

## Table of Contents

I.	Introduction.....	I-1
A.	Session Law 2009-479 / House Bill 709 .....	I-2
B.	Public Consultation .....	I-3
C.	Selection of Study Sites.....	I-5
D.	Limitations of Study.....	I-8
II.	Physical Assessment .....	II-1
A.	Function of a Terminal Groin.....	II-1
B.	Geological Framework and Physical Processes .....	II-3
1.	Wave Energy and Longshore Sediment Transport.....	II-3
2.	Tides and Tidal Currents .....	II-3
3.	Effects of Storms at Inlets .....	II-4
4.	Storm Effects on Barriers .....	II-5
5.	Interpretation of Historical Data Bases .....	II-5
6.	Geological Framework .....	II-5
7.	Dredging and Sediment Disposal .....	II-6
8.	Sea-Level Rise .....	II-7
C.	Assessment Methodology .....	II-7
1.	Shoreline Change.....	II-7
2.	Volumetric Changes, Beach Nourishment and Dredging Effects .....	II-8
D.	Assessment of Oregon Inlet Terminal Groin .....	II-11
1.	Qualitative Assessment.....	II-11
2.	Quantitative Assessment.....	II-23
3.	Summary.....	II-36
E.	Assessment of Fort Macon Terminal Groin .....	II-38
1.	Qualitative Assessment.....	II-38
2.	Quantitative Assessment.....	II-49
3.	Summary.....	II-62
F.	Assessment of Amelia Island Terminal Groin.....	II-64
1.	Qualitative Assessment.....	II-64
2.	Quantitative Assessment.....	II-71
3.	Summary.....	II-82
G.	Assessment of Captiva Island Terminal Groin .....	II-83
1.	Qualitative Assessment.....	II-83
2.	Quantitative Assessment.....	II-89
3.	Summary.....	II-100
H.	Assessment of John's Pass Terminal Groin .....	II-101
1.	Qualitative Assessment.....	II-101
2.	Quantitative Assessment.....	II-108
3.	Summary.....	II-120
I.	Overall Findings, Comparisons, and Summary .....	II-121
III.	Environmental Assessment .....	III-1
1.	Technical Approach of Analysis .....	III-1
2.	General Environmental Effects .....	III-3

---

3.	Federally Threatened and Endangered Species Effects.....	III-10
4.	Water Quality Effects .....	III-17
5.	Anthropogenic Effects (Recreation/Aesthetics/Public Access) .....	III-18
6.	Summary of General Environmental Effects.....	III-19
<b>B.</b>	<b>Environmental Assessment of the Five Study Sites.....</b>	<b>III-21</b>
1.	Oregon Inlet .....	III-21
2.	Fort Macon, Beaufort Inlet, North Carolina .....	III-46
3.	Amelia Island, Nassau Sound, Florida .....	III-73
4.	Captiva Island .....	III-94
5.	John's Pass, Florida .....	III-110
<b>C.</b>	<b>Overall Findings and Summary of NC and FL Study Sites .....</b>	<b>III-123</b>
<b>IV.</b>	<b>Engineering Construction Techniques .....</b>	<b>IV-1</b>
<b>A.</b>	<b>Overview of Approach .....</b>	<b>IV-1</b>
<b>B.</b>	<b>Characteristics of the Five Study Site Structures .....</b>	<b>IV-1</b>
1.	Oregon Inlet .....	IV-1
2.	Fort Macon .....	IV-4
3.	Amelia Island.....	IV-6
4.	Captiva Island .....	IV-10
5.	John's Pass.....	IV-11
6.	Analysis of Existing Sites.....	IV-15
<b>C.</b>	<b>Literature Review and Discussion of Approaches to Minimize Impacts .....</b>	<b>IV-20</b>
1.	Length .....	IV-20
2.	Height .....	IV-21
3.	Permeability.....	IV-22
4.	Configuration.....	IV-24
5.	Material.....	IV-25
6.	Alternative Construction Techniques .....	IV-30
<b>D.</b>	<b>Overall Findings and Summary.....</b>	<b>IV-31</b>
<b>V.</b>	<b>Economic Assessment .....</b>	<b>V-1</b>
<b>A.</b>	<b>Overview of Economic Considerations.....</b>	<b>V-1</b>
1.	Inlets Considered .....	V-1
2.	30-Year Risk Areas (30YRAs).....	V-1
3.	Imminent Risk Properties (IRPs).....	V-2
4.	Types of Economic Value Considered.....	V-2
<b>B.</b>	<b>Economic Impact of Shifting Inlets .....</b>	<b>V-5</b>
1.	Economic Value At Inlets.....	V-5
<b>C.</b>	<b>Discussion of Other Factors That Influence Economics .....</b>	<b>V-43</b>
1.	Recreation and Environmental Value.....	V-43
2.	Transfer of Property Values to Remaining Structures Following Erosion Losses.....	V-50
<b>D.</b>	<b>Overall Findings and Summary.....</b>	<b>V-52</b>
<b>VI.</b>	<b>Initial Construction and Maintenance Costs .....</b>	<b>VI-1</b>
<b>A.</b>	<b>Overview of Costs and Key Factors.....</b>	<b>VI-1</b>
<b>B.</b>	<b>Development of Terminal Groin Unit Costs .....</b>	<b>VI-1</b>
1.	Rock.....	VI-3

---

2.	Concrete and Steel .....	VI-3
3.	Timber .....	VI-5
4.	Geotextile.....	VI-6
C.	Cost Evaluation of Five (5) Selected Study Sites .....	VI-6
1.	Fort Macon .....	VI-6
2.	Oregon Inlet.....	VI-7
3.	Amelia Island.....	VI-8
4.	John's Pass.....	VI-10
5.	Captiva Island .....	VI-11
D.	Potential Range of Initial Construction Costs for North Carolina Terminal Groins.....	VI-11
E.	Potential Range of Maintenance Costs for North Carolina Terminal Groins	VI-16
1.	Structure Maintenance Costs .....	VI-16
2.	Beach Nourishment Costs .....	VI-17
3.	Other Costs .....	VI-17
F.	Overall Findings and Summary .....	VI-18
VII.	Potential Locations.....	VII-1
A.	Literature Review of Existing Terminal Groin Sites .....	VII-1
B.	Siting Lessons Learned from Five Study Sites .....	VII-4
VIII.	Summary of Findings.....	VIII-1
IX.	References.....	1

Appendix A Committee Lists

Appendix B Session Law 2009-479 / House Bill 709

Appendix C Engineering Activity Logs

Appendix D Physical Data

Appendix E Environmental Contacts

## List of Figures

Figure I-1. Overall Project Structure .....	I-2
Figure I-2. Project Website .....	I-4
Figure I-3. Potential Study Sites .....	I-6
Figure I-4. Selected Study Sites.....	I-7
Figure II-1. Terminal Groin at Saint Pete Beach, Florida.....	II-2
Figure II-2. Inlet Geologic Features.....	II-4
Figure II-3. Shoreline to Beach Volume Change Relationship .....	II-9
Figure II-4. Analysis Procedure .....	II-10
Figure II-5. Aerial Photographs of Oregon Inlet A. Looking Landward (Photograph from Ramanda, Nags Head) and B. Seaward (Photograph by D.A. Harvey).....	II-12
Figure II-6. Oregon Inlet Terminal Groin & Revetment .....	II-13
Figure II-7. Comparison of 1991 and 2006 Shorelines Along Bodie and Pea Islands .	II-14
Figure II-8. Bodie Island Illustrating Recurved Ridges Comprising Spit End .....	II-15
Figure II-9. Bathymetric Changes at Oregon Inlet Showing A. Cross-sectional Changes from 1999 to 2001 and B. Erosional-depositional Changes Over the 2001 – 2003 Period (Vandever and Miller, 2003).....	II-17
Figure II-10. Historical Aerial Photographs of Oregon Inlet Illustrating Different Ebb-tidal Delta Morphologies. ....	II-18
Figure II-11. Photographs of Northern Pea Island and Terminal Groin Area. ....	II-18
Figure II-12. 2001 Aerial Photograph of Oregon Inlet Showing Wave Refraction Around Ebb Delta Producing Northerly Transport Along Pea Island Feed Sand to the Fillet Region.....	II-19
Figure II-13. Sequential Photographs of Oregon Inlet Depicting the Shoreline Changes Associated with Spit Accretion at Bodie Island and Southerly Migration of Oregon Inlet (Cleary, 2009) .....	II-20
Figure II-14. Historical Changes of the Northern Pea Island Shoreline .....	II-21
Figure II-15. Historic Shorelines – Oregon Inlet .....	II-24
Figure II-16. Oregon Inlet Shoreline Change Calculation Transects .....	II-25
Figure II-17. Shoreline Change – Bodie and Pea Islands (Intervals) .....	II-27
Figure II-18. Shoreline Change – Bodie and Pea Islands (Total Average) .....	II-27
Figure II-19. Beach Volume Changes – Bodie and Pea Islands (Intervals) .....	II-30
Figure II-20. Beach Volume Changes – Bodie and Pea Islands (Cumulative).....	II-30
Figure II-21. Volume Changes Without Nourishment – Bodie and Pea Islands (Intervals) .....	II-33
Figure II-22. Volume Changes Without Nourishment – Bodie and Pea Islands (Cumulative) .....	II-33
Figure II-23. Fort Macon Terminal Groin .....	II-38
Figure II-24. Fort Macon Revetment-Groin Protection (1961) .....	II-39
Figure II-25. Historical Coastal Charts of Beaufort Inlet in 1876 and 1994 .....	II-40
Figure II-26. Aerial Photographs Showing Shoreline Changes in the Vicinity of Fort Macon Terminal Groin. ....	II-42
Figure II-27. Photographs Illustrating Progradation of the Beach West of the Groin and Along Inlet Shore.....	II-43

---

Figure II-28. Compilation of Historic Shorelines in the Vicinity of Fort Macon Terminal Groin (Cleary, 2009).....	II-44
Figure II-29. A. Dredge Disposal Sites Used in Maintaining Navigation Channels for Morehead City and Beaufort Inlet. B. DEM Showing Build-up of Sand at Nearshore Site.....	II-45
Figure II-30. Digital Elevation Model Illustrating the Relief of the Ebb-tidal Delta. ..	II-47
Figure II-31. Comparison of Bathymetry between ca. 1900 and 2004 (Olsen, 2004)..	II-48
Figure II-32. Historic Shorelines – Fort Macon (Beaufort Inlet).....	II-50
Figure II-33. Fort Macon (Beaufort Inlet) Shoreline Change Calculation Transects ...	II-51
Figure II-34. Shoreline Change – Shackleford Banks and Fort Macon (Intervals) .....	II-53
Figure II-35. Shoreline Change – Shackleford Banks and Fort Macon (Total Average) .....	II-53
Figure II-36. Beach Volume Changes – Fort Macon (Intervals) .....	II-56
Figure II-37. Beach Volume Changes – Fort Macon (Cumulative) .....	II-56
Figure II-38. Volume Changes w/o Nourishment – Shackleford Banks and Fort Macon (Intervals) .....	II-59
Figure II-39. Volume Changes w/o Nourishment – Shackleford Banks and Fort Macon (Cumulative) .....	II-59
Figure II-40. Amelia Island Terminal Groin.....	II-65
Figure II-41. Amelia Island Terminal Groin and Breakwater .....	II-65
Figure II-42. Sequential Vertical Aerial Photographs of Amelia Island between 1994 and 2008 (from Google Earth).....	II-67
Figure II-43. Shoreline Changes on Southern Amelia Island between 2002 and 2008	II-69
Figure II-44. Bathymetric Changes of Nassau Sound Determined from Repetitive Bathymetric Surveys from 2003 - 2008 (Olsen, 2008).....	II-70
Figure II-45. Historic Shorelines – Amelia Island.....	II-72
Figure II-46. Amelia Island Shoreline Change Calculation Transects .....	II-73
Figure II-47. Shoreline Change – Amelia and Little Talbot Islands (Intervals) .....	II-75
Figure II-48. Shoreline Change – Amelia and Little Talbot Islands (Total Average)..	II-75
Figure II-49. Beach Volume Changes – Amelia and Little Talbot Islands (Intervals). II-78	II-78
Figure II-50. Beach Volume Changes – Amelia and Little Talbot Island (Cumulative) .....	II-78
Figure II-51. Volume Changes w/o Nourishment – Amelia and Little Talbot Islands (Intervals) .....	II-81
Figure II-52. Volume Changes w/o Nourishment – Amelia and Little Talbot Islands (Cumulative) .....	II-81
Figure II-53. Captiva Island Terminal Groin .....	II-84
Figure II-54. Terminal Groin Rehabilitation .....	II-84
Figure II-55. View of the Ebb-tidal Delta That Has Been Used as a Source of Sand for Nourishing the Beach Along Captiva Island .....	II-85
Figure II-56. View of the Terminal Groin at Redfish pass .....	II-85
Figure II-57. Shoreline Changes of Beach Inside Redfish Pass .....	II-86
Figure II-58. Sequential Vertical Aerial Photographs of Captiva Inlet between 1994 and 2007.....	II-87

---

Figure II-59. Comparison of Photographs Taken Before and Immediately After the Passage of Hurricane Charley Showing Beach Erosion Inside the Inlet .....	II-88
Figure II-60. Historic Shorelines – Captiva Island .....	II-90
Figure II-61. Captiva Island Shoreline Change Calculation Transects.....	II-91
Figure II-62. Shoreline Change – Captiva and North Captiva Islands (Interval) .....	II-93
Figure II-63. Shoreline Change – Captiva and North Captiva Islands (Total Average) .....	II-93
Figure II-64. Beach Volume Change – Captiva and North Captiva Islands (Intervals) .....	II-96
Figure II-65. Beach Volume Change – Captiva and North Captiva Islands (Cumulative) .....	II-96
Figure II-66. Volume Changes w/o Nourishment – Captiva and North Captiva Islands (Intervals) .....	II-99
Figure II-67. Volume Changes w/o Nourishment– Captiva and North Captiva Islands (Cumulative) .....	II-99
Figure II-68. John's Pass Terminal Groins .....	II-102
Figure II-69. Shoreline Changes Along Madeira Beach between 1957 and 1974.....	II-102
Figure II-70. Historical Morphological Changes of John's Pass from 1883 to 2000 (Davis & Vinther, 2002) .....	II-104
Figure II-71. Vertical Aerial Photograph of the Terminal Groin at the North Side of John's Pass.....	II-105
Figure II-72. Vertical Aerial Photograph of the Terminal Groin at the South Side of John's Pass at the Northern End of Treasure Island.....	II-106
Figure II-73. Sequential Vertical Aerial Photographs of John's Inlet between 1995 and 2008.....	II-107
Figure II-74. Historic Shorelines – John's Pass.....	II-109
Figure II-75. John's Pass Shoreline Change Calculation Transects .....	II-110
Figure II-76. Shoreline Change – Madeira Beach and Treasure Island (Intervals) ....	II-112
Figure II-77. Shoreline Change – Madeira Beach and Treasure Island (Total Average) .....	II-112
Figure II-78. Beach Volume Changes – Madeira Beach and Treasure Island (Intervals) .....	II-115
Figure II-79. Beach Volume Change – Madeira Beach and Treasure Island (Cumulative) .....	II-115
Figure II-80. Volume Changes Without Nourishment – Madeira Beach (Intervals) .....	II-118
Figure II-81. Volume Changes Without Nourishment – Treasure Island (Cumulative) .....	II-118
Figure II-82. Volume Rate Changes Without Nourishment – Oregon Inlet.....	II-126
Figure II-83. Volume Rate Changes Without Nourishment – Fort Macon .....	II-126
Figure II-84. Volume Rate Changes Without Nourishment – Amelia Island.....	II-127
Figure II-85. Volume Rate Changes Without Nourishment – Captiva Island.....	II-127
Figure II-86. Volume Changes Without Nourishment – John's Pass.....	II-128
Figure III-1. Oregon Inlet Terminal Groin and Revetment .....	III-22
Figure III-2. 2001 Oregon Inlet Aerial Photograph .....	III-23

---

Figure III-3. Coastal Classification of Habitat for Oregon Inlet, NC .....	III-26
Figure III-4. Species Occurrence for Oregon Inlet, NC.....	III-28
Figure III-5. Loggerhead Sea Turtle Nesting Data from PINWR .....	III-29
Figure III-6. Seagrass Habitat for Oregon Inlet, NC .....	III-32
Figure III-7. Shorebird Survey Data in the Vicinity of Oregon Inlet .....	III-33
Figure III-8. 1991 Oregon Inlet Aerial Photograph.....	III-35
Figure III-9. 2009 Oregon Inlet Aerial Photograph.....	III-36
Figure III-10. Shorebird and Colonial Waterbird Nesting Activity on Sand Shoal Island, Formerly Located within the Vicinity of Oregon Inlet.....	III-37
Figure III-11. Shorebird and Colonial Waterbird Nesting Activity on the Northern End of PINWR.....	III-37
Figure III-12. Shorebird and Colonial Waterbird Nesting Activity for Oregon Inlet Shoal .....	III-38
Figure III-13. Annual Piping Plover Observations in the Vicinity of Pea Island .....	III-39
Figure III-14. Annual Piping Plover Observations in the Vicinity of Bodie Island Spit .....	III-39
Figure III-15. Beaufort Inlet .....	III-46
Figure III-16. Hard Structure Located on Western End of Shackleford Banks.....	III-47
Figure III-17. Coastal Classification of Habitat for Beaufort Inlet, NC .....	III-49
Figure III-18. Seabeach Amaranth Plants for the Beaufort Inlet Area .....	III-50
Figure III-19. Seagrass Habitat for Beaufort Inlet, NC .....	III-52
Figure III-20. Species Occurrence for Beaufort Inlet, NC.....	III-54
Figure III-21. Sea Turtle Nesting Activity for the Beaufort Inlet Area .....	III-55
Figure III-22. 1998 Aerial Photograph of Beaufort Inlet, NC .....	III-57
Figure III-23. Wilson's Plover Nesting Survey Data (CALO) .....	III-59
Figure III-24. Nesting Surveys for the Least Tern, Black Skimmer, Common Tern, and Gull-Billed Tern (Shackleford Point) .....	III-60
Figure III-25. Annual Least Tern and Wilson's Plover Observations (Fort Macon State Park).....	III-60
Figure III-26. Annual Piping Plover Observations for Fort Macon and Shackleford Banks, NC .....	III-61
Figure III-27. Annual Piping Plover Observations for Core Banks, NC .....	III-62
Figure III-28. Location of Hardbottom and Cultural Resource Surveys Offshore of Beaufort Inlet, Source USACE 2007 .....	III-72
Figure III-29. Amelia Island, Florida.....	III-75
Figure III-30. Coastal Classification of Habitat for Nassau Sound, FL.....	III-79
Figure III-31. Species Occurrence for Nassau Sound, FL .....	III-80
Figure III-32. Sea Turtle Nesting Data from Amelia Island and Little Talbot State Park .....	III-82
Figure III-33. Amelia Island State Park Non-Nesting Shorebird Observations .....	III-85
Figure III-34. Amelia Island Nesting Shorebird Observations .....	III-85
Figure III-35. Bird Islands Non-Nesting Shorebird Observations.....	III-86
Figure III-36. Bird Islands Nesting Shorebird Observations .....	III-86
Figure III-37. Little Talbot Island State Park Non-Nesting Shorebird Observations .....	III-87
Figure III-38. Little Talbot Island State Park Nesting Shorebird Observations .....	III-88

---

Figure III-39. Piping Plover Observations for Little Talbot Island and Bird Islands, Nassau Sound.....	III-90
Figure III-40. Captiva Island, Florida .....	III-94
Figure III-41. Coastal Classification of Habitat for Redfish Pass, FL.....	III-97
Figure III-42. Coastal Habitats of Redfish Pass (1991).....	III-98
Figure III-43. Seagrass and Mangrove Habitat for Redfish Pass, FL.....	III-99
Figure III-44. Species Occurrence for Redfish Pass, FL .....	III-101
Figure III-45. Sea Turtle Nesting Data from Captiva Island, North Captiva State Park, and Sanibel Island West.....	III-102
Figure III-46. John's Pass, Florida.....	III-110
Figure III-47. John's Pass, Florida.....	III-111
Figure III-48. Coastal Classification of Habitat for John's Pass, FL.....	III-114
Figure III-49. Species Occurrence for John's Pass, FL .....	III-115
Figure III-50. Sea Turtle Nesting Data for Mid and North Pinellas Beaches .....	III-116
Figure III-51. Seagrass and Tidal Flats for John's Pass, FL.....	III-117
Figure III-52. Habitat Change for John's Pass, FL from 1999 to 2006 .....	III-118
Figure IV-1. Oregon Inlet Terminal Groin and Revetment .....	IV-2
Figure IV-2. Oregon Inlet Terminal Groin Typical Cross-Section.....	IV-4
Figure IV-3. Fort Macon Terminal Groin Typical Cross-Section .....	IV-5
Figure IV-4. Fort Macon Terminal Groin Initial Construction (1961) .....	IV-6
Figure IV-5. Amelia Island Terminal Groin Cross-Sections .....	IV-8
Figure IV-6. Amelia Island Terminal Groin .....	IV-9
Figure IV-7. 2006 Terminal Groin at Captiva Island .....	IV-10
Figure IV-8. Captiva Island Terminal Groin .....	IV-11
Figure IV-9. John's Pass Terminal Groin Typical Cross-Section .....	IV-13
Figure IV-10. John's Pass Terminal Groins .....	IV-14
Figure IV-11. Difference in Total Average Shoreline Change Rate (ft/yr) .....	IV-16
Figure IV-12. Cumulative Difference in Volume Change Rate (cy/yr) - With Nourishment.....	IV-16
Figure IV-13. Cumulative Difference in Volume Change Rate (cy/yr) - Without Nourishment.....	IV-17
Figure IV-14. Interval Difference in Shoreline Change Rate (ft/yr) .....	IV-17
Figure IV-15. Interval Difference in Volume Change Rate (cy/yr) - With Nourishment.....	IV-18
Figure IV-16. Interval Difference in Volume Change Rate (cy/yr) - Without Nourishment.....	IV-18
Figure IV-17. Typical Terminal Groin Profile .....	IV-22
Figure IV-18. Permeable Groin vs. Typical Groin .....	IV-23
Figure IV-19. Possible Groin Configurations (taken from USACE Coastal Engineering Manual, 2002).....	IV-24
Figure IV-20. Example of Concrete Sheet Piles .....	IV-26
Figure IV-21. Examples of Concrete Armor Units.....	IV-26
Figure IV-22. Example of Steel Sheet Pile Terminal Groin .....	IV-27
Figure IV-23. Example of a Timber Groin .....	IV-28
Figure IV-24. Example of a Geotextile Tube .....	IV-29

---

Figure IV-25 Example of Notched Groins (New Jersey DEP Website).....	IV-30
Figure V-1. 30-yr Risk Line and Sandbags at Beaufort Inlet .....	V-6
Figure V-2. 30-yr Risk Line and Sandbags at Bogue Inlet.....	V-9
Figure V-3. 30-yr Risk Line and Sandbags at New River Inlet.....	V-12
Figure V-4. 30-yr Risk Line and Sandbags at New Topsail Inlet.....	V-15
Figure V-5. 30-yr Risk Line and Sandbags at Rich Inlet.....	V-18
Figure V-6. 30-yr Risk Line and Sandbags at Mason Inlet .....	V-21
Figure V-7. 30-yr Risk Line and Sandbags at Masonboro Inlet .....	V-24
Figure V-8. 30-yr Risk Line and Sandbags at Carolina Beach Inlet .....	V-27
Figure V-9. 30-yr Risk Line and Sandbags at Cape Fear Inlet .....	V-30
Figure V-10. 30-yr Risk Line and Sandbags at Lockwood Folly Inlet.....	V-33
Figure V-11. 30-yr Risk Line and Sandbags at Shallotte Inlet .....	V-36
Figure V-12. 30-yr Risk Line and Sandbags at Tubbs Inlet .....	V-39
Figure VI-1. Terminal Groin Length along a Steep Slope.....	VI-2
Figure VI-2. Terminal Groin Length along a Flat Slope .....	VI-2
Figure VI-3. Rubble Mound Construction.....	VI-3
Figure VI-4. Example of Concrete Sheet Piles .....	VI-4
Figure VI-5. Example of Steel Sheet Pile Terminal Groins .....	VI-5
Figure VI-6. Example of a Timber Groin .....	VI-6
Figure VI-7. Typical Cross Section for Fort Macon Terminal Groin.....	VI-7
Figure VI-8. Oregon Inlet Typical Cross-Section.....	VI-8
Figure VI-9. Amelia Island Terminal Groin Typical Cross-Section .....	VI-9
Figure VI-10. Typical Cross-Section for John's Pass Terminal Groin .....	VI-10
Figure VI-11. Typical Cross Section for Short Groin Scenario.....	VI-12
Figure VI-12. Short Groin along a Flat-Sloped Beach .....	VI-13
Figure VI-13. Short Groin along a Steep-Sloped Beach.....	VI-13
Figure VI-14. Typical Long Groin Scenario Cross Section .....	VI-14
Figure VI-15. Long Groin Cross Section on a Flat-Sloped Beach .....	VI-15
Figure VI-16. Long Groin Cross Section on a Steep-Sloped Beach.....	VI-15
Figure VII-1. Potential Study Sites .....	VII-1

## **List of Tables**

Table I-1. Terminal Groin Study Meetings and Presentations .....	I-3
Table I-2. Public Hearings .....	I-5
Table II-1. Factors Affecting Terminal Groins.....	II-3
Table II-2. Shoreline Change – Bodie Island (Intervals).....	II-26
Table II-3. Shoreline Change – Bodie Island (Total Average) .....	II-26
Table II-4. Shoreline Change – Pea Island (Intervals).....	II-26
Table II-5. Shoreline Change – Pea Island (Total Average).....	II-26
Table II-6. Beach Volume Changes – Bodie Island (Intervals).....	II-29
Table II-7. Beach Volume Changes – Bodie Island (Cumulative) .....	II-29
Table II-8. Beach Volume Changes – Pea Island (Intervals).....	II-29
Table II-9. Beach Volume Changes – Pea Island (Cumulative) .....	II-29
Table II-10. Beach Nourishment and Nearshore Placement – Pea Island .....	II-31
Table II-11. Beach Nourishment and Nearshore Placement – Pea Island .....	II-31
Table II-12. Volume Changes Without Nourishment – Bodie Island (Intervals).....	II-32
Table II-13. Volume Changes Without Nourishment – Bodie Island (Cumulative) ....	II-32
Table II-14. Volume Changes Without Nourishment – Pea Island (Intervals).....	II-32
Table II-15. Volume Changes Without Nourishment – Pea Island (Cumulative) .....	II-32
Table II-16. Dredging Volumes – Oregon Inlet.....	II-34
Table II-17. Dredging Volumes – Oregon Inlet.....	II-35
Table II-18. Volume Change Scenarios Including Dredging Effects – Bodie Island (3 miles).....	II-35
Table II-19. Volume Change Scenarios Including Dredging Effects – Pea Island (6 miles) .....	II-35
Table II-20. Shoreline Change – Shackleford Banks (Interval) .....	II-52
Table II-21. Shoreline Change – Shackleford Banks (Total Average) .....	II-52
Table II-22. Shoreline Change – Fort Macon (Interval) .....	II-52
Table II-23. Shoreline Change – Fort Macon (Total Average) .....	II-52
Table II-24. Beach Volume Changes – Shackleford Banks (Intervals).....	II-55
Table II-25. Beach Volume Changes – Shackleford Banks (Cumulative) .....	II-55
Table II-26. Beach Volume Changes – Fort Macon (Intervals) .....	II-55
Table II-27. Beach Volume Changes – Fort Macon (Cumulative).....	II-55
Table II-28. Beach Nourishment – Fort Macon.....	II-57
Table II-29. Beach Nourishment – Fort Macon.....	II-57
Table II-30. Volume Changes Without Nourishment – Shackleford Banks (Intervals).....	II-58
Table II-31. Volume Changes Without Nourishment – Shackleford Banks (Cumulative) .....	II-58
Table II-32. Volume Changes Without Nourishment – Fort Macon (Intervals) .....	II-58
Table II-33. Volume Changes Without Nourishment – Fort Macon (Cumulative).....	II-58
Table II-34. Dredging Volumes – Beaufort Inlet.....	II-61
Table II-35. Dredging Volumes – Beaufort Inlet.....	II-61
Table II-36. Volume Change Scenarios Without Nourishment and Dredging – Shackleford Banks (3 miles) .....	II-62

Table II-37. Volume Change Scenarios Without Nourishment and Dredging – Fort Macon (3 miles) .....	II-62
Table II-38. Shoreline Change – Amelia Island (Intervals).....	II-74
Table II-39. Shoreline Change – Amelia Island (Total Average).....	II-74
Table II-40. Shoreline Change – Little Talbot Island (Intervals) .....	II-74
Table II-41. Shoreline Change – Little Talbot Island (Total Average) .....	II-74
Table II-42. Beach Volume Changes – Amelia Island (Intervals).....	II-77
Table II-43. Beach Volume Changes – Amelia Island (Cumulative).....	II-77
Table II-44. Beach Volume Changes – Little Talbot Island (Intervals) .....	II-77
Table II-45. Beach Volume Changes – Little Talbot Island (Cumulative).....	II-77
Table II-46. Beach Nourishment – Amelia Island .....	II-79
Table II-47. Beach Nourishment – Amelia Island .....	II-79
Table II-48. Volume Changes Without Nourishment – Amelia Island (Intervals).....	II-80
Table II-49. Volume Changes Without Nourishment – Amelia Island (Cumulative) ..	II-80
Table II-50. Volume Changes Without Nourishment – Little Talbot Island (Intervals) .....	II-80
Table II-51. Volume Changes Without Nourishment – Little Talbot Island (Cumulative) .....	II-80
Table II-52. Shoreline Change – Captiva Island (Intervals) .....	II-92
Table II-53. Shoreline Change – Captiva Island (Total Average) .....	II-92
Table II-54. Shoreline Change – North Captiva Island (Intervals).....	II-92
Table II-55. Shoreline Change – North Captiva Island (Total Average).....	II-92
Table II-56. Beach Volume Changes – Captiva Island (Intervals) .....	II-95
Table II-57. Beach Volume Changes – Captiva Island (Cumulative) .....	II-95
Table II-58. Beach Volume Changes – North Captiva Island (Intervals).....	II-95
Table II-59. Beach Volume Changes – North Captiva Island (Cumulative) .....	II-95
Table II-60. Beach Nourishment – Captiva Island .....	II-97
Table II-61. Beach Nourishment – Captiva Island .....	II-97
Table II-62. Volume Changes Without Nourishment – Captiva Island (Intervals).....	II-98
Table II-63. Volume Changes Without Nourishment – Captiva Island (Cumulative) .	II-98
Table II-64. Volume Changes Without Nourishment – North Captiva Island (Intervals) .....	II-98
Table II-65. Volume Changes Without Nourishment – North Captiva Island (Cumulative) .....	II-98
Table II-66. Shoreline Change – Madeira Beach (Intervals) .....	II-111
Table II-67. Shoreline Change – Madeira Beach (Total Average) .....	II-111
Table II-68. Shoreline Change – Treasure Island (Intervals) .....	II-111
Table II-69. Shoreline Change – Treasure Island (Total Average) .....	II-111
Table II-70. Beach Volume Changes – Madeira Beach (Intervals).....	II-114
Table II-71. Beach Volume Changes – Madeira Beach (Cumulative) .....	II-114
Table II-72. Beach Volume Changes – Treasure Island (Intervals) .....	II-114
Table II-73. Beach Volume Changes – Treasure Island (Cumulative).....	II-114
Table II-74. Beach Nourishment – Treasure Island.....	II-116
Table II-75. Beach Nourishment – Treasure Island.....	II-116
Table II-76. Volume Changes Without Nourishment – Madeira Beach (Intervals)...	II-117

Table II-77. Volume Changes Without Nourishment – Madeira Beach (Cumulative) .....	II-117
Table II-78. Volume Changes Without Nourishment – Treasure Island (Intervals) ..	II-117
Table II-79. Volume Changes Without Nourishment – Treasure Island (Cumulative) .....	II-117
Table II-80. Dredging Volumes – John’s Pass .....	II-119
Table II-81. Dredging Volumes – John’s Pass .....	II-119
Table II-82. Volume Change Scenarios Without Nourishment and Dredging – Madeira Beach.....	II-120
Table II-83. Volume Change Scenarios Without Nourishment and Dredging – Treasure Island.....	II-120
Table II-84. Environmental Climate of the Five Study Sites.....	II-121
Table II-85. Terminal Groin Physical Characteristics .....	II-121
Table II-86. Comparison of the Shoreline Change Rates .....	II-124
Table II-87. Shoreline Change to Beach Volume Ratios.....	II-124
Table II-88. Total Annual Beach Nourishment .....	II-125
Table II-89. Volume Changes Without Nourishment.....	II-125
Table II-90. Dredging Summary.....	II-129
Table II-91. Volume Change Scenario Net Nourishment and Dredging – 25% Scenario .....	II-129
Table II-92. Volume Change Scenario Net Nourishment and Dredging - 50% Scenario .....	II-130
Table III-1. Enumerated list of representatives contacted for environmental data and/or information as it relates to terminal groins .....	III-2
Table III-2. Threatened and endangered species potentially present within the selected study sites.....	III-11
Table III-3. Sea turtle management zones south of Oregon Inlet .....	III-30
Table III-4. Sea turtle management zones north of Oregon Inlet .....	III-30
Table III-5. Piping plover counts--results of Morehead City Audubon Christmas Bird Count, for 1971 through 2008.....	III-63
Table III-6. Peak larval abundance of seven important fish species near Beaufort Inlet .....	III-66
Table III-7. Shorebird species confirmed to nest in the Nassau Sound area, with known nesting locations indicated.....	III-84
Table III-8. Fish species within and adjacent to the Nassau Sound.....	III-92
Table III-9. Common bird species within the vicinity of Redfish Pass .....	III-105
Table III-10. Number of shorebird nests on Sanibel Island in 2002 and 2003 .....	III-106
Table III-11. Commercial values of fish species harvested in Lee County for the period between 1992 through 1998.....	III-108
Table III-12. Invertebrates within and adjacent to John’s Pass .....	III-121
Table IV-1. Oregon Inlet Terminal Groin and Revetment Structural Information.....	IV-3
Table IV-2. Fort Macon Terminal Groin Structural Information .....	IV-5
Table IV-3. Amelia Island Terminal Groin Structural Information .....	IV-7
Table IV-4. John's Pass Terminal Groin Structural Information .....	IV-12
Table IV-5 Groin Lengths for Five Study Sites.....	IV-15

---

Table IV-6. Groin Height Relative to MTL for Five Study Sites .....	IV-19
Table V-1. Economic Value at Risk Within 30-yr Risk Lines at Beaufort Inlet .....	V-7
Table V-2. Economic Value at Imminent Risk (Sandbags) – Beaufort Inlet .....	V-8
Table V-3. Economic Value at Risk Within 30-yr Risk Lines at Bogue Inlet.....	V-10
Table V-4. Economic Value at Imminent Risk (Sandbags) – Bogue Inlet.....	V-11
Table V-5. Economic Value at Risk Within 30-yr Risk Lines at New River Inlet.....	V-13
Table V-6. Economic Value at Imminent Risk (Sandbags) – New River Inlet.....	V-14
Table V-7. Economic Value at Risk Within 30-yr Risk Lines at New Topsail Inlet ...	V-16
Table V-8. Economic Value at Imminent Risk (Sandbags) – New Topsail Inlet.....	V-17
Table V-9. Economic Value at Risk Within 30-yr Risk Lines at Rich Inlet .....	V-19
Table V-10. Economic Value at Imminent Risk (Sandbags) – Rich Inlet.....	V-20
Table V-11. Economic Value at Risk Within 30-yr Risk Lines at Mason Inlet .....	V-22
Table V-12. Economic Value at Imminent Risk (Sandbags) – Mason Inlet .....	V-23
Table V-13. Economic Value at Risk Within 30-yr Risk Lines at Masonboro Inlet....	V-25
Table V-14. Economic Value at Imminent Risk (Sandbags) – Masonboro Inlet .....	V-26
Table V-15. Economic Value at Risk Within 30-yr Risk Lines at Carolina Beach Inlet .....	V-28
Table V-16. Economic Value at Imminent Risk (Sandbags) – Carolina Beach Inlet... V-29	
Table V-17. Economic Value at Risk Within 30-yr Risk Lines at Cape Fear Inlet..... V-31	
Table V-18. Economic Value at Imminent Risk (Sandbags) – Cape Fear River Inlet . V-32	
Table V-19. Economic Value at Risk Within 30-yr Risk Lines at Lockwood Folly Inlet .....	V-34
Table V-20. Economic Value at Imminent Risk (Sandbags) – Lockwood Folly Inlet. V-35	
Table V-21. Economic Value at Risk Within 30-yr Risk Lines at Shallotte Inlet..... V-37	
Table V-22. Economic Value at Imminent Risk (Sandbags) – Shallotte Inlet .....	V-38
Table V-23. Economic Value at Risk Within 30-yr Risk Lines at Tubbs Inlet .....	V-40
Table V-24. Economic Value at Imminent Risk (Sandbags) – Tubbs Inlet .....	V-41
Table VI-1. Fort Macon Terminal Groin Estimated Costs .....	VI-7
Table VI-2. Oregon Inlet Terminal Groin Estimated Costs.....	VI-8
Table VI-3. Amelia Island Terminal Groin Estimated Costs .....	VI-9
Table VI-4. John's Pass Terminal Groin Estimated Costs .....	VI-11
Table VI-5. Captiva Island Terminal Groin Estimated Costs.....	VI-11
Table VI-6. Short Groin Scenario Unit Costs .....	VI-12
Table VI-7. Long Groin Scenario Unit Costs .....	VI-16
Table VI-8. Summary of Estimated Costs for 5 Selected Sites .....	VI-18
Table VI-9. Estimated Costs for Potential North Carolina Groins .....	VI-19
Table VI-10. Total Project Costs .....	VI-20
Table VII-1. Potential Terminal Groin Study Site Locations .....	VII-2
Table VII-2. Environmental Conditions at Five Selected Study Sites.....	VII-3
Table VII-3. Dredging Summary .....	VII-4