

NC 12 Transportation Management
Plan – Phase II
Peer Exchange Meeting

for

NC 12 Replacement of
Herbert C. Bonner Bridge

(Bridge No. 11) over Oregon Inlet

TIP Project No. B-2500
Dare County, North Carolina

Federal Highway Administration
North Carolina Department of Transportation

Final Report

June 2012

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1.0 Executive Summary

Background

On October 24 and 25, 2011, NCDOT assembled a Panel of coastal science and engineering experts from the Federal Highway Administration (FHWA), the US Army Corps of Engineers (USACE), the US Fish and Wildlife Service (USFWS) Pea Island National Wildlife Refuge (Refuge), and several universities. This meeting was held as part of Phase II of the Bonner Bridge Replacement Project, which includes the replacement of the Herbert C. Bonner Bridge over Oregon Inlet and the long-term maintenance of NC 12 between Oregon Inlet and Rodanthe. The Selected Alternative for the project is titled the Parallel Bridge Corridor with NC 12 Transportation Management Plan Alternative. It is described in Section 3.3.2 of the project's Record of Decision (ROD).

As a part of the NC 12 Transportation Management Plan, NCDOT committed to work together with USFWS to develop and assess alternative future scenarios including possible site-specific events and remedies, in part through the implementation of a periodic Refuge habitat/NC 12 vulnerability study. The October 2011 Panel was conducted as a part of meeting this commitment in the context of the changes in the setting at both Pea Island and at Rodanthe as a result of Hurricane Irene.

Objectives

The meeting agenda focused on asking Panel members to address the following issues:

- Changes in coastal conditions as a result of Hurricane Irene (Section 3.1);
- Potential long-term transportation options for the Pea Island inlet site (Section 3.2);
- Potential long-term transportation options for the Rodanthe breach site (Section 3.3); and
- Recommendations on future coastal studies for the entire project area (Section 3.4).

Key Findings and Recommendations

The Panel's key findings and recommendations were:

- Both the Pea Island and the Rodanthe breaches were caused by a soundside storm surge as a result of Hurricane Irene passing west of Hatteras Island in Pamlico Sound.
- Pea Island Inlet
 - At the Pea Island inlet, there will continue to be a risk of future beach erosion and storm dependent inlet formation.

- The future of the Pea Island inlet, including whether it will close on its own or remain open, is uncertain. If the inlet remains open, it would migrate to the south. The inlet should be monitored and actions taken to protect the temporary bridge as needed. Sheet piling could be used to help close the inlet or help keep it from moving farther south.
 - If constructing a bridge in the existing NC 12 easement, the height of the bridge should be determined based upon waves, tides, storm surge, and overwash. The bridge should span the New Inlet Complex (area prone to inlet formation).
 - The Panel agreed that nourishment is not a good long-term solution at the Pea Island inlet because it would not address the area's proneness to inlet formation.
 - The Panel did not come to a consensus as to whether filling the inlet and rebuilding NC 12 in the existing easement was a good long-term solution, but USFWS did not like the idea of closing the inlet because it prefers to allow natural processes to occur.
- Rodanthe Breach
 - The Panel agreed that a bridge within the existing NC 12 easement/right-of-way is not the best long-term solution at the Rodanthe breach site because of the high shoreline erosion rate in the area. The panel was concerned such an alternative would ultimately result in the structure being in the ocean a notable distance from shore.
 - The Panel agreed that placing NC 12 on a bridge in the sound was a better option than a bridge in the existing NC 12 easement because it would be less vulnerable to potential future changes in Hatteras Island resulting from shoreline erosion and breach formation.
 - The Panel recommended that beach nourishment not be used as a long-term solution at the Rodanthe breach site.
 - The Panel indicated that road relocation to the west in Rodanthe could be considered, but the Panel acknowledged that impacts to the Refuge, wetlands, and homes within Rodanthe are concerns with that alternative.
 - Two other options, each suggested by individual panelists, were the construction of a bridge in Pamlico Sound from just north of Pea Island inlet to Rodanthe (approximately 6 to 7 miles in length) and the expansion of the existing NCDOT ferry system.
 - The Panel recommended considering the strategies and data collection activities discussed in Section 3.4.3 to assist with future coastal monitoring efforts in the project area, including monitoring the Pea Island inlet's future performance.

Next Steps

After completion of the summary report for the Peer Exchange Meeting, the following steps will take place in the near-term:

- The meeting summary will be made available to the agency partners and the public.
- Actions that NCDOT will pursue to protect the temporary bridge (e.g., installing temporary sheet piling) will be assessed.
- NCDOT will update the beach nourishment cost at Rodanthe.
- A Concurrence Point 2 Merger Meeting with the Merger Team agencies to discuss Phase II alternatives will take place in December 2011.
- Investigations and further discussions concerning the alternative suggested by Mr. Stewart (i.e., a bridge in Pamlico Sound from north of the Pea Island inlet to the southern end of the Bridge South Alternative in Rodanthe) will occur.

2.0 Introduction

2.1 Project Description

The Bonner Bridge Replacement Project consists of both the replacement of Bonner Bridge over Oregon Inlet (Phase I) and future phases that provide for the long-term maintenance of NC 12 from Oregon Inlet to Rodanthe. NCDOT has begun implementing its Selected Alternative (Parallel Bridge Corridor with NC 12 Transportation Management Plan Alternative), as documented in the December 2010 ROD.

Hurricane Irene hit the North Carolina coast on August 27, 2011, and breached NC 12 in two locations – northern Rodanthe (the “Rodanthe breach”) and within the Pea Island National Wildlife Refuge (Refuge) approximately six miles south of Oregon Inlet (the “Pea Island inlet”). As a result of the damage caused by the storm in these locations and the “temporary” nature of the current repairs, NCDOT decided that Phase II of the Bonner Bridge Replacement project will consist of long-term NC 12 modifications in the two breach areas.

Temporary repairs at the Pea Island inlet consisted of building a temporary bridge over the inlet. The temporary bridge is 662 feet long with 5 spans and 4 internal bents, with 200 feet of sheet piling around the end bents (i.e., the foundation at the end of the bridge structure). NCDOT is monitoring changes to the Pea Island inlet and intends to retrofit bridge and road protection systems, as needed, so that the temporary bridge can fulfill its function until a long-term Phase II project is completed. At the Rodanthe breach, sand was used to close the breach and re-build the roadbed. The sand-bag filled dune just north of Rodanthe was repaired. NCDOT is monitoring road and dune conditions

at the Rodanthe breach and intends to make repairs, as needed, until a long-term Phase II project is completed.

The project area for the Parallel Bridge Corridor with NC 12 Transportation Management Plan Alternative is shown in Figure 1, along with the location of Phases I and II of the project. Natural features within the project area include coastal wetlands, submerged aquatic vegetation, and wildlife and fish habitats. Along NC 12, there are three “hot spots” where the roadway is most vulnerable to overwash and shoreline erosion. The coastal conditions within the project area include five potential breach locations; shoreline erosion caused by ocean waves, tides, and storms; accelerated sea level rise; and inlet migration. As a result of these conditions, the project alternatives considered as part of the Selected Alternative take into consideration a high-erosion 2060 shoreline and the potential breach locations so as to withstand potential future changes to coastal conditions.

2.2 Meeting Purpose and Expected Outcomes

As a part of the NC 12 Transportation Management Plan, a meeting was held with a Panel of coastal scientists and engineers on October 24 to 25, 2011. The purposes of the meeting were to:

- Evaluate the changes in the setting at both Pea Island and at Rodanthe as a result of Hurricane Irene;
- Provide engineering advice regarding the design constraints of long-term options at both locations; and
- Identify any concerns regarding the future maintenance of NC 12.

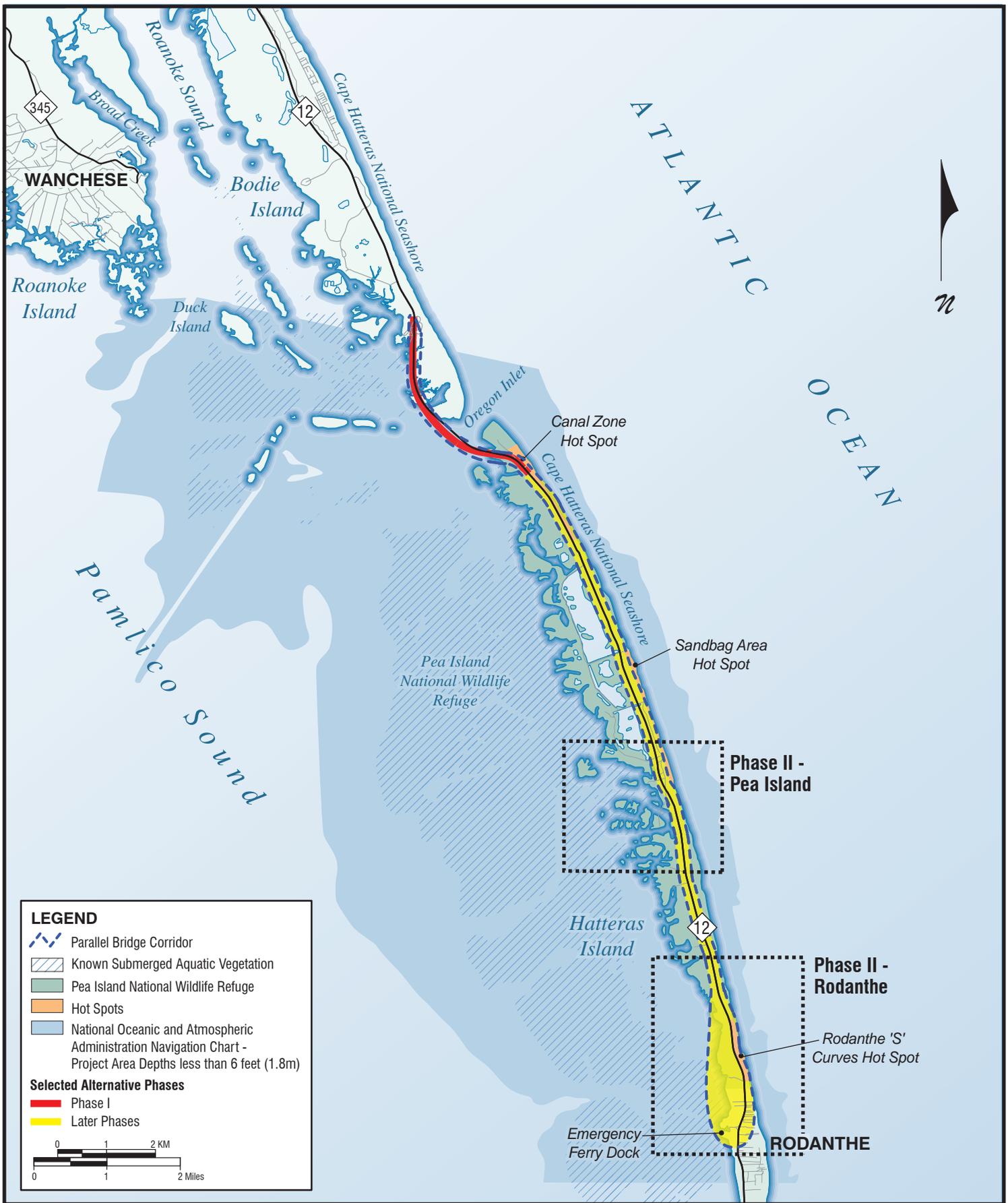
The outcomes that NCDOT expected to gain from the meeting included:

- An evaluation of previous project area coastal and natural resource studies;
- A forecast of changes to the area setting;
- Recommendations of long-term options for the Pea Island site and the Rodanthe site; and
- Recommendations regarding future monitoring of coastal conditions.

2.3 List of Attendees

2.3.1 Peer Exchange Panel Members

In order to assemble a Panel of coastal scientists and engineers with the knowledge and skill sets to assist decision-makers, NCDOT and FHWA, along with the USFWS,



PARALLEL BRIDGE CORRIDOR WITH NC 12 TRANSPORTATION MANAGEMENT PLAN ALTERNATIVE AND PHASE I AND II LOCATIONS

Figure
1

suggested names of people based on areas of expertise. The goal in selecting Panel members was to obtain a range of experience while also having those with specific knowledge of the project area. The Panel members who attended were:

Dr. Robert Dolan
Professor
Department of Environmental Sciences
University of Virginia

Dave Henderson
Senior Hydraulic Engineer
Federal Highway Administration

Dr. Margery Overton
Professor of Coastal and Environmental Engineering
Department of Civil, Construction, and Environmental Engineering
NC State University

Dr. Stan Riggs
Professor of Geology
Thomas Harriot College of Arts and Sciences
East Carolina University

Spencer Rogers
Coastal Construction and Erosion Specialist
NC Sea Grant

Dr. Max Sheppard
President
Ocean Engineering Associates, Inc.
Professor Emeritus
Coastal and Oceanographic Engineering Department
University of Florida

Dr. Greg Williams
Chief, Engineering Branch
US Army Corps of Engineers – Wilmington District

Dennis Stewart
Refuge Biologist
US Fish and Wildlife Service
Pea Island National Wildlife Refuge

2.3.2 Other Attendees

In addition to the peer exchange Panel members, other agency and NCDOT staff attended the meeting to provide technical expertise and project background, as well as to assist in facilitating the meeting. These other attendees were:

Cathy Brittingham – NCDENR-DCM
Donna Dancausse – FHWA
John Sullivan – FHWA
Ron Lucas – FHWA
Earl Dubin – FHWA
Clarence Coleman – FHWA
Jim Trogdon – NCDOT – Chief Operating Officer
Jerry Jennings – NCDOT – Division 1
Beth Smyre – NCDOT – Project Development and Environmental Analysis (PDEA)
Brittney Kelly – NCDOT – PDEA
Rob Hanson – NCDOT – PDEA
Karen Capps – NCDOT – PDEA
Brian Yamamoto – NCDOT – PDEA
Steve Mitchell – NCDOT – Natural Environment Unit
Kathy Herring – NCDOT – Natural Environment Unit
Jerry Lindsey – NCDOT – Hydraulics Unit
Marshall Clawson – NCDOT – Hydraulics Unit
Gary Lovering – NCDOT – Roadway Design
Glenn Mumford – NCDOT – Roadway Design
David Hering – NCDOT – Transportation Program Management Unit
Greg Perfetti – NCDOT – Structure Design Unit
John Page – Parsons Brinckerhoff
Bobby Norburn – Parsons Brinckerhoff

2.4 Meeting Format

The peer exchange meeting followed the agenda that is included in Appendix A. The meeting began with presentations by NCDOT on the overall project and on current and potential future coastal conditions. The slides from these presentations are included in Appendix C. These presentations were followed by Panel discussions of post-Hurricane Irene project area conditions, potential long-term options for the Pea Island inlet and Rodanthe breach sites, and recommendations on future coastal studies and monitoring for the project area.

Prior to the peer exchange meeting, NCDOT mailed an information letter to each Panel member on October 13, 2011 (see Appendix B). Attached to the letter was a packet of information that included: the meeting agenda; a list of potential questions that NCDOT could ask; and two DVDs that contained recent aerial photography of the project area

and a sampling of the previous coastal studies that had been completed as part of the Bonner Bridge Replacement Project and other NC 12 studies (see Appendix B).

3.0 Panel Discussions

3.1 Post-Irene Project Area Conditions

3.1.1 Objectives

The first task for the Panel was an analysis of the post-Hurricane Irene project area conditions. The objectives of this part of the Panel discussion were to:

- Identify the main changes to the Phase II project area (see Figure 1);
- Identify the aspects of the storm that caused these changes;
- Determine the long-term implications to the Phase II project area of these storm-related changes; and
- Determine how these changes might affect habitat and NC 12 within the Pea Island National Wildlife Refuge and in the Rodanthe area.

3.1.2 Discussion

Contributing Factors to Formation of Pea Island Inlet

The Panel members discussed the contributing factors to the formation of the Pea Island inlet as a result of Hurricane Irene. The Panel members agreed that Hurricane Irene produced a soundside (western shore) storm surge that caused the breach that led to the Pea Island inlet. The Panel members also agreed that the strongest part of the storm was backside surf caused by the 6- to 7-foot storm surge, driven by strong northwest winds.

Panel members discussed previous storm-created inlets in the vicinity of the Pea Island inlet, as well as the historic trends in the subsequent migration of these inlets. It was also noted that the Pea Island inlet is part of the New Inlet channel complex, which consisted of multiple channels in the vicinity of the former New Inlet.

Dr. Overton discussed data illustrating pre-storm and post-storm elevations. There was general Panel consensus that topography was a contributing factor in the formation of the inlet. Consistent with Dr. Riggs' work, Dr. Overton said that studies have also confirmed that geological formations also contributed to the breach locations.

Mr. Rogers noted that ocean water level elevations also may have contributed to the formation of the Pea Island inlet.

NCDOT staff and some panelists noted that Pamlico Sound possibly went dry in some areas during the storm.

After reviewing a draft description of the Panel findings included in this report, several Panel members provided additional thoughts on the contributing factors to the formation of the Pea Island inlet:

- Mr. Rogers said that although the shoreline erosion threat to NC 12 near the Pea Island inlet is much lower than many other sections of NC 12, he believes that the risk of an inlet breach prior to Hurricane Irene was moderate to high in this area because of the low ground elevations, the adjacent soundside channels, the paved driveway to the Refuge maintenance facility, and the wildlife impoundment dikes north of the breach. He said that he believes the last two man-induced factors in particular were significant in the opening location of Pea Island inlet. He noted that the inlet opening following the previous driveway alignment was not coincidental, in that the shore-perpendicular paving affected the speed of water flow. In addition, the 4 miles of higher elevation dikes for the wildlife impoundment to the north would have at least limited, if not prevented, the soundside storm surge from overtopping that section of the island, funneling more flow toward the breach after it opened.
- Mr. Henderson indicated that he mostly concurred with Mr. Roger's comments, but had some additional thoughts related to the paved driveway. He believes that the driveway pavement was less of a factor than the driveway being situated at the same location as the toe and rise in natural topography in this part of the island, which is likely the fundamental reason the Refuge located their maintenance facility there. He added that another contributing factor was likely the influence of the dune line that was reconstructed when NC 12 was relocated in this area. The southern flank of the inlet is situated where natural vegetated dunes align with reconstructed dunes. The post-storm debris line indicates the stability of the reconstructed dune line. The natural dunes on the southern flank, however, had deteriorated in height and mass, and this area is at the same location as the inlet.

Contributing Factors to Formation of Rodanthe Breach

Panel members discussed the contributing factors to the formation of the Rodanthe breach, concluding that the damage at the Rodanthe site was also caused by the storm surge from the sound. Dr. Riggs added that the storm surge created the breach and flooded man-made ditches. Panel members agreed that the breaches were not caused by the storm surge on the ocean side.

Dr. Overton said that the theory of soundside overwash was affirmed by the absence of damage to sandbags on the east side of NC 12 that remained intact during the storm.

Panel members agreed that the ponds located on the west side of NC 12 were not a factor in the Rodanthe breach.

Dr. Riggs said that Wimble Shoals is the cause of high wave energy in the Rodanthe area. Wimble Shoals is a rock formation offshore that causes high wave refraction. Though it was not a factor in the recent Rodanthe breach, it is one factor in why beach erosion rates are historically high at the north end of Rodanthe.

Potential Future Coastal Conditions at Pea Island Inlet

Panel members discussed the possible future behavior of the Pea Island inlet and had differing opinions regarding whether or not the inlet may close naturally in the future. Dr. Dolan suggested that it is likely that the inlet will close rapidly, within a year, noting that the pilings of the temporary bridge may influence sediment transport behavior and facilitate closure of the inlet. He added that NCDOT could close the inlet quickly if it wished. There are measures that could be taken to accelerate the filling in of the inlet. Installing sheet piling across the breach to an elevation near the top of the water line, which would reduce the energy of the water flow, was specifically mentioned by Panel members. Mr. Rogers agreed that the inlet will eventually close, but he was not sure about the timing of the closure. Dr. Overton said that water velocities will help to forecast inlet behavior.

Dr. Dolan said the future of the Pea Island inlet also will be determined by future storm surges. Dr. Riggs showed a chart of recent storm activity. He said the trends indicate that we are in a high activity period for storms, so the inlet could stay open. He agreed that whether or not the inlet stays open is somewhat storm dependent. Dr. Riggs reiterated that there likely will be an active storm period this decade, possibly resulting in additional inlets opening and closing in this area.

In reviewing recent aerial photography of the site (provided during the meeting), Dr. Overton noted that the spit formation at the Pea Island breach (as shown in aerial photography of the site) during the second week of October was a surprise to her. Dr. Dolan and Dr. Sheppard said that the Pea Island inlet was similar to Oregon Inlet in that both inlets are naturally inclined to migrate south. Dr. Sheppard noted that the roadway to the Refuge buildings (just south of the inlet) may inhibit some of the inlet's potential southward migration. Dr. Riggs said that undercutting will occur in the vicinity of the driveway, and eventually the driveway will be washed away, allowing the southward migration of the inlet to continue. Dr. Riggs also affirmed that the southern migration of the inlet is consistent with historical trends.

Dr. Riggs noted that the inlets "breathe," a process of contraction and opening that is dependent on storms. He also discussed the expansion and contraction of Oregon Inlet that occurred until the groin was built; currently, only the north shoulder of Oregon Inlet fluctuates. Dr. Riggs described the New Inlet complex as a series of historic tidal channels that are vulnerable to breaches, and he discussed which channels may open

next in the New Inlet area and which areas are more stable. He also discussed the locations of old flood tide deltas in the area to the south of the Pea Island inlet.

Mr. Rogers discussed the shorter-term evolution of the Pea Island site. He predicted that the small channels adjoining the main inlet will fill in and close. He explained that there would be no offshore shoaling initially, but shoaling would grow in the future. He thought the inlet would be filled-in by natural processes by next summer because there is not enough water flow to the inlet and longshore sand transfer would close it.

Mr. Stewart said that, from the perspective of what is best for wildlife, it is his opinion that the inlet should remain and not be closed artificially. He believes that habitat for shorebirds has improved in the vicinity of the inlet as a result of the moist substrate, intertidal pools, quality of habitat, increase of habitat types, and overwash terraces. Mr. Stewart explained that providing shorebird habitat is one of the primary purposes of the Refuge, so the Refuge will not take any measures to close the inlet.

The Hurricane Isabel (2003) inlet was discussed by Panel members. Several Panel members expressed that the Isabel inlet was not a good indicator of forecasting the future of the Pea Island inlet. Dr. Williams said that the Isabel inlet was growing at the time it was filled. Dr. Riggs said that Hurricane Isabel blew out tidal channels and undercut peat banks, resulting in the widening of the breach and erosion.

Dr. Sheppard said that Pamlico Sound was large enough to support additional inlets; the historical data indicated the ability of the sound to support multiple inlets, so he was somewhat surprised that inlets located at the New Inlet complex have always closed in the past.

Mr. Stewart discussed that sea level rise will affect coastal processes in the future. Mr. Rogers said that sea level rise will likely affect erosion, but not necessarily inlet formation.

Dr. Overton referenced a 1948 study concerning the barrier islands. Dr. Overton noted that New Inlet opened in 1875 and closed in 1922. In 1924, the inlet was dredged, but closed naturally within hours. In 1932, New Inlet reopened in about the same location as the Pea Island inlet as a result of soundside storm surge. It grew to 600 to 800 feet wide and 7 feet deep, with a flow rate of 3.5 cubic feet/second. The inlet migrated approximately 0.5 mile to the south and eventually closed in 1939.

Although the Panel did not come to a consensus as to whether or not the Pea Island inlet will close naturally, the Panel did agree that if the inlet stayed open, southward migration was likely.

Dr. Riggs indicated that Dr. Overton's forecasts of potential future shoreline positions and the assumptions used in the study prepared for previous Bonner Bridge project

environmental impact documentation (documented on page 3-57 of the FEIS) were appropriate.

The Panel summarized that the future performance of the inlet depends on the following factors:

- Storm activity
- Storm surge
- Storm direction
- Sand placement/displacement
- Tide range

Potential Future Coastal Conditions at Rodanthe Breach

The Panel discussed that the erosion rates at Mirlo Beach (Rodanthe) were amongst the highest rates along the North Carolina coast. Mr. Rogers noted that the erosion is not necessarily linear along the breach, with high erosion at the north end of the beach, and accretion at the south end.

Dr. Riggs said that inlets need to occur in this area and that flushing of the water from the sound through the inlet to the ocean needs to occur. Flushing is the natural process of water current removing sediment deposited by waves and currents. This flushing process reduces the potential for the inlet to be blocked by sand. Dr. Riggs noted that this site is similar to the Hurricane Isabel inlet site.

3.1.3 Findings

Pea Island Inlet

The Panel indicated that the following factors contributed to the formation and location of the Pea Island inlet:

- Storm surge from the Pamlico Sound as a result of the hurricane passing to the west of Hatteras Island in the sound.
- The inlet occurred at a point with low topography, and an opening in the marsh islands west of Hatteras Island.
- The location of the breach was within the historic New Inlet complex, and there is a history of inlets opening and closing at this location. The last time New Inlet opened, it was near this location.

The Panel indicated the following about potential future conditions at the Pea Island inlet and the potential effect of changed conditions on the temporary bridge:

- The Panel indicated that the Pea Island inlet could close naturally in the near-term or could remain open as it has in the past, but the Panel did not reach consensus on this issue. The Panel agreed that the inlet is likely to migrate to the south if it remains

open. They also agreed that the smaller channels created by Hurricane Irene at the Pea Island inlet would likely fill in naturally, and that an offshore shoal would grow over time near the inlet if it remains open.

- The Panel indicated that future conditions at the Pea Island inlet would be highly dependent on future storm activity and resulting storm surge direction, and that the inlet should be closely monitored to help assess its future behavior.
- The Panel expressed that this section of NC 12 will continue to be vulnerable to future storm-related damages, but the Panel indicated that this area is likely more vulnerable to inlet formation than to beach erosion.
- The Panel agreed that elements related to the temporary bridge, such as bridge piles and sheet piling, would affect the migration and performance of the Pea Island inlet.
- Finally, Mr. Stewart believes that Refuge habitat has improved in the vicinity of the Pea Island inlet in terms of providing a higher diversity of habitat for birds and providing for fish movement between the ocean and sound. Refuge management's preference is for the inlet to remain open, but they also want to let natural processes take their course even if this leads to the inlet closing.

Breach North of Rodanthe

The Panel indicated that the following factors contributed to the formation of the breach north of Rodanthe:

- The Panel found that the damage at the Rodanthe site was caused by a soundside storm surge as a result of the hurricane passing west of Hatteras Island in Pamlico Sound. This storm surge flooded a man-made ditch to the west of the breach location and continued to the ocean to create the breach.
- The subsurface rock structure (Wimble Shoals) in the vicinity of the northern Rodanthe area concentrates wave energy in the area and leads to wave refraction that contributes to high beach erosion and vulnerability for breaches. This also contributes to the susceptibility of the area to ocean flooding and overwash, but was not a factor in this particular breach since the surge came from the sound side.
- Mr. Stewart did not believe that there was a significant change to Refuge habitat in the vicinity of the Rodanthe breach.

3.2 Potential Long-Term Options for Pea Island Inlet Site

3.2.1 Objectives

The second topic on the agenda was the potential long-term options for maintaining a transportation corridor at the Pea Island inlet site. The objectives of this part of the Panel discussion were to:

- Obtain coastal engineering recommendations on inlet performance (including confirmation on the location of the area susceptible to breaches in the Pea Island inlet site that was presented in the FEIS);
- Obtain the Panel’s input on possible long-term options (e.g., bridging, fill/pave, beach nourishment, etc.) for maintaining NC 12 through the area of the inlet;
- Obtain the Panel’s opinions on potential near-term changes in the inlet; and
- Determine how those changes could affect the temporary bridge now in place.

3.2.2 Discussion

Mr. Henderson suggested that sheet piling be installed across the inlet to an elevation below low tide. It would reduce the dynamics of the inlet and support wet sand habitat for shorebirds. Mr. Henderson explained that the sheet piling could be placed temporarily, until a long-term solution is constructed.

The Panel discussed the possibility of another storm affecting the stability of the temporary bridge. The Panel agreed that such an event is a possibility and thought needs to be given concerning the protection of the temporary bridge. The Panel agreed that sheet piling installed parallel to the structure as suggested by Mr. Henderson would reduce tidal flow, energy, and volatility within the inlet. Mr. Rogers felt that the inlet would close with the installation of sheet piles in this configuration.

Dr. Riggs and Dr. Williams said that if the long-term solution for the site is a bridge, the bridge should span the New Inlet complex. Dr. Williams said that the pilings of the long-term bridge may influence where an inlet may open, therefore reducing the length of the bridge that is needed in this area. Dr. Sheppard noted that the advantage of the closure of the inlet (naturally or man-made) would be that shorter bridge lengths would be required to span the site. Dr. Sheppard said that if the inlet stayed open, migration to the south will be an issue for the temporary structure. Dr. Overton suggested “managing” the inlet location in order to ensure that NCDOT can maintain transportation by controlling its location where practicable.

Dr. Sheppard suggested that if the long-term solution is intended to function for 50 years, then it would be cost effective to control the inlet’s migration, thus reducing the bridge’s required length. Mr. Rogers agreed that accelerating the inlet’s closure would result in a more simple solution; if the inlet were to remain open, the solution could be very complex given the likelihood of inlet migration. Mr. Rogers said that if the inlet does not close, there could be a 300-foot per year migration rate. Dr. Dolan disagreed with this suggested migration rate; he said that the inlet is likely to close within a year naturally.

Mr. Rogers expressed that man-made closure would be a lot less intrusive, although the new habitat characteristics provided by the inlet also would be gone. Mr. Rogers noted

that habitat would be gone either way if the inlet closes naturally. Mr. Stewart said that closure of the inlet will remove the shorebird habitat, but if the inlet stays open, marsh habitat will be lost. Mr. Stewart also said that while he preferred that the inlet remain open, most of all he preferred that the natural processes be allowed to occur.

Ms. Brittingham talked about CAMA's laws prohibiting hardened structures along the shoreline. Mr. Henderson and Dr. Sheppard noted that the sheet piles would be a temporary measure.

The Panel noted that even if closed (naturally or through actions by NCDOT) conveyance from the sound may open the inlet back up in the future. Dr. Riggs said that upcoming nor'easter storms may cause more soundside issues as these storms track northward.

Mr. Hanson acknowledged the Panel's opinion concerning the vulnerability of the temporary bridge and asked whether sheet piling could be installed perpendicular to the bridge where it could limit southward migration, similar to the Oregon Inlet terminal groin. Ms. Brittingham noted that the NC General Assembly has made allowance for four new terminal groins in North Carolina.

Mr. Rogers and Dr. Dolan said that the temporary bridge could be in jeopardy if the inlet does not close. The southward migration would extend south of the temporary bridge before its planned service life is over. Mr. Rogers also said that if the inlet is open, bridging is the only permanent option.

Dr. Riggs estimated that a bridge approximately 2.4 kilometers (1.5 miles) in length would be needed to span the New Inlet complex. Dr. Riggs said that this recommended length is based on geological data. Dr. Overton noted that the different sets of data associated with the history of the New Inlet match with the New Inlet complex defined by Dr. Riggs. Dr. Williams asked if topographical data could help adjust the bridge length that Dr. Riggs recommended.

Mr. Stewart explained his concern that the Pea Island inlet was caused by a minimal hurricane that followed a path that could have caused substantial destruction.

Dr. Overton said that although Pamlico Sound may support another inlet, inlet formation may reduce pressure at other "hotspot" locations.

The Panel agreed that even if the inlet closes naturally, there is a possibility of another inlet reopening.

Dr. Riggs suggested that a bridge on existing alignment at the Pea Island inlet have deep piles. Mr. Rogers stated that NCDOT should not build bridges that would end up in the ocean as a result of long-term shoreline erosions. Dr. Sheppard asked if the NC 12

easement can be moved. Mr. Stewart responded that only minor modifications to the NC 12 easement for safety purposes within the Refuge are allowed.

Dr. Riggs said that a bridge should allow for storm surge and overwash. Mr. Henderson said that establishing bridge height should be site specific. Dr. Sheppard noted that the factors considered when establishing bridge heights are design water elevations and wave heights, as well as information used to compute design storm surge and wave loads on the superstructure.

The Panel agreed that nourishment is not a good long-term solution for this site in that it would not address the area's proneness to inlet formation. Another long-term option that was discussed was filling the inlet and re-building the road in the existing NC 12 easement. This option would probably also require ongoing beach nourishment from the vegetation line to the ocean. Mr. Rogers said that road relocation also could be considered as an alternative, assuming the inlet is closed. USFWS did not like the idea of closing the inlet because it prefers to allow natural processes to occur.

A bridge in Pamlico Sound from north of the Pea Island inlet to the southern end of the Bridge South Alternative in Rodanthe was suggested by Mr. Stewart. This bridge would remove NC 12 from the entire southern portion of the Refuge to the south of the ponds and could possibly be considered a minor modification by USFWS.

After reviewing a draft description of the Panel findings included in this report, several Panel members provided additional thoughts relevant to long-term options at the Pea Island inlet site:

- Mr. Rogers again emphasized that it is his opinion that closure of the inlet, either natural or man-induced, is a reasonable mid- to long-term solution for the Pea Island inlet area. In fact, his closer review of nearby low ocean tide predictions since the Panel meeting has led him to conclude that the inlet may close naturally. However, he also believes that, based on several factors, closing the inlet with steel sheet piles would be a relatively easy process, but to ensure closure the sheet piles should extend well above mean high water. In addition, to reduce the likelihood of another inlet breach, it would be prudent to build a dune in or near the ocean side of the NC 12 easement because now that the Refuge maintenance facility driveway and buildings are gone, the threat of a new breach can be better managed. Once closed, the inlet channel seaward of the barrier would quickly fill with longshore-transported sand from both directions, and the now developing offshore shoal would collapse back to the shoreline, accelerating the recovery. Mr. Rogers said that the filled channel and adjacent beaches would provide a large, short-term increase in the bare sand beach habitat that Refuge staff indicated is highly valued. If left to natural processes, dune vegetation will start to recover after around 3 years, eventually retuning to pre-Hurricane Irene conditions.

- Mr. Henderson said that he concurred with the use of sheet piling up to an elevation above mean high water. However, he indicated that his previous recommendation of a lower crest elevation for the sheet piles was an attempt to make the proposal of removing normal tidal energy from the inlet with sheet piles more acceptable to USFWS and NCDENR-DCM, both of which may view this proposal as shoreline hardening. The sheet piles could be placed within the existing NC 12 easement and removed as the inlet closes. He added that installing sheet piling to close the inlet may be worth pursuing at this time because inlet migration could threaten the temporary bridge's southern abutment.
- Dr. Williams added that Hurricane Irene also caused a breach of the spit at the southern end of Bodie Island (i.e., immediately to the north of Oregon Inlet). He said that USACE believes that the new inlets have robbed water from Oregon Inlet and, thus, created an even more difficult navigation maintenance problem in Oregon Inlet than prior to Hurricane Irene. He said that USACE is concerned that having multiple openings in this part of the barrier island system will make it nearly impossible to maintain any semblance of a navigation channel at Oregon Inlet. In addition, because federal funding for dredging is limited, it was already difficult even before Hurricane Irene to get enough funding to keep Oregon Inlet open even part of the year. Therefore, the discussions of long-term options at the breaches should consider these issues. Dr. Riggs responded that his opinion based on historical data is that the shoaling problems at Oregon Inlet are independent of the formation of the Pea Island inlet. Dr. Sheppard indicated that he agreed with Dr. Riggs' assessment. Dr. Williams responded that he does not dispute Dr. Riggs historical data, but rather he was noting that multiple inlets in the area are not conducive to helping keep Oregon Inlet navigable. He added that it is probable that the greatest impact on the recent navigation channel maintenance issues in Oregon Inlet is the breach of the spit north of Oregon Inlet and to a much lesser extent the influence of the Pea Island inlet.

3.2.3 Findings

- The Panel agreed that NCDOT needs to determine how best to protect the temporary bridge so that it will remain in place for its expected service life, because the Pea Island inlet is likely to evolve and migrate to the south if it stays open.
- The Panel agreed that installation of sheet piles along the south side of the inlet would protect the temporary bridge structure across the Pea Island inlet because the sheet piling would help to keep the inlet from migrating to the south. In addition, the sheet piles would be temporary because they could be removed once the long-term solution for maintaining NC 12 in this area is in place. Scour and channel depth would need to be considered in determining sheet pile depth. CAMA requirements would need to be considered.

- The Panel agreed that adding sheet pile in the Pea Island inlet in a north-south orientation would reduce the dynamics of the inlet. The top of the sheet piles in this case would be below mean low tide, thus allowing natural flushing. CAMA requirements and USFWS preferences related to the closure of the inlet would need to be considered.
- The Panel agreed that nourishment is not a good long-term solution at the Pea Island inlet because it would not address the area's proneness to inlet formation.
- The panel also discussed filling the inlet and re-building the road in the existing NC 12 easement or road relocation. The Panel did not come to a consensus as to whether filling the inlet and re-building NC 12 in the existing easement was a good long-term solution, but USFWS did not like the idea of closing the inlet because it prefers to allow natural processes to occur.
- If a long-term bridge is built in the existing NC 12 easement at the Pea Island inlet, the Panel agreed with Dr. Riggs' recommendation that the bridge should completely span the New Inlet complex.
- A bridge in Pamlico Sound from north of the Pea Island inlet to the southern end of the Bridge South Alternative in Rodanthe was suggested by Mr. Stewart.

3.3 Potential Long-Term Options for Rodanthe Breach Site

3.3.1 Objectives

The objectives of the Panel discussions related to potential long-term options for the Rodanthe breach site included obtaining from the Panel coastal engineering recommendations on breach performance (including affirming the area in Rodanthe susceptible to breaches), as well as determining possible long-term options (e.g., bridging, fill/pavement, beach nourishment, etc.) for maintaining NC 12 through the area of the breach.

3.3.2 Discussion

The Panel recommended that beach nourishment not be used as a long-term solution at the Rodanthe breach site. The Panel noted that there are issues with a suitable sand source, the amount of sand and dredging required, dredging limitations (time), and the cost of regular nourishment. Several Panel members raised the question related to conducting sand analysis for suitability. Dr. Williams explained that USACE averages 6 to 8 months to complete a sand suitability analysis. Mr. Rogers noted that the sand analysis at Topsail Beach took one year to complete.

Dr. Williams said that he will contact appropriate USACE staff (John Caldwell) for cost information for dredging. Dr. Williams gave a rough cost estimate of \$2,000,000 for mobilization and \$9 to 12 per cubic yard for dredging and fuel for two hopper dredges.

Mr. Stewart said that if NC 12 is abandoned at the southern end of the Refuge, an access plan would be developed by the Refuge.

Mr. Hanson asked the Panel if a breach at Rodanthe would be susceptible to migrating southward. The Panel responded that a breach/inlet could migrate southward to the Rodanthe pier. Dr. Riggs noted that the subsurface geology becomes stable south of the Rodanthe pier (which is located south of the Bonner Bridge Replacement project area).

Mr. Rogers indicated that the historic erosion rate may not be an accurate predictor of future erosion rates in Rodanthe. Mr. Page noted that a confidence interval is built into future predictions prepared by Dr. Overton for the FEIS.

Mr. Rogers said that NC 12 could be relocated to the west at Rodanthe. Mr. Rogers explained that a bridge on the existing alignment in Rodanthe is not a good idea because it will end up in the ocean in the short-term. The Panel agreed that a bridge within the existing NC 12 easement/right-of-way is not the best long-term solution at the Rodanthe breach site because of the Panel's concerns that the high shoreline erosion rate in this area could be challenging. The Panel was concerned that the high erosion rate would ultimately result in the structure being in the ocean a notable distance from shore.

After reviewing a draft description of the Panel findings included in this report, Mr. Rogers added the following regarding long-term options for the Rodanthe breach site:

NC 12 at the Rodanthe breach, in contrast to the situation at the Pea Island inlet, is highly threatened by long-term erosion as a result of the close proximity of the road to the active beach and a long-term erosion rate of over 12 feet per year. The sandbag revetment, restricted in size by state law, is too small to tolerate much additional erosion. The area also remains one of the most likely locations for a new and larger inlet breach during either sound or ocean storm surges. Based on these factors, a bridge in the sound is the most likely mid- to long-term solution at the Rodanthe breach. NCDOT can expect it to be the most frequent problem area for NC 12, and it will continue to deteriorate until a solution is implemented. Therefore, a solution that can be implemented sooner is better.

3.3.3 Findings

- The Panel recommended that beach nourishment not be used as a long-term solution at the Rodanthe breach site. This is based partially on concerns about the probable lack of an adequate sand supply for the recurring beach nourishment that would be required as a result of the high shoreline erosion rates in the area, as well as on concerns about the cost of beach nourishment.
- The Panel agreed that a bridge within the existing NC 12 easement/right-of-way is not the best long-term solution at the Rodanthe breach site because of the Panel's

concerns about the high shoreline erosion rate in the area, which would put the structure in the ocean a notable distance from shore.

- The Panel indicated that road relocation to the west in Rodanthe could be considered, but the Panel acknowledged that impacts to the Refuge, wetlands, and homes within Rodanthe are concerns with that alternative.
- The Panel agreed that a bridge built in the sound to the west of the southern end of the Refuge and northern Rodanthe would be less vulnerable to potential future changes in Hatteras Island resulting from shoreline erosion and breach formation.

3.4 Recommendations on Future Coastal Studies for Project Area

3.4.1 Objectives

The Panel discussed recommendations on future coastal studies for the project area, focusing on the following issues and questions:

- The current NCDOT coastal monitoring program, which was a commitment in the Bonner Bridge Replacement Project ROD and is to inform the decision-making related to future phases of the Bonner Bridge Replacement Project.
- Expected permit conditions.
- What additional data sources/research should be considered as part of future coastal studies?
- Are there similar studies of coastal areas that can inform NCDOT's future work?

3.4.2 Discussion

Ms. Smyre discussed the coastal monitoring program as described in the ROD. Ms. Smyre asked the Panel what should be considered as part of the program.

Dr. Williams suggested that obtaining satellite imagery from the USACE should be considered. Dr. Williams said that this imagery is produced more frequently than NCDOT's quarterly aerial photographs.

Dr. Dolan suggested the need for input from meteorologists concerning trends. Dr. Dolan also said that there should be more focus on non-tropical storms. Mr. Henderson noted that the Morehead City office of the National Weather Service is conducting a study regarding nor'easters.

Mr. Stewart recommended modeling hurricane events for barrier island changes.

Dr. Williams recommended that the monitoring should include gathering hydraulic information for the Pea Island inlet, including water depth, tidal prism, and flow during tides.

Dr. Overton recommended partnering with other agencies/entities to allow cost-sharing in acquiring data that is valuable to both entities.

The Panel agreed at this point in the discussion that the following should be monitored/implemented for coastal monitoring:

- Bathymetry (monthly cross-sections) of the Pea Island inlet and adjoining ocean and sound areas
- Pea Island inlet flow velocities
- Field verifications/surveys of coastal change
- Meteorological data
- Oceanward flight coverage (to cover the Hatteras Flats so the behavior of waves and shoaling can be completely seen)
- Mapping of pre-storm ground features (based on LIDAR data), including:
 - Vegetation
 - Vertical elevations at dunes
 - Overwash fans (including volume of sand in fans)
 - Wrack (debris) line
 - Island width

Dr. Overton explained that the new flight parameters for aerial photography now include elevation information. Dr. Overton also noted that extensive beach erosion and shoreline position data are available for the northern part of the Refuge, and she thought it would be beneficial to acquire the same intensity of data for the southern part of the Refuge.

Dr. Sheppard suggested placing gauges to collect water elevation and other data on the western side of the island, as well as placing some gauges on the western shore of the Pamlico Sound (e.g., at the Stumpy Point ferry terminal). Dr. Riggs said there has been a re-mapping of the mainland shoreline that will be available soon. It includes recession rates. Mr. Rogers said that gauges need to be replaced regularly, so easy access is important. Also, gauges must be placed so they remain wet at low tide.

3.4.3 Findings

- The Panel recommended considering the collection of the following data to assist with future coastal monitoring efforts in the project area:
 - Water depth in the Pea Island inlet.
 - Tidal prism data (i.e., quantity of water flow through the Pea Island inlet in tidal cycle).
 - Water depths in Pamlico Sound during different phases of the tide.
 - Bathymetric data in the Pea Island inlet, as well as in the ocean and sound adjacent to the Refuge.
 - Water flow velocity in the Pea Island inlet.
 - Cross-sectional width data of the Pea Island inlet.
 - Elevation and LIDAR data, including vertical elevations at dunes to monitor dune stability.
 - Mapping of vegetation between NC 12 and dunes (indicator of dune stability).
 - Mapping of debris (wrack) line following major storm events.
 - Island width.
 - Beach erosion rates (in particular, more data points than considered in the past in the portion of the Refuge to the south of the Refuge's ponds).
 - Meteorological data.
 - Mapping of overwash fans.
- The Panel made the following additional recommendations with respect to future coastal monitoring strategies for the project area:
 - Partner with other agencies on funding for data collection, as well as for determining what data should be collected.
 - Consider using satellite imagery that includes oceanward coverage to monitor coastal conditions in addition to aerial photography (provides more coverage at less cost and can look at earlier time periods).
 - Include more of the ocean in future aerial photography to cover Hatteras Flats.
 - Considering consulting with a meteorologist for physics of storms (especially winter storms), as well as geospatial/geophysical specialists for predicting island change into the future.
 - Consider placing gauges to measure water elevation change and other data in the western part of the sound (e.g., Stumpy Point ferry terminal).
 - Assess the probability of changes based on different storm characteristics, based on historical events of nor'easters and hurricanes.
 - Make use of "eyes in the field" to report changes in coastal conditions, including webcams.

3.5 Additional Topics Discussed by Panelists

Dr. Riggs suggested the consideration of other transportation options, such as ferries, because of the vulnerable location of NC 12. He thinks that there will be an increase in the number of times that NC 12 will need emergency repairs in the future, based on the potential for a higher number of storms. Dr. Riggs said he believed that road maintenance has been a “death sentence to the barrier islands,” as it doesn’t allow for the natural barrier island processes to occur. He said that NCDOT already has the capabilities to implement a ferry service, citing the Stumpy Point to Rodanthe route used in emergencies. He noted that while he is not a ferry expert, he has reviewed the use of high speed ferries and passenger ferries that are already used successfully elsewhere. Dr. Riggs said that his new book looks at the economics of how ferries would work on the NC coast. He felt that North Carolina is a prime candidate for high speed ferries.

Mr. Stewart suggested an option at the Pea Island inlet that would involve NC 12 leaving the Refuge on a bridge at the southern end of the Refuge’s ponds (just to the north of the Pea Island inlet), continuing through the Pamlico Sound just west of Hatteras Island but outside of the Refuge boundary, and ending in Rodanthe at the same location as the Bridge on New Location at Rodanthe. Mr. Stewart noted that even though the alignment would cross the Refuge on new right-of-way for a short distance as its alignment moves from existing NC 12 to the sound, it would substantially reduce the extent of NC 12 within the Refuge. In addition, the change possibly could be considered a minor modification, which is allowable according to National Wildlife Refuge regulations. [NCDOT concluded after the meeting that with such an alternative, approximately 0.56 mile of new NC 12 easement would be needed within the Refuge and approximately 5.8 miles of existing NC 12 easement would be returned to the Refuge.]

4.0 Peer Exchange Meeting Conclusions and Next Steps

4.1 Peer Exchange Meeting Conclusions

The Panel’s overall general findings and recommendations were:

- Both the Pea Island and the Rodanthe breaches were caused by a soundside storm surge as a result of Hurricane Irene passing west of Hatteras Island in Pamlico Sound.
- Pea Island Inlet
 - At the Pea Island inlet, there will continue to be a risk of future beach erosion and storm dependent inlet formation.

- The future of the Pea Island inlet, including whether it will close on its own or remain open, is uncertain. There was agreement that if the inlet remained open, it would migrate to the south. The inlet should be monitored and actions taken to protect the temporary bridge as needed. Sheet piling could be used to help close the inlet or help keep it from moving farther south.
 - If constructing a bridge in the existing NC 12 easement, the height of the bridge should be determined based upon waves, tides, storm surge, and overwash. The bridge should span the New Inlet Complex (area prone to inlet formation).
 - The Panel agreed that nourishment is not a good long-term solution at the Pea Island inlet because it would not address the area's proneness to inlet formation.
 - The Panel did not come to a consensus as to whether filling the inlet and rebuilding the NC 12 roadway in the existing easement was a good long-term solution, but USFWS did not like the idea of closing the inlet because it prefers to let natural processes occur.
- Rodanthe Breach
 - The Panel agreed that a bridge within the existing NC 12 easement/right-of-way is not the best long-term solution at the Rodanthe breach site because of the high shoreline erosion rate in the area. The panel was concerned such an alternative would ultimately result in the structure being in the ocean a notable distance from shore.
 - The Panel agreed that placing NC 12 on a bridge in the sound was a better option than a bridge in the existing NC 12 easement because it would be less vulnerable to potential future changes in Hatteras Island resulting from shoreline erosion and breach formation.
 - The Panel recommended that beach nourishment not be used as a long-term solution at the Rodanthe breach site.
 - The Panel indicated that road relocation to the west in Rodanthe could be considered, but the Panel acknowledged that impacts to the Refuge, wetlands, and homes within Rodanthe are concerns with that alternative.
 - Two other options, each suggested by individual panelists, were the construction of a bridge in the Pamlico Sound from just north of the Pea Island inlet to Rodanthe (approximately 6 to 7 miles in length) and the expansion of the existing NCDOT ferry system.
 - The Panel recommended considering the following strategies and data collection activities to assist with future coastal monitoring efforts in the project area, including monitoring the Pea Island inlet's future performance:

- Partnering with other agencies.
- Monitoring water depth, tidal prism (i.e., quantity of water flow in tidal cycle), water velocity, and cross-section within the inlet.
- Using satellite imagery and aerials to monitor position of inlet and estimate erosion rates.
- Consulting with meteorologists for physics of storms.
- Looking at the probability of changes to the inlet based on types of storm and historical events of nor'easters.
- Collecting bathometric data near the inlet.
- Using eyes in the field to report changes, including webcams.
- Monitoring elevation (LIDAR) and island width data near the inlet.
- Monitor and map changes in vegetation between NC 12 and the dunes as an indicator of dune stability.
- Monitor the wrack (i.e., debris) line on the shoreline adjacent to the inlet.
- Placing gauges to collect water elevation and other data on the western side of Hatteras Island and on the western shore of the Pamlico Sound (e.g., at the Stumpy Point ferry terminal).

Additional information related to each of these conclusions is presented in the “Findings” subsections following each Panel discussion described in Section 3.0.

4.2 Next Steps

A draft of the meeting summary (this document) will be distributed to participants for review. Following this review period, the following steps will take place in the near-term:

- The meeting summary will be finalized and made available to the agency partners and the public.
- Actions that NCDOT will pursue to protect the temporary bridge (e.g., installing temporary sheet piling) will be assessed.
- NCDOT will update the beach nourishment cost at Rodanthe.
- A Concurrence Point 2 Merger Meeting with the Merger Team agencies to discuss Phase II alternatives will take place in December 2011.
- Investigations and further discussions concerning the alternative suggested by Mr. Stewart will occur.

These steps are part of fulfilling the commitments made for implementing the NC 12 Transportation Management Plan Alternative described in Section 3.3.2 of the ROD, including the sections on “Environmental Review for Future Phases” and “Selection of Future Phases for Implementation.”