A pre-dredging inspection of the endangered species equipment was performed by USACE–Wilmington District inspectors in accordance with the protocol Sea Turtle Compliance Inspection checklist. Table 6.1 lists the summary of such inspections for each hopper dredge. GLDD maintained the USACE-approved equipment (including sea turtle deflectors, in-flow basket screening and drag head grating) in operational condition to minimize the possibility of incidental sea turtle takes during the project, and adhered to the protocols and requirements contained in the Regional Biological Opinions (NMFS 1997, USFWS 2008) and the state and federal permits.

TABLE 6.1. Endangered species equipment inspection summary.

Dredge Name	Inspection Date	Inspector Name	Inspection Comments	GLDD Actions
Liberty Island	24 May 2011	Doug Piatkowski	All tests were successful except for the slotted TEDs	Deflector heads were modified within 48 hours of the directives
Dodge Island	19 August 2011	Hugh Heine	All tests were acceptable	Not needed
Padre Island	22-23 August 2011	Hugh Heine	All tests were acceptable	Not needed

6.1.2 Endangered Species Observers

During dredging operations, observers approved by NMFS were required to provide 24 hours per day, year-round coverage on board all the hopper dredges to monitor for the presence of endangered species including sea turtles, sturgeon, and whales.

During dredging operations, the observers monitored the inflow boxes for the presence of any threatened or endangered species. After each dredge load, the observer inspected the drag heads to assure that no turtles were caught in the head itself. Inflow boxes and screens were then inspected for any endangered species. Any abiotic and biotic debris caught in the screens were documented and removed so the screens were clear for the next load. A camera was provided to the observers should they need to document a take event. A report of all findings and observations was completed for each dredge load, a summary for each day, a summary for each week, and a summary for the entire project. Completed load, daily, and weekly reports were submitted to the USACE Regulatory Project Manager and the Project Engineer (CSE) along with GLDD's dredging operation reports.

Overall, observers confirmed that the material dredged from borrow areas was clean, medium-coarse sand with few shell fragments. All inflow screening was in good condition and highly effective. Sample screen contents included clearnose skate, horseshoe crab, blue crab, spider crab, clam, angel shark, cow nose ray, shrimp, etc. There were no incidents with protected or endangered species during the dredging operations.

6.2 Non-Capture Trawling for Hopper Dredges

To minimize or reduce incidental taking of turtles during hopper dredging operations, non-capture sweep trawling was required and utilized in this project. This type of trawling is designed to sweep a trawl in the proximity of the dredging operations and to stimulate any sea turtles present to move out of the dredge path. The open trawl is intended to allow sea turtles to pass through the net without capture.

In compliance with the permits, GLDD and its subcontractor conducted non-capture trawl sweeping 48 hours prior to initiating dredging and continued throughout hopper-dredging operations. Trawlers conducted non-capture trawl sweeping operations in the vicinity of dredge operations, but maintained a safe distance from the dredge(s). The trawler was equipped with two 60-ft, flat-style trawling nets with the bag or cod end of the nets removed to create a completely open net. The lead line across the mouth of the trawl was rigged to ensure that it maintained contact with the sediment bottom.

In accordance with the permits, one operating trawler was working per hopper dredge during dredging operations; however, trawling was not required during periods when a hopper dredge was pumping out or otherwise not dredging (due to weather or mechanical delays). When two hopper dredges were on site, they alternated between digging and pump-out so that one trawler could provide protection during all digging operations.

A summary of trawler operations is listed in Table 6.2. A daily log was kept for all non-capture trawl sweeping operations and is included in Appendix A9 of this report. Data recorded in this daily log included GIS coordinates of trawl locations at the start and end of each sweep, times recorded for the duration of each trawl sweep, general notes as appropriate (such as condition of equipment, snags occurring during each sweep, incidental debris), and water quality and physical measurements (such as water temperature, air temperature, wind speed and direction, tidal information, sea state, precipitation, etc).

TABLE 6.2. Summary of trawler operations.

Trawler Name	Dredge Name	Borrow Area	Duration	Any Incidents
Catina Renea	*Liberty Island*	2	22 May 2011 to 12 Aug 2011	NO
Winds Of Fortune	*Dodge Island* *Padre Island*	2 or 3	19 Aug 2011 to 27 Oct 2011	NO

The trawler *Catina Renea* began operations in the offshore borrow site at Nags Head at 11:17 am the morning of 22 May 2011, more than 48 hours before the *Liberty Island* started dredging in borrow area 2. They were towing two 60-ft, flat shrimp nets (mesh size <2 inches) with the tail bags removed. They recorded times and locations for the terminal end of each sweep as well as the start and end of each tow. A sweep is one single unidirectional pass. A tow is completed each time the nets are actually hauled back and inspected. A tow is comprised of several sweeps. Tows were limited to one hour during the initial 48 hours of sweep trawling. Subsequently, tows were three hours in duration if all was going smoothly. The trawler would alert GLDD to the exact locations of any bottom obstructions that were encountered. The *Catina Renea* was photographed from the *Liberty Island* while the trawler was on duty on 24 June 2011 (Fig 6.1).

FIGURE 6.1.

The trawler, *Catina Renea,* on duty (photo taken by CSE from the *Liberty Island* on 24 June 2011).

Overall, non-capture trawling at borrow areas was highly effective. A few clear-nose skates and crabs were documented, but no sea turtles were collected in any sweeps. The first sea turtle was observed on 29 May 2011 in the water column around borrow area 2. There were less than 5 individual observations of sea turtles in the water column by endangered species observers on board the trawlers and dredges over the five-month duration of dredging. There were no turtle takes during the project.

Trawling was not conducted for any cutterhead suction dredging.

6.3 Sea Turtle Monitoring on the Beach

The project was conducted within the sea-turtle nesting moratorium, which extends from 1 May through 15 November. To avoid impacts to sea-turtle nesting, nest incubation, and/or hatchlings, detailed monitoring requirements were developed in coordination with NCWRC, USFWS, and USACE. The scope of work for the sea-turtle monitoring services reflected requirements in the NCDCM Consistency Determination, and the USFWS Biological Opinion. The scope of work dated 18 May 2011 (revised on 22 May 2011) can be found in Appendix G. A summary of the monitoring work during the project is as follows.

1) Nighttime Monitoring:
   a) One or two sea turtle monitors were provided for each section of "Non-Active Construction Area" for 10 hours per night as required by the USACE. Monitors patrolled (on foot) the pipeline route four times per night looking for injured/stranded sea turtles, nesting sea turtles, signs of crawls, and hatchlings on either side of the pipeline. Patrols took place between 9:30 pm and 10:30 pm, 12:30 am and 1:30 am, 3:30 am and 4:30 am, and close to dawn. There were no sea-turtle activities observed during the entire construction period by nighttime monitors. Had there been any activity, it would have been documented including latitude and longitude of event and appropriate contacts with NCWRC and Network for Endangered Sea Turtles (NEST) representatives. Per requirements of the permits, sea turtles or signs of sea turtles would trigger suspension of work in the immediate vicinity and would require coordination with NCWRC and NEST.

   b) During pipeline patrols, monitors observed the "Active Construction Area" from outside the safety fence. As necessary, given indications of activity, one

monitor would be scheduled to continuously monitor the "Active" area from outside the safety fence or go inside the fence under escort for safety. There was no sea-turtle activity observed around the active construction area during the project. If there had been, the foreman of GLDD would have been notified and instructed to stop work per the special conditions of the permits.

c) Monitors accompanied vehicles operating along the beach at night and watched for signs of turtle activity ahead of the vehicle. If activity was discovered, the vehicle would stop or reverse direction until the activity ceased and the monitor cleared the forward progress of the vehicle. Monitoring of vehicle operation was coordinated with the GLDD crew foreman with the aid of two-way radios.

d) Monitoring hours were determined by the dusk and dawn times for Nags Head (NC). Between 24 May and 5 September 2011, the dusk and dawn times were 8 pm to 6 am; between 6 and 12 September, they were 8 pm to 7 am; and between 13 September and 27 October, they were 7 pm to 7 am every day.

2) Morning Monitoring:

a) Daily morning monitoring was conducted by NEST personnel beginning at sunrise. Signs of sea-turtle activity were documented including latitude and longitude of the event. Appropriate NCWRC and NEST representatives were contacted if any activity was discovered.

b) Morning patrols used ATVs and were coordinated to arrive just after the nighttime patrols had completed their shift.

c) Observations made by the morning patrols were reported as part of the overall monitoring. At least two sea-turtle monitors were present at the project site on a continuous basis from dusk to dawn to monitor sea-turtle activity for the period commencing with any construction activities on the beach and ending upon completion of all construction activities (ie – until all construction material was removed from the beach). One monitor provided continuous monitoring between safety fences at the actual discharge site and the other conducted three monitoring sessions during the night along the pipeline route. In cases where more than one discharge site was active, there was one team of monitors dedicated to each construction area.

A daily quality control report was prepared for each day when activities were conducted, and a weekly status report was prepared to document the contractor's progress from the previous Monday through the previous Sunday. Specific encounters with strandings, false crawls, nesting sea turtles, incubating nests, and/or hatchlings along with the actions taken were recorded in the daily and weekly status reports.

6.3.1 Turtle Nesting During Construction

Based on information provided by NCWRC, Nags Head has averaged less than 2 nests per year over the past 25 years. Table 6.3 provides sea-turtle data at Nags Head for each year between 1981 and 2005.

The year 2011 was more active than normal for turtle nesting at Nags Head. There were a total of four (4) nests laid within the project area and one (1) just a quarter mile north of the project but still within the Nags Head town limit. All nests were loggerhead sea-turtle nests and were first found by NEST volunteers during their morning ATV patrols. The four (4) nests were laid outside the active work areas and pipeline corridors at various times between 29 June and 27 July. Each nest was relocated outside of Nags Head by NEST professionals, and the nest laid outside of the project area was carefully monitored by the same group of professionals. As is customary for research purposes whenever a nest is relocated, one egg was removed from the nest for DNA study later in NEST's lab.

FIGURE 6.2. The first loggerhead turtle nest was found on 29 June, 2011 near McCall Street. 132 eggs were laid in this nest.

A map of the nest locations is shown in Figure 6.3, and details of the four (4) nests within the project area are listed in Table 6.4.

TABLE 6.3. Sea turtle nesting activities at Nags Head (Source: NC WRC Database)

Sea Turtle Nesting Activities, from NC WRC Database.
Nags Head, NC Sea Turtle Management Zones (STMZ) 41-52

SEASON	NESTS	FALSE CRAWLS	HATCHLING SUCCESS (%)	STMZ	NOTES
1981	2	N/A	78	51, 51	n=2 hatching success
1982	1	N/A	80	46	n=1 hatching success
1983	1	N/A	43	42	n=1 hatching success
1984	1	N/A	N/A	UNKNOWN	N/A
1985	N/A	N/A	N/A	N/A	N/A
1986	N/A	N/A	N/A	N/A	N/A
1987	N/A	N/A	N/A	N/A	N/A
1988	N/A	N/A	N/A	N/A	N/A
1989	4	N/A	N/A	UNKNOWN	N/A
1990	1	N/A	N/A	UNKNOWN	N/A
1991	1	N/A	0	42	n=1 hatching success
1992	2	N/A	0	42, 45	n=2 hatching success
1993	1	N/A	N/A	45	N/A
1994	2	N/A	0	54, 54	n=1 hatching success
1995	4	N/A	45	41, 43, 47, 47	n=4 hatching success
1996	3	N/A	64	47, 48, 48	n=3 hatchings success, one green turtle nest.
1997	N/A	N/A	N/A	N/A	N/A
1998	2	N/A	96	41, 47	n=2 hatching success
1999	4	N/A	0	46, 49, 51, 52	n=4 hatching success
2000	4	1	86	44, 46, 50, 50, 51	n=4 hatching success
2001	5	1	48	45, 45, 46, 46, 46, 51	n=5 hatching success, one green turtle nest
2002	8	2	93	42, 42, 42, 43, 46, 50, 51, 51, 52	n=8 hatching success
2003	0	0	no nests	N/A	N/A
2004	0	2	no nests	45, 46	N/A
2005	0	1	no nests	49	N/A

STMZ 41 is north Nags Head
STMZ 52 is south Nags Head

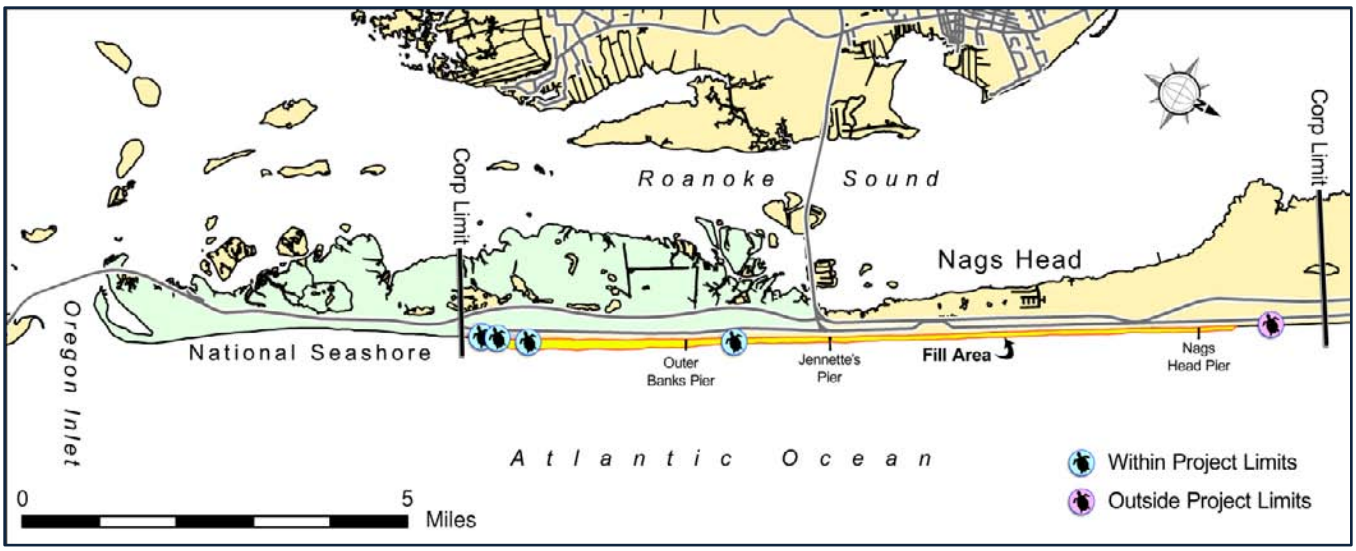

FIGURE 6.5. A map of turtle nests laid at Nags Head during the 2011 turtle-nesting season. Four nests were found within the project limits but outside the active work area and pipeline corridor, and were subsequently relocated. Hatching success rates ranged from 77 percent to 94 percent, making 2011 one of the most productive years on record at Nags Head (NC) (see Table 6.3).

TABLE 6.4. Sea turtle nests observed at Nags Head project area in 2011 during construction.

Date	Coordinates	Street Name	CSE Station	Egg Number	Relocated To	Hatching Success Rate
June 29	35.84886 -75.56457	McCall Street	1020+00	133	36.02433 -75.6614	82.5%
June 30	35.89257 -75.58679	Tides Drive	850+00	111	36.02428 -75.6614	92%
July 1	35.85519 -75.56725	Seagull Drive	990+00	123	Kill Devil Hills	77%
July 27	35.850473 -75.565259	Loon Street	1005+00	90	Kill Devil Hills	94%

6.3.2 Turtle Events

There were a couple of non-dredging-related turtle incidents during the time of construction. The first incident occurred on 16 July 2011. A dead sea turtle was found in the project area near Loon Street (station 1003+00) in the morning of that day. Highly decomposed when it was found, it appeared to be an adult loggerhead sea turtle. Photos were taken by the turtle monitoring coordinator, and a necropsy was conducted by NEST professionals. CSE immediately reported the find to the regulatory project manager, the Town, and the contractor.

At the time of the sighting, the active construction area was about 1 mile north of the dead turtle's location. Since there were no reports of incidents on the dredge (ie - the *Liberty Island* was working in the area), the trawler, or on the beach in the active project area, on-site personnel (including NEST representatives) assumed that this was a non-project-related incident. The USACE regulatory project manager and representatives from NCWRC evaluated the situation and determined that all authorized, beach-nourishment activities could continue. After further investigation, regulators agreed with on-site personnel that the decayed carcass probably washed ashore from some distant location; however, the cause of death was indeterminate.

According to the NEST observers on the scene and the turtle-monitoring coordinator, such strandings are common and occur nearly every summer along Dare County beaches. For example, there were three (3) dead sea-turtle strandings found in Nags Head in 2010, and seven (7) were found in 2009.

Another sea turtle incident occurred on 11 October 2011. A live sea-turtle stranding was observed on the beach near the Outer Banks Pier (station 875+00) on the evening of that day. This sea turtle's injury appeared to have been caused by blunt force trauma with the wound being rather recent. There was no indication of what caused the injury, but it apparently was not related to the dredging activity. The turtle professionals on scene indicated that similar turtle incidents have been reported previously in this area. The turtle was considered a juvenile (between 15-20 years old) and was rehabilitated at the NEST/NC Aquarium rehabilitation facility.

7.0 SUMMARY OF BORROW AREA DREDGING IMPACT

The Nags Head beach nourishment project was completed between 24 May and 27 October 2011. It involved excavation of ~4,615,126 cubic yards (final contractor surveys) from two USACE-approved offshore borrow areas (subareas 2 and 3 shown in Fig 2.1). Pre-project bathymetry data were collected by Tidewater Atlantic Research Inc in July 2009, and post-project bathymetry data were collected by CSE in December 2011 following completion of the construction.

Figures 7.1 and 7.2 show the post-project bathymetry of the borrow areas (subareas 2 and 3 within USACE S1). These maps may be compared with the pre-project bathymetry depicted on the construction drawings Sheets 14 and 15 (Appendix D). Figures 7.1 and 7.2 also include representative cross-sections through each borrow area, highlighting the excavation. Color-coded digital terrain models (DTMs) (Fig 7.3) show before-dredging and after-dredging conditions. Figure 7.4 shows the elevation difference between the July 2009 condition and December 2011 after-dredging conditions. CSE estimates that ~85 percent of each borrow area was used (ie – ~480 acres out of a total of 575 acres).

Because construction took place over a five-month period and the borrow areas have been subject to considerable storm-wave action during Hurricane *Irene* (27 August) and several strong extratropical storms, the margins of the borrow areas show evidence of sloughing into the excavation basins. Borrow subarea 3 was excavated primarily via suction cutterhead dredge. Subarea 2 was excavated by self-propelled hopper dredges. As shown in the cross-sections (Figs 7.1–7.2), a majority of each borrow area was utilized with the expectation that these areas will not be used in the future per restrictions of the permits. Each area left significant undisturbed portions from which biological recruitment may occur.

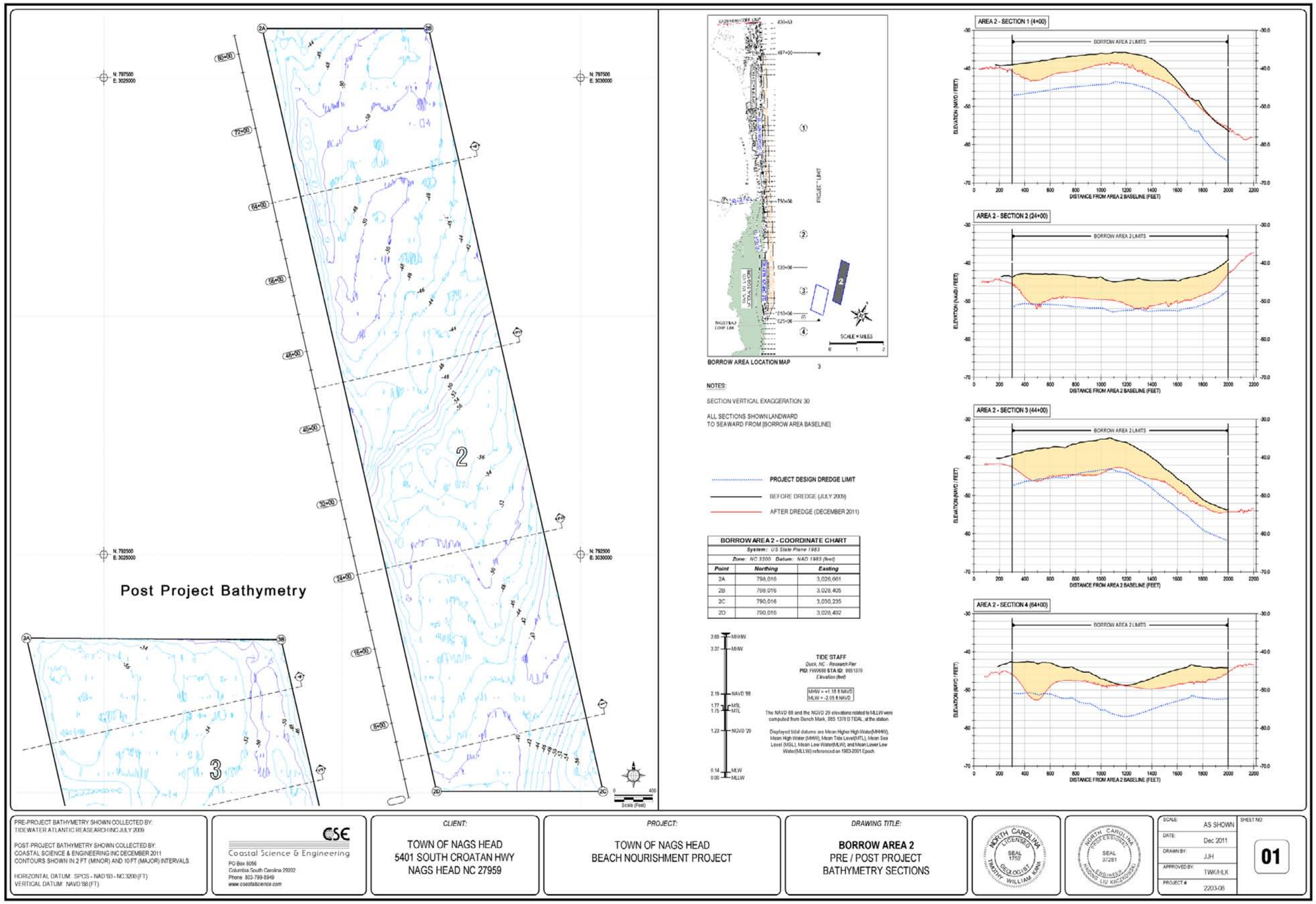

FIGURE 7.1. Borrow subarea 2 showing pre- and post-project bathymetry.

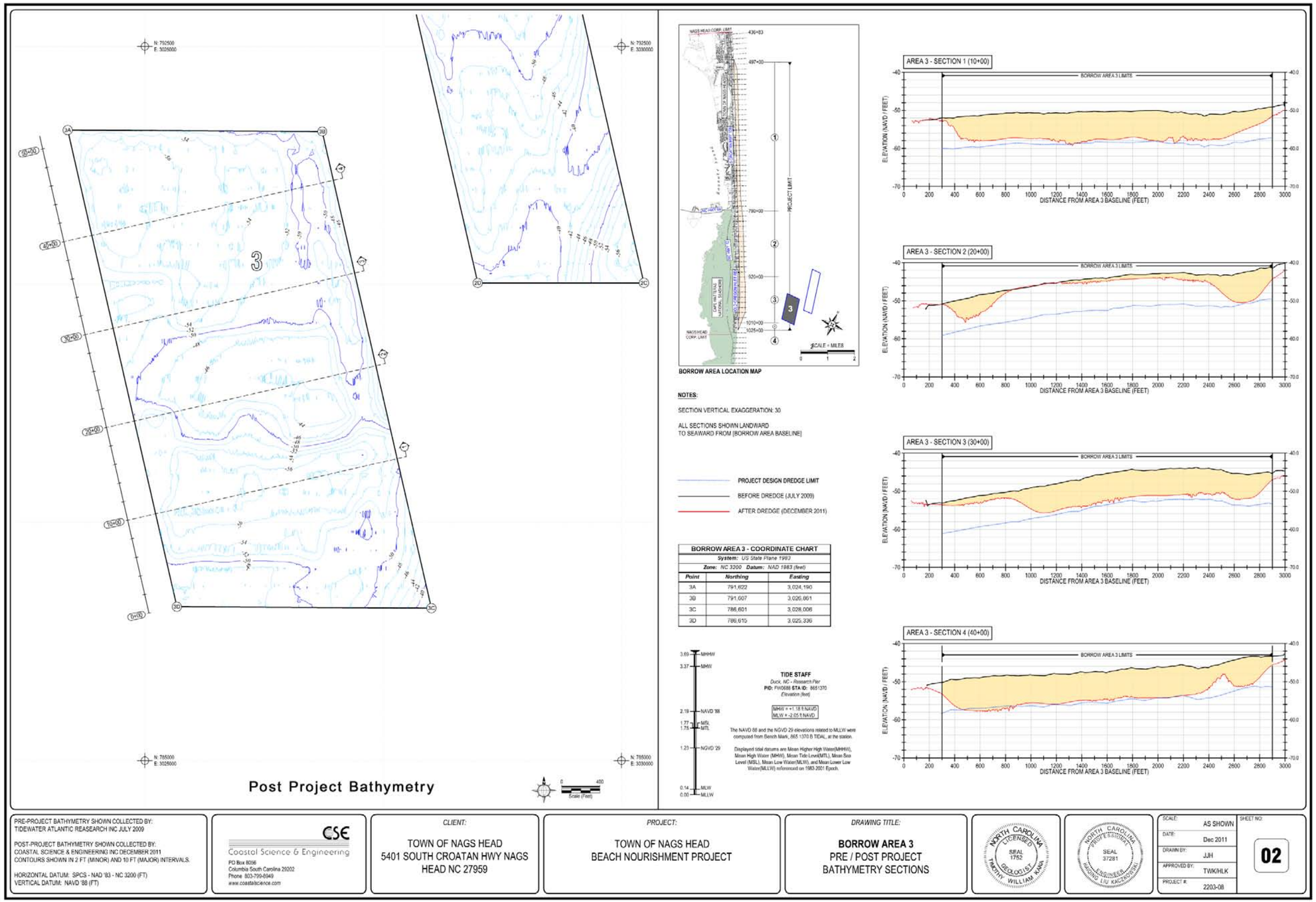

FIGURE 7.2. Borrow subarea 3 showing pre- and post-project bathymetry.

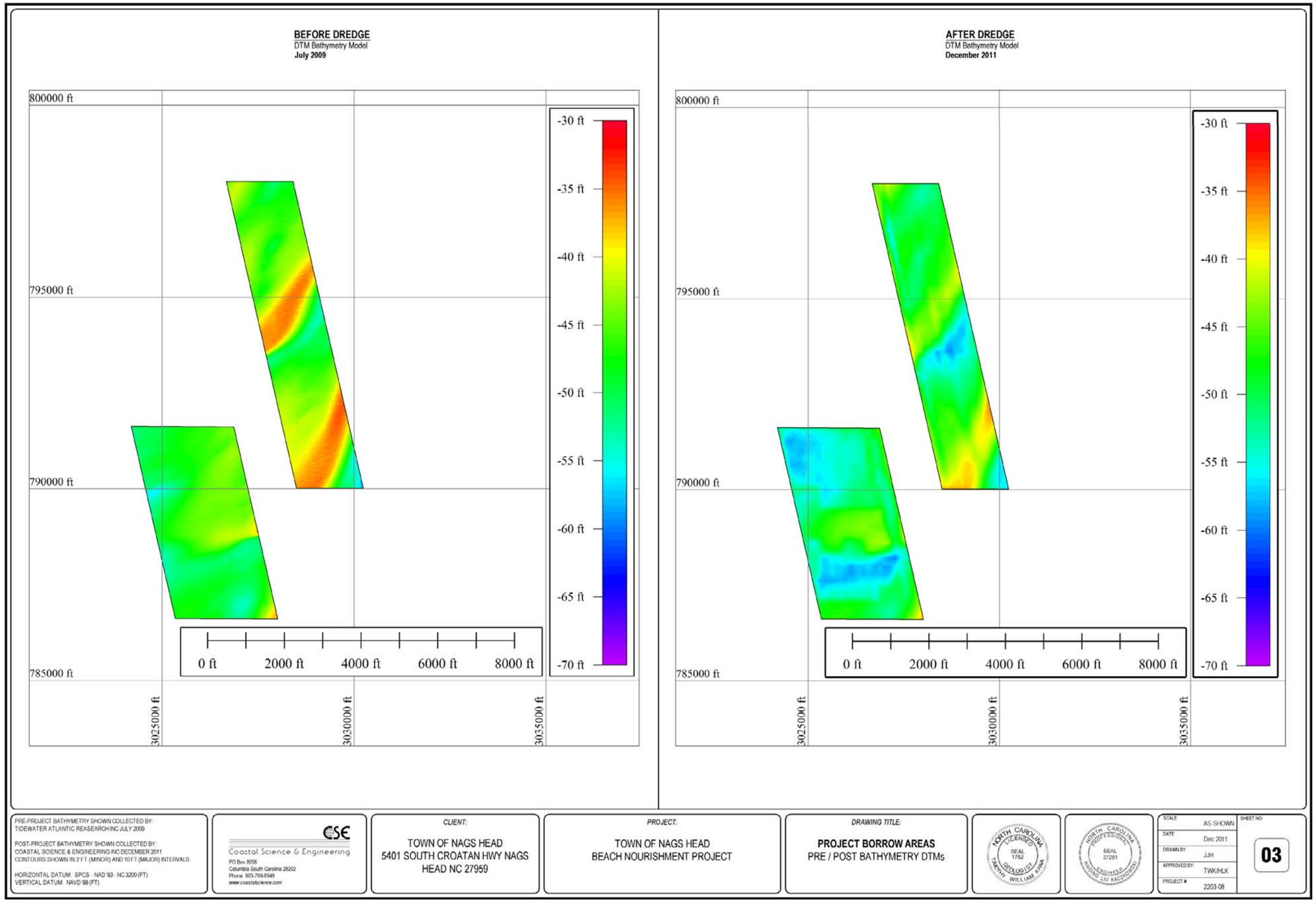

FIGURE 7.3. Borrow subareas 2 and 3 pre-project and post-project bathymetry DTMs.

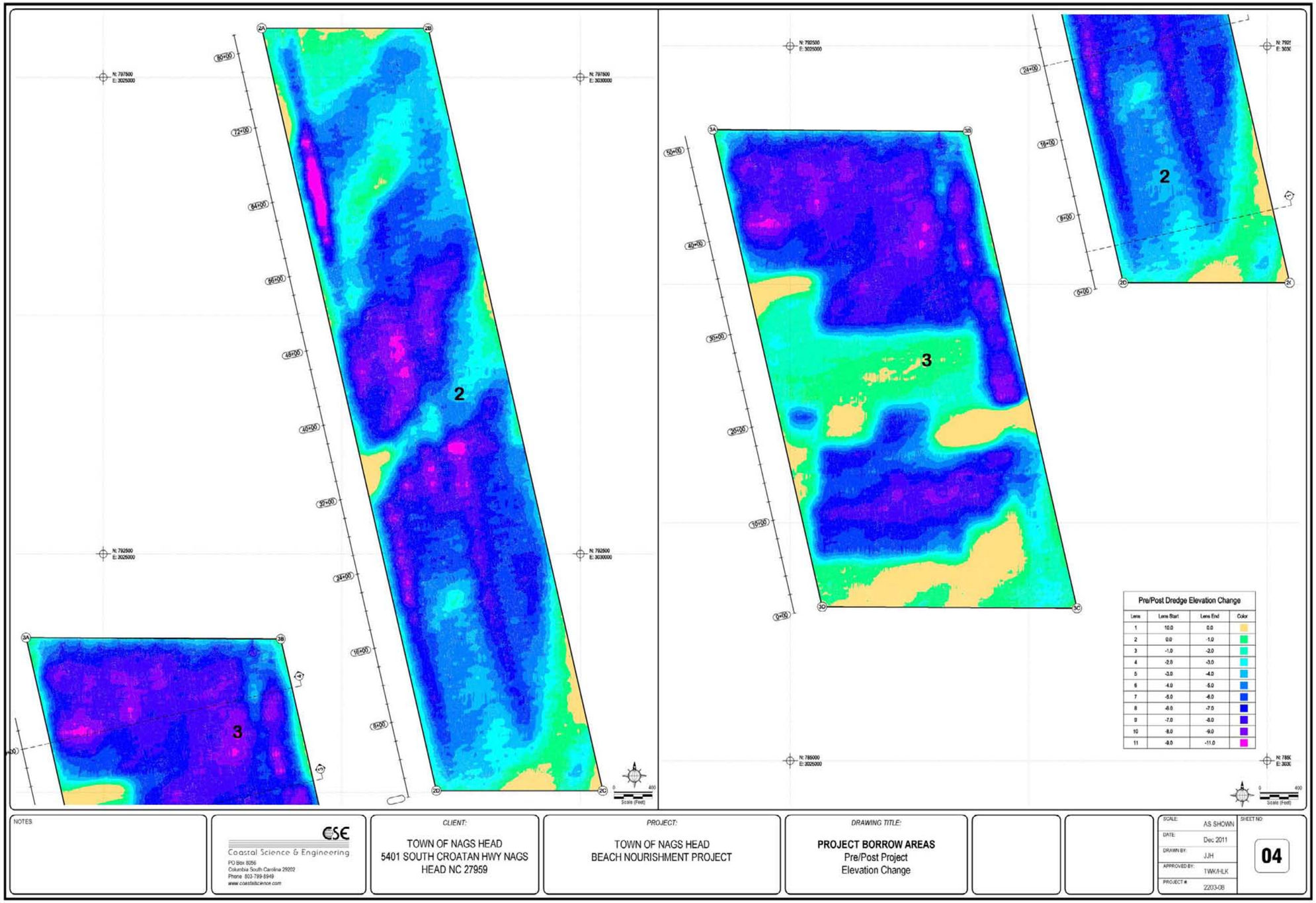

FIGURE 7.4. DTM's showing borrow areas bathymetry changes between pre-project and post-project.

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8.0 SUMMARY OF BEACH PROFILES AND FILL VOLUMES

Between 24 May and 27 October 2011, the contractor (GLDD) placed 4,615,126 cy of sand along the ten-mile project area at Nags Head (based on before- and after-dredging surveys). The comparison of actual fill volume and design volume for each reach is listed in Table 8.1.

TABLE 8.1. Summary of fill volume versus design volume for each reach based on before-dredging and after-dredging surveys by GLDD and November 2010 (pre-project) and November 2011 (post-project) surveys by CSE. Volume calculations for the November 2011 survey extended to the -12 FT depth contour approximately 800 FT from the foredune.

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Reach	Limits	Length (ft)	CSE Design Volume (cy)	GLDD Applied Fill Volume (cy)	Diff between Design and Fill (%)	CSE Verified Volume (cy)
1	497+00 to 790+00	29,900	1,634,700	1,645,812	0.68%	1,819,532
2	790+00 to 920+00	13,000	1,366,500	1,405,498	2.85%	1,358,359
3	920+00 to 1010+00	9,000	1,480,000	1,423,771	-3.80%	1,377,313
4	1010+00 to 1025+00	1,500	118,800	140,045	17.88%	158,723
Total	**497+00 to 1025+00**	**52,800**	**4,600,000**	**4,615,126**	**0.33%**	**4,713,927**

GLDD's before-dredging (BD) and after-dredging (AD) survey data showed that 70 percent of the sand was placed above MLW (−2.05 ft NAVD) and 30 percent was placed below MLW. GLDD's BD and AD data along with design templates for stations at 100-ft spacing are included in Appendix B1.

CSE completed a detailed survey of the beach and inshore zone in November 2011 within one month of project completion and compared the post-project conditions against the November 2010 condition (same-season comparison). Profiles of the pre-project and post-project conditions for stations at 500-ft spacing are including in Appendix B2, and a summary of unit volumes and total volumes of each station surveyed is in Appendix B3. CSE confirmed that there are 4,713,927 (±3 percent) cubic yards more sand volume in the ten-mile project area after nourishment (Table 8.1 and Figure 8.1). Following normal adjustment and fall storms, 52 percent of the nourishment sand remains on the visible beach above MLW, and 48 percent is contained between MLW and the 12-ft depth contour (~800 ft offshore from the foredune). Sand losses out of the project area to date have been negligible.

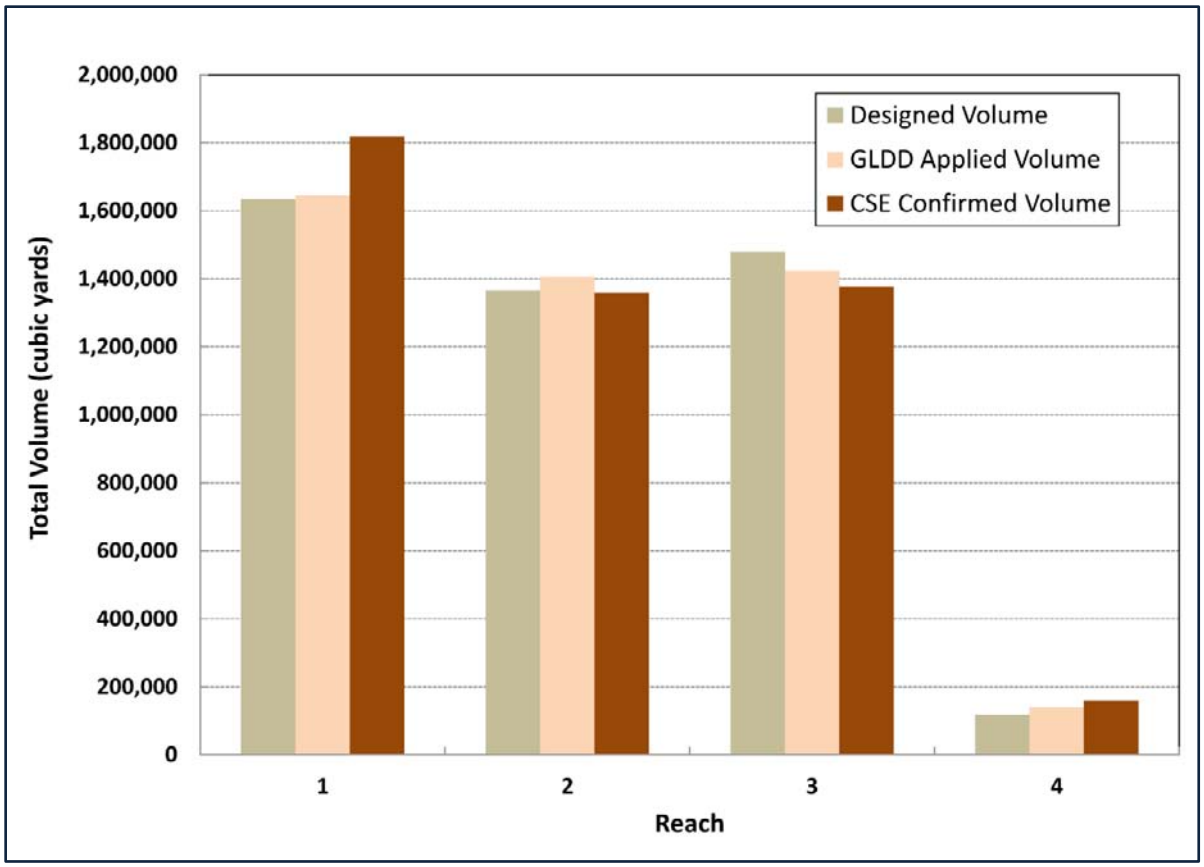


FIGURE 8.1. Comparison of design volume, GLDD applied fill volume and CSE confirmed volume for each reach based on before-dredging and after-dredging surveys on the beach by GLDD and November 2010 (pre-project) and November 2011 (post-project) surveys on the beach by CSE

Figure 8.2 shows typical cross-sections ("profiles") of the beach before and after nourishment. The upper diagram shows the initial shape of the nourished beach as sand was pumped into place. The constructed beach averaged more than 200 ft wide, and nearly all the new sand was contained within 400 ft of the foredune. This beach shape allowed the contractor to control the volume placed with the expectation that waves would soon reshape the nourishment into a natural profile.

It is typical to build a "fill template" whereby more sand is initially placed on the visible beach and the sloping seaward edge is steeper than normal (Dean 2002). This is a practical way to control the sediment slurry and insure that each section of beach receives its allotted volume. Such fill templates create an unnatural profile which is inherently unstable.

A simple analogy is that of an iceberg which has most of its volume below water. If ice is added to the tip of the iceberg, it causes it to settle lower in the water until a new hydrostatic balance is achieved. Similarly, if nourishment sand is placed entirely on top of the visible beach, some of it will be unstable and will end up shifting underwater until a balanced profile with normal slope is achieved.

The middle diagram of Figure 8.2 shows the profile of the beach after Hurricane *Irene* (27 August 2011) and several fall northeasters. Storm waves pushed some sand higher on the dry-sand beach (note yellow wedge) while, at the same time, the wet-sand beach receded landward. Thus, the dry beach narrowed by about 25–33 percent. Some sand from the wet beach shifted offshore and formed a bar 400–600 ft from the foredune (note the underwater sand buildup). CSE determined the limit of significant sand volume change over the course of the past year was at the 12-ft depth contour. While sand movement and bottom changes during the 2011 fall storms occurred in deeper water, there was little net change in sand volume along Nags Head seaward of the 12-ft contour.

The lower diagram of Figure 8.2 compares the nourishment profile (referred to as "fill template") and the adjusted profile. The yellow zone shows the portion of the nourishment profile that shifted onshore (to build the dry beach higher) and offshore (to form a new bar in shallow water). The green zone shows the net buildup of the beach and underwater area following nourishment and natural adjustments. These changes in the average profile reflect one to six months of adjustment of the nourishment sections. While more adjustment will occur over the next several years, the major adjustment is considered complete given the intensity of fall storms.

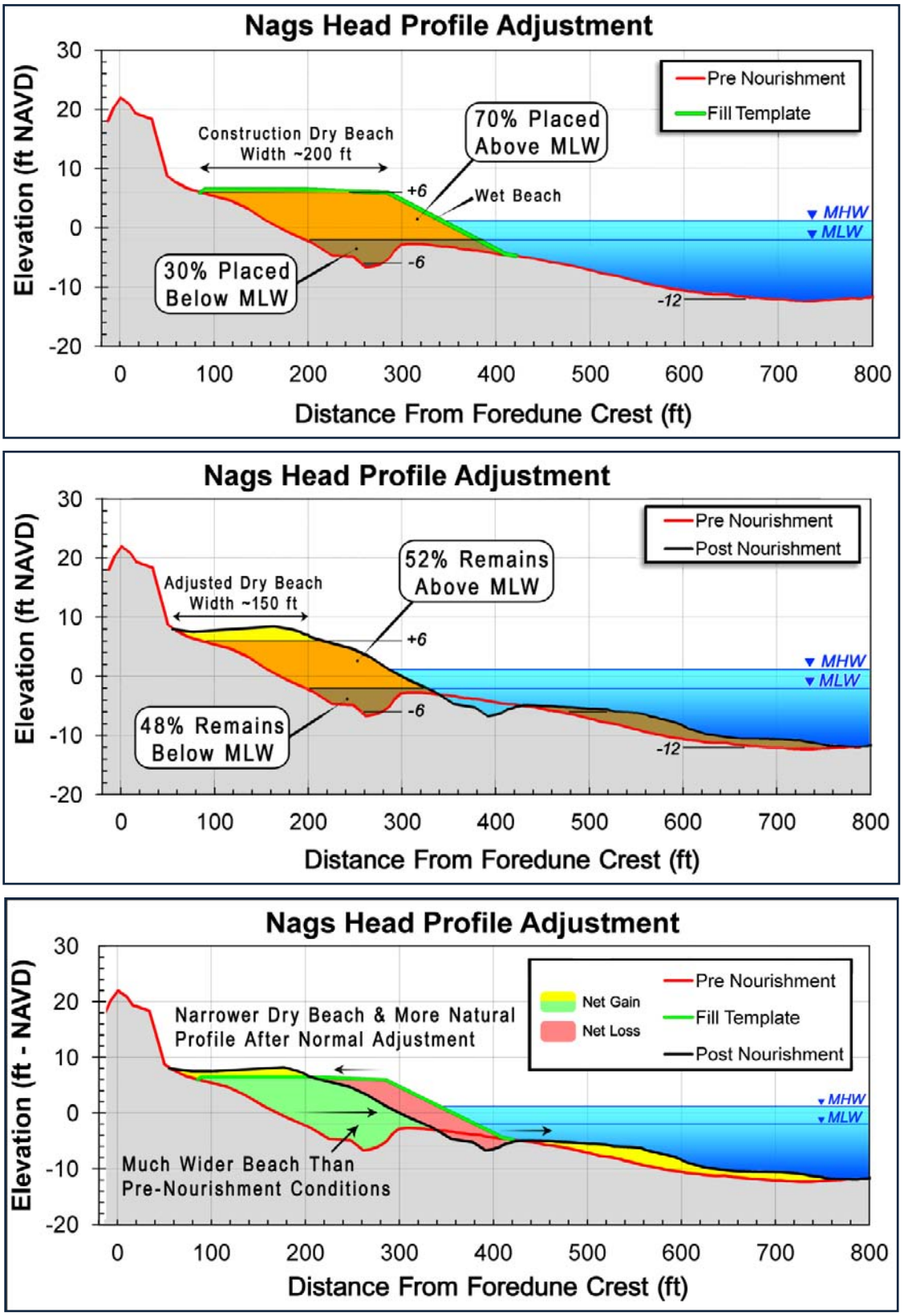


FIGURE 8.2. Schematic profiles illustrating the changes along Nags Head due to nourishment and fall 2011 storms. **[UPPER]** Before nourishment and fill template. **[MIDDLE]** Before and post-nourishment/post-storm. **[LOWER]** All three profiles with red, yellow and green, "net" erosion/accretion zones.

Figure 8.3 illustrates conditions before and after nourishment at Seagull Drive near station 995+00. Prior to nourishment, condemned houses along Seagull Drive were sitting in the surf. State regulations precluded nourishment over exposed sandbags, so the project had to work around the Seagull houses. This resulted in no sand placement in the low areas around the houses, thus leaving a pond (see middle photo). Fall northeasters washed over the nourished beach and eventually pushed sand into the pond (see bottom photo).

The landward and offshore shift of sand had the important effect of creating a more natural profile with new sand bars forming in shallow water. Prior to the adjustment of the nourishment project, surf conditions were unfavorable and dangerous in some areas because of the steep slope of the wet beach. However, after storms impacted Nags Head and modified the profile, the resulting underwater bars produced more favorable surfing conditions.*

> **All beaches experience profile adjustment which is simply the response of the beach to changing wave heights and water levels. Beaches absorb and dissipate wave energy with the universal response being a flattening of the profile as wave energy increases (Komar 1998). A flatter profile provides a broader wet-sand beach over which waves lose their energy. The character of breaking waves and swash also produces favorable changes. This is why the wave runup across the wide nourished beach did not attain the heights along some narrow-beach sections of Dare County. After storms subside, the flatter profile tends to adjust again. Lower waves will shift sand from the shallow-water bars back to the dry beach.*
>
> *The initial adjustment of the Nags Head beach nourishment project was, therefore, a combination of offshore movement due to the inherently unstable configuration of sand upon placement and the adjustment due to storms. Profile volumes, as measured before and after the project, provide an objective measure of the net impact. CSE believes the single most important finding of the pre- and post-construction surveys is the negligible loss of nourishment sand within the project limits. The critical boundaries of concern are the ten-mile alongshore length and the cross-shore between the foredune and −19-ft NAVD contour. These boundaries define a box which contained 4.6 million cubic yards less sand before the project. The volume of nourishment sand remaining in that box over time will define the performance of the project.*

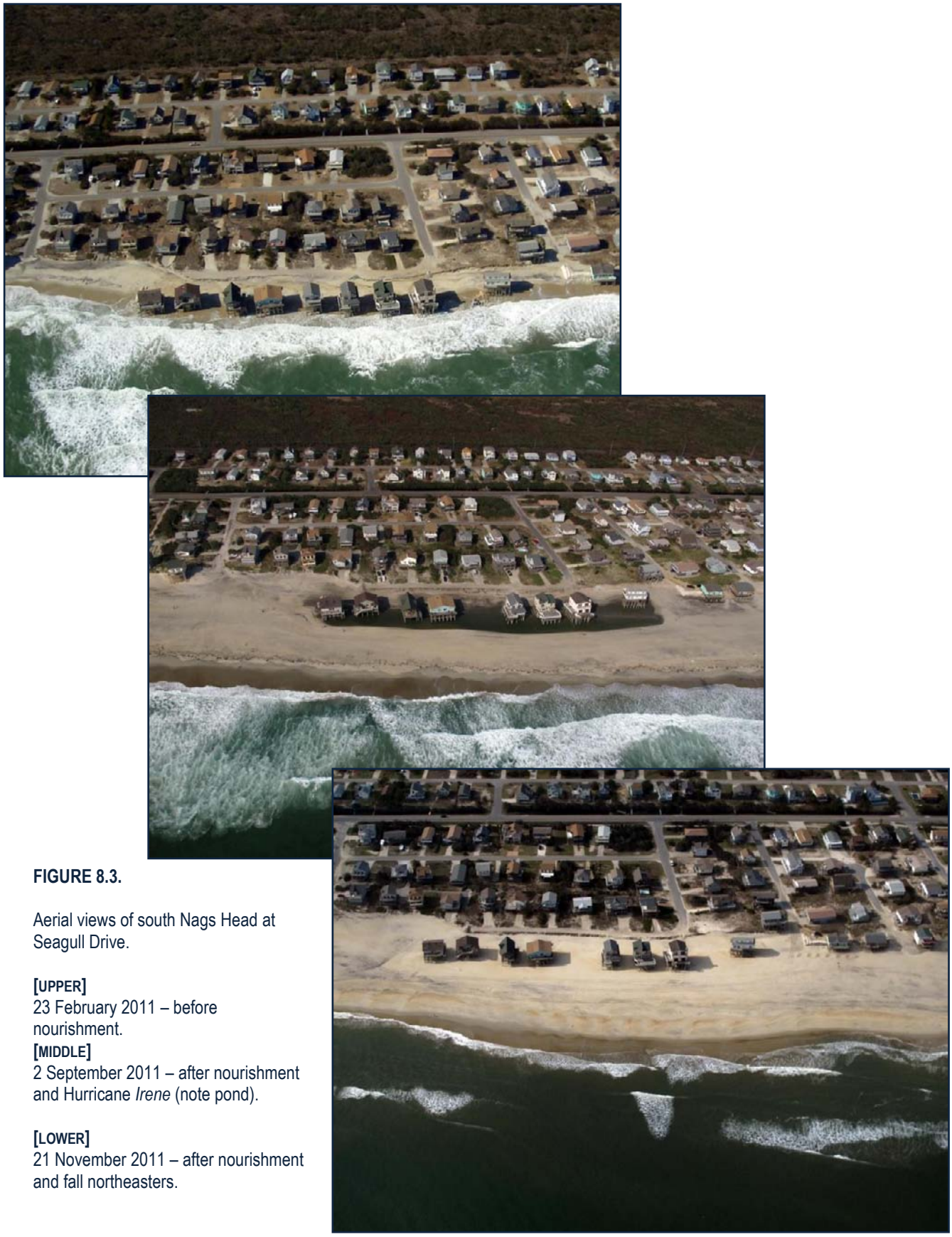


FIGURE 8.3.

Aerial views of south Nags Head at Seagull Drive.

[UPPER]
23 February 2011 – before nourishment.
[MIDDLE]
2 September 2011 – after nourishment and Hurricane *Irene* (note pond).

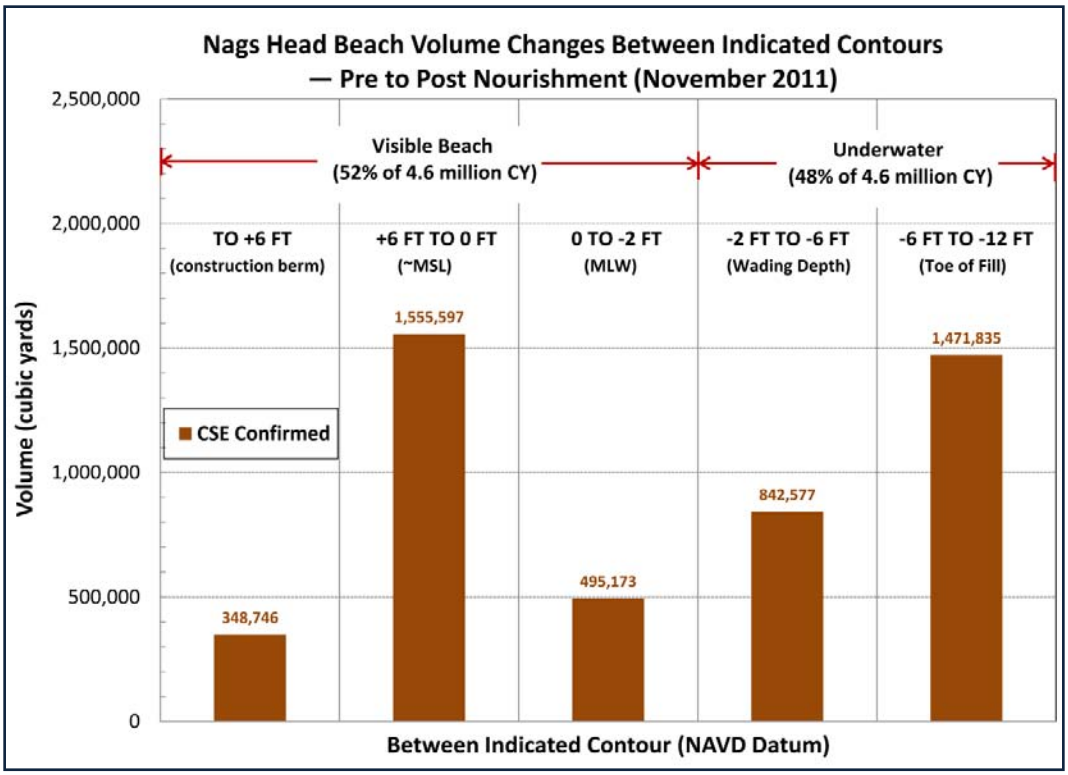
[LOWER]
21 November 2011 – after nourishment and fall northeasters.

Figure 8.4 (upper) shows the sand volumes contained in particular slices of the beach. Note that after adjustment, 52 percent of the nourishment sand was in the visible beach above MLW, and ~48 percent was close to shore between MLW and the 12-ft depth contour (~800 ft from the foredune). At least half of the nourishment sand had been expected to end up below low water after initial profile adjustment in accordance with the normal boundaries of the littoral zone along Nags Head. The shift of some sand offshore serves as a necessary foundation for the dry-sand beach.

Figure 8.4 (lower) shows the accumulated total volumes between the foredune and indicated depth contour. Surveys during construction confirmed that ~94 percent of the nourishment sand (~4.3 million cubic yards) was placed above low-tide wading depth (−6 ft NAVD) and only ~6 percent settled in deeper water. After Hurricane *Irene* and the fall storms, ~70 percent of the nourishment sand (~3.2 million cubic yards) remained above low-tide wading depth. The remainder was found between the 6-ft and 12-ft depth contours, which are about 400–800 ft from the foredune.

CSE's measurements in November 2011 detected over 4.7 million cubic yards **more** sand along Nags Head beach (calculated to −12 ft contour) compared with conditions in November 2010. This result is better than expected and suggests there has been no loss of sand by natural processes over the past year within the project limits and a gain of at least 4.6 million cubic yards via nourishment. Little or no sand has shifted out of the project area into deep water (>12 ft).

Project losses have been negligible to date within the boundaries set forth for the FEMA post-storm restoration criteria (−19 ft NAVD). CSE's measurements detected ~4.45 million cubic yards more sand between the foredune and the −19 ft contour. The difference between this volume and the nourishment volume (~150,000 cy) is about 3 percent which is considered within the limits of accuracy of underwater surveys for projects of this type. [Note: A similar calculation using a boundary of −24 ft NAVD yielded ~4.76 million cubic yards, which is also within ~3 percent of the placed volume.]



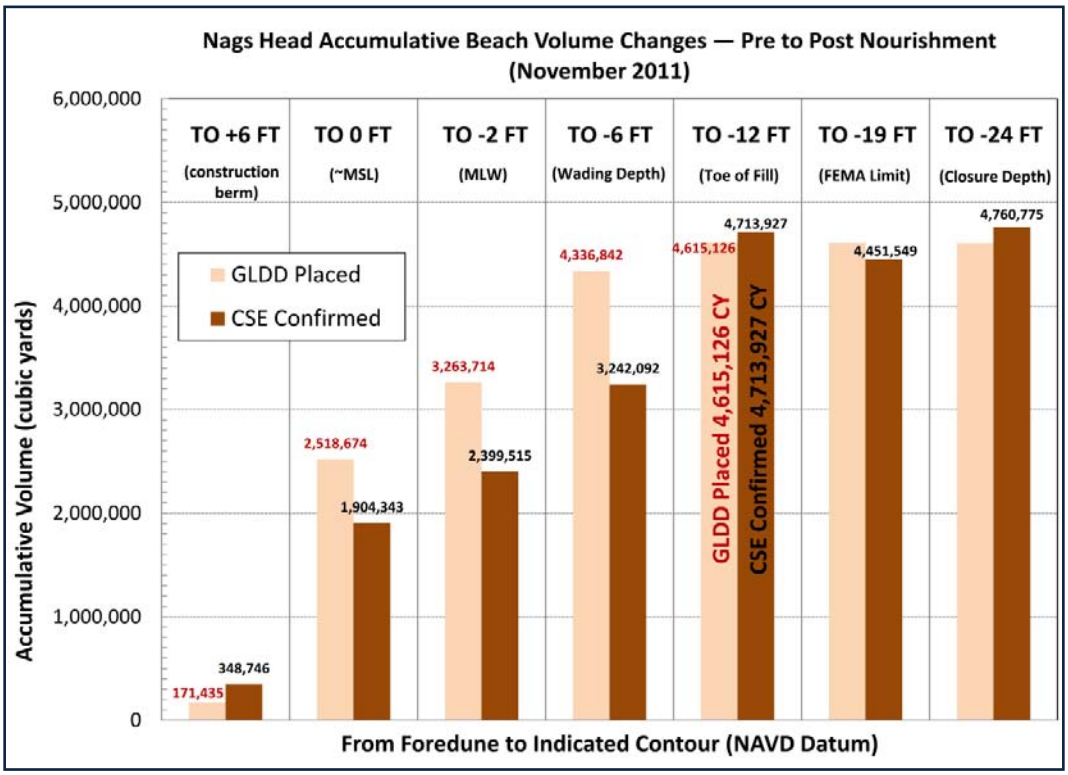


FIGURE 8.4. Beach volume changes between November 2010 and November 2011. **[UPPER]** Sand volume changes between representative contours. **[LOWER]** Accumulated volume changes between the foredune crest and the indicated contour.

The results also indicate that negligible quantities of nourishment sand have shifted downcoast to the National Seashore. This is better than expected at this stage of the project because the southern end has had a few months to adjust and spread southward under northeast storms. Sand is expected to shift downcoast over time. The measurements in November 2011 suggested that if any sand has shifted to south Bodie Island since nourishment, an equal volume has shifted to Nags Head from Kill Devil Hills. Otherwise, the volume change detected in the project area would be less than the nourishment volume. CSE concludes from this that nourishment sand has not reached Oregon Inlet in any measurable quantity or has not increased the rate of shoaling in the channel.

In summary, the Nags Head nourishment project is performing better than expected, and the profile is adjusting to a shape and configuration which is indistinguishable from a natural beach. CSE expects the higher dry beach (formed by storm overwash) will remain dry most of the time and will serve as a feeder for dune growth. Areas where the dry beach is wide are also likely to sprout vegetation in spring.

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9.0 SELECTED PHOTOGRAPHS BEFORE, DURING, AFTER CONSTRUCTION

PHOTO 1 — Nags Head beach before nourishment project. Photo was taken on 23 February 2011. Jennette's Pier is in the middle of the photo.

PHOTO 2 — Beach fill operations in Reach 2 on 22 July 2011 at two discharge points: Station 840+00 (upper left) via the hopper dredge, *Liberty Island*, and Station 900+00 (lower right) via the cutterhead dredge, *Texas*. Outer Bank's Pier is situated between the two active discharge points, and Jennette's Pier is at the top of the photo.

PHOTO 3 — Nourishment progress on 17 August 2011 (ten days before Hurricane *Irene*'s landfall) in the same area as Photo 2. Note limited extent (<500 FT) of sediment plumes at the discharging point.

PHOTO 4 — Reach 2 conditions on 2 September 2011 (six days after Hurricane *Irene*'s landfall).

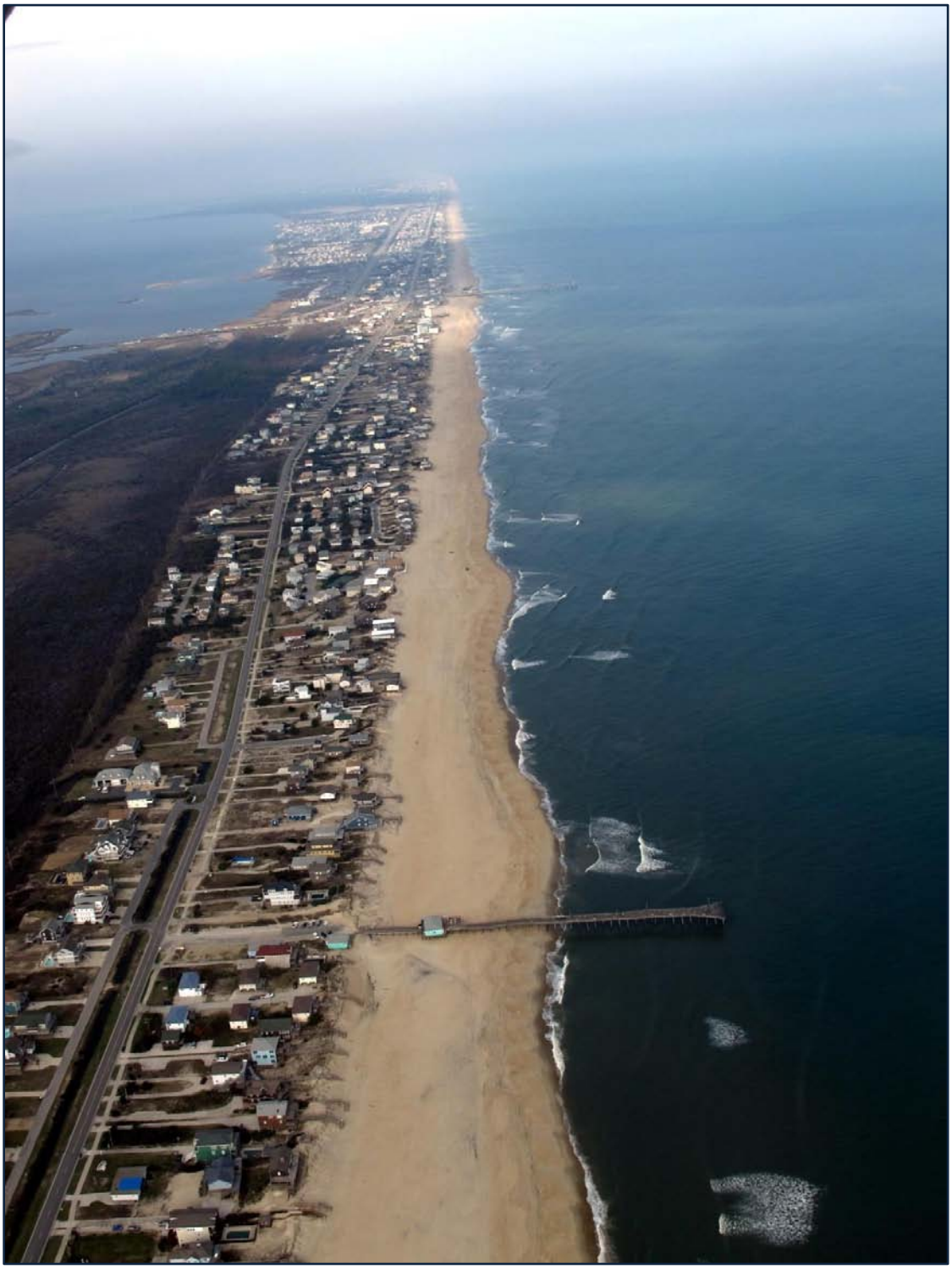

PHOTO 5 — Reach 2 conditions November 21, about four weeks after construction was completed.