................132
Table 5: Urbanized delta typologies .........................................................................135
Table 6: Savannah Typology ......................................................................................137
Table 7: Matrix of delta urbanism concepts ...............................................................137
Table 8: Comprehensive Matrix ................................................................................138
CHAPTER ONE
INTRODUCTION

Much research has focused on coastal cities, resiliency, and flood risks. However, with relatively recent natural disaster such as Hurricanes Katrina and Sandy, deltaic and estuarine cities have started to reconsider how they develop and adapt to their increasingly complex systems. The phrase “delta urbanism” is used to signify the study of complex environments characterized by the spatial relationship with land, river, and ocean, and has recently been defined as a “... new initiative that explores the growth, development, and management of deltaic cities and regions, with the aim of balancing various goals in a sustainable manner: urbanization, port commerce, industrial development, flood defense, public safety, ecological balance, tourism, and recreation.” (Meyer, Bobbink, and Nijhuis 2010). However, there has been little research on the concepts and frameworks found in delta urbanism literature. This thesis researches, compiles, and outlines concepts and frameworks found within delta urbanism literature, and then applies those concepts and frameworks to study the estuarine city of Savannah, Georgia.

The purpose of this thesis is to explore deltaic and estuarine cities, the nexus between the natural and built environment, and how concepts of delta urbanism can be applied to study these complex systems. In general, urbanized estuaries and deltas are complex environments characterized by the spatial relationship with land, river, and ocean. Throughout history, societies have gravitated towards these areas due to the
availability of natural resources. Reker et al describe these areas as urban magnets because they are “...generally fertile and easy to cultivate. The freshwater of the river can be used for irrigation. In addition, there are often rich fishing grounds where the sea and river meet” (Reker et al. 2006). Once watercrafts were invented and rivers themselves became the highroads, these areas are speculated to be histories first maritime ports because of their spatial location to the ocean (Mumford 1961, Meyer and Nijhuuis 2011). Early settlements along rivers, estuaries, and deltas regularly experienced inundation due to seasonal flooding and storms. Over time, urbanized estuaries and deltas developed ways to control, mitigate, and adapt to their wet environments. However, climate change, sea level rise, increasing populations, and urbanization are beginning to exacerbate natural hazards and increase the complexity of urbanizing deltas.

Today, large cities and populations are located on or near estuaries and deltas, with trends showing an increase in the development of coastal megacities (Nicholls 1995). There are close to 500 million people and 37 of the world’s 136 coastal ports in or around deltas. Two-thirds of the world’s 32 most populous cities are found along estuaries (Campanella 2010b, Ross 1970, Syvitski and Saito 2007). However, coastal cities increasingly find themselves at risk of hurricanes, typhoons, and flooding. Coastal cities that develop near rivers are not only concerned with flooding from the ocean (i.e. storm surge), but also from the river (i.e. seasonal flooding). Most scientists, academics, and planners agree that climate change will intensify these risks in the future (Mosley 2014).

Most deltaic and estuarine cities are dealing with increasing complexity and changing dynamics due to climate change; however, climate change is not the only
reason for the increased complexity in these areas. The urbanization process itself has also increased the complexity of these areas due to changes in the dynamics of land-use, urbanization, industrialization, port-development, agriculture and leisure/tourism (Meyer 2014b). Concentrated populations, agriculture, flood control, and port activities on or near coastal regions have had deleterious environmental consequences. Urban systems have drastically changed the flows of water, energy, and resources in marsh and wetlands, negatively effecting these ecosystems (Rakodi and Treloar 1997). These natural occurring ecosystems can provide vital protection against hurricanes, typhoons, flooding, as well as provide tourism, recreation, and sea food industries. Urban estuaries and deltas are at the frontline when it comes to managing these increasingly complex systems, and are now faced with reconsidering how they will develop going forward.

In the Netherlands and Dutch Delta, the threat of climate change and increasing populations at risk of flooding has led to a break in traditional flood management techniques (i.e. dykes, dams, levees) and urban planning practices. The Dutch have a long history and tradition of water management and control. Dutch skill at water management goes back to dikes, dams and windmills that helped them reclaim much of their land from the seas and rivers starting in the Middle Ages. In the 1950s, they constructed the Delta Works, a revolutionary series of storm-surge barriers along the North Sea coast (Meyer 2009). However, thinking has evolved since then. With the increasing threat caused by climate change, Dutch engineers and planners have developed strategies that go beyond simply trying to keep water out, but to allow the water in. Known as the Room for the River Program, the Dutch government has selected over 30 sites in which river floodplains are widened and allowed to flood, residents and development relocated, and
recreational and public land uses assigned. Since the Room for the River Program, Dutch water management and delta urbanization have become recognized as a new way in which other deltaic cities can develop in the face of climate change.

Changes in temperature, precipitation and sea level rise are inevitable, and coastal cities must be able to adapt to these increased risks (IPCC 2007). Recent floods in urbanized deltaic areas (New Orleans 2005, Japan 2011, New York 2012, etc.) indicate the need for a reexamination of urban development near deltas and estuaries (Meyer 2014a). This reexamination of how deltaic and estuarine cities develop in a sustainable and resilient manner has led to an increase in delta urbanism literature. While many deltaic and estuarine cities have recently been the focus of delta urbanism, but much less attention has focused on the estuarine city of Savannah. Through literature review, mapping and historical analysis, this thesis examines the estuarine city of Savannah through the lens of delta urbanism.

Justification of Study

The need to reexamine how deltaic and estuarine cities develop in a sustainable and resilient manner has led to an increase in delta urbanism literature. However, there has been little research on the concepts and frameworks found in delta urbanism literature. This thesis researches, compiles, and outlines concepts and frameworks found within delta urbanism literature, and then applies those concepts and frameworks through comparative analysis between the estuarine city of Savannah, Georgia with the deltaic city of New Orleans, Louisiana. New Orleans and the Mississippi Delta are used for comparative analysis in this thesis because New Orleans has been well studied using concepts of delta urbanism, and has recently been used in comparative mapping with
other deltas around the world. Conversely, Savannah has not been studied using concepts proposed in delta urbanism literature. By using these deltaic and estuarine cities in comparative analysis, and using Geographic Information Systems to map the Savannah area, specific delta urbanism concepts such as urbanized delta typologies, can be examined and critiqued.

Both cities resemble each other in several ways: large transportation networks with major port activates, large tourism and fisheries’ industries, humid subtropical climate with occasional hurricanes, areas of natural and urban land uses within the flood plain, history with the U.S. Army Corps of Engineers, and decades of substantial modifications, engineering, and alterations made to its waterway. However, there are subtle differences between the cities. For instance, Savannah does not have traditional flood control measures, such as levees, that are commonly seen in riverine cities such as New Orleans. Moreover, Savannah houses a remarkable amount of natural resources, such as marshes, wetlands, and barrier islands, despite decades of alterations to the natural environment.

Recent delta urbanism literature can help deltaic and estuarine cities to start reexamining how they develop going into the future. Concepts such as complex systems, hard vs soft engineering, urbanization, and spatial planning can be utilized in these dynamic urbanized environments.

Methodology

Comparative historical analysis and mapping are used in this thesis in order to gain a better understanding of concepts and frameworks of delta urbanism. In urban planning, there is a long tradition of using maps and comparative research (Moudon
Mapping has been used as a means to generate knowledge for planning and design in urbanized areas, and to discover various successes and failures of cities coping with deltaic environments. In delta urbanism, the objective of mapping is to address the challenging situation of intensive cultivation and habitation in flood prone lowlands. Comparative historical analysis, on the other hand, is used as a central method of investigation in social sciences, and seeks to discover patterns in the histories of different cultures, cities, or landscapes (Mahoney and Rueschemeyer 2003). While comparative historical analysis in the social sciences have expanded into many fields of study, all work in comparative historical analysis share a common concern with causal analysis, processes over time, and the use of systematic and contextualized comparison.

New Orleans and the Mississippi Delta are used for comparative analysis in this thesis because New Orleans has been well studied under delta urbanism, and has recently been used in comparative mapping with other deltas around the world. Since delta urbanism uses a specific concept of “urbanization”, then this thesis discusses urbanization in New Orleans and Savannah through spatial pattern, land uses, and water management (flood control and river navigation). These urbanization characteristics are used for comparative historical analysis between New Orleans and Savannah.

After Hurricane Katrina in 2005, New Orleans and the Mississippi Delta has been studied in great detail under delta urbanism. The comparative mapping analysis used in Urbanized Deltas in Transition, edited by Han Meyer and Steffen Nijhuis, generated standardized mapping layers which were used to compare eight world deltas. New Orleans and the Mississippi were included in Urbanized Deltas. Global datasets were used in order to make it possible to analyze and compare the deltas in a consistent and
systematic way (Meyer 2014b, Campanella 2014). This thesis contributes to the comparative mapping analysis of urbanized deltas by using the same standardize mapping layers to study the estuarine city of Savannah. Whenever possible, this thesis will use similar datasets and layers in order to contribute to the comparative analysis. Using Geographic Information Systems (GIS) for mapping analysis also allows this thesis to provide quantitative measurements of Savannah and compare them to specific delta urbanism concepts, particularly proposed typologies of urbanized deltas found within recent delta urbanism literature. Most maps generated for Savannah will be at the city scale, or ~ 10 miles, and land use statistics will be generated for the study area.

The following layers for the Savannah area will be used for GIS mapping and will be presented directly after the Savannah chapter for analysis: urban settlements, substratum, climate, transportation, and land use:

**Substratum:** Elevation data is used as a surrogate for a variety of stratum factors including: drainage, suitability for vegetation growth, geomorphology, and ecosystems (figure 1) (Nijhuis and Poudroijen 2014). To identify the coastal or deltaic flood plain, the zone less than 5 meters above mean sea level was determined, which indicates areas of flooding and areas vulnerable to sea level rise (McGranahan, Balk, and Anderson 2007).

**Climate:** Average annual precipitation in inches (1981-2010), average annual temperature in Fahrenheit (1981-2010), and hurricane tracks (1851-2013) will be combined to illustrate the climate mapping. No wind
Figure 1. Diagram of deltas as complex adaptive systems. Substratum illustrated as the layer incorporating soil, water, ecosystems, and geomorphology (Dammers et al. 2014).

data was found for the Savannah area, and will not be included in the comparative analysis.

**Transportation:** Transportation infrastructure are important factors, creating conditions for settlements, economic activities, and mobility. For this analysis, the transportation network will include roads, rails, ports and airports.
Land Use: Land uses are important for considering spatial patterns of
development. Agriculture is one of the dominant land uses in most deltas,
providing food, economic activities, and effects on the environment.

Urban settlements are another important form of land use, and is important for
this work. To provide vulnerability of land uses to flooding, the acres of land uses
that lay five meters below sea level are calculated.

Historical analysis is also utilized for the comparative analysis between Savannah
and New Orleans. Comparative historical analysis has long history of use in the social
sciences. The “founding fathers” of social sciences, from Adam Smith to Karl Marx,
pursued comparative historical analysis as a central mode of investigation. While
comparative historical analysis in the social sciences have expanded into many fields of
study, all work in comparative historical analysis share a common concern with causal
analysis, processes over time, and the use of systematic and contextualized comparison
(Mahoney and Rueschemeyer 2003). By acknowledging that each deltaic city has its own
natural and built evolutions and processes, researchers and planners are able to compare
similarities and differences in how certain processes in deltaic regions have evolved over
time. Moreover, comparative historical analysis allows researchers to explore concepts
and theories of delta urbanism. This understanding allows researchers and designers to
identify various successes and failures of delta urbanism. Comparative historical analysis
provides a qualitative comparison between New Orleans and Savannah.

In order to study the concepts of delta urbanism and the histories of New Orleans
and Savannah in a standardize way, these two urbanized deltas are broken down into
sections, each describing the evolution and progress of the natural and urban environments, and uses concepts of delta urbanism discussed in the delta urbanism chapter of this thesis, i.e. typology, urbanization, and complex adaptive systems. First, a description of the natural processes and environments of each deltaic landscapes is discussed. Second, a history and evolution of urbanization patterns from early colonial times to the 21st century is discussed, while highlighting how the urbanization process contributed to the alteration of the landscape.

Both comparative historical analysis and GIS mapping will be discussed in greater detail within the context of delta urbanism in chapter three.

Outline

Chapter two of this thesis provides a summary of the history of the U.S. Army Corps of Engineers and how the agency has developed, engineered, and altered estuaries, rivers, and deltas in the United States. This section identifies various ways in which the Corps have altered and controlled natural processes in order to reduce risks of flooding, or to increase the economic success of coastal port cities through navigation projects. Moreover, chapter two highlights how the activities of Corps have changed over time, and what those changes have meant to delta urbanism. The activities of the Corps have directly influenced the resiliency of cities and ecosystems of both New Orleans and Savannah.

Chapter three focuses on delta urbanism literature. It discusses how delta urbanism has evolved as a recent field of study in planning and design, how and why urbanized deltas are classified into typologies, why deltaic environments are considered complex systems, and what tools are used to study urbanized deltas. Chapter three
provides specific detail on concepts and methodologies that will be used in later chapters discussing delta urbanism, such as typologies, urbanization, and complex adaptive systems. Chapter three also discusses GIS mapping and historical analysis in the context of delta urbanism.

Chapters four and five apply the tools and concepts discussed in chapter three to study New Orleans and Savannah, respectively. Chapter four is a well-researched and established example delta urbanism in the United States, while chapter 5 is a lesser known example of delta urbanism. Since one of the aims of this thesis is to contribute to the comparative analysis of urbanized deltas through the city of Savannah, then more maps, detail and discussion will be included in chapter five. Moreover, chapters four and five will review how the natural environments of both locations form and function, and issues with urbanization and water management from the 18th century to 21st century. These chapters provide information for the comparative historical analysis of this thesis.

Chapter six presents the GIS mapping layers and generates empirical data for the Savannah area, which is used to analyze certain concepts of delta urbanism. Chapter six presents each mapping layer of the Savannah area, a summary of the data used for each layer, and graphs or tables generated from each mapping layer. Chapter six also discusses and analyzes the concepts of delta urbanism, such as typology, urbanization, and complex adaptive systems, through the comparative historical analysis of New Orleans and Savannah.

Chapter seven draws conclusions and what lessons can be learned by using delta urbanism to study Savannah. Chapter seven also highlights recommendations for coastal development, and what certain planning principles and practices can help prepare coastal
cities from flooding in the future. Chapter seven also discusses limitations of this research and proposes further research.

Conclusion

The purpose of this thesis is to explore deltaic and estuarine cities, the nexus between the natural and built environment, and how concepts of delta urbanism can be applied to study these complex systems. Recent disasters in coastal cities highlights that urbanized deltas and estuaries are at the frontline of reconsidering urbanization in the face of climate change and sea level rise. Acknowledging this, delta urbanism attempts to study these complex systems and understand how they can and should develop into the future. This thesis researches, compiles, and outlines concepts and frameworks found within delta urbanism literature, and then applies those concepts and frameworks to compare the estuarine city of Savannah, Georgia with the deltaic city of New Orleans, Louisiana. In order to gain a better understanding of concepts and frameworks of delta urbanism, this thesis utilizes literature review, mapping and historical analysis between New Orleans and Savannah.

This thesis contributes to the comparative mapping analysis of urbanized deltas by using the same standardize mapping layers outlined in recent delta urbanism literature to study the estuarine city of Savannah. Using GIS for mapping analysis allows this thesis to provide quantitative measurements of the Savannah area. Major concepts discussed and outlined in the delta urbanism chapter, such as urbanized delta typologies, urbanization, and complex adaptive systems, will be used during the historical analysis between New Orleans and Savannah. Afterwards, these concepts will be explored through the mapping and historical analysis between New Orleans and Savannah.
CHAPTER TWO

UNITED STATES ARMY CORPS OF ENGINEERS

The following chapter will discuss a brief history of the United States Army Corps of Engineers (the Corps). This chapter identifies various ways in which the Corps have altered and controlled the natural processes of deltaic and estuarine environments in order to reduce risks of flooding, or to increase the economic success of coastal port cities through navigation projects. The justification for reviewing the history of the Corps is because of the agency has altered and manipulated many deltaic and estuarine environments in the United States for the purpose of flood control and river navigation. The activities of the Corps have directly influenced the resiliency of cities and ecosystems of both New Orleans and Savannah. While this chapter provides a brief history of the Corps, chapters four and five will include specific details and activities of the Corps within New Orleans and Savannah, respectively.

Recent natural disasters have highlighted that although traditional engineered flood control measures have reduced flooding, they still have limitations. Colloquially referred to as “hard vs soft” engineering, cities have started to reconsider traditional engineered flood control measures and are looking towards flood control and mitigation measures that mimic naturally occurring ecosystems and services. This new approach relies on spatial planning, allows more room for natural processes, mitigates the effects of flooding, and provides acceptable land uses within flood prone areas.
The Corps

In terms of waterway improvements and flood control, the United States Army Corps of Engineers have played a leading role in developing the natural and built environments of major U.S. cities. Even before the permanent institution of the Corps was created in 1802, engineering was a crucial part in supporting the Continental Army and the Nation during the American Revolutionary War, mainly through defensive fortifications (Barber and Gann 1989). However, as the nation started expanding, the Corps role in civil works started to increase. The Corps role in the development of a national transportation system included surveying, mapping, and developing roadways, rail, and waterways of national military and economic importance (Harrison 1979). After flooding events on the Mississippi Delta in the 1850s drew national attention, the Corps focus on flood control started to increase as well (USACE 2008). While not reviewing the entire history of the Corps, this section focuses on what role the agency has played in shaping the natural and built environments in the United States, particularly in terms of waterway improvements and flood control. These developments heavily influenced coastal cities in their development, national importance, and resiliency.

Early History of Navigation Improvement

While the Federal government was responsible for major waterway improvements post-American Revolution, it should be noted that the states were not inactive in improving commercial waterways during the nation’s early history. Some of the first acts of Congress gave approval to state projects for improving commercial waterways by removing snags, wrecks, and other obstacles to water transportation. The states also had a list of “canals which they were planning to build to improve and connect the natural
system of river navigation.” (Harrison 1979). The Corps were officially involved in navigation improvement of waterways by the congressional acts of 1823 and 1824. The appropriation of 1823 was made in the sum of $150 for examination of the harbor of Presque Isle on Lake Erie in Pennsylvania, and was the first legislative assignment to the Corps of Engineers of a survey for navigation improvement (USACE 2008). However, congressional acts of 1824 were far more reaching and were the beginning of expanded role of the federal government and the Corps in developing the waterways of the nation.

In early 1824, in the landmark decision of *Gibbons v. Ogden*, the Supreme Court interpreted the Commerce Clause of the United States Constitution to permit the federal government to finance and construct road and river improvements (Arnold 1988). Within two months, Congress appropriated funds and authorized the Corps to remove certain navigation obstructions from the Ohio and Mississippi rivers, appropriating $75,000 for the effort (Harrison 1979, Wright 2000). In the following years, the Corps investigated a number of additional rivers, with many early navigation improvements resulting from trial and error, without strict devotion to theory (USACE 2008). Later in the century, harbor and river work went from “... about $3.5 million for 49 projects and 26 surveys in 1866 to nearly $19 million for 371 projects and 135 surveys in 1882.” (USACE 2008).

As railroads and trucking companies provided alternative methods of transportation, many once important river passages were bypassed. The move away from improvement projects in small harbors had begun in the early 20th century, and this trend continued in the years following (Barber and Gann 1989). However, for American cities located near major ports, the expansion of navigation projects continued to play a crucial role in the well-being of America’s economy. It is estimated that one-sixth of all intercity
cargo is transported via water, and this waterborne commerce is recognized as the least expensive and energy-consumptive means of transportation (Harrison 1979). Locks and dams built and maintained by the Corps have also aided in the growth of commercial water transport. The Corps dredges more than 300 million cubic yards of material annually to retain authorized channel depths and builds bank stabilization projects in its role as primary developer of the Nation’s waterways (USACE 2008).

*Early History of Flood Control*

Large floods in the lower Mississippi delta during 1849 and 1850 drew national attention, moving Congress to formulate a plan for flood control. As a result, an appropriation of $50,000 was made for a “topographical and hydrographical survey of the Delta of the Mississippi, with such investigations... to determine the most practicable plan for securing it from inundation.” (Arnold 1988). The appropriation was split in order to fund two separate surveys, resulting in two sharply disagreeing reports that had an unforeseen and substantial impact on future flood control practices (Moore and Moore 1989, Wright 2000).

The first report, by Charles S. Ellet Jr., asserted the flood problem was increasing as agricultural cultivation increased in the lower Mississippi Valley (Ellet Jr 1853). Ellet suggested enlarging natural river outlets, constructing higher and stronger levees, and building a system of headwaters reservoirs on the Mississippi River and its tributaries. The second report by Captain Andrew A. Humphreys, Corps of Topographic Engineers, assisted by Lieutenant Henry L. Abbot, unequivocally advocated for levee systems and excluded alternative flood control plans (Wright 2000). This second report was adopted, and was the inception of the “levee only” flood protection policy of the Corps, which
would last for almost 60 years. The “great flood of 1927” tested the levees only policy and confirmed the major problems associated with a one-sided approach to flood control. During the 1927 flood, much of the levee systems along the lower Mississippi were breached or overtopped, and flood torrents fanned over the delta (Wright 2000).

The 1936 Flood Control Act recognized that flood control was “... a proper activity of the Federal Government in cooperation with States, their political subdivisions, and localities thereof.” (Congress 1936). Congress gave responsibility for federal flood control projects to the U.S. Army Corps of Engineers, while projects dealing with watershed run-off and soil erosion were assigned to the Department of Agriculture. This law held the Corps responsible for flood control throughout the Nation, working in cooperation with the Bureau of Reclamation. In the years following passage of this law, the Corps built close to four hundred reservoirs whose primary benefit was flood control; however, flood control alone would not have justified the construction of these reservoirs. In the age of multipurpose projects, possible navigation, water storage, irrigation, power, and recreation were considered before final construction plans were completed (Barber and Gann 1989). The Flood Control Act of 1960 authorized the Corps of Engineers to provide information, technical planning assistance, and guidance to nonfederal agencies in identifying flood hazards and planning the wise use of flood plain land (Congress 1960).

Environmental Concerns

Increasing ecological and environmental concerns during the 1960s and 70s resulted in national environmental policies that provided a new area of activity for the Corps. The National Environmental Policy Act of 1970 and amendments to the Federal
Water Pollution Control Act in 1972 provided for Corps of Engineers jurisdiction over the discharges of dredged or fill materials into any waters of the United States, and the permit program that resulted gave environmental protection the fullest consideration (Congress 1969, 1972). In 1970, the Corps began the Dredged Material Research Program to identify dredging and dredged material disposal systems that would be compatible with the new environmental protection mission. Completed in 1978, the Dredged Material Research Program reversed some traditional thinking about the effects of dredging. It indicated that dredging need not have adverse impacts on aquatic life and that dredged materials can create new wetland sand wildlife management areas. Section 404 authority of the amended Federal Water Pollution Control Act has been exercised to all “... navigable waters up to headwater streams having an average flow of 5 cubic feet per second or greater (Engineers 1981).

In the Water Resources Development Act of 1986, Congress authorized the Corps to review the operation of completed water resources projects to determine the need for modifications to improve environmental quality. In 1990, Congress officially directed the Secretary of the Army to include environmental protection as one of the Corps’ primary missions. Subsequently, in 1992 and 1996, the Corps received additional authorization to protect, restore, and create aquatic and ecologically related habitats, including wetlands. In the twenty-first century, the Corps actively promotes and is directly involved in ecosystem restoration (USACE 2008).

*Hard vs. Soft Engineering*

Recent natural disasters such as Hurricanes Katrina and Sandy have highlighted that traditional engineered flood control measures have limitations. Colloquially referred
to as “hard vs soft” engineering, cities have started to reconsider traditional engineered flood control measures (levées, seawalls, dykes, etc.) and are looking towards flood control and mitigation measures that mimic naturally occurring ecosystems (wetlands, hydrology, dunes, green infrastructure, etc.). There is growing appreciation of the value of soft engineering in helping to mitigate coastal hazards. Soft engineering, or green infrastructure, has been defined as the integration of natural systems and processes, or engineered systems that mimic natural systems, into investments in resilient infrastructure.

Soft engineering takes advantage of the services and natural defenses provided by land and water systems such as wetlands, natural areas, vegetated sand dunes, and forests, while contributing to flood mitigation, public safety, and quality of life (Force 2013). The Georgia Environmental Protection Division (GAEPD) defines “Green Infrastructure Practices” as meaning the combination of three complementary groups of natural resource protection and stormwater management practices, including better site planning and design, and low impact development practices, which can be used to “protect valuable terrestrial and aquatic resources from the direct impacts of land development, maintain pre-development site hydrology and reduce post construction stormwater runoff rates, volumes and pollutant loads” (GAEPD 2009). The GAEPD utilizes this definition of green infrastructure, found in the Georgia Coastal Stormwater Supplement of 2009, for direction and guidance in issuing stormwater permits, which directly influences local practices to green, or soft, engineering solutions.

Along this line, the Corps have designed and employed soft engineered, or “nonstructural”, projects to provide some level of flood protection. These nonstructural
measures are meant to reduce or avoid flood damages without significantly altering the nature or extent of flooding. Nonstructural methods include “... moving communities away from a flood’s destructive path, raising and flood proofing buildings, acquiring vulnerable structures, preserving wetlands, buying out floodplains, and establishing a flood warning system.” (USACE 2008). In this sense, soft engineering or ‘nonstructural’ projects allow more room for natural processes, mitigate the effects of flooding, and provide acceptable land uses within flood prone areas.

**Conclusion**

The United States Army Corps of Engineers have been involved in major navigation improvements, flood control, and civil work projects within the United States. While navigation improvements consisted of much of the early works of the Corps, railroads and trucking companies provided alternative methods of transportation than by waterway, many once important waterways were bypassed. The move away from improvement projects in small harbors had begun before 1940, and it accelerated in the years following. During the mid-19th century flood control became an important function of the Corps, and a “levees only” policy was adopted that lasted 60 years. Afterwards, dams and reservoirs became a main function of the Corps flood control projects, while also serving hydroelectric power and recreation functions. For decades each Corps project was measured in terms of its economic effect on navigation, flood control and hydroelectric power generation. Later, social and environmental factors affected Corps activities, and by the 1960s and 70s these new roles were competing with traditional navigation projects.
Recent disasters, and increasing environmental concerns, have highlighted that traditionally engineered flood control projects have limitations. Soft engineering has emerged as a new approach to flood control that incorporates the services and natural defenses provided by land and water systems such as wetlands, natural areas, vegetated sand dunes, and forests, while contributing to flood mitigation, public safety, and quality of life. In many ways, balancing hard and soft engineering approaches to flood control are at the heart of delta urbanism. Soft engineering, or ‘nonstructural’ projects, allow more room for natural processes, mitigate the effects of flooding, and provide acceptable land uses within flood prone areas.
CHAPTER THREE
DELTA URBANISM

The study of urbanization in or near coastal landscapes is not new. There is a plethora of literature discussing, analyzing, and studying the development of cities near coastal systems (Ascalone and Frongia 2007, Allchin and Allchin 1997, Campanella 2010b, Meyer 2014a, Mumford 1961, Nicholls 1995, Timmerman and White 1997). However, recent disasters in and around major deltaic cities have highlighted that urbanization, planning, and design of these cities needs to be reconsidered. This realization can be thought of as the origins of delta urbanism. An example of this realization can be understood through the Delta Works in the Netherlands, implemented after the North Sea storm surge of 1953, which claimed 1,800 lives and flooded 165,000 hectares of land (Dammers et al. 2014).

The Delta Works includes a series of dams and storm surge projects in the delta of the Netherlands to protect a large area of land from the sea. However, while these works improved water safety in the delta, they also had serious impacts on water systems, ecology, and the economy (Meyer 2009). They destroyed several salt and brackish water ecosystems, causing the urban communities at the edges of the delta to change the focus of their economies from trading and fishing to industry, intensification of agriculture, and recreation (Dammers et al. 2014). A similar, and more recent, example of how disasters highlight the necessity to reconsider urbanization, planning, and design in deltaic regions is New Orleans following Hurricane Katrina. Over centuries, on the Mississippi Delta,
the city New Orleans had manipulated and altered its natural environment through flood control measures, such as levees and dykes. While the city improved its water safety via extensive levee construction, it also developed into historically flood prone, agricultural areas via municipal draining. The combination of levee construction and urbanization resulted in negative environmental effects and placed large portions of city at a higher risk of flooding when Hurricane Katrina struck in 2005.

Events such as these have highlighted the vulnerability of deltaic cities and the importance of planning to mitigate these risks in the future. After Hurricane Katrina, planners, engineers, and politicians from the United States and the Netherlands met to discuss if and how Dutch principles of delta urbanism could be applied to New Orleans or elsewhere in the world. In turn these discussions, known as the Dutch Dialogues, gave rise to the American Planning Association’s project on Delta Urbanism, which included two urban planning publications that focused on urban planning in both the Netherlands and New Orleans (Meyer, Bobbink, and Nijhuis 2010). These publications highlighted that both hard and soft engineering approaches to flooding infrastructure are necessary. Hard engineering solutions (such as levees) have allowed for increased habitable land, but also allow populations to inhabit flood prone areas as well as destroy natural ecosystems that provide flood mitigation services (such as buffers to storm surge and runoff collection). A balanced approach between hard and soft flood control measures, along with proper land uses, are essential in reevaluating urbanization in deltaic and estuarine environments.

Originally, delta urbanism focused on urbanized areas that were strictly identified as deltas, and was considered in the context of climate change and flooding. In recent
years, delta urbanism has expanded its scope to include various urbanized environments, and issues other than climate change and flooding. Today, the phrase “delta urbanism” is used to signify the study of the complex nexus of cities, rivers, and oceans (Meyer 2014b). Delta urbanism has been defined as a the study of complex adaptive systems and a “… new initiative that explores the growth, development, and management of deltaic cities and regions, with the aim of balancing various goals in a sustainable manner: urbanization, port commerce, industrial development, flood defense, public safety, ecological balance, tourism, and recreation.” (Meyer, Bobbink, and Nijhuis 2010).

In order to discuss delta urbanism in a meaningful way, a baseline understanding of key theories and histories is required. The following sections review literature, topics, and concepts found in recent delta urbanism literature that are specifically used within this thesis, including: urbanization, typologies, complex adaptive systems, and comparative analysis.

**Urbanization**

The term urban has its root in Latin – *urbs* – meaning city. “Urban” environments have been defined by natural and social sciences alike. However, what constitutes urban, and thus urbanization, still remains unclear (McIntyre, Knowles-Yánez, and Hopee 2008). At a basic level, any landscape that shows human influence can be defined as urban. This fundamental description of urban can be interpreted as any remote site that has been influenced by humans at some point. Obviously this depiction of urban is too general, and it muddles the differences between human-influenced (i.e. agricultural fields) and truly urban areas. In order to gain a better definition of urban, definitions proposed by natural and social scientists and delta urbanism literature will be explored.
The natural sciences have defined urban environments or systems in many ways. However, by looking towards the social sciences and delta urbanism literature, a clearer image of what constitutes an urban environ becomes evident.

Ecological studies in which urban environments have been the focus, the definition of urban is mostly assumed, not definitively (McIntyre, Knowles-Yánez, and Hopee 2008). In some cases, urban is defined as simply “built-up”, or an area under human influence (Erskine 1992, Majzlan and Holecova 1993). For example, Kemp and Spotila express that: “The term ‘urbanization’ refers to development... such as road and building construction, and other changes of land use from rural to residential and industrial that result in an increase of impermeable surface, accumulation of toxic substances, increase of domestic wastewater load, and increase in water demand due to increased human population...” (Kemp and Spotila 1997). Hendrix et al. use a definition that is used widely by landscape ecologists: “All residential land at densities greater than one dwelling unit per acre, all commercial and public institutions, rail yards, truck yards and highways.”(Hendrix, Fabos, and Price 1988). In some studies, urban areas are analyzed as a linear gradient starting with the most densely populated area as the urban core, and moving outwards in a line until reaching beyond agricultural lands.

Social Sciences offer some standardized definitions of urban, but these differ between sources. For example, the U.S. Bureau of the Census defines urban as “…all population and territory within the boundaries of urbanized areas and the urban portion of places outside of urbanized area that have a decennial census population of 2,500 or more.” (Bureau). The United Nations, on the other hand, has defined urban as an area with more than 20,000 people (Nations 1968). Lewis Mumford, while describing urban
societies, states that: “... the transformation of village into city was no mere change of scale and size...” (Mumford 1961). Mumford is highlighting that definitions of cities solely based on size and area are missing important elements of what constitutes urban societies. Further confusing of what constitutes urban, there seems to be an assumption that urban describes a city, and does not apply with describing farming villages or similar settlements (Cowgill 2004).

Other social studies have used an even broader description of urban that focuses on the presence of certain signposts that we culturally associate with cities (e.g., presence of centers for performing arts) or density dependent differences in relationships among people (McIntyre, Knowles-Yáñez, and Hopee 2008). Likewise, urban has been described as “...a place-based characteristic that incorporates...population density, social and economic organization, and the transformation of the natural environment into a built environment.” (Weeks 2010). Urban planners may take a more descriptive approach in defining what is urban, paying more attention how the built environment of urban areas can influence social structure and vice versa:

“Our image of a city consists not only of people but also of buildings—the homes, offices, and factories in which residents and workers live and produce. This built environment forms contours which structure social relations, causing commonalities of gender, sexual orientation, race, ethnicity, and class to assume spatial identities. Social groups, in turn, imprint themselves physically on the urban structure through the formation of communities, competition for territory, and segregation...” (Fainstein 1994).
In delta urbanism literature, urbanization is discussed in terms of spatial pattern or development, and the changes in land uses that are typically encouraged in deltaic regions. It focuses on where development has occurred over time (i.e. high or low elevations), and acknowledges that urbanization is directly related to the different natural systems of each city (Campanella 2010b, Meyer, Bobbink, and Nijhuis 2010, Zagare 2014). In this sense, urbanization in each deltaic city is unique and characterized by different issues and problems depending on the natural environment in which they rest. Moreover, changing land uses in flood prone areas (particularly urban and agricultural) and water management projects are considered key elements in the urbanization process of delta urbanism.

By considering land use changes, delta urbanism has adopted a concept of urbanization similar to the ecological reference to urbanization, in which the term “... ‘urbanization’ refers to development... such as road and building construction, and other changes of land use from rural to residential and industrial...” (Kemp and Spotila 1997). These land-uses vary depending on the economic and environmental factors for settling in a delta. Shortly after New Orleans and Savannah were settled, for example, they saw their early land uses change because of their strategic position for trade, navigation, and agriculture. As will be discussed in later chapters, these economic reasons directly affected land uses over time.

Vulnerability of urbanized areas in deltaic regions has undoubtedly increased, but not solely because of climate change and sea level rise. Water management projects such as levee construction and river dredging can also increase a cities vulnerability to natural disasters. The urbanization process itself can result in serious deterioration of deltaic
environment, such as land subsidence, loss of marshlands, and coastal erosion, that
increases the vulnerability of urbanized deltas to storm surge and flooding (Barbier et al.
one variable (environment) which affects another variable (vulnerability). Delta urbanism
acknowledges the interaction between these variables, and argues that urbanized deltas
are complex systems, which are comprised of several systems that can affect other
systems within a city. Since delta urbanism uses this framework of “urbanization”, then
this thesis discusses urbanization in New Orleans and Savannah through spatial pattern,
land uses, and water management (flood control and river navigation). These
urbanization characteristics will be used for historical comparative analysis between New
Orleans and Savannah.

Delta Urbanism Typologies

Delta urbanism has been defined as a “…new initiative that explores the growth,
development, and management of deltaic cities and regions…” (Meyer, Bobbink, and
Nijhuis 2010). However, this definition leaves the term delta undefined, and there are
different meanings for the term between scientists, academics, and planners. Does delta
urbanism also apply to other types of coastal cities and regions, particularly estuarine
cities? For the purpose of this section, a literature review of the terms delta and estuary
will be discussed in order to gain a better understanding of delta urbanism.

Today, deltas are described as the landmass formed from the deposit of alluvial
sediment into a body of water, including oceans, seas, lakes, and reservoirs (Moore and
Asquith 1971). Many deltas of today started to form between 4,000 BC and 6,000 BC
with the recovery of global sea level (Syvitski and Saito 2007). The term delta has its
roots as the fourth letter of the Greek alphabet. Represented as the symbol \( \Delta \), it has been used to describe the natural triangular formation of sediment deposited at the mouth of river systems into bodies of water (Merriam-Webster 2015a). While the ancient Greek, Herodotus, uses the term delta fourteen times in his *History*, he uses it not as a technical term, but as the name of a place, the Delta. Instead, the first to be attributed with using the term delta in direct relation to rivers was Onsicritus of Astypalaea during his ventures with Alexander the Great. When Onsicritus wrote of the mouth of the Indus River, he notes that it has a "triangular shape" and that it is formed by the dividing of a river into two mouths (Celoria 1966). This use of the term delta is closer to the modern definition.

However, not all deltas form the “triangular shape” described by Onsicritus. Today, it is generally accepted that deltas can be broken down into different types, delineating the various environmental forces that shape their morphology. In general, deltas are characterized into three major types: river, wave, or tide dominated (figure 2), with various subsets within each type (Galloway 1975, Syvitski and Saito 2007). One of the most familiar river-dominated deltas is the Mississippi River Delta. Since the Mississippi River’s high water volume and sediment load over-power the relatively weak tides of the Gulf of Mexico, new land is built faster than the waves or tide can sweep them away (Campanella 2010b). Depending on a variety of factors like sediment load, tidal ranges, and waves, deltas can have morphologies and functions that vary in time and space. For example, a delta may originate in a tidal-dominated system, but later evolve to a wave-dominated system (Correggiari 2005).
Furthermore, deltas are sometimes considered only as units of larger systems, a fact that increases the difficulty of defining delta. For instance, the coast of Georgia is classified geologically as a Bar-Built estuary, and does not include deltas in the traditional sense. Instead, the Bar-Built estuaries of the Georgia coast are comprised of ebb-tide deltas, which are described as inlet-affiliated sedimentary units of tide-dominated coasts. These ebb-tidal deltas temporarily act as sediment sources, at the intersection of rivers and oceans, and occasionally deposit sediment into the surrounding areas (Foyle et al. 2004). In this case, deltas do not necessarily make up a large landscape.

Figure 2. Types of deltas. Based on environmental forces that shape their morphology: Wave, tide, or river dominated deltas (J.D. Myers, 2015).
or ecosystem, but are a smaller unit of the environment which is the Tide-Dominated, Mixed-Energy Coastal System of Georgia (Hayes and FitzGerald 2013, Henry 2014).

Conversely, estuaries are described as the transition from land to sea, where freshwater from rivers empty into coastal bays and inlets. The etymology of the term estuary can be traced back to the Latin -aestus – meaning tides (Merriam-Webster 2015b). Estuaries cover much of North American coastline, and were formed near the end of the last ice age between 10,000-18,000 years ago. As glaciers receded and melted, sea levels rose and inundated low-lying river valleys (NOAA 2008). Estuaries form along the coast where freshwater from rivers and streams meet and mixes with salt water from the ocean, and are generally described as flooded river valleys.

In terms of geological classification, estuaries can be classified into five types based on how they are formed: Coastal Plain, Bar-Built, Delta System, Tectonic, or Fjords. In this sense, deltas are a type of estuary. Conversely, estuaries can also be categorized by water circulation. This classification system also offers five types of estuaries: Salt-Wedge, Fjord, Stratified, Vertically-Mixed, or Freshwater (NOAA 2008). In the case of the coastal Georgia, its estuaries are classified as either Bar-Built estuaries (geologically) or Stratified estuaries (water circulation). *Ceteris paribus*, the key difference between delta and estuary seems to largely result from the amount of sediment and water volume deposited into the receiving body of water. Sometimes deltas are classified within estuarine systems (i.e. the geological classification of estuary), or as distinct features of larger systems (i.e. ebb-tide deltas within Bar-Built estuaries).

Recently, delta urbanism research from the Delft University of Technology in the Netherlands has focused on New York and New Jersey, which are traditionally classified
as estuaries. More to this effect, a recent issue of Built Environment, dedicated entirely to
delta urbanism, states that “... recent floods in urbanized delta areas shows the need for a
fundamental reconsideration of urban development in delta, coastal and river plain
areas.” (Meyer 2014a). It is clear that delta urbanism includes deltas not only in a strict
sense, but in a way that includes regions where river(s) and ocean meet. This expansion
of delta urbanism to include estuarine cities is important, because it signifies that
different urbanized deltas and estuaries have already been studied under the framework of
delta urbanism. In this sense, delta urbanism has been expanded the definition of delta to
incorporate areas other than traditional deltas, such as estuaries. Studying the estuarine
city of Savannah under delta urbanism, then, is justified and accepted in delta urbanism
literature.

Recent literature of delta urbanism identifies although coastal areas have similar
problems (climate change, flooding, erosion, ports, etc.), they have different
morphological and functional characteristics which need to be considered in spatial
planning and design; and it is therefore necessary to create a typology of urbanizing
deltas to introduce site-specific strategies for urban development (Meyer and Nijhuuis
2011). Progress has been made in this respect, with a typology or classification of four
variations of urbanized deltas being put forth in recent delta urbanism literature (table 1);
mudflat, plain, estuary, and lagoon deltas (Meyer 2014b). For example, the Mississippi
Delta is classified as a mudflat delta, which are described as having large amounts of
siltation and land building processes, with urbanization taking place on higher elevations
next to rivers. Conversely, in the same literature, estuaries are categorized tidal, flooded
river valleys and as having little or no coastal plain with urban settlement on higher land
Table 1. Typologies of urbanized deltas (Nijhuis and Pounderoinen 2014).

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mudflat</td>
<td>A delta where silt (potentially) builds up. These continental-shelf margin deltas are typically formed by rivers with very large sediments loads. These deltas continue to build seaward, extending the continental margin into deeper waters. Urban settlements are concentrated on the higher grounds or next to the delta, which consists of wetlands.</td>
</tr>
<tr>
<td>Plain</td>
<td>A delta with a large deltaic flood plain (below 5 meters elevation). These deltas are characterized by a large alluvial plain which is mainly used for agriculture and by a sprawled pattern of human settlements and concentrated cities.</td>
</tr>
<tr>
<td>Estuary</td>
<td>A tidal mouth of a river, widening as it enters the sea, with almost no deltaic flood-plain. Estuaries are typically drowned river valleys and have concentrated, large cities on adjacent high ground and agriculture in the lower areas.</td>
</tr>
<tr>
<td>Lagoon</td>
<td>A delta or part of a delta protected by barrier-island systems or topographical remnants. Lagoon or bayhead deltas are usually part of a bigger coastal and/or deltaic zone. Cities are located at the river mouth, on islands, or peninsulas. The coastal flood plain consists of wetlands.</td>
</tr>
</tbody>
</table>

and agriculture in the lowlands. Moreover, Lagoons are categorized as being a part of large coastal systems and protected by barrier island systems. By using mapping and historical analysis, this thesis will explore how the estuarine city of savannah fits within the urbanized delta typology used in Urbanized Deltas in Transition (Meyer 2014b, Nijhuis and Pounderoinen 2014). This thesis will test these typologies by mapping the Savannah area and try to place Savannah within one of the four typologies presented here.

The common denominator in the four types of urbanized deltas is that they all include rivers and deltaic lowlands or flood plains; and once human habitation of these lowlands progressed by means of urbanization, navigation, and agricultural exploitation, the conditions of these lowlands changed dramatically (Campanella 2010b, Colten 2000, Meyer 2014a). Delta urbanism then, categorize deltaic regions not only identified by specific natural conditions, but also by specific human development. Manipulation and
alteration of deltaic regions through the construction of flood control defenses (dykes, levees, etc.), navigational enhancements (dredging, canals, etc.), and agricultural cultivations (rice, cotton, indigo, etc.) have altered the natural environment in drastic fashion. Both New Orleans and Savannah share these common denominators, and represent two out of four type’s urbanized deltas presented in recent delta urbanism literature: mudflat and estuary, respectively.

Resilience and Complex Adaptive Systems

The concept of a resilient city has gained substantial attention in planning over recent years (Eraydin and Taşan-Kok 2013). However, the definition of resilience is murky, with different professions using different definitions of the word (Manyena 2006). Indeed, a major critique of resilience is its ambiguity, which may cause vagueness and come to represent no more than a hallow concept for planning (Davoudi et al. 2012). This ambiguity results from the variety of it origins and concepts, including ecology, economics, engineering, and psychology (Gunderson 2000, Holling 1973, Hyslop 2007). Since the discussion of urban resilience could include the swath of topics, the following section will not go into detail of other forms of urban resilience (i.e. psychology, economics, etc.) that do not fall within the scope of this thesis. Because one of the aims of this thesis is to better understand deltaic and estuarine cities in terms of delta urbanism, the following sections will briefly explore how resilience has been discussed in engineering, ecological, urban planning, and delta urbanism literature. Despite the obvious discrepancies in how the term resilience is used and understood, there have been strides in how urban planning and delta urbanism can help create resilient cities in the face of climate change.
The word resilience is derived from the Latin word -resilio- meaning ‘to jump back’ (Klein, Nicholls, and Thomalla 2003). Engineering resilience typically refers to physically built man-made systems, and has been described as the ability of a system to return to an equilibrium or steady-state after a disturbance (Holling 1973, 1986). In this sense, the resistance to disturbance and the speed by which the system returns to equilibrium is the measure of resilience. The faster the system bounces back, the more resilient it is (Davoudi et al. 2012, Lu 2014). The emphasis is on return time, “efficiency, constancy and predictability”, all of which are sought-after qualities for a “fail-safe” engineering design (Holling 1996).

Some of the earliest literature on resilience comes from studies of ecological equilibrium and disturbances (Holling 1973). Most of the studies around this time focused on the management of large-scale ecological disturbances that can transform the ecological system for a certain period of time (Lu 2014). Ecological resilience, moreover, was defined as “the magnitude of the disturbance that can be absorbed before the system changes its structure” (Holling 1996). Here, resilience is defined not just according to how long it takes for the system to bounce back after a shock, but also how much disturbance it can take and remain within critical thresholds. Ecological resilience focuses on “the ability to persist and the ability to adapt” (Lloyd, Peel, and Duck 2013). This self-organization or reorganization (adaptation) ability is a key characteristic of resilience (Ludwig, Jones, and Holling 1978, Walters 1986).

In social sciences, the interest in resilience has increased due to the perceived increases in complexity, uncertainty, and insecurity in which new approaches to adaptation are being sought (Lloyd, Peel, and Duck 2013, Christopherson, Michie, and
Many social studies have taken the ecological definitions of resilience and applied it in analyzing the capacity of self-organizing systems such as people, settlements, or societies to endure impacts such as natural disasters, disease or crisis without being destroyed (Vayda and McCay 1975, Zimmerer 1994). An emphasis on settlements that have the ability to learn or adapt is specifically highlighted in social science literature concerning resilience. An example of urban resilience could be a settlement that remains functional when experiencing disturbances, such as flood or disruption of telecommunications (Lu 2014).

For instance, in *Planning for Resilient Coastal Communities*, Lamson poses that a fishing settlement would have more resilience than a new modern town in facing flood disasters. This is because the population in the fishing village has learned to be “water-resistant” through their experiences with flooding throughout centuries, while the population in the modern town has less experience with flooding and relies on modern engineering solutions to water safety (Lamson 1986). In this sense, change is a primary consideration in resilience, and being resilient focuses on adapting to disturbances (or change) and actions to deal with disturbances once they have occurred (Lu 2014).

Resilience in urban planning literature also emphasizes the ability of urban systems to withstand disturbances and to reorganize following disturbance-driven changes (Walker et al. 2002). Urban planning literature also brings forth the idea of “socio-ecological” or “evolutionary” resilience. The socio-ecological perspective broadens the engineering and ecological description of resilience to incorporate the dynamic interaction of persistence, adaptability and transformability across multiple scales and systems (Gunderson and Holling 2002, Walker et al. 2004, Davoudi et al.)
In this sense, resilience is not considered as a return to stability, but as the ability of complex systems to change, adapt, and transform in response to stresses and strains (Carpenter, Westley, and Turner 2005). Systems are conceived as “complex, non-linear, and self-organising, permeated by uncertainty and discontinuities” (Berkes, Folke, and Colding 2000).

The focus in urban planning literature as also been concerned with preparation and mitigation actions, particularly at the local scale (Godschalk 2003). In this context, building resilient communities is related to traditional land use designations to minimize existing or future disturbances. As an example, land use planning identifies different land uses in order to avoid development in flood prone areas. Recent studies have stated the spatial planning can play an important role in promoting resilience in the face of climate change (IPCC 2007, Davoudi et al. 2012, Wilson and Piper 2010). By organizing land use change or requiring certain forms of urban development, spatial planning provides both adapting to impacts of climate change and mitigating hazards such as flooding.

In delta urbanism literature, urbanized deltas are thought of as complex systems. System theories state that complex systems are characterized by many variables (subsystems), the many non-linear relations between them, and the great uncertainty about the state of the elements (Dammers et al. 2014). In systems theory, when a complex system is able to deal with sudden changes to one of subsystems, it is considered to be a relatively stable system. Likewise, when a complex system is temporarily disordered by an extreme event, but able to recover quickly, it is considered a resilient system (ecological and engineering resilience). When a complex system is able to adapt to changes, it is called a complex adaptive system (Mayer, Bekebrede, and van Bilsen 2010, 2012).
As discussed previously, in urban planning literature when a complex system is able to adapt to change, it is described as resilient. Delta urbanism argues that complex deltaic regions of today need to be able to adapt to immediate changes, and uncertain changes in the far future.

The idea of complex adaptive systems is relevant to delta urbanism and builds upon the work of Ian McHarg, who considered urban landscapes as layered systems (McHarg 1969). The layers that Ian McHarg describes (natural substratum, climate, transportation network, and land use patterns) represent the subsystems of complex systems theory. Each layer, or subsystem, has its own dynamism, and is also related to and influences other layers, or subsystems (Meyer 2014b). Recent delta urbanism literature has used Geographic Information Systems (GIS) to study these layered systems of urbanized deltas. This thesis uses GIS and the layered, systems approach to understand the Savannah Estuary.

**Mapping and Comparative Historical Analysis**

The earliest examples of comparative research has been through mapping (Tooley 1999). Geographers of the 19th century recognized the landscape as a complex system of systems. In order to gain a better understanding of these complex systems, they used graphic techniques to compare and reason through scientific data (Kilpinen 2005). In this early research, rivers and their natural contexts were compared and classified in order to discover differences and similarities in a visual way. In urban planning, there is a long tradition of using maps and comparative research (Moudon 1994). Mapping has been used as a mean to generate knowledge for planning and design in urbanized areas, and to discover various successes and failures of cities coping with deltaic environments. In
Delta urbanism, the objective of mapping is to address the challenging situation of intensive cultivation and habitation in flood prone lowlands.

Delta urbanism has recently used this type of research as a way to understand urbanization in deltaic landscapes and to determine future guidelines for development (Campanella 2014). Using the four delta typologies discussed earlier (mudflat, coastal plain, estuary, and lagoon), researchers are able to classify, map, and compare multiple urbanized deltaic landscapes. This is an important tool for studying urbanized deltas because it allows researchers and designers to understand different types of deltas, and different design challenges for each. As Steffen Nijhuis and Michiel Pouderoijen explain, “an urban settlement entirely located in the lowlands requires a different design strategy than one that originated on higher grounds and partially extends into the lowlands.” (Nijhuis and Pouderoijen 2014). Additionally, visual representations, like maps, allow planners and designers to determine these characteristics and to communicate them effectively.

By mapping different layers of the deltaic landscape, such as the substratum (or elevation), transportation network, climate, and land use, the relationships between environmental conditions and human interactions can be explored. In the recently published *Urbanized Deltas in Transition*, these map layers were standardized in the comparative analysis of eight major deltas found around the world (Meyer 2014b). Mapping the substratum layer allowed researchers to determine the coastal plain (< 5 m elevation) for each delta, which indicate areas that are vulnerable to sea level rise and flooding. Additionally, researchers used six standardized land uses (urban, forest, agriculture, wetlands, sparsely vegetated, and open water) across each delta. This allowed
researchers to determine how much of each land use was being utilized in areas vulnerable to flooding.

This thesis uses the same standardized layers and land uses found in *Urbanized Deltas in Transition* (figure 3, table 2), to generate maps and data for the Savannah Estuary. The analysis and results of the GIS mapping layers for the Savannah subsystem layers will be presented in the chapter six.

On the other hand, historical analysis of the natural and built environments are also important aspects of the comparative analysis of delta urbanism (Campanella 2010b, Meyer, Bobbink, and Nijhuis 2010). Comparative historical analysis was originally used as the central method of investigation in early social sciences, and seeks to discover patterns in the histories of different cultures, cities, or landscapes (Mahoney and Rueschemeyer 2003). The “founding fathers” of social sciences, from Adam Smith to Karl Marx, pursued comparative historical analysis as a central mode of investigation. While comparative historical analysis in the social sciences have expanded into many fields of study, all work in comparative historical analysis share a common concern with causal analysis, processes over time, and the use of systematic and contextualized comparison.

Acknowledging that each deltaic city has its own natural and built histories allows researchers and planners to compare similarities and differences in how deltaic regions have evolved. This understanding allows researchers and designers to understand and identify various successes and failures of concepts of delta urbanism. In order to study the histories of New Orleans and Savannah in a standardize way, they are broken down
Figure 3. Comparative mapping layers for the Mississippi Delta. Used in “Urbanized Deltas in Transition”. Recently used in the comparative analysis of eight world deltas, using standardized mapping layers (Nijhuis 2014).

Table 2. Comparative land uses for the Mississippi Delta. Used in “Urbanized Deltas in Transition”. These land uses were recently used in the comparative analysis of eight world deltas, using standardized mapping layers (Nijhuis and Ponderoijen 2014).

<table>
<thead>
<tr>
<th>Land Use in Coastal Plain (&gt; 5m mean sea level)</th>
<th>km²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban</td>
<td>112.9</td>
</tr>
<tr>
<td>Forest</td>
<td>4533.6</td>
</tr>
<tr>
<td>Agriculture</td>
<td>1784.1</td>
</tr>
<tr>
<td>Wetlands</td>
<td>6804.9</td>
</tr>
<tr>
<td>Sparsely Vegetated</td>
<td>4.7</td>
</tr>
<tr>
<td>Open Water</td>
<td>4780.3</td>
</tr>
<tr>
<td>Total</td>
<td>18020.5</td>
</tr>
</tbody>
</table>
into sections, each describing the evolution and progress of the natural and urban environments, and concepts of delta urbanism previously discussed in this chapter (i.e. typology, urbanization, and complex adaptive systems) will be compared between the two cities. First, a description of the natural processes and formations of the specific deltaic landscape are discussed. The descriptions of the natural environments of each city will be used to analyze the typologies of urbanized deltas. Second, a history and evolution of urbanization patterns relative to the natural deltaic landscapes are discussed, while also highlighting how the urbanization process contributed to the alteration of the landscape. Since delta urbanism uses a broadened framework of “urbanization”, then this thesis discusses urbanization in New Orleans and Savannah through spatial pattern, land uses, and water management (flood control and river navigation). These urbanization characteristics will be used for historical comparative analysis between New Orleans and Savannah.

Conclusion

In delta urbanism literature, urbanization is discussed in terms of spatial pattern or development. Moreover, changing land uses in flood prone areas (particularly urban and agricultural), water management projects, and balancing various subsystems found in complex deltaic systems are considered key elements in the urbanization process of delta urbanism. This thesis discusses urbanization in New Orleans and Savannah through spatial pattern, land uses, and water management (flood control and river navigation). These urbanization characteristics will be used for historical comparative analysis between New Orleans and Savannah.
Delta urbanism is not only concerned with climate change and sea level rise, but also with spatial planning, flood defense, land-use, industrial and port development, tourism, and resilience. Delta urbanism has been defined as a “...new initiative that explores the growth, development, and management of deltaic cities and regions...” (Meyer, Bobbink, and Nijhuis 2010). However, literature review of definitions, classifications, and concepts of what constitutes a deltaic city is unclear. Cities are sometimes defined as new and distinct formations of landscape (built up) or result from interaction between two systems (i.e. river and ocean, or built and social). The term urban is often assumed to describe a city, and that small, coastal agricultural settlements might not have the population density or enough built environment to be considered urban. Interpreted this way, delta urbanism could excluding many coastal areas, particularly estuarine environments of small agricultural or fishing settlements.

Delta urbanism literature in recent years has described deltas in a way that includes many urban areas that are located at the nexus of river and ocean, but are not traditionally classified as deltas. By identifying the differences in coastal landscape morphology and function, delta urbanism has provided typologies that include areas where two systems, river and sea, both meet and influence each other, and influence the built and natural environments (Meyer and Nijhuis 2011). Delta urbanism identifies the various urban deltaic typologies, and acknowledges that deltas have different morphological and functional characteristics which need be considered in spatial planning and design (Meyer and Nijhuis 2011). By expanding the definition of delta, estuarine cities can be considered in the framework of delta urbanism. Since the aim of this thesis is to study an estuarine city Savannah in a delta urbanism framework, then the
typologies of recent delta urbanism literature that intentionally incorporates estuarine cities are used. By using mapping and comparative historical analysis, this thesis will explore how the estuarine city of Savannah fits within the urbanized delta typology used in *Urbanized Deltas in Transition*.

After reviewing the concept of resilience, it is clear that various concepts and definitions of resilience are used by various fields of study. This has led to uncertainty, ambiguity, and potentially creating a hollow “buzz-word”. Despite that they are rooted in different disciplinary traditions, what underline both is the belief in the existence of equilibrium in systems, (Davoudi et al. 2012). Resilience is often used to indicate how systems cope with, and adapt to, shocks and surprises in order to remain functional (Gunderson and Holling 2002). These systems could be urban, ecological, or social systems. Moreover, resilience often refers to the ability to initiate change in order to become robust enough to face disturbances (Newman, Beatley, and Boyer 2009). In other words, resilience is not only concerned with the ability to “bouncing back”, but also the ability to adapt to changes. In general, the ability of complex systems to learn and adapt to disturbances is a key principle in social science and urban planning resilience.

In delta urbanism literature, urbanized deltas are thought of as complex systems. When a complex system is able to adapt to changes, it is called a *complex adaptive system* (Mayer, Bekebrede, and van Bilsen 2010, Meyer 2014b). As discussed previously, in urban planning literature when a complex system is able to adapt to change, it is described as resilient. Delta urbanism argues that complex deltaic regions of today need to be able to adapt to immediate changes, and uncertain changes in the far future. Despite the murkiness of the word resilience, planners have been able to help communities
prepare, mitigate, and adapt to disturbances related to natural hazards and climate change. Urbanized deltas are complex systems, but should be able to adapt to potential disturbances in the further.

Delta urbanism uses historical analysis, along with mapping, as tools for comparative analysis across various complex urbanized deltas. As the purpose of this thesis is to contribute to the comparative analysis of delta urbanism, the same tools will be used when discussing Savannah, Georgia in the United States. Standardized map layers (substratum, climate, transportation, and land use) have been identified as a tool for systematically studying and comparing urbanized deltas. This thesis uses the same standardized layers and land uses found in *Urbanized Deltas in Transition* to generate maps and data for the Savannah Estuary.

Comparative analysis of the historical developments can be useful tool in delta urbanism. This allows planners and designers to understand and identify various successes and failures of concepts of delta urbanism, and the different types of design challenges for different urbanized deltas. Moreover, through mapping and historical analysis, this thesis will explore various concepts of delta urbanism, such as: typologies, complex adaptive systems, and urbanization. The results and comparison between the New Orleans and Savannah subsystem layers will be presented in chapter six.
CHAPTER FOUR

DELTA URBANISM: NEW ORLEANS, LOUISIANA

In many ways post-Katrina New Orleans offers a valuable case study for urban planners because its situation positions it in a foretelling role between world cities. What New Orleans experienced after Hurricane Katrina foreshadows what similar coastal cities will be undertaking in future generations. Because of its young age and recent urbanization, Richard Campanella argues that New Orleans is North America’s “...purest case study of delta urbanism.” (Campanella 2010b). New Orleans is unique in its natural, built, and social histories. There are, however, still lessons that can be gleaned from New Orleans during pre and post-Hurricane Katrina that can be of particular interest to urban planners in other estuarine or deltaic cities. Phil Steinberg points out in the introductory chapter of What Is a City? Rethinking the Urban after Hurricane Katrina, that even before “...the floodwaters had subsided . . . scholars and planners were beginning to reflect on Hurricane Katrina and its disastrous aftermath, and they were beginning to ask bigger questions with implications for cities as a whole.” (Steinberg and Shields 2008).

Some of the overarching themes in this chapter include the historical and contemporary conditions of the deltaic city of New Orleans, problems of water management and land use, and the history and challenge of city-building, maintenance, and adaption to the deltaic landscape. The following sections will attempt to outline the evolution of the natural and built environment of New Orleans and how this evolution effected the resiliency of the deltaic city. This chapter serves as a comparison of delta
urbanism in the United States, offering similar histories, development, and management as found in other coastal cities within the continental United States.

**The Mississippi Delta**

The city of New Orleans lies on the relatively young, dynamic Mississippi Delta (figure 4). Unlike most American cities, which are located on the ancient North American lithosphere, New Orleans and its urban landscape sits upon the youngest lands in the United States; and the lifespan of New Orleans accounts for roughly 6 percent of the lifespan of its underlying geology (Campanella 2008, 2010b). The entire lower Mississippi Valley, from Cairo, Illinois to the Gulf of Mexico, constitutes the continent’s youngest surface soils. During the last ice age, large quantities of water lay frozen in ice sheets. The ice sheets covered large areas of North America, along with the rest of the world, and dramatically changed the topography and hydrology of the continent. As global temperatures began to rise, the ice sheets began to melt, sending large quantities of water and sediment towards low lying coastal areas, i.e. Southern Louisiana via the Mississippi River (NOAA 2008).

In the case of the Mississippi River Basin, 41 percent of the of the continental United States drains into the Mississippi River and ultimately into Louisiana and the Gulf of Mexico (EPA 2015). When moving water loaded with sediments suddenly hits a slack body of water, such as the Gulf of Mexico, it loses it kinetic energy and dumps its sediment load (Syvitski and Saito 2007). Because of the Mississippi River’s immense water volume and sediment load vis-à-vis relatively weak tides and currents in the Gulf of Mexico, the river’s force overpowered those of the gulf and extended the coastline
Figure 4. Context Map of New Orleans. The city of New Orleans (red) in context of the state of Louisiana along the Gulf of Mexico (created by author, 2015).
farther into the Gulf of Mexico. This process was the incunabula of Southern Louisiana and the Mississippi Delta.

Visitors of New Orleans in the early to mid-nineteenth century noted this land building process of the Mississippi Delta, stating the delta was “silently pushing...into the sea” and resembled to an “arm projecting into the sea and spreading its fingers on the surface of the water.” (figure 5) (Hall 1830, Réclus 1855). As mentioned earlier in the literature review chapter, the Mississippi Delta is classified as river-dominated, and visitors to New Orleans were describing the processes that designate it as such. River-dominated deltas only occur in areas where rivers bear enough sediment and water to overpower its receiving body of water. In most cases, river-dominated deltas are found in lakes rather than oceans because few of the world’s rivers are large enough to overpower coastal currents and tides (Syvitski and Saito 2007). However, the Mississippi Delta is just that, a river-dominated delta protruding into an ocean. By the early 18th century, most of the landscape around the Mississippi Delta had developed into what would be recognizable today (Campanella 2008).

Like many coastal habitats, Southern Louisiana and the Mississippi Delta consists of vast areas of wetlands. Specifically, the Louisiana’s wetlands extend as much as 130 kilometers inland and along the coast for about 300 kilometers. The swamps and marshes of coastal Louisiana are among the Nation's most delicate and valued wetlands, vital not only to agricultural and recreational interests, but also the State's more than $1 billion per year seafood industry (Williams 2011). These natural ecosystems are not only important for their agricultural, recreation, and economic value, but are vital in the reduction of damages due to storm surge and flooding (Barbier et al. 2013, Costanza et al. 2008).
Louisiana's wetlands today represent about 40 percent of the wetlands of the continental United States, but about 80 percent of the losses (Williams 2011). It is estimated that human activities, such as dredging wetlands for canals or draining and filling for agriculture, grazing, or development, are largely responsibility for marsh habitat loss.

In the deltaic plain of the Mississippi River, the highest elevations are found alongside moving freshwater (figure 6). This is unlike most undulating landscapes, which water carves downward and into the lowest elevations. During springtime flooding
events, the river would overflow and deposit fine particles alongside its banks. By the time the first Europeans arrived, areas closest to the Mississippi River had formed natural levees, rising about 10 to 20 feet above sea level (Kelman 2003). As one moves away from the river, the elevation drops and the water table rises closer to the surface, often times becoming inundated.

This typography helps explain early settlement patterns of New Orleans, with the natural occurring levees providing high ground suitable for development (Colten 2000). In later decades this typography would change due to man-made levees constructed along the banks of the Mississippi River, preventing flooding of the adjacent land and stopping the depositional processes that naturally maintained the altitude of the land surface in
southeast Louisiana above sea level (Burkett, Zilkoski, and Hart 2002). Moreover, the volume of sediment delivered by the Mississippi River to Louisiana has been reduced by almost one-half since 1950 by the construction of reservoirs on the major tributaries of the Mississippi River (Meade and Moody 2010).

Early Settlement and Transformation

Before the first Europeans settled New Orleans, Native Americans were occupying and transforming the great Mississippi Delta. The earliest archaeological sites in the region date as far back as 2000 BCE, and were continuously occupied until the end of the 18th century (Kidder 2000). These indigenous people settled on the elevated natural levees provided by the seasonal flooding of the Mississippi River and transformed the natural environment through hunting, clearing and burning vegetation, building middens (oyster mounds), and planting crops on the delta. Over millennia, these actions provided natural resources that made the city’s location desirable to early settlers: building up key locations and biodiversity used by hunters, fisherman, and trappers, and providing resources that would be incorporated into future city’s infrastructure, i.e. shell roads, lime plaster, and timber for the construction of levees (Lewis Peirce 1976). However, large scale transformation of the natural environment did not occur until the arrival of European settlers (Campanella 2008, Colten 2000, Lopez 2009).

18th Century Urbanization and Water Management

Although early Spanish expeditions throughout the 16th century came close to the Mississippi Delta, they did no leave any permanent mark on the landscape; as they were interested in riches rather than colonization. It was not until the late 17th century that French explorers realized that the mouth of the Mississippi River was an important
connection to the interior of North America, and a strategic location for defending trade routes and other would be colonizers. This location also provided connected to the Caribbean and Atlantic oceans, fertile soils for agriculture, and deep water for docking ships (Campanella 2010b). This realization prompted the French government to establish defenses and settlements along the Louisiana coast, and particularly near the mouth of the Mississippi River (Morris 2000).

In the early 18th century Jean-Baptiste Le Moyne de Bienville, future governor of Louisiana and founder of New Orleans, was tasked with settling and securing this strategic location. In 1718, just as the Native Americans before him, Bienville chose to settle on one of the elevated natural levees of the Mississippi, a site that is occupied today by the French Quarter, and one of the only locations in New Orleans that was not flooded during Hurricane Katrina in 2005. For the first couple of years after its 1718 founding, New Orleans grew in an unplanned, haphazard fashion, without “any order or regularity” as one observer in 1720 wrote (Jefferys 1761). However, a 1722 hurricane swept most of the existing facilities and houses away, leaving almost a blank slate for engineers Le Blond de la Tour and Adrien de Pauger to create a new street system and urbanization pattern in New Orleans (Campanella 2010b).

This “new” city plan was not actually new, as it was modeled after the Roman castrum style of military outpost development. The plan consisted of 66-block grid around a central plaza (figure 7), with fortifications surrounding the settlement (Heard and Bernhard 1997). Landscape transformations happened on several levels; from geophysical and biological to hydrological and cultural. Its plantation owners, along with slave labor, cleared vegetation via cattle grazing and farming of rice, tobacco, and indigo.
Figure 7. Plan de la Ville La Nouvelle Orleans, 1755. Plan de la Ville La Nouvelle Orleans Capitale de la Province de la Louisiane, 1755. A map of New Orleans illustrating the 66 block grid implemented after the hurricane of 1722. The Mississippi River shown in the south (The Historic New Orleans Collection).

Plantations replaced old-growth forests, and introduced livestock replaced indigenous species (Colten 2000). As more land was brought into cultivation, plantation owners sought to protect it from the annual springtime flooding of the Mississippi River.

In 1724, New Orleans saw the first attempt at flood control, with the first artificial levee being constructed out of cut timber from cypress and old growth forests. These first man-made levees were three feet high earthen embankments built upon the natural levees running parallel to the Mississippi River (Morris 2000, Campanella 2010b). The creation of artificial levees changed the geography of individual farms and plantations. Originally, landowners settled, built, and developed homesteads on the natural levees of the Mississippi. However, over time they moved into low-lying areas that were drained and protected by artificial levees.
This gradual spatial development away from the river placed settlers in greater risk of inundation, which in turn obliged still higher levees and more elaborate networks of drainage canals (Morris 2000). By 1752, the “levee line” along the cities’ riverfront spanned 20 miles below the city to 30 miles upriver and advanced in that direction by about one mile per year (Gould 1889). Throughout the French colonial era, the creation and maintenance of levees, dykes, ditches, and canals were almost entirely left to private property owners. The first real efforts at a centralized levee oversight came with Spanish rule (1763-1800) of Louisiana and New Orleans (Wood 1939).

Francisco Luis Héctor de Carondelet, governor of Louisiana and New Orleans from 1791-1797, issued the first levee ordinance in 1792 requiring residents to raise levees to the recent high-water mark of the river, to plant grass and forbid livestock grazing on existing levees (de Carondelet 1927). The Carondelet Canal, also known as the Old Basin Canal, was also constructed under Carondelet, and was operational from 1794 into the 1920s. It served dual purposes of storm water drainage and facilitating shipping (Powell 2012). Notwithstanding, failure of individual landowners to install and maintain their portion of the levee would compromise the entire levee system. As a result, colonial levees often fell short of their intended goal, with river water inundations of farms, plantations, and New Orleans occurring in 1719, 1735, 1785, 1791, and 1799 (Campanella 2010b).

**19th Century Urbanization and Water Management**

Ironically, despite the strategic location of New Orleans, it was not considered a prominent asset by its French and Spanish rulers. Its value changes, however, after ownership of Louisiana and New Orleans transfers to the Americans during the Louisiana
Purchase in 1803, and as agricultural and transportation breakthroughs began to affect the lower Mississippi Valley. With these changes, New Orleans transforms from the “colonial orphan of two Old World monarchies” into a “treasured port city... under the dominion of an ascendant, expanding, unabashedly capitalistic New World democracy.” (Campanella 2010b). The Louisiana Purchase greatly enhanced New Orleans’s role as entrepôt to the Mississippi Valley, with trade from the North American hinterland now moving downstream to the port city. Increasing reliable transportation via steam-boat navigation and the advent of the cotton gin greatly altered the importance of New Orleans. Cotton cultivation became more lucrative, its cultivation up the Mississippi River increased, and its transport along the Mississippi River via steam boats ended at New Orleans before shipping out into world markets. The arrival of steamboats on the Mississippi River marked the moment of a pre-capitalist, largely colonial period of resource exploitation, and an era that people increasingly depended on industrial technologies as they engineered the world around them (Kelman 2003).

Under American administration the population of New Orleans doubled every 10 to 20 years, with the majority of its urban footprint moving up the Mississippi River along its natural levees (Campanella 2008). During the early 19th century, urban development was planned at the subdivision scale, with unwritten “rules” dictating where development occurred (figure 8). As Richard Campanella argues, these general rules of development were as follows: immediate adjacency to existing urbanized areas or readily accessible by transportation, elevated and well drained land, and land legally acquirable for development. The first suburbs of New Orleans (Faubourgs Ste. Marie, Marigny, Duplantier, Solet, La Course, and Annunciation) were created immediately upriver,
Figure 8. Plan of the City and Suburbs of New Orleans, 1816. A map plan of the city and suburbs of New Orleans from a survey made by J. Tanesse in 1815. Notice urbanization taking place directly upriver and down river (The Historic New Orleans Collection).

downriver, and surrounding the original city. Transportation (roads, rail, and canals) expanded the *adjacency* rule to include *accessibility*, with new subdivisions occurring on previously unconnected areas from New Orleans. The creation of the Carondelet Canal, for instance, connected a nearby, old agricultural settlement to the city, and shortly afterward it was subdivided. Additionally, for much of the 18th and 19th century, development occurred on dry, well drained land, which happened to be on natural levees. By the late 19th century, however, these development patterns start to change with the increase in transportation technologies, flood control, and municipal draining.

As with the 18th century, flood control and water management during the first half of 19th century was still strictly local, with individual property owners responsible for maintaining levees located on their property. The practice of local flood control would
soon change however, when a failed levee in 1849 flooded “...220 city blocks, 2,000 structures, and 12,000 residents” in and around New Orleans (figure 9) (Campanella 2010b). As mentioned earlier in this thesis, this flooding event on the lower Mississippi grabbed national attention, and resulted in increased Federal involvement in flood control, two competing Army Corps of Engineer studies, and ultimately a 60 year “levees only” policy adopted by the Corps. By 1879, increasing pressure for navigation improvements and flood control prompted Congress to establish the Mississippi River Commission, an organization responsible for executing a comprehensive plan for flood control and navigation works on the Lower Mississippi (USACE 2008). The creation of this commission marked the beginning of federal, state, and local cooperation in flood control.

Despite repeated flood disturbances and haphazard localized flood control, New Orleans still managed to grow in population, economy, and urban context. Much of this success can be attributed to urban form, which accommodated flooding via raised structures in high density on elevated ground. This changes however, as municipal drainage takes root during the late 19th century. The 1890s saw an increase in serious municipal drainage efforts, and in 1895 a proposed drainage plan was created that included a series of outfall canals, pipelines, and pumps to be installed to drain runoff from sub-basins. Ten years later, hundreds of miles of drains and pipelines, 40 miles of canals, and six pumps draining 22,000 acres were installed (Campanella 2010b).

The draining of swamplands and marshes drastically transformed the natural and built landscape of New Orleans. For the first time in the history of human habitation of
the lower Mississippi Delta, vast areas of once inundated, low lying areas were made suitable for urbanization. These vast areas of freshly drained soils sunk, or subsided, as much as 10 feet because of lower water levels, and development that was once constrained to natural topographies was now free to spread into low lying areas. By the early 20th century, the cities’ morphology shifted from a compact, naturally elevated cityscape into a spreading, subsided cityscape.

20th and 21st Century Urbanization and Water Management

From the early 18th century to the early 20th century, most New Orleanians lived on high, well drained natural levees close the Mississippi river. These lands were vastly
more attractive, and cheaper to urbanize than low-lying cypress swamps and salt marshes (Colten 2000). The turn of the 20th century flood control and municipal drainage changed this relationship. The previously undevelopable, uninhabitable, and economically useless landscapes of New Orleans were now developable real estate. Once drained and “protected”, urban infrastructures such as roads, potable water, sewer, electricity, and telephones were soon installed. Not surprisingly, 20th century low density, suburban development followed, complete with bungalows, villas, and ranch houses that included lawns, col-de-sacs, driveways, and modern amenities (Campanella 2010a). While urban sprawl has its’ own critiques, when it’s coupled with urbanization below sea level and soil subsidence it can have seriously deleterious consequences.

Artificial levees and municipal draining drastically limited the amount of water and sediment deposited into vast areas of New Orleans. When the water component is removed from these soils bodies, fine sediments settle into void air cavities, compacting the soil and lowering its elevation, resulting in soil subsidence. By 1935, about 30 percent of the urbanized land surface of New Orleans had fallen below sea level (Burkett, Zilkoski, and Hart 2002). Subsidence worsened as more and more people moved into subsiding areas. While the majority of people living in New Orleans lived above sea level in the early 1900s, only 48 percent remained above sea level by the 1960s. Nearly 300,000 people in 1960 resided in the 20th century subdivisions built on drained landscapes, landscapes that had dropped vertically by one to two meters below sea level (Campanella 2010b). This put people directly in harm’s way during Hurricane Katrina in 2005.
When Congress created the Mississippi River Commission, it initially authorized the commission to build and repair levees *only* if the work was part of a general navigation improvement plan. Monumental floods in 1912 and 1913, however, highlighted the need for federal flood relief legislation. Finally in 1917, Congress passed the first Flood Control Act. This legislation appropriated $45 million specifically for flood control on the Lower Mississippi (Congress 1917). The Mississippi River Commission, cooperating with the Army Corps of Engineers, offered “...advice, technical data, and two-thirds of the funds required for construction” of levees systems in Louisiana (Kelman 2003). It was not until 1927, when a catastrophic flood hit the Lower Mississippi, that the Corps’ policy of “levees only” changed. This flood event had taken between 250 and 500 lives in the Lower Mississippi Basin, had flooded more than sixteen million acres, and had left more than half a million people needing temporary shelter (USACE 2008). The following year saw the passage of the Flood Control Act of 1928, in which the Federal government, and the Corps, became firmly committed to flood control on the Mississippi (Congress 1928). These events lead to the sophisticated, the modern-day flood control systems of Louisiana and New Orleans.

Today, seasonal flooding required for the growth of wetlands and marshes has been virtually eliminated by construction of massive levees that channel the river for nearly 2000 kilometers (Williams 2011). Sediment carried by the river is now discharged far from the coast, depriving wetlands of vital sediment. Throughout the wetlands, an extensive system of dredged canals and flood-control structures, constructed to facilitate oil exploration and production, has enabled salt water from the Gulf of Mexico to intrude brackish and freshwater wetlands. Since the 1930s, Louisiana has lost roughly 2,000
square miles of coastal wetlands – about 1/3 of the deltaic plain (Campanella 2010b, Costanza et al. 2008). Coastal wetlands act as a natural buffer to hurricane-induced storm surges and help reduce flooding. Any friction or impedance that can be placed between open water and populated areas serves to reverse a certain level of incoming storm surge.

Convinced that infrastructure and technology had neutralized historical hydrological disasters, residents of New Orleans had unknowingly increased their exposure to natural hazards. By the early 21st century, half of the city proper had sunk below sea level (Burkett, Zilkoski, and Hart 2002). In late summer of 2005, Hurricane Katrina made landfall in New Orleans, resulting in one of the biggest natural and made-made disasters in American history. The flood protections and drainage systems had not neutralized hydrology and topographies, and the natural buffers that once reduced storm surge were now greatly diminished. Centuries of manipulating the deltaic landscape had allowed exposure to flooding risks to increase. Decades of subsidence had turned the port city into a vulnerable bowl, and when multiple levees were broke and toppled after repeated storm surge impacts, Katrina filled the bowl with saltwater (figure 10).

After the 2005 catastrophe, New Orleans and the State of Louisiana have recognized that the natural processes of the Mississippi Delta have been overly restricted, and a strategy of controlled fluidity was necessary. The State of Louisiana has consolidated its several agencies into one Louisiana Coastal Protection and Restoration Authority, which enables funds and resources to be directly focused into a single organization whose prime function is the protection and restoration of coastal environments. Within New Orleans, plans have taken shape that intend to utilize rainwater with the goal of recharging groundwater and slowing further subsidence. The
Greater New Orleans Urban Water Plan, or GNO Urban Water Plan, proposes reconfiguring the drainage system, transforming sections of the city into watersheds and central parks, while proposing to lower flood walls and modifying the beds into amenities connecting adjacent neighborhoods (Campanella 2014). The GNO Urban Water Plan hopes to shift New Orleans from a city that resists its delta fluidity, to a city that embraces and encourages the regions deltaic fluidity.

Conclusion

The high grounds of the Mississippi Delta were created via processes of flooding and sedimentation. This typography helps explain early settlement patterns in and around New Orleans, with the natural occurring levees providing high ground suitable for habitation. New Orleans was strategically positioned for protection of enemy incursions, waterborne access for trade and commerce, and its spatial relation to the Mississippi
River and the Gulf of Mexico. Early Europeans drastically altered the natural landscape of New Orleans via the introduction of livestock, agriculture, and urbanization. From its founding in the early 18th century to the 21st century, artificial levees have been a part of its urban landscape.

Initially flood control measures such as canals, dykes, and levees were strictly local, but eventually became a cooperation between federal, state, and local authorities. The 19th century saw the city of New Orleans increase in population and importance as a major port city, particularly through the advances in transportation (steam engines) and agriculture (cotton-gin). The early urban form of New Orleans adapted to flooding events via raised structures in high density on elevated ground.

Through a series of serious flood events, the 19th and 20th centuries saw the increase in the Army Corps of Engineers involvement in waterway navigation improvements and flood control along the Mississippi River. During the 20th century, municipal draining altered the landscape in order to settle in locations that were previously uninhabitable. Engineered flood control measures formed the single most influential man-made features in the deltaic landscape of New Orleans, protecting people, creating real estate, and encouraging urban development in subsided areas. These developments enticed urbanization and people into harm’s way with a fatally false sense of security.

Due to man-made levees and municipal drainage, flooding of low-lying land and the depositional processes that naturally maintained the altitude of the land surface in southeast Louisiana stopped. Flood control structures paradoxically increased flood damage by encouraging floodplain development. Additionally, centuries of
environmental manipulation greatly diminished the delta’s ability to build natural buffers (i.e. marshes) and undermined the buffer it had built during previous millennia. The loss of important wetlands and marshes reduced the resiliency of New Orleans. This reality became abundantly clear after Hurricane Katrina devastated New Orleans in 2005. After 2005, New Orleans developed new water management plans that accommodated the natural fluidity of the Mississippi Delta, hoping to restore the natural landscape that had once provided its inhabitance with security and safety.
CHAPTER FIVE

DELTA URBANISM: SAVANNAH, GEORGIA

Many of the attributes which originally made New Orleans suitable for settlement and urbanization may also apply to Savannah, Georgia (figure 11); freshwater, arable soils, colonial defense, and waterborne accessibility. Unlike New Orleans, however, not much research has discussed Savannah through the lens of delta urbanism. Even though the city of Savannah has not been devastated by a major hurricane in recent history, other estuarine cities along the eastern continental United States have not been so lucky. Recent disasters, such as Hurricane Sandy hitting New York and New Jersey in October of 2012, have increased the urgency of coastal cities to seriously consider how they develop, urbanize, and deal with similar catastrophic events.

A partial reason Georgia has avoided catastrophic disasters from hurricanes is because of what is commonly referred to as the “Georgia Bight”, which has been shown to push tropical storms and hurricanes away from Georgia (Stewart 2002). Notwithstanding, since 1853 there have been 91 coastal storms that have impacted Chatham County and the city of Savannah, five of which have developed into hurricanes (UCC 2012). Increase intensity of hurricanes and sea level rise from climate change has the potential to put large populations of people, businesses, and infrastructure in harm’s way. Flooding events in Savannah have already been influenced by sea level rise, as major roadways are becoming flooded with more regularity during “king tides”.

Figure 11. Context map of Savannah. The city of Savannah (yellow) in context of the state of Georgia along the Atlantic Ocean. Red box indicates extent of maps created for comparative analysis (created by author, 2015).
Notwithstanding, the Savannah area has a remarkable amount of its natural resources through marshlands and undeveloped barrier islands, potentially reducing the impacts of flooding from storm surge. Savannah is also an economic hub in terms of port commerce and trade, as well as a major tourist attraction because of its unique historic urban design. Balancing these complex variables is what makes Savannah a complex system.

As in the previous chapter, the overarching themes in this chapter include the historical and contemporary conditions of the estuarine city of Savannah, problems of water management and land use, and the history and challenge of city-building, and adaption to the estuarine landscape. The following sections will attempt to outline the evolution of the natural and built environment of Savannah and how this evolution effected the resiliency of the estuarine city. The purpose of the following chapter is to draw a comparison between different, but similar coastal cities.

The Savannah Estuary

The city of Savannah is located in the Coastal Plain, one of the five major physiographic provinces of Georgia which are based on geologic age, topographic expression, and rock type (Clark Jr and Zisa 1976). The boundary separating the Coastal Plain from the other, older provinces is demarcated by the fall line, the upriver point where river navigation becomes difficult or impossible due to outcropping rocks and increased land slope (Roland 1914). This fall line marks the inland edge of the oldest Coastal Plain soils, which were deposited more than 100 million years ago. Although the Coastal Plain is the youngest province of Georgia, it occupies more than half of the state's land surface (Gore 2013). Georgia's Lower Coastal Plain (figure 12), an environmental region of the Coastal Plain Province, contains the state's lowest elevations and its highest
Figure 12. Five physiographic regions of Georgia. The five physiographic provinces of Georgia are the Coastal Plain (subdivided into upper and lower regions on the map at left), the Piedmont Region, the Blue Ridge Region, the Ridge and Valley Region, and the Appalachian Plateau (Georgia Museum of Natural History, 2008).

percentage of wetlands—including tidal, salt, and brackish marshes, bottomland hardwood swamps – and its climate is classified as humid subtropical, with thunderstorms prevalent during summer months (Seabrook 2014, Peel, Finlayson, and McMahon 2007). The city of Savannah is located on this dynamic landscape.

The Lower Coastal Plain reaches inland about sixty-five miles between the Savannah and St. Marys Rivers, and contains several physiographic districts, based on
topography, geology, soil, and other factors. Within this area, the most prominent of these districts are the Barrier Island Sequence, which are the remains of increasingly higher and older shorelines (Henry 2014). The Barrier Island Sequence (figures 13, 14) includes prehistoric seashores and the present day coastline, and is composed primarily of a series of six prehistoric terraces. These parallel terraces were formed during the Ice Ages, which began nearly 2 million years ago (Seabrook 2014).

At the beginning of the Ice Ages, most of southeast Georgia was under the ocean and part of the continental shelf. This geologic period was a time of changing sea levels as the continental glaciers of North America and Eurasia advanced and retreated, causing sea levels to rise and fall (Roland 1914). The old shorelines, or terraces, formed where the fluctuating sea levels momentarily stopped or stabilized. The old shorelines were similar to Georgia's present day seashore, marked by sweeping salt marshes, tidal creeks, and short, wide barrier islands separated by deep sounds (Seabrook 2014).

The highest elevations within the Lower Coastal Plain are found on these ancient sand bodies, providing dry, safe, high ground for early Indian occupation, as well as for early Europeans colonizing Georgia and Savannah (Stewart 2002, Swanson 2012, Wilson 2012). Modern transportation routes, including U.S. highway 17 and Interstate 95, are partially located along these high grounds (Henry 2014). This geological feature, with its vestigial high, dry elevation, would be an integral consideration for early Europeans trying to establish the colonial settlement of Savannah, and the state of Georgia.

Throughout most of its course, the Savannah River forms the boundary between the states of Georgia and South Carolina. Like the Altamaha, seventy one miles south, the
Figure 13. Ancient barrier island sequence. The one farthest west (Wicomico) represents the highest sea level reached in the past few million years. Savannah is the northern most city along Georgia’s coast (Photograph by Anthony Martin, taken of a display at the Sapelo Island Visitor Center).
Savannah River is an alluvial river that starts in the mountains and Piedmont and meanders its’ way across the Coastal Plain to the Atlantic Ocean. Unlike the Altamaha, the Savannah River’s three hundred mile long run to the sea is constrained by over eleven barricades or dams, most built by the Corps of Engineers (Barber and Gann 1989). The Savannah River Basin (figure 15) drains roughly 8,620 square miles, and the river provides drinking water for four major cities; Augusta and Savannah in Georgia, and Beaufort and Hilton Head in South Carolina (Loeffler and Meyer 2015). Additionally, it assimilates treated sewage and pollution discharge from these urban areas. The upper sections of the Savannah River are utilized to generate electricity via the Hartwell, Russell, and Thurmond dams. The Vogtle Nuclear Power Plant, about thirty five miles downriver of Augusta, uses millions of gallons of water from the Savannah to cool its twin cooling towers (Seabrook 2013a). However, the most heavily used and altered section of the river is near its mouth at the city of Savannah. This section of the river, or the twenty-one mile Savannah Harbor, will be the main focus in later sections of this chapter.

Figure 14. Ancient shorelines. Recognized in southeastern Georgia, the highest and oldest shorelines being in the west and progressively younger and lower shorelines occurring to the east. Modified from Hails and Hoyt (1969).
The Savannah’s freshwater flow and sedimentation are essentially at the mercy of the three federal dams mentioned above, and are key to the coastal estuary ecosystem. The Savannah River carries tons of nutrient laden sediments that are crucial in the development of coastal islands and estuaries. The river is a major silt carrier, and shoaling has always posed a threat for the harbor near the mouth of the river. Like many south Atlantic rivers, in its natural and original condition the Savannah River contained numerous islands in its lower reaches that divided it into various shallow channels and branches, causing the harbor to lack a effective natural scour to maintain a deep, stable channel (Barber and Gann 1989). River flooding, or freshets, can and has occurred during all times of the year, but the typical flooding season for Georgia is from mid-January through early April with a peak in early to mid-March. While tropical storms and

Figure 15. Savannah River Basin. The Savannah River Basin drains roughly 8,620 square miles and serves several functions for multiple states and cities (USDA, 2015).
hurricanes can cause river flooding in the late summer and fall, they are far less common relative to the spring season floods (Dobur 2009). Because of these characteristic, coupled with snags and stumps and the demand for continued improvement, the Savannah Harbor has always been a major challenge in terms of navigation development and maintenance.

The Bar-Built estuaries are a dominant and vital ecosystem along Georgia's coast, and are transition zones between the rivers and sea that provide critical habitat for an assortment of plants and animals. Large sand bars or barrier island systems are characteristic of Bar-Built estuaries, and are built up by ocean waves and currents along coastal areas fed by one or more rivers or streams. Less freshwater coming down the river result in saltier estuaries, which can do harm to ecosystems which house nurseries of crab, shrimp, and oysters. The availability of sand largely determines whether the shoreline will erode or build (Henry 2014). Less sedimentation from the river limits or impedes the formation of barrier islands, causing erosion rates to outpace the accumulation of sediments (Foyle et al. 2004, Hayes and FitzGerald 2013). The major estuaries of Georgia generally connect with the Atlantic Ocean through large bodies of water called sounds or lagoons, which lie between coastal barrier islands and separate them from the mainland. More than 70 percent of Georgia's recreationally and commercially important fishes, crustaceans, and shellfish spend at least part of their lives in estuaries (Seabrook 2013b). Georgia's estuaries have formed vital relationships with its tourism, economies, and resilience.

Today, Georgia boasts 393,000 acres of salt marsh, which amounts for almost 1/3 of the total salt marsh on the eastern seaboard (Kundell et al. 1988, Wiegert and Freeman
Of the land cover below five meters of elevation in the Savannah Estuary, over 50% is marsh and wetlands. This is mainly due to legislation passed during 1970 known as the Georgia Coastal Marshland Protection Act, which was the first legislation of its kind in the United States and protects vast areas of marshlands of the Georgia coast (Harris 2008). Marshes develop in estuaries where the rate of sedimentation equals or exceeds the rate of rising sea level. Together, the estuaries and the marshes are some of the most biologically productive ecosystems on Earth (Seabrook 2013b, Seabrook 2013a). In regards to coastal hazards, the salt and freshwater marshes act as buffers against offshore storms. As previously stated, this vegetation has a dissipating effect on wave intensity (Costanza et al. 2008). Without the natural marsh and vegetation of coastal Georgia, hurricanes and storm surges would create a larger scale of damage to the infrastructure that coastal Georgia’s economy heavily relies on.

Known as the Golden Isles or Sea Islands, the Georgia coast is bordered by a series of relatively short, wide barrier islands separated by relatively deep tidal inlets, or sounds. The barrier islands formed by the interaction of wind, waves, currents, sediment supply, and a slowly rising or stable sea level (Hayes and FitzGerald 2013). Eight major islands and island groups comprise the 100 miles of coast between the Savannah and St. Marys rivers. These are Cumberland, Jekyll, St. Simons, Sapelo, St. Catherines, Ossabaw, Wassaw, and Tybee. The only islands that are accessible via roadways are Tybee, St. Simons/Sea Island, and are the only developed barrier islands along the Georgia coast. In addition to providing natural habitat for numerous plant and animal communities, as well as recreational destinations for nearby human populations, the barrier islands protect the
mainland from the brunt of major storms and hurricanes. The developed barrier islands have no such outer defense.

**Early Settlement and Transformation**

Long before European contact, Native American populations inhabited and transformed coastal Georgia and the area where the city of Savannah is today. The southeastern Atlantic coast had been occupied by Native Americans for thousands of years, with indication of continuous occupation and development for at least thirty-five hundred years before European contact (DePratter and Howard 1977). Early archaeological evidence shows a culture which knew how to use various coastal resources, and well adapted to the estuarine environment (Stewart 2002). Marsh and estuarine organisms, along with plants and animals from the barriers islands and mainland, appear to have provided much of the sustenance for the native human populations until three or four hundred years before Europeans arrived. Shell middens are the most common features along the coasts of southeastern North America, and are found on barrier islands and underneath marshlands along the Georgia coast. Other archaeological features include burial mounds, canals, and houses, some of which were constructed of shellfish remains (Thompson and Worth 2011).

Contrary to common belief, Native Americans were living in large, centralized settlements, and were altering vast areas of the natural landscape (Barber and Gann 1989, Larsen et al. 1982, Redford 1991, Stewart 2002). The Lower Creeks, one of two large Native American tribes in Georgia, lived in “… towns on large beautiful creeks or rivers where the lands are fertile” (Adair 1775). By the time of European contact, Native Americans were growing their own food, supplementing wild plants and animals with
domesticated species (Larsen et al. 1982). Additionally, frequent fires ignited by both lightning and Native Americans helped sustain the longleaf pine-grassland (*Pinus palustris-Poaceae*) ecosystem, which occupied over 30 million ha in the southeastern Coastal Plain, from Texas to Virginia, at the time of European discovery (Van Lear et al. 2005). These are mostly likely the trees General Oglethorpe, founder of Savannah and Georgia, described a few days after selecting the site of Savannah ... “vast Woods of Pine-trees, many of which are an Hundred, and few under Seventy Feet high.” (Candler et al. 1906). While Native Americans might have helped sustain and increase the longleaf ecosystem in centuries past, Europeans would cut, log, and strip the Georgia landscape of this ecosystem in later centuries.

The southeastern Atlantic coastal region was the first part of North America to experience direct contact with European explorers and colonists during the 16th century (i.e. Hernando De Soto in Georgia, Florida, and Mississippi etc.). As colonial settlements were established along the Atlantic and Gulf Coasts from the late 16th through the 18th centuries, these estuarine regions quickly became “ground zero” for following European penetration of the interior (Thompson and Worth 2011). Essentially these were port cities, and were direct links with an increasingly global network of maritime transportation of people and goods. For these reasons, indigenous Native Americans of the southeastern coastal region experienced the earliest and most substantial impact from European colonization.

The Yamacraw Indians, for example, were a small group that existed from the late 1720s to the mid-1740s near and on the Yamacraw Bluff (figure 16), future site of the city of Savannah (Sweet 2014). This “bluff” is actually one of the ancient barrier islands
Figure 16. Map of Georgia, 1745. Shows the territory inhabited by the Yamacraw Indians, a group formed in 1728 by disaffected Creek and Yamasee Indians. The Yamacraws, led by Tomochichi, established their first community on the bluffs of the Savannah River. After the arrival of James Oglethorpe in 1733, the group agreed to move north to accommodate Oglethorpe’s plans to build an outpost, which later became the city of Savannah. (C. Howell, 1926).
in the Pamlico Island Sequence, and signifies that both Americans and Europeans acknowledged the value in settling elevated, dry land close to waterways. Before the Yamacraws' were an independent group, the Creeks and Yamasees dominated an area that is now known as the state of Georgia. However, tensions grew between the two groups after the Yamasee War of 1715, which resulted from Yamasees attacking British traders and settlers, mainly from debt disputes, in the port city of Charleston, South Carolina. After two years of fighting the war ended, and the Creeks were quick to reestablish trade with the British, which offended their Yamasee allies and resulted in a split of allegiances (Barber and Gann 1989, Stewart 2002, Sweet 2014). A group of about 200 individuals who disagreed with these alliances broke away to form the Yamacraw.

By the time British colonizers appear along the Savannah River to found the city of Savannah in the early 18th century, the native population had already altered and adjusted to the natural and built environments of coastal Georgia, and had adjusted to European trade, commerce, and society.

18th Century Urbanization and Water Management

Among other things, such as social reform and utopian ideals, the founding of Savannah and the colony of Georgia in 1733 by General James Edward Oglethorpe was largely due to interests in increasing trade, protecting neighboring colonies from Native American attacks, and securing territory from Spanish competitors (Stewart 2002, Wilson 2012). Unlike New Orleans, the city of Savannah was designed and planned before the arrival of its colonizers. The Savannah, or Oglethorpe, Plan was designed to be an agrarian town, not a city. Oglethorpe envisioned the function of Savannah as a low-density capital, with a large hinterland of interconnected gardens, farms, estates, and
villages (Wilson 2012). As mentioned earlier, the location of Savannah was strategically located upriver, on top of a mile-long bluff that was about forty feet above mean high water. General Oglethorpe clearly understood the relationship with high, elevated landscapes and access to maritime navigation when selecting the location of Savannah:

*I fixed upon a healthy situation on about ten miles from the sea... The plain high ground extends into the country five or six miles, and along the river side about a mile. Ships that draw twelve foot water can ride within ten yards of the bank. Upon the riverside in the centre of this plain I have laid out the town.* (Oglethorpe 1975).

This location provided easy access to the mouth of the Savannah River and enough dry, elevated land for the implementation of the gridded, ward based Oglethorpe Plan. Oglethorpe, when laying out the initial grid system, established a benchmark, or reference point, from which the grid system and all of its elements were to be laid. This benchmark location was set in the middle of the Yamacraw Bluff on the Savannah River, and three hundred feet from the river bank. This location allowed for elevated high ground in either direction for half a mile. Within the first five months, the landscape was cleared of pine trees, and block houses, a guardhouse, and nine houses were built on top of the Yamacraw Bluff (Wilson 2012).

The plan for Savannah consisted of multiple, integrated layers, ranging from the built environment of the town core to the overall land use of the regional area. The town center, consisting of six wards (figures 17, 18), was to be surrounded by a large hinterland of interconnected gardens, farms, village, and estates (figures 19, 20). All of these features were located upon the elevated and dry Yamacraw Bluff, except for the garden districts which were situated near low-lying areas around swamps. The wards
Figure 17. Ward design specifications. Ward Design Specifications by Thomas Wilson (Wilson 2012).

Figure 18. Six-ward plan for Savannah in 1770 (Archives 1954).
Figure 19. Conceptual regional plan of Savannah by Thomas Wilson (Wilson 2012).

Figure 20. Copy of the John McKinnon map, 1798. Map showing the regional plan of Savannah. (McKinnon 1798).
were the basic building blocks of the town proper, and were infused with Roman and Renaissance town planning, showing unmistakable elements of the *castrum* system and elements of the “ideal city”, respectively (Wilson 2012). This gridded, symmetrical design was used for several other settlements of Georgia shortly after the establishment of Savannah (i.e. Darien and Ebenezer). While Savannah was the capital of the colony of Georgia, most new growth occurred by creating new towns upriver of the Savannah or to other river systems down the coast, each with its own region, resulting in towns with substantial countryside in between themselves.

Shortly after Savannah and the surrounding settlements were being established, the first roads in Georgia were constructed to connect Savannah to the other settlements in the region, mainly for defensive reasons. Oglethorpe understood that transportation facilitated urban develop, and settlement along the southern border of the Savannah region was necessary in deterring attacks by the Spanish in Florida. Around 1736, workers started constructing a ninety-mile road connecting the southern regions of Georgia to Savannah, with the hopes of having a village every six miles along the coast (Wilson 2012). U.S. 17 now incorporates much of Oglethorpe’s original right-of-way that linked Savannah with southern regions along the Georgia coast. In order to facilitate trade, a road that would eventually extend to Augusta was constructed, tying into an existing road to the nearest port city of Charleston in South Carolina. One of the first roads constructed was parallel to the Savannah River and connected Savannah to a trading post and the Ebenezer settlement sixteen miles upriver (Wilson 2012). Georgia route 21 now traces this colonial route, connecting several modern towns to the northwest.
During the second half of the 18th century, Savannah saw its lowlands, and its economy, change dramatically with the cultivation of rice by plantation owners. Savannah transformed from the “town in the pine barrens”, into a thriving marketplace for staple crops produced in the low-country and the countryside of the coastal plain (Stewart 2002). Along with harvesting timber and raising cattle, wet-culture rice grown by the tidal flow method demanded the vigorous reshaping of the environment. Originally plantation owners grew rice on swamplands along low-lying rivers and streams or on inland watersheds which they diked and drained in order to make productive croplands. This technique of rice cultivation required simpler irrigation system than those constructed for tidewater rice production.

River swamp rice production required that swamp lands adjacent to rivers be cleared and divided by dikes in order to separate water and land, and then flood gates installed to manage the flow of water between them. This method followed the natural features more closed than the tidal method. However, the tidal method allowed planters to tap into the tidal energy that swelled into rivers twice a day and supplied nutrient and sediment rich water into fields on command. The tidal method gave planters more control of the over floodwaters, and was more efficient and productive than its river swamp counterpart (Stewart 2002). The land on rice plantations was heavily engineered in order to streamline the natural environment for the specific purpose of profitable exploitation. These hydraulic systems took shape in the form of ditches, drains, and canals enclosed by check banks, all enclosed within an outer embankment (Savannah Writer's 1972). However, seasonal river flooding, or freshets, and storm surge from hurricanes
commonly breached dikes and banks, resulting in the loss of agricultural produce, buildings, and lives that were found in the lowlands.

By the time of the American Revolution in 1765, rice, indigo, sea island cotton, lumber, furs, and meat made the wheel of commerce turn on the Georgia coast, and resulted in drastic alterations of the natural environment (Stewart 2002). The economy of Georgia revolved around two centers: Augusta, 250 miles upriver from Savannah, oriented toward the hinterlands, and Savannah oriented toward the sea (Barber and Gann 1989). Like many other early American ports, the Savannah Harbor developed in a protective estuary with barrier islands and several miles inland from the sea. Others, like Portland, Boston, and New York, were opened more directly on the ocean, but were nonetheless relatively protected by natural breakwaters of islands and headlands (Parkman 1983).

However, the upriver streams and passages of lowland Georgia were too shallow to allow navigation by large vessels. Thus, many small craft were used to transport produce downstream to the larger centers of Savannah, Brunswick, and Darien. These were the only places along the Georgia coast where large vessels could land to sell goods and pick up local products (Phillips 1908). During the colonial period, the only attempt of dredging navigable waterways on the eastern coast was in 1774, when Philadelphians employed a horse-powered grab dredge to clear out ship slips. Almost all of Georgia’s internal improvements to navigable waterways and roads were financed and constructed by private citizens and corporations (Parkman 1983). Notwithstanding, dredging did not become common practice until the latter half of the 19th century.
Successive generations reapplied Oglethorpe’s ward system, increasing the number of wards from six during the early 18th century, to over twenty wards by the mid-19th century (figure 21). After this point, the city adopted the conventional urban grid as the template for future growth. For much of the 19th century, the city of Savannah grew inward more than outward. This densification occurred by subdividing the original lots in the ward design and by increasing the typical height of building to three or four stories. However, by the mid-19th century, the city and urban footprint had expanded outside of its original boundaries (figures 22, 23), and started developing into lower lying areas (Wilson 2012).

By end of the 19th century, what remained of the original town common and most of the original farm land directly south of the common were altered into the modern grid layout. Outward growth gave way when greater mobility, offered by street cars, led to garden suburbs. By late 19th century, most growth was taking place in the old farm districts south of the town common, an area now commonly referred to as the “streetcar suburbs” (Wilson 2012). The farm districts of the Oglethorpe Plan occupied higher ground, whereas the garden districts fell in the lower, flood prone areas. As a result, residential expansion took place in the former farm districts (high elevation), while rice plantations, and later, industrial land uses occupied much of the former garden districts.

Since the colonial era, the barriers islands off the Georgia coast were mostly utilized as military defenses and navigation via forts and lighthouses, respectively, with some islands being utilized for crop cultivation. However, the barrier islands started to
Figure 21. Evolution of wards, 1733-1856. Illustration of the development of downtown Savannah’s ward design, starting in 1733 in the top left and going until 1856 in the bottom right (Reps 1965).

Figure 22. Map of Savannah, 1812. Areas outside the original town common are undeveloped, while lowlands are used for rice cultivation (red polygons) (Houston 1812).
become popular as tourist destinations during the mid and late 19th century (Seabrook 2013a). The qualities of the islands – mild winters, beaches, and breezes – made them prime locations for investors trying to lure the increasing middle-class Americans looking for vacation. By the 1840s local residents of Savannah were taking day excursions to Tybee Island just off shore. After the Civil War, Tybee Island became a local vacation paradise with a hotel, tramway, cottages, and artesian wells. In 1887 a railroad was constructed on Tybee Island (figure 24), making a forty-five minute commute from Savannah possible (Stewart 2002). While other barrier islands along the Georgia coast...
also became tourist retreats during this time, Tybee Island near Savannah would become the most urbanized barrier island of Georgia in the following centuries.

Beginning in 1817, when vast areas of Georgia were procured from Native Americans (figure 25), the cultivation of cotton and harvesting of trees increased significantly in the hinterlands of Georgia. As a result, settlements moved farther away from streams and rivers, and cotton and timber shipments became too large for vessels to carry them down stream (Harrison 1979). Rice plantation owners in the low country were demanding navigation improvements in order to reduce market costs. Additionally, the rice plantations were seeing freshets worsen after extensive cotton cultivation and extensive clearcutting upriver stripped woodlands that once helped retain storm runoff (Stewart 2002). Georgia’s transportation problem during the 19th century, then, was the
need to connect the increasingly prosperous cotton belt and the interior with improved navigable waters. Thus river and harbor improvements, along with the construction of railroads, increased in the Savannah area.

The Savannah Harbor had long been one of the major ports in the South during the colonial era, and the harbor was maintained by the city and private corporations (Harden 1913). However, navigation had always been difficult because of the sediment loads carried down each season, causing shoaling, sandbars, and snags to obscure the waterway (Barber and Gann 1989, Parkman 1983, Seabrook 2013a). Because of extensive cotton cultivation and clearcutting of forests in the hinterlands of Georgia, these problems intensified. An increase in fine sediments were carried downstream and joined the mud and silt in the lower reaches of the Savannah River. These sediments
caused increased shoaling downstream, and impeded oceangoing ships near the Savannah Harbor.

In 1817 Georgia made its first appropriations for river improvement, which allocated funds for each of the important streams in the state and were to be funded by local commissioners. However, improvements came slowly and disappointingly, so much so that in 1825 the state established a Board of Public Works to inaugurate a more centralized and effective program. In its 1826 report, the Georgia Board of Public Works recommended a system that would improve the major river systems to the heads of navigation, and to examine the streams above these points to determine whether they could be adapted for use by smaller boats (Barber and Gann 1989). Money was appropriated for over thirty years to engineer the Savannah River to navigable widths of up to 300 feet, and deepen the river from 8 feet to 17 feet. The next year, however, the state abolished the board and went back to a policy of appropriations expended by local commissioners. By 1829 local efforts declined, and river navigation had been little improved (Parkman 1983). The same year, the Federal U.S. Army Corps of Engineers Savannah District was established for the survey of the Savannah River. Responsibility for river maintenance would eventually be passed onto the U.S. Army Corps of Engineers Savannah District (Barber and Gann 1989).

Before the Civil War several schemes were proposed for deepening the Savannah Harbor, but little was actually accomplished. It was not until after the Civil War, when a new economic, technological, and political climate changed in the nation, that the federal government and the Corps initiated a vigorous and continuing program of river and harbor improvements (Parkman 1983). The city of Savannah recognized that the need for
sea worthy ships to be able to access the harbor were necessary if Savannah were to continue to prosper as a major seaport. Since the Civil War, much of the river and coastal traffic had been replaced by rail, and only ports with sufficient depths for oceangoing vessels could survive (Stewart 2002). As a result, the harbor has ranked as the primary civil project of the Corp’s Savannah District.

In 1867 the city dredged a channel 18 feet deep at mean high water through the Savannah Harbor. From 1868 to 1870, several locations along the Savannah Harbor were dredged, allowing a channel deepened enough to admit a ship drawing 17.5 feet of water. However, the channel was very crooked and continued to shoal (Barber and Gann 1989). Several projects were adopted from 1873 to 1910, and straightened and increased the channel depth of the Savannah River to the port of Savannah from 7 feet at mean low water to 26 feet (Parkman 1983). Ironically, as a result of dredging and deepening the river, sedimentation from the river and the ocean increased, dumping sediments into the tidewater of the harbor (Stewart 2002). In short, dredging facilitated more dredging.

Along with Charleston to the north and New Orleans to the west, Savannah became a center of trade and commerce in America, serving a wide geographical area in the 18th and 19th centuries. Railroads made the city a major terminus for their lines (figure 26). Recognizing the economic importance of the city of Savannah, the U.S. Government designated the port city as a principal candidate for river and harbor improvements in the 20th century.

20th Century Urbanization and Water Management

With the increase in automobiles in the 1920s, the original village district of Oglethorpe’s Plan began to fall to development. By mid-century, suburbanization had
consumed the village district, and was growing into the estate districts and into the surrounding farmlands (figure 27). The square grid pattern of the colonial era promoted dense growth throughout the streetcar and early suburban areas. However, the same cannot be said of areas outside of the original plan, which took the shape of traditional, low density, single land use characteristics of suburbanization of post WWII cities. As downtown Savannah’s growth reached the limits of its growth potential, the former, flood prone, garden districts were targeted for redevelopment (Wilson 2012). These flood prone areas were once too expensive to develop for commercial or residential real estate because of the costs of fill and drainage structures. However, areas adjacent to the historic downtown saw real estate prices increase, increasing the feasibility of more expensive construction costs.
Figure 27. The Savannah area in 1910. Development has expanded into low lying areas and well into former farming and village districts of the Oglethorpe Plan (Howard 1910).

By the end of WWII, most of the barrier islands along the Georgia coast were owned by private or public agencies. Most of the island have become tourist destinations or nature preserves. During the 20th century, Tybee Island’s tourism industry increased tremendously. The population and economic growth in Savannah together with postwar prosperity and the automobile attracted more people, both Georgians and non-Georgians, to Tybee Island (Clayton 1992). In the 1920s, U.S. Route 80 was completed, connecting Tybee Island via road with the mainland. By 1940, the island had four hotels and numerous smaller lodges. The City of Tybee Island has experienced continued population growth during the late 20th century. The City’s population of 2,240 people in 1980 increased by roughly 27% to 2,842 in 1990 (Bureau 2014). The City of Tybee Island
offers a unique set of demographic circumstances; although the island has a year round resident population, the overall population increases greatly during the summer vacation season. The tourism industry in city of Savannah and Tybee Island have become large economic drivers in the area (Brimmer 2013). Other barrier islands off the coast of Savannah also gave way to urban development, with Skidaway and Willington Islands succumbing to suburban development. The increased urban development on barrier islands poses several threats; increased populations are more exposed to storm surge, beach erosion threatens buildings, and stormwater runoff has deleterious effects on surrounding saltmarsh (Freudenrich 2001).

Agriculture during the late 19th century to early 20th century slowly moved out of the lowlands of the coast into the hinterlands of Georgia. The river and hydraulic systems that rice plantations once relied upon, not to mention the slave labor they lost after the civil war, had changed with increased river dredging from the Corps and increased flooding from clearcutting. The deepening of the river increased current speeds, which increased bank erosion, which required owners to spend more on maintenance. Dredging and deepening also allowed saltwater to flow further upstream, which the owners had to worry about when flooding their fields because rice can also sustain certain levels of salinity (Stewart 2002). Rice plantation owners were also continually confronted with increasingly powerful freshets from upriver and hurricanes from the sea during the early 20th century. Many plantation owners could not keep up with repair and maintenance costs of fixing dykes, ditches, embankments, and canals after consecutive flooding events which occurred at this time. Few rice plantations continued to operate in the early 20th century. While rice production diminished, wood production increased dramatically in
the 20th century. Advances in wood pulp manufacturing made all pine species along the Georgia coast potential paper products. In the 1940s the largest paper plant was built in the outskirts of Savannah (figure 28), and paper mills were occurring throughout the Georgia coast by the 1960s. By midcentury, Savannah was providing a flow of paper products in large shipments to world markets.

In 1912 the navigation channel of the Savannah River was deepened from 21 feet Mean Low Water (MLW) to a depth of 26 feet MLW to accommodate larger ships. In 1936, 1945, and 1972 the navigation channel depths increased to 30, 36, and 40 feet MLW, respectively. The harbor itself was deepened to 34 feet with a width of 400 feet in 1959. In 1994, much of the authorized depth of the channel was increased to 42-feet MLW (Barber and Gann 1989). At one point in the early 20th century, the Corps began using a technique called “agitation dredging,” which used the tidal flow to facilitate removal of dredge materials. This process demonstrated that the tidal currents could be used as a valuable natural aid to expanding and maintaining Savannah Harbor (Rhodes 1949). Later, when WWI was declared in 1939, the Savannah Engineers were using agitation dredging to help carry sediment brought down by the river on out into the ocean in an attempting to reduce their maintenance costs. Additionally, since the early 20th century the Savannah District of the Corps had been charged with developing the 7-foot deep Intracoastal Waterway from Beaufort, South Carolina, to St. Johns River in Florida.

In 1937 and 1938 the channel dimensions of the Intracoastal Waterway increased from 12 feet deep and 90 feet in land cuts and narrow waters to 150 feet in open water, and following the earlier established 1917 route. Work was completed in 1940 and was the last major improvements in the Georgia section of the Intracoastal Waterway.
Figure 28. Union Bag and Paper Company, 1942. The largest paper mill in the country, at the time, was built and locate near Savannah (Foltz 1942).


During the 1920s and 1930s railroads and trucking companies provided alternative methods of transportation other than waterways, and many once important river passages were bypassed. The move away from improvement projects in small harbors had begun before 1940, and it accelerated in the years following WWI. However, Savannah was still the preeminent South Atlantic port by midcentury, and served by ten railroad lines (Stewart 2002). The deepening of the harbor and Intracoastal Waterway
ensured Savannah’s connection to other ports and markets around the world. While the increase use of rail and road networks affected the nature of the Corps’ work on navigation improvements, they also broadened the Corps’ civil works mission.

For decades each Corps project had been measured in terms of its effect on navigation, but the period beginning with the Flood Control Act of 1944 and extending up to the National Environmental Policy Act of 1969, Corps projects included comprehensive river basin projects related to flood control, hydroelectric power production, and recreation (Barber and Gann 1989). In this vein, the Corps built and operates three large multipurpose dams on the Savannah River. The furthest downstream is Thurmond Dam (there are no dams or levees within Chatham County and Savannah) which was constructed in 1954, and is operated primarily for flood control. Thurmond Dam has been effective in controlling floods and high-flow pulses, with small and large floods being eliminated, and high-flow pulses occurring with less frequency, particularly since 1980 (Richter and Thomas 2007). The Savannah District of the Corps has also provided various flood plain management services under the 1960 Flood Control Act. As of 1989, the Savannah District had completed 27 Flood insurance studies in Georgia and 13 in South Carolina (Barber and Gann 1989).

21st Century Urbanization and Water Management

As of 2013 the Savannah Metropolitan Area had a population over 360,000 (SEDA 2013). Today, the city of Savannah is known for its historic downtown, urban tree canopy, and unique urban design, all of which are a product of the vestigial Oglethorpe Plan. The ward design has allowed the historic downtown to be dotted with urban parks, apparent walkability, and dense mixed land uses. These features, including
beaches and vast areas of marshland, makes the tourism sector of Savannah one of the largest economic drivers in the area. In 2012, there were over 12 million visitors in Savannah, including 7.0 million overnight visitors and 5.3 million day-trippers (SAC 2012). Notwithstanding, increasing development outside the original extent of elevated land into flood prone areas have also continued to increase. The agricultural land uses that were once within the lower elevations of Savannah were replaced with urban land uses. In 2012 approximately 16,456 structures were located with the flood zone, with 15,353 of these structures being single and multifamily residential houses (UCC 2012, SEDA 2013). As of 2014, there were 15,699 residential properties at risk of storm surge (Savannah 2014).

By the 21st century, Savannah’s port (figure 29) has become the fourth busiest container port in the United States and the second busiest on the Eastern Seaboard (Conway 2013). The Port of Savannah has been the fastest growing container port in the country since 2001, and in 2006 it became the top container port of the Southeast. Currently, the Savannah area as over 3 million square feet of warehouse space available within thirty miles of port facilities and the largest concentration of import distribution centers on the eastern coast of the United States (GPA 2014). The port serves a large geographic area, and influences local industrial land uses, transportation (figure 30), and economic stability.

As the writing of this thesis (2015), the city of Savannah and the Corps are embarking on the $652 million Savannah Harbor Expansion Project (SHEP), which is dredging 32 miles of the Savannah Harbor navigation channel from 42 to 47 feet in order
Figure 29. The port of Savannah, 2015. Ocean and Garden City Terminals (burgundy), railroads (yellow), and the current SHEP dredge route (blue) (created by author, 2015).
to attract and provide accommodations for Post-Panamax ships (Ramos 2014, USACE 2012). The Corps role in Savannah have helped elevate the port city into one of the busiest U.S. ports in the 21st century. However, projects under the Corps not been beneficial to all, as has been shown with an increase in environmental studies.

An assessment of the hydrologic alteration associated with the Thurmond Dam exposed significant changes in virtually all aspects of the flow regime, particularly in higher flow events (Richter and Thomas 2007). This flow regime is important for the Shortnose Sturgeon, an endangered species found in the Savannah River. Anthropogenic
alterations of the Savannah Harbor and estuary to control sedimentation in the harbor and channel deepening have altered the distribution of salinity, and this shift in the salinity has been identified as one of the more adverse environmental impacts to the various ecosystems within the estuary (Mendelsohn et al. 1999). Moreover, less sedimentation from the river limits or impedes the formation of barrier islands, causing erosion rates to outpace the accumulation of sediments (Foyle et al. 2004, Hayes and FitzGerald 2013). This effect can be seen on various islands along the Georgia coast. Before the start for the current SHEP dredging project, ecological effects to the river and adjacent wetland ecosystems had to be addressed. Studies projected the conversion of freshwater marsh into saltwater marsh due to increased salinity upriver, compromised drinking water quality for Savannah, and habitat loss for the Striped Bass and the Shortnose Sturgeon. Mitigation actions were taken to address these issues, but not without increasing the project budget from $203,174,000 to $652 million (Ramos 2014, USACE 2012).

Chatham County has recently updated its’ Food Mitigation Plan and Tricentennial Plan, which serve as development and flood mitigation guides to the Savannah region (UCC 2012, MPC 2013). The plans call for the reduction in the number of repetitive loss properties (i.e. properties that continually flood) through acquisitions and demolition. Since local flooding as increased as a result of increased impervious surfaces, improving the county’s water management systems is a high priority. In order to accomplish flood mitigation goals, the county is continuing “aggressive” mitigation, governmental ordinances, and land use regulations in order to provide planning strategies for future development (UCC 2012). Building codes are regulated for new construction of residential and business structure to ensure reduction in potential hazards. Future
development is limited in flood prone areas and barrier islands, and there are even plans
to elevate or retrofit repetitive loss properties to reduce the risk of flooding. Protection of
natural resources, such as wetlands, open space, coastal erosion, and water quality are also
part of the mitigation plan. The 2013 Tricentennial Plan for Chatham – Savannah has
included zoning parameters for barrier islands, such as requiring a buffer that’s 100 feet
in width from the shoreline, enforced for the protection of marshes and estuaries.
Moreover, a proposed natural resource protection ordinance would provide protection
from land disturbing activities, soil erosion and sediment control, stormwater
management, and flood damage prevention (MPC 2013).

However, while these plans identify planning strategies for flood risk and
mitigation, they do not include specific design elements or spatial considerations for
future trends in sea level rise. In order for Savannah to be complex adaptive system in the
future, it must be prepared to adapt to changing trends in the environment, trends that will
directly influence other subsystems of Savannah. As of right now, there is no stand-alone
plan or proposal that has been adopted that is strictly concerned with how the Savannah
area is to develop in terms of climate change and sea level rise.

Conclusion

Today, the Georgia coast boasts 1/3 of the saltmarsh along the eastern coast of the
United States, mainly due to the Georgia Coastal Marshland Protection Act of 1970, the
first legislation of its kind in the nation. The estuaries and marshes provide habitat for
large amounts of shrimp, crustaceans, and oysters; they are directly connected to its’
tourism and fishing industries. Marshlands also provide some protection from hurricanes,
dissipating the effects of storm surge. Alluvial loads carried by the Savannah River
provide nutrient rich sediments to the estuaries and marshlands. The Savannah River runs 300 hundred miles to the Atlantic Ocean, providing various serves and resources to urban centers through its route. The lower portions of the Savannah River near the Savannah Harbor have been the most altered and transformed section of the entire river.

The high grounds of the Savannah Estuary are a product of prehistoric sea level change, resulting in several barrier island sequences. The town of Savannah was established one of these vestigial, elevated typographies, and explains settlement patterns in the early colonial era. Savannah was strategically positioned for protection of enemy incursions, waterborne access for trade and commerce, and its spatial relation to the Savannah River and Atlantic coast. The early Oglethorpe Plan established a gridded, ward based design that influenced development and land use into the 19th century. As transportation and population increased, and rice cultivation decreased, the urban development of Savannah started encroaching into the low flood plain and barrier islands.

Originally the barrier islands were utilized as navigation and military defense. During the 19th and 20th century, transportation access to some of the barrier islands increased and facilitated urban development in the form of tourism. While many of the barrier islands in the 21st century remain undeveloped along the Georgia coast, Tybee Island near Savannah has become a major tourist destination, with the neighboring Skidaway and Willington Islands becoming suburban neighborhoods. While barrier islands can reduce storm surges for Savannah, the islands themselves are at great risks of flooding. Increased urban development on the barrier islands poses threats to human safety, infrastructure, and the natural environment.
Early Europeans drastically engineered the tidal flood plain of Savannah via wet-culture rice agriculture through dykes, ditches, canals, and embankments. Agriculture during the late 19\textsuperscript{th} century to early 20\textsuperscript{th} century slowly moved out of the lowlands of the coast into the hinterlands of Georgia. During this time, cotton cultivation and forest harvests took its toll on the Savannah Estuary with increased freshets and debris being deposited into the lowlands. With agriculture no longer being utilized in the flood plain, urban developments such as industrial and residential land uses increased in flood prone areas.

Initially river navigation improvements such as dredging and removing snags were strictly local, but eventually became a cooperation between federal, state, and local authorities. Dredging intensified during the 19\textsuperscript{th} and 20\textsuperscript{th} century, with consecutive dredging projects routinely deepening the navigation channel and harbor of the Savannah port. With these navigation improvement, the city of Savannah increased in importance as a major port city, particularly through the advances in transportation, agriculture, and forestry. Port activities are an important driver in land uses, transportation, and economic changes in Savannah. Navigation improvements via dredging and canalizing, along with flood control measures via dams, have dramatically altered the Savannah Estuary and caused deleterious environmental changes to the natural processes of the Savannah Estuary. Sedimentation has decreased, threatening marsh and barrier islands alike. River flow regime has changed, causing concern for threatened species of fish. The levels of salinity upriver has increased, causing once freshwater marsh to be replaced with more salt tolerant species.
In the 21st century, Savannah has started to consider urban development and flooding events in more detail. The acquisition of flood prone properties, restrictions to development in flood areas and barrier islands, protection of natural resources/open space, building codes, and improving the county’s water management systems are all strategies in which Savannah and Chatham County has in place to for future development and planning. However, unlike New Orleans and the Netherlands, there is not a standalone comprehensive water management plan that accommodates the natural fluidity of the Savannah River and Atlantic coast, allowing them to occasionally flood into areas of the city which recreational and public land uses are assigned.
CHAPTER SIX
MAPPING AND COMPARATIVE HISTORICAL ANALYSIS

This chapter presents the mapping results for the Savannah area and generates qualitative measurements to better understand and test concepts found within Urbanized Deltas in Transition; this chapter also presents the various concepts of delta urbanism (typology, urbanization, and complex adaptive systems) analyzed through the comparative historical analysis between New Orleans and Savannah. This chapter analyses the various concepts and frameworks of delta urbanism that were used in this thesis to study New Orleans and Savannah, and highlights whether delta urbanism can be useful in studying the estuarine city of Savannah. Comparative analysis of urbanized deltas allow planners and designers to highlight the differences in urbanized deltas, but also to analyze concepts found within delta urbanism literature.

Mapping Analysis

In order for Savannah to be mapped in a standardized fashion, the substratum, climate, land use, and transportation networks were mapped using GIS for the Savannah Estuary, Chatham County region. The Savannah mapping layers generated for this chapter use the same standardized layers and land uses that were used for the Mississippi Delta in Urbanized Deltas in Transition. By using the standardized GIS mapping layers proposed in Urbanized Deltas in Transitions, we are able to compare the subsystems of the Savannah Estuary. These mapping layers represent the complex subsystems of urbanized deltas. It should be noted that while the same units of measurements and
resolutions were used for both cases, the Savannah Estuary is at city scale (or ~ 16 km) while the Mississippi Delta is at the metropolitan scale (or ~ 50 km). After each layer is presented for the Savannah area, the corresponding layer will be presented of the Mississippi Delta found in *Urbanized Deltas in Transition*.

Following are a list of maps that show the urban settlements, substratum, climate, transportation network, and land use layers of the Savannah area. By using GIS mapping, quantitative information can be used to generate tables and graph of the Substratum, Climate, and Land Use layers of the Savannah area. The urban settlement and transportation network layers were mapped for the Savannah area, but were not included in the comparative analysis because standardized quantitative measurements were not provided in recent delta urbanism comparative analyses.

*Urban Settlements in the Savannah and Mississippi Delta Area (figures 31 and 32)*

The urban settlements layer for Savannah uses the 2011 National Land Cover Dataset, which offers 30 meter resolution and over 16 land use classes (USGS 2011). All urban land uses were combined in order to illustrate areas of urban settlement within the Savannah area.

The Savannah area includes urban settlements of various size and population. As of 2013 the Savannah Metropolitan Area had a population over 360,000 (SEDA 2013). Immediately surrounding Savannah are local municipalities such as Garden City, Pooler, and Thunderbolt. The city of Savannah is the largest municipality in the direct area, with the cities of Richmond Hill and Hinesville to the south and the city of Tybee to the east on Tybee Island. North of Chatham County and Savannah is the State of South Carolina and Hilton Head on Hilton Head Island.
Figure 32. Urban settlements (red) of the Mississippi Delta area. The coastal plain (<5 m mean sea level) illustrated in shades of blue. Original settlements taking place on the elevated river banks of the Mississippi River. Map was generated in the comparative analysis found in “Urbanized Deltas in Transition” (Nijhuis and Pounderoijen 2014).
Substratum Layer in the Savannah and Mississippi Delta Area (figures 33 and 34)

The 1/3 arc-second (~ ten meter) high resolution digital elevation model (DEM) of the Savannah area is available through the National Oceanic and Atmospheric Administration (NOAA), and is used for the substratum elevation layer for Savannah (Taylor 2008). To identify the coastal/deltaic flood plain, the zone less than 5 meters above mean sea level was determined, which indicates areas of flooding and areas vulnerable to sea level rise (McGranahan, Balk, and Anderson 2007).

The coastal plain of the Savannah area accounts for nearly a third of all landmass. In figure 35, the substratum layer is used to highlight the differences in the amount of territory which constitutes the coastal/delta flood plain. This size of flood plain area has been characterized in the recently proposed delta typologies, which describe estuaries as having less coastal plains than their mudflat counterparts. However, this thesis argues that the estuary typology and description found in delta urbanism literature only partially describes the Savannah Estuary. Estuaries are categorized as having little or no coastal plain. This categorization of estuaries in delta urbanism literature can be analyzed through the mapping. Savannah has a small amount of coastal plain (1,884 square kilometers) relative to the Mississippi Delta (18,020 square kilometers). However, this information does not indicate that the Savannah Estuary has little or no coastal plain. By considering the entire study area above mean sea level in the Savannah Estuary, we can see that the coastal plain accounts for 34% of all the land cover above mean sea level (figure 36). Said another way, 34% of the Savannah area is between 1 – 5 meters of elevation above mean sea level.
Figure 34. The substratum of the Mississippi Delta. Consists of an 18,000 square kilometer flood plain (<5 m mean sea level). The Mississippi River drains roughly 41 percent of the US mainland. Map was generated in the comparative analysis found in “Urbanized Deltas in Transition” (Nijhuis and Pouderoijen 2014).
**Figure 35. Savannah Substratum.** The Savannah Estuary includes a large portion of landmass that is below 5 meters of elevation.

**Figure 36.** Percentage of coastal plain. Percentage of coastal plain within the Savannah Estuary vs total area of Savannah Estuary.
Climate Layers in the Savannah and Mississippi Delta Area (figures 37, 38, and 39)

For the Savannah area, parameter-elevation Regressions on Independent Slopes Model (PRISM) is used for average precipitation and temperature layers (USDA 2012). Historical Hurricane and Tropical Storm tracks were downloaded via the National Climatic Data Center at NOAA (Knapp 2010, Leimbach et al. 2010). Average annual precipitation in inches (1981-2010), average annual temperature in Fahrenheit (1981-2010), and hurricane tracks (1851-2013) will be combined to illustrate the climate mapping. No wind data was found for the Savannah area, and will not be included in the mapping analysis.

The average precipitation in the Savannah area ranges from forty-three to fifty inches per year. The average temperature for the Savannah area ranges from seventy-three to eighty degrees Fahrenheit. The Savannah area has frequently seen tropical storms and hurricanes, but no major hurricane has hit in recent decades.

Figures 40 and 41 use the climate layers to compare the average of precipitation (mm) and temperatures (Celsius) of the Savannah area. While there is a slight difference in the precipitation, the average temperatures of both locations are very similar. Both New Orleans and Savannah experience heavy rainfall and high temperatures during the summer months, with relative mild temperature during the winter. Both of these locations are considered humid, subtropical environments with occasional tropical storms and hurricanes.
Figure 37. Climate in Savannah Area

Legend:
- Historical Hurricane Paths
- Average Precip. in Inches
- Elevation in Meters

Created by Stephen Morgan
Figure 39. Climate in the Mississippi Delta area. The Mississippi Delta is located in a humid temperate region with average annual precipitation of 1,500 mm of from a mix of winter snowfall, frontal and convective storms, with maximum runoff during the spring. Average annual temperatures ranges from 3 to 32 degrees Celsius. Area is prone to occasional hurricanes and storms. Map was generated in the comparative analysis found in “Urbanized Deltas in Transition” (Nijhuis and Pounderoijen 2014).
Figure 40. Comparison of average precipitation. Both locations are considered humid, subtropical environments with occasional flood events.

Figure 41. Comparison of average temperature. The average high and low temperatures are very similar.
Transportation Network in the Savannah and Mississippi Area (figures 42 and 43)

Transportation network in the Savannah area uses the United States Department of Transportation’s (USDOT) National Transportation Atlas Databases 2014 (USDOT 2014). Transportation infrastructure are important factors, creating conditions for settlements, economic activities, and mobility. For this layer, the transportation network will include roads, rails, ports and airports. Since Urbanized Deltas in Transition did not include specific metrics for comparative analysis between cities, this thesis does not provide quantitative comparison between New Orleans and Savannah’s transportation network.

The Savannah area includes a vast transportation network of roads, rails, ports, and airports. The Port of Savannah is the nation's fastest-growing container port, is the 4th busiest in the USA and 2nd busiest on the East Coast (GPA 2014). Because of Savannah’s large container port activities it has become a terminus for major rail lines, with 2,958,165 tons of inbound rail freight and 1,709,255 tons of outbound rail freight in 2014. Moreover, major interstate expressways are in close proximity to the port facilities in downtown Savannah, and freight cargo is within two or fewer days by truck from 80% of the U.S. industrial and commercial markets. Additionally, Chatham County is home to 125 warehousing and distribution facilities (total 26,471,243 sq/ft of storage space), and 324 logistics providers that employ a total of 9,605 in the County and generate $1,623,621,000 in annual sales (Georgia Logistics 2014).
Figure 43. Transportation Network in the Mississippi Delta area. The ports of New Orleans and south Louisiana form the second largest port-complex in the US. The Gulf of Mexico is heavily used as a deep water port for oil-platforms and pipelines. Major expressways and rail lines make New Orleans a hub of land transportation and freight movement. Map was generated in the comparative analysis found in “Urbanized Deltas in Transition” (Nijhuis and Pounteroin 2014).
Land Use Layer in the Savannah and Mississippi Delta Area (figures 44 and 45)

The land use layer for Savannah uses the 2011 National Land Cover Dataset (NLCD), which offers 30 meter resolution and over 16 land use classes (USGS 2011). The six land uses that were used in Urbanized Deltas in Transition were also used for this thesis, which include: Open Water, Urban, Forest, Wetland, Sparsely Vegetated, and Agricultural. The land use classes from the 2011 National Land Cover Dataset were broken into the six land uses mentioned previously, and their definitions are as follows:

**Open Water**: NLCD Water class 11. Areas of open water, generally with less than 25% cover of vegetation or soil.

**Urban**: NLCD Developed classes 22, 23, and 24. Low Intensity (class 22) - areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20% to 49% percent of total cover. These areas most commonly include single-family housing units. Medium Intensity (class 23) – areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50% to 79% of the total cover. These areas most commonly include single-family housing units. High Intensity (class 24) - highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses and commercial/industrial. Impervious surfaces account for 80% to 100% of the total cover.

**Forest**: NLCD Forest classes 41, 42, and 43. Deciduous Forest (class 41) - areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75% of the tree species shed foliage simultaneously in response to seasonal change. Evergreen Forest (class 42) - areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75% of the tree species maintain their leaves all year. Canopy is never without green foliage. Mixed Forest (class 43) - areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover.
Figure 44. Land Uses for the Savannah Area
Figure 45. Land uses in the Mississippi Delta area. The coastal plain is dominated by wetlands, forest and open water. 10 percent of land use within the coastal plain is agricultural. Much of the coastal plain and delta has a flourishing fisheries and shellfish industry. Map was generated in the comparative analysis found in “Urbanized Deltas in Transition” (Nijhuis and Pounderoijen 2014).
Neither deciduous nor evergreen species are greater than 75% of total tree cover.

**Wetlands:** NLCD Wetland classes 90 and 95. Woody Wetlands (class 90) - areas where forest or shrubland vegetation accounts for greater than 20% of vegetative cover and the soil or substrate is periodically saturated with or covered with water. Emergent Herbaceous Wetlands (class 95) - areas where perennial herbaceous vegetation accounts for greater than 80% of vegetative cover and the soil or substrate is periodically saturated with or covered with water.

**Sparsely Vegetated:** NLCD Shrubland class 52 and Herbaceous class 71. Shrub/Scrub (class 52) - areas dominated by shrubs; less than 5 meters tall with shrub canopy typically greater than 20% of total vegetation. This class includes true shrubs, young trees in an early successional stage or trees stunted from environmental conditions. Grassland/Herbaceous (class 71) - areas dominated by graminoid or herbaceous vegetation, generally greater than 80% of total vegetation. These areas are not subject to intensive management such as tilling, but can be utilized for grazing.

**Agricultural:** NLCD Planted/Cultivated classes 81 and 82. Pasture/Hay (class 81) – areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle. Pasture/hay vegetation accounts for greater than 20% of total vegetation. Cultivated Crops (class 82) – areas used for the production of annual crops, such as corn, soybeans, vegetables, tobacco, and cotton, and also perennial woody crops such as orchards and vineyards. Crop vegetation accounts for greater than 20% of total vegetation. This class also includes all land being actively tilled.

Land uses are important for considering spatial patterns of development. Agriculture is one of the dominant land uses in most deltas, providing food, economic activities, and effects on the environment. Urban settlements are another important form
of land use, and is important for this work. To provide vulnerability of land uses to flooding, the acres of land uses that lay five meters below sea level are calculated.

The vast majority of land use below 5 meters of elevation in the Savannah area is comprised of wetlands (fresh, brackish, and salt). Figure 46 show the percentage of land uses within the coastal plains of the Savannah area. Notice that over 85% of Savannah’s coastal plain is comprised of wetlands, forest, or sparsely vegetate land uses, with wetlands accounting for over 50% of total land use within this area. Moreover, notice the agricultural land use in the Savannah Estuary that fall within the coastal plain, which are areas susceptible to flooding. Further illustrating land uses within the coastal plain, table 3 show the amount of land uses within the coastal plain in kilometers squared.

![Figure 46. Percentages of land uses within the Coastal Plain of the Savannah area.](image-url)
Table 3. Total square kilometers for each land use in the Savannah Estuary.

<table>
<thead>
<tr>
<th>Land Use in Coastal Plain (≥ 5m mean sea level)</th>
<th>km²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban</td>
<td>118.9</td>
</tr>
<tr>
<td>Forest</td>
<td>466.9</td>
</tr>
<tr>
<td>Agriculture</td>
<td>11.8</td>
</tr>
<tr>
<td>Wetlands/Marsh</td>
<td>1081.3</td>
</tr>
<tr>
<td>Sparsely Vegetated</td>
<td>133.5</td>
</tr>
<tr>
<td>Open Water</td>
<td>71.6</td>
</tr>
<tr>
<td>Total</td>
<td>1884.1</td>
</tr>
</tbody>
</table>

Comparative Historical Analysis

Trends

Both Savannah and New Orleans were chosen as sites for settlement because of strategic defense, natural resources, access to hinterlands via river, and connection to open ocean. Both cities originally settled the highest grounds available to avoid flooding from their respective rivers and oceans, and both cities originally utilized low-lying areas for agriculture. However, they eventually outgrew the high ground and development took place into flood prone areas that were once utilized for agriculture. Today, both cities have large seafood, tourism, recreation, and port industries.

Geologically speaking, the natural landscape of New Orleans changes more frequently than Savannah because of the constant sedimentation and “land building” that naturally occur in river dominated deltas. Recently, New Orleans has been faced with increased flood risks from subsidence, a result of the natural processes of the delta formation and land building processes no longer being functional. Likewise, the marshes and barrier islands of the Savannah Estuary depend on sedimentation and tidal forces to
function properly, but navigation improvements and upriver flood control measures have altered these functions.

While both New Orleans and Savannah originally had vast areas of marsh and wetlands, New Orleans has lost large amounts of its marshes through dredging, draining, over engineering, and altering the natural function of its delta ecosystem. Savannah has been better off in this regard (over 50% of the land below five meters are wetland/marsh), mainly because of Georgia’s early legislation to protect the marshes, fewer alterations of the natural environment, and fewer developed coastlines. However, in and around Savannah these natural flood buffers are now threatened via decreased sedimentation, increasing erosion, degradation, and/or development. Savannah should recognize lessons learned from New Orleans, who is now trying to restore its natural landscape from years of manipulation, development, and degradation.

Both Savannah and New Orleans are major port cities, with long histories in navigation improvements and flood control. While both New Orleans and Savannah have altered their natural environments through engineering projects, New Orleans has a higher level of hard engineering of its natural landscape via pumps, levees, and dredging. The limitations of engineered flood control measures became apparent after levees failed during Hurricane Katrina, and New Orleans is now in the process of developing plans that allow for natural processes in the urban landscape. Even though the Corps have continually engineered the harbor itself in the form of dredging and channelization, Savannah does not have many federal flood control structures common in other U.S. deltaic cities. There are no engineered dykes nor levees within Savannah, but there are local canals and flood gates. There are federal flood control structures upriver from
Savannah, however, and while these engineered dams have reduced seasonal flooding events in Savannah, they have also reduced sedimentation and water flow downstream. These natural processes are necessary for the dynamic and diverse habitat along the coast.

_Urbanization_

In delta urbanism, urbanization is concerned with not only the spatial development of cities into low-lying areas, which are at more risk of being flooded, but also with the effects that land uses and water management have on the natural environment. More specifically, land uses such as agriculture and urban, and water management such as flood control and water navigation, all of which are typically encouraged in deltaic regions. These land-uses vary depending on the economic reasons for settling in a delta.

Savannah, for example, owes its existence and success mainly for their strategic position for trade, navigation, defense, and agriculture. Indeed, Savannah’s original location was based of its suitable riverine and ocean access with dry, elevated land. Early urbanization took the form of dense settlements on top of an elevated landscape, with wet-rice agricultural land uses in the lower flood-prone tidal areas. Savannah’s original urban design for the establishment of the colony helped influenced future growth of the estuarine city until relatively recent. Eventually, as agricultural land uses diminished in the Savannah area, urban land uses started occupying low elevated areas, increasing the risk of residential, industrial, and commercial flooding. Over time, Savannah’s successful navigation and harbor improvements increased its ties with rail, trucks, warehouses, and other port related uses. However, navigation improvements via dredging and canalizing, along with flood control measures via dams upriver, have dramatically altered the
Savannah Estuary and caused deleterious environmental changes to the natural processes of the Savannah Estuary. River sedimentation has decreased, threatening marsh and barrier islands alike. River flow regime has changed, causing concern for threatened species of fish. The levels of salinity upriver has increased, causing once freshwater marsh to be replaced with more salt tolerant species. The urbanization process itself can result in deterioration of estuary formation and function by the loss of marshlands, coastal erosion, and salinization.

Moreover, delta urbanism literature also identifies that the urbanization process itself can place urbanized deltas in more vulnerable situations of flooding. As expressed in the study of New Orleans and the Mississippi Delta, the urbanization process resulted in the serious deterioration of delta formation and function (Barbier et al. 2013, Foyle et al. 2004, Meyer 2014b). Through engineered flood control measures, New Orleans has drastically altered its built and natural environments and placed large populations at greater risk of flooding, and resulted in loss of marshlands and subsidence.

This thesis highlights that by using an expanded concept of urbanization that includes spatial pattern, land uses, and water management, researchers are able to gain a thorough understanding of the evolution of the natural and built environments of deltaic and estuarine cities. Table 4 highlights delta urbanism’s concept of urbanization as seen through the comparative historical analysis between New Orleans and Savannah.

Complex Adaptive Systems

Urbanized deltas are framed as complex systems, with many dynamic interconnected layers. This framework resembles the way that the urban planning profession has defined resilience, in which resilience incorporates the dynamic
Table 4. Urbanization characteristics. Used in delta urbanism literature, as seen through comparative historical analysis of New Orleans and Savannah.

<table>
<thead>
<tr>
<th>Urbanization Characteristics</th>
<th>New Orleans</th>
<th>Savannah</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spatially, urban development from high elevation to low</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Land Uses in flood prone areas, specifically agriculture and urban</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Water management via flood control and navigation improvements</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Negative environmental impact</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

interaction of persistence, adaptability and transformability across multiple timeframes and systems. Delta urbanism argues that the balance and adaptability between these systems (or layers) is necessary for urbanized deltas to be successful in the future. When a complex deltaic system, comprised of interconnected sublayers, is able to adapt to changes it is considered a complex adaptive system in delta urbanism literature. This thesis argues that the study of deltaic and estuarine cities by considering them complex adaptive systems is beneficial to planners, researchers, and designers that are currently faced with ensuring urban resilience. These cities have dynamic environments, climates, land uses, economies, and functions that directly and indirectly influence each other. Delta urbanism argues that complex deltaic regions of today need to be able to adapt to immediate changes, and uncertain changes in the future.

The deltaic New Orleans has highlighted that urbanized deltas are indeed complex adaptive systems, and that the need for adapting to changing environments is necessary in order for these areas to remain successful. The development into low lying areas and engineered levees adversely influence the natural ecosystem and the vulnerability of the human population. After 2005, New Orleans developed new water management plans
that accommodated the natural fluidity of the Mississippi Delta, hoping to restore the natural landscape that had once provided its inhabitance with security and safety. New Orleans has started to adapt to a new way of urbanizing with water.

When it comes to being a complex system, the estuarine city of Savannah is no exception. The estuarine city of Savannah is a complex system, with many competing and interrelated subsystems. Savannah has to balance port, urban, and economic development with tourism, recreation, natural resources, and flood risks. The port of Savannah is strongly connected to the city itself, and port related development in the form of industrial land uses and transportation influence spatial relationships throughout the area. Increased port activity can have an effect on industrial land uses, such as increasing warehousing and distribution centers. As seem with the Jimmy DeLoach “Loop” transportation routes and improvements in Savannah are immediately influenced by port activity. Conversely, increased port activity has had a negative effect on the estuary, marshes, and beaches through regular dredging. While these natural resources of Savannah provide for large economic sectors such as tourism, recreation, and fisheries, they also provide ecosystem services such as storm water management, flood surge buffers, and water quality. These ecosystem services are beginning to be threatened from increased urban development within flood prone areas and barrier islands.

It is clear the urbanized Savannah Estuary is a complex system. However, what is yet to be seen is if Savannah can become a resilient system by adapting to changes in its built and natural environments. Recent planning efforts reflect the realization that the Savannah area should start reconsidering its urbanization in the light of climate change and sea level rise. However, there has been is not a unique, stand-alone plan for how
Savannah should adapt to future changes that balance its many subsystems. With uncertainties in future trends in sea level rise and climate change, Savannah should be ready to adapt to future trends and changing circumstances.

This thesis highlights that deltaic and estuarine cites can be considered complex systems, and that urbanized deltas and estuaries should be able to balance each subsystem and to adapt to uncertain changes in the future.

*Delta Urbanism Typology*

Delta urbanism identifies that although deltaic and estuarine areas have similar issues, they have different morphological and functional characteristics which needs to be considered in planning and design. The typologies proposed by recent delta urbanism literature identify that distinctions needs to be made between different coastal cities that are spatially located near rivers (table 5). Recent literature includes a proposed typology of urbanizing deltas in order to introduce delta-specific strategies for coastal development. By including estuaries into the typology of delta urbanism, the similarities and differences of the estuarine city of Savannah can be highlighted in comparison with another deltaic city. As observed in this thesis, deltas and estuaries can be considered distinct natural processes and landscapes, and although deltaic and estuarine areas have similar problems such as flooding and sea level rise, they have different morphological and functional characteristics. The differences in the morphologies and functions of urbanized deltas can be seen highlighted by comparative analysis between deltaic New Orleans and estuarine Savannah.

In delta urbanism literature the Mississippi Delta is categorized as a mudflat delta, which are described as having large amounts of siltation and land building processes,
with urbanization taking place on higher elevations next to rivers. As discussed during the historical analysis of New Orleans, the Mississippi Deltas as continuously built the natural landscape of lower Louisiana for the past thousand years. Vast amounts of sedimentation were deposited parallel to the river banks, resulting in the creation of new, “built up” land masses which were utilized by early urban settlements. The importance of the sedimentation function of the Mississippi Delta was realized when it was restricted by levee construction, resulting in the natural process that built the natural landscape to be reduced, leaving large areas of New Orleans below sea level and vulnerable to flooding. The mudflat classification used in delta urbanism literature accurately describes the researched about the Mississippi delta during the historical analysis of this thesis.

In *Urbanized Deltas in Transition*, urban estuaries are categorized as tidally influenced river mouths with little or no flood-plain, with large cities on adjacent high ground with agricultural land uses in lower flood prone areas. However, through the
comparative analysis, this thesis argues that the estuarine city of Savannah only partially fits within this estuary typology. The Savannah Estuary includes characteristics of all four of the proposed typologies (table 6). During the historical analysis we learned that much of the urbanization process took place on higher elevations, with agriculture being primarily located in the lowlands. In this respect, delta urbanisms classification of urbanized estuaries is correct. However, today, there is relatively little agricultural land uses within the coastal plain of the Savannah Estuary. Moreover, we have learned during the historical analysis that the sedimentation and tidal processes are very important for a functioning marshes, wetlands, and barrier islands. Sedimentation characteristics are not mentioned as a key functions in the estuary typology. Through mapping and historical analysis, this thesis argues that the estuary typology and description found in delta urbanism literature only partially describes the Savannah Estuary by failing to incorporate barrier islands, sedimentation, and by underestimating the amount of coastal plain found within estuaries.

Conclusion

This chapter presents the mapping results for Savannah and New Orleans; this chapter also presents the various concepts of delta urbanism (typology, urbanization, and complex adaptive systems) analyzed through the historical analysis between New Orleans and Savannah. This chapter analyzes the various concepts and frameworks of delta urbanism that were used in this thesis to study New Orleans and Savannah, and highlights whether these concepts are accurate in studying the estuarine city of Savannah (table 7). Comparative analysis is an important tool for studying delta urbanism because it allows
Table 6. Savannah Typology. Table showing how Savannah fits within the delta urbanism typologies.

<table>
<thead>
<tr>
<th>Typology</th>
<th>Savannah</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mudflat</td>
<td>Partially accurate, urbanization on high elevations</td>
</tr>
<tr>
<td>Plain</td>
<td>Partially accurate, large flood plain</td>
</tr>
<tr>
<td>Estuary</td>
<td>Partially accurate, tidally flooded river valley</td>
</tr>
<tr>
<td>Lagoon</td>
<td>Partially accurate, barrier islands</td>
</tr>
</tbody>
</table>

Table 7. Matrix of delta urbanism concepts. As seen through the results of mapping and historical analysis of New Orleans and Savannah.

<table>
<thead>
<tr>
<th>Typology</th>
<th>New Orleans</th>
<th>Savannah</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typology</td>
<td>Accurate</td>
<td>Partially Accurate, needs further research</td>
</tr>
<tr>
<td>Urbanization</td>
<td>Accurate</td>
<td>Accurate</td>
</tr>
<tr>
<td>Complex Adaptive</td>
<td>Accurate</td>
<td>Accurate</td>
</tr>
<tr>
<td>Systems</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Researchers and designers to understand different types of concepts and frameworks proposed in delta urbanism literature. Comparative analysis through mapping and historical research of natural and built environments also allows different deltaic cities to be compared in order to highlight similarities and differences (table 8). The deltaic and estuarine cities discussed in this thesis are similar in terms of their natural and built histories, climate, spatial location, and risk of flooding. However, even with major similarities between two deltaic cities, there are subtle differences in their built and natural histories and urbanization.

Mapping analysis of the Savannah area provides quantitative analysis of areas below 5 meters of elevation which are more susceptible to flooding and sea level rise. By considering the total area of the Savannah area, this thesis has shown that the coastal
Table 8. Comprehensive Matrix. Similarities and differences within each subsystem layer of the Savannah Estuary and Mississippi Delta areas can be highlighted through the mapping analysis. The accuracy of delta urbanism concepts can be highlighted through the comparative historical analysis.

<table>
<thead>
<tr>
<th>Mapping Analysis</th>
<th>Savannah</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban Settlement (&lt;5m MSL)</td>
<td>Less than 10%</td>
</tr>
<tr>
<td>Substratum</td>
<td>1884.1 km² (&lt;5 m MSL) of coastal flood plain (33% of total area)</td>
</tr>
<tr>
<td>Climate</td>
<td>1,270 mm precipitation 5-33 degrees Celsius</td>
</tr>
<tr>
<td>Transportation</td>
<td>Hub for port, road, rail</td>
</tr>
<tr>
<td>Top 3 Land Uses (&lt;5m MSL)</td>
<td>Wetlands (57%), forest (25%), sparsely vegetated (7%)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Comparative Historical Analysis</th>
<th>Savannah</th>
<th>New Orleans</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urbanization</td>
<td>Accurate</td>
<td>Accurate</td>
</tr>
<tr>
<td>Complex Systems</td>
<td>Accurate</td>
<td>Accurate</td>
</tr>
<tr>
<td>Typologies</td>
<td>Mudflat, accurate</td>
<td>Estuary, partially accurate</td>
</tr>
</tbody>
</table>

plain constitutes a considerable amount of the Savannah Estuary. This fact highlights that the estuary typology proposed in recent delta urbanism literature is incorrect in assuming that estuaries have little or no coastal plain. Moreover, while the Savannah area has a larger amount of urban land uses within its coastal plain, it also has a remarkable amount of wetlands, forests, and vegetation found in the coastal plain.

Comparative historical analysis between New Orleans and Savannah provides qualitative analysis of delta urbanism concepts such as urbanization, typology, and
complex systems. Both New Orleans and Savannah saw early urbanization take hold on higher elevations, and slowly move into low lying areas. Agricultural land uses were first utilized in areas that were prone to flooding, but soon moved into the hinterlands. Through water management such as levees, dams, and dredging, both cities have negatively affected their natural environments, arguably resulting in increased risk of flooding and sea level rise. However, New Orleans has begun to rethink their water management practices by allowing more room for the Mississippi River. Historical analysis of Savannah also highlights that the Savannah Estuary partially fits within each of the proposed typologies of recent delta urbanism literature. Both New Orleans and Savannah are complex systems, with each layer of the system directly and indirectly interacting with one another. Both cities are starting to adapt to increased flooding and sea level rise.
CHAPTER SEVEN

CONCLUSION

Most deltaic and estuarine cities are dealing with increasing complexity and changing dynamics due to climate change; however, climate change is not the only reason for the increased complexity in these areas. The urbanization process itself has also increased the complexity of these areas due to changes in the dynamics of land-use, urbanization, port-development, agriculture, leisure/tourism, etc. Concentrated populations, agriculture, flood control, and port activities on or near coastal regions have had deleterious environmental consequences. Urban systems have drastically changed the flows of water, energy, and resources in marsh and wetlands, negatively effecting these ecosystems. These natural occurring ecosystems can provide vital protection against hurricanes, typhoons, flooding, as well as provide tourism, recreation, and sea food industries. Urban estuaries and deltas are at the frontline when it comes to managing these increasingly complex systems, and are now faced with reconsidering how they will develop going forward.

Acknowledging this, delta urbanism attempts to study these complex systems and understand how they can and should develop into the future. This thesis researches, compiles, and outlines concepts and frameworks found within delta urbanism literature, and then applies those concepts and frameworks to compare the estuarine city of Savannah with deltaic New Orleans. In order to gain a better understanding of concepts
and frameworks of delta urbanism, this thesis utilized literature review, mapping and historical analysis between New Orleans and Savannah.

This thesis contributes to the comparative mapping analysis of urbanized deltas by using the same standardized mapping layers outlined in recent delta urbanism literature to study the estuarine city of Savannah. Using GIS for mapping analysis allowed this thesis to provide quantitative measurements of the Savannah area. Major concepts discussed and outlined in the delta urbanism chapter, such as urbanized delta typologies, urbanization, and complex adaptive systems, were analyzed during the historical analysis between New Orleans and Savannah.

This thesis demonstrates that analysis, through mapping and comparative contextual history, can be a useful tool in studying and understanding concepts in delta urbanism literature. While deltas and estuaries can be defined as distinct geologic features or landscapes, delta urbanism has provided a typology of urban deltas that acknowledges their similarities and differences. Through mapping and historical analysis, this thesis argues that the estuary typology and description found in delta urbanism literature only partially describes the Savannah Estuary by failing to include estuarine barrier islands, incorrectly describing its urbanization pattern, and by underestimating the amount of coastal plain found within estuaries. However, both the Mississippi Delta and the Savannah Estuary share a common denominator: these two types of urbanized deltas include deltaic lowlands or flood plains; and once human habitation of these lowlands progressed by means of urbanization, navigation, and agricultural exploitation, the conditions of these lowlands changed dramatically when it comes to the functioning
natural environment. This thesis has shown through comparative historical analysis that this is true when considering both Savannah and New Orleans.

Through comparative historical analysis, this thesis highlights that using a concept of urbanization that includes spatial pattern, land uses, and water management, researchers are able to gain a thorough understanding of the evolution of the natural and built environments of deltaic and estuarine cities. As expressed in the study of New Orleans and Savannah, the urbanization process itself can result in the serious deterioration of delta/estuary formation and function, resulting in loss of marshlands, subsidence, costal erosion, and salinization. Levee construction in New Orleans resulted in subsidence, loss of wetlands, and increased populations in flood prone areas. Moreover, the comparative analysis of this thesis argues that the study of deltaic and estuarine cities by considering them complex adaptive systems is beneficial to planners, researchers, and designers that are currently faced with ensuring urban resilience. Urbanized deltas have been defined as a complex, adaptive systems. These cities have dynamic environments, climates, land uses, economies, and functions that directly and indirectly influence each other.

Lessons Learned

Strategic natural advantages of deltas and estuaries have been utilized for urbanization for much of human history. Diverse natural resources, access to waterway navigation and port activities, and large tourism, fishery, and recreation industries are elements in many deltaic and estuarine cities. However, deltaic and estuarine cities are constantly challenged with flooding from rivers and oceans alike. Deltas and estuaries need freshwater and sediments, and are extensively tied to occasional inundation.
Building and designing deltaic and estuarine cities in a way that accommodates seasonal flooding balances urban requirements with natural processes. Hard engineering approaches to flood control, such as levees and dams, are premier tools in anthropogenic control of the flood prone environments. When built and constructed properly, these flood control measures succeed in reducing occasional flooding, but they also eliminate freshwater and sediment inputs that are critical in the development of healthy ecosystems. Existing hard engineered flood control should be maintained, but new construction of hard engineered approaches to flood control are ill-advised, as they smother coastal processes and encourage development into hazardous areas. Soft engineering approaches to flood control allow for natural processes in deltaic and estuarine environments to continue, but also encourage sustainable land uses and maximizes natural buffers to flooding.

Using Savannah and New Orleans as vehicles for comparative analysis is useful for understanding concepts in delta urbanism, but also in understanding success and failures of previous delta urbanization. Pre-Katrina New Orleans dramatically restricted and altered its natural environment, resulting in encouraged urbanization into flood prone areas and destruction of natural ecosystems that help reduce flood risks. These factors can be considered failures in delta urbanism. However, in light of these failures, post-Katrina New Orleans is currently reconsidering their traditional water management practices and are now allowing more fluidity and room for its flood waters and restoration of its natural ecosystems. New Orleans is now considering balancing hard and soft engineering approaches to flood control, restoring its marshes, wetland and barrier islands, and
assigning recreation and public land uses within flood prone areas. The estuarine city of Savannah resembles pre and post Katrina New Orleans in several ways.

Water management practices such as continuous dredging and multi-purpose dams have resulted in deleterious environmental impacts, and urbanization that was once restricted to higher elevations are now within areas that are at risk of flooding and sea level rise. However, Savannah has started to consider urban development and flooding events in more detail. The acquisition of flood prone properties, restrictions to development in flood areas and barrier islands, protection of natural resources/open space, building codes, and improving the county’s water management systems are all strategies in which Savannah and Chatham County has in place to for future development and planning. However, unlike New Orleans and the Netherlands, there is not a standalone comprehensive water management plan that accommodates the natural fluidity of the Savannah River and Atlantic Ocean, balances hard and soft engineering flood control measures, and allows flood waters into areas of the city which recreational, natural resource, and public land uses are assigned.

Successes in delta urbanism can also be highlighted through comparative analysis between Savannah and New Orleans. Savannah boasts successful port, recreation, fishery, and tourism industries along with vast areas of natural resources. In terms of balancing complex systems, Savannah has done a better job of balancing its various dynamic systems compared to New Orleans. Despite its long history of port activities and navigation improvements, coastal Georgia and the city of Savannah are home to a vast amount of natural resources such as marshes, wetlands, and barrier islands. Due to the Coastal Marshland Protection Act and largely undeveloped barrier islands, the state of
Georgia has protected an invaluable resource to its coastal communities. The estuaries, marshes, and wetlands provide habitat for large amounts of shrimp, crustaceans, and oysters; they are also directly connected to its’ tourism and recreation industries. Marshlands and barrier islands also provide protection from hurricanes, dissipating the effects of storm surge and flooding.

Notwithstanding, even though this thesis highlights failures and successes of applying delta urbanism concepts to Savannah though comparative analysis, there is still a need for more specific recommendations in which Savannah can move forward in coastal development in the face of climate change and sea level rise. The following section provides principles and elements of coastal planning and delta urbanism that can be specifically applied in the Savannah area.

**Recommendations**

The Chatham County – Savannah Metropolitan Planning Commission recognizes the need to formulate a comprehensive approach for coastal development in the face of sea level rise and climate change, and acknowledges that certain planning principles and practices can help the Savannah area prepare and adapt for the future. The following are principles and elements that the Savannah Metropolitan Planning Commission are currently attempting in order to aid in the development of a resilient community:

1. **Flooding and Sea Level Rise Mapping**: To study Savannah using maps that don't include land loss projections and that depict the coast as a static line between land and water would be to turn a blind eye to the realities of sea level rise. As recent hurricanes such as Katrina and Sandy revealed, the line between land and water is not static. Sea level rise mapping can be represented in the form of maps, which could then use as a
basis for planning against future risks. Using GIS to map various extents of future sea level rise will allow planners to isolate areas that are not currently within designated flood zones, but will need redevelopment, redesign, retrofitting, or even demolition in the future. Sea level rise mapping can aid in design strategies and proposals made for the Savannah area. Current Flood Insurance Studies (FIS) and Flood Insurance Rate Maps (FIRM) are being utilized to accurately identify structures within the “100 year flood zone” (or Flood Zones V, A, and Coastal-A) in the Savannah area. Recreational, public, and natural resource land uses can be assigned to areas that are known to flood or are expected to inundate with future sea level rise.

The City of Savannah, the Savannah Area GIS (SAGIS) along with other partners, such as Skidaway Institute of Oceanography and Georgia Department of Natural Resources Coastal Resources Division, have been actively working on this effort and have baseline data in place.

2. Land Use Policy: There are three policies for primarily dealing with sea level rise: retreat, accommodate, and protection. Retreat policies minimize hazards from sea level rise by restricting, prohibiting, or removing development from areas vulnerable to sea level rise. Examples include government land acquisition, rolling easement, and setback requirements. Accommodation policies minimize damage to building/structures from storm surge or flooding. Examples include minimum floor elevations, structural bracing, and water drainage systems. Protection policy measures attempt to defend against sea level rise, and are usually divided into two approaches: soft and hard structural options. Examples of soft options include beach nourishment, dune building, restoring wetlands and barrier islands. Examples of hard options include sea walls, levees, dykes, and
bulkheads. While the Savannah area does not include levees or dykes, it does include canals and flood gates. Areas adjacent or perpendicular to these flood control measures can be used for public and recreational land uses and also to accommodate occasional flooding.

The Savannah area currently uses all 3 of the noted policies to include retreat (land acquisition and setback requirements), accommodation (strengthened freeboard requirements), and protection (restoration and land purchase to allow for natural migration of the systems).

3. **Land Use Law:** Most state legislators have delegated local government’s legal authority to designate what type of development may occur in disaster-prone and vulnerable coastal areas. This authority can be utilized by local governments to create disaster-resilient communities that have the ability to adapt to the effects of sea level rise and natural disasters. Traditional local land use laws can be utilized as a key objective of a communities land use planning. Most zoning enabling acts adopted in states makes it clear that one of its purpose is to encourage the most appropriate within a municipality. Laws that reduce the prospect of damage from storm surge and flooding can encourage the most appropriate use of land. Additionally, most subdivision statues and site plan regulations clearly permit standards to be included that prevent and control the impacts of storms and flooding (Nolon 2014).

4. **Coastal Zone Management Act (CZMA):** The CZMA is nationwide effort administered by NOAA to provide funding, guidelines, and technical help for coastal and great lake states, and it acknowledges the interconnected concerns of economic development, environmental protection, and sea level rise. CMZA can be used to gain two types of
federal funding grants: coastal resource improvement grants and coastal zone enhancement grants. These grants can be used for stabilization and resiliency projects including improvement to public access, structural reinforcement, protecting/restoring/enhancing coastal wetlands, and controlling coastal growth. In order for Savannah to be eligible CZMA funding, a voluntarily drafted coastal management plan must be created that follows specific guidelines set by the federal government.

The City of Savannah, through the Georgia Department of Natural Resources Coastal Resources Division, actively participates in this program and receives funding for projects to both research and employ resiliency efforts.

5. Natural Resource Planning: Natural resources such as marsh, wetlands, hammocks, and barrier islands provide multiple services including: stormwater management, storm surge protection, water quality, recreation, tourism, and erosion control. Planning for these resources is a crucial part of preparing for future growth and risk, and they directly affect the flooding risks and hazards of the Savannah area. Again, balancing the economic gain against the increase in flood hazard is necessary.

The City of Savannah has had an active stormwater management program and NPDES permit in place since the mid 1990’s. Millions of SPLOST and Capital Improvement dollars have gone into improving the City’s drainage systems. The City also has a program in place (The Chatham County Resources Protection Program) that purchases natural areas that can provide protection through natural migration and water quality improvement opportunities for the community.

6. Resilient Designs and Building Codes: The adoption of flood resistant designs and construction codes for new and substantially improved buildings in designated flood zone
should be considered. Building codes that establish minimum structural and programmatic requirements for all new and improved buildings in these flood zones should be adopted, and should follow construction and design standards found in The National Flood Insurance Program's (NFIP's) Community Rating System (CRS). The CRS is a voluntary incentive program that recognizes communities for implementing floodplain management practices that exceed the Federal minimum requirements to provide protection from flooding.

The City of Savannah participates in the Community Rating System program and is very proactive in strengthening its building code requirements to ensure flood protection is taken into account (i.e. additional freeboard requirements in specific zones).

**Future Research**

This thesis demonstrates that future research into the typologies of urbanized deltas is necessary. There is a need for more research on what ways delta urbanism can more accurately classify urbanized estuaries. The coastal estuaries of Georgia only partially fit within the typology of estuary proposed by delta urbanism literature.

While a large portion of this thesis consists of the activities of the Corps in developing navigable waterways and flood control, there was little detail and research on local flood control measures of the Savannah area. While there are no major levees or dams within the Savannah area, there are canals, flood gates, and other local forms of flood control or mitigation. Major rain events routinely flood the streets of Savannah, and more research on the local flood control measures in the Savannah area is necessary to understand the risks of flooding in the future.
This thesis did not map future trends in sea level rise for the Savannah area. Future mapping research that specifically identifies areas that are threatened by different estimates of sea level rise should be considered in future research. By using current GIS data to physically map areas threatened by sea level rise, strategies and design proposals can be applied to specific areas. Moreover, since one of the goals of this thesis was to contribute to the existing, standardized comparative analysis of urbanized deltas, then certain datasets were not used. For instance, for areas at risk of storm surge and flooding, this thesis used an elevation below five meters for consistency with other studies. However, Digital Flood Insurance Rate Map (DFIRM) data could be utilized for more accurate spatial analysis, and should be considered in future research.

Additionally, additional layers could be added to the systems mapping in delta urbanism literature. For instance, adding an “underground hydrology” layer to the GIS mapping analysis could potentially highlight the complex hydrological features of the Savannah area, including: inter-stream flow, groundwater, water recharge areas, and water tables. Moreover, GIS mapping of the Savannah area at the metropolitan scale (~50 km) could be utilized to compare the Savannah area with other deltas in *Urbanized Deltas in Transition*. This would allow Savannah to be quantitatively compared with other world deltas by researchers, and to further analyze concepts found within delta urbanism literature.

This thesis could be used to consider specific urban design proposals that could be applied in the Savannah area. Specific water and flood management and urban development designs tailored to the Savannah area should be considered in future research. A design charrette could be considered for areas identified as flood hazards.
Charrette teams could identify different design solutions that incorporate flood protection, sustainable land uses, natural resources, and water management systems.

**Conclusion**

Delta urbanism has been defined as a “... new initiative that explores the growth, development, and management of deltaic cities and regions, with the aim of balancing various goals in a sustainable manner: urbanization, port commerce, industrial development, flood defense, public safety, ecological balance, tourism, and recreation.” (Meyer, Bobbink, and Nijhuis 2010). This thesis demonstrates how the city of Savannah can be studied within this definition of delta urbanism by mapping, researching, and analyzing the city of Savannah’s history of urban spatial pattern and land use, developing port activities, and the effects of these developments on its natural environment.

This thesis demonstrates that analysis through mapping and contextual history can be a useful tool in studying and understanding concepts in delta urbanism literature. While current delta urbanism typologies are insufficient in classifying the estuarine city of Savannah, other frameworks found in delta urbanism literature, i.e. urbanization and complex adaptive systems, are beneficial to the study of deltaic and estuarine cities. Through comparative analysis, successes and failures in delta urbanism can also be highlighted between deltaic and estuarine cities. Moreover, differences between New Orleans and Savannah can also be highlighted through comparative analysis.

Recent hurricanes such as Sandy and Katrina have highlighted that urbanization in deltaic and estuarine environments should encourage land use decisions that allow for more fluidity of natural processes within urban areas. Water management plans that accommodate the natural fluidity of the Savannah River and Atlantic Ocean, balances
hard and soft engineering flood control measures, and allows flood waters into areas of
the city which recreational, natural resource, and public land uses are assigned are
recommended ways in which Savannah can become more resilient and sustainable. There
are several planning tools that can be used to help Savannah adapt to future changes,
including: flooding and sea level rise mapping, land use policy, land use law, natural
resource planning, and resilient building codes and designs.

This thesis demonstrates that future research into the urbanized delta typologies
found in recent delta urbanism literature is necessary. Moreover, further research into
local flood control measures in the Savannah area is also necessary. Current GIS data,
such as sea level rise and DFIRM, should be used to more accurately identify areas that
are in need of future development strategies and designs within the Savannah area.
Specific research by design proposals should be utilized within the Savannah area to
identify different design solutions that incorporate flood protection, sustainable land uses,
natural resources, and water management systems.


Archives, Georgia. 1954. Chatham County Map Portfolio. Cover Title: Early Georgia Plantations and the Township of Savannah, 1752-1871.


Clark Jr, WZ, and AC Zisa. 1976. "Physiographic map of Georgia. Georgia Department of Natural Resources." Environmental Protection Division, Atlanta, GA.


*An Act To provide for the control of the floods of the Mississippi River and of the Sacramento River, California, and for other purposes*. 64th Congress, 2nd Session, March 1st, 1917.

*An Act For the control of floods on the Mississippi River and its tributaries, and for other purposes*. 70-391. 70th Congress, 1st Session.

Congress, US. 1936. *An Act Authorizing the construction of certain public works on rivers and harbors for flood control, and for other purposes*. 74th Congress, 2nd Session ed: United States of America.

*An Act authorizing the construction, repair, and preservation of certain public works on rivers and harbors for navigation, flood control, and for other purposes*. 86-645. 86th Congress, 2nd Session, July 14, 1960.

*An Act to establish a national policy for the environment, to provide for the establishment of a Council on Environmental Quality, and for other purposes* 91-190. 91st Congress, January 1, 1970.

*An Act to amend the Federal Water Pollution Control Act*. 92-500. 92nd Congress, 2nd Session, October 18, 1972.


Cooper, John M. 1856. Map of the city of Savannah. edited by University of Georgia Hargrett Rare Documents Library.

Correggiari, Annamaria. 2005. "Depositional patterns in the late Holocene Po delta system."


DePratter, Chester B, and James D Howard. 1977. "History of shoreline changes determined by archaeological dating: Georgia coast, USA."


Harris, Reid W. 2008. *And the coastlands wait : how a small group of legislators, scientists and concerned citizens helped save 500,000 acres of the world's most productive area*: Self published.


Jefferys, Thomas. 1761. *The natural and civil history of the French dominions in North and South America [electronic resource]: With an historical detail of the acquisitions and conquests made by the British arms in those parts. Giving a particular account of the climate, soil, minerals, animals, vegetables, manufactures, trade, commerce, and languages. Together with the religion, government, genius, character, manners and customs of the Indians and other inhabitants. Illustrated by maps and plans of the principal places, collected from the best authorities, and engraved by T. Jefferys, geographer to His Majesty. Part I. Containing a description of Canada and Louisiana*: T. Jefferys, at Charing-
Cross; W. Johnston, in Ludgate-Street; J. Richardson in Pater-noster-Row; and B. Law and Company in Ave-Mary-Lane.


Larsen, Clark Spencer, David Hurst Thomas, Chester B DePrattter, and Donald K Grayson. 1982. "The Anthropology of St. Catherines Island. 4: The St. Catherines


Lewis, Samuel. 1817. Map of Georgia.


McKinnon, John. 1798. Copy of a certified copy of a Plan of the forty five and five acre lots in the township of Savannah lodged in the Surveyors Office of the County of Chatham. Hargrett Rare Documents Library: University of Georgia.


Steinberg, Philip E, and Rob Shields. 2008. *What is a city?: rethinking the urban after Hurricane Katrina*: University of Georgia Press.


Sugden, Perry. 1890. Part of a plan of Tybee Island. Hargrett Rare Documents Library: University of Georgia.


Tinkler, William P. 1976. *The U. S. Army Corps of Engineers Atlantic Intracoastal Waterway project in Georgia: a study of its history, maintenance, and present use*. Georgia Dept. of Natural Resources Game and Fish Division Marshland Protection Section: Brunswick, GA.


Wilson, Elizabeth, and Jake Piper. 2010. Spatial planning and climate change: Routledge London.


