APPENDIX I

PHYSICAL MONITORING

FIRE ISLAND INLET TO MONTAUK POINT NEW YORK

INTRODUCTION

This Appendix presents the Fire Island to Montauk Point (FIMP) Reformulation Feasibility Study physical monitoring plan. The environmental monitoring plan is not included in this appendix. In general, shore protection projects are periodically monitored in order to:

- Measure project performance;
- Improve the understanding of the physical processes at work and their interaction with project performance; and
- Plan the timing and volumetric requirements of renourishment and any other required maintenance or mitigation measures.

Monitoring can, in the long run, reduce project costs by optimizing future renourishment, maintenance and mitigation procedures. Moreover, a comprehensive engineering monitoring program can greatly increase knowledge of basic physical processes within the project area. Due to the vast size of the area covered by FIMP, monitoring of the project is, in fact, monitoring of the physical processes of the entire southeastern Atlantic shore region of Long Island. The monitoring area includes ocean, bay, coastal ponds, and inlet coastal processes. It is intended that the project post-construction monitoring will become a useful component in intelligent management of the overall Fire Island to Montauk Point region. A schedule of recommended physical monitoring activities and estimated costs are presented in Table D-1, with detailed discussion in the following sections.

PROJECT DESCRIPTION

The project includes a 14 ft high design dune (NAVD88) with a 90 ft wide berm placed along the Minimum Real Estate Impact (MREI) line. This line extends along Great South Bay and Moriches Bay and has a planned renourishment life of 50 yrs. Furthermore, a 12 ft high dune (NAVD88) and Proactive Breach Response Plan (BRP) is included along Shinnecock Bay. Additionally, modification of the Westhampton groin field; an Inlet Management Plan with sand bypassing at the three inlets; and a non-structural building retrofit plan for structures in the 10 year floodplain, in conjunction with road raising are also included. Interim sediment management projects have been initiated along Fire Island and Downtown Montauk. A general site map describing the locations of each plan components is presented in Figure D-1. Because of the long history of this project, some reference elevations remain in NGVD29. For future survey work, the elevations shall be updated to NAVD88. Due to the length of the project the conversion factor between NGVD and NAVD varies with location. Example of conversion factors are shown in Table 1. A 1-ft conversion is assumed in this Appendix for simplicity.

Table 1 – Datum Conversions

Location	NGVD29 to NAVD88 Conversion (ft)
Fire Island Inlet	-1.168
Moriches Inlet	-1.007
Shinnecock Inlet	-0.912

Montauk Point Lighthouse	-0.945
Average	-1.008

The components of the plan include:

Beach Fill Plan

- Layout: Minimum Real Estate Impact plan-beachfill plan by reaches and maintained for 50 years;
- Typical Profiles: El. +14 ft dune, 90 ft berm at +8.5 ft NAVD;
- Proactive BRP Profiles: El. +12 ft dune, 90 ft berm at +8.5 ft NAVD;
- Estimated initial fill 4.7MCY;
- Estimated renourishment volume/period : 5MCY/4 years

Non-Structural Plan

- 100-year level of protection for structures inside 10-year flood plain;
- Road raising and building retrofit measures are proposed, no relocation or buyout;
- 4,400 structures retrofitted,

Inlet Management Plan

It is important to note that the following quantities were computed using a 2001 sediment budget and may be subject to change depending on current conditions.

- Shinnecock Inlet – Authorized Plan (AP) + Ebb Shoal Dredging and -17' NAVD DB
  - 2 year cycle;
  - 85,000 CY/year AP
  - 52,000 CY/year Ebb Shoal;
- Moriches Inlet – AP + Ebb Shoal Dredging:
  - 1 year cycle;
  - 98,000 CY/year AP;
  - 73,000 CY/year Ebb Shoal;
- Fire Island Inlet – AP + Ebb Shoal Dredging and DB Expansion, updrift disposal:
  - 2 year interval;
  - 490,000 CY/yr AP;
  - 190,000 CY/year Ebb Shoal;

Groin Modification Plan

Shortening (or tapering) of Westhampton groin field (13 of 16 existing):

- Preliminary design – shortening 70 – 100 ft;
- Shortening in stages from west to east;
- Releases total estimated 0.5 to 3.2M CY of sand to west

Breach Response Plan (BRP)

BRP can be implemented at any location along the barrier islands fronting Great South Bay, Moriches Bay, and Shinnecock Bay (emphasis Shinnecock Bay),

- Breach Closure Template: +12' NAVD dune, Berm height is +8.5 ft NAVD. Berm width would be specifically defined at each location depending on conditions prior

to the breach and within adjacent areas;
- Proactive Response Plans

MONITORING ELEMENTS

The Physical Monitoring Plan includes inspection, measurement and analysis of the following physical phenomena and coastal processes within the project boundary and project life:

a. General:
- Periodic site inspection of shoreline condition and structure functionality;
- LIDAR topography or aerial photography;
- Shoreline changes and sediment budget update;
- Ocean wave height, period and direction;
- Water level measurement;
- Borrow area infilling;

b. Beach Fill:
- Beachfill/dune profile evolution;
- Sediment sample collection and analysis;
- Post-placement fill characterization;
- Fill compatibility analysis for each renourishment;

c. Inlet Management:
- Inlet morphology evolution;
- Ebb/Flood shoal evolution;
- Deposition basin in-filling rate;

d. Groin Modification:
- Shoreline and dune evolution including one mile both updrift and downdrift;
- Volume changes;
- Regional sediment budget;

e. Breach Response Plan:
- Storm, overwash and breach impacts;
- Cross-sectional volume;

f. Sediment Transport Modeling:
- Inner-shelf bathymetric changes;
- Sub aerial morphologic change;
- Wave, current, bed load and suspended sediment concentration measurements;
- Sediment transport modeling between the inner shelf and western Fire Island;

MONITORING ITEMS AND METHODOLOGY

The procedures and level of details of each monitoring elements are discussed in the following sections. More detailed scope of works will be prepared for individual monitoring elements during PED phase.

a. GENERAL:

a1) **Site Inspections:** Site inspections will be performed regularly for on-the-ground evaluation of the condition of all project elements; all project shoreline fronting ocean and bay, and shoreline vicinity of project elements. Prior to initial construction, a thorough site visit will be performed to document pre-construction baseline conditions. Site inspections will be repeated immediately after completion of construction, and seasonally (every three months) for the first year post-construction. Site visits will be performed a minimum of twice a year (March-April and Sept-October time frame) for the second through fourth years post-construction which will coincide with the duration of the first full nourishment cycle. Following the first nourishment cycle, site inspections will be performed annually, in the March-April time frame. Additional site visits will be performed following major storm events as needed. For cost estimating purposes, one post-storm site visit per year is assumed. Both shoreline and structures are inspected with the following procedure:

- **Shoreline Inspection**. Site visits will document the general condition of all shoreline reaches, and will note observable erosion or accretion of beaches and dunes. Changes to bay shoreline will be observed and documented. Inspections will document any unusual conditions, newly observed phenomena, or incursions into the project that are either natural or man-induced. Brief memoranda of all observations including still photographs will be compiled following each site inspection and kept as part of the project records. Recommendations will be included for any required maintenance, or more detailed investigation.

- **Structure Inspection.** All hard structures included in the project such as the groins, inlet jetties, and bulkheads as well as other shore protection elements will be visually inspected and documented. Structures will be inspected for both condition and functionality. Stone structures will be examined for any settlement, shifting or breakage of stone units, loss of interlocking, scour, overtopping, vandalism, etc. Structure function will be evaluated by examining the nearby beach and shoreline for evidence of impoundment, flanking, change in fill elevation, slope or width, up or downdrift impacts, etc. Recommendations will be made for further investigation or appropriate maintenance actions.

a2) **LIDAR.** Topographic LIDAR will be used to examine beach characteristics between measured profiles, including plotting Mean High Water shoreline evolution over time. Beach profile surveys and LIDAR need to be coordinated in time to accurately correlate the two types of data. LIDAR will also capture visible portions of ebb and flood shoal formations at inlets. LIDAR will be acquired preconstruction, and twice each year, concurrent with semi-annual beach profile surveys during years 1- 4 (first nourishment cycle). Following the first nourishment cycle, one post-winter (late February-early

March) LIDAR survey per year will be performed at the fourth year after each nourishment cycle.LIDAR will be taken at the time of low tide. Note that the NY State program of controlled orthophotography is anticipated to continue to be flown at four-year intervals. The state orthophotography will be available to augment project obtained data. An example Scope of Work (SOW) for LIDAR is shown in Attachment C.

In the event that LIDAR is unavailable, georeferenced aerial photography is also acceptable, but shall meet the following requirements. Each over flight mission will be a single flight line with 60% overlap stereo coverage including the entire project area shoreline, including both ocean and bay. Bay shoreline will be included as separate single flight lines where the width of landforms requires more than a single flight line. Aerial coverage of inlets will include complete flood shoal and ebb shoal formations. Color film with a 9-inch x 9-inch format is recommended with a scale such that shoreline features are readily identifiable (e.g. 1 inch = 800 feet). All images shall be georeferenced to New York State Plane Lambert projection, Long Island Zone, NAD83 with units in feet. Digital scans of each 9x9 will be provided at a minimum of 300 dpi resolution.

a3) **Shoreline Change Monitoring**. Mean High Water shorelines will be extracted from spring (late February-early March) LIDAR topography and plotted in overlays to show shoreline evolution over time within the project and immediately up and down drift. Plotting successive shorelines will illustrate the extent of erosion or accretion and will provide a means of measurement of the rate of loss or gain of littoral material. Comparative shoreline plots will be prepared for the entire length of the oceanfront, bay, pond, and island shorelines within the project boundaries. The sediment budget will be updated based on combined shoreline evolution and measured beach profiles;

a4) **Wave Measurements.** Directional wave gages will be deployed in two locations, one in waters off of Fire Island Inlet, and a second off the Westhampton Beach shore. Gages will be deployed prior to construction and will remain in place for the length of the first nourishment cycle (project years 1-4). The primary purpose of wave measurement is to assist in quantifying the driving forces behind changes to the native and constructed beach, as well as providing records of storm data. Wave gages will also provide information on wave conditions during construction, as well as for user communities such as homeowners, surfers, fishermen, environmental scientists, etc. during the instrument deployment period. Wave height data will be obtained under storm conditions over the deployment period and will be compiled to develop more accurate wave height-frequency relationships.

The wave gages should be deployed in a nearshore water depth of –25 to –35 ft. NAVD and should be cabled to shore. If cabling to shore is precluded, internal recording gages will be utilized. Data will be posted in real time on a project internet site for cabled gages and following data recovery for internal recording gages and archived to a web-accessible database. Both the bulk wave parameters, mean currents and wave spectra should be displayed and archived in the database, along with links to water level data from nearby USGS tide gages and wind/wave data from NOAA Buoy #44025.

a5) **Water Level Measurements.** Long term water level gages will be installed in Great South Bay (3 gages), Moriches Bay (2 gages) and Shinnecock Bay (2 gages) and tied in to verified bench marks (bench marks to be established if needed) for accuracy. Subsurface gages will be installed in the nearshore area. Real-time data will be recorded and posted on the project monitoring web server. Water level data will be used to record still water levels for confirmation of economic damage projections and to provide calibration data for any future modeling work. Water level data obtained under storm conditions will be compiled to develop more accurate water level-frequency relationships. Water level measurements will be obtained pre-construction through the first nourishment cycle.

a6) **Borrow Area Monitoring.** Offshore borrow areas will be monitored to document material removal, and to determine borrow area infilling rates for possible borrow area reuse. As part of construction, pre- and post- dredge hydrographic survey will be taken at the designated borrow areas. Some nearby, similar area outside the designated borrow area will be included in the survey to serve as a control (i.e. to document naturally occurring bottom changes). Computations will be done to verify quantity and location of material removed from the borrow areas during initial construction and renourishment operations. For cost estimating purposes, it is assumed that pre- and post-construction survey of the borrow areas will be included in the construction costs.

Midway through the life of the project, hydrographic surveys will be repeated to determine pattern and depth of material accumulation to date. Vibracores will be taken and subbottom seismic profiling will be performed to obtain sediment layering and grain size distribution curves in the in-filled areas. Thirty (30) cores, twenty feet in length are assumed for cost estimating purposes. The actual number and length will be determined based on bathymetry and subbottom survey results. Vibracore data analysis will include a representative number of material samples taken from each core, determined by an experienced geologist, that will be used to characterize each core and sub area within the borrow region. All lab analyses and operations on cores will be standardized as to description of sediment type and grain size distribution. All surveys will be mapped to indicate spatial changes in the borrow area both horizontally and vertically. Suitability of material taken from the cores as beachfill material will be determined. Areas dredged for initial construction or earlier renourishment operations will be examined for possible reuse in future renourishment cycles based on material suitability and available quantities.

b. <u>BEACH FILL</u>

Placed beach fill will be monitored to measure its evolution over time. The beach berm and dune will be measured to record characteristics including:

- Berm width and elevation;
- Dune crest and base widths and elevations;
- Dune ocean side and land side slopes;
- Dune baseline;

Measurement will be done to aid in determining how the construction profile evolves towards a more stable long-term profile, at what rate erosion or accretion of the advanced nourishment and/or design berm occur, and any changes that occur to the dunes including sand loss or dune growth. Beachfill monitoring will aid in identifying areas of greater than normal erosion (“hot spots”) as well as any locations that experience sand buildup (accretion). Shoreline updrift and downdrift of the placed fill will be examined for any excessive sand losses or gains due to construction of the project or other causes. Other phenomena including but not limited to beach scarping, offshore bar changes, sand wave migration, overwash, etc. will be documented and quantified. Information gained from beach fill monitoring will be used in design of any future construction activities including renourishment.

Beachfill monitoring is also a critical component in expanding the understanding of coastal processes affecting the project area. Measurements of sand loss and/or gain will allow refinement of local and regional sediment budgets. Greater understanding of coastal processes will allow regional sediment management to be performed effectively. Ultimately, greater understanding of coastal processes will allow more accurate prediction of sediment accumulations and deficits on ocean side shorelines, within the bays, in navigation channels, and in the vicinity of inlets.

- **Beach Profiles**. Beach profiles will be one of the primary measurement techniques for beach fill monitoring. Beach profiles will be surveyed before and after initial construction to establish pre-fill baseline conditions, and conditions immediately following placement. Under the monitoring program beach profiles will be surveyed twice per year throughout the first nourishment cycle (four years). One survey will capture the characteristics of the beach following winter condition, and will be surveyed in late February-early March, before endangered shorebird nesting season. The second survey will capture the characteristics of the summer beach and will be surveyed in September-October, following departure of nesting shorebirds. Following the first nourishment cycle, one post-winter (late February-early March) profile survey per year will be performed at the fourth year after each nourishment cycle. Should the design four-year cycle need adjustment, timing of profile surveys will be adjusted accordingly. Note that endangered plant species (e.g. seabeach amaranth) may also be present, and surveys should be performed in such a way as to not disturb rare plants.

  A total of 122 long-range profiles will be surveyed over the entire project area in each survey (Figure D-2). This includes 102 long ranges at 1500 ft. spacing in the areas where fill is to be placed, plus 20 additional control profiles in non-fill areas. Profiles shall extend from a location landward of the dune and berm, along a repeatable line normal to the shoreline, and seaward out to closure depth (-31 ft NAVD) or a minimum of 2500 feet in length from the landward starting point. Profiles will be taken from established benchmarks that are documented and recoverable. Each monitoring survey will cover the same profile locations, unless observations of phenomena indicate that a change in profile locations is warranted. Repetitive surveys of profiles will be the basis for estimates of erosion and accretion volumes. Changes observed in beach profiles will help track the movement of placed fill alongshore and offshore.

- **Beach Sediment Grab Samples.** Beach sediment grab samples will be collected concurrently with beach profile measurements on 30 long-range profiles (every fourth long range). Samples will be taken at a minimum of nine (9) locations per profile: the seaward and landward edges of the berm, three subaerial locations (Mean high water, mid-tide level, and mean low water), and at three locations offshore (-7 ft. NAVD or bar crest, -13 ft. NAVD, –19 ft. NAVD, and –31 NAVD). Beach sediment sampling will provide pre- and post-construction grain size distribution data that will allow comparison of native and placed fill material. Beach sediment sampling during subsequent surveys will aid in determining sediment redistribution after placement.

  Beach sediment grab samples will be taken concurrent with the pre- and post-construction profile surveys, to obtain baseline information and a measure of placed material characteristics. Sediment samples will be taken concurrent with profile surveys before each nourishment placement to aid in material compatibility analyses for each nourishment operation.

  In addition to sediment sampling along profile lines, which will capture characteristics of borrow area material, sediment grab samples will be taken and grain size distribution curves prepared of inlet dredged material when it is placed on the beach. Samples of placed inlet material will be taken at the time of placement. For cost estimating purposes, it is assumed that funds will be added to the dredging & placement contract for obtaining and analyzing up to 50 samples per operation, and that inlet dredging with beach fill placement will occur every other year at Fire Island Inlet and every third year at Shinnecock and Moriches Inlets.

c. <u>INLET MANAGEMENT</u>

Bathymetry measurement will be obtained to measure morphological changes over time at Fire Island, Moriches and Shinnecock inlets. Measurements will cover the entire flood shoal area, ebb shoal area, and inlet throat. This will allow evaluation of inlet modification performance and will provide a basis for future actions, if any. Accurate, full-inlet bottom surface data will also improve the quality of any modeling efforts performed over the course of the project life. Hydrographic multibeam surveys will be performed of the each inlet to include the entire flood shoal, ebb shoal, and inlet throat. All surveys will be performed with kinematic GPS and referenced to Geographic NAD83 (horizontal) and NAVD88 (vertical). Inlet multibeam surveys will be performed prior to construction and at 10-year intervals thereafter. In-filling rates at deposition basins will be analyzed based on periodic hydrographic survey data.

d. <u>GROIN MODIFICATION</u>

LIDAR topography and beach profiles collected during the monitoring program will be used to estimate the effects of groin shortening at Westhampton groin field. The information to be analyzed includes initial and annual sand volumes released, updrift and downdrift shoreline impact, and dune and shoreline evolution vicinity of the project site.

e. BREACH RESPONSE PLAN

Baseline condition of bay bottom elevations will be obtained during the pre-construction period in those areas identified as most likely to experience overwash & breaching. Overwashes and breaches will be documented after they have formed by project aerial photography. Regular project aerial photography will allow comparison of pre- and post-storm conditions, computation of surface disturbance acreage, and evolution of the overwash landforms through time. Site visits will include observation of any overwash and breach locations. At the time of significant overwashes and/or breaches, elevations will be obtained in profile line form extending across the overwash/breach area(s) and affected bay bottom.

It is assumed that physical monitoring of breach and overwash areas will occur over the entire project length, whether or not the overwash is fronted by constructed improvements. For cost estimating purposes, 30 bayside overwash/breach profiles per major storm event have been assumed at 10-year intervals, having a minimum length of 2500 ft., plus a similar baseline survey pre-construction. Additionally, one set of post-storm beach profiles and one additional post-storm LIDAR topography flight have been assumed for cost estimating purposes at 10-year intervals.

f. SEDIMENT TRANSPORT MODELING

It has been hypothesized that the shoreface-attached ridges offshore of western Fire Island potentially facilitate transport from the inner shelf to the surfzone and the shoreline. If this transport does occur, the processes are thus far unknown, although they would be likely to be very complex, varying in space and time. Sediment transport modeling will be performed in order to increase our ability to predict the effects of alterations in the ridge system (by borrow area dredging) on the shoreline. The below tasks, needed to accomplish this modeling, and the modeling and the modeling itself will be cost shared at 50%/50% between the U.S.G.S and U.S.A.C.E.

- **Inner-shelf bathymetric changes**. A high resolution bathymetric survey will be collected using interferometric sonar swath and RTK-GPS techniques within the following boundaries: Fire Island Inlet to the west, Old Inlet to the east, the -8 m NAVD contour to the north, and a line 10km seaward of the -8 m contour. Repeated nearshore-surf zone grid bathymetry will be collected using the Coastal Carolina BERM system (reconfigured for launching from the beach) with the same east and west boundaries, and between the shoreline and the -8 m NAVD contour.

- **Sub aerial morphologic changes**. Repeated surveys of the beach and dune system in western Fire Island will be collected (preconstruction, and in project years 1 and 2) using the U.S.G.S. beach buggy system incorporating RTK-GPS and potentially LIDAR in a grid pattern to produce a 3-Dimesional surface. This data, along with previous conventional topographic data will be compiled to produce a time series of beach/dune changes.

- **Wave, current, bed load and suspended sediment concentration measurements**; The above oceanographic data will be collected by internally-recording equipment mounted on tripod frames. A total of six tripods will be deployed on the ocean bottom: four offshore of the western portion of Fire Island where the shoreface-attached ridge system is present; and two offshore in areas having no attached ridge system. All six gages will record surface waves, currents, pressure, conductivity and temperature; two will also record bottom stress and suspended sediment concentration. Some will be placed in the offshore, and some closer to shore. The offshore ones are expected to remain in place for several months, the nearshore ones for several weeks.

- **Sediment transport modeling between the inner shelf and western Fire Island;** The U.S.G.S ROMS-SWAN modeling system will be used to investigate how the morphology of the inner-shelf and shoreface influence beach behavior on western Fire Island, with and without the borrow areas. Outputs will include wind-driven waves, regional circulation patterns, nearshore/surf zone wave-driven currents, and the resulting sediment transport due to bed load and suspended sediment processes.

ANALYSIS AND REPORTS

A data analysis report will be prepared each year for the first nourishment cycle (four years). The first year report will also include pre-construction conditions as surveyed and post-construction data, and will establish the project baseline condition for all subsequent evaluations. The data analysis report will be a complete compilation of all monitoring data taken, plus analysis of the data with trends as observed, evaluation of project performance, and recommendations for future actions including both monitoring and construction actions as appropriate. Analyses to be performed include but are not limited to:

- All site inspection reports;
- Summary of construction activities including estimates of volumes placed;
- Comparison of assumptions made in design with monitoring data;
- Profile volume change;
- Profile shape adjustment;
- Volume of fill remaining in the project, volume of fill moving updrift, downdrift, offshore, and into inlet storage;
- Assessment of alongshore transport and cross-shore fill movement from the beach and nearshore areas with updates to the sediment budget;
- Grain size distribution curves and statistics pre- and post- construction;
- Seasonal responses;
- Repetitive shoreline change plots;
- Wave data recorded and statistical analysis;
- Water level data recorded;

- Borrow area bathymetry pre- and post-construction, plus seismic and vibracore data when applicable;
- Site visit inspection results including structure condition reports;
- Overwash and breach monitoring results;
- Lidar survey of the project area as available;
- Inlet and bay bathymetry data, with plots of changes between survey intervals;
- An event log of occurrences within the project boundaries including record of all construction activities, storms, high water events, and other observed phenomena that may affect project performance;
- Nearshore and sub aerial change plots in western Fire Island;
- Wave, current, bed load and suspended sediment concentration data recorded in western Fire Island;
- With and without-project wind driven waves, circulation, nearshore currents and sediment transport modeling results in western Fire Island.

Following the first nourishment cycle, a data analysis report will be prepared once each nourishment cycle. A final summary report will be prepared in the last year of the project life.

COSTS

The estimated costs for physical monitoring are summarized in Table D-1. The monitoring items and cost basis are included in Attachment A. Monitoring costs are annualized based on 50 year project life and 3.375% interest rate for October 2015. The total cost is approximately **29.6 million** at present worth and the annual cost is approximately **$673,000**. The cost basis is October 2015.

OMRRR-Project Operation, Maintenance, Repair, Replacement, and Rehabilitation

As part of the Project Cooperation Agreement, an Operations, Maintenance, Repair, Replacement, and Rehabilitation Manual (OMRRR) will be prepared which will outline the responsibilities of the local sponsor over the course of the project life. A brief description of the duties of the local sponsor is shown in Attachment B, as per ER 1110-2-2902(30 June 1989) and ER 1110-2-1407 (30 Nov 1997).

TABLE D-1
ANNUAL PHYSICAL MONITORING ACTIVITIES AND FIRST COST
FIRE ISLAND TO MONTAUK POINT, NY
(October 2015 Price Level)

PROJECT YEAR	NOURISH-MENT CYCLE	SITE VISIT/ STRUCTURE INSPECTION	LONG RANGE BEACH PROFILES	SEDIMENT SAMPLES	LIDAR TOPOGRAPHY	INLET BATHY METRY	WAVE GAGES	WATER LEVELS GAGES	OVERWASH/ BREACH BAY PROFILES	POSTSTORM LIDAR TOPOGRAPHY	BORROW AREA MONITOR	WEB SERVER	INNER-SHELF SEDIMENT TRANSPORT MODELING	DATA ANALYSIS (REPORT)	TOTAL
Pre-con.		4,800	608,979	195,000	395,795	536,000	526,000	279,000	75,000			25,000	1,143,000		3,788,574
1	1	19,200	608,979		791,591		378,000	132,000				25,000	489,000	72,000	2,515,769
2		14,400	608,979	37,500	791,591		378,000	132,000				25,000	785,000	36,000	2,808,469
3		14,400	608,979		791,591		378,000	132,000				25,000	380,000	36,000	2,365,969
4		14,400	608,979	135,000	791,591		396,000	132,000				25,000	133,000	36,000	2,271,969
5	2	9,600										25,000			34,600
6		9,600		37,500								25,000			72,100
7		9,600										25,000			34,600
8		9,600	304,489	135,000	395,795							25,000		72,000	941,885
9	3	9,600										25,000			34,600
10		9,600		37,500		536,000			75,000	241,477		25,000			924,577
11		9,600										25,000			34,600
12		9,600	304,489	135,000	395,795							25,000		72,000	941,885
13	4	9,600										25,000			34,600
14		9,600		37,500								25,000			72,100
15		9,600										25,000			34,600
16		9,600	304,489	135,000	395,795							25,000		72,000	941,885
17	5	9,600										25,000			34,600
18		9,600		37,500								25,000			72,100
19		9,600										25,000			34,600
20		9,600	304,489	135,000	395,795	536,000			75,000	241,477		25,000		72,000	1,794,362
21	6	9,600										25,000			34,600
22		9,600		37,500								25,000			72,100
23		9,600										25,000			34,600
24		9,600	304,489	135,000	395,795							25,000		72,000	941,885
25	7	9,600									346,000	25,000			380,600
26		9,600		37,500								25,000			72,100
27		9,600										25,000			34,600
28		9,600	304,489	135,000	395,795							25,000		72,000	941,885
29	8	9,600										25,000			34,600
30		9,600		37,500		536,000			75,000	241,477		25,000			924,577
31		9,600										25,000			34,600
32		9,600	304,489	135,000	395,795							25,000		72,000	941,885
33	9	9,600										25,000			34,600
34		9,600		37,500								25,000			72,100
35		9,600										25,000			34,600
36		9,600	304,489	135,000	395,795							25,000		72,000	941,885
37	10	9,600										25,000			34,600
38		9,600		37,500								25,000			72,100
39		9,600										25,000			34,600
40		9,600	304,489	135,000	395,795	536,000			75,000	241,477		25,000		72,000	1,794,362
41	11	9,600										25,000			34,600
42		9,600		37,500								25,000			72,100
43		9,600										25,000			34,600
44		9,600	304,489	135,000	395,795							25,000		72,000	941,885
45	12	9,600										25,000			34,600
46		9,600		37,500								25,000			72,100
47		9,600										25,000			34,600
48		9,600	304,489	135,000	395,795							25,000		72,000	941,885
49	13	9,600										25,000			34,600
50		9,600										25,000		84,000	118,600
Totals		508,800	6,394,275	2,265,000	7,915,909	2,680,000	2,056,000	807,000	375,000	965,909	346,000	1,275,000	2,930,000	1,056,000	29,574,893

Notes:

1. Length of nourishment cycle assumed to be 4 years.
2. Borrow Area monitoring includes one hydrographic survey of 12 borrow areas plus 30 line miles of seismic profiling and 30 20-ft. long cores in project year 25

TABLE D-2 ANNUAL ENGINEERING MONITORING COST ESTIMATE FIRE ISLAND TO MONTAUK POINT, NY (October 2015 Price Level)			
YEAR	**FUTURE WORTH**	**PRESENT WORTH FACTOR**	**PRESENT WORTH**
Pre- and post-construction	$3,788,574	1.00000	$3,788,574
1	$2,515,769	0.96735	$2,433,634
2	$2,808,469	0.93577	$2,628,080
3	$2,365,969	0.90522	$2,141,719
4	$2,271,969	0.87566	$1,989,484
5	$34,600	0.84708	$29,309
6	$72,100	0.81942	$59,080
7	$34,600	0.79267	$27,426
8	$941,885	0.76679	$722,227
9	$34,600	0.74175	$25,665
10	$924,577	0.71754	$663,419
11	$34,600	0.69411	$24,016
12	$941,885	0.67145	$632,429
13	$34,600	0.64953	$22,474
14	$72,100	0.62832	$45,302
15	$34,600	0.60781	$21,030
16	$941,885	0.58797	$553,795
17	$34,600	0.56877	$19,679
18	$72,100	0.55020	$39,669
19	$34,600	0.53224	$18,415
20	$1,794,362	0.51486	$923,846
21	$34,600	0.49805	$17,233
22	$72,100	0.48179	$34,737
23	$34,600	0.46606	$16,126
24	$941,885	0.45085	$424,644
25	$380,600	0.43613	$165,990
26	$72,100	0.42189	$30,418
27	$34,600	0.40811	$14,121
28	$941,885	0.39479	$371,846
29	$34,600	0.38190	$13,214
30	$924,577	0.36943	$341,568
31	$34,600	0.35737	$12,365
32	$941,885	0.34570	$325,612
33	$34,600	0.33442	$11,571
34	$72,100	0.32350	$23,324
35	$34,600	0.31294	$10,828
36	$941,885	0.30272	$285,127
37	$34,600	0.29284	$10,132
38	$72,100	0.28328	$20,424
39	$34,600	0.27403	$9,481
40	$1,794,362	0.26508	$475,652
41	$34,600	0.25643	$8,872
42	$72,100	0.24806	$17,885
43	$34,600	0.23996	$8,302
44	$941,885	0.23212	$218,633
45	$34,600	0.22454	$7,769
46	$72,100	0.21721	$15,661
47	$34,600	0.21012	$7,270
48	$941,885	0.20326	$191,449
49	$34,600	0.19663	$6,803
50	$118,600	0.19021	$22,558
SUM OF PRESENT WORTHS	$25,786,319		$16,140,317
TOTAL ANNUAL COST			**$672,684**
NOTES:		INTEREST RATE =	3.375%
		PROECT LIFE =	50
		CAPITAL RECOVERY FACTOR =	0.04168

Figure D-1 Project Plan

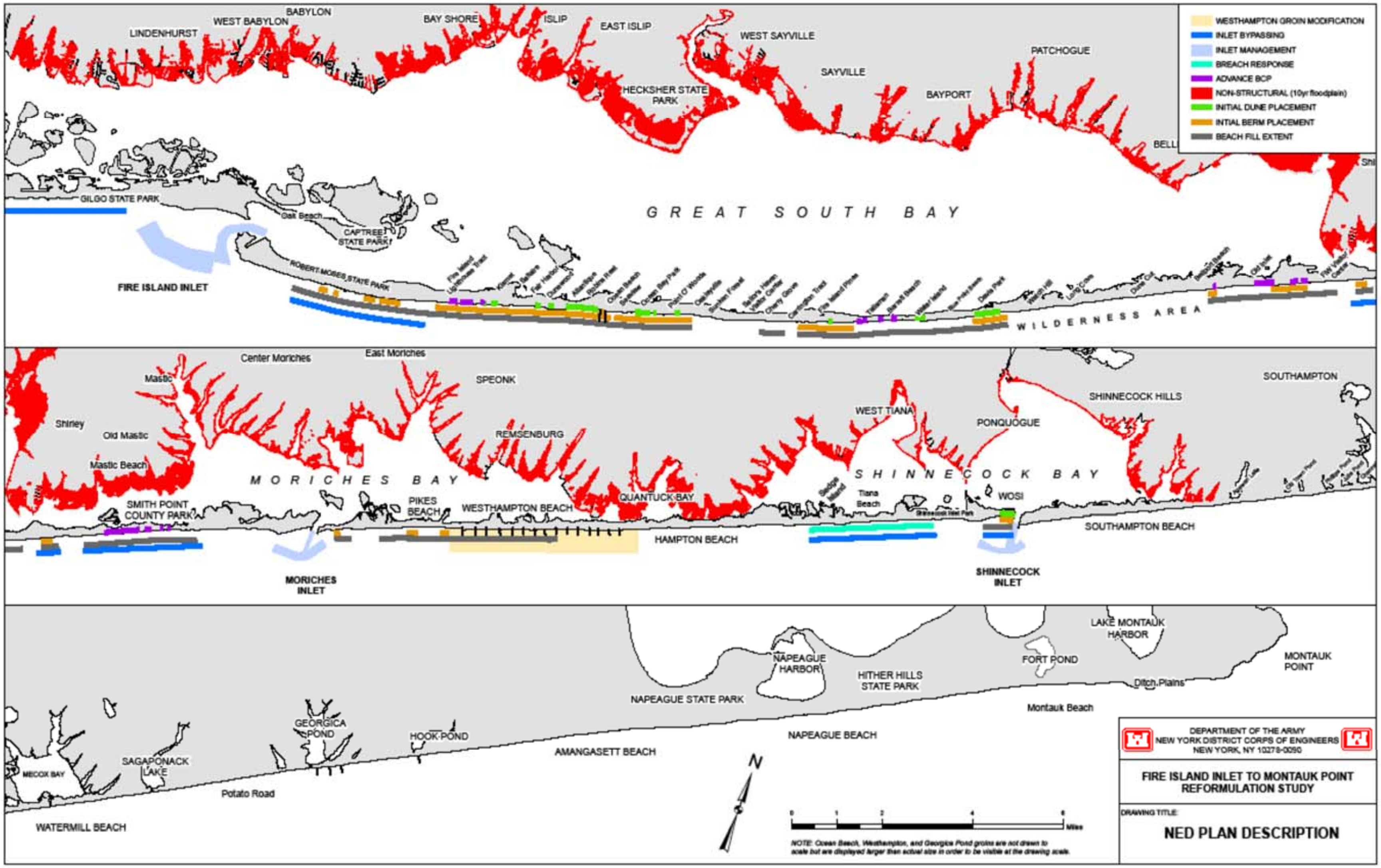
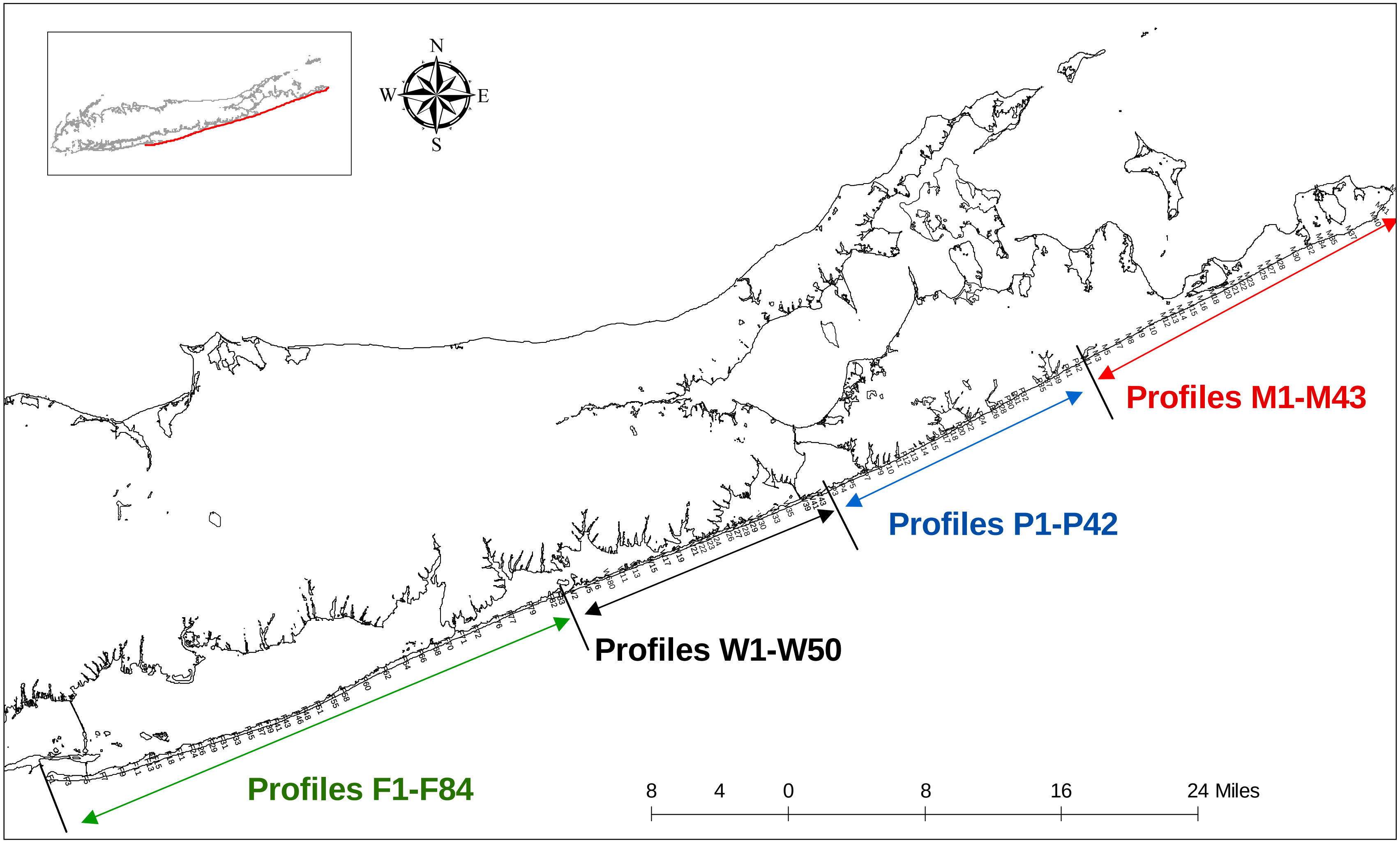


Figure D-2 Beach Profile Locations



INSERT FIGURE with water level gage locations

ATTACHMENT A

COST BACKUP

TABLE DA-1 SITE INSPECTION & ANALYSIS/REPORT PREPARATION FIRE ISLAND TO MONTAUK POINT, NY (October 2015 Price Level)							
SITE INSPECTIONS							
Assume 2 persons per site visit, 2 days each visit.							
Assume auto & foot access to all locations (ie no boat)							
number persondays	cost per pd	total cost per visit					
4	$1,200	$4,800					
Assume 4 site visits in year 1							
Assume 2 site visits in years 2-4							
Assume 1 site visit in years 4-50							
Cost pd includes per diem expenses							
ANALYSIS AND REPORTAGE							
First Year:							
Report to include pre- and post-construction data and analysis							
Assume	60	pd @	$1,200	=	$72,000		
Includes preparation of basemaps, shoreline change plots, and figures							
and all necessary tables and calculations							
2nd, 3rd & 4th year:							
Report to include each year's data plus analysis of all data taken to date							
Assume	30	pd @	$1,200	=	$36,000		
5th through 49th year:							
Report to be prepared once per nourishment cycle, at end of cycle.							
Report to include all data taken in the cycle plus analysis of all data to date.							
Assume	60	pd @	$1,200	=	$72,000		
50th year:							
Final report to include summary of all prior reports to date.							
Assume	70	pd @	$1,200	=	$84,000		

TABLE DA-2
BEACH PROFILE UNIT COST
FIRE ISLAND TO MONTAUK POINT, NY
(October 2007 Price Level)

1. OCTI input. OCTI surveyed this reach 2x/year for the ACNYMP 1995-2000 and monitoring surveys at Westhampton and Shinnecock thereafter. OCTI has relatively low overhead, main base in Pennsylvania, and work long days.

FIELD WORK:

Reach	Cost per line First 10 lines	Cost per line 10+ lines	Weather Days (1) 1 day per 20 lines
East of Fire Island:	$2,320	$1,500	$4,250
Fire Island (3)	$3,016	$2,300	$4,250

Assuming 50 lines:	East of Fire Island	$72,945
	Fire Island	$105,641
Average cost per line, field work:		$1,786
Field Work for 50 line survey:		$89,293
CAD at $600/day, 4 LR per day:		$7,500
Management: 15 hrs plus 3 hrs per field day @ $1000/day		$1,913
TDY @ $120/day field time		$7,513
SUBTOTAL		$106,218
20% markup for NY company higher overhead		$21,244
SUBTOTOTAL for 50 lines		$127,462
In-house scoping and review (15%)		$19,119
TOTAL cost per line		$146,581
Cost per line including processing, survey company management, & in-house:		$2,931.62

SAY $3000/LINE (LONG RANGE)

(1) 5-man crew plus LARC $4250/day. Survey Branch estimate as of March 2004
(2) Production rate: field work - 4 long ranges per day, 10 short ranges per day. Same rate for CAD work.
(3) Rates on Fire Island higher due to access limitations, permitting complications, logistic complications

2. In-house estimate: prepared by John Mraz (see estimate in file). Per John, costs have actually gone down in last few years due to advances in GPS and other technologies.

In-house estimate was $1500/long range.
Increase by 30% for Fire Island access difficulties = $1950/long range.
Say $2000/long range.

Use average of OCTI/in-house estimate: (3000 + 2000)/2 = $2500/LONG RANGE

Assume 2.5 short ranges = 1 long range based on production rates of 4 LR/day and 10 SR/day

TABLE DA-3
BEACH PROFILE INVENTORY
FIRE ISLAND TO MONTAUK POINT, NY

Reach Designations						Alternatives							Monitoring Surveys			Monitoring Surveys		
Project Reach	Design Reach	Design Subreaches	Profile Reach	Reach Designation	Approximate Length (ft)	Beachfill: Alignments	Beachfill: Max. Possible Fill Length [ft] (2)	Beachfill: Design Sections (4)	Structural/Non-Str.: Structural.	Structural/Non-Str.: Non-Str.	Environmental Measures	Remarks	Number of Long Range Profiles - Fill Area Only: 1000 ft line spacing	1500 ft. line spacing	2000 ft line spacing	Number of Long Range Profiles - Entire Island: 1000 ft line spacing	1500 ft. line spacing	2000 ft line spacing
Fire Island Inlet									Inlet Mod.			See Inlet Alternatives						
GSB	GSB-1	1A		Robert Moses State Park	25,700	1	16,458	Berm only: 90 ft					15	11	8	23	17	13
		1B		FI Lighthouse Tract	6,700	1	5,468	13/90 (LLOP)				FINS Track	5	4	3	6	4	3
	GSB-2	2A		Kismet to Lonelyville	8,900	3	8,880	13/90 15/90 17/90		acq / relocate		2 Small FINS Tracks	8	6	4	8	6	4
		2B		Town Beach to Corneille States	5,100	3	4,556	13/90 15/90 17/90		acq / relocate		2 Small FINS Tracks	4	3	2	5	3	3
		2C		Ocean Beach & Seaview	3,800	3	3,696	13/90 15/90 17/90		acq / relocate			3	2	2	3	3	2
		2D		OBP to Point O' Woods	7,400	3	7,267	13/90 15/90 17/90		acq / relocate			7	5	4	7	5	4
		2E		Sailors Haven	8,100			None				FINS Track	0	0	0	7	5	4
	GSB-3	3A		Cherry Grove	3,000	1	2,928	13/90 15/90 17/90		acq / relocate		FILL ONLY AT RENOURISHMENT	3	2	1	3	2	2
		3B		Carrington Tract	1,500			None				FINS Track	0	0	0	1	1	1
		3C		Fire Island Pines	6,600	3	6,424	13/90 15/90 17/90		acq / relocate			6	4	3	6	4	3
		3D		Talisman to Water Island	7,300	1	7,076	13/90				FINS Track	6	5	4	7	5	4
		3E		Water Island	2,000	1	1,202	13/90 15/90 17/90		acq / relocate			1	1	1	2	1	1
		3F		Water Island to Davis Park	4,700	1	5,445	13/90				FINS Track	5	4	3	4	3	2
		3G		Davis Park	4,100	3	4,042	13/90 15/90 17/90		acq / relocate			4	3	2	4	3	2
		3H		Watch Hill	5,000			None				FINS Track	0	0	0	5	3	3
	GSB-4	4A		Wilderness Area - West	19,000			None					0	0	0	17	13	10
		4B		Old Inlet	16,000	1	15,023	13/90			Wetland	Low Level Design	14	10	8	15	11	8
MB	MB-1	1A		Smith Point CP-West	6,300	1	1,889	Berm only: 90 ft		acq / relocate			2	1	1	6	4	3
		1B		Smith Point CP - East	13,500	1	13,174	13/90			Wetland		12	9	7	12	9	7
	MB-2	2A		Great Gun	7,600			None					0	0	0	7	5	4
		2B		Moriches Inlet - West	6,200			None					0	0	0	6	4	3
Moriches Inlet									Inlet Mod.			See Inlet Alternatives	0	0	0	0	0	0
		2C		Cupsogue Co Park	7,500	1	2,000	13/90					2	1	1	7	5	4
		2D		Pikes	9,700	1 (Interim)	9,630	15/90 17/120		acq / relocate			9	6	5	9	6	5
		2E		Westhampton	18,300	1 (Interim)	10,908	-/90	Groin Mod.	acq / relocate		Groin Shortening, FILL ONLY at Ren	10	7	5	17	12	9
SB	SB-1	1A		Hampton Beach	16,800			None					0	0	0	15	11	8
		1B		Sedge Island	10,200	1	4,967	13/90					5	3	2	9	7	5
		1C		Tiana Beach	3,400	1	3,361	13/90		Road Raising	Wetland	See BCP Alternatives	3	2	2	3	2	2
		1D		Shinnecock Inlet Park West	6,300		6,288	13/90		Road Raising	Wetland	for western end only	6	4	3	6	4	3
	SB-2	2A		Ponquogue	5,300			None					0	0	0	5	4	3
		2B		WOSI	3,900	1 WOSI	3,875	13/90 15/90 17/120	T-Groin			See Inlet Alternatives	4	3	2	4	3	2

TABLE DA-3
BEACH PROFILE INVENTORY
FIRE ISLAND TO MONTAUK POINT, NY

Shinnecock Inlet									Inlet Mod			See Inlet Alternatives	0	0	0	0	0	0
	SB-3	2C		Shinnecock Inlet - East	9,800			None					0	0	0	9	7	5
		3A		Southampton Beach	9,200			None		acq / relocate			0	0	0	8	6	5
		3B		Southampton	5,300			None		acq / relocate			0	0	0	5	4	3
		3C		Agawam	3,800			None		acq / relocate			0	0	0	3	3	2
P	P-1	1A		Wickapogue	7,700			None		acq / relocate			0	0	0	7	5	4
		1B		Watermill	8,800			None		acq / relocate			0	0	0	8	6	4
		1C		Mecox Bay	1,400			None			Bay Manag.	See Bay Manag. Plan	0	0	0	1	1	1
		1D		Mecox to Sagaponack	10,400			None		acq / relocate			0	0	0	9	7	5
		1E		Sagaponack Lake	1,100			None			Pond Manag.		0	0	0	1	1	1
		1F		Sagaponack to Potato Rd	9,300			None		acq / relocate			0	0	0	8	6	5
		1G		Potato Rd	4,300	1	3500	15/90 17/90 17/120 (or 19/90)		acq / relocate			3	2	2	4	3	2
		1H		Wainscott	4,600			None		acq / relocate			0	0	0	4	3	2
		1I		Georgica Pond	1,200			None			Pond Manag.		0	0	0	1	1	1
		1J		Georgica to Hook Pond	11,200			None	Groin Mod	acq / relocate			0	0	0	10	7	6
		1K		Hook Pond	1,100			None					0	0	0	1	1	1
		1L		Hook Pond to Amagansett	19,200			None	Groin Mod	acq / relocate			0	0	0	17	13	10
M	M-1	1A		Amagansett	10,400			None		acq / relocate			0	0	0	9	7	5
		1B		Napeague State Park	9,100			None		acq / relocate			0	0	0	8	6	5
		1C		Napeague Beach	9,900			None		acq / relocate			0	0	0	9	7	5
		1D		Hither Hills SP	7,000			None		acq / relocate			0	0	0	6	5	4
		1E		Hither Hills to Montauk B	15,800			None		acq / relocate			0	0	0	14	11	8
		1F		Montauk Beach	4,700	1	4,636	15/90 17/90 17/120 (or 19/90)		acq / relocate		Western Taper of M-D1G	4	3	2	4	3	2
		1G		Montauk B to Ditch Plains	4,700			None		acq / relocate	Dune Restoration		0	0	0	4	3	2
		1H		Ditch Plains	3,400			None		acq / relocate	Dune Restoration		0	0	0	3	2	2
		1I		Ditch Plains to Montauk Pt	19,300			None		acq / relocate			0	0	0	18	13	10
NOTES:												TOTAL	139	102	76	402	295	221

(1) If BCP is required, breaching risk and a range of possible templates are shown
(2) Actual Length of fill depends of section and alignment
(3) No fill is likely to be required during initial construction
(4) In areas where 3 sections are considered, these 3 sections are referred to as Large, Medium and Small in other documents
(5) Berm width and overall closure length and width will mimic conditions prior to breach and conditions in adjacent areas
In addition, a range of elevations will be considered: a flat "berm only" closure with an elev of +9.5 and two additional alternatives with a small dune at elev of +11 or +13
Assume reaches to receive beachfill as per drawing
"Approximate Beach Fill Extents and Location of Structural Features (Preliminary Draft)

TABLE DA-4
Beach Profiles - Comparative Cost Varying Number of Lines
FIRE ISLAND TO MONTAUK POINT, NY
(October 2015 Price Level)

	Profiles in Fill Area Only			Profiles Entire Shoreline			ACNY
	Total Number Long Ranges (1)			Total Number Long Ranges			Monitor Program
	1000 ft	1500 ft	2000 ft	1000 ft	1500 ft	2000 ft	# of lines
Fire Island	94	69	52	153	112	84	38
Moriches to Shinnecock	37	27	21	74	54	41	23
Shinnecock to Montauk Pt.	7	5	4	175	128	96	54
Total # long ranges	159	122	96	402	295	221	115
Cost @ $2500/long range	$397,031	$304,489	$240,867	$1,005,909	$737,667	$553,250	$287,500

Notes:

(1) Includes 20 control profiles outside fill area

(2) for comparison, in Spring 1998, 87 long ranges were surveyed in FIMP area for $164,250

Recommend 1500 ft. spacing in fill area only, plus 20 control profile lines per survey.

TABLE DA-5 **LIDAR Topographic Survey** **FIRE ISLAND TO MONTAUK POINT, NY** **(October 2015 Price Level)**				
Assume $10,000 per square mile				
WORK ITEMS:				COST
Prepare Scope of Work & review products				$5,000
Shoreline				
23.6	sq mi @	$10,000	per sq mi	$235,795
Inlets				
15	sq mi @	$10,000	per sq mi	$150,000
Survey Branch Administration				$3,500
Labor Contracting Division				$1,500
Total FI Inlet to Montauk Point				$395,795

TABLE DA-6
Water Level Gages
FIRE ISLAND TO MONTAUK POINT, NY
(October 2007 Price Level)

Item	Annual Cost for 1 Gage	5 Gages	7 Gages
Internal Recording Year 1 (Install):			
Establish/verify bench mark with RTK	$5,000	$25,000	$35,000
Install gage	$10,000	$50,000	$70,000
Retrieve, process and submit data	$24,000	$72,000	$96,000
Includes replacing batteries			
To be done every three months			
at $6k per 3-month interval			
For additional gages, add $3k per			
gage per 3-months			
Total Year 1	$39,000	$147,000	$201,000
Internal Recording Year 2, etc:			
Establish permanent bench mark	$0	$0	$0
Install gage	$0	$0	$0
Retrieve, process and submit data	$24,000	$72,000	$96,000
Includes replacing batteries			
To be done every three months			
at $6k per 3-month interval			
For additional gages, add $3k per			
gage per 3-months			
Total Year 2, etc	$24,000	$72,000	$96,000
Real Time Gage Year 1 (Install)			
Establish/verify bench mark with RTK	$5,000	$25,000	$35,000
Install gage	$10,000	$50,000	$70,000
Install real-time system at $6k per gage	$6,000	$30,000	$42,000
Cell transmitter and web server	$48,000	$96,000	$120,000
at $4k/month for first gage, $1k/month			
additional for additional gages			
Mid-year maintenance trip	$8,000	$8,000	$12,000
Total Year 1	$77,000	$209,000	$279,000
Real Time Gage Year 2, etc.:			
Establish/verify bench mark with RTK	$0	$0	$0
Install gage	$0	$0	$0
Install real-time system at $6k per gage	$0	$0	$0
Cell transmitter and web server	$48,000	$96,000	$120,000
at $4k/month for first gage, $1k/month			
additional for additional gages			
Mid-year maintenance trip	$8,000	$8,000	$12,000
Total Year 2, etc.	$56,000	$104,000	$132,000

Quote from B. Grosskopf, 11/30/2005
1) Assume nearshore installation and subsurface gages.
2) Costs below included labor, expenses, normal hardware replacements
3) RTK = Real time kinematic
4) Includes quality assurance checks every three months
for real time and internal recording.

TABLE DA-7
Wave Gage
FIRE ISLAND TO MONTAUK POINT, NY
(October 2007 Price Level)

Cost per gage, from Dec 2004 estimate for wave gage at Long Branch, NJ:	Line Item Cost	Total Cost/year (2004 estimate)	15% increase for increasing boat, labor & fuel costs	10% differential for NY labor rates vs NJ	Total Annual NY Cost
YEAR 0 Preconstruction (Includes Installation)					
Directional wave gage yearly rental	$65,000				
Cable to shore for real time hook up,	$60,000				
pod base for underwater installation & data phone hook-up					
4 Cruises per year (assume mobilization, demobilization, and service visits equal in cost) to include -5 man crew @ $2818/9-hr day -$1396/day boat -civil or coastal engineer @ $850/day -4-man dive crew @ $3053/day subtotal $8117/day x 2 days = $16,234 per cruise (2)	$64,936				
Data review To include weekly review and Quarterly review. Assume 10 pd @ $750pd	$7,500				
In-house Scoping, Coorination & Review	$10,000				
Total Year Zero		$207,436	$31,115	$23,855	**$262,407**
YEAR ONE, TWO, Etc. (normal operation)					
Directional wave gage yearly rental	$65,000				
4 Cruises per year (assume mobilization, demobilization, and service visits equal in cost) to include -5 man crew @ $2818/9-hr day -$1396/day boat -civil or coastal engineer @ $850/day -4-man dive crew @ $3053/day subtotal $8117/day x 2 days = $16,234 per cruise plus 3% inflation = $16,234*1.03=$16,721	$66,884				
Data review pd @ $750pd	$7,500				
In-house scoping, coordination & review	$10,000				
Total Year One, Two, etc.		$149,384	$22,408	$17,179	**$188,971**
YEAR FOUR (demob year):					
Directional wave gage yearly rental	$65,000				
4 Cruises per year (assume mobilization, demobilization, and service visits equal in cost) to include -5 man crew @ $2818/9-hr day -$1396/day boat -civil or coastal engineer @ $850/day -4-man dive crew @ $3053/day subtotal $8117/day x 2 days = $16,234 per cruise plus 12% inflation = $16,234*1.12=$18,182	$72,728				
Data review To include weekly review and Quarterly review. Assume 10 pd @ $750pd	$8,250				
In-house scoping, coordination & review	$10,000				
Total Year Four		$155,978	$23,397	$17,937	**$197,312**

TABLE DA-8
IDENTIFICATION AND DELINEATION OF SAND BORROW SOURCES
FIRE ISLAND TO MONTAUK POINT, NY
(October 2015 Price Level)

TASK	**HOURS PER DISCIPLINE**				
	PM	G	AG	T	WP
Detailed Investigation of Borrow Sources					
1. Management Plan	4	8			8
2. Seismic Survey - 30 miles, lump sum includes:					
Beacon site selection, Preparation,					
and Operation of seismic lines					
3. Seismic Analysis					
a. Mark seismic data		4	8	8	
b. Prepare post plot		4	8	8	
c. Detailed study reflectors		4	8		
d. Plot data on two profile lines at all core sites			8		
e. Determine volumes of sand at each site and lens		8	8		
f. Mapping, text, drafting	8	4	16	8	4
4. Beach Grain Size Curve Evaluation		2			
5. Cores					
a. Schedule of Operations - lump sum includes:					
Assume 30 cores @ 5 cores/day (average which					
accounts for weather downtime). Includes boat, crew,					
equipment, on-board scientist, mob/demob					
b. Cores - logging/penetration, graphs and photo album		24	32	24	16
6. Upland Sand Analysis					
a. Collection of random samples			24		
b. Grain size analysis			24		
7. Borrow Source Analysis					
a. Composite grain size distributions			16		
Table median and standard deviation in phi and mm			8		
b. Compatibility analysis for each sand core & upland sample			24		
c. Tables, maps of suitable - marginal material area,					
thickness and volumes	8	16	16	8	8
FINAL REPORT					
1. Plan Maps		16	16	16	
2. Seismic cross-sections		16	16	16	
3. Isopach maps		16	16	16	
4. Maps, tables, text	8	32	32	40	40
TOTALS	28	154	280	144	76
RATES USED (1)					
PM: Project Manager:	$86.11	/hr x	28	2,411	
G: Geophysicist: =	$73.83	/hr x	154	11,370	
AG: Asst. Geophysicist: $19.53/hr x 2.6 OH =	$50.80	/hr x	280	14,224	
T: Technician: =	$36.90	/hr x	144	5,314	
WP: Word Processor: =	$36.90	/hr x	76	2,804	
			SUBTOTAL		36,123
DIRECT COSTS					
Seismic Survey				36,250	
Vibracoring $3200/core plus $300/core for analysis				105,000	
	SUBTOTAL Direct Costs				141,250
In-House Scoping, Coordination & Review					18,850
			TOTAL		**196,223**
Add 5% per year increase for raising cost of labor, fuel					
or Estimated Cost * 1.05^4 =	**$250,436**	**Round to**		**$251,000**	
NOTES:					
1. Rates shown are from Long Beach 2011 borrow site investigation.					
2. Borrow Area Seismic & Cores Taken from Long Beach Estimate of2011					
3. Assume effort as per below (30 miles seismic, 30 cores (20 ft. length)					
4. 2011 seismic estimate (Long Beach) 20 nautical miles @ $12,500					
Assume 30 nautical miles = $18750 plus mob/demob vessel & crew = $17,500					
Total for seismic = $36,250					

TABLE DA-9
Hydrographic Survey
FIRE ISLAND TO MONTAUK POINT, NY
(October 2007 Price Level)

Hydrographic survey of borrow areas:			
Assume single beam hydrographic survey of borrow areas.			
Assume 3 kn/hr boat speed during measurement			
1 kn =	1.151	statute miles	
Assume 6 hours survey time in each 9-hr day			
(one hour travel to site, one hour set up, one hour home)			
at 200 ft. line spacing, 1 sq. mi plus 200 ft. turn-around on each side			
5280 ft/200 ft = 26.4 lines per sq. miles			
26.4 lines * (5280+400)ft/line = 149952 linear feet or 28.4 line miles per sq. mile			
28.4 statue miles/3.453 mph = 8.2 hours per square mile			
8.2/6 = **1.4 days per square mile** (at 200 ft. line spacing)			
4-man crew @		$3,907	per 9-hr day
boat		$2,000	per day
equipment		$200	per day
total		$6,107	per day
FIMP Borrow Area Acreage (from 29 Sep 05 draft Borrow Area Appendix)			
Borrow Area / **Acreage of Suitable Material**			
2A1	706		
2A2	271		
2B	529		
2C	1205		
3A	900		
4A	174		
4B	83		
5A	336		
5B	561		
6A	230		
7A	211		
8A	713		
Total Acreage	5919		
Total square miles	9.25		
9.25 sq. mile/1.4 days per sq. mi = **6.6 days needed for survey time**			
Assume Mob/demob of 1 day to reach site, 1 day return			
plus additional 1 day travel time between borrow areas, or 3 days total			
Assume 2 weather days			
Total days: 6.6+3+2 = 11.6			
say 12 days			
12 days @ $6107/day =		$73,284	
Plotting 2 days @ $750/day		$1,500	
Survey Branch Management (15%)		$11,218	
CRB In-House Scoping, Coordination & Review		$8,000	
TOTAL		**$94,002**	

TABLE DA-10
Multibeam Hydrographic Survey at Inlets
FIRE ISLAND TO MONTAUK POINT, NY
(October 2007 Price Level)

Item	**Hours**	**Rate**	**Total**
1. Hydrographic Multibeam Survey			
a. Principal	4	$38.55	$154.20
b. Project Manager	24	$23.29	$558.96
c. Certified Hydrographer	24	$25.36	$608.64
d. Survey Party Chief	40	$23.29	$931.60
e. Survey Instrument Operator	40	$21.29	$851.60
f. Hydrographic Surveyor	40	$25.36	$1,014.40
g. Survey Technician	40	$10.71	$428.40
h. CADD Operator	32	$16.04	$513.28
subtotal labor			$5,061.08
OVERHEAD (115.0%			$5,820.24
SUBTOTAL			$10,881.32
PROFIT (12%)			$1,305.76
Subtotal Labor plus overhead and profit			**$12,187.08**
EXPENSES (1)	**Days**	**Rate**	**Total**
1. EQUIPMENT			
a. GPS Base Station	5	$115.00	$575.00
b. Survey boat w/crew	5	$1,300.00	$6,500.00
c. Total Station	5	$25.00	$125.00
d. Multibeam survey equipm	5	$125.00	$625.00
e. Sea Sled	5	$225.00	$1,125.00
f. Survey Vehicle	5	$75.00	$375.00
g. Per Diem (4 men @ 5 day	20	$175.00	$3,500.00
EQUIPMENT SUBTOTAL			$12,825.00
(1) Rates based on rates for similar work for Rogers Surveying, Inc.			
TOTAL for approx. .65 square miles			**$25,012.08**
Proportional per square mile rate: $38,480, say			**$40,000**

Estimated square miles in flood shoal, ebb shoal and inlet throat for FIMP inlets:

Inlet	Total Area Sq. Miles	Area Source	Cost @ $40k/sq.mi.
Fire Island	11	NOAA #12326	$440,000
Moriches	1.2	NOAA #12353	$48,000
Shinnecock	1.2	CIRP TR CHL-98-32	$48,000
Total			$536,000

Estimate from multibeam hydro survey done at E. Rockaway Inlet Sept. 05

TABLE DA-11
Sediment Sampling
FIRE ISLAND TO MONTAUK POINT, NY
(October 2015 Price Level)

Per Survey Branch cost of sediment sampling and grain size distribution			
curve development ranges from $200-$300 per sample, depending			
on how many gradations are requested.			
Use $250/sample, including composites.			
Beach Profile Sampling:			
Assume 9 samples per profile line, and four composites per line			
(above MHW, MHW-MLW, below MLW, total)			
Total 13 gsd curves per profile line @ $250 per curve or $3250 per profile			
Assume any numerical averaging of samples to be performed as part of			
Analysis and Reportage costs.			
Samples will be collected on every fourth long range profile			
or 122/4 =	30	profiles	
30 profiles * $3250 per profile line	=	$97,500	
Inlet Dredge Placements:			
Assume inlet dredge material is placed on adjacent shoreline			
within project boundaries at each of three inlets at 2 year intervals.			
Sediment samples should be taken of the placed dredge material			
at the time of placement.			
Assume $12,500 added to inlet dredging contract to take			12500
up to 50 sediment grab samples per placement, plus			
development of grain size distribution curves, per inlet.			
For three inlets, assume total = $37,500 every other year.			37500

TABLE DA-12
Storm, Overwash & Breach Monitoring
FIRE ISLAND TO MONTAUK POINT, NY
(October 2007 Price Level)

Overwash & Breach profiling:
Assume 30 profiles per major storm event, 2500 lf each @ $2500/profile
30 * $2500 = $75,000

Acreage of overwash areas (from 14 Nov. 2005 computation)

	Overwash Acreage	
Simulated storm	Above MSL	Below MSL
SEP38HYP	114	207
NOV50HYP	14	16
SEP85HYP	59	137
Total	187	360
Average	62	120

Total average acreage: 182

Total average sf: 7,942,440 or 2816 ft x 2816 ft.

Assume 30 profile lines at 1000 ft. spacing over area
2500 ft length per profile @ $2500/per profile line

Cost per major storm: $75,000

TABLE DA-13				
WEB SERVER				
FIRE ISLAND TO MONTAUK POINT, NY				
(October 2015 Price Level)				
Cost of web server, for wave gages & water level data:				
(from 12/06//04 estimate of Long Branch wave gage)				
$18000-$19000 per year				
SAY	$25,000	/year		

TABLE DA-14
Sediment Transport Modeling
FIRE ISLAND TO MONTAUK POINT, NY
(October 2007 Price Level)

		Pre-Construction				Project Year 1				Project Year 2				Project Year 3				Project Year 4			
Task	Description	Quantity	UOM	Price	Subtotal	Quantity	UOM	Price	Subtotal	Quantity	UOM	Price	Subtotal	Quantity	UOM	Price	Subtotal	Quantity	UOM	Price	Subtotal
High Resolution Offshore Bathymetry	Ship	18	days	$ 8,000	$ 144,000																
	Salary (12-hour shifts, 3 men each)	18	days	$ 6,000	$ 108,000																
	Overtime	18	days	$ 750	$ 13,500																
	Travel	1	Job	LS	$ 5,000																
	Supplies/Expendibles	1	Job	LS	$ 6,000																
	Mob/Demob	1	Job	LS	$ 5,000																
	Equipment/Spares	1	Job	LS	$ 15,000																
Nearshore Bathymetry	Salary	1	Job	LS	$ 19,200	1	Job	LS	$ 19,200	1	Job	LS	$ 19,200								
	Overtime	1	Job	LS	$ 4,000	1	Job	LS	$ 4,000	1	Job	LS	$ 4,000								
	Travel	1	Job	LS	$ 7,000	1	Job	LS	$ 7,000	1	Job	LS	$ 7,000								
	Supplies/Expendibles	1	Job	LS	$ 8,000	1	Job	LS	$ 8,000	1	Job	LS	$ 8,000								
	Equipment	1	Job	LS	$ 15,000	1	Job	LS	$ 5,000	1	Job	LS	$ 5,000								
Bathymetry Data Processing, Interpretation, and Support for Modeling Input	Salary	50	days	$ 1,000	$ 50,000	50	days	$1,000	$ 50,000	50	days	$ 1,000	$ 50,000	25	days	$1,000	$ 25,000	25	days	$1,000	$ 25,000
	Travel	1	Job	LS	$ 4,000	1	Job	LS	$ 4,000	1	Job	LS	$ 4,000	1	Job	LS	$ 4,000	1	Job	LS	$ 4,000
Subaerial Topography Grid	Salary	19	days	$ 1,000	$ 19,000	19	days	$1,000	$ 19,000	19	days	$ 1,000	$ 19,000								
	Overtime	19	days	$ 130	$ 2,500	19	days	$ 130	$ 2,500	19	days	$ 130	$ 2,500								
	Contract Support	1	Job	LS	$ 20,000	1	Job	LS	$ 20,000	1	Job	LS	$ 20,000								
	Travel	1	Job	LS	$ 8,000	1	Job	LS	$ 10,000	1	Job	LS	$ 10,000								
	Supplies/Expendibles	1	Job	LS	$ 2,500	1	Job	LS	$ 2,500	1	Job	LS	$ 2,500								
	Equipment/Spares	1	Job	LS	$ 65,000	1	Job	LS	$ 15,000	1	Job	LS	$ 15,000								
Subaerial Topography Data Processing, Interpretation, and Support for Modeling Input	Salary	47	days	$ 1,000	$ 47,000	47	days	$1,000	$ 47,000	47	days	$ 1,000	$ 47,000	47	days	$1,000	$ 47,000	23	days	$1,000	$ 23,000
	Contract Support	1	Job	LS	$ 58,000	1	Job	LS	$ 58,000	1	Job	LS	$ 58,000	1	Job	LS	$ 58,000				
	Travel	1	Job	LS	$ 8,000	1	Job	LS	$ 8,000	1	Job	LS	$ 8,000	1	Job	LS	$ 4,000	1	Job	LS	$ 4,000
	Supplies/Expendibles	1	Job	LS	$ 10,000	1	Job	LS	$ 10,000	1	Job	LS	$ 10,000	1	Job	LS	$ 5,000				
	Report Preparation									4	days	$ 1,000	$ 4,000	8	days	$1,000	$ 8,000				
Oceanographic Data Collection	Two Ships	8	days	$13,000	$ 104,000					8	days	$13,000	$ 104,000								
	Salary (12-hour shifts, 3 men each)	8	days	$12,000	$ 96,000					8	days	$12,000	$ 96,000								
	Overtime	8	days	$ 1,500	$ 12,000					8	days	$ 1,500	$ 12,000								
	Supplies/Expendibles	1	Job	LS	$ 15,000					1	Job	LS	$ 15,000								
	Mob/Demob	1	Job	LS	$ 11,000					1	Job	LS	$ 11,000								
	Equipment/Spares	1	Job	LS	$ 180,000					1	Job	LS	$ 105,000								
	Contract Support	1	Job	LS	$ 30,000					1	Job	LS	$ 30,000								
Oceanographic Data Processing and Sediment Transport Modeling	Salary	166	days	$ 1,000	$ 166,000	170	days	$1,000	$170,000	170	days	$ 1,000	$ 170,000	170	days	$1,000	$170,000	90	days	$1,000	$ 90,000
	Contract Support	1	Job	LS	$ 75,000	1	Job	LS	$105,000	1	Job	LS	$ 75,000	1	Job	LS	$105,000				
	Travel	1	Job	LS	$ 10,000	1	Job	LS	$ 10,000	1	Job	LS	$ 10,000	1	Job	LS	$ 10,000	1	Job	LS	$ 4,000
	Supplies/Expendibles	1	Job	LS	$ 18,000	1	Job	LS	$ 8,000	1	Job	LS	$ 8,000	1	Job	LS	$ 8,000				
	Report Preparation									5	days	$ 1,000	$ 5,000	8	days	$1,000	$ 8,000	8	days	$1,000	$ 8,000
SUBTOTAL					$1,360,700				$582,200				$ 934,200				$452,000				$158,000
Contingency	20%				$ 272,100				$116,400				$ 186,800				$ 90,400				$ 31,600
SUBTOTAL					$1,632,800				$698,600				$1,121,000				$542,400				$189,600
USGS Portion	50%				$ -				$ -				$ 2,500				$ 4,000				$ 4,000
USGS Overhead	40%				$ -				$ -				$ 1,000				$ 1,600				$ 1,600
USGS Subtotal					**$ -**				**$ -**				**$ 4,000**				**$ 6,000**				**$ 6,000**
USACE Portion	50%				$ 816,400				$349,300				$ 560,500				$271,200				$ 94,800
USACE CRB Scoping and Reviews	20%				$ 163,300				$ 69,900				$ 112,100				$ 54,200				$ 19,000
USACE Engineering Management	15%				$ 122,500				$ 52,400				$ 84,100				$ 40,700				$ 14,200
USACE CRB Management	5%				$ 40,800				$ 17,500				$ 28,000				$ 13,600				$ 4,700
USACE Subtotal					**$1,143,000**				**$489,000**				**$ 785,000**				**$380,000**				**$133,000**

ATTACHMENT B

OMRRR SUMMARY

General OMRRR Duties of the Local Sponsor

(1) Appoint a Project Superintendent. Appoint a permanent local official who shall be directly in charge of an organization responsible for the efficient operation of all project structures and facilities, and for inspection, maintenance, and record keeping of the project works at no cost to the Federal government.
(2) Operate and maintain required locally furnished appurtenant facilities.
(3) Develop a storm emergency plan. Develop a storm emergency plan to cope with storm events greater than the project design storm.
(4) Prevent encroachment and alteration to project features. Ensure that no other construction or improvement shall be constructed over, under or through the beach fill or other protective feature or right-of-way without suitable coordination and approval from the District Commander. Nor shall any change be made in the project without prior written approval of the District Commander or authorized representative.
(5) Maintain orderly records. Maintain records of all maintenance, operation, condition, repair, and replacement actions taken.
(6) Ensure Federal access. Ensure access to all portions of the project for the District Commander and authorized representative(s).
(7) Perform inspections, maintenance and repair in a timely manner. Ensure that maintenance measures or repairs deemed necessary by the District Commander are carried out in a timely manner.

Local OMRRR responsibilities are generally grouped into administrative, maintenance, and operational areas. Typical operational and maintenance tasks for shore protection projects as may be required to insure serviceability of the berm and beach in time of hurricane or other severe storms or events in which above normal tides may be generated are listed below. Note that all OMRRR responsibilities will be finalized during preparation of the Project Cooperation Agreement and items listed below are for example only.

Typical Local Sponsor OMRRR Operational Responsibilities

(1) Insure the proper functioning of sand bypass systems, closure structures, and other features requiring operation or adjustment as prescribed in the operations and maintenance manual.
(2) Inspect the beach berm and dune as well as structures incorporated into the shore protection project (such as, but not limited to, groins, revetments, seawalls, bulkheads, breakwaters, closure structures, and sand bypassing systems) prior to the storm season, immediately following each major storm, and otherwise at intervals not exceeding 90 days. During such inspections the Superintendent should be certain that:
   a. Regular profile data is obtained.
   b. The dry beach width above normal high tide is measured periodically to determine seasonal changes and any sand deficiencies.
   c. Any unusual conditions of the beach fill such as scarping, excessive erosion, etc. are identified.
   d. Identification of conditions that may indicate renourishment should be initiated.

e. Condition of dune vegetation is inspected, and actions detrimental to dune vegetation such as burning, grazing or unauthorized mowing of vegetation are precluded.
f. No drains discharge onto the beach.
g. The beach and structures are being kept free of trash and hazardous debris.
h. There is no unauthorized vehicular or pedestrian traffic on the beach or dunes.
i. Post storm condition surveys are made as required by the operations and maintenance manual.
j. There are no encroachments upon structures or rights-of-way that might endanger the project feature or hinder its function or repair.
k. Structures are checked to ensure:
    i. no seepage, saturated areas, piping, or scour are endangering structures.
    ii. No undue settlement has occurred which affects the stability of structures.
    iii. Concrete is not cracking, spalling, or breaking to an extent that might affect the integrity of the structure.
    iv. No bank caving, toe scour**,** or flanking erosion exists adjacent to structures.
    v. Drainage systems and mechanical features such as pumps or floodgates are in good working condition.
    vi. No excessive loss of materials such as stones or armor units exist that may endanger stability or functioning of structures.
    vii. No floating plant or boats are allowed to lie against or tie up to structures unless they are designed for such use or it is necessary for repair efforts.

(3) Appurtenant facilities shall be operated to provide safe and healthful public recreation.

<u>Typical Local Sponsor OMRRR Maintenance Responsibilities</u>

(1) <u>Beach and berm</u>.

a. The berm and beach shall be graded and reshaped to original elevations to repair erosion caused wind or wave action, or loss of elevation caused by human activities. This may include moving sand from areas of excessive accumulation to areas of depletion, within practical limits of grading equipment.
b. In the event of scarping, the scarp shall be flattened at controlled vehicle access points to allow safe passage to the beach.
c. Hazardous conditions shall be eliminated where possible. Abrupt variations in berm grade shall be smoothed out and the beach berm and foreshore shall be kept free of trash and hazardous debris during periods of recreational use. Hazardous conditions that cannot be eliminated shall be clearly marked and isolated from public access to the extent practicable.
d. Vehicle access shall be restricted to authorized access ways.

(2) Dune.

a. Walkovers and accessways are properly repaired and replaced as needed.
b. Devices and/or vegetation used to catch blowing sand and stabilize the dune cross-section are repaired and replaced as needed.
c. Damage to the dune cross-section is repaired immediately.

(3) Groins or other structures.

a. Causes of seepage, saturated areas, piping, or scour that endanger the stability or functioning of structures are removed.
b. Areas of undue settlement or material loss are filled.
c. Cracking, chipping, or breaking of concrete that affects the integrity or functioning of structures is repaired.
d. Trash and debris adjacent to the structure are removed and disposed of properly.
e. Bank caving, toe scour, or flanking erosion that endangers structure stability or functioning is remedied.
f. Drainage systems and mechanical features are repaired or replaced as needed and maintained in working condition.

(4) Appurtenant Facilities and Services.

a. Provide maintenance to ensure safety and serviceability of required public access, parking areas, and sanitary facilities during periods of recreational use of the project beach or other features.

Some OMRRR requirements overlap with cost-shared project monitoring functions and must be coordinated accordingly. In cases where an OMRRR function is covered under the project monitoring program, local OMRRR responsibilities may be waived. Per ER 1110-2-1407, when the project includes a protective beach fill and/or periodic nourishment as a project construction feature, permanent features in support thereof, such as bench marks, survey markers, gauges, and other instruments are considered part of the continuing construction of the project. These items are cost-shared as construction costs, and are included in the project monitoring program.

ATTACHMENT C

EXAMPLE LIDAR SOW

LIDAR REQUIREMENTS

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APPENDICES:

1. GENERAL

The US Army Corps of Engineers New York District (NAN) needs to collect airborne topographic LIDAR data to enable accurate and consistent measurement of the shoreline extending from Fire Island Inlet to Montauk Point. The shoreline is defined as the land water interface at a specific tidal datum. Topographic LIDAR is employed as an accurate, efficient way to collect data for generation of a DEM which is in turn used to compile vectors for generating the Mean High Water (MHW) level at the shoreline. This includes areas of wave run up.

This Scope of Work defines requirements and standards for LIDAR data acquisition and processing to support the Fire Island Inlet to Montauk Point (FIMP) monitoring program. These standards were developed in conjunction with the Joint Airborne Lidar Bathymetry Technical Center of Expertise (JALBTCX) partner agencies (U.S. Army Corps of Engineers (USACE), U.S. Naval Oceanographic Office), and the U.S. Geological Survey (USGS) Center for Coastal and Watershed Studies.

Project Instructions will provide project-specific information.

The following conventions have been adopted for this document. The term "shall" means that compliance is required. The term "should" implies that compliance is not required, but is strongly recommended. All times shall be recorded in Coordinated Universal Time (UTC).

2. GOVERNMENT

2.1 PROPERTY OF DATA

All original data, from the instant of acquisition, and other deliverables required through this contract including final data, are and shall remain the property of the United States Government. This includes data collection outside the project area. These items include the contractor-furnished materials.

2.2 PROVIDED BY GOVERNMENT

The government will provide to the Contractor:

A. PROJECT INSTRUCTIONS – Project Instructions are a separate document providing specific project information, containing any unique project requirements, and may have the following attachments:
    i. Small scale maps showing the coastline and/or coastal ports to be acquired
    ii. Tide coordination time windows for data acquisition, see Section 8

B. LIDAR ACQUISITION REQUIREMENTS (this document)

C. REJECTED DATA – If data are rejected by NAN, NAN will send sample data upon request showing the problem areas.

3.0 DELIVERY SCHEDULE AND DATA FLOW

3.1 REGULAR PRODUCTION

Any request to deviate from these standards shall be submitted, in advance of data acquisition, to NAN for written approval.

3.1.1 DATA ACQUISITION STANDARDS

A. Position Dilution of Precision (PDOP) shall be <3.

B. LIDAR point cloud post spacing shall not exceed limits defined in separate Project Instructions.

C. Digital Surface Model (DSM) grid size (spatial resolution) shall not exceed limits defined in separate Project Instructions. The DSM is defined as a regular grid of elevations that depict heights of the top surfaces of vegetation, buildings, towers and other elevated features above the bare earth. Additional guidance on the gridding, vertical datum, and processing instruction may be defined further in the Project Instructions.

D. Aircraft bank angle shall not exceed 15 degrees

3.1.2 DATA PROCESSING

A. The point cloud and DSM data shall be projected in New York State Plane Lambert projection Long Island Zone, NAD83, units in feet.

B. The vertical datum shall be NAVD88.

C. Contractor shall remove outliers in raw data prior to interpolation. Outliers include obvious noise or clutter in the data such as returns from birds or atmospheric particles, or due to electronic noise; however be careful to not reclassify real features such as offshore rocks. In the LAS file, no points shall be permanently removed; rather they should be assigned to the appropriate class. Interpolation shall be completed with industry standard software to facilitate validation of DSM. Contractor shall provide details of interpolation process (software and method). If possible, the contractor should utilize Delaunay triangulation with linear interpolation for the gridding of these data sets. This is performed by first creating a Triangular Irregular Network (TIN) from the LIDAR point data. A filter or constraint should be applied to the TIN that limits the length of a triangle side in the surface being created. The maximum triangle side shall be 3X the resolution of the grid being created. Therefore no triangle side greater than 3X the resolution of the grid in meters will be created. In areas beyond 3X the resolution of the grid in any direction of a LIDAR return where another LIDAR return cannot be found, a null value is specified to that particular portion of the surface being generated. A regular grid is then populated through the extraction of elevation information for each grid cell from the corresponding

TIN using linear interpolation.

C. There shall be no holidays in the data (no data gaps) unless unavoidable (e.g., water areas) in which case other mapping methods may be used if approved by NAN. Interpolation across or smoothing over holidays is unacceptable and may result in rejection of the data by NAN. Any holidays shall be filled with additional data collection unless approved by NAN.

E. Contractor shall record all process steps and software used including version number.

F. Contractor shall use either the rapid or precise ephemeris for Global Positioning System (GPS) processing.

3.1.3 ACCURACY STANDARDS / SPECIFICATIONS

Accuracy reporting, i.e. Root Mean Square Error (RMSE) $_{X,Y,Z}$, shall follow methods set forth by the American Society of Photogrammetry and Remote Sensing (ASPRS) Lidar Committee (PAD) at http://www.asprs.org/society/committees/lidar/Downloads/Vertical_Accuracy_Reporting_for_Lidar_Data.pdf.

Accuracy shall be determined by the following methods:

A. The contractor shall obtain a minimum of 30 validation check points using geodetic quality measurements distributed throughout the project area on flat terrain, or on uniformly sloping terrain along the entirety of the project area. The X, Y, and Z components shall all be referenced to the NSRS (National Spatial Reference System) and in the same coordinate system and datum used in the rest of the project. As a rule of thumb, the accuracy of the check points should be an order of magnitude better than the LIDAR data. At a minimum, based on the ASPRS LIDAR guidelines, the check point accuracy should be at least three times better than the accuracy of the LIDAR data they are being used to test.

B. Contractor shall verify internal consistency of range measurements in areas of overlap among swaths that shall agree with system specifications of the LIDAR instrument.

A. Computing Errors:

Errors shall be calculated for both Point Clouds and DSM deliverables.

Point Cloud: The difference or error for each checkpoint shall be computed by subtracting the surveyed elevation of the checkpoint from the LIDAR dataset elevation interpolated at the x/y coordinate of the checkpoint.

DSM: The difference or error for each checkpoint shall be computed by subtracting the surveyed elevation of the checkpoint from the DSM grid cell that corresponds with the x/y coordinate of the checkpoint.

$$\text{Vertical Error}_{(1)} = (Z_{data(i)} - Z_{check(i)})$$

$Z_{data(i)}$ is the vertical coordinate of the i^{th} checkpoint in the data set.
$Z_{check(i)}$ is the vertical coordinate of the i^{th} checkpoint in the independent source of higher accuracy.
i is the integer from 1 to n; n = the number of points being checked

D. Systematic errors shall be identified and eliminated from the delivered data set

E. Calculating and Reporting Vertical Accuracy:

The fundamental vertical accuracy of a dataset must be determined with the checkpoints only in open terrain. Fundamental vertical accuracy shall be calculated at the 95 percent confidence level as a function of $RMSE_{z.}$

i. Compute $RMSE_{(z)} = \text{Sqrt}[(\sum(Z_{data(i)} - Z_{check(i)})^2)/n]$
ii. Compute $\text{Accuracy}_{(z)} = 1.9600 * RMSE_{(z)}$ = Vertical Accuracy at 95 percent confidence level.
iii. Report $\text{Accuracy}_{(z)}$ as:

“Tested _________(meters) fundamental vertical accuracy at 95 percent confidence level in open terrain using RMSE(z) x 1.9600.”

F. All validation data shall be submitted to the NGS, as well as an accuracy report that includes a statistical summary of the data quality. This shall include presentation of the $RMSE_{(z),}$ a table summarizing the overall statistics of both the $RMSE_{(z)}$ consisting of: number of points, mean, median, mode, skewness, standard deviation, minimum, and maximum representative of the $RMSE_{(z)}$ calculation, as well as a table and separate histogram that illustrate the derived delta between each validation checkpoint and that of both the LIDAR mass point cloud and the derived DSM.

G. The expected horizontal accuracy of elevation products as determined from system studies or other methods shall be reported.

The contractor shall adhere to the LIDAR Common Specifications issued by JALBTCX as outlined in Table 1 and which can be found in entirety at:
http://www.jalbtcx.org/Standards.aspx

Vertical Accuracy	15 cm RMSE

Horizontal Accuracy	1 m RMSE
Spot Spacing	1 m
Percent Coverage	Ensure 100% coverage
Percent Overlap	Ensure 100% coverage
Effective Footprint	10 cm
Tide Coordination	When possible low tide
Pulse Width	NA
Return Logic	Threshold detect -2 returns
Classification	LAS 1 and 2

Table 1 Coastal Mapping Specific LIDAR Standard

In addition to LIDAR data, the contractor may supply ortho-imagery. The standards for the imagery shall adhere to or supersede those outlined in Table 2 below (from JALBTCX, Draft Common Specifications Matrix http://www.jalbtcx.org/Standards.aspx).

Horizontal Accuracy	2m
Spatial resolution	20cm RGB, 1m
Spectral Resolution	19nm FWHM
Spectral Range	VNIR
Spectral Bands	36
Tide Coordination	When possible low tide
Camera Calibration	Yes
Stereo Coverage	Yes
Endlap / Sidelap	60% / 30%
Sun Angle	>20° elevation
Max Cloud Cover	10%
Patch	Yes
Visibility	8miles

Table 2 Ortho-Imagery Specifications

3.2 DATA FORMAT AND STANDARDS

A. Format of deliverables shall be:

i. Point Cloud: LAS 1 and 2 in addition to any more recent version of the LAS standard at time of delivery will be required and specified further in the Project Instructions. The LAS file shall contain all recorded returns (i.e. first, last, and any intermediate returns), return number, scan angle, scan direction, GPS time, intensity, X, Y, Z, and the edge of the flight line (if available) for points used to generate the DSM. If digital aerial imagery is collected concurrently the LAS file should be version 1.2 and contain an associated RGB and/or IR value for each LIDAR point. Details on LAS format standards can be found at:

http://www.asprs.org/society/committees/lidar/lidar_format.html

ii. ASCII files

iii. Laser reflectance images

iv. Shoreline output in NAVD 88

v. Land Cover Classification

vi. Hyperspectral reflectance (standards TBD)

vii. Digital Surface Model (DSM) and Digital Elevation Model (DEM): GEOTIFF.

viii. Orthomosaics

ix. Shoreline vectors: shape file.

B. The media for deliverable shall be a portable hard drive formatted as NTFS. Contractor shall maintain a copy of the data until NAN acknowledges receipt.

3.3 DATA FLOW

A. Acquisition Contractor (AC) acquires data

B. AC processes data to NAN specifications

C. AC validates data versus check points

D. AC ships data to NGS,

E. NGS receives data, acknowledges receipt, reviews data, notifies AC of review outcome.

F. If during the NGS review, the data are found to not meet the Scope of Work (SOW), the contractor may be required to re-acquire the data.

3.4 COMPLETION DATE

All deliverables shall be received by NGS, as specified, no later than the date in the Project Instructions.

<u>4. EQUIPMENT AND MATERIAL</u>

4.1 INERTIAL MEASUREMENT UNIT

The Inertial Measurement Unit (IMU) employed in the LIDAR system shall meet or exceed the following performance specifications:

A. Accuracy in roll and pitch (RMS): 0.015°

B. Accuracy in heading (RMS): 0.050°

4.2 LIDAR SENSOR

A. MAINTENANCE – Prior to commencing data acquisition, the contractor shall provide the following to NAN: certification that both preventive maintenance and factory calibration have been completed either in accordance with the manufacturer's scheduled intervals, or as justified by apparent lack of calibration stability, whichever interval is shorter.

B. DATA COLLECTION

i. Carrier-phase L1 and L2 kinematic GPS shall be acquired and used in processing the trajectories. See section 9 for further details.

ii. The LIDAR system must acquire and output "intensity" data (i.e., data values proportional to the amplitude of each received laser echo).

iii. The LIDAR system shall record the "true" last pulse. For example, in a system that collects three returns, the third return must correspond to the last detectable pulse within the return waveform to maximize the probability of getting the true (or closest to true) terrain measurement below the vegetation; it is not acceptable to simply record the first three events.

C. MALFUNCTIONS – All LIDAR system malfunctions shall be recorded, and NAN notified. A malfunction is defined as a failure anywhere in the LIDAR sensor that causes an interruption to the normal operation of the unit Also, record and report any malfunctions of the GPS or IMU collection systems.

4.3 AIRCRAFT

A. PLATFORM TYPE – The type of aircraft and the aircraft tail number used shall be stated on the LIDAR Flight Log (Attachment C1) and all aircraft used in the performance of this Project shall be maintained and operated in accordance with all regulations required by the Federal Aviation Administration. Any inspection or maintenance of the aircraft for performance of this Project which results in missed data collection shall not be considered as an excusable cause for delay. The contractor shall ensure that the aircraft has a proven service ceiling, with operating load (fuel, crew, sensor, and other required equipment), of not less than the highest altitude required to acquire the data.

B. PORT OPENING – The design of the port opening(s) in the aircraft shall be such that the field of view is unobstructed when a sensor is mounted with all its parts above the outer structure. The field of view shall, so far as is practicable, be shielded from air turbulence and from any outward flows, such as exhaust gases, oil, etc.

C. OPTICAL FLAT – NAN recommends that an optical flat not be used. If an optical flat is used, the physical characteristics of the window (such as size, thickness, smoothness, flatness, parallelism, glass quality, and optical transmissivity) shall be reported to NAN prior to use. The optical flat shall meet the following specifications:

i. High transmittance at the laser wavelength;

ii. Mounted in material eliminating mechanical stress to the window;

iii. Free of blemishes, dirt, significant scratches, etc.;

iv. Not degrade the accuracy of the range measurements.

5. SYSTEM CALIBRATION

Inadequate calibration or incomplete calibration reports shall be cause for rejection of the data by NAN. Calibration reports for each LIDAR system used shall be supplied to NAN at the beginning and end of the project. The calibration reports shall cover each of the following types of calibration:

A. FACTORY CALIBRATION – Factory calibration of the LIDAR system shall address both radiometric and geometric performance and calibration. The following briefly describes the parameters to be tested according to test procedures defined by the manufacturer. Some of these procedures and parameters may be unique to a manufacturer since hardware varies from manufacturer to manufacturer.

i. Radiometric Calibration (sensor response):

- Ensure that the output of the laser meets specifications for pulse energy, pulse width, rise time, frequency, and divergence for the model of LIDAR being tested.
- Measure the receiver response from a reference target to ensure that the response level of the receiver is within specification for the model of LIDAR system being tested.
- Check the alignment between transmitter and receiver and certify that the alignment is optimized and within specification. (Misalignment can lead to poor signal to noise ratios, as well as intensity "banding" or "striping" artifacts.)
- Measure T0 response of receiver (i.e., the response at the time the laser is fired) to ensure that the T0 level is within specification.

ii. Geometric Calibration:

- Range Calibration – Determine rangefinder calibrations including first/last range offsets, temperature dependence, and frequency offset of rangefinder electronics, range dependence on return signal strength. Provide updated calibration values.
- Scanner Calibration – Verify that the scanner passes accuracy and repeatability criteria. Provide updated scanner calibration values for scanner offset and scale (or additional parameters [coefficients], if a higher order polynomial correction is used).
- Position Orientation System (POS)-Laser Alignment Alignment check of output

beam and POS. Also, provide updated POS misalignment angles.

- Overall, the system shall be tuned to meet the performance specifications for the model being calibrated. The contractor shall ensure that, for each LIDAR system used, factory calibration has been performed within the 12 month period preceding the data collection. Recalibration is required at intervals no greater than 12 months. Contractors who wish to apply for a waiver to this requirement must send a written request to NAN stating the date of the last factory calibration and a detailed justification for the waiver.

B. FIELD CALIBRATION – Field calibration is performed by the system operator through flights over a calibration site that has been accurately surveyed using GPS or conventional survey techniques such as triangulation or spirit leveling. The calibration may include flights over the site in opposing directions, as well as cross strips. The field calibration is used to determine corrections to the roll, pitch, and scale calibration parameters. Field calibration must be performed for each project or every month, whichever is shorter.

C. DETERMINATION of sensor-to-GPS-antenna offset vector components ("lever arm"): The offset vector shall be determined with an absolute accuracy (1σ) of 1.0 cm or better in each component. Measurements shall be referenced to the antenna phase center. The offset vector components shall be determined each time the sensor or aircraft GPS antenna is moved or repositioned in any way.

D. SPECIAL CONSIDERATIONS – Wavelength
It is recommended that in the majority of shoreline applications, 1.5 micron systems not be used, or at least tightly constrained to NOAA specified operating envelopes.

Eye safety in the deployment of laser-based remote sensing systems is a critical consideration. While 1.5microns are well-suited to providing low-altitude eye safe deployment, they are not necessarily effective in providing reasonable signal returns from the shoreline/littoral zone.

Application (to the shoreline) of LIDAR systems based on lasers with a 1.5micron wavelength is likely to prove problematic.[1] The 1.5micron systems are inherently inferior to 1micron based systems due to the phenomenology of the interaction of the wavelengths with water and surfaces covered in water, such as shorelines. Due to the absorption characteristics of 1.5micron wavelengths, only a fraction of the available energy emitted is available for return to the sensor. This results in drastic reduction in the number of "returns" or points available for mapping the shoreline. Additionally, it implies that to become more effective, the 1.5micron based sensor must be flown at a reduced altitude, thereby substantially reducing flight economics and creating potential reduced safety conditions due to the lower altitudes.

[1] *High-Level Analysis & Scientific Assessment of the Utility of Applying a 1.5Micron-Range Wavelength Laser Based Airborne LIDAR System to Shoreline Mapping*, John F. Hahn, August, 2009.

The selection of eye-safe wavelengths is based in the ability of water to absorb the energies at 1.5 microns. This means that 1.5 micron based systems will require approximately 10 times the power of a comparably configured 1micron system The inverse way to look at this is that 2 similarly powered systems will result in $1/10^{th}$ the number of available returns in the case of the 1.5micron system.

Additionally, the detectors typically associated with 1.5micron based systems are usually inferior to the types integrated into 1micron based systems (based primarily on available detector surface area). Therefore, it makes it even more unlikely that 1.5 micron based systems will perform as effectively (collect suitable amount of return signal) as 1micron based systems.

The one area where the disparity between 1micron and 1.5micron is much smaller is in the mapping of wet vegetation. Due to the tendency of water to bead on vegetation/foliage, there remains a large amount of "dry" surface area of the foliage available as a surface to provide a decent return signal.

(See: *High-Level Analysis & Scientific Assessment of the Utility of Applying a 1.5Micron-Range Wavelength Laser Based Airborne LIDAR System to Shoreline Mapping*, John F. Hahn, August, 2009.)

6. MISSION PLANNING AND CLEARANCES

6.1 MISSION PLANNING

A. COVERAGE AND PARAMETERS – The Contractor shall plan flight lines for the project area (described in the Project Instructions) and ensure complete coverage of the project area. The mission planning parameters of: point cloud post spacing, swath width, swath overlap, navigation, GPS, visibility, and tide-coordination shall be considered in planning. NAN may supply recommendations and/or requirements for planning parameters in the Project Instructions. The separate Project Instructions may define the point density of the point clouds, DSM, and other requirements.

B. OVERLAP – Adjacent swaths shall have a minimum overlap of no less than 25% of the mean swath width, all the while maintaining 100% coverage.

C. FLIGHT DIRECTION – Flight lines shall be flown in either direction, but adjacent, parallel lines should be flown in opposite directions to help identify systematic errors.

B. LIDAR SURVEY PLAN REPORT

i. PROPOSED FLIGHT LINES – Prior to data acquisition, the Contractor shall submit paper map(s) clearly showing all proposed flight lines, and include coverage, scale, tide stage, proposed ground control, and project area boundaries. Also included shall be information about scan angle, pulse repetition frequency (PRF), flying height, and flying speed over ground. Prepare a separate, one-sheet map for each stage of the tide. The base map shall be the largest scale nautical chart covering the entire project area, if possible.

ii. ACTUAL LINES FLOWN – Similar map(s) showing the actual flight lines shall be included in the Final Report, see Section 13 U 3.

E. CROSS LINES – At least one cross line (i.e., perpendicular to the primary flight lines) is required per survey. For longer survey areas, one cross line is required every 25 km.

6.2 FLYING HEIGHT

Sensor shall not be flown at an altitude that exceeds that given in the manufacturer's specifications or that results in a significant number of "drop-outs" (i.e., pulses for which no return is received.) The altitude must be low enough such that the average laser footprint (per survey block) is ≤ 10cm diameter.

6.3 FLIGHT CLEARANCES

The Contractor shall comply with all required Federal Aviation Administration Regulations, including obtaining all required clearances.

7. WEATHER AND TIME OF YEAR

7.1 WEATHER CONDITIONS

LIDAR data acquisition missions shall be flown in generally favorable weather. Inclement weather conditions such as rain, snow, fog, mist, high winds, and low cloud cover shall be avoided. Such weather conditions have been known to affect or degrade the accuracy of the LIDAR data. If clouds are present, data capture is only permitted if cloud coverage is above the height of the sensor and airborne platform. LIDAR shall not be conducted when the ground is covered by water (flood), snow, or ice, and shall not be conducted when the land-water interface is obscured by snow, ice, etc. Storm systems and events (e.g. hurricanes, northeasters, and frontal boundaries) that may cause an increase in water levels, tidal heights, and wave activity shall be avoided.

7.2 TIME OF DAY

Data acquisition operations may occur during either day or night, unless specifically called out in the Project Instructions. Unlike aerial photography, sun angle is not a factor unless supplemental imagery (e.g., digital imagery) is required to be acquired concurrently with the capture of LIDAR data to help assist in identifying features in post-processing production. Digital imagery should only be acquired simultaneously with LIDAR during the day.

8. TIDE COORDINATION

8.1 DATA COLLECTION AND TIDE CONDITIONS

All data collection shall be at or below Mean Lower Low Water (MLLW), unless otherwise specified in the individual project instructions. Data shall not be collected during strong onshore winds, high waves or other anomalous weather conditions. Contractor shall acquire and submit an offshore buoy report for the project area during time of data acquisition

8.2 NAN SUPPLIED WINDOWS

The government will supply data acquisition time/tide windows for each coastal area to be mapped. These "windows" cover an extended range of possible flying dates. These time/tide windows will be determined by NAN initially to help ensure that all data meet the NAN tolerances for tide–coordinated data acquisition. If tide windows for additional dates are required, contact NAN.

8.3 CONTRACTOR-DETERMINED WINDOWS

If required by the Project Instructions, the contractor shall determine predicted or actual acquisition time/tide windows (data acquisition times for tide coordination) for Mean High Water (MHW) and/or MLLW. Note, MHW is the mean of 19 years of high water and is not the high water level for any given day, except by coincidence. The same holds true for MLLW time/tide windows. The Project Instructions may also require the Contractor to install and/or monitor tide gages in the project areas for either real–time or post–flight tidal height comparisons.

A recommended approach to tide coordination and suggested software is described in Attachment C3. This method is only an example of how NOAA NGS (National Geodetic Survey) currently is able to coordinate surveys around tide states. The contractor may elect use their own methods, but they must be approved by NAN prior to commencing project work. The contractor is solely responsible for tide planning, unless otherwise stated in the individual project instructions.

The contractor must account for wave run-up in ensuring continuous coverage across the land-datum interface within the lidar dataset. This is critically important and if not adhered to may be cause for NAN to reject the data.

8.4 REQUIREMENTS

The Contractor shall acquire all data within the given time/tide windows and shall produce a table showing the times of the time/tide windows and the times of the data acquisition. Be sure to take into account time zones and daylight savings time, and to use UTC time.

9. POSITIONING AND ORIENTATION FOR THE DATA

9.1 POSITIONING

A. GPS COLLECTION

i. All LIDAR data shall be positioned using kinematic GPS using dual frequency receivers and oriented with an inertial navigation system.

ii. All kinematic GPS (KGPS) solutions should use differential, ionosphere-free, carrier-phase combinations with phase ambiguities resolved to their integer values.

iii. Aircraft trajectories shall be processed using carrier-phase GPS. Dual L1 and L2 frequency receivers and one-second or better collection shall be used.

iv. All KGPS shall use at least two ground stations. The ground stations shall be accurately tied to the NSRS (stations in the NGS database); shall be positioned to 0.05 meter accuracy, or better; shall be within or near the project area; and shall be within 50 kilometers of the entire project area. Additional ground GPS stations may be required, and Continuously Operating Reference Stations (CORS) can be used as ground stations. The ground stations should be positioned on opposite sides of the operating area. The ground stations shall be positioned, or the flight path arranged, so that during flight operations the aircraft will pass within 10 kilometers of each ground station at least once.

v. The maximum GPS baseline shall not exceed 50 kilometers at any time during flight. Regardless of aircraft flight time, GPS ground station data shall be collected for a minimum of four hours.

vi. Ground station data shall be submitted to NAN.

B. GPS SOLUTION PROCESSING

i. The Contractor shall collect, process, and submit the ground and airborne GPS data, both raw data and final processed data.

ii. Differential KGPS solutions for the aircraft shall be obtained independently using each ground station.

iii. These independent KGPS solutions shall be compared and any differences in the north-south, east-west, and vertical components during the operational portions of the flights shall be displayed and reported.

iv. The RMS of these differences shall not exceed 5 cm in the horizontal and 10 cm in the vertical.

v. The KGPS solutions shall model the tropospheric delay using average surface meteorological values at the ground stations collected near the midpoint of operations.

vi. The final KGPS solution will be an average of the separate ground station solutions.

C. ANTENNA

i. The GPS receivers should be equipped with antennas that have been recently calibrated. A choke-ring antenna to minimize multipath is preferred but not required.

ii. The antenna height shall be accurately measured.

9.2 GROUND-BASED GPS RECEIVERS

Unless otherwise specified, NGS standards shall be used for ground-based GPS receivers as follows:

A. MARK – The ground-based receiver shall be set up over a known (or to-be determined) marked ground station and shall run continuously during the mission. If a known ground station is used, it shall be provided by NAN. If a new ground station is used, it shall be marked permanently (to NAN/NGS specifications) or temporarily marked (such as a PK type nail or iron pin). Specifications on the accuracy of horizontal and vertical positioning of the mark will be further defined in the Project Instructions.

C. OBSERVATIONS – The position of an existing mark shall be checked by processing one GPS session and comparing the computed position with the provided published position. A new mark shall be referenced to the NSRS by tying to one or more NGS CORS by static GPS methods. If the distance to the nearest NGS CORS is less than 50 miles, use at least two independent sessions, each 2 hours long. If the distance to the nearest NGS CORS is greater than 50 miles, use at least two sessions, each 4 hours long. **Make a separate tripod set-up and height measurement for each session.** Take care in the accurate recording of the height of the antenna both before and after the flight (i.e. before and after each GPS recording session). Record all heights, equipment serial numbers, etc. on the NGS similar forms: Visibility Obstruction Diagram and GPS Observation Log. For a listing of these and other forms on the NGS website see:

http://www.ngs.noaa.gov/PROJECTS/FBN/ . Also, static observations may be processed using the NGS "On-Line User Positioning Service" (OPUS) found at: http://www.ngs.noaa.gov/OPUS/ . Observations to establish a new, permanent mark shall be submitted in NGS "Blue Book" format.

D. RECOVERY – For an existing NSRS station, write a digital recovery note in NGS

format using NGS software WDDPROC. For a new, permanent station write a digital station description in NGS format using Windesc. For a new, temporary mark write a brief description adequate to recover the station. Take three photographs of the ground station (photographs of the CORS station are not required). For additional specification guidance on mark setting, GPS observations, data processing, and data submittal in NGS format, see:
http://www.ngs.noaa.gov/ContractingOpportunities/ReferencedLinks!.htm

9.3 AIRCRAFT GPS RECEIVER

A. GPS OBSERVATIONS – The aircraft's GPS receiver shall be able to collect carrier phase observations and record, at least once per second, from a minimum of four satellites (five or more preferred) at both the aircraft and the ground GPS receivers, for off-line processing. All data shall be collected with a Position Dilution of Precision (PDOP) of less than 3. After the post–processing, the GPS observation and ephemeris files shall be used to determine a flight path trajectory.

B. GPS LOCK – The aircraft shall maintain GPS satellite lock throughout the entire flight mission. If satellite lock is lost, on-the-fly ambiguity resolution methods may be used to recapture lock while airborne. Report these instances, procedures used, and any other unusual occurrences. The GPS post-processing software may be capable of providing an output log of all incidents, such as loss of GPS satellite lock. The formatted output log is acceptable as the report.

9.4 AIRBORNE ORIENTATION

An Inertial Measurement Unit (IMU) shall be incorporated into the LIDAR unit. The IMU system shall be capable of determining the absolute orientation (roll, pitch, and yaw) at a minimum of 50Hz. See Section 4.1.

9.5 AIRBORNE POSITIONING AND ORIENTATION REPORT

The Report shall include at least the following paragraphs:

- Introduction
- Positioning
    - Data Collection
    - Static Processing
    - Kinematic Processing
    - Data Sets
- Orientation
    - Data Collection
    - Data Processing
    - Data Sets
- Final Results

A. INTRODUCTION - Provide an overview of the project and the final processed data sets and list the data sets in table form with the following columns: Dataset ID, Date of Acquisition, Projects covered by the data set, and Description/Flight Line(s) Identification.

B. POSITIONING – Discuss the methodology, the hardware and software used (including models, serial numbers, and versions), the CORS station(s) used, a general description of the data sets, flight lines, dates and times of sessions, the processing (including the type of solution–float, fixed, ion–free, etc.), and the results (discussion of the coordinates and accuracy). Submit a description of the data sets, and the raw and processed data. If the NGS OPUS website was used to process the static data, the Contractor shall provide a copy of the OPUS report. If a known station was used from the NGS database, the Contractor shall identify the station by name and Permanent IDentifier (PID), and provide the published coordinates used in the kinematic position step. If multiple ground stations were used, provide processing details, coordinates, and accuracy for all stations.

C. ORIENTATION – Discuss the factors listed above for Positioning.

D. FINAL RESULTS - Describe any unusual circumstances or rejected data, and comment on the quality of the data.

10. EYE SAFETY

Because LIDAR systems typically employ Class 4 lasers, safety is a paramount concern. ANSI standards for safety shall be followed. See ANSI Z136.1 Safe Use of Lasers and ANSI Z136.6 Safe Use of Lasers Outdoors. For further details regarding safety issues in LIDAR data collection, refer to *Eye Safety Concerns in Airborne Lidar Mapping* (Flood, 2001, ASPRS Conference Proceedings). The contractor shall assume sole responsibility for adherence to all safety regulations and shall implement necessary internal controls to ensure the safety of all persons in the aircraft and in the survey area below.

11. DATA LABELING

All portable hard drives shall be labeled with the project name, collection date(s), contractor name, and disk contents. LIDAR data Portable Hard Drives shall be able to be easily matched with the corresponding LIDAR flight log(s).

12. DATA SHIPMENT AND PROCESSING

12.1 SHIPMENT

The contractor shall ship final deliverables in NAN format (on hard disk), directly to NAN, to arrive at NAN within ten working days from the date of completion of data processing. Copies of the LIDAR Flight Log and the raw navigation files may be made and used by the contractor to produce and check the final deliverables.

12.2 NAN NOTIFICATION

The same day as shipping, the contractor shall notify NAN of the data shipment's contents and date of shipment by transmitting to NAN a paper or digital copy of the data transmittal letter via email or fax.

13. DELIVERABLES

13.1 LABOR, EQUIPMENT AND SUPPLIES – The Contractor shall provide all labor, equipment (including aircraft and LIDAR system), supplies and material to produce and deliver products as required under this document.

13.2 LIDAR SURVEY AND QUALITY CONTROL PLAN – Prior to data acquisition, submit a proposed LIDAR Survey and Quality Control Plan which specifies the data collection parameters to be used and contains a map of the flight lines and the project coverage area, including flying height and speed over ground, scan angle, and Pulse Repetition Frequency (PRF). The separate Project Instructions supplied by NAN will define the project area(s) and may define the point density of the point clouds, DEMs/DSMs, and other requirements. See Section 6. NAN will review the proposed mission planning reports, normally within five business days, and will respond in writing with approval and/or comments. The Final Report shall contain map(s) showing the flight lines and boundaries of LIDAR data actually collected.

13.3 LIDAR TEST – The Contractor shall acquire and deliver an example dataset over a section of coastline and/or coastal ports which are similar to the contract work (see separate Project Instructions). VDatum shall be utilized in the project area to convert to the specified vertical datum as stated in the Project Instructions. VDatum is a software tool that converts elevation data (heights and soundings) among 28 different vertical datums (http://vdatum.noaa.gov). Tide coordination and Ellipsoid/Tidal relationship support may be required, and will be further defined in the Project Instructions.

13.4 LIDAR RAW DATA – Submit the completed data collection raw output.

13.5 LIDAR PRODUCTS – Required products may include: Shoreline shape files, LAS files, and DSM. The Project Instructions will specify which additional products, if any, are required.

13.6 FLIGHT REPORTS – Submit the completed, original LIDAR Flight Logs with the data, as well as a copy directly to NAN. For a sample flight log see Attachment C1.

13.7 GLOBAL POSITIONING SYSTEM (GPS)/INERTIAL MEASUREMENT UNIT (IMU) FILES – The contractor shall submit the original, raw data files and processed trajectory files directly to NAN, to arrive at NAN along with the raw data points and final products. The raw data files shall include RINEX files generated from each receiver's proprietary data files. See sections 9.1 and 9.4.

13.8 AIRBORNE POSITIONING AND ORIENTATION REPORT – Submit raw GPS and IMU data (in the manufacturer's format) along with the final processed GPS trajectory and post processed IMU data. Also submit a report covering the positioning and orientation of the LIDAR. See Section 9.5.

13.9 RANGE AND SCANNER ANGLE FILES – The contractor shall submit the original, raw data files directly to NAN, to arrive at NAN along with the raw data points and final products.

13.10 GPS CHECK POINTS – Submit an organized list of all GPS points used for the project as ground stations and check points. Indicate which GPS points are pre-existing ground control and which stations are new, and positioned relative to the NSRS. See Project Instructions and sections 3.1 C and 9.2 A and B.

13.11 NGS SURVEY FORMS – The Contractor shall prepare and submit the following NGS forms for each GPS check point and the GPS ground station(s): Visibility Obstruction Diagram, GPS Observation Log, Recovery Note or Station Description. See Section 9.2.

13.12 TIDE COORDINATION TABLE – Supply table(s) showing the actual times of acquisition flights and the tide coordination time "windows." See Section 8. Explain any discrepancies.

13.13 CALIBRATION REPORTS – There is no standard format for the calibration reports. However, the calibration reports shall contain, at a minimum, the following information:

A. The date the calibration was performed.
B. The name of the person, company, or organization responsible for performing the calibration.
C. The methods used to perform the calibration.
D. The final calibration parameters or corrections determined through the calibration procedures.

13.14 SENSOR MAINTENANCE – Provide maintenance history directly to NAN of the sensor to be used for acquiring LIDAR. See Section 4.2 A.

13.15 SENSOR PORT WINDOW – Report the physical characteristics of any port window used to NAN. See Section 4.3 B.

13.16 DATA SHIPMENT – See Sections 3, 12, and 15 for instructions.

13.17 DATA SHIPMENT REPORTING – The Contractor shall notify NAN of each data shipment's contents and date of shipment by transmitting to NAN a paper or digital copy of the LIDAR Flight Log (marked "copy" at the top) and a copy of the data transmittal letter via email or facsimile. This shall be done the same day the data is shipped to the data processing contractor. See Section 12.

13.18 UNUSUAL CIRCUMSTANCES – The contractor shall also notify NAN of any unusual circumstances that occur during the performance of this project which might affect the deliverables or their quality and especially of any deviation from this project. This may be included in the weekly email required below, unless urgent.

13.19 DEVIATIONS FROM SCOPE OF WORK – Requests to exceed or deviate from the Project Instructions will be considered if written justification is provided to NAN in advance. No deviation is permitted until written approval is received from NAN.

13.20 STATUS REPORTS – The Contractor shall submit project status reports via email to the Contractor Officer's Representative (COR) contacts in Section 15 every week, until the work is complete. **These reports are due at NAN by 2:00 p.m. EST each Monday.** These reports shall include a summary of completed data acquisition, with dates completed; data shipped, and dates; and any unusual circumstances, equipment malfunctions, and/or any disturbance of the sensor. **A weekly status report is required even if no progress has been made.**

13.21 FINAL REPORT - The Contractor shall supply to NAN a Final Report incorporating all of the information in this Deliverables section including, at least, the sections suggested below:

A. For work performed under this contract, discuss each deliverable including: the maximum range from the ground station, the minimum swath overlap, percent of good laser returns (if available), standard deviation and residuals in GPS trajectories, and an explanation of the Portable Hard Drive labeling;

B. Equipment used to perform this work, including hardware models and serial numbers, calibration reports, and software names and versions (include aircraft and LIDAR info);

C. Flight line map(s), and project coverage area;

D. Discussion of data quality including Quality Assurance (QA)/Quality Control (QC) procedures;

E. Ground Control Report, including a station list in table format;

F. Aircraft Navigation;

G. Airborne kinematic GPS Report, including ground stations;

H. Weather, solar altitude, and time of year;

I. Tide Coordination Report and Table;

J. Any unusual circumstances or problems, including equipment malfunctions (including those already reported);

K. Any deviations from this LIDAR SOW, including those already reported;

L. Any recommendations for changes in the LIDAR SOW for future work.

13.22 PROPERTY OF DATA – All original data, from the instant of acquisition, and other deliverables required through this contract including raw data and final products, are and shall remain the property of the United States Government. This includes data collection outside the project area.

14. REVIEW

Data and other deliverables not meeting these specifications may be rejected.

15. POINTS OF CONTACT

TBD

16. REFERENCES

Flood, M. *Eye Safety Concerns in Airborne Lidar Mapping*. Proceedings of the ASPRS 2001 Annual Convention, 23-27 April, St. Louis, Missouri (American Society for Photogrammetry and Remote Sensing, Bethesda, Maryland), unpaginated CD-ROM, 2001.

Hahn, John F., *High-Level Analysis & Scientific Assessment of the Utility of Applying a 1.5Micron-Range Wavelength Laser Based Airborne LIDAR System to Shoreline Mapping*, August, 2009.

Attachment C1 – LIDAR Flight Log (NOT YET CREATED)

Attachment C2 – JALBTCX Draft Common Specifications Matrix

Draft Common Specification Matrix for Airborne Coastal Mapping and Charting

Survey type	Engineering	Charting	Environmental Assessment, Modeling, Regional Coastal Mapping	Emergency Response, Reconaissance
Bathy Lidar				
Vertical accuracy		50 cm 2s	15 RMSE	
Horizontal accuracy		5 m 2s	1 m RMSE	
spot spacing		2 X 2,3X3	4 m	
Percent coverage		100,200	100	
Percent overlap		30?	ensure 100% coverage	
Effective footprint		NA	NA	
tide coordination		NA	when possible high tide	
Pulse width		NA	NA	
Topo Lidar		shoreline mapping		
Vertical accuracy		15 cm RMSE	15 cm RMSE	
Horizontal accuracy		1 m RMSE	1 m RMSE	
spot spacing		1 m	1 m	
Percent coverage		100	ensure 100% coverage	
Percent overlap		30	ensure 100% coverage	
Effective footprint			10 cm	
tide coordination		yes	when possible low tide	
Pulse width		NA	NA	
Return logic		"true" last	threshhold detect -2 returns	
Classification		not required	LAS 1 and 2	
QA/QC				
GPS PDOP		<= 3	<=3.5	
Crossline spacing		25 km	25 km	
Crossline number		1 per alongshore block	1 per alongshore block	
Combine separation		10 cm	10 cm	
Ground control		30 checkpoints	20 points/3 classes/100 miles	
TPE Horizontal & vertical		no	no	
Qualitative assessment		targeted to shoreline	yes	
Imagery				
Horizontal accuracy		2 pixels	2 m	2 m
Spatial resolution		50 cm	20 cm RGB, 1 m	35-50 cm
Spectral resolution		NIR >740 nm	19 nm FWHM hyperspectral	
spectral range		VNIR	VNIR	RGB
Spectral bands		4	36	3
Tide coordination		yes low tide	when possible low tide	NO
Camera callibration		yes and certification	yes	yes
Stereo coverage		yes	yes	yes
Endlap sidelap		60%/30%	60%/30%	60%/30%
Sun angle		>30 elevation	>20 elevation	>10 elevation
Max cloud cover		no on shoreline	10%	avoid where possible
Patch		yes	yes	yes
Visibility		8 miles	8 miles	see the ground
Products			ASCII	orthomosaics
			LAS	mosaics
			DEM	
			DSM	
			orthomosaic	
			laser reflectance images	
			NAVD88 shoreline	
			land cover classification	
			hyperspectral reflectance mosaics	

Attachment C3 - Tide Coordination

NGS Remote Sensing Division's Coastal Mapping Program

Tide coordination of Airborne Topographic LIDAR collection using TCARI

The NGS Remote Sensing Division's primary motivation to collect airborne topographic lidar data is to enable accurate and consistent measurement of the national shoreline. The shoreline is defined as the land water interface at a specific tidal datum. NOAA charts both MHW and MLLW shoreline vectors on its nautical charts. This is not trivial as a tidal datum is by definition local, meaning that the vertical reference is only valid for a specific location. In order to define a tidal datum, a gauge must be installed and used to collect data for up to 18.6 years (an astronomical tidal epoch) depending upon the required level of accuracy. Throughout a survey project area of any useful size, the tidal datum can vary significantly. As a matter of practice, it is not viable to measure the MLLW shoreline using topographic lidar. The MHW shoreline however, can be extracted from lidar data so long as the data is collected at a sufficiently low tide stage. In order to accomplish this, NOAA has developed tools for airborne survey planning, as well as data quality assurance. Tidal Constituent and Residual Interpolator (TCARI) is an algorithm that models the tidally driven water level in space and time. It is an efficient method to determine when the water level in a specified area is predicted to be at, above, or below a certain tide level. Following a survey, it can also be used to check the actual water level at time of collection, which can deviate from predictions due to meteorological phenomena.

TCARI begins by establishing a boundary for a particular area using the shoreline vector (Fig C1).

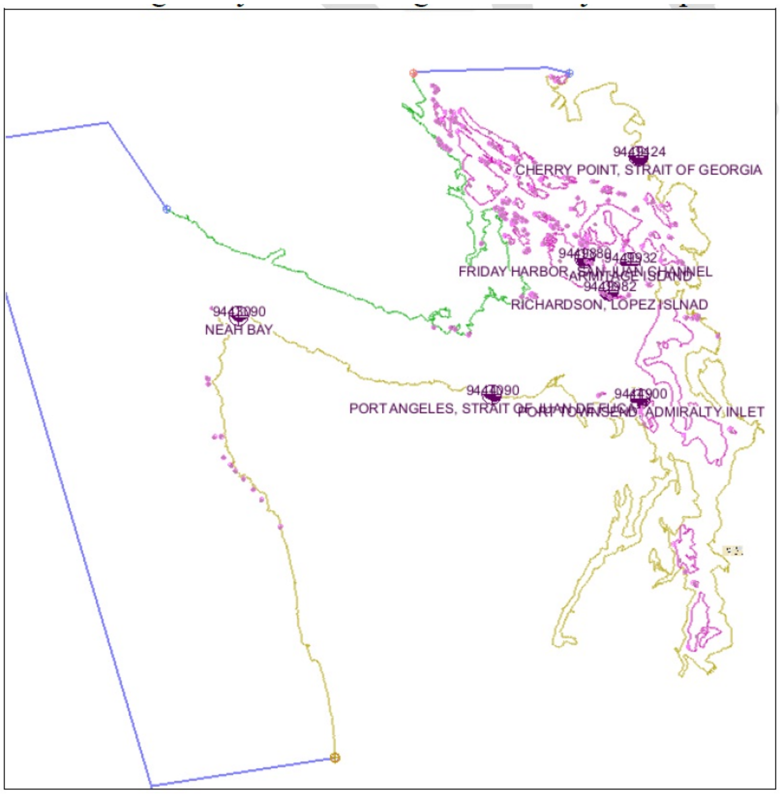

Figure C1 – Example of a TCARI grid boundary

Tidal datum locations as well as active water level gauge sites are applied, and a triangular network is created to enable the constituent and residual interpolation (Fig C2).

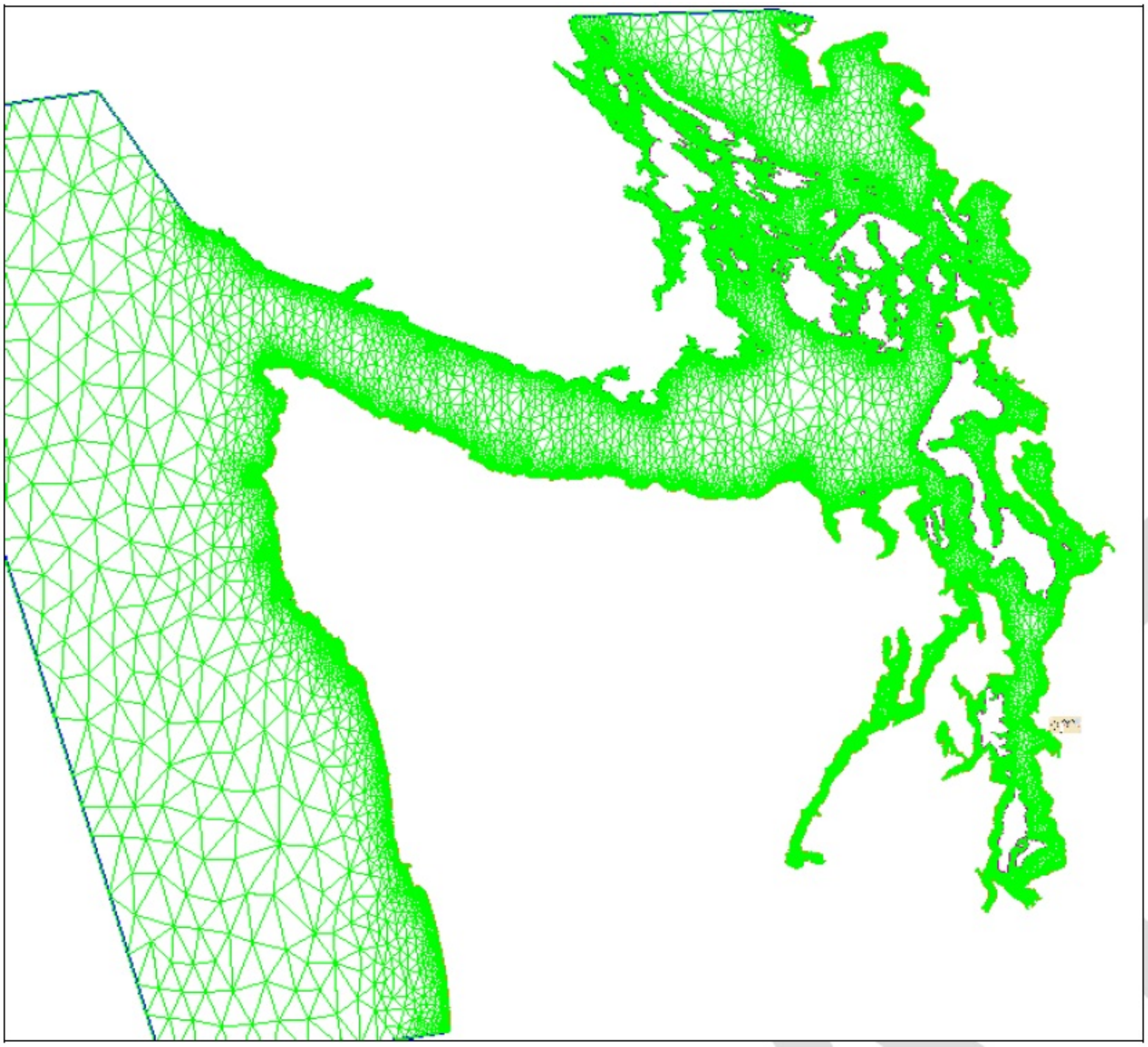

Figure C2 – Triangular network of example area

Once this is done, a predicted or actual (predicted plus residual) water level model can be created (Fig C3).

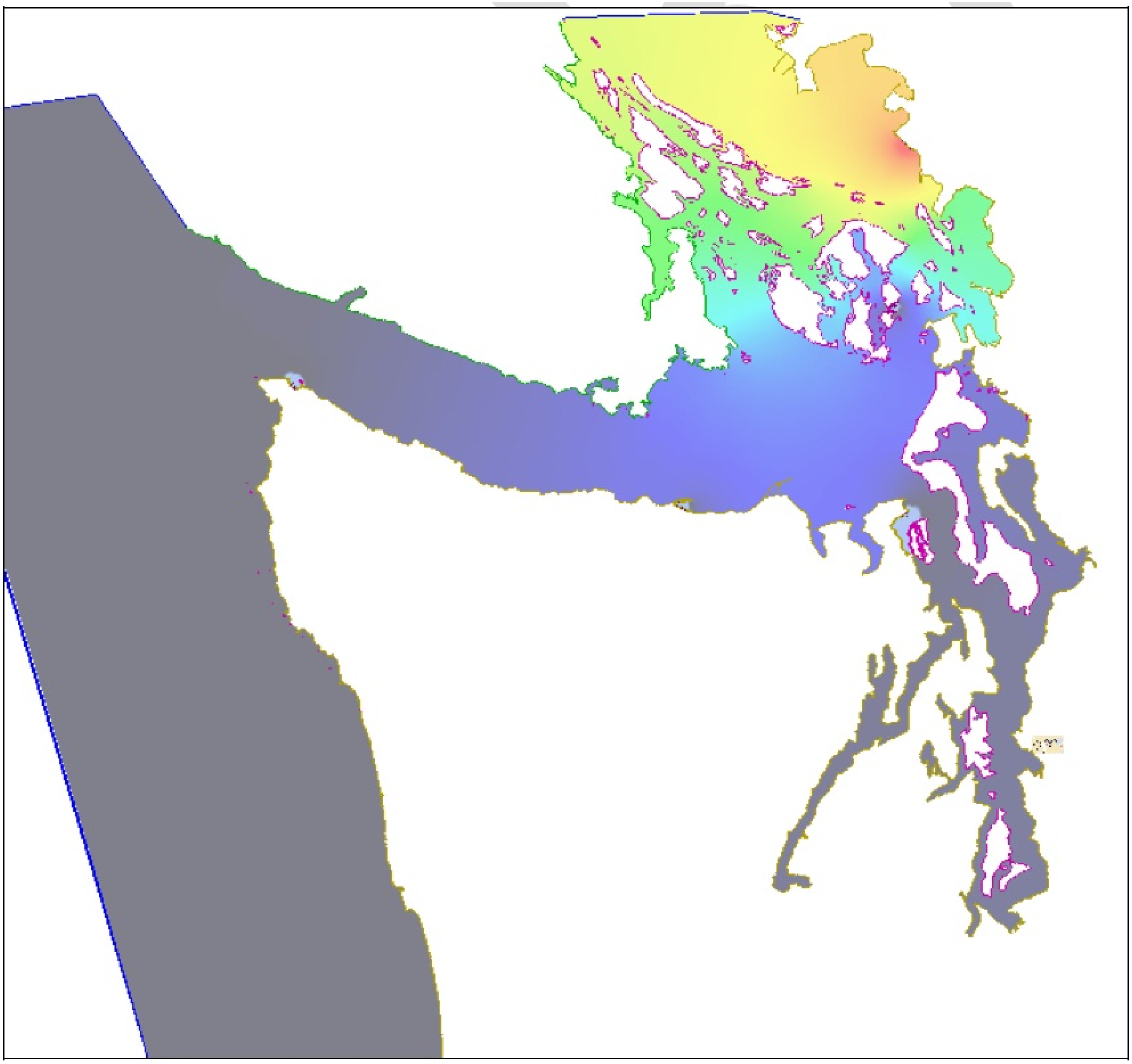

Figure C3 – Color ramped example of water level prediction using TCARI

The technique is scalable and can be used for small and very large project areas. In the case of topographic lidar collection, the requirement is to collect data when the water level is a pre-defined margin below the desired datum. In the case of MHW collection, this can be expressed as WL<(MHW – x), where x is the predefined margin. This margin value will depend upon both the specific instrument characteristics, as well as the meteorological conditions, specifically wave height and run-up on the open coast.

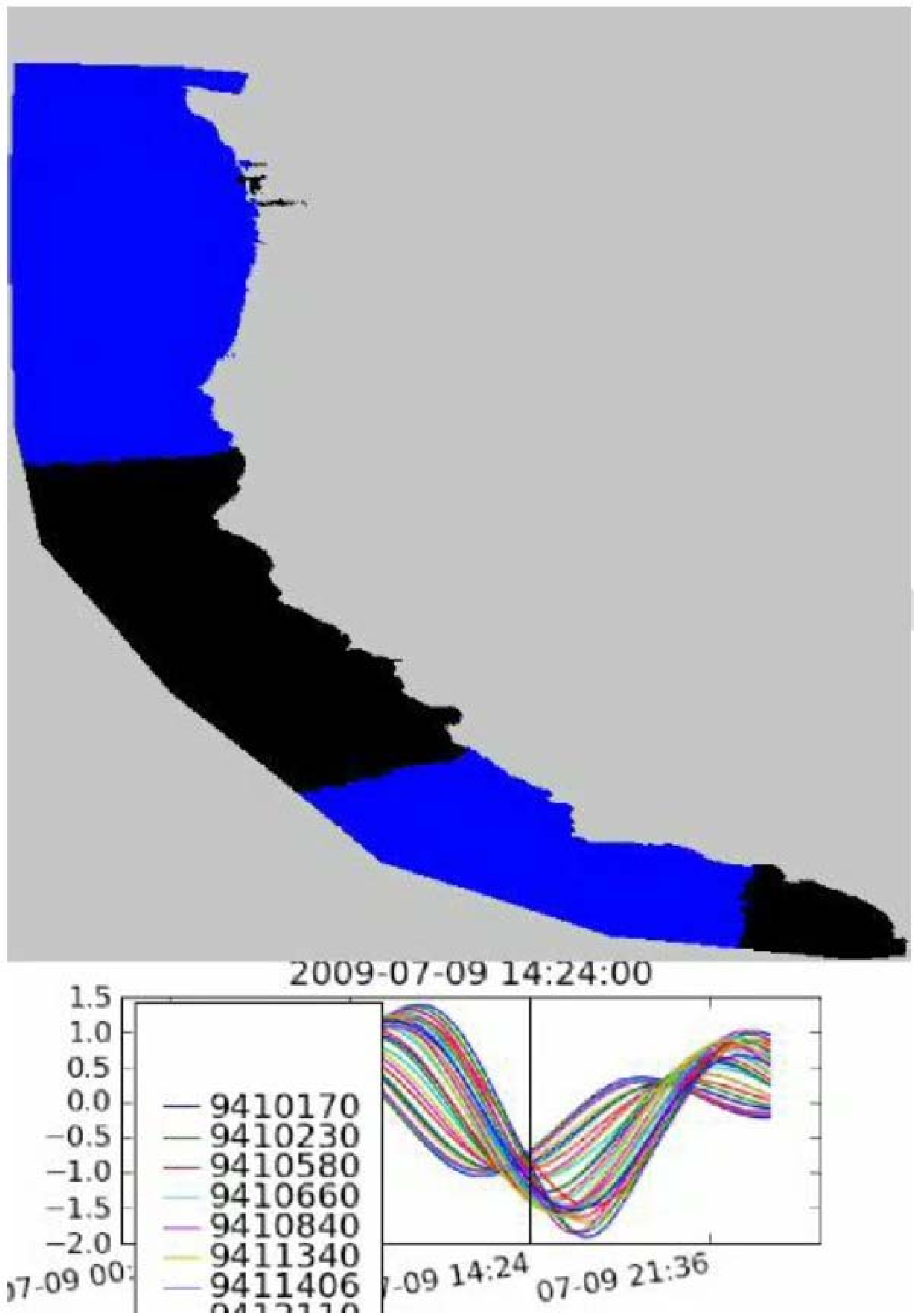

Figure C4 – Map of water level meeting a pre-defined survey condition