National Park Service
U.S. Department of the Interior

Northeast Coastal and Barrier Network Geomorphological Monitoring Protocol: Part III—Coastal Landform Elevation Models

Version 1.0

Standard Operating Procedures

July 2018

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Standard Operating Procedure (SOP) #1 – Equipment and Supplies

Version 1.0 (May 2018)

The following table lists all changes that have been made to this Standard Operating Procedure since the original publication date. Any recommended or required changes added to the log must be complete and concise and promptly brought to the attention of the Project Leader. The project leader will review and incorporate all changes, officially complete the revision history log, and change the date and version number on the title page. For complete instructions, please refer to SOP #9 – Revising the Protocol.

Revision History Log:

New Version #	Previous Version #	Revision Date	Author (full name, title, affiliation)	Location in Document and Description of Change	Reason for Change

This SOP is divided into the following sections:

1.1 Field Equipment

1.2 Office Equipment

This SOP details the items needed to execute the Coastal Landform Elevation Models monitoring protocol. The field equipment and office equipment are described and a field item checklist provided. The procedural steps in this and each of the following SOPs will be illustrated using Trimble survey equipment. Similar operations can be applied using other equipment produced by other manufacturers.

1.1 Field Equipment

1.1.1 Geodetic GPS System

The GPS system for the purpose of topographic data collection principally consists of 2 GPS components:

1. A rover receiver for the collection of the topographic data. (Figure S1.1)
2. A reference for differential correction, such as a base station set up by the surveyor (Figure S1.2) or the network of Continually Operating Reference Stations (CORS).

The GPS system can be operated in different ways, depending on the equipment available, but as a minimum the Park must have one Rover receiver unit and one field survey controller. Fully integrated receivers with built-in antennas combine the GPS receiver, antenna, and radio into a single compact unit (for example the Trimble R10 units – Fig. S1.1 and Fig S1.2). Most of these units come with Bluetooth wireless technology built in, and therefore do not need cables. Older GPS systems are composed of modular units and require an external radio and an external GPS antenna, and therefore the setup is more complex (for example the Trimble 5700 unit – Fig. S1.3). Although the operational settings and setup may differ depending on the equipment used, there are critical settings and components that must be used to allow for consistent data collection across platforms. These requirements are explained in SOP #4 - Settings for Collection of Topography.

Figure S1.1. The Trimble R10 GNSS receiver and Trimble TSC3 field survey controller (Critical Zone, Sandy Hook, March 2016).

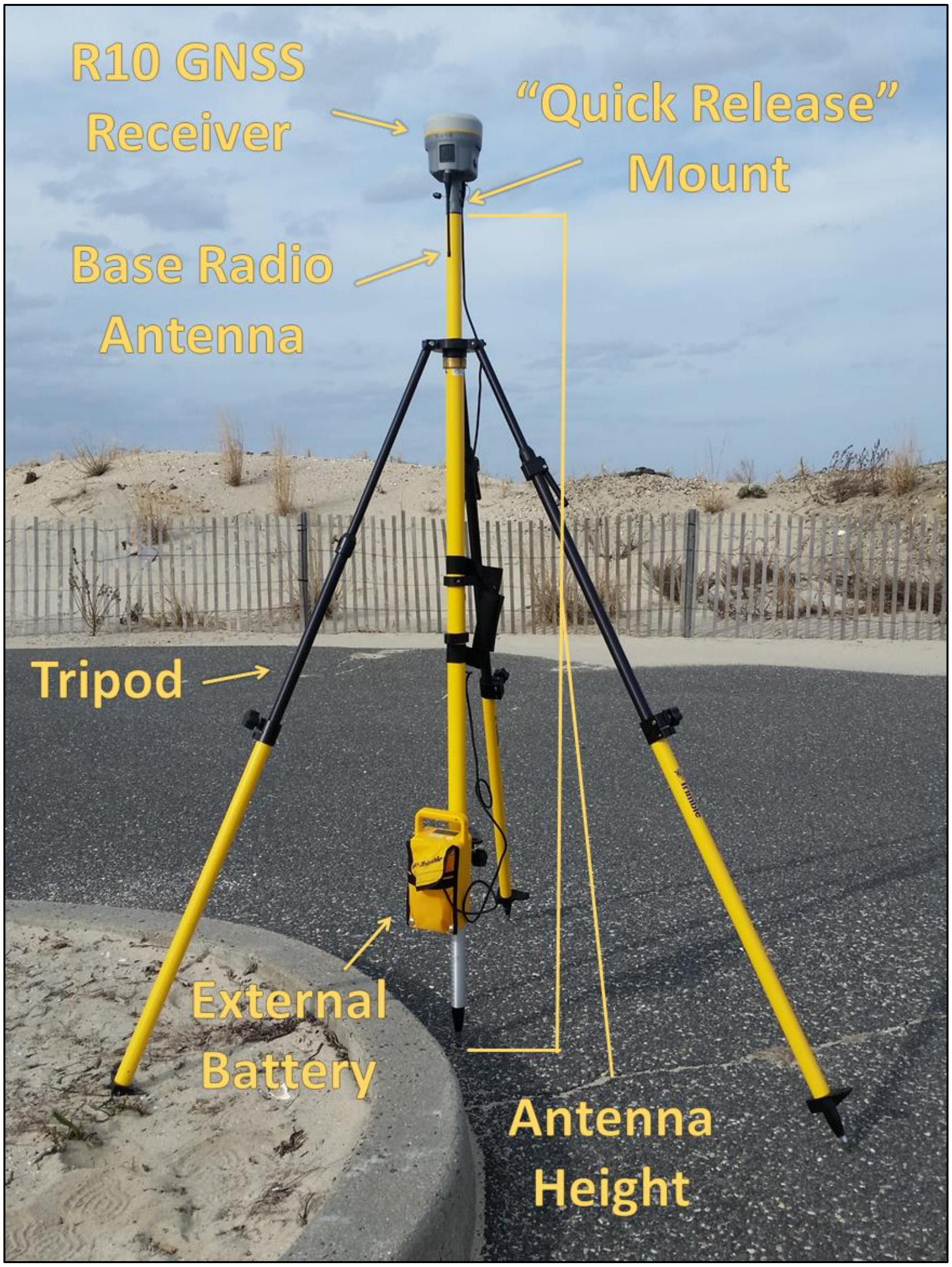

Figure S1.2. The Trimble R10 GNSS receiver set up as a base station (Critical Zone, Sandy Hook, March 2016).

- Field Reference Sheet:
- The Field Reference Sheet is specific to each Area of Special Interest and provides a brief description of the site in addition to each elevation control benchmark location, aerial photos of the site, ground photos, and coordinates and elevation information. The creation of the Field Reference Sheet is described in SOP #2 - Establishment of Benchmarks, Transects and Database.

- Waders or rubber boots:
- They are needed by the surveyor to collect data in the water, if the intersection of the water level and topographical surface is inland of the seaward boundary of the topographical survey. The necessity of collecting data seaward of the water/land contact should be minimized according to the mission planning described in SOP #3 - Survey Timing and GPS Mission Planning.
- Digital Camera, preferably with GPS capabilities
- Field copy of Field Data Form (Form S5.1)
- Field copy of SOP #5 - Conducting the Survey
- Emergency and Safety Supplies:
- The surveyor must carry a cell phone or radio, and a list with the Park's contacts and emergency phone numbers
- Field copy of the Field Equipment Checklist (Form S1.1) (See Figure S1.3)
- Four-wheel drive transportation (if necessary)
- Accessories for collection of topographical data, such as rover poles and survey wheels.
- Measuring tape

1.2 Office Equipment

- Computer:
  A PC that meets the minimum specifications for running GPS and GIS software, and is capable of communicating with the field survey controller. The NPS minimum standard for computer equipment meets these requirements.
- Software:
  1. A program capable of transferring the data from the field survey controller and processing the collected field data (for example, Trimble Business Center) is required.
  2. ESRI ArcGIS or similar software for visualization, manipulation, and archiving of the data.
  3. Microsoft Office Excel for any additional post-processing or corrections to the data.
- Internet connectivity:
  An internet connection is needed for viewing the satellite almanac and tide charts (SOP #3) and maintaining the GPS software/firmware updates.

FIELD ITEM CHECKLIST **Form S1.1**

1. GPS Equipment

Depending on the equipment used and set-up selected, the following items are amongst those required for the establishment of the GPS system:

Fully-Integrated Receiver Setup:			
Rover setup:		**Base-station setup:**	
□ Rover receiver	□ Pole	□ Base receiver	□ External battery
□ Internal batteries (fully charged)	□ Flat foot for pole	□ Internal batteries (fully charged)	□ Tripod
□ Radio antenna	□ Pole clamp	□ Radio antenna	
□ Survey Wheel (optional)			
□ Field survey controller			
□ Internet capable mobile device with data plan for CORS network correction. (if necessary)			

Modular Unit Receiver Setup:			
Rover setup:		**Base-station setup:**	
□ Rover receiver	□ Pole	□ Base receiver	□ Internal batteries (fully charged)
□ Rover GPS antenna	□ Flat foot for pole	□ Base GPS antenna	□ External batteries (full charged)
□ Rover radio antenna	□ Pole clamp	□ Base radio transmitter	□ Base receiver tripod
□ Internal batteries (fully charged)		□ Base radio antenna	□ Radio antenna tripod
□ Cables		□ Cables	
□ Field survey controller			
□ Internet capable mobile device with data plan for CORS network correction option. (If necessary)			

2. Other Items

□ Field Reference Sheet
□ Waders or rubber boots
□ Digital Camera, preferably with GPS capabilities
□ Field copy of SOP #5 – Conducting the Survey
□ Field copy of Field Data Form (Form S5.1)
□ Cell phone or radio with charged battery
□ List of emergency and park contact phone numbers
□ GPS manual (optional)
□ Measuring tape and small toolkit for adjustment or assembly of equipment

Figure S1.3. An example of Field Item Checklist (Form S1.1).

Standard Operating Procedure (SOP) #2 – Establishment of Benchmarks, Survey Areas, and Database

Version 1.0 (May 2018)

The following table lists all changes that have been made to this Standard Operating Procedure since the original publication date. Any recommended or required changes added to the log must be complete and concise and promptly brought to the attention of the Project Leader. The project leader will review and incorporate all changes, officially complete the revision history log, and change the date and version number on the title page. For complete instructions, please refer to SOP #9 – Revising the Protocol.

Revision History Log:

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This SOP is divided into the following sections:

2.1 Benchmarks

2.2 QA/QC Transect

2.3 Survey Transect Lines

2.4 Survey Photo Locations

2.5 Survey Transect Buffer Lines

2.6 GIS Database

2.7 Field Reference Sheet

2.8 Database maintenance

This standard operating procedure illustrates and describes in detail the types of survey benchmarks, transect lines, and associated spatial data files that are needed to conduct the Coastal Landform Elevation Model Protocol within sites designated as Areas of Special Interest. Benchmarks, or survey monuments, are permanent and long-lasting structures with a well-established geodetic position used to provide a robust basis for long-term monitoring, either (or both) as a reference for Real Time Kinematic (RTK) correction or as a test for the accuracy of the collected topographical data. The QA/QC Transect is a topographical profile, established on a stable surface, generated for the purpose of testing the proper function of specialized equipment configurations, such as the incorporation of a survey wheel into the data collection procedure. The Survey Transect Lines identify the beach-dune profiles collected during the topographical GPS surveys, as well as the landward extent of the data collection. Each transect line will possess related buffer lines that are used during the field survey to ensure that the topographical data are collected within a 2.0 m distance orthogonal to the transect lines.

This procedure describes methods of installation of new survey benchmarks, as well as the method for creating the Survey Transect Lines, the QA/QC Transect, and the associated QA/QC survey shapefiles. Information on the network of survey benchmarks in the vicinity of each Area of Special Interest, the respective Survey Transect Lines, and the location of the QA/QC Transect are presented within a field reference sheet containing a description of the locations and attributes of the survey benchmarks.

2.1. Benchmarks

Each site will contain at least one survey benchmark to serve as a reference to test vertical and horizontal accuracy of the survey equipment. Two benchmarks are required if one will be used to set up a GPS base station that provides RTK corrections to a second receiver collecting the survey data points. The survey benchmarks need to be highly accurate topographical points, within centimeter accuracy computed through the Online Positioning User Service (OPUS). They form the basis for standard surveying techniques using the RTK survey style. At least one benchmark is reoccupied at the beginning and at the end of each survey. Moreover, a survey benchmark can be interchangeably used for either QA/QC or as a position for base-station configuration, because the two points are established in the same manner.

2.1.1 Benchmark Establishment

The establishment of a new survey monument, either for the purpose of a QA/QC check or a base station setup, must be conducted according to the following criteria:

1. A survey control benchmark should be a permanent and long-lasting structure. Potential marks preferentially ordered according to suitability include:
    a. A pre-existing, survey control monument with a published datasheet (example: monuments installed by NGS, USACE, or NPS).
    b. A pre-existing or installed structure, such as a PK nail driven into pavement.
    c. A metal rod or PVC pipe driven into the ground. The PVC pipe option should only be used in the absence of the preceding options, and may need to be reestablished at a recurring interval considering the stability of the substrate.
2. Benchmarks should be located inland and far from the reach of wave action:
    a. Inland of the foredune
    b. Far from the bluff’s edge
3. Benchmarks should be accessible to the surveyor throughout the year:
    a. Outside of protected shorebird nesting areas
    b. Outside of private property
    c. Far from vegetation that might cause allergic reaction, such as poison ivy

d. Away from areas that are likely to accumulate sand or soil that may obscure the benchmark

4. Benchmarks should be located far from objects that might obstruct or interfere with the broadcast of the GPS radio signal:

   a. Far from buildings or tree canopy

2.1.2 Pre-existing Survey Monuments

If a monument from the NGS Data Explorer is available for the general area, it is recommended that it is used as a benchmark for the purposes of applying this protocol. These are stable, identifiable points (usually metal disks) established for the purpose of survey control. To access the complete list of these monuments, go to the online interactive map at: http://www.ngs.noaa.gov/NGSDataExplorer/. Each benchmark has an associated PID (Permanent Identifier), and a datasheet that provides information on the coordinates and elevation, as well as a description of its location and when it was last accessed (Figs. S2.1 and S2.2).

A control point(s) that provides both horizontal (coordinates) and vertical (elevation) control should be selected. If there are a number of potential control monuments available, it is preferable to select the point with the highest level of accuracy, given by the lowest order number. This information is accessed by either selecting a point within the map view (Fig. S2.1), or by navigating to the "View List" option within the online interactive map that will provide the vertical and horizontal accuracies for all survey monuments within a specified search radius.

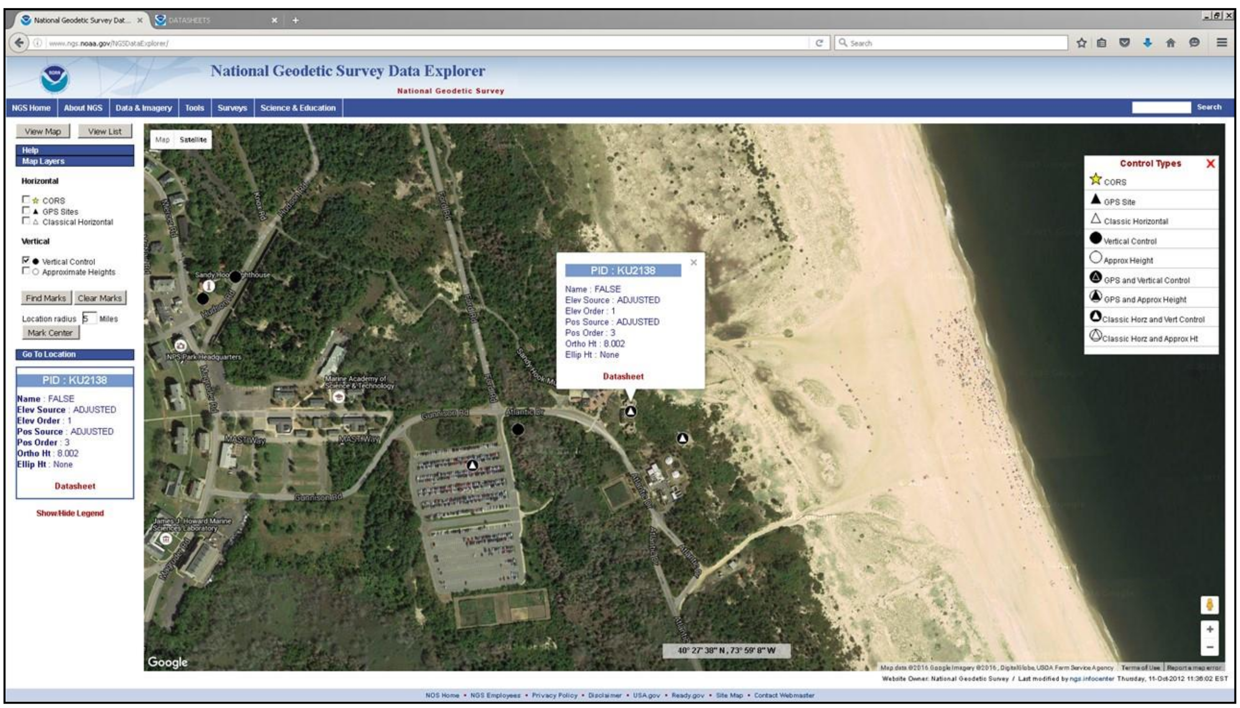
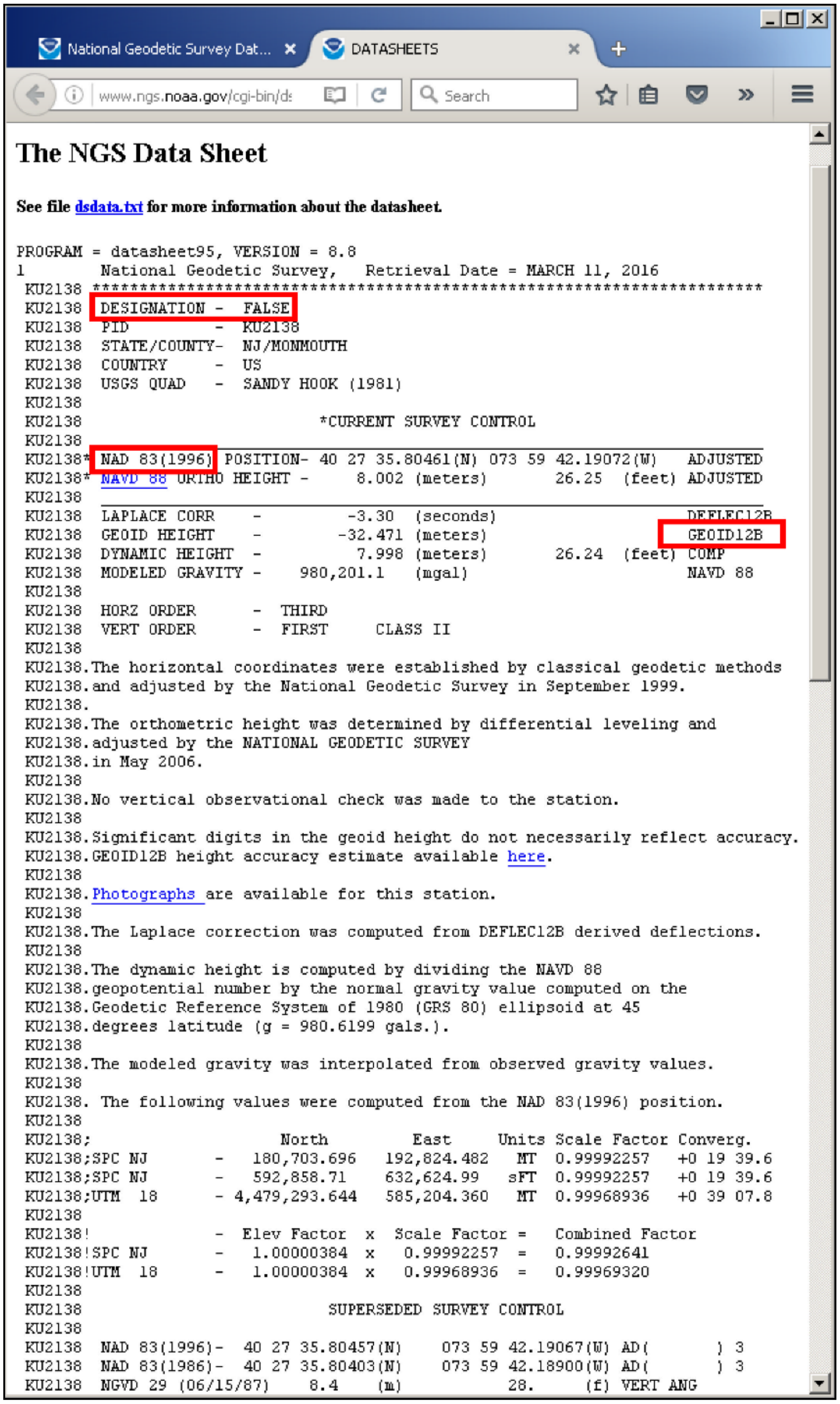


Figure S2.1. The NGS Survey Control Map website, showing the selection of a monument at Gunnison Beach of the Sandy Hook Unit at Gateway National Recreation Area – PID *KU2138* (http://www.ngs.noaa.gov/NGSDataExplorer/).

Use the information on the datasheet to locate the benchmark in the field. Read the description of the station location carefully, and use a handheld GPS and an updated geo-referenced aerial photo to locate the metal disk in the field (Figure S2.2).

Figure S2.2. The monument *PID KU2138* located in the field at Gunnison Beach, Sandy Hook Unit, Gateway National Recreation Area. Note the designation that is inscribed on the disk and assigned to it as an identifier by the NGS, “FALSE”, that is also noted on the datasheet associated with this monument in Figure S2.3.



National Geodetic Survey Dat... DATASHEETS

www.ngs.noaa.gov/cgi-bin/ds

The NGS Data Sheet

See file dsdata.txt for more information about the datasheet.

```
PROGRAM = datasheet95, VERSION = 8.8
1        National Geodetic Survey,   Retrieval Date = MARCH 11, 2016
 KU2138 ***********************************************************************
 KU2138  DESIGNATION -  FALSE
 KU2138  PID         -  KU2138
 KU2138  STATE/COUNTY-  NJ/MONMOUTH
 KU2138  COUNTRY     -  US
 KU2138  USGS QUAD   -  SANDY HOOK (1981)
 KU2138
 KU2138                        *CURRENT SURVEY CONTROL
 KU2138
 KU2138* NAD 83(1996) POSITION- 40 27 35.80461(N) 073 59 42.19072(W)   ADJUSTED
 KU2138* NAVD 88 ORTHO HEIGHT -     8.002 (meters)       26.25  (feet) ADJUSTED
 KU2138
 KU2138  LAPLACE CORR    -         -3.30  (seconds)                    DEFLEC12B
 KU2138  GEOID HEIGHT    -        -32.471 (meters)                     GEOID12B
 KU2138  DYNAMIC HEIGHT  -          7.998 (meters)       26.24  (feet) COMP
 KU2138  MODELED GRAVITY -    980,201.1   (mgal)                       NAVD 88
 KU2138
 KU2138  HORZ ORDER      -  THIRD
 KU2138  VERT ORDER      -  FIRST     CLASS II
 KU2138
 KU2138.The horizontal coordinates were established by classical geodetic methods
 KU2138.and adjusted by the National Geodetic Survey in September 1999.
 KU2138.
 KU2138.The orthometric height was determined by differential leveling and
 KU2138.adjusted by the NATIONAL GEODETIC SURVEY
 KU2138.in May 2006.
 KU2138
 KU2138.No vertical observational check was made to the station.
 KU2138
 KU2138.Significant digits in the geoid height do not necessarily reflect accuracy.
 KU2138.GEOID12B height accuracy estimate available here.
 KU2138
 KU2138.Photographs are available for this station.
 KU2138
 KU2138.The Laplace correction was computed from DEFLEC12B derived deflections.
 KU2138
 KU2138.The dynamic height is computed by dividing the NAVD 88
 KU2138.geopotential number by the normal gravity value computed on the
 KU2138.Geodetic Reference System of 1980 (GRS 80) ellipsoid at 45
 KU2138.degrees latitude (g = 980.6199 gals.).
 KU2138
 KU2138.The modeled gravity was interpolated from observed gravity values.
 KU2138
 KU2138. The following values were computed from the NAD 83(1996) position.
 KU2138
 KU2138;                   North         East     Units Scale Factor Converg.
 KU2138;SPC NJ       -   180,703.696   192,824.482   MT  0.99992257   +0 19 39.6
 KU2138;SPC NJ       -   592,858.71    632,624.99   sFT  0.99992257   +0 19 39.6
 KU2138;UTM  18      - 4,479,293.644   585,204.360   MT  0.99968936   +0 39 07.8
 KU2138
 KU2138!             -  Elev Factor  x  Scale Factor =   Combined Factor
 KU2138!SPC NJ       -   1.00000384  x   0.99992257  =   0.99992641
 KU2138!UTM  18      -   1.00000384  x   0.99968936  =   0.99969320
 KU2138
 KU2138                        SUPERSEDED SURVEY CONTROL
 KU2138
 KU2138  NAD 83(1996)-  40 27 35.80457(N)    073 59 42.19067(W) AD(       ) 3
 KU2138  NAD 83(1986)-  40 27 35.80403(N)    073 59 42.18900(W) AD(       ) 3
 KU2138  NGVD 29 (06/15/87)     8.4     (m)             28.     (f) VERT ANG
```

Figure S2.3. Example of the datasheet retrieved from the NGS Survey Control Map interactive website for the Monument *PID KU2138* (http://www.ngs.noaa.gov/cgi-bin/ds_mark.prl?PidBox=KU2138). The red boxes note the horizontal datum that the geoid model used to reference the position and orthometric height of this reference mark, and the designation of this disk that correlates this datasheet to the physical monument in the field.

In case the available NGS published benchmark closest to the selected profile location does not provide vertical or horizontal information or references an outdated horizontal datum or geoid model, the mark may still be used as a Profile or Base-station Benchmark (note the NAD83(1996) horizontal datum in Figure S2.3). In this case, improved coordinates and elevation of the point will have to be established through an occupation of the mark with a GPS receiver for a duration of 4+ hours and obtaining an OPUS solution – as detailed below.

2.1.3 Pre-existing Monuments/Structures

Where no NGS monument is available for the selected location, then a new control monument must be established. Pre-existing structures are preferable, such as a preinstalled PK nail in a parking lot (Figure S2.4.), and therefore should be used whenever possible. In this case, consideration should be given to whether or not a particular structure will be used for QA/QC as a known elevation for a base station setup, because marks on some structures will not be suitable for repeated assembly of equipment over them.

Figure S2.4. PK nail, "P10", located within the parking lot E at Sandy Hook, Gateway National Recreation Area.

2.1.4 Installation of New Survey Monuments

If no pre-existing benchmarks or structures are available, a new one must be created. A procedure for the establishment of very stable benchmarks is provided by the NPS-URI Monumentation Project (http://www.edc.uri.edu/monumentation/Protocols/). The installations described involve steel rods driven to depth or brass disks that are secured to bedrock or a stable concrete pad. The NPS-URI method is preferred for the application of this protocol. However, a PVC pipe benchmark installation is provided here as an alternative if the NPS-URI methods are not feasible. PVC pipes set into a concrete base are safe, easy to install, and long-lasting structures. Furthermore, 5 cm diameter PVC pipes provide a functional base for the flat foot of the rover pole to collect XYZ data for QA/QC purposes. To prepare the PVC pipe and install it as a viable benchmark, the following items are needed:

- PVC pipe that is at least 1.3 meters long and 5 cm in diameter

- Drill
- Field hand-corer
- Container with fresh water (c. 2-3 L per benchmark)
- Cement (c. 4 kg per benchmark)
- Hammer
- Stickers with NPS logo
- PK Nail
- Measuring tape

<u>2.1.4.1 Procedure to prepare the PVC pipe and install it as a benchmark</u>

1. In the office or lab, drill holes into a portion, about 0.5 m, of the PVC pipe (Fig. S2.5a)
2. In the field, use the hand-corer to excavate a hole at least 1 m deep (Fig. S2.5b)
3. Insert the PVC pipe into the hole (the part with the drilled holes in the hole), leaving no more than 35-40 cm of the pipe extending above the surface. Hammer the pipe into the ground until only 30 cm of the pipe is showing (it is recommended that a flat piece of wood be placed on top of the PVC pipe and strike the wood rather than the pipe directly) (Fig. S2.5c).
4. Insert a mixture of cement, water, and the sand that was dug out of the hole into and around the pipe (Figs. S2.6a and S2.6b) until the PVC pipe is full.
5. Insert a PK nail into the concrete mixture at the top of the PVC pipe at the center of the column. This will be used to determine the precise XYZ coordinates of the benchmark.
6. Place a sticker with the NPS logo on the PVC pipe (Fig. S2.6c).

Figure S2.5. PVC pipe benchmark; a) PVC pipe with holes; b) Coring in field, and c) final driving of PVC pipe into sand.

Figure S2.6. Installation of the PVC pipe benchmark, a) and b) Inserting the cement, water, and sand into and around the pipe, and c) NPS logo on PVC pipe.

2.1.5 Benchmark Identification

Pre-established benchmarks created within the 2D protocol (Psuty et al. 2012) may be utilized for the purposes of applying the 3D protocol. However, if they do not have a published position or a position collected using static occupation methods, a new position must be obtained according to SOP #2.1.6. If new benchmarks are created specifically for the Area of Special Interest, it is suggested that the ID be assigned according to the name of the Area of Special Interest and the purpose of the installed or reoccupied mark. Ideally, these topographic points should carry a suffix that indicates their intended purpose. For example, a recently created QA/QC benchmark at a site on the western margin of Floyd Bennett Field carries the Benchmark ID of FBFW_BM.

Table S2.1. Identification of existing benchmarks at current sites designated Areas of Special Interest at Gateway National Recreation Area (GATE).

Unit	Section	Area of Special Interest	Benchmark ID
Sandy Hook	N/A	Critical Zone	P10, SH3
	N/A	Gunnison Beach	GBBM, SH7
	N/A	Kingman Mills	KM_BM, SH13, SH14
Jamaica Bay	Breezy Point	Roxbury Cove	RC_BM
	Breezy Point	Fort Tilden	BP3
	Breezy Point	Breezy Point Tip	BP6
	Plumb Beach	N/A	PB_BM, PB5
	Floyd Bennett Field	FBF West	FBFW_BM
	Floyd Bennett Field	FBF North	FBFN_BM
	Floyd Bennett Field	Aviation Road	AR_BM
	JB Wildlife Refuge	West Pond	WP_BM
	Riding Academy	RA North	RAN_BM
	Riding Academy	RA South	RAS_BM
Staten Island	Great Kills	N/A	GK2, GK7
	Miller Field	N/A	MF_BM, MF1

2.1.6. Establishment of Benchmark Height and Position Information

The benchmark's coordinates and elevation will be acquired with a geodetic GPS unit, with an occupation time of no fewer than four hours, and will be registered to the following spatial references:

- Grid Coordinate System: Universal Transverse Mercator (UTM)
- UTM Zone Number: 18 (GATE, ASIS and FIIS)
  19 (CACO)
- Horizontal Datum: North American Datum of 1983 (2011)
- Vertical Datum: North American Vertical Datum of 1988
- Geoid Model: GEOID12B (or, the most recent geoid model)
- Units: Meters

To acquire high-accuracy GPS positions in the field, the surveyor will need a geodetic GPS Unit. Refer to the GPS Equipment list under the Field Equipment Checklist (Form S1.1) in SOP #1-Equipment and Supplies. The following description on how to measure the benchmark coordinates and elevation is based on Trimble's software terminology (as an example).

<u>2.1.6.1 Obtaining a survey control position for benchmarks</u>

Base stations and QA/QC Benchmarks are control points that require higher accuracy and therefore are computed through the Online Positioning User Service (OPUS).

- In the field, set up the receiver antenna on a fixed-height tripod (or bipod) at the benchmark location, determine that the receiver is level
- Create a Project/Job with the spatial references identified above
- Change the survey type to FastStatic within the survey style setting
- Ensure that the antenna height is entered correctly. This is the height of the tripod or rover pole (see Fig S1.1 for determination of antenna height).
- Enter 5 seconds for the receiver epoch rate
- Select Save Data to the Receiver. (You may alternatively select Field Controller, but only if it can be kept connected to the receiver on-site.)
- Enter the appropriate point ID – the benchmark ID
- Measure the point for at least 4 hours, but not more than 24 hours. A longer-duration data file will improve the accuracy of the solution.
- Download the GPS raw data file (format: .t01 if it was stored in the Receiver, or .dat if it was stored in the Controller) using the Import command on the Trimble Business Center software (for example)
- Wait at least 24 hours before submitting your data file to OPUS
- 24 hours after the data collection, open an Internet Browser and go to: http://www.ngs.noaa.gov/OPUS/
- Follow the instructions (Fig. S2.7):
    1. Enter your e-mail address
    2. Attach the GPS raw data file (only one data file may be uploaded at a time)
    3. Select the antenna type used in the field data collection
    4. Enter the antenna height (in meters)
    5. Select: Upload to **STATIC**

Opus will email the solution usually in 10-15 minutes (Fig. S2.8). The report will include the northing, easting, and elevation data (noted as ortho height in the report) as well as the information about the processing of the data file.

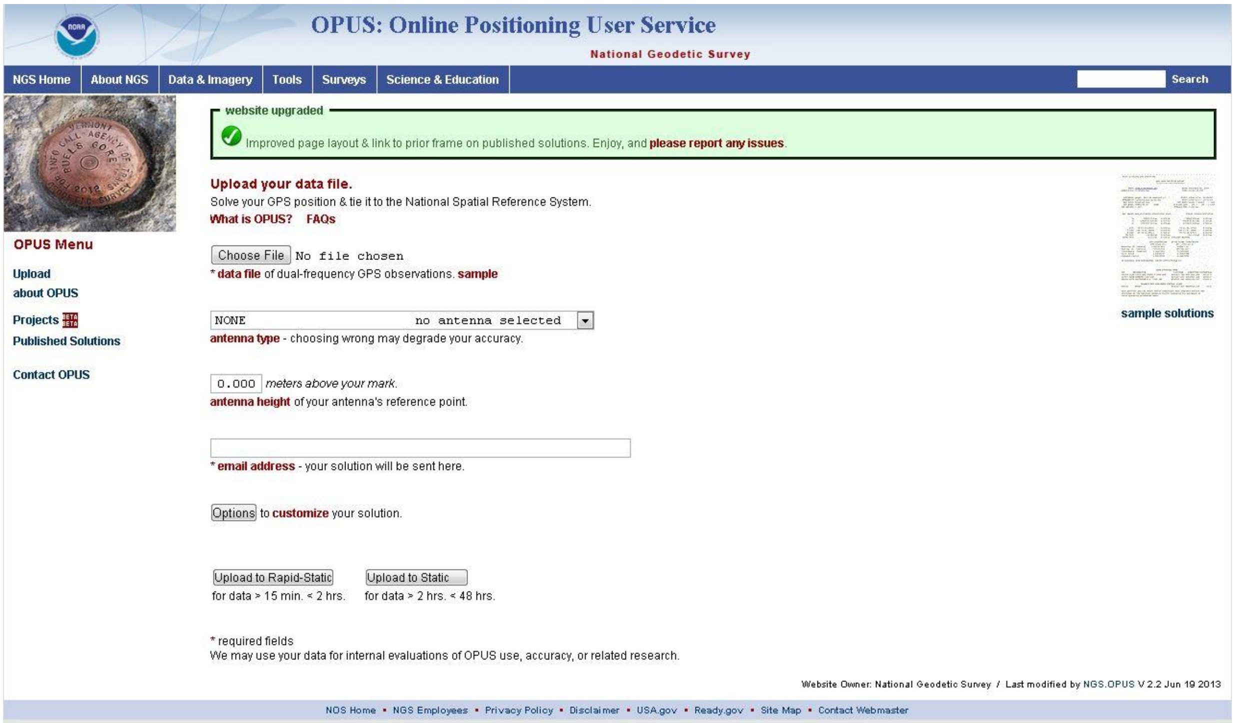
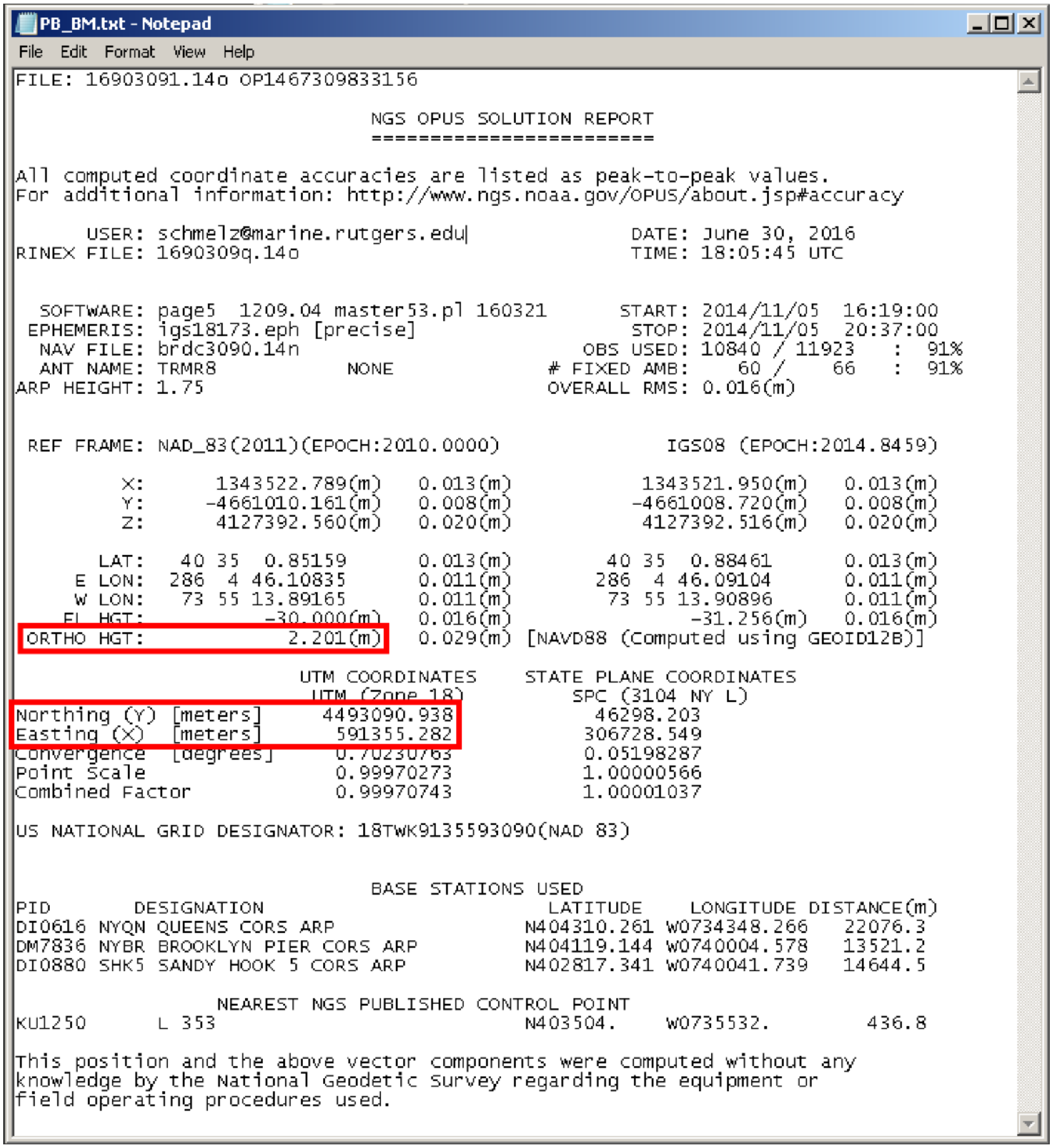


Figure S2.7. The OPUS Upload webpage and the fields required for data entering (http://www.ngs.noaa.gov/OPUS/).



```
PB_BM.txt - Notepad
File  Edit  Format  View  Help
FILE: 16903091.14o OP1467309833156

                         NGS OPUS SOLUTION REPORT
                         ========================

All computed coordinate accuracies are listed as peak-to-peak values.
For additional information: http://www.ngs.noaa.gov/OPUS/about.jsp#accuracy

      USER: schmelz@marine.rutgers.edu              DATE: June 30, 2016
RINEX FILE: 1690309q.14o                            TIME: 18:05:45 UTC


  SOFTWARE: page5  1209.04 master53.pl 160321      START: 2014/11/05  16:19:00
 EPHEMERIS: igs18173.eph [precise]                  STOP: 2014/11/05  20:37:00
  NAV FILE: brdc3090.14n                        OBS USED: 10840 / 11923   :  91%
  ANT NAME: TRMR8          NONE               # FIXED AMB:    60 /    66   :  91%
ARP HEIGHT: 1.75                              OVERALL RMS: 0.016(m)


 REF FRAME: NAD_83(2011)(EPOCH:2010.0000)              IGS08 (EPOCH:2014.8459)

         X:      1343522.789(m)   0.013(m)          1343521.950(m)   0.013(m)
         Y:     -4661010.161(m)   0.008(m)         -4661008.720(m)   0.008(m)
         Z:      4127392.560(m)   0.020(m)          4127392.516(m)   0.020(m)

       LAT:   40 35  0.85159      0.013(m)       40 35  0.88461      0.013(m)
     E LON:  286  4 46.10835      0.011(m)      286  4 46.09104      0.011(m)
     W LON:   73 55 13.89165      0.011(m)       73 55 13.90896      0.011(m)
    EL HGT:          -30.000(m)   0.016(m)             -31.256(m)    0.016(m)
 ORTHO HGT:            2.201(m)   0.029(m) [NAVD88 (Computed using GEOID12B)]

                        UTM COORDINATES    STATE PLANE COORDINATES
                         UTM (Zone 18)         SPC (3104 NY L)
Northing (Y) [meters]     4493090.938           46298.203
Easting (X)  [meters]      591355.282          306728.549
Convergence  [degrees]     0.70230763          0.05198287
Point Scale                0.99970273          1.00000566
Combined Factor            0.99970743          1.00001037

US NATIONAL GRID DESIGNATOR: 18TWK9135593090(NAD 83)


                             BASE STATIONS USED
PID       DESIGNATION                        LATITUDE    LONGITUDE DISTANCE(m)
DI0616 NYQN QUEENS CORS ARP                N404310.261 W0734348.266   22076.3
DM7836 NYBR BROOKLYN PIER CORS ARP         N404119.144 W0740004.578   13521.2
DI0880 SHK5 SANDY HOOK 5 CORS ARP          N402817.341 W0740041.739   14644.5

                 NEAREST NGS PUBLISHED CONTROL POINT
KU1250      L 353                          N403504.     W0735532.        436.8

This position and the above vector components were computed without any
knowledge by the National Geodetic Survey regarding the equipment or
field operating procedures used.
```

Figure S2.8. Example of an OPUS Solution report sent via e-mail. Coordinates and elevation data are highlighted in red boxes (http://www.ngs.noaa.gov/OPUS/).

2.2 QA/QC Transect

The collection of a densely spaced topographic dataset can be facilitated through the use of a survey wheel or other apparatus. The incorporation of these survey accessories within the configuration of the GPS survey needs to be empirically verified. This equipment is often unwieldy and it is generally difficult to accomplish, if not impossible, to collect a spot elevation point over a benchmark, because the equipment is designed to collect an elevation transect. Therefore, each site should contain one topographical profile that is established in an area of unchanging topography for reoccupation prior to each survey to test the configuration of the survey equipment and associated accessories that might be used, such as a survey wheel. The QA/QC Transect provides the basis for the accuracy of the survey because it is collected over a transect of known elevation in the same manner as the Survey Transect Lines. The precise coordinates establishing the transect end points are produced in a GIS environment after the approximate location of the transect is made within the field. After the spatial location of the transect is established, topographical coordinates along the transect are to be measured with the GPS equipment utilizing a rover pole on two occasions separated by at least 8 hours. The location of the QA/QC Transect should be generated according to the following criteria:

- The transect must be located on a stable topographic surface that is not likely to have significant compaction, erosion, or accumulation of underlying sediments. A paved surface is preferable.
- The topographic surface should be generally flat.
- The transect should be reasonably accessible to reoccupy at all times during the year considering the presence and convenience of park visitors.

2.3 Survey Transect Lines

Each ASI will contain a network of closely spaced cross-shore transects, along which the topographical measurements are collected in the field. From a cross-shore perspective, the transects should extend landward across all features of geomorphological interest. The seaward extent of the survey should be a predetermined elevation threshold tied to NAVD88 and possibly also related to elevations such as MSL, NGVD29, or MLLW. The cross-shore length of the survey transects should incorporate a distance seaward of this threshold to accommodate fluctuations in the location of the intersection of the beach and this elevation. The alongshore spacing of the transects should be determined considering the dimensions of the geomorphological features to be measured, the spatial extent of the Area of Special Interest, and resources assigned to the completion of the surveys. The topographical data must be dense enough that interpolation between transect lines accurately represents the geomorphology. However, the transects should not be so numerous that the collection of the survey is not possible in a timely manner. Typically, the transect spacing ranges from 5 m for sites of 100-200 m in alongshore length to 25 m for sites that span over 2 km. Transect lines are generally parallel and oriented perpendicular to the general trend of the shoreline, but may be assigned slightly varying azimuths to accommodate shore parallel data collection for curvilinear shoreline configurations – an important consideration if the data will be utilized for 2D analysis in addition to the 3D covered within this document.

The Park’s GIS expert will produce the transect lines in a GIS environment. Characteristics of a set of transects will incorporate:

- The landward extent of the Area of Special Interest to be characterized and volumetrically analyzed.
- A seaward extent of transect lines below NAVD88 that can accommodate a spatial seaward fluctuation in the position of the intersection of the beach and an elevation threshold

- Transect spacing dense enough to represent alongshore variation in geomorphological features without exceeding an absolute number of transects that would make the collection of the survey difficult given resources.
- A generally parallel configuration of transects oriented perpendicular to the trend of the shoreline

2.4 Survey Photo Locations

Documenting the geomorphological evolution through photography is a valuable supplement to the topographical data collection. An acquisition of comparable photography from survey to survey can be accomplished by selecting specific transects from the Survey Transect Lines for the photography. On the selected transects, it is suggested that these photos are taken at the intersection of the beach and the foredune, parallel to the orientation of the shoreline and roughly orthogonal to the collected transect line. If there is no foredune, the photos should be taken at the landward margin of the beach, at the intersection of the beach and the adjacent landscape (e.g., washover flat, wetland, anthropogenic surface). At the photo locations, three photos should be taken in both directions, orthogonal to the transect line, to maximize photographic coverage of the area and minimize the time within the survey to stop and restart data collection. In each direction, one photo should always be directly orthogonal to the transect line. The two additional photos, in each direction, should angle towards the inland geomorphological features and seaward towards the beach face to capture images of the features in the landscape. This will result in 6 photos The Survey Photograph Locations will be defined by a polygon shapefile marking the specific Survey Transects that survey photos will be taken on. The shapefile will be created in a GIS environment by the Park's GIS expert. These transects are, preferably, spaced regularly throughout the survey. The number of Survey Photo Locations within a site will vary depending upon the size of the site. A 2.5 km site such as Great Kills Park, a component of the Staten Island Unit within Gateway National Recreation Area, with ~90 transects might contain 5 survey photo locations, resulting in 30 photos per survey. Whereas a smaller site might contain just a single Survey Photo Location. The surveyor is encouraged to take any additional photos of notable features or concerns. All photos should be capable of being georeferenced with either a GPS camera or by noting the photo location in the Field Data Form.

Characteristics of the Survey Photo Locations include:

- A polygon surrounding individual survey transects (Fig. S2.9)
- Roughly equal spacing between the transects selected for acquisition of photography
- Features of special interest, such as engineered structures affecting geomorphological processes, might be considered when selecting the Survey Photo Locations

2.5 Survey Transect Buffer Lines

An auxiliary shapefile – the Survey Transect Buffer Lines– is to be created. This is a polygon dataset, offset 2.0 m on either side of the Survey Transect Lines that will be utilized alongside the Survey Transect Lines during the survey. These polygons provide the surveyor with real-time, visual guidelines in the field to maintain a position of 2.0 m on either side of the Survey Transect Lines, wherein data may be collected, as well as a dataset to be used within the data processing step (SOP

#6 – Initial Post-Survey Processing) to confirm that the data were collected to this standard. The shapefiles will be created in a GIS environment by the Park's GIS expert.

Figure S2.9. Survey shapefiles for the Critical Zone site within the Sandy Hook Unit, Gateway National Recreation Area.

2.6 Overview of Survey Shapefiles

The survey shapefiles are a group of spatial data files that are utilized during the topographical surveys to ensure the systematic and precise collection of data. A shapefile will be created for each of the items established within SOP #2.1 – 2.5 (Fig. S2.9). The five shapefiles, described above, that will be generated to facilitate the collection of accurate data and/or confirm its accuracy, for each Area of Special Interest, are:

1. A point shapefile with all survey benchmarks (established according to SOP #2.1) proximal to the Area of Special Interest that will indicate the position of the base station setup and/or the location of a QA/QC position to be collected prior to each survey.
2. A polyline shapefile with the location of the QA/QC Transect (created according to SOP #2.2) that defines a transect with established elevations will be recollected prior to each survey to confirm the proper configuration of the GPS equipment and any accessories utilized to facilitate the collection of a high density of survey points.
3. A polyline shapefile containing the set of Survey Transect Lines (created according to SOP #2.3) that will constrain where the GPS survey data are collected, ensuring that data have been and will be collected along the same beach-dune transects in preceding and subsequent topographical surveys.

4. A polygon shapefile containing the set of Survey Photo Locations that will indicate the specific transects where photos should be taken along during each survey (created according to SOP #2.4).
5. A polygon shapefile containing the set of Survey Transect Buffer Lines that bracket the Survey Transect Lines with a parallel orientation at a distance of 2.0 m will ensure that collected data points are in close proximity to the Survey Transect Lines (SOP #2.5).

2.7 GIS Database

Each Area of Special Interest will have a GIS database to store the Benchmarks, Survey Transect Lines, Survey Transect Buffer Lines, and Survey Photo Locations as five *feature classes* within an ESRI *geodatabase* (Fig. S2.10) created and maintained by the NCBN Data Manager. The characteristics and properties of the *feature classes* are detailed below. All of the feature classes will have metadata, to be provided by the NCBN Data Manager.

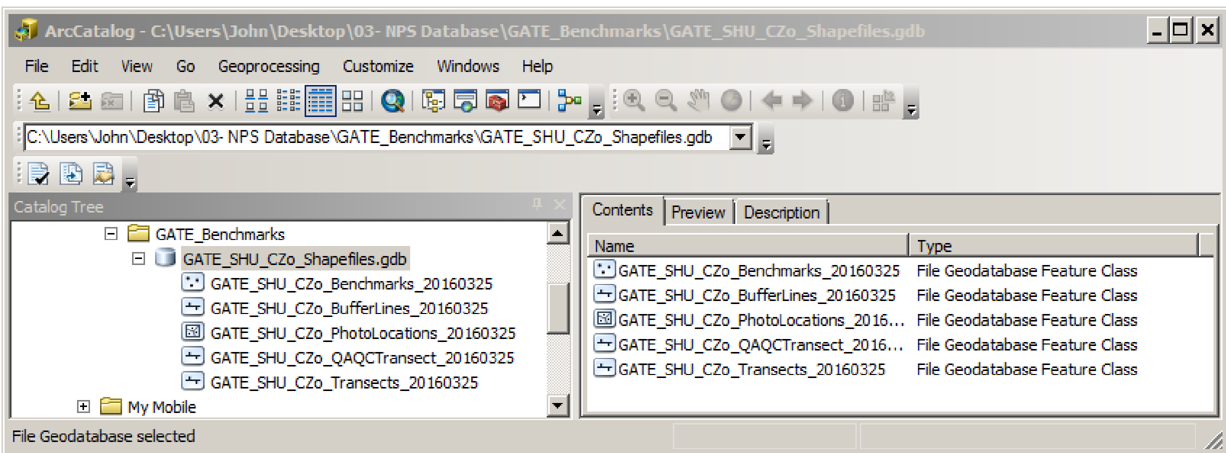


Figure S2.10. An example of the Critical Zone site, Sandy Hook Unit of Gateway National Recreation Area, GIS data stored within an ESRI *geodatabase*.

2.7.1 Benchmarks

The benchmark height and position information will be stored as ESRI *point features* with the following attribute fields and respective information (Table S2.2 and Fig. S2.10).

Table S2.2. An example of the attribute fields of the Benchmarks *feature class* for the Critical Zone site, Sandy Hook Unit of Gateway National Recreation Area. These attribute fields are in addition to the automatically generated "OBJECTID" and "SHAPE" fields associated with file geodatabase feature classes.

Attribute	Field Name	Example	Type
Benchmark ID	ID	P10	Text
Easting coordinate	X	590656.062	Double
Northing coordinate	Y	4493107.404	Double
Elevation	Z	3.085	Double
Date benchmark was established	Date_est	3/18/2009	Text
Who established benchmark	Source	Rutgers University	Text
Short description of what is the benchmark	Descrip	PK Nail	Text
Purpose of benchmark	Purpose	Base station or QA/QC	Text
Quality of the benchmark establishment	Quality	OPUS	Text
Date position was last established	Date_xyz	11/08/2011	Text

The Benchmarks *feature class* name will contain a shorthand acronym for the Area of Special Interest and the NPS acronym for the Park (and Park Unit, if applicable) that it is located within. The *feature class* will also be marked with the date of creation of the benchmark as a mechanism for assigning a temporally identifiable version to the data contained within it, to allow for future alterations of the database. For example:

GATE_SHU_CZo_Benchmarks_20160125

Protocol nomenclature – "Benchmarks" – Version

2.7.2 Survey Transect Lines

The Survey Transect Lines' *feature class* will contain three attribute fields in addition to the automatically generated "OBJECTID" and "SHAPE" fields associated with file geodatabase feature classes (Table S2.3).

Table S2.3. Attribute fields of the site's Survey Transect Lines' feature class.

Attribute	Field Name	Type	
Survey Transect ID	ID	Long Integer	
Transect Azimuth	Az	Double	
Transect Length	Shape_Length	Double	
Elevation Threshold	Threshold	Double	

Similar to the benchmarks, the Survey Transect Lines' *feature class* name will contain a shorthand acronym for the Area of Special Interest and the NPS acronym for the Park (and Park Unit, if applicable) that it is located within. The *feature class* will also will be marked with the date of creation as a mechanism for assigning a temporally identifiable version to the data contained within it, to allow for future alterations of the database, such as:

GATE_SHU_CZo_Transects_20160325

Protocol nomenclature – "Transects" – Version

2.7.3 QA/QC Transect

The QA/QC Transect's *feature class* will contain three attribute fields in addition to the automatically generated "OBJECTID" and "SHAPE" fields associated with file geodatabase feature classes (Table S2.4).

Table S2.4. Attribute fields of the site's QA/QC Transect's feature class.

Attribute	Field Name	Type
QA/QC Transect ID	ID	Long Integer
Transect Azimuth	Az	Double
Transect Length	Shape_Length	Double

The QA/QC Transect's *feature class* name will contain a shorthand acronym for the Area of Special Interest and the NPS acronym for the Park (and Park Unit, if applicable) that it is located within. The *feature class* will also will be marked with the date of creation as a mechanism for assigning a temporally identifiable version to the data contained within it, to allow for future alterations of the database, such as:

GATE_SHU_CZo_QAQCTransect_20160325

Protocol nomenclature – "QAQCTransect" – Version

2.7.4 Survey Photo Location

The Survey Photo Locations' *feature class* will contain one attribute field in addition to the automatically generated "OBJECTID" and "SHAPE" fields associated with file geodatabase feature classes (Table S2.5):

Table S2.5. Attribute field of the site's Survey Photo Locations' feature class.

Attribute	Field Name	Type
Survey Photo Location ID	ID	Long Integer

The Survey Photo Locations' *feature class* name will contain a shorthand acronym for the Area of Special Interest and the NPS acronym for the Park (and Park Unit, if applicable) that it is located within. The *feature class* will also will be marked with the date of creation as a mechanism for assigning a temporally identifiable version to the data contained within it, to allow for future alterations of the database, such as:

GATE_SHU_CZo_PhotoLocations_20160325

*Protocol nomenclature – "*PhotoLocations*" – Version*

2.7.5 Survey Transect Buffer Lines

The Survey Transect Buffer Lines' *feature class* will contain the transect ID in the attribute fields in addition to the automatically generated "OBJECTID" and "SHAPE" fields associated with file geodatabase feature classes. The Survey Transect Buffer Lines' *feature class* name will contain a shorthand acronym for the Area of Special Interest and the NPS acronym for the Park (and Park Unit, if applicable) that it is located within. The *feature class* will also will be marked with the date of creation as a mechanism for assigning a temporally identifiable version to the data contained within it, to allow for future alterations of the database, such as:

GATE_SHU_CZo_BufferLines_20160325
Protocol nomenclature – "BufferLines" – Version

2.8 Field Reference Sheet

Each Area of Special Interest will have a Field Reference Sheet that will include the following: (Fig S2.11 and Appendix A):

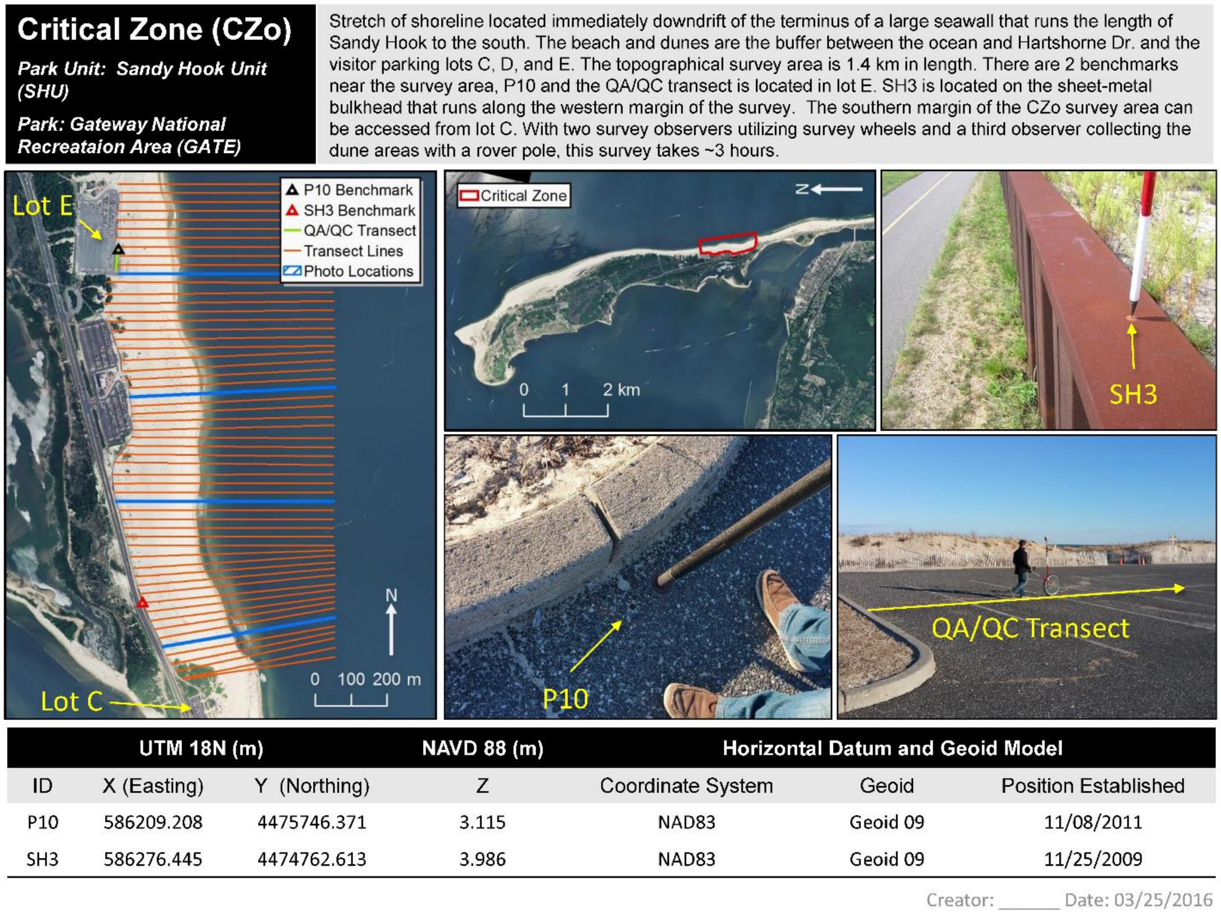
- Background information:
  The field reference sheet should include a short description of the site. There should also be information regarding the number and location of benchmarks, the creator of the Field Reference Sheet, and the date of creation. Additional information that may be helpful to surveyors might be recommendations regarding where to park and/or walking paths available to access the site, what equipment or survey configurations should be used, and the amount of time a typical survey might take.

- Small scale locator map:
  Identifying the location of the Area of Special Interest within the Park or Park Unit.

- Large scale site map:
  Portraying the entirety of the survey area and indicating the location of the Benchmarks associated with the site, the QA/QC Transect, the extent of the Survey Transect Lines, and the Survey Photo Locations.

- Ground photos:
  At least one ground photo should clearly show the benchmark(s) associated with the site. A second ground photo should portray the QA/QC Transect. Photos must incorporate the surrounding area to help the surveyor locate it on the ground. The direction of the QA/QC transect should be added to the image, as well as the identification of the distinctive structures or features in the area.

- Topographical Coordinates of Benchmarks:
  A table with the benchmark's ID, easting, northing, and elevation values. It should also include the date when the benchmark was established, the date the position was obtained, and the Geoid model referenced by the orthometric elevation.



Critical Zone (CZo)

Park Unit: Sandy Hook Unit (SHU)

Park: Gateway National Recreataion Area (GATE)

Stretch of shoreline located immediately downdrift of the terminus of a large seawall that runs the length of Sandy Hook to the south. The beach and dunes are the buffer between the ocean and Hartshorne Dr. and the visitor parking lots C, D, and E. The topographical survey area is 1.4 km in length. There are 2 benchmarks near the survey area, P10 and the QA/QC transect is located in lot E. SH3 is located on the sheet-metal bulkhead that runs along the western margin of the survey. The southern margin of the CZo survey area can be accessed from lot C. With two survey observers utilizing survey wheels and a third observer collecting the dune areas with a rover pole, this survey takes ~3 hours.

UTM 18N (m)			NAVD 88 (m)	Horizontal Datum and Geoid Model		
ID	X (Easting)	Y (Northing)	Z	Coordinate System	Geoid	Position Established
P10	586209.208	4475746.371	3.115	NAD83	Geoid 09	11/08/2011
SH3	586276.445	4474762.613	3.986	NAD83	Geoid 09	11/25/2009

Creator: ______ Date: 03/25/2016

Figure S2.11. Example of a Field Reference Sheet for the Critical Zone site, Sandy Hook Unit of Gateway National Recreation Area.

2.9. Database Maintenance

The GIS database (with Benchmarks, QA/QC Transect, Survey Transect Lines, Survey Photo Locations, and Survey Transect Buffer Lines) and Field Reference Sheets will be stored and maintained by the GIS specialist of each Park and the NCBN data manager. Any alterations made to these items must be reported.

To access any of the Park's GIS Databases and Field Reference Sheets, contact the Data Manager at:

Northeast Coastal & Barrier Network
Data Manager
URI Dept. of Natural Resources Science
1 Greenhouse Rd.
Kingston, RI 02881

Standard Operating Procedure (SOP) # 3 – Survey Timing and Mission Planning

Version 1.0 (May 2018)

The following table lists all changes that have been made to this Standard Operating Procedure since the original publication date. Any recommended or required changes added to the log must be complete and concise and promptly brought to the attention of the Project Leader. The project leader will review and incorporate all changes, officially complete the revision history log, and change the date and version number on the title page. For complete instructions, please refer to SOP #9 – Revising the Protocol.

Revision History Log:

New Version #	Previous Version #	Revision Date	Author (full name, title, affiliation)	Location in Document and Description of Change	Reason for Change

This SOP is divided into the following sections:

3.1 Survey Frequency

3.2 Survey Window

3.3 Tide Conditions

3.4 Resource Related Issues

3.5 Tide Stage

3.6 Satellite Availably and Geometry

3.7 Storm Events

3.8 Continuously Operating Reference Systems (CORS)

The objective of this Standard Operating Procedure (SOP) is to detail the process for selecting the survey frequency and temporal windows for conducting the survey depending on the chosen frequency. It describes the procedure for the long-range identification of the spring tide conditions as well as space weather conditions, the satellite availability, and geometric configuration – measured as Position Dilution of Precision (PDOP). It establishes the basis for short-term evaluation of storm conditions that may affect coastal topography. It addresses the variety of local resource-related variables that may constrain conducting the survey, such as nesting seasons of endangered species.

Preparation for the field surveys will be done both in the beginning of the year, when the survey windows are identified, and shortly before each survey window (Table S3.1).

Table S3.1. Specific variables taken into consideration for selection of the survey days.

Beginning of the year:	Prior to the surveys:
Survey windows	Tide stage
Tide condition	Satellite availability
Resource related issues	Storm events

3.1 Survey Frequency

Four possible survey frequencies are suggested for the Coastal Landform Elevation Model collection: monthly, quarterly, semi-annually, or annually. Factors to be considered in determining the most appropriate frequency are the objectives of the study, the seasonal and event-driven variability of the site, and the duration of the monitoring program. Rates of change can be more accurately calculated with a greater number of measurements because the event and short-term process-driven change that may influence the beach profile collected during a particular survey is reduced in weight when comparing the totality of the measurements over the duration of the monitoring program. The frequency of the data collection will be determined by the park to fit the monitoring and research needs of the area.

3.2 Survey Windows

The frequency of the surveys will determine the appropriate survey windows. Observations of past summer and winter beaches at the Sandy Hook Unit of Gateway National Recreation Area demonstrate that beaches are typically at their narrowest by the middle of April (end of winter) and widest near the beginning of October (end of summer). These observations and coincident general trends on other beaches in the Northeast Coastal Barrier Network (NCBN) provide a basis for the collection of comparable data that represents the spectrum of seasonal and event driven forcing within these parks.

3.2.1 Annual Survey Window

Annual data collection should be conducted within a consistent portion of the calendar year to maximize comparability between datasets. Collection of data at this frequency will not capture seasonal variability in the beach profile, but will focus on changes in the net condition after the seasonal cycles. For annual data collection, a survey window within the late summer months is recommended, because this is typically a period of quiescence in oceanographic processes influencing the beach profile. The selection of a 5-week interval from late-July to late-August will reduce the influence of event-driven change on individual surveys, and ensure that the survey is conducted within the same seasonal regime each year. This option should be chosen for sites where general measures of geomorphological change are desired because this scale of change analysis is less robust than the monthly, quarterly, or semi-annual intervals.

3.2.3 Semi-Annual Survey Windows

Considering the intervals of maximum and minimum beach width at Sandy Hook and other NCBN beaches, it is important to conduct surveys within these periods (early Fall and early Spring) to properly represent the signal of seasonal variation within the record of collected data. Semi-annual surveys should be conducted within a consistent five-week window during the following periods:

Spring survey → mid-March to late April

Fall survey → mid-September to late October

3.2.2 Quarterly Survey Windows

In addition to the early Fall and early Spring surveys, the summer and winter months can be surveyed because they provide some additional context regarding the seasonal amplitude of event- driven forcing and recovery throughout the year. In addition to providing information regarding process driven geomorphological change, collecting four datasets per year provides more data for trend analyses. Quarterly surveys should be conducted within a consistent five-week window during the following periods:

Spring survey → mid-March to late April

Summer survey → mid-June to late July

Fall survey → mid-September to late October

Winter survey → mid-December to late January

3.2.4 Monthly Survey Windows

The collection of monthly surveys provides the opportunity to examine a range of temporal variations in the dimensions of geomorphological change. Monthly surveys can provide metrics on seasonal signals, storm/event impacts and responses, and alongshore migration of littoral cells. For the monthly surveys, it is suggested to choose a consistent temporal spacing of surveys throughout the year. This can be accomplished by planning surveys during the spring tide period that occurs 25-31 days following the previous spring tide that the preceding topographical survey was conducted around.

3.2.5 Pre- & Post-Storm Survey Windows

In the event that a notable storm or weather event will be occurring at the park, the field survey team and park resources managers should discuss the option of conducting a pre- and/or post-storm survey. The mission planning for a storm survey should consist of: 1) an evaluation of current data to determine if a pre-storm survey is required, and 2) a discussion of having access to the beach to conduct the post-storm survey at the earliest possible time. All of the survey standard operating procedures should be maintained.

3.3 Tide Condition

The NCBN parks have semi-diurnal tides. There are two uneven high tides and two uneven low tides each day. Each month there are two periods when the difference between high and low tide (the tidal range) is at a maximum - spring tides – and two periods when it is at a minimum – neap tides (Fig. S3.1).

Within the five-week survey seasons, monitoring periods are best selected to occur when the tidal range is maximized - spring tides. Field surveys will be conducted around the lowest of the low tide levels reached during the spring tides, to take advantage of the condition when the subaerial beach profile is at its maximum exposure. For example, in the five-week quarterly survey windows, there will be three instances of spring tide conditions – if the beginning of the survey window is set to coincide with the onset of spring tide.

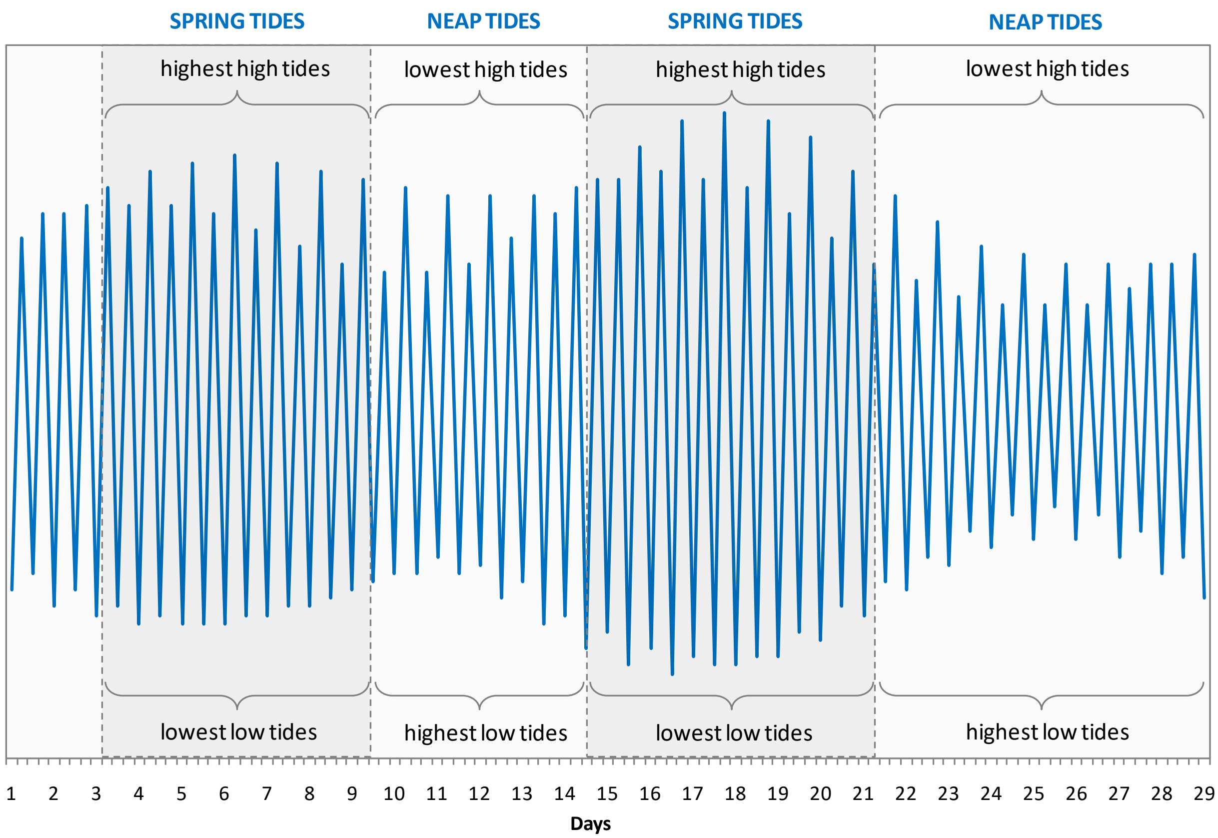


Figure S3.1. Tide predictions for Sandy Hook, NJ, depicting the periodic variations in semi-diurnal tidal ranges and the occurrence of spring tide ranges and neap tide ranges during the span of a month.

To select the best calculated for the tide gauge station closest to the Park:

1. Go to the predicted tide calculations available at the following NOAA website: http://tidesandcurrents.noaa.gov/

2. Select the "NOAA Tide Predictions" under the "Tides/Water Levels" tab for the tide gauge station closest to the Park:

• ASIS	MD	Outer Coast	Ocean City Inlet
• GATE	NJ	Sandy Hook Bay	Sandy Hook (Fort Hancock)
• FIIS	NJ	Sandy Hook Bay	Sandy Hook (Fort Hancock)
• CACO	MA	Cape Cod Bay	Provincetown

The predictions are displayed in annual tables that include the following information on the two highest and two lowest daily water levels at the tide gauge station:

- Date Month, day and year (mm/dd/yyyy)
- Day Day of the week
- Time Predicted time of occurrence (hh:mm)
  Time refers to Local Standard Time (LST) or, Local Daylight Time (LDT)
- Height Predicted elevation of the water level
  Height refers to the High tide (H) or Low tide (L) levels

The height information in the table retrieved from the NOAA website is recorded in feet and centimeters referenced to the Mean Lower Low Water (MLLW) tidal datum for that tide gauge station.

Within each of the five-week survey windows designated for the annual, semi-annual, and quarterly surveys, there will be many available survey days around the dates of spring tide water levels. The surveyor should plan to conduct the surveys on the days with the lowest low-tide levels that occur during the daytime, and as early as possible within the survey window to allow for rescheduling if necessary. For the monthly frequency, the surveyor should initially schedule the surveys, considering water levels and daylight, at the earliest opportunity within the designated spring tide window each month to reduce the probability of weather-related delays resulting in a missed opportunity to survey during that spring tide period.

The following is an example of the spring 2016 survey planning for GATE, based on the tide prediction tables for the Sandy Hook Tide Gauge (Figure S3.2). A span of five and a half weeks within the mid-March to late April period includes three episodes of spring tides - the ideal time for conducting the coastal topography surveys because the relatively low water levels surrounding the spring tide low-tide condition provide an opportunity to collect data at the lower elevations of the beach profile.

StationId:8531680
Source:NOAA/NOS/CO-OPS
Station Type:Harmonic
Time Zone:LST/LDT
Datum:mean lower low water (MLLW) which is the chart datum of soundings

NOAA Tide Predictions

SANDY HOOK (Fort Hancock),New Jersey,2016

Times and Heights of High and Low Waters

March

	Time (h m)	Height (ft)	Height (cm)		Time (h m)	Height (ft)	Height (cm)
1 Tu ◑	12:31 AM	4.3	131	16 W	02:36 AM	5.0	152
	06:52 AM	0.9	27		09:25 AM	0.3	9
	12:51 PM	3.7	113		03:13 PM	4.4	134
	06:51 PM	0.9	27		09:34 PM	0.4	12
2 W	01:19 AM	4.3	131	17 Th	03:38 AM	4.8	146
	08:03 AM	0.9	27		10:29 AM	0.3	9
	01:44 PM	3.7	113		04:15 PM	4.3	131
	08:08 PM	0.9	27		10:37 PM	0.4	12
3 Th	02:14 AM	4.3	131	18 F	04:40 AM	4.7	143
	09:08 AM	0.8	24		11:24 AM	0.2	6
	02:45 PM	3.8	116		05:17 PM	4.4	134
	09:17 PM	0.7	21		11:33 PM	0.3	9
4 F	03:16 AM	4.5	137	19 Sa	05:40 AM	4.8	146
	10:05 AM	0.5	15		12:14 PM	0.1	3
	03:49 PM	4.0	122		06:13 PM	4.6	140
	10:15 PM	0.4	12				
5 Sa	04:18 AM	4.8	146	20 Su	12:23 AM	0.2	6
	10:57 AM	0.1	3		06:33 AM	4.9	149
	04:50 PM	4.3	131		12:59 PM	0.0	0
	11:10 PM	0.1	3		07:02 PM	4.9	149
6 Su	05:16 AM	5.1	155	21 M	01:10 AM	0.0	0
	11:47 AM	-0.3	-9		07:18 AM	5.0	152
	05:44 PM	4.8	146		01:41 PM	-0.1	-3
					07:45 PM	5.1	155
7 M	12:02 AM	-0.3	-9	22 Tu	01:54 AM	-0.1	-3
	06:08 AM	5.5	168		07:59 AM	5.1	155
	12:36 PM	-0.6	-18		02:20 PM	-0.2	-6
	06:33 PM	5.2	158		08:24 PM	5.2	158
8 Tu	12:54 AM	-0.6	-18	23 W ○	02:36 AM	-0.1	-3
	06:56 AM	5.8	177		08:38 AM	5.0	152
	01:23 PM	-0.9	-27		02:58 PM	-0.1	-3
	07:20 PM	5.5	168		09:01 PM	5.2	158
9 W ●	01:45 AM	-0.9	-27	24 Th	03:16 AM	-0.1	-3
	07:44 AM	5.9	180		09:15 AM	4.9	149
	02:10 PM	-1.1	-34		03:33 PM	-0.1	-3
	08:07 PM	5.8	177		09:37 PM	5.1	155
10 Th	02:35 AM	-1.0	-30	25 F	03:54 AM	-0.1	-3
	08:32 AM	5.9	180		09:51 AM	4.8	146
	02:56 PM	-1.1	-34		04:07 PM	0.1	3
	08:56 PM	5.9	180		10:13 PM	5.0	152
11 F	03:25 AM	-1.0	-30	26 Sa	04:31 AM	0.0	0
	09:23 AM	5.7	174		10:28 AM	4.6	140
	03:42 PM	-1.0	-30		04:38 PM	0.3	9
	09:48 PM	5.8	177		10:47 PM	4.9	149
12 Sa	04:15 AM	-0.8	-24	27 Su	05:06 AM	0.2	6
	10:18 AM	5.4	165		11:05 AM	4.3	131
	04:29 PM	-0.8	-24		05:08 PM	0.5	15
	10:43 PM	5.7	174		11:23 PM	4.7	143
13 Su	06:09 AM	-0.5	-15	28 M	05:42 AM	0.4	12
	12:15 PM	5.1	155		11:45 AM	4.1	125
	06:19 PM	-0.4	-12		05:39 PM	0.7	21
14 M	12:40 AM	5.4	165	29 Tu	12:01 AM	4.6	140
	07:08 AM	-0.1	-3		06:21 AM	0.6	18
	01:13 PM	4.8	146		12:29 PM	4.0	122
	07:17 PM	0.0	0		06:13 PM	0.9	27
15 Tu ◐	01:38 AM	5.2	158	30 W	12:45 AM	4.5	137
	08:15 AM	0.2	6		07:10 AM	0.8	24
	02:12 PM	4.5	137		01:18 PM	3.9	119
	08:24 PM	0.3	9		07:02 PM	1.0	30
				31 Th ◑	01:36 AM	4.5	137
					08:17 AM	0.9	27
					02:12 PM	3.9	119
					08:22 PM	1.1	34

April

	Time (h m)	Height (ft)	Height (cm)		Time (h m)	Height (ft)	Height (cm)
1 F	02:33 AM	4.6	140	16 Sa	04:10 AM	4.6	140
	09:28 AM	0.8	24		10:55 AM	0.4	12
	03:11 PM	4.1	125		04:51 PM	4.6	140
	09:43 PM	0.9	27		11:09 PM	0.6	18
2 Sa	03:36 AM	4.7	143	17 Su	05:08 AM	4.6	140
	10:30 AM	0.5	15		11:42 AM	0.3	9
	04:15 PM	4.3	131		05:45 PM	4.8	146
	10:48 PM	0.6	18		11:59 PM	0.5	15
3 Su	04:42 AM	4.9	149	18 M	06:02 AM	4.7	143
	11:24 AM	0.2	6		12:25 PM	0.2	6
	05:18 PM	4.7	143		06:33 PM	5.0	152
	11:46 PM	0.2	6				
4 M	05:44 AM	5.2	158	19 Tu	12:44 AM	0.3	9
	12:15 PM	-0.2	-6		06:49 AM	4.8	146
	06:16 PM	5.2	158		01:06 PM	0.2	6
					07:16 PM	5.2	158
5 Tu	12:40 AM	-0.3	-9	20 W	01:28 AM	0.2	6
	06:41 AM	5.5	168		07:31 AM	4.8	146
	01:05 PM	-0.6	-18		01:45 PM	0.1	3
	07:08 PM	5.7	174		07:55 PM	5.3	162
6 W	01:34 AM	-0.6	-18	21 Th	02:10 AM	0.1	3
	07:33 AM	5.8	177		08:10 AM	4.9	149
	01:55 PM	-0.8	-24		02:23 PM	0.1	3
	07:57 PM	6.0	183		08:31 PM	5.4	165
7 Th ●	02:27 AM	-0.9	-27	22 F ○	02:51 AM	0.0	0
	08:23 AM	5.9	180		08:48 AM	4.8	146
	02:44 PM	-1.0	-30		03:00 PM	0.2	6
	08:46 PM	6.3	192		09:06 PM	5.4	165
8 F	03:19 AM	-1.0	-30	23 Sa	03:31 AM	0.0	0
	09:13 AM	5.9	180		09:24 AM	4.7	143
	03:32 PM	-1.0	-30		03:36 PM	0.3	9
	09:35 PM	6.3	192		09:40 PM	5.3	162
9 Sa	04:10 AM	-1.0	-30	24 Su	04:08 AM	0.1	3
	10:06 AM	5.7	174		10:01 AM	4.5	137
	04:20 PM	-0.8	-24		04:09 PM	0.4	12
	10:27 PM	6.2	189		10:13 PM	5.2	158
10 Su	05:01 AM	-0.8	-24	25 M	04:45 AM	0.2	6
	11:01 AM	5.4	165		10:38 AM	4.4	134
	05:08 PM	-0.5	-15		04:42 PM	0.6	18
	11:22 PM	5.9	180		10:47 PM	5.0	152
11 M	05:53 AM	-0.5	-15	26 Tu	05:21 AM	0.3	9
	11:59 AM	5.1	155		11:19 AM	4.2	128
	05:59 PM	-0.2	-6		05:14 PM	0.8	24
					11:26 PM	4.9	149
12 Tu	12:19 AM	5.6	171	27 W	06:00 AM	0.5	15
	06:49 AM	-0.1	-3		12:04 PM	4.1	125
	12:58 PM	4.9	149		05:51 PM	0.9	27
	06:56 PM	0.3	9				
13 W	01:16 AM	5.3	162	28 Th	12:13 AM	4.8	146
	07:52 AM	0.2	6		06:45 AM	0.6	18
	01:56 PM	4.7	143		12:55 PM	4.1	125
	08:01 PM	0.6	18		06:39 PM	1.0	30
14 Th ◐	02:14 AM	5.0	152	29 F	01:07 AM	4.8	146
	08:59 AM	0.4	12		07:43 AM	0.7	21
	02:54 PM	4.6	140		01:49 PM	4.2	128
	09:10 PM	0.8	24		07:51 PM	1.1	34
15 F	03:11 AM	4.8	146	30 Sa ◑	02:04 AM	4.8	146
	10:01 AM	0.4	12		08:51 AM	0.6	18
	03:52 PM	4.5	137		02:46 PM	4.4	134
	10:14 PM	0.8	24		09:14 PM	1.0	30

May

	Time (h m)	Height (ft)	Height (cm)		Time (h m)	Height (ft)	Height (cm)
1 Su	03:05 AM	4.9	149	16 M	04:29 AM	4.4	134
	09:55 AM	0.4	12		11:04 AM	0.5	15
	03:46 PM	4.7	143		05:09 PM	4.8	146
	10:23 PM	0.6	18		11:29 PM	0.7	21
2 M	04:10 AM	5.0	152	17 Tu	05:23 AM	4.4	134
	10:51 AM	0.1	3		11:47 AM	0.4	12
	04:49 PM	5.1	155		05:58 PM	5.0	152
	11:23 PM	0.2	6				
3 Tu	05:14 AM	5.2	158	18 W	12:15 AM	0.6	18
	11:44 AM	-0.2	-6		06:13 AM	4.5	137
	05:48 PM	5.5	168		12:27 PM	0.4	12
					06:43 PM	5.2	158
4 W	12:20 AM	-0.2	-6	19 Th	12:59 AM	0.4	12
	06:15 AM	5.4	165		06:59 AM	4.6	140
	12:36 PM	-0.5	-15		01:08 PM	0.3	9
	06:44 PM	6.0	183		07:23 PM	5.4	165
5 Th	01:15 AM	-0.5	-15	20 F	01:43 AM	0.2	6
	07:10 AM	5.6	171		07:41 AM	4.6	140
	01:27 PM	-0.7	-21		01:48 PM	0.3	9
	07:35 PM	6.3	192		08:01 PM	5.5	168
6 F ●	02:10 AM	-0.8	-24	21 Sa ○	02:26 AM	0.1	3
	08:03 AM	5.7	174		08:21 AM	4.6	140
	02:18 PM	-0.8	-24		02:28 PM	0.4	12
	08:25 PM	6.5	198		08:37 PM	5.5	168
7 Sa	03:03 AM	-0.9	-27	22 Su	03:07 AM	0.1	3
	08:55 AM	5.7	174		08:59 AM	4.6	140
	03:09 PM	-0.8	-24		03:07 PM	0.4	12
	09:15 PM	6.5	198		09:11 PM	5.4	165
8 Su	03:54 AM	-0.9	-27	23 M	03:47 AM	0.1	3
	09:48 AM	5.5	168		09:37 AM	4.5	137
	03:59 PM	-0.6	-18		03:45 PM	0.5	15
	10:07 PM	6.3	192		09:45 PM	5.4	165
9 M	04:45 AM	-0.8	-24	24 Tu	04:26 AM	0.1	3
	10:44 AM	5.3	162		10:15 AM	4.4	134
	04:49 PM	-0.3	-9		04:22 PM	0.6	18
	11:01 PM	6.0	183		10:22 PM	5.3	162
10 Tu	05:36 AM	-0.5	-15	25 W	05:03 AM	0.2	6
	11:41 AM	5.1	155		10:58 AM	4.3	131
	05:39 PM	0.0	0		04:59 PM	0.7	21
	11:57 PM	5.7	174		11:04 PM	5.2	158
11 W	06:28 AM	-0.1	-3	26 Th	05:43 AM	0.3	9
	12:39 PM	4.9	149		11:45 AM	4.3	131
	06:33 PM	0.4	12		05:39 PM	0.8	24
					11:53 PM	5.1	155
12 Th	12:53 AM	5.3	162	27 F	06:26 AM	0.4	12
	07:25 AM	0.2	6		12:36 PM	4.4	134
	01:35 PM	4.8	146		06:28 PM	0.9	27
	07:34 PM	0.8	24				
13 F ◐	01:47 AM	5.0	152	28 Sa	12:47 AM	5.0	152
	08:26 AM	0.4	12		07:18 AM	0.4	12
	02:29 PM	4.7	143		01:30 PM	4.5	137
	08:40 PM	1.0	30		07:34 PM	1.0	30
14 Sa	02:41 AM	4.7	143	29 Su ◑	01:43 AM	5.0	152
	09:25 AM	0.5	15		08:19 AM	0.4	12
	03:23 PM	4.7	143		02:25 PM	4.8	146
	09:43 PM	1.0	30		08:51 PM	0.9	27
15 Su	03:34 AM	4.5	137	30 M	02:42 AM	5.0	152
	10:18 AM	0.5	15		09:22 AM	0.2	6
	04:17 PM	4.7	143		03:22 PM	5.0	152
	10:39 PM	0.9	27		10:02 PM	0.6	18
				31 Tu	03:43 AM	5.0	152
					10:21 AM	0.0	0
					04:23 PM	5.4	165
					11:04 PM	0.3	9

Figure S3.2. NOAA tide predictions for the period of March through May, 2016 for Sandy Hook, NJ. A five week survey window from mid-March to late-April contains three spring tide periods, they are highlighted with blue dashed boxes.

3.4 Resource Related Issues

The Park resource managers must be contacted, once the survey windows have been determined, to identify the constraints that may exist due to park specific issues. The nesting seasons of endangered and protected species, or the occurrence of public activities may confine the survey window by restricting the access to locations within Areas of Special Interest.

The NCBN’s geodetic GPS units are available for all researchers to use and share, and are intended to be used in the myriad of field surveys that are undertaken in the NCBN’s parks. Therefore, the units should be reserved in advance, by contacting the park GIS Coordinator.

Additionally, contact should be made with any cooperating or neighboring agency, including management at State Parks, County Parks, other Federal Agencies, or other jurisdictional partners to alert them to the planned survey activity.

3.5 Tide Stage

A couple of weeks prior to the established survey window, the surveyor must consult the tide prediction tables and select the days that allow for surveying during very low tides and during daylight. To maximize the surveying effort, the survey should be accomplished during the 6 hours around low tide, 3 hours before and 3 hours after the predicted time of low tide. This time period provides the opportunity to collect more profile data during the span of time that the beach face is exposed.

3.6 Satellite Availability and Geometry and Space Weather Conditions

The positional data recorded by the geodetic GPS unit are derived from the time signals sent from the constellation of satellites. For a RTK solution, influences on the accuracy of a derived 3-dimensional position include the atmospheric delays to transferring the satellite signal, multi-path, and receiver associated errors, as well as the number of satellites in the sky and the satellite geometry (the locations of the satellites in view relative to each other and to the receiver). The effect of the satellite geometry can be quantified through a metric called Position Dilution of Precision (PDOP). The PDOP value can be calculated prior to the survey, and is an important planning consideration for surveys to be undertaken utilizing GPS receivers that are not capable of processing data from the entirety of available GNSS constellations. For GNSS capable receivers, this planning step is not necessary, but horizontal and vertical precision thresholds should be set within the survey controller to prevent the collection of inaccurate and/or imprecise data.

3.6.1 PDOP and Mission Planning

PDOP is a unit-less value that describes the geometrical spatial distribution of the broadcasting satellites and it changes continuously as the satellites move across the sky. A PDOP below six is necessary to collect accurate and precise positions (Trimble, 2007) and therefore needs to be considered in the date and time selection of the survey.

PDOP is a predictable value and, therefore, the best data collection time can be selected based on reports and graphs showing expected PDOP values. Values range from 1 to infinity, and a low PDOP indicates a higher probability of accuracy, whereas a high PDOP indicates a lower probability of accuracy.

A couple of weeks prior to the survey window, the surveyor must consult the predicted PDOP values for the planned survey days:

1. Download the latest GPS Almanac files with the information about the entire GPS satellite constellation and data on every satellite's orbit from the Trimble website at: http://www.trimble.com/gpsdataresources.shtml
2. ***Note:** Predictions of PDOP value are valid for a maximum of thirty days in advance.*
3. Use the Trimble Business Center "Planning Utility" Tool (for example) to examine the DOP Position Plot (Fig. S3.3)
4. Schedule the survey days based on the satellite coverage information and considering that a PDOP below 6 is necessary to collect accurate and precise positions

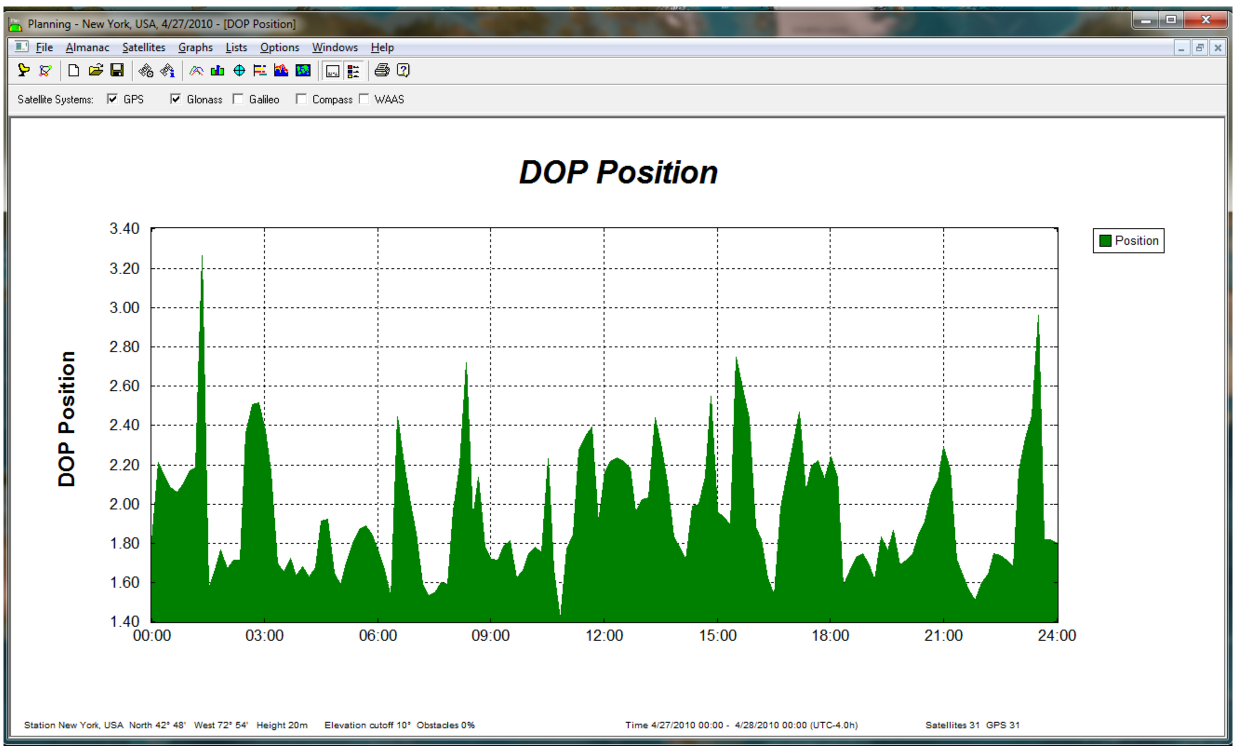


Figure S3.3. An example of the distribution of "DOP Position" (PDOP) values using the Trimble Planning Utility software. PDOP values between 0 and 6 are needed to collect accurate and precise positions.

3.6.2 Space Weather Conditions

Space weather events can have impact on GPS functions; for example, signal variations may occur during geomagnetic storms or other disturbances to the ionosphere. Space weather conditions should be checked online 24 hours before a planned surveys and on the day of the survey.

To check space weather conditions:

1. Go to https://www.swpc.noaa.gov/
2. Browse to Global Positioning System (GPS) tab.
3. Observe the 24-Hour, Latest, and Predicated Conditions on the top of the page (Figure S3.4). Ensure that there are no predicated events and that current conditions are green or "none".

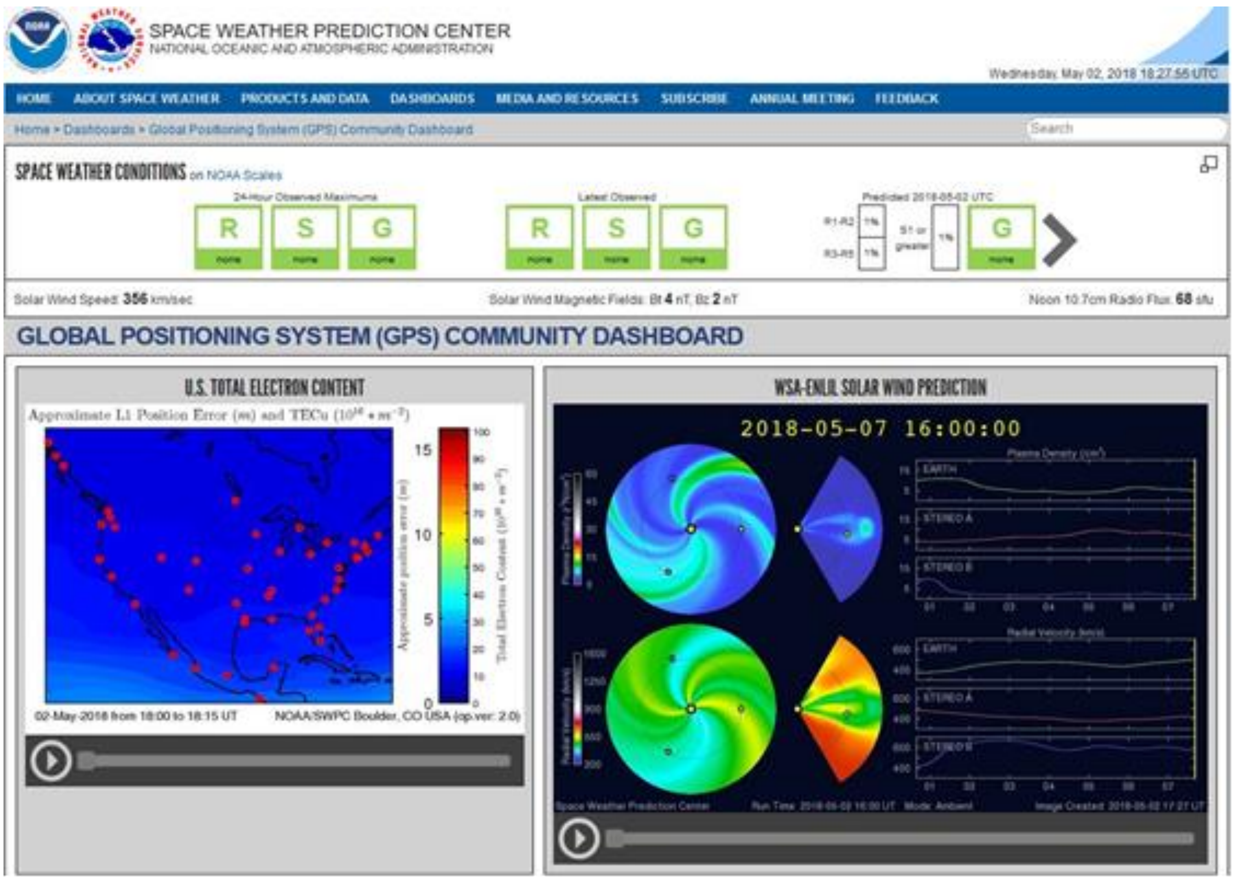


Figure S3.4. An example of space weather conditions for a given day. Note that all observations are in green and there are no impacts expected.

3.7 Impacts of Storm Events on Seasonal Schedule

Storm events should not unduly delay the seasonal collection of the topographical data. Some consideration should be given towards delaying surveys for a period of one week following storm events, defined by a water level that facilitates the influence of waves on the upper beach and dunes. For example, waves during a water level above 2 m relative to MLLW at the Sandy Hook tide gauge station have been observed to influence the topography of the upper beach and dunes at that site. Conduct the survey once the storm surge has receded and an initial recovery of the beach profile has been achieved. The rescheduled survey should be conducted within the survey window. Thus, the occurrence of storm events should not disrupt the pre-determined temporal windows of collection, because maintaining the regular intervals will allow for the collection of comparable data across Parks.

A particular consideration for the quarterly and semi-annual survey frequencies is that the occurrence of a storm that delays the spring survey will not bias the end of the winter season beach condition. However, this is not true for the fall survey and the summer beach condition. Because the occurrence of storms will only increase by the end of the year, the fall surveys should be conducted as early as possible in the fall period.

3.8 Continuously Operating Reference Stations (CORS)

The operational status of individual CORS is an important planning consideration if the CORS network is the source of RTK correction (see SOP #5). This can be verified utilizing the NGS CORS map following these steps:

1. Go to this link: http://www.ngs.noaa.gov/CORS_Map/
2. Zoom to the stations closest to the survey areas
3. Click on the icon for the needed stations and check the Status.

This step can also be done on the website of the operator of the CORS (such as Leica SmartNet North America or Trimble KeyNetGPS).

Standard Operating Procedure (SOP) # 4 - Settings for Collection of Topography

Version 1.0 (May 2018)

The following table lists all changes that have been made to this Standard Operating Procedure since the original publication date. Any recommended or required changes added to the log must be complete and concise and promptly brought to the attention of the Project Leader. The project leader will review and incorporate all changes, officially complete the revision history log, and change the date and version number on the title page. For complete instructions, please refer to SOP #9 – Revising the Protocol.

Revision History Log:

New Version #	Previous Version #	Revision Date	Author (full name, title, affiliation)	Location in Document and Description of Change	Reason for Change

This SOP is divided into the following sections:

4.1 Survey Style Properties

4.2 Job Properties

This SOP details the settings to configure a topographical survey conducted using geodetic GPS survey equipment with Real Time Kinematic differential correction (GPS-RTK). There are a number of parameters that need to be preconfigured within the Survey Style options as well as in the Job properties, so that data collection is within the centimeter-accuracy specification. The standardization of the criteria for collecting topographical data ensures that the survey is replicable and comparable.

4.1 Survey Style Properties

Survey Styles define the parameters for configuring and communicating with the GPS units (base and rover receivers) and for measuring and storing points. The Coastal Landform Elevation Model Protocol uses Real-Time Kinematic differential correction, a survey style that corrects for the difference between triangulated positions from the satellite constellation and a known position, then broadcasts that correction to receivers in the field through the internet or radio to provide the basis for highly accurate measurements in real time. The correction is calculated from a network of Continually Operating Reference Stations (CORS) or a base-station receiver that is set up over a known position at the survey site. As an example, when using the Trimble R10, configure the survey style properties using the following settings:

- Elevation mask — Minimum 10º (angle below which satellites are not considered)
- PDOP mask — 6.0 (highest PDOP value used by the receiver to compute positions)
- Roving precision — Horizontal and Vertical tolerance of 0.05 m
- Antenna settings — Set to suit your equipment

Note: *The survey style configurations can be stored as a template within the field survey controller and re-used in each of the coastal topography seasonal surveys.*

4.2 Job Properties

The following are the necessary inputs in the properties of the Job that are created for running the survey and storing the points. The Job, as an example, can either be created in the office using Trimble Business Center and then transferred to the field survey controller, or directly on the field survey controller.

- Name of the Job: CZo_3D_20160325
Area of Special Interest_"3D"_date (yyyymmdd)
- Grid Coordinate System: Universal Transverse Mercator (UTM)
- UTM Zone Number: 18N (GATE, ASIS and FIIS)
19N (CACO)
- Horizontal Datum: North American Datum of 1983 (NAD83) [1, 2]
- Vertical Datum: North American Vertical Datum of 1988
- Geoid Model: GEOID12B [1, 3]
- Units: Meters
- Active Map: The 5 shapefiles from the Area of Special Interest's GIS database (created according to SOP #2) [4]

[1]*The National Spatial Reference System (NSRS) is the spatial standard used to locate the coastal topography in this protocol. As technology progresses, the spatial reference system undergoes periodic updates related to datum realizations, thereby causing adjustments in the coordinates of the surveyed points. The NOAA National Geodetic Survey (NGS) releases these updates for the USA. As the NSRS is updated, shifts in position will occur depending on location and will produce offsets in horizontal and vertical coordinates. The current horizontal datum used for this protocol is NAD83 (2011) (2010.0). The contemporary geoid model is GEOID12B. The horizontal datum and geoid model is subject to future change and specific attention needs to be paid to the datums that collected survey data are referencing so that comparisons of surveyed topography can be confidently undertaken. The current geodetic datums can be confirmed through the National Geodetic Survey website at: http://www.ngs.noaa.gov/.*

[2]*Check with equipment manufacturer to confirm the horizontal datum file that is to be used by their survey equipment relative to the datum at your base-station or the CORS reference.*

[3]*Download the Geoid file from the Trimble website and upload it to Trimble Business Center and to the field survey controller. Download the Geoid file at:*
http://www.trimble.com/geomaticsoffice_ts.asp?Nav=Collection-71

[4]*Upload the shapefiles from the Area of Special Interest's GIS database (the Benchmarks, QA/QC Transect, Survey Transect Lines, Survey Photo Locations, and Survey Transect Buffer Lines created according to SOP #2) onto the field survey controller, using the Trimble Data Transfer Utility*

Standard Operating Procedure (SOP) # 5 - Conducting the Survey

Version 1.0 (May 2018)

The following table lists all changes that have been made to this Standard Operating Procedure since the original publication date. Any recommended or required changes added to the log must be complete and concise and promptly brought to the attention of the Project Leader. The project leader will review and incorporate all changes, officially complete the revision history log, and change the date and version number on the title page. For complete instructions, please refer to SOP #9 – Revising the Protocol.

Revision History Log:

New Version #	Previous Version #	Revision Date	Author (full name, title, affiliation)	Location in Document and Description of Change	Reason for Change

The objective of this SOP is to describe the methods of data collection for tracking volumetric changes in coastal topography within Areas of Special Interest. A preliminary part of the monitoring program is the selection of the survey window using the procedure in SOP #3.

This SOP consists of four sections:

5.1 Pre-Survey Procedures

5.2 Conducting the Survey

5.3 Interruptions to the Survey

5.4 Ending the Survey

The Field Data Form, Form SOP #5-1, is provided at the end of this SOP.

5.1 Pre-Survey Procedures

5.1.1 GPS-RTK Set-up

Prior to the beginning of the survey, the GPS-RTK unit must be properly configured. Depending on the equipment and personnel available, and the area to be covered, the surveyor can set up the instrument in one of two ways:

1. **Base-station and Rover(s)**: This procedure uses one GPS receiver that is temporarily set up over a known location (control benchmark) to send differential corrections through a broadcast radio signal to a second or multiple additional GPS receivers collecting data in the field. From the perspective of accuracy, this configuration facilitates the collection of

topographical data within a 20 km distance radius from the base station. However, the broadcast range of a standard GPS receiver is only two kilometers, at most. This range can be increased using radio signal amplifiers and repeaters (see below). However, as the distance between the base station and rover receiver increases, the atmospheric influence on the incoming satellite signals received at the rover and base station will become increasingly different. This results in a decrease in the accuracy of corrected positions. The base receiver must be set up over a base-station benchmark (as described in SOP #2) and located as close as possible to the planned survey area.

2. **RTN and Rover(s):** With an internet connection to the survey equipment, the surveyor can access an external network of reference stations provided by the National Geodetic Survey (NGS), known as CORS (see SOP #3.8 for information on reference station locations). Reference stations should be less than 50 km from the rover to maintain desired accuracies. The RTK differential correction is provided through the internet and accessed by the GPS receiver in the field via a sim card and an internal modem or a Wi-Fi device. This option has costs associated with mobile data connections and subscriptions to RTK differential correction services (such as SmartNet North America or KeyNetGPS).

Additionally, a radio repeater (e.g., TRIMMARK from Trimble) may be used to increase the broadcast range of a base radio by receiving the base transmission and then rebroadcasting it on the same frequency. The radio repeater should be set up at a high location and within the range of the broadcasting capability of the base station.

For further details on how to set up the GPS-RTK for topographical surveying, refer to the equipment's user manual, or contact the supplier.

Whichever configuration is used, the setup of the survey job must follow the guidelines in SOP #4. The surveyor must ascertain that once the rover unit is started, the Survey Controller demonstrates that (Fig. S5.1):

- RTK initialization has been achieved
- Radio link to a base station or connection to a network providing CORS-based differential correction is active
- At least 5 satellites are available
- Antenna height is correctly assigned
- Battery is full

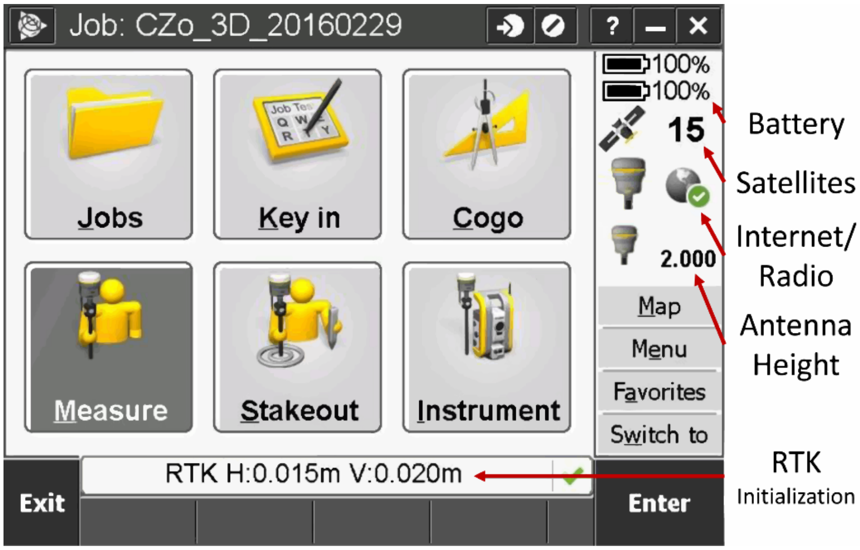


Figure S5.1. Example of a Trimble R10 Survey Controller screen showing information about the rover unit status.

5.1.2 Display Survey Shapefiles on the Survey Controller

Once the rover is working, the surveyor must determine that the background files with the Area of Special Interest's Benchmarks, QA/QC Transect, Survey Transect Lines, Survey Photo Locations, and Survey Transect Buffer Lines (created according to SOP #2 and uploaded according to SOP #4) are activated in the Map feature of the Survey Controller (Fig. S5.2).

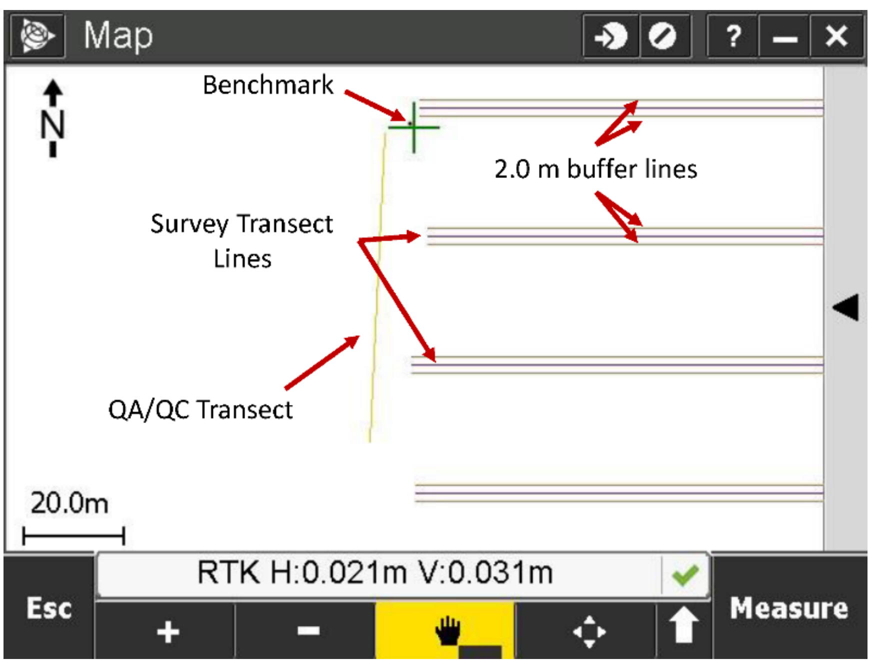


Figure S5.2. Survey Controller Map feature screen showing the Benchmark, QA/QC Transect, Survey Transect Lines, and the Survey Transect Buffer Lines for the Critical Zone site within an Area of Special Interest in the Sandy Hook Unit, Gateway National Recreation Area. (The current position of the GPS unit – green cross - is on top of the Benchmark.)

5.1.3 Initial Pre-Survey Completion of the Field Data Form

The Field Data Form (FDF) is used for all field notations (Figure S5.3 and Form SOP #5-1). There should be one FDF completed for each Job created for a given survey, even if multiple receivers are used in the collection of data. This information is necessary for post-processing of the data and facilitates the generation of accurate metadata. At the beginning of the survey, complete the following fields – the rest will be completed during or following the survey - of the FDF using the following formats:

1. Event Information
   a. Survey Date (mm/dd/yyyy) - enter the date in the format shown.
   b. Job Name – Name of the survey file created according to the guidelines in SOP #4.
   c. Park – The 4-character park identifier, CACO, ASIS, GATE, FIIS
   d. Park Unit – The unit within the park, if applicable.
   e. Area of Special Interest – Survey location within the park and unit, if applicable.
   f. Surveyor's Name (First Last) – Write the surveyor's first and last name.
   g. Protocol/SOP Version (GMP version #/SOP version #) – Version of the protocol used to guide field data collection.
   h. Date of last storm event – This information should have been gathered during mission planning (see SOP #3).
2. GPS-RTK Device
   a. Make and Model
   b. Setup – indicate whether a base station or CORS network was used for RTK correction
   c. Base Station Benchmark / CORS used (If multiple benchmarks or CORS are used, update this field accordingly after the survey

Whereas many of the inputs to the FDF may be entered prior to going into the field, the following should be filled in as the surveyor conducts the survey and collects the topographical data along the Survey Transect Lines or after the survey is completed:

1. Event Information
   a. Start Time – Time of first data point collected within the survey
   b. End Time – Time of final data point collected within the survey
   c. Equipment used– enter information regarding the apparatus that the GPS receivers were mounted on to conduct the survey. This will likely be a rover pole, survey wheel, or other accessory, or a combination of the two. If multiple pieces of equipment are used, document the range of point ID numbers each was used for.
   d. Antenna Height(s) – The antenna height associated with each piece of equipment that the GPS receiver is mounted on needs to be documented. If multiple pieces of equipment are used, enter each piece of equipment and the appropriate associated antenna heights.

e. QA/QC Benchmark – Identify the Benchmark collected for QA/QC purposes within the survey

f. QA/QC Transect – Identify the QA/QC Transect collected within the survey if an accessory such as a survey wheel is utilized for topographical data collection

2. Survey Photos

a. Photos [Y/N] - If photos were taken at the site.

b. Number – Number of photos taken at the site.

c. Photo Transects – the Survey Photo Transects where the photos were taken.

3. Survey Notes

a. Notes - Enter information specific to the topographical survey, such as obstructions, equipment issues, presence of scarps or bars, as well as the condition of the benchmarks. Note the location of the issue if applicable.

b. Time of Incident – Indicate the time of the issue and its relationship to any part of the survey.

c. Record intended elevation threshold.

Field Data Form - Landorm Elevation Model Survey

Event Information

Survey Date:	3/26/2016	Park:	Gateway National Recreation Area
Unit or Subarea:	Sandy Hook Unit	Area of Special Interest:	Critical Zone
Surveyor's name:	Joe Smith	Job Name:	CZo_3D_20160229A
Start Time:	10:48	End Time	14:21
Equipment Used:	Wheel (10000-15421) / Rover Pole (P10, 20000-20074)	Antenna Height(s):	Wheel: 1.265 m / Rover Pole: 2.00 m
Protocol/SOP version:	GMP v 1.0 / SOP# 5 v 1.0	QA/QC Benchmark:	P10
Date of last storm event:	02/01/2016	QA/QC Transect:	CZo_QAQCTransect_20160325

GPS-RTK Device		**Survey Photos**	
Make and Model:	Trimble TSC3 controller and R10 receiver	Photos [Y/N]:	Y
Set-up:	CORS and Rover	Number:	4
Base-Station Benchmark / CORS ref. station(s) used:	NYJB, NYQN, NYOB	Photo Transects:	1 and 2

Survey Notes (List any equipment problems, radio signal issues or obstacles encountered, etc.)

Time of incident (from GPS-RTK unit)	Notes:
11:35 to 11:41	No RTK correction from CORS network
14:03	Construction obstructed the collection of two survey lines at the southern margin of the site

For extra survey notes, use additional blank page and attach to this form

Figure S5.3. Example of entries on the Field Data Form (Form SOP #5-1).

5.2. Conducting the Survey

The survey is the collection of the topographical data used to generate the landform elevation models as well as data that will serve as an internal check of accuracy. This involves four main components: 1) the collection of a GPS point over a benchmark to be compared to a pre-established position for that benchmark (established in SOP #2); 2) collection of topographical data over a QA/QC transect to confirm the proper configuration of survey accessories utilized to facilitate the collection of topographic data, such as a survey wheel (Fig. S5.4); 3) the collection of the topographical data in the Area of Special Interest along predefined Survey Transect Lines; and 4) the acquisition of photos of the survey area within the Survey Photo Locations (established in SOP #2).

The topographical survey is collected with either the GPS rover receiver mounted onto a standard survey rover pole with a wide base topo shoe and a typical height of 2 m or an apparatus such as a survey wheel that has a receiver mount elevation that may vary slightly from survey to survey. If an apparatus such as a survey wheel is used to facilitate efficient data collection, the height of the GPS antenna, from the ground to the base of the quick release mount for Trimble equipment (Fig. S5.4), must be measured carefully prior to each survey (Figure S5.5). This value should be entered into the Field Data Form immediately after it is measured, in the Antenna Height field.

Figure S5.4. Survey wheel constructed to facilitate the collection of topographical data.

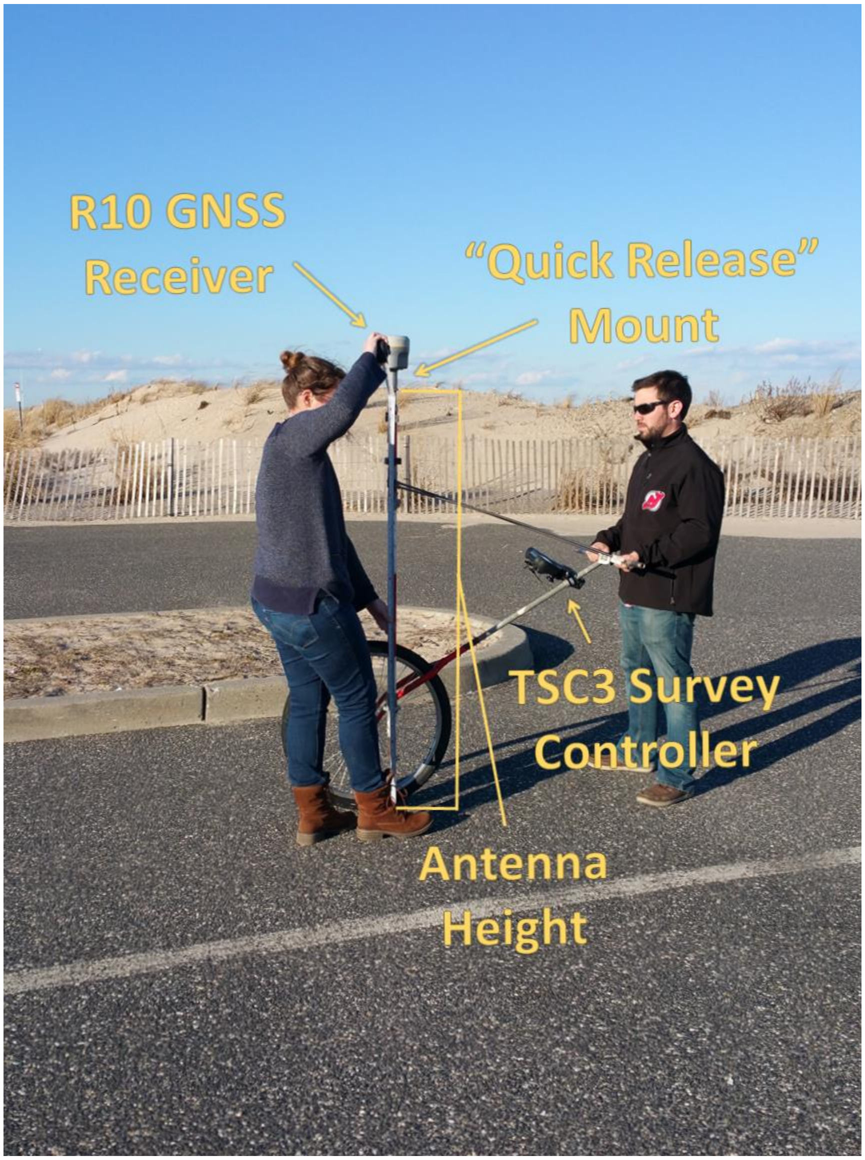


Figure S5.5. Measurement of the antenna height of a R10 GNSS Receiver mounted on a survey wheel constructed to facilitate the collection of topographical data along transects.

5.2.1 Identification and Collection of a Survey Control Benchmark

The surveyor should use the Survey Controller Map feature **(**with the background files added to the screen) and the indications on the Field Reference Sheet (map, photos, and description) to locate the benchmark that was established for QA/QC purposes according to SOP #2. For quality-control purposes, the first measurement taken during a survey is this Benchmark location. A 30 second measurement will be taken over this position. This procedure is to be completed for each GPS receiver used in the survey that is mounted onto a rover pole. As an example, the following steps apply when using the Trimble Survey Controller (TSC3) and its software (Fig. S5.6):

1. Identify the benchmark shown as a background file in the Map feature screen of the field survey controller.

2. Position the rover over this benchmark.
3. In the controller main menu go to:
   - **Survey → Measure points**
   - Under –***point name***- key in the Benchmark's ID (e.g., P10)
   - Under –***code***- enter the season and year of the survey (e.g., Winter 2016)
   - Under –***method***- select –***topo point***-
   - Verify that the –***antenna height***- is set to the correct height
   - Verify that the –measured to- is set to the appropriate reference, such as –***bottom of quick release***-
   - Verify that the antenna is vertical and directly above the benchmark, and hit –***measure***-
   - Wait for ***-30s***- to show in the –***time so far***- and hit –***store***-
   - (the antenna must remain stationary and vertical while the point is measured)

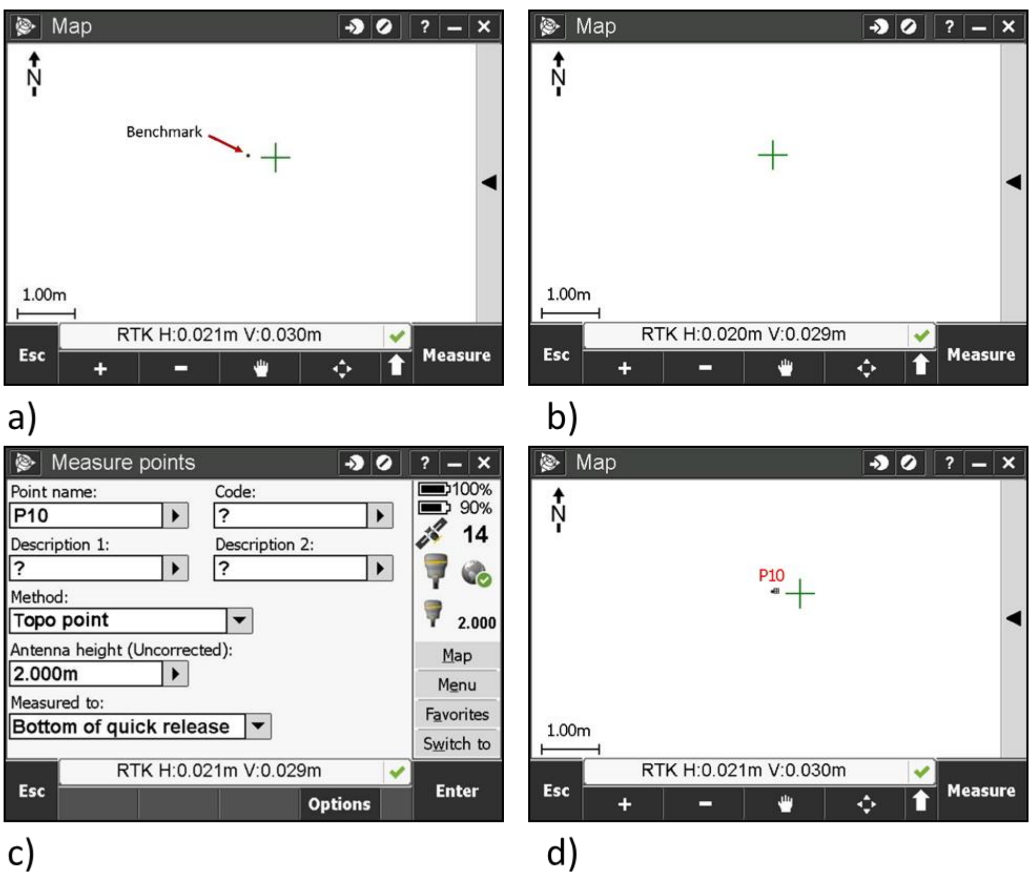


Figure S5.6. Survey Controller screen showing the collection of the benchmark position. a) Map screen showing the position of the rover (cross) near the benchmark, P10; b) map screen showing the position of the rover over the benchmark; c) *Measure Points* screen showing the options for the measurement of the topo point; d) map screen showing the stored observation at monument P10. "H" and "V" values at bottom of each Survey Controller screen image are the horizontal and vertical precisions of the RTK solutions.

5.2.2 Identification and Collection of Topographic Points along the QA/QC Transect Line

Having collected a measurement for each GPS receiver at a Benchmark with the use of a rover pole, any auxiliary equipment, such as a survey wheel (Fig. S5.4) to be used to facilitate the collection of the survey, should be assembled at this time. The surveyor should use the Survey Controller Map feature with the background files, specifically the QA/QC Transect Shapefile, and the indications on the Field Reference Sheet (map, photos and description) to locate the QA/QC Transect that was established according to SOP #2. A series of rapid point measurements will be taken along this transect. This procedure is to be completed for each GPS receiver used within the survey that is mounted onto an accessory, such as a survey wheel, that is unwieldy and/or unrealistic to position precisely over a spot elevation Benchmark. As an example, the following steps apply when using the Trimble Survey Controller (TSC3) and its software (Fig. S5.7):

1. Identify the QA/QC Transect shown as a background file in the Map feature screen of the field survey controller.
2. Position the rover on this QA/QC Transect, at one endpoint of the line.
3. In the controller main menu go to:
    - ***Survey → Measure points***
    - Under -***point name***- key in the QA/QC Transect ID followed by the number 1 (e.g., CZo_PT1_1)
    - Under -***code***- enter the season and year of the survey (e.g., Spring 2016)
    - Under -***method***- select -***rapid point***-
    - Verify that the -***antenna height***- is set to the correct height (height of the mount for the receiver on the assembled survey wheel or other survey accessory)
    - Verify that the -***measured to***- is set to the appropriate reference, such as -***bottom of quick release***-
    - Verify that the antenna is vertical and directly above the benchmark, and hit -***measure***-
    - Walk approximately 3-5 m along the QA/QC transect line and repeat the collection of rapid topographical points until the length of the transect has been surveyed. After the first point, there is no need to change the point name. The following points will keep the prefix and will change the last number in an increasing order.

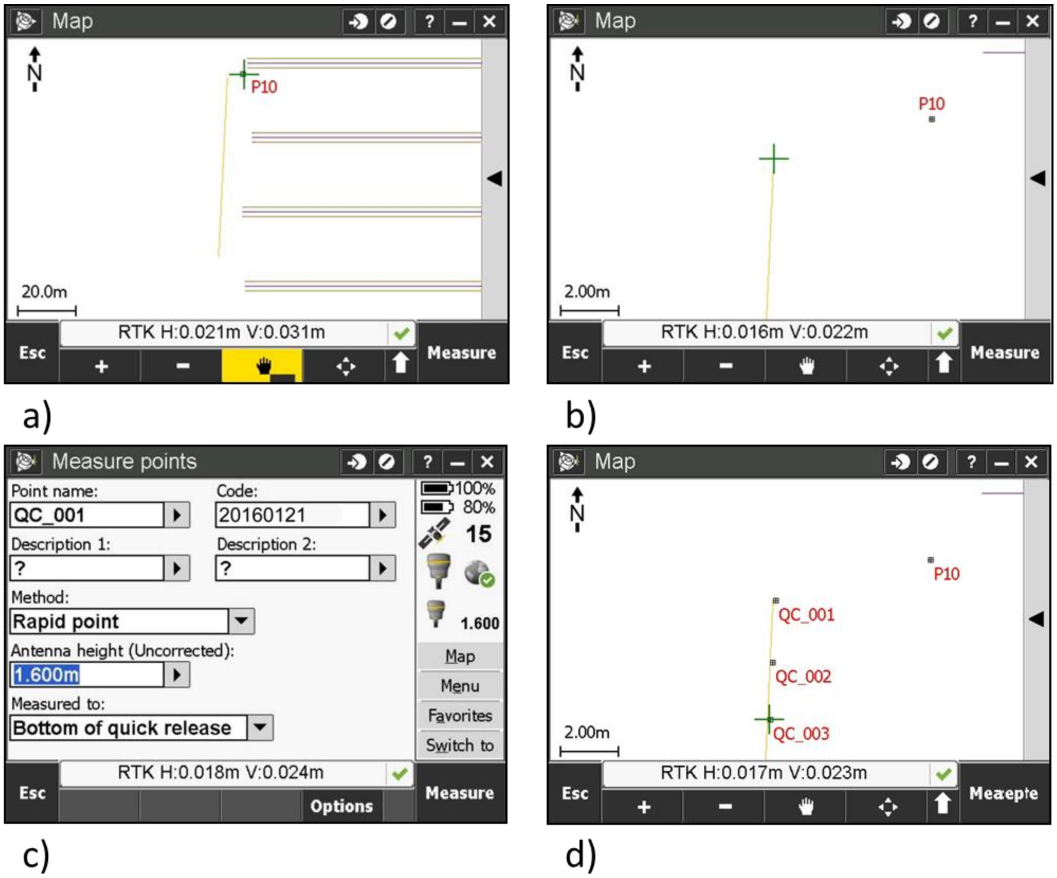


Figure S5.7. Survey Controller screen showing the collection of the QA/QC Transect. a) Map screen showing the position of the rover (cross) near the QA/QC Transect (yellow line); b) Map screen showing the position of the rover at the start of the QA/QC Transect Line; c) *Measure Points* screen showing the options for the measurement of the initial survey control point; d) Map screen showing the stored observations along the QA/QC Transect Line.

5.2.3 Collection of Topographical Data along Survey Transect Lines

After measuring the QA/QC Transect, collecting the topographical data along the Survey Transect Lines is the next step in the survey. To begin, the rover is positioned at the start of a survey transect line shown as a background file in the Map feature screen of the field survey controller. Point measurements (X, Y, and Z) are then collected with the GPS rover receiver as it moves along the pre-established cross-shore transect. The surveyor should use the map screen as a visual guide to ensure points are collected within the 2.0 m buffer of the Survey Transect Lines. Once the entirety of the transect has been surveyed, the procedure is repeated for the adjacent transect until each transect within the survey area has been surveyed. As an example, the following steps apply when using the Trimble Survey Controller and its software (Fig S5.8):

For collection with the GPS receiver mounted on a rover pole:

1. Set the scale bar to ***-2m-*** in the Map screen, to establish a scale on the survey controller screen that facilitates the collection of precise measurements

2. Position the rover over the survey transect line. Verify on the ***-map-*** screen, that the cross (rover position) aligns closely with the survey transect, and within the two survey transect buffer lines.
3. Hit ***-measure-***
4. In the new screen, key in the following information:
   - Under ***-point name-*** key in the initial ID of the point[1]:
   - **SiteArea_200000** (e.g., CZo_200000)
   - Under ***-code-*** enter the date of the survey (e.g., 20160712)
   - Under ***-method-*** select ***-rapid point-***
   - Verify that the ***-antenna height-*** is set to the correct height
   - Verify that the ***-measured to-*** is set to the appropriate reference, such as ***-bottom of quick release-***
   - Verify that the antenna is stationary and vertical, and hit ***-measure-***
   - Confirm that the point is within the survey transect buffer lines
5. Go to the next point and repeat steps 2 through 4[2,3]

<u>Selection of the locations for measurement:</u>

- At least 1 point is measured every 5 meters for planar surfaces
- One point is measured at every change in slope to characterize the main geomorphological features: dune crest, dune toe, berm crest, etc. (Fig. S5.9)
- Points are measured for the entire length of the survey transect, from the landward boundary of the survey area to either an elevation threshold at the seaward margin or a designated seaward boundary.[4, 5]

For collection with the GPS receiver mounted on a survey wheel or other apparatus that facilitates the rapid collection of topographical data:

1. Set the scale bar to ***-2m-*** in the Map screen to establish a scale on the survey controller screen that facilitates the collection of precise measurements
2. Position the rover over the survey transect line. Verify on the ***-map-*** screen that the cross (rover position) aligns with the survey transect.
3. From the map screen, return to the ***–general survey-*** screen within Trimble Access and select ***-measure-***, then select ***–continuous topo-*** from the menu that appears.
4. In the new screen, key in the following information:
   - Under ***-point name-,*** key in the initial ID of the point[1]:
   - **SiteArea_100000** (e.g., CZo_100000)
   - Under ***-code-,*** enter the date of the survey (e.g., Winter 2016)

- Under –***time interval-,*** enter the amount of time to elapse between collected points (e.g., 1s)
- Under ***-method-,*** select –***fixed time-***
- Verify that the ***-antenna height-*** is set to the correct height (height to the base of the quick release mount from the ground)
- Verify that the ***-measured to-*** is set to the appropriate reference, such as ***-bottom of quick release-***
- Verify that the antenna is stationary and vertical, and hit ***-start-***
- The position and elevation of the GPS receiver will be collected every *n* seconds depending on the ***-time interval-*** entry[2].

5. Navigate back to the ***-map-*** screen and maneuver the wheel and GPS receiver along the length of the survey transect, constantly verifying that the collected data are within the survey transect buffer lines.[3]
6. At the end of the transect, navigate back to the ***-continuous topo-*** screen and select ***-end-*** to stop the collection.
7. Go to the next survey transect and repeat steps 2 through 6[2, 3].

<u>Selection of the locations for measurement:</u>

- A one second sampling interval will provide sufficient data density to capture all relevant coastal topography.
- If certain areas within a survey are infeasible for collection with a survey wheel - possibly due to obstruction - pause the collection, navigate around the barrier and resume collection on the other side of the obstruction; if possible, return later with a rover pole to measure positions within the data gap.
- Points are measured for the entire length of the survey transect, from the landward boundary of the survey area to either an elevation threshold at the seaward margin or a designated seaward boundary.[4,5]

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[1]*Start point numbers should be unique to each surveyor participating in the data collection to ensure that the names of the collected points are unique within the survey*

[2]*After the first point, there is no need to change the point name. The following points will keep the prefix and will change the last number in an increasing order.*

[3]*Recollect the point at the same location if the point does not fall within the survey transect buffer lines.*

[4]*If an elevation threshold is utilized, verify that the elevation has been crossed by selecting from the main menu: Instrument > Position. The current position and elevation of the GPS receiver will be displayed.*

[5]*The direction of collection is irrelevant, survey points along transects can be collected in a seaward or landward progression.*

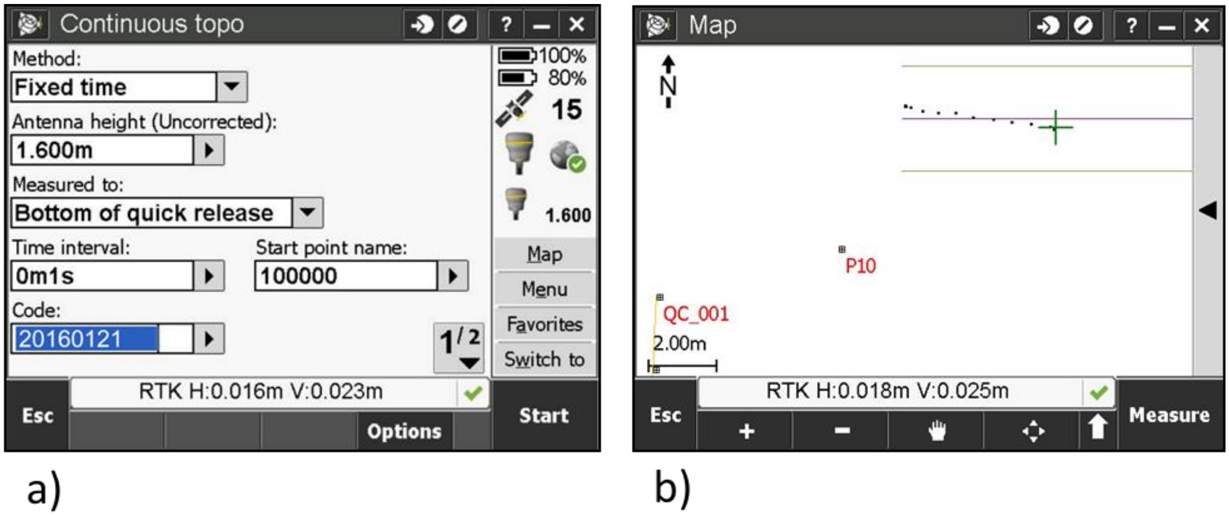


Figure S5.8. Survey Controller screen showing the collection of topographic points along a survey transect line. a) *Continuous topo* screen showing the options for the measurement of the survey points collected with a survey wheel; b) *Map* screen showing the collection of topographical survey points along the survey transect, within the 2.0 m buffer lines created according to SOP #2.

Figure S5.9. Measurement of topographic points along a Survey Transect Line at Plumb Beach, within the Jamaica Bay Unit of GATE, with the GPS receiver mounted on a rover pole.

5.2.4 Photographic Record

Survey photos should be taken along transects designated as Survey Photo Locations within SOP #2. These locations are identifiable on the survey controller during the survey as a polygon area surrounding single survey transects. It is suggested that these photos are taken along these specified transects at the intersection of the beach and the foredune, parallel to the orientation of the shoreline, and roughly orthogonal to the collected transect line (Fig. S5.10). If there is no foredune, the photos should be taken at the landward margin of the beach, at the intersection of the beach and the adjacent landscape (e.g., washover flat, wetland, anthropogenic surface). At the photo locations, a photo should be taken in both directions orthogonal to the transect line to maximize photographic coverage of the area. The photograph taken orthogonal to the transect must always be taken from the same angle so that the record is comparable. If the beach is particularly wide, and the photos taken orthogonal to the transect do not adequately portray the landscape, additional photos should be taken. The additional photos should be taken from the same location as the others, but angled towards the inland geomorphological features and/or seaward towards the beach face to capture images of the features in the landscape. Additionally, the surveyor should take more photographs at other locations if there are natural or artificial features that are creating unusual perturbations to the topography (see below) and that are worth documenting. The total number of photographs taken within a survey must be entered in the FDF in the “Number” field under the “Survey Photos” section.

Figure S5.10. Photograph taken parallel to the orientation of the dune and orthogonal to the survey transect line. This photo was taken during a Fall 2009 Coastal Topography survey conducted at Fort Tilden, Jamaica Bay Unit of Gateway National Recreation Area.

5.3 Interruptions to the Survey

Natural or artificial features may be present along the beach and promote perturbations to the topography. Common interruptions and the appropriate corrective field procedures are described in Table S5.1. In the case of an interruption to the survey, a note should be entered in the FDF under the survey notes section.

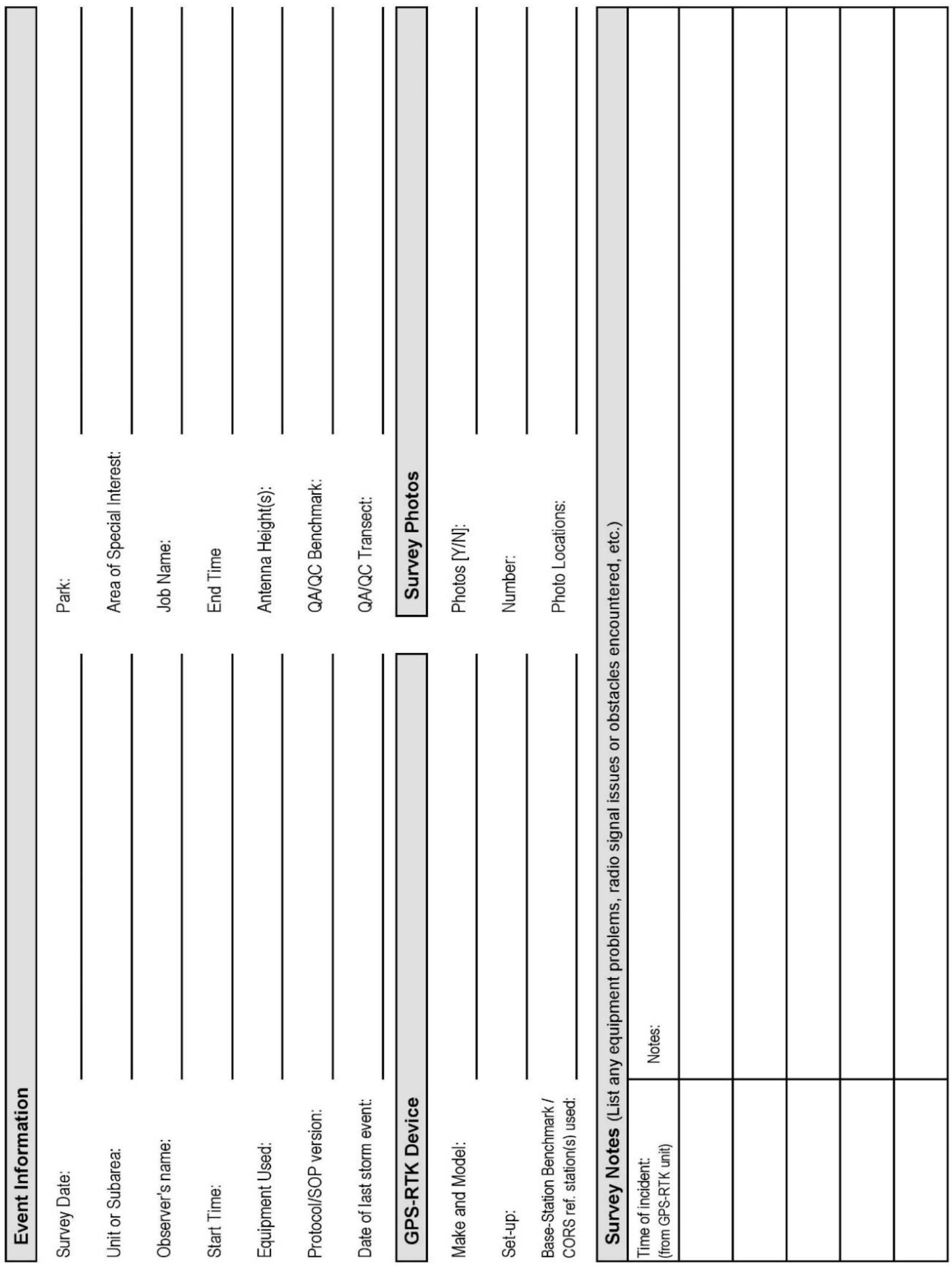
Table S5.1. Common interruptions to the survey and suggested corrective actions.

Type of the perturbation:	Action in the field:
Natural features: Bluffs, Scarps, Ridges, Swales	If the natural features are prominent – on the decimetric scale – collect points at the changes in slope in order to reproduce the feature on a profile and in the data analysis. In addition, collect repeated points along the edge(s) of the feature to be used as breaklines when creating the TIN. An example would collect points along the entire edge of a bluff, parallel to the shoreline.
Hard structures: Seawalls, Groins, Bulkheads	If a human-made structure intersects a Survey Transect, the surveyor should measure points at the changes in slope of these features to reproduce them in the DEM analysis (at least on the first survey). In addition, if the structure is a prominent part of the topography, collect repeated points along the edge(s) of the feature to be used as breaklines when creating the TIN. Structures of this nature are usually permanent and therefore do not have to be surveyed every time. After the first survey, skip the area where the structure is present and proceed with the survey only in the natural area. Make a note on the FDF.
Human interference: Anglers, Tire tracks	Avoid anglers or other visitors that may be on a given survey transect line by shortening the distance between points, never by increasing it. Do the same thing for tire tracks, unless these occupy an area larger than 10 meters. In this case, select a less disturbed surface within the area to measure the topographic point.

5.4. Ending the Survey

After the survey is completed, end the topographical survey within the survey controller, shut down the survey controllers and GPS receivers, and return to the office to:

1. Complete the Field Data Form;
2. Download the data and make a backup copy (SOP #6) to avoid losing it due to an equipment malfunction;
3. Download and catalogue the photographs (SOP #6);
4. Clean (to avoid equipment corrosion due to the salt water and sand, and to have it ready for the next day’s survey if needed), store, and charge the equipment.



Field Data Form - Landorm Elevation Model Survey

Event Information			
Survey Date:		Park:	
Unit or Subarea:		Area of Special Interest:	
Observer's name:		Job Name:	
Start Time:		End Time	
Equipment Used:		Antenna Height(s):	
Protocol/SOP version:		QA/QC Benchmark:	
Date of last storm event:		QA/QC Transect:	

GPS-RTK Device		Survey Photos	
Make and Model:		Photos [Y/N]:	
Set-up:		Number:	
Base-Station Benchmark / CORS ref. station(s) used:		Photo Locations:	

Survey Notes (List any equipment problems, radio signal issues or obstacles encountered, etc.)

Time of incident: (from GPS-RTK unit)	Notes:

For extra survey notes, use additional blank page and attach to this form

Figure S5.10. An example of Form SOP #5-1.

Standard Operating Procedure (SOP) # 6 - Initial Post-Survey Processing

Version 1.0 (May 2018)

The following table lists all changes that have been made to this Standard Operating Procedure since the original publication date. Any recommended or required changes added to the log must be complete and concise and promptly brought to the attention of the Project Leader. The project leader will review and incorporate all changes, officially complete the revision history log, and change the date and version number on the title page. For complete instructions, please refer to SOP #9 – Revising the Protocol.

Revision History Log:

New Version #	Previous Version #	Revision Date	Author (full name, title, affiliation)	Location in Document and Description of Change	Reason for Change

This SOP describes how to download, export, and perform QA/QC checks of the survey data immediately following the field data collection. It is meant to ensure that no data are lost due to equipment failure and to determine if the survey needs to be repeated.

This SOP consists of the following sections:

6.1 Data download, export and creation of ESRI shapefiles

6.2 QA/QC check and metadata creation

6.3 Management of the Photographic record

6.4 Final Product Delivery

As an example, the procedural steps are illustrated using the Trimble Business Center software, a proprietary software used to download and process data collected with Trimble equipment. Similar operations should be applied using other software coupled to equipment produced by other manufacturers.

6.1 Data Download, Export, and Creation of ESRI Shapefiles

6.1.1 Data Download

Immediately upon completion of the survey and return to the office, the RTK data file is downloaded from the field survey controller to a computer hard-drive. For Trimble equipment, use the Trimble Data Transfer software to transfer the Job File (.job) to a computer. Create a backup copy of the .job file by saving it to a secondary storage space (e.g., cloud, external hard disk drive, CD/DVD, etc.). The data should be retained on the survey controller until quality checks have been completed.

6.1.2 Data Export

Create a project file (.vce) on Trimble Business Center (TBC) software with the settings described in SOP #4 - Settings for Collection of Topography, and save it with the name that includes: 1) an acronym identifying the Area of Special Interest where data were collected; 2) the protocol designation describing the dimension of data collected – "3D"; and 3) the survey date in yyyymmdd format. The filename should follow this format:

Survey location_"3D"_survey date (yyyymmdd)

For example, a survey collected utilizing the 3D protocol within the area dubbed the Critical Zone at Sandy Hook on January 21, 2015 should be assigned the following filename:

CZo_3D_20150121.vce

Once the project has been created:

1. Import the .job file that was downloaded from the survey controller
2. Select the entirety of the job's survey points
3. Select the *Custom tab* under the Export command pane and save the data as a Comma Separated Values (CSV) file (.csv) with the following format:

P, E, N, elev, Code
(Point ID, Easting, Northing, Elevation, Code)

The file name will be the same as the Job file from which the data are being exported. These parameters will be portrayed in a spatial context in the "Plan View" of TBC project (Fig. S6.1).

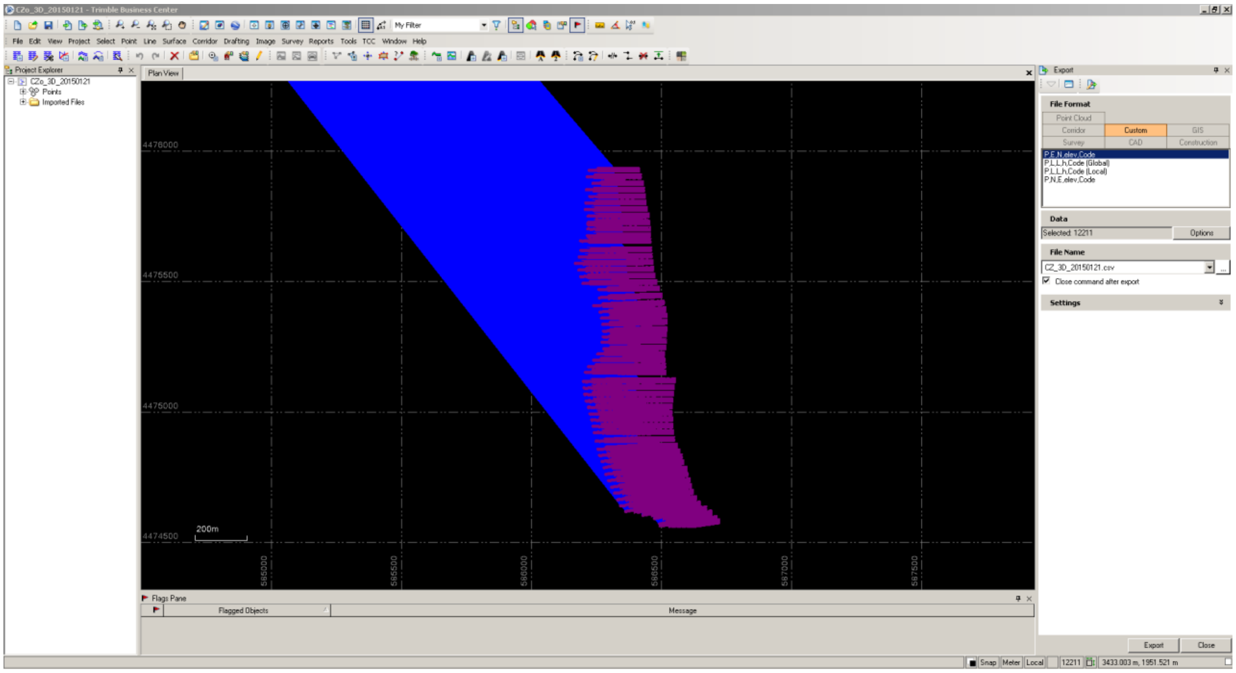


Figure S6.1. TBC software screen showing the plan view of the points collected in the field at the Critical Zone site (57 transects). All 12,211 points are actively selected and the Export command pane (on the right) is set to export them as a CSV text file.

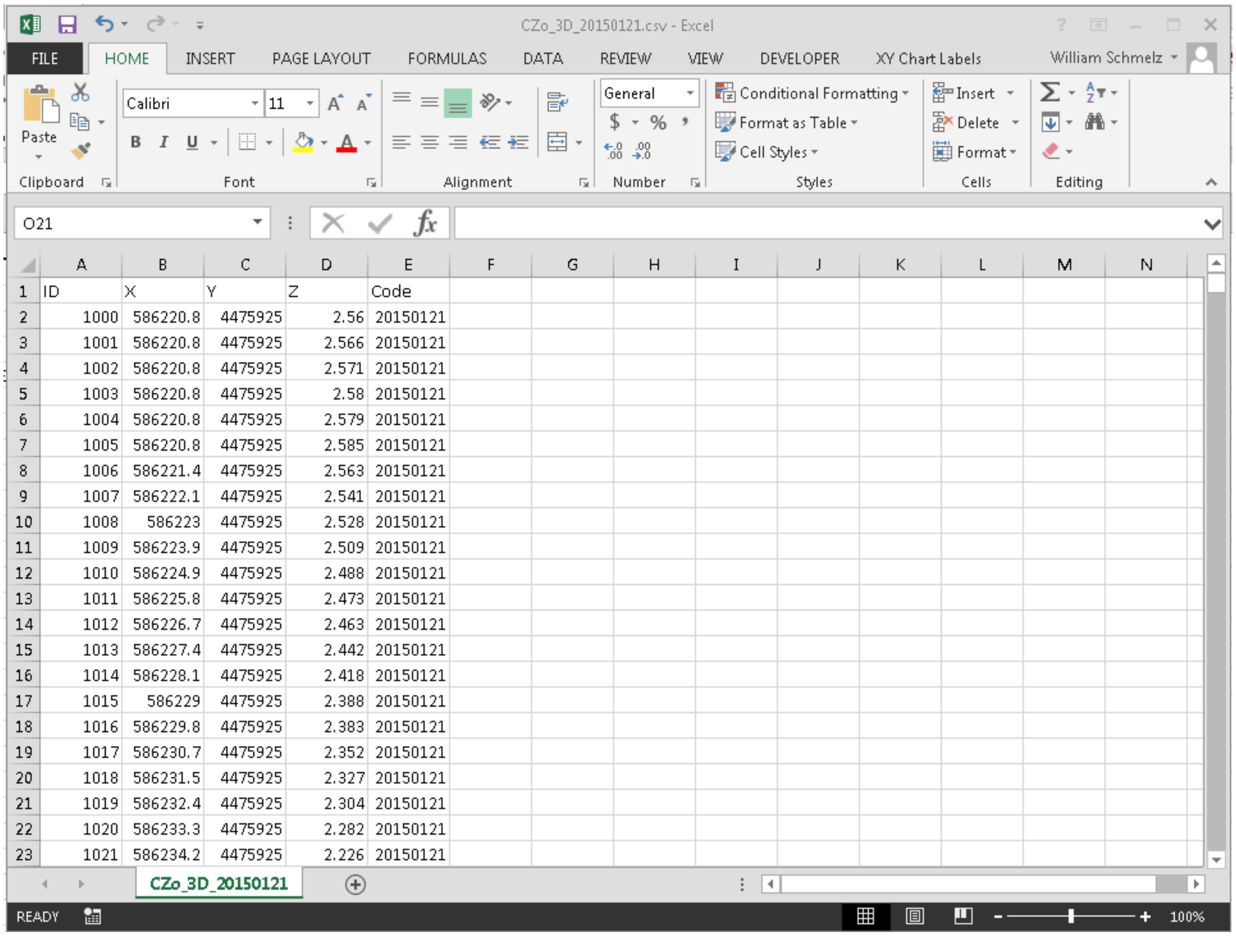
TBC will automatically create a file folder (in the same folder selected to create the TBC project) with all the imported Job files (.job) and with the exported CSV text data files (.csv).

6.1.3 Shapefile Creation

The exported .csv file will be converted to an ESRI shapefile through the following steps:

1. Use Microsoft Office Excel to open the .csv data file and create a header row:
    a. Insert a line above the first row of values and add the names of the fields containing data (ID, X, Y, Z, Code) according to Figure S6.2
    b. Close the file and verify retention of the same name and CSV file format (.csv).
2. Locate the altered .csv data file within ArcCatalog and follow these steps:
    a. Right click on the .csv file
    b. Scroll mouse over “Create Feature Class” and select “From XY Table”
    c. Within the “Input Fields” section of the “Create Feature Class From XY Table” utility, set “X Field” as “X”, “Y Field” as “Y”, and “Z Field” as “Z”. Click on “Coordinate System of Input Coordinates” button and assign the data to the appropriate coordinate system (according to SOP #4).
    d. Within the “Output” section of the “Create Feature Class From XY Table” utility, assign the data as a shapefile (.shp) with the same name as the .csv data file and within the folder created by the TBC project (as described above).

e. Select “OK” to create the file.



	A	B	C	D	E
1	ID	X	Y	Z	Code
2	1000	586220.8	4475925	2.56	20150121
3	1001	586220.8	4475925	2.566	20150121
4	1002	586220.8	4475925	2.571	20150121
5	1003	586220.8	4475925	2.58	20150121
6	1004	586220.8	4475925	2.579	20150121
7	1005	586220.8	4475925	2.585	20150121
8	1006	586221.4	4475925	2.563	20150121
9	1007	586222.1	4475925	2.541	20150121
10	1008	586223	4475925	2.528	20150121
11	1009	586223.9	4475925	2.509	20150121
12	1010	586224.9	4475925	2.488	20150121
13	1011	586225.8	4475925	2.473	20150121
14	1012	586226.7	4475925	2.463	20150121
15	1013	586227.4	4475925	2.442	20150121
16	1014	586228.1	4475925	2.418	20150121
17	1015	586229	4475925	2.388	20150121
18	1016	586229.8	4475925	2.383	20150121
19	1017	586230.7	4475925	2.352	20150121
20	1018	586231.5	4475925	2.327	20150121
21	1019	586232.4	4475925	2.304	20150121
22	1020	586233.3	4475925	2.282	20150121
23	1021	586234.2	4475925	2.226	20150121

Figure S6.2. Using Microsoft Office Excel to create headers on the exported CSV data file.

6.2 QA/QC Check and Metadata Creation

6.2.1 QA/QC Checks

1. Verify configuration and accuracy of survey equipment using a survey benchmark (established according to procedures in SOP #2).

   a. Using a benchmark associated with the Area of Special Interest, verify that the coordinates of observations collected with the geodetic GPS receivers (collected according to procedures outlined in SOP #5) occupying that position are within 0.05 m (horizontal error) and elevations are within 0.05 m (vertical error) of the position established according to SOP #2.

   b. The horizontal error and vertical error values within the following equations must be less than 0.05 for each observed benchmark point.

      i. $$\boldsymbol{horiz.error} = \sqrt{(x_{observed} - x_{benchmark})^2 + (y_{observed} - y_{benchmark})^2}$$

ii. $\boldsymbol{vert.error = |z_{observed} - z_{benchmark}|}$

2. If a survey wheel is used, the calibration of this equipment within the survey needs to be verified against a QA/QC transect with an established accuracy (established according to procedures in SOP #2).
   a. Within the “Survey_Wheel_QA/QC.xslm” Microsoft Excel worksheet provided along with this protocol, plot both the established QA/QC Transect positions and elevations (x,y,z), as well as those observed over that QA/QC Transect with the survey wheel(s) on the date of the survey.
   b. Verify that the observed horizontal positions are within 0.1 m and elevations are within 0.05 m of the established transect coordinates (x,y,z). (Fig. S6.3)
3. Having confirmed the accuracy of the survey equipment, the proximity of collected data relative to the Survey Transect Lines (created in SOP #2) needs to be verified. If data are collected at a distance greater than 2.0 m, measured orthogonally from the survey transect, the measured topography may be unreliable for comparison to other surveys collected along that transect.
   a. Plot the exported ESRI point shapefile (created in SOP #6.1, above) against the Survey Transect Lines and Survey Transect Buffer Lines that are plotted 2.0 m from the survey transects (from the GIS database created according to SOP #2) in ArcMap and verify that survey points collected along individual transects are aligned with the pre-established transect lines and within the 2.0 m buffer lines. (Fig. S6.4)

If one of these QA/QC checks fails, the surveyor must evaluate the need to return to the site and re-collect either the entire survey (in the case of check 1 or 2) or individual transects (in the case of check 3). In this evaluation, it is important to identify the source(s) of the error and its influence on the subsequent analysis. In the case of checks 1 and 2, the data files should be compared with the Field Data Form to confirm that the survey was properly configured. For example, GPS receiver antenna heights in the data files should be confirmed to match the values entered on the Field Data Form. If an action can be taken to rectify the error, this correction should be applied and noted in the Field Data Form. In the case of check 3, it is important to consider the topography that data were collected over and the objective of the analysis (see SOP #7 for a detailed description). There will be, at times, unavoidable obstructions to the survey and the topography of the site will determine whether or not usable data have been collected for analysis. Surfaces with little to no alongshore dip are more forgiving to data collected outside of the survey transect buffers. This is characteristic of the beach berm topography, an area that is frequently occupied by Park visitors, whose presence may require a diversion from the collection of data along the survey transect lines. Data collected outside of the survey transect buffer lines in areas with sharp slopes dipping alongshore will affect the consistency of elevation measurements between surveys. This is characteristic of dunal and, particularly, hummocky dunal topography.

Once the data have been verified and checked for accuracy, finish filling in the Field Data Form.

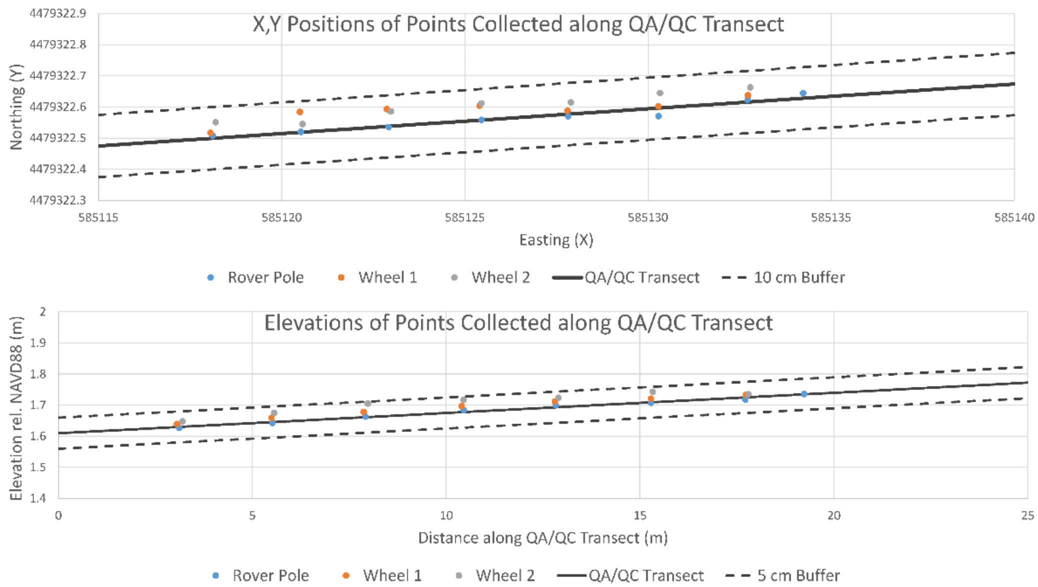


Figure S6.3. Horizontal positions and elevations of survey points collected with two different survey wheels and with a rover pole over a QA/QC Transect in the parking lot near Gunnison Beach within the Sandy Hook Unit of Gateway National Recreation Area. The QA/QC Transect is represented as a continuous black line and the dashed lines display the 10 cm horizontal and 5 cm vertical thresholds established as acceptable error utilizing a survey wheel.

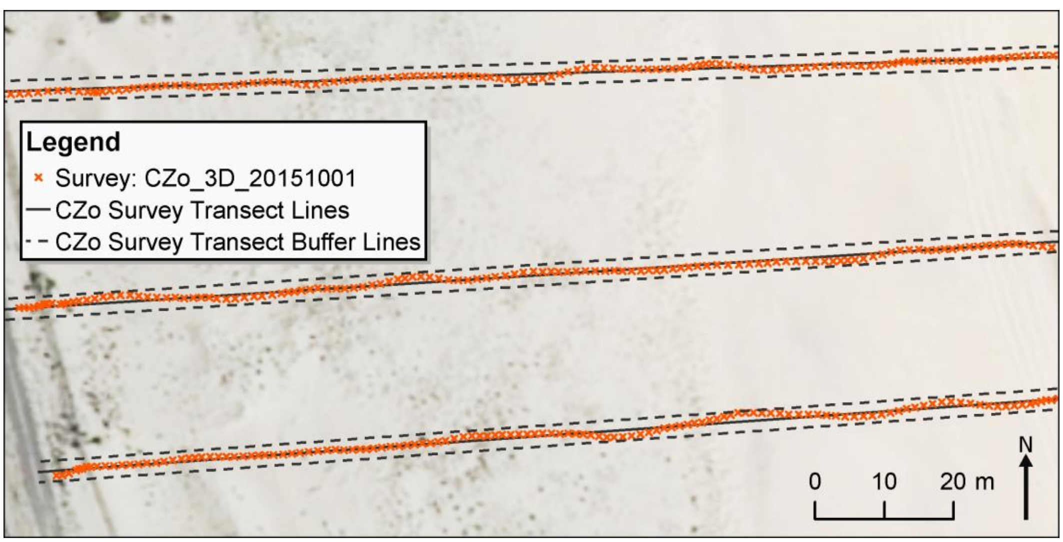


Figure S6.4. Location of the survey points collected at the Critical Zone site on Oct. 10, 2015. The positions of the survey points are confirmed to be within the Survey Transect Buffer Lines that are positioned 2.0 = m to both sides of each of the Critical Zone Survey Transect Lines.

6.2.2 Metadata Creation

The data download, export, and verification must be done at the end of each daily survey. At the end of the survey period, when all surveys have been run and verified for accuracy, a single shapefile must be derived from the collected surveys for each study area. Metadata must be created for each of these shapefiles.

The NCBN data manager will provide the parks with a FGDC compliant metadata template for the Area of Special Interest Protocol that already contains much of the relevant information regarding the collection of the profile points. Most of the remaining information to be included will be derived directly from the Field Data Form completed before and during the data collection process. Table S6.1 summarizes where this information should be included in the metadata file.

Table S6.1. Organizational comparison of field data and metadata files.

Field form data	Metadata tag
Park Unit	Abstract, Keywords
GPS unit Make and Model	Process step, Process description
Who processed the data	Process step, Process contact
Software used to download, post-process data, Base station(s) used; description of any data editing	Process step, Process description

6.3 Management of the Photographic Record

The photographs must be downloaded into the computer and catalogued. Photos are collected in the field at regular alongshore intervals specifically identified as the Survey Photo Locations (created within SOP #2) and collected according to the procedures established within SOP #5. The correlation of a particular photo to a particular Survey Photo Location is, ideally, completed in the field through an entry into the Field Data Form. Check the Field Data Form to verify how many photos were taken at particular Survey Photo Locations and rename the photographs to reflect the ID associated with a particular Survey Photo Location, the approximate cardinal direction that the photo was taken, and the date of the survey. If necessary, this information can be confirmed or supplemented using the information within the Job file in TBC to verify the time of collection for particular transects and compare it to the time of the photo to correlate it to an approximate spatial location within the survey area. The filename should use the following format:

Area of Special Interest_protocol designation_survey date (yyyymmdd)_Photo Location ID_Direction

For example, a photo taken looking south from Survey Photo Location 2 during a Critical Zone survey collected on October 1, 2015 should be named:

CZo_3D_20151001_2_S

Each photo must not exceed 800 x 600 pixels in size, to facilitate sharing the photo file with the NCBN data manager. Use an image/photo editing software (e.g., Office Picture Manager from Microsoft) to resize the photographs if needed.

Create a backup copy of the raw (full-quality) photographs to the same directory used to save the backup copy of the Job (.job file), established in SOP #6.1.1.

6.4 Final Product Delivery

Following all of the quality control procedures and creation of metadata, the final dataset of the topographical survey will be sent to the NCBN data manager. The following raw data products should be delivered to the NCBN data manager for storage, analysis, and archiving in the Coastal Topography Database:

- All original job files downloaded from the GPS-RTK unit
- A project file and folder with all the jobs imported
- A Comma Separated Values data file (.csv) (one per survey)
- ESRI point shapefile (.shp) (one per survey) with metadata
- Hard or scanned copies of all Field Data Forms
- Photographs taken during the survey

These items should be emailed to the data manager (see website for address: http://www.nature.nps.gov/im/units/ncbn/), posted via the NPS public FTP site, or saved to disc and mailed to:

Northeast Coastal & Barrier Network
Data Manager
URI Dept. of Natural Resources Science
1 Greenhouse Rd.
Kingston, RI 02881

Standard Operating Procedure (SOP) # 7 - Data Analysis and Reporting

Version 1.0 (July 2016)

The following table lists all changes that have been made to this Standard Operating Procedure since the original publication date. Any recommended or required changes added to the log must be complete and concise and promptly brought to the attention of the Project Leader. The project leader will review and incorporate all changes, officially complete the revision history log, and change the date and version number on the title page. For complete instructions, please refer to SOP #9 – Revising the Protocol.

Revision History Log:

New Version #	Previous Version #	Revision Date	Author (full name, title, affiliation)	Location in Document and Description of Change	Reason for Change

The objective of this SOP is to describe the way the Coastal Landform Elevation Models are to be utilized to derive volumetric quantification of coastal geomorphological change.

This SOP consists of five sections:

- 7.1 Generation of Digital Elevation Models
- 7.2 Creating Alongshore Compartments
- 7.3 Calculating volumetric changes
- 7.4 Generation of Spatial and Temporal Metrics of Volumetric Change
- 7.5 Production of Reports

Together these procedures comprise a methodology to carry out a 3D volumetric analysis utilizing ESRI ArcGIS software; however, this does not preclude the application of other valid methodologies. This information is presented utilizing the Critical Zone Area of Special Interest in Gateway National Recreation Area (Fig. S7.1) as an example site.

Figure S7.1. The Critical Zone Area of Special Interest at Sandy Hook, Gateway National Recreation Area. The coordinates provided are meters in UTM18N.

7.1 Generation of Digital Elevation Models

The Coastal Landform Elevation Model protocol makes use of the collected survey data to calculate the spatial distributions of erosional, depositional, and net volumetric changes and to facilitate the representation of those analyses. The inputs to the analyses are: 1) a shapefile for each survey dataset; 2) DEMs derived from those topographical data; and 3) a set of compartments to segregate the analyses to form an alongshore comparison. The outputs are three data tables (erosion, deposition, and net change) providing values of change for each temporal comparison pertaining to the entire study area, or to individual compartments. The first step involves the generation of DEMs. The following steps are suggestions towards generating a DEM within ESRI ArcGIS software.

7.1.1 Generation of a Base Surface Surface

Consistent boundaries for the comparison of DEM datasets, applied in both the horizontal and vertical dimensions, are an integral requirement for consistently measuring topography and volumetric change through time. Defining a threshold elevation is necessary to maintain consistent boundaries in the vertical dimension of the DEM. This is achieved through the creation of a base surface in a GIS environment. The base surface is required because the procedures in SOP #5 identify the collection of topographical data seaward until a point is collected beyond the elevation threshold that defines the boundary of the ASI; this causes some data points be collected below the elevation threshold. Considering the objective to be a comparison of DEMs, elevations below the threshold need to be removed from the dataset to facilitate consistency in the comparison. The concept of the base surface is the application of the elevation threshold to the collected data so that values below the base surface (threshold elevation) are given the value of the base surface and values above the base surface are the surveyed values. The base surface is simply a flat raster surface with every grid cell assigned the orthometric height of the elevation threshold.

A merger of this base raster surface with the survey-generated DEM that selects the highest elevation between the two datasets will identify and maintain the interpolated elevations at spatial locations within the survey DEM that are higher than the threshold. Conversely, it will reassign the elevations at spatial locations where the survey DEM is lower than the threshold to the value of the base raster and, by extension, the value of the elevation threshold. Reclassification of these values ensures that if data are collected lower than the threshold, and the shoreline accretes in a subsequent survey, the comparison is not going to include data that were collected to elevations below it. Second, it also provides a surface for comparison because the extent of the collected data varies from survey to survey, a common condition caused by the dynamic position of the shoreline. For example, in a prograding coastal situation, the seaward boundary of the survey may be shifting and the base raster merged with the survey DEM accommodates that shift by comparing accumulations that extend the beach above the threshold elevation. Thus, the base raster surface is utilized to maintain the interpolated value of the intersection of the data and the vertical survey boundary at the dynamic margins of the ASI.

The output dataset from the merger contains the topographical surface that lies above the elevation threshold and a flat surface of elevation threshold values where the real-world topographical surface is below the threshold value. Comparison of this output with a similarly processed dataset will provide:

1. The difference in topographical elevation that occurs in spatial locations where values in both datasets were are above the threshold;
2. Zero values where the topographical surface was are lower in each dataset;
3. The difference between one of the datasets and the threshold in spatial locations where there was an accumulation (or erosion) of sediment that resulted in a topographical surface

elevation above the threshold where the other dataset possessed an elevation below the threshold.

This comparison allows for the calculation of volumetric change that has occurred above the threshold elevation and within the planimetric boundaries of the Area of Special Interest.

To create a base raster within ArcMap, complete the following steps:

1. Determine the spatial extent of the base raster and the coordinate values of the four vertices that will define its boundaries. The base raster should be large enough to contain the entire Area of Special Interest.
2. Generate a csv (comma separated values) text file within a text editor that will store the bounding coordinates (x,y) (determined by the user in step 1) of the base raster surface and the elevation (z) of the elevation threshold. The initial line in the file will contain “x”, “y”, and “z” separated by commas. (Fig S7.2)
3. Append the x, y coordinates of each vertex that defines the boundary of the base raster, along with the elevation threshold value (z), into the csv file as an individual row. (Fig S7.2)
4. Import the csv text file into ArcMap. Right click on the dataset and select “Display XY data…”. Use this tool to generate a point dataset from the csv file, appropriately assigning the x, y, and z values in the text file to the new ArcMap point dataset.
5. Utilizing the ArcGIS 3D Analyst Tools toolbox, apply the “Trend” tool to interpolate a raster dataset using the ArcMap point dataset. This will generate the base raster surface of a constant elevation (Fig S7.3) The tool should be applied to generate a raster dataset with a cell size consistent with the DEMs generated from topographical survey data (see SOP #7.1.3).

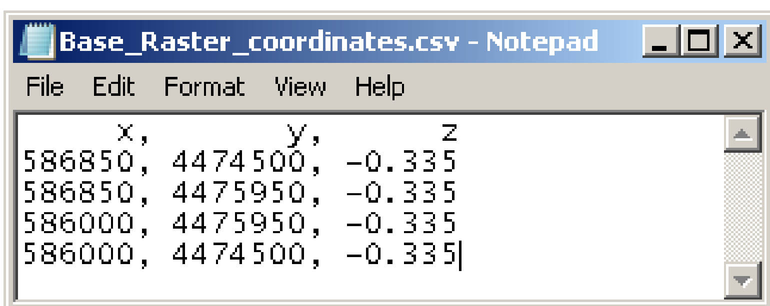


Figure S7.2. Example of a csv text file of the coordinates for the generation of the base raster dataset for the Critical Zone Area of Special Interest. The file contains three columns: the first two are the x, y coordinates of the vertices and the last is the value of the elevation threshold.

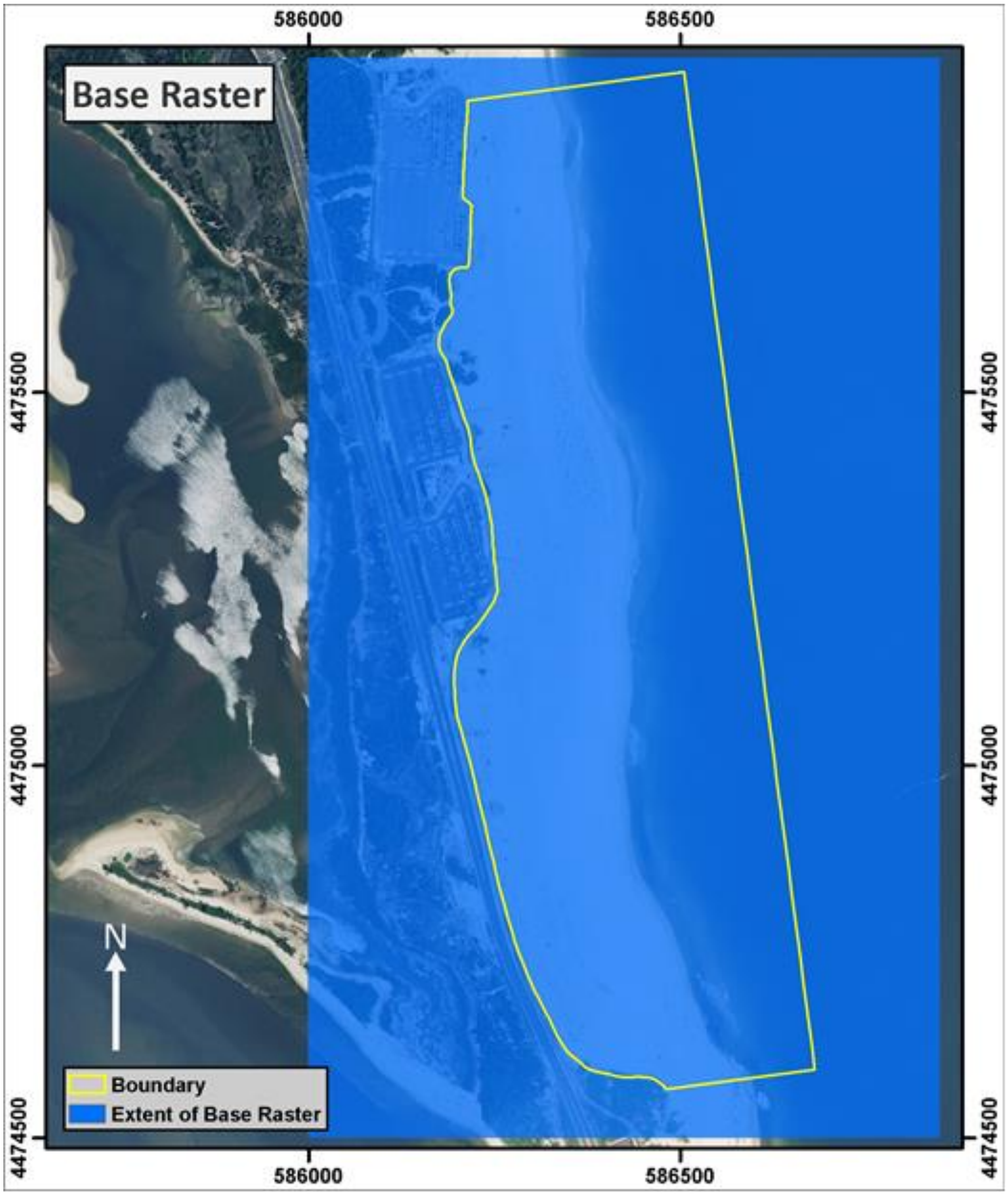


Figure S7.3. Distribution of the base raster dataset (blue area) for the Critical Zone Area of Special Interest (outlined in yellow). Note that the elevation of the dataset and the coordinates of the vertices match those specified in the csv text file in Fig. S7.2.

7.1.2 Triangulated Irregular Network (TIN)

A linear interpolation through Delaunay triangulation is the suggested method for generating a DEM from the collected survey points because it exactly preserves the data points collected in the field. This can be accomplished within ArcGIS through the creation of a TIN (Figure S7.4), the data structure that creates a continuous surface using the Delaunay triangulation method.. The following generalized steps are suggested, without specific instructions on parameters that may be site specific:

1. Within the ArcGIS 3D Analyst Tools toolbox under Data Management, select TIN and then Create.
2. Select a survey shapefile as input data and define the output filename.
3. Check the Contstrained Delaunay box.
4. Create the TIN
5. Repeat steps in 7.1.2 with all survey datasets that will be used for analysis and comparison.

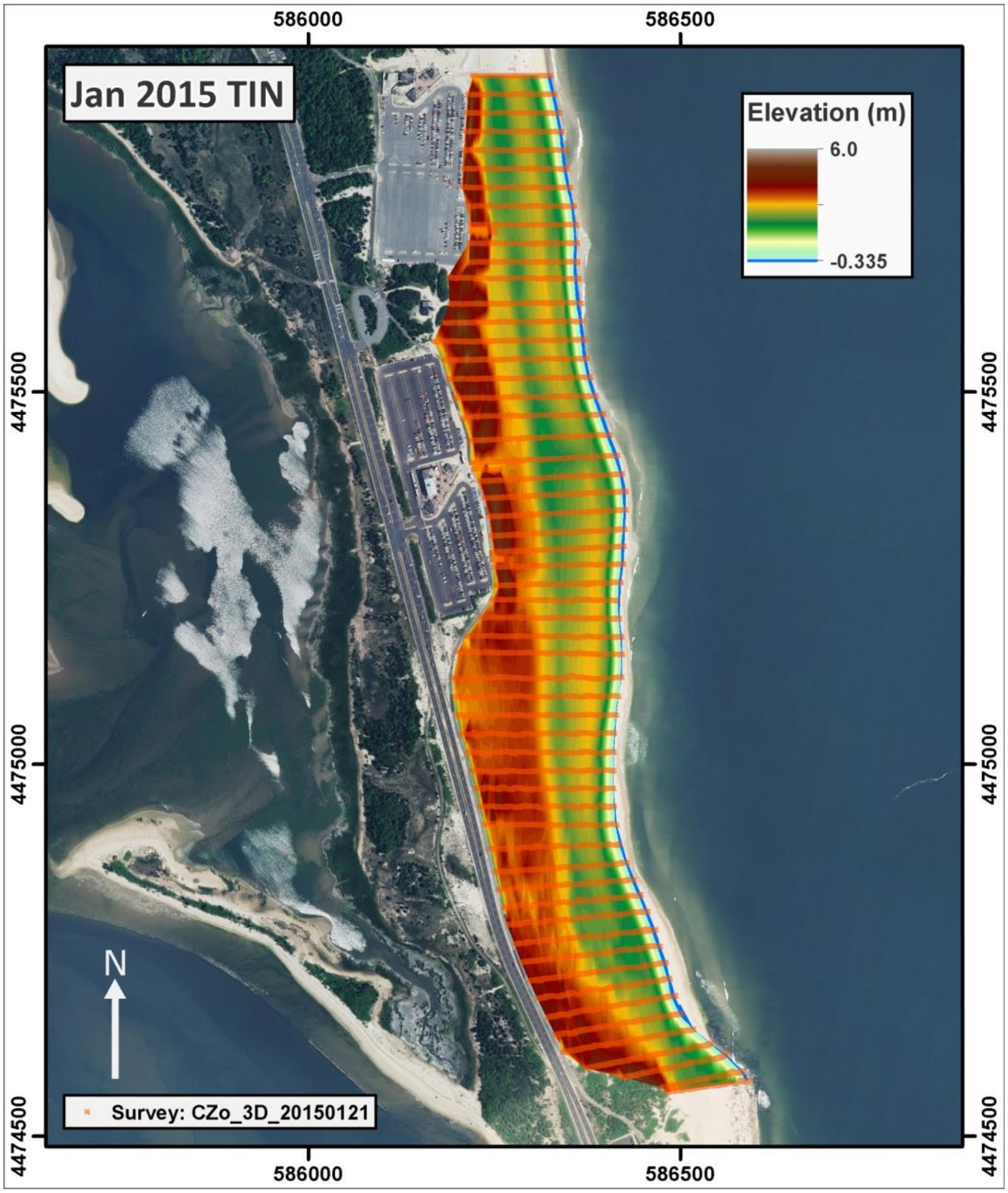


Figure S7.4. An elevation model created through Delaunay Triangulation and stored as a TIN. Elevation is relative to NAVD88.

7.1.3 Conversion to Raster Data Storage Structure

The TIN data structure is composed of triangles that connect adjacent data points, whereas a raster data model uses regularly spaced grid cell matrix (Fig S7.5). The raster data structure is a more convenient arrangement for making comparisons, and a required step is to convert the TIN to a raster. This facilitates the comparison of datasets utilizing the ArcGIS raster math tools. The conversion is accomplished in the following steps:

1. Open the TIN to Raster tool, in the 3D Analyst Tools in the Conversion toolbox within ArcGIS.
2. Within the tool, select linear under Method and set Sampling Distance to CELLSIZE, then insert a value that is small enough to represent the coastal topography within the Area of Special Interest. For most sites, a cell size smaller than 3 m would be required to represent the topography, but there is likely little benefit choosing a value smaller than 0.5 m considering the spacing of the survey data. Smaller cell sizes are suggested for sites with more complex features.
3. The processing extent within environment settings of this tool should be set to the extent of the base raster dataset generated in SOP #7.1.1. This spatial limitation directs ArcGIS to interpolate elevations from the TIN at geographic coordinates coinciding with the centroid of the base raster grid cells. Applying this processing extent while generating a raster from the TIN for each survey dataset serves to generate DEMs with consistent grid cell centroids and boundaries.
4. Execute the TIN to Raster tool.
5. Repeat steps in 7.1.3 with all survey TIN's that will be used for analysis and comparison.

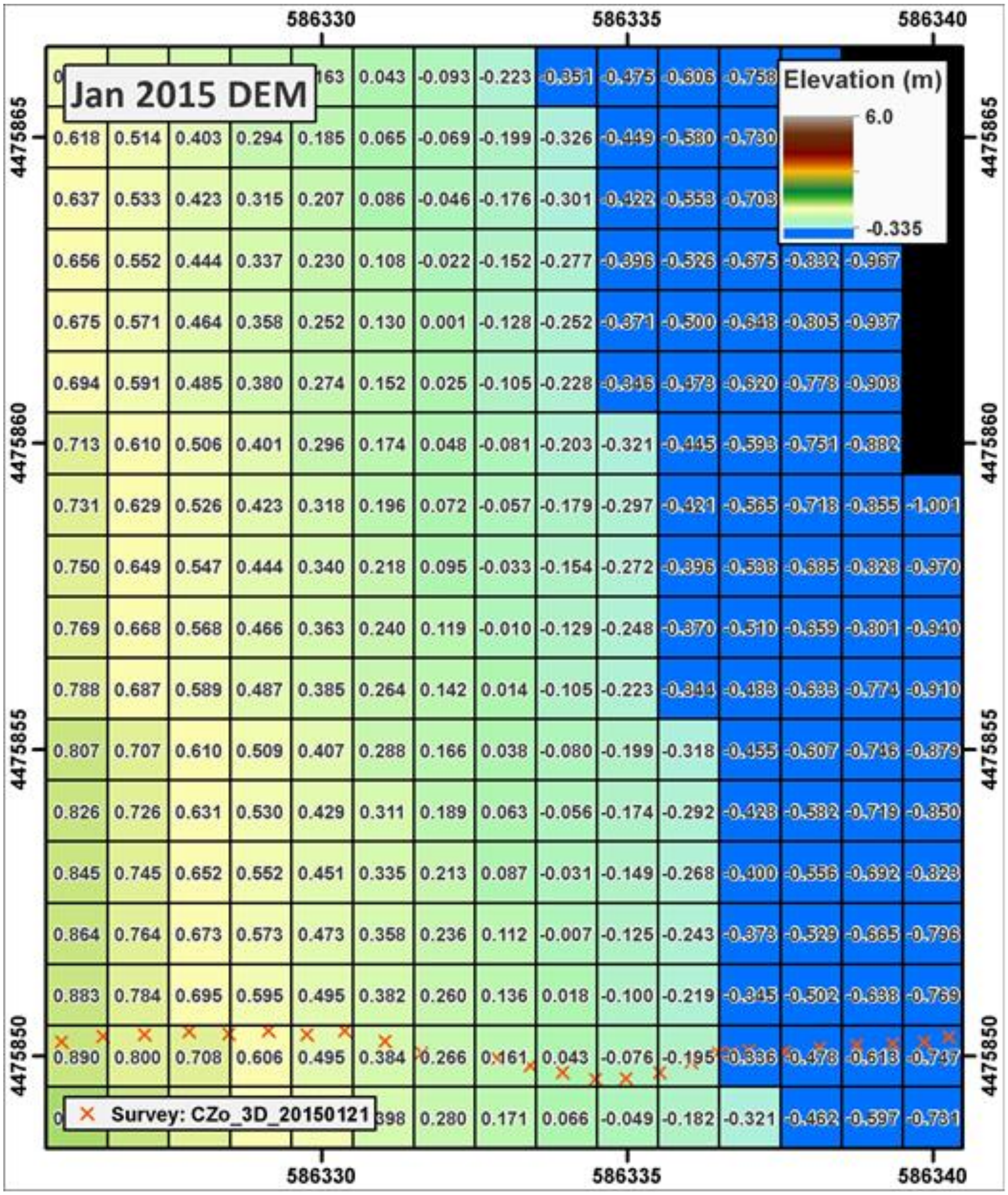


Figure S7.5. A January 2015 elevation model generated for a portion of the Critical Zone that is interpolated into a raster (grid cell matrix) storage structure with a cell size of 1m x 1m. The value within each grid cell is the elevation of that cell in meters (NAVD88) with blue values below the base raster.

7.1.4 Merge Base and Data Rasters

The final step in creating the raster DEM for a topographical survey data collection is to merge the base raster created in step 7.1.1 with the survey raster created in step 7.1.3 (Figure S7.6). This is accomplished through the following steps:

1. Open the Data Management toolbox in ArcGIS.

2. Under the Raster Toolbox, open Raster Dataset and use the Mosaic To New Raster tool within,
3. Select the Base Raster and Survey Raster as the Input Rasters; then define an output location.
4. Set Pixel Type to 32_BIT_FLOAT; Number of Bands to 1; and Mosaic Operator to MAXIMUM.
5. Repeat the steps in 7.1.4 with all Survey Rasters that will be used for analysis and comparison.

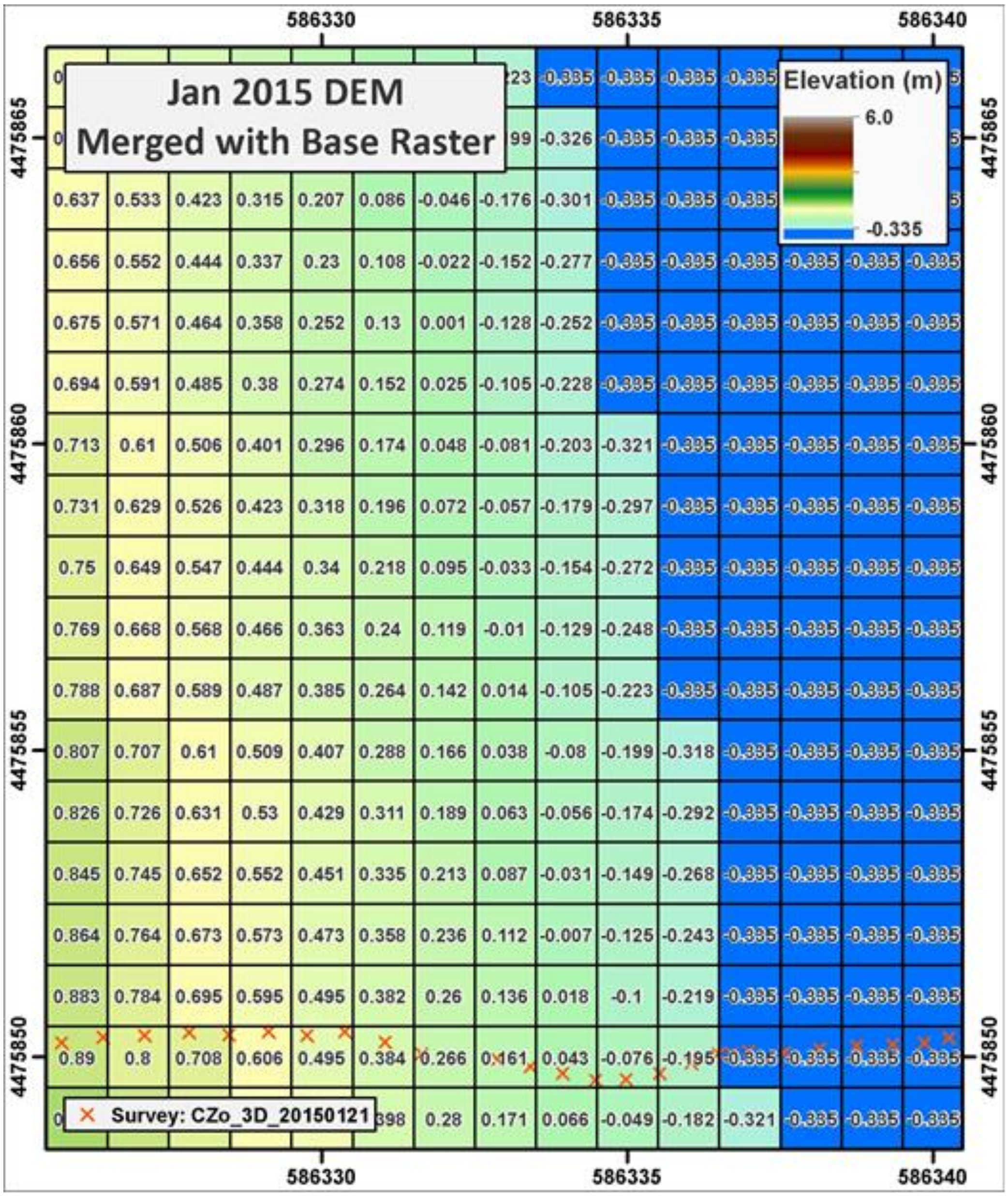


Figure S7.6. A January 2015 raster DEM merged with a base raster, maintaining only the highest elevation for a particular grid cell and eliminating values within the survey DEM that are below the elevation threshold. The value within each grid cell is the elevation of that cell in meters (NAVD88).

The purpose of this step is twofold and is necessary considering the reality of a dynamic shoreline. First, if survey data have been collected below the elevation threshold (determined in SOP #2), it will naturally be interpolated into the DEM as a value below the elevation threshold. Considering the objective to be a comparison of DEMs, elevations below the threshold need to be removed from the dataset to facilitate consistency in the comparison. Any elevations below the elevation threshold within the raster created according to step 7.1.3 are reclassified to the elevation threshold's exact value. This step ensures that if data are collected lower than the threshold, and the shoreline accretes in a subsequent survey, the comparison is not going to include data that were collected to elevations below it. Second, the use of this base raster also provides a surface for comparison because the extent of the collected data varies from survey to survey, a common condition caused by the dynamic position of the shoreline. In the case of a prograding shoreline, the intersection of the beach and its elevation threshold may extend well past the seaward most data point in a previous survey. The base raster provides a surface for comparison where the survey data do not extend into corresponding space.

7.2 Creating Alongshore Compartments

Detailed information about alongshore gradients in topographical change can be generated from the survey data by utilizing a set of compartments segmenting the survey area. Creating these compartments facilitates the quantification of a sediment budget for segments of the shoreline. Characteristics of a set of compartments will incorporate:

- A generally parallel succession of compartments oriented perpendicular to the trend of the shoreline
- A landward extent that is clipped to the boundaries of the Area of Special Interest to be characterized and volumetrically analyzed
- A seaward extent of the compartments that can accommodate a spatial fluctuation in the position of the intersection of the beach and an elevation threshold
- A width equal to or greater than the spacing of transects created in SOP #2

Following the guidelines above, the compartments can be created using the follow steps:

1. In ArcGIS, create a large polygon of the survey area or import a copy of the survey boundary shapefile.
2. Start Editing.
3. Use the Cut Polygons Tool in Editor to cut the polygon of the survey area into the compartments while adhering to the guidelines outlined above.

As an example, compartments created for the purpose of quantifying spatial patterns of volumetric geomorphological change in the Critical Zone site were assigned a 30 m alongshore width. (Fig. S7.7)

Figure S7.7. Compartments shapefile (30m spacing) generated for the Critical Zone.

7.3 Calculating Volumetric Changes

The calculation of a volume of topographical change for a given parcel of land involves multiplying the average change in elevation within it by the planimetric area that comprises its extent. Within a GIS framework, utilizing raster datasets to derive topographical change over time, this calculation is described by equation 1. In this equation, z_1 and z_2 are the elevations (m NAVD88) of a given grid cell i within a spatial matrix at time 1 and time 2, respectively; n is the number of grid cells utilized in a comparison of the two temporally assigned datasets; and d_x and d_y are the spacing of the grid cells in the x and y directions, respectively, in meters.

$$\text{volumetric change} = \frac{\sum_{i=1}^{n} z2_i - z1_i}{n} \times \left(n \times d_x \times d_y\right) \text{ (equation 1)}$$

ArcGIS provides a variety of tools to calculate volumetric change, so there are a variety of valid methodologies. Building on the steps described in SOP #7.1 and SOP #7.2, one of these methods is presented here to obtain; 1) a model of elevation change between surveys within an Area of Special interest; 2) a quantification of volumetric deposition represented by areas of increased elevation shown by the survey data; 3) a quantification of volumetric erosion represented by areas of decreased elevation; and 4) net volumetric change for the entire survey area. It involves four basic steps. They will be illustrated in sections SOP #7.3.1 to SOP #7.3.4 through the comparison of two survey datasets to provide a quantification of volumetric change for the entirety of an Area of Special Interest. This process can be repeated incorporating additional survey datasets or within a subsection of the Area of Special Interest, utilizing the compartments shapefile created in SOP #7.2.

7.3.1 Subtract Raster Elevation Datasets

The comparison of two survey elevation datasets, generated and stored in a raster data structure according to SOP #7.1, is conducted through raster subtraction. Subtracting matrices involves the subtraction of corresponding indices within each individual matrix. For example, for a matrix A minus a matrix B:

$$\begin{bmatrix} A_{1,1} & A_{1,2} \\ A_{2,1} & A_{2,2} \end{bmatrix} - \begin{bmatrix} B_{1,1} & B_{1,2} \\ B_{2,1} & B_{2,2} \end{bmatrix} = \begin{bmatrix} A_{1,1} - B_{1,1} & A_{1,2} - B_{1,2} \\ A_{2,1} - B_{2,1} & A_{2,2} - B_{2,2} \end{bmatrix} \text{ (equation 2)}$$

This is applied with raster datasets incorporating indices within each matrix representing an elevation assigned to coordinates utilizing the UTM coordinate system. The calculation is made within ArcGIS using the Extract by Mask and Raster Math tools according to the following steps:

1. Apply the Extract by Mask tool within the Spatial Analyst Tools toolbox to each of the raster elevation datasets to be compared. The purpose of this step is to exclude any data collected outside the boundary of the Area of Special Interest so that they are not incorporated in the comparison.
    a. The input raster is the merged survey and base raster elevation dataset (Fig. S7.8) and the feature mask is the set of compartments, because the set of compartments together comprises the entirety of the survey area.
    b. Similar to the procedure described in SOP #7.1.3, the processing extent within the environmental settings of this tool should be set to the extent of the base raster created in SOP #7.1.1 to generate consistent grid cell boundaries for the new raster dataset clipped to the extent of the compartments
    c. The output will be a raster elevation dataset clipped to the boundary of the compartments shapefile (Fig. S7.9).
2. Apply the ArcGIS Raster Calculator tool that is incorporated within the Spatial Analyst Tools toolbox. Having generated raster elevation datasets of identical size, the differences in elevation between them is to be derived by subtraction.

a. Within this tool, a "Map Algebra Expression" is to be generated that will subtract the initial elevation raster dataset from the more recent one.

b. The output raster dataset will be a dataset representing the change in elevation within each spatially assigned grid cell (Fig S7.10).

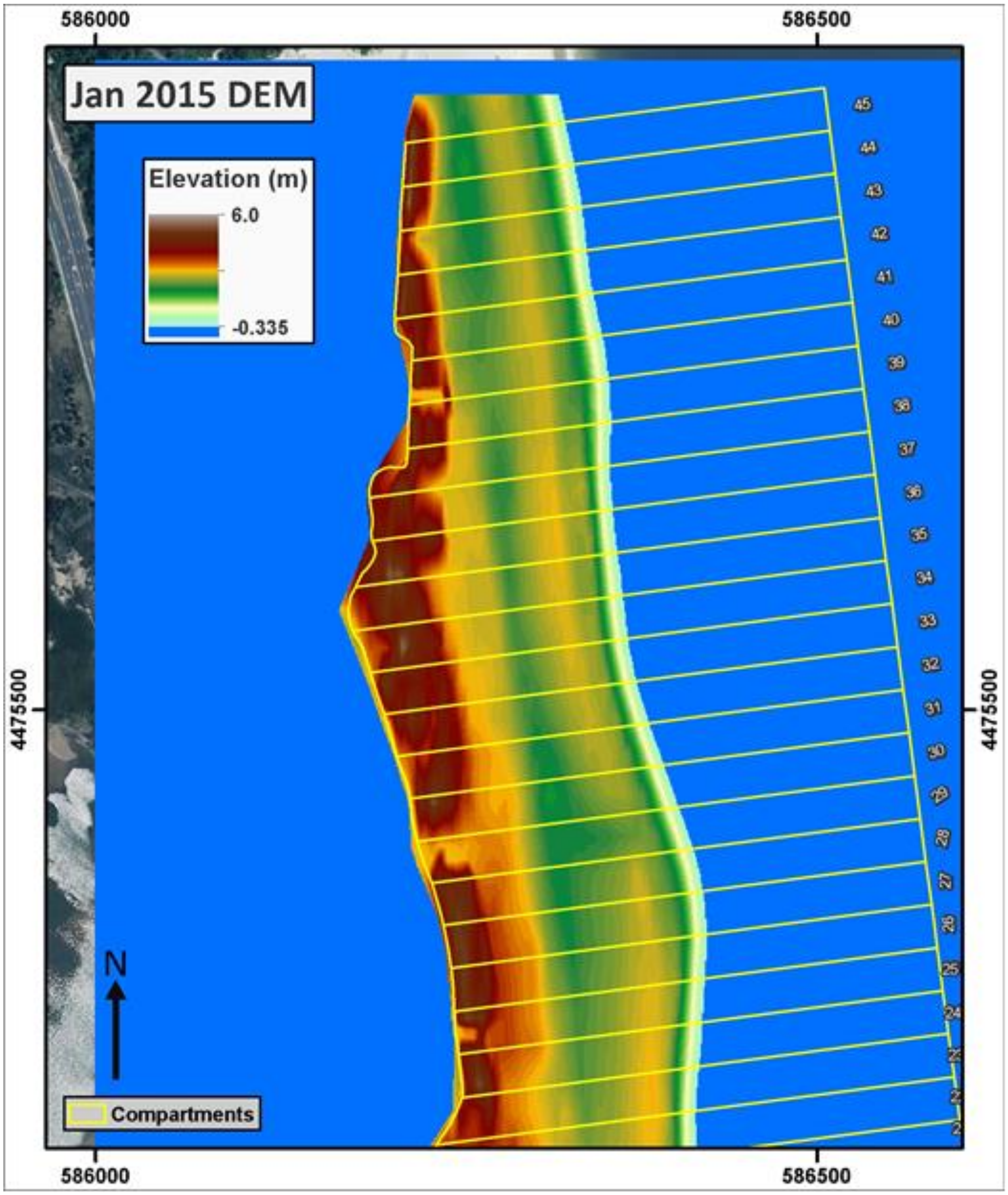


Figure S7.8. A portion of the January 2015 DEM, merged with the base raster, before it is clipped by the extent of the compartments. Location of image is provided in Figure S7.9.

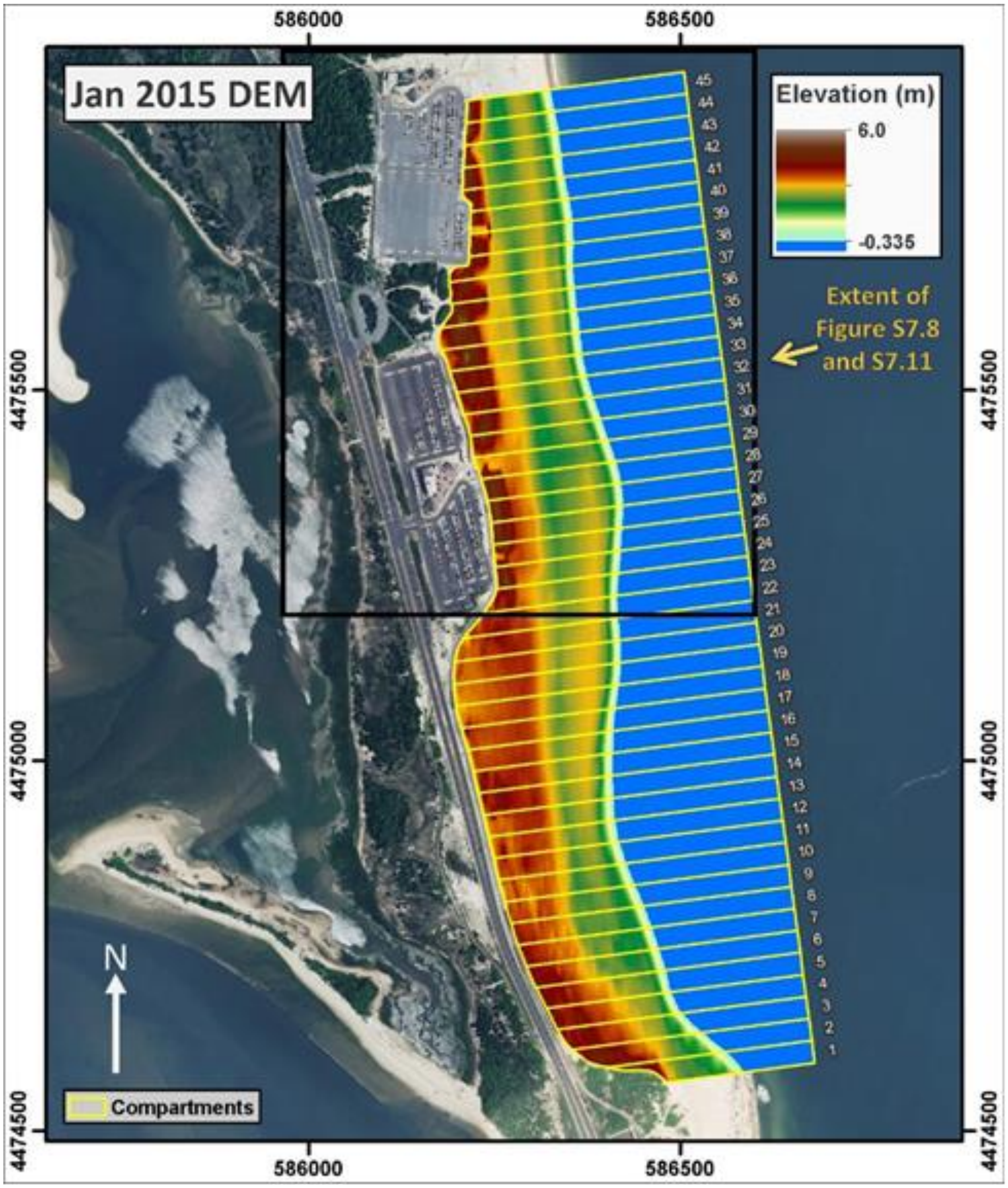


Figure S7.9. January 2015 DEM, merged with the base raster (shown in blue) and clipped by the extent of the compartments to create a consistently-sized grid cell matrix for accurate volumetric calculation.

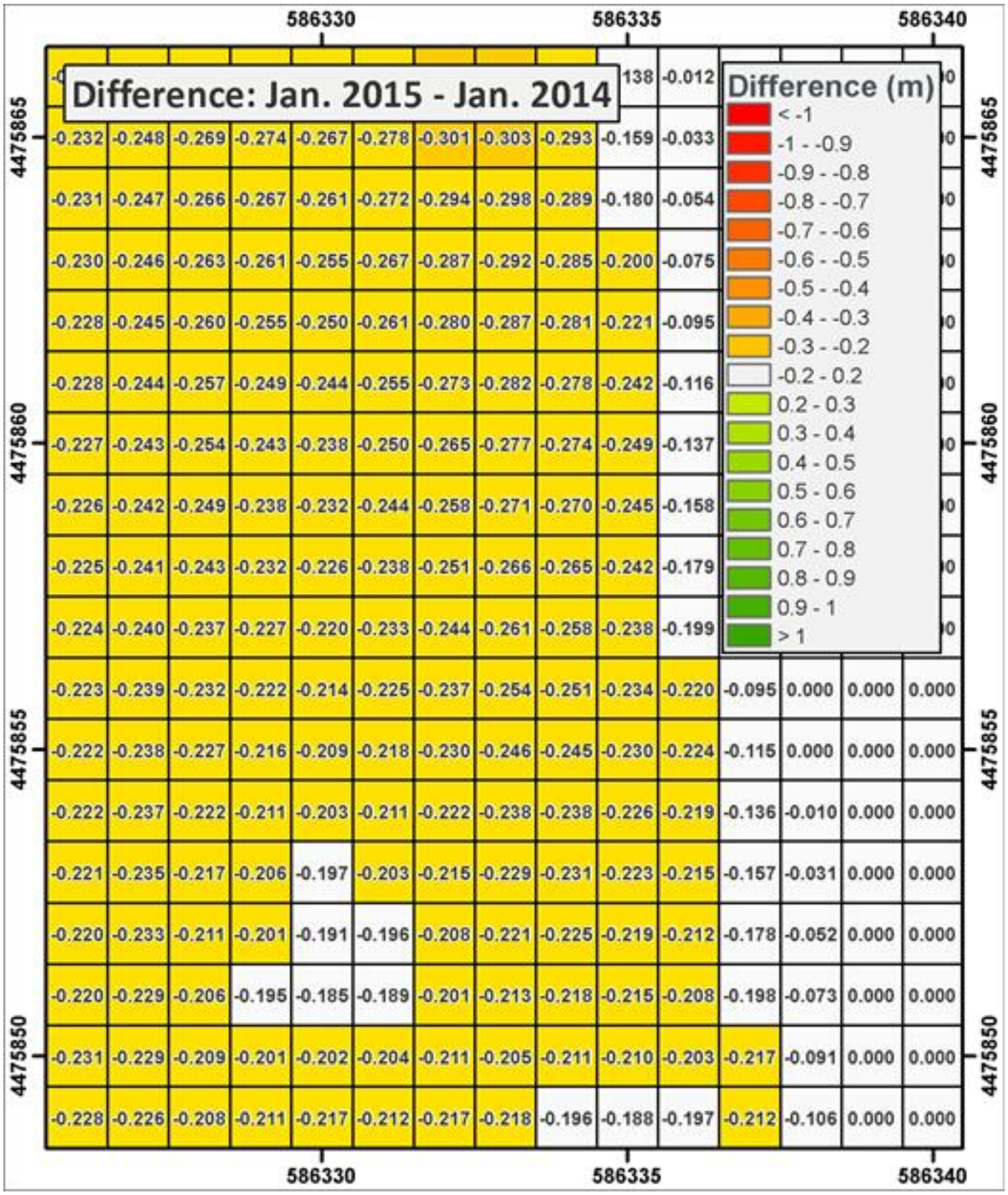


Figure S7.10. The results of the subtraction of a raster derived from January 2014 survey data from a January 2015 raster, site is identical to Figures S7.6 and S7.7. Areas with less than 20 cm of change are shown in white, whereas areas of yellow show -20 to -30cm of change. Areas of 0.000 change along seaward extent are sites of the common base raster elevation on each survey.

7.3.2 Calculate Volumetric Deposition

This step calculates the volume of deposition occurring within the Area of Special Interest during the interval between two surveys. This is applied within ArcGIS utilizing the Surface Volume tool within the 3D Analyst Tools toolbox. Within the tool, the following parameters must be utilized:

1. The input surface is the difference raster generated according to SOP #7.3.1.

2. The tool is set to calculate volume “ABOVE” a reference plane.
3. The reference plane height is set to 0 (elevation change).

The output of this tool is the volume of deposition.

7.3.3 Calculate Volumetric Erosion

This step calculates the volume of erosion occurring within the Area of Special Interest during the interval between two surveys. This is applied within ArcGIS utilizing the Surface Volume tool within the 3D Analyst Tools toolbox. Within the tool, the following parameters must be utilized:

1. The input surface is the difference raster generated according to SOP #7.3.1.
2. The tool is set to calculate volume “BELOW” a reference plane.
3. The reference plane is set to 0.

The output of this tool is the volume of erosion in cubic meters.

7.3.4 Calculate Total Volumetric Change

Having calculated the volume of areas of accumulation and erosion within the Area of Special interest, the total volumetric change is the difference of these two results. Total volumetric change is equal to the volumetric deposition minus volumetric erosion for a given area.

7.3.5 Application to Multiple Surveys and within Individual Compartments

The procedures described within SOP #7.3.1 to SOP #7.3.4, apply to the comparison of two surveys, but are intended for application to multiple surveys. The process is simply repeated with subsequently-collected survey data.

An additional calculation would be the application of the volumetric analysis procedure to individual compartments. To obtain these metrics for a compartment, small adjustments to the procedures are to be implemented within SOP #7.3.2 and SOP #7.3.3. The change is made to the portion of the methodology directed towards calculating the volumetric erosion and deposition from the difference raster datasets. For the derivation of volumes of the entire Area of Special Interest, difference rasters comprising the entirety of the extent of the compartments dataset are generated. To accomplish the derivation of volumes for an individual compartment, the ArcGIS Extract by Mask tool is to be applied to the difference raster dataset prior to volumetric calculations in SOP #7.3.2 and SOP #7.3.3, using an individual compartment as the “feature mask”. The rest of the procedure in SOP #7.3.2 to SOP #7.3.4 is followed identically using the output of the Extract by Mask tool, and repeated for additional compartments. The additional step should be applied as follows:

1. Apply the Extract by Mask tool within the Spatial Analyst Tools toolbox to the difference raster elevation dataset derived from the steps described in SOP #7.3.1. The purpose of this step is to clip any data located outside of a single compartment within the Area of Special Interest, thus identifying this compartment as the area of comparison. Having completed this additional step, continue to apply the steps for the calculation of volumetric change described

in SOP #7.3.2 to SOP #7.3.4 utilizing its output as the difference raster. This procedure is to be repeated for each compartment within the compartments shapefile:

a. The input raster is a difference in elevation dataset generated in SOP #7.3.1 and the feature mask is a single compartment within the set of compartments. A single compartment is applied by selecting the compartment of interest within the compartments shapefile, by ESRI's definition of feature selection, and setting the compartments shapefile as the feature mask in the Extract by Mask tool options. The active selection of a single compartment constrains the execution of the tool to the area of the selected compartment.
b. Similar to the procedure described in SOP #7.1.3, the processing extent within the environment settings of this tool (Extract by Mask) should be set to the extent of the base raster created in SOP #7.1.1 to generate consistent grid cell boundaries for the new difference raster dataset clipped to the extent of the compartments
c. The output will be a difference raster dataset clipped to the boundary of the compartment actively selected within the compartments shapefile (Fig. S7.11).

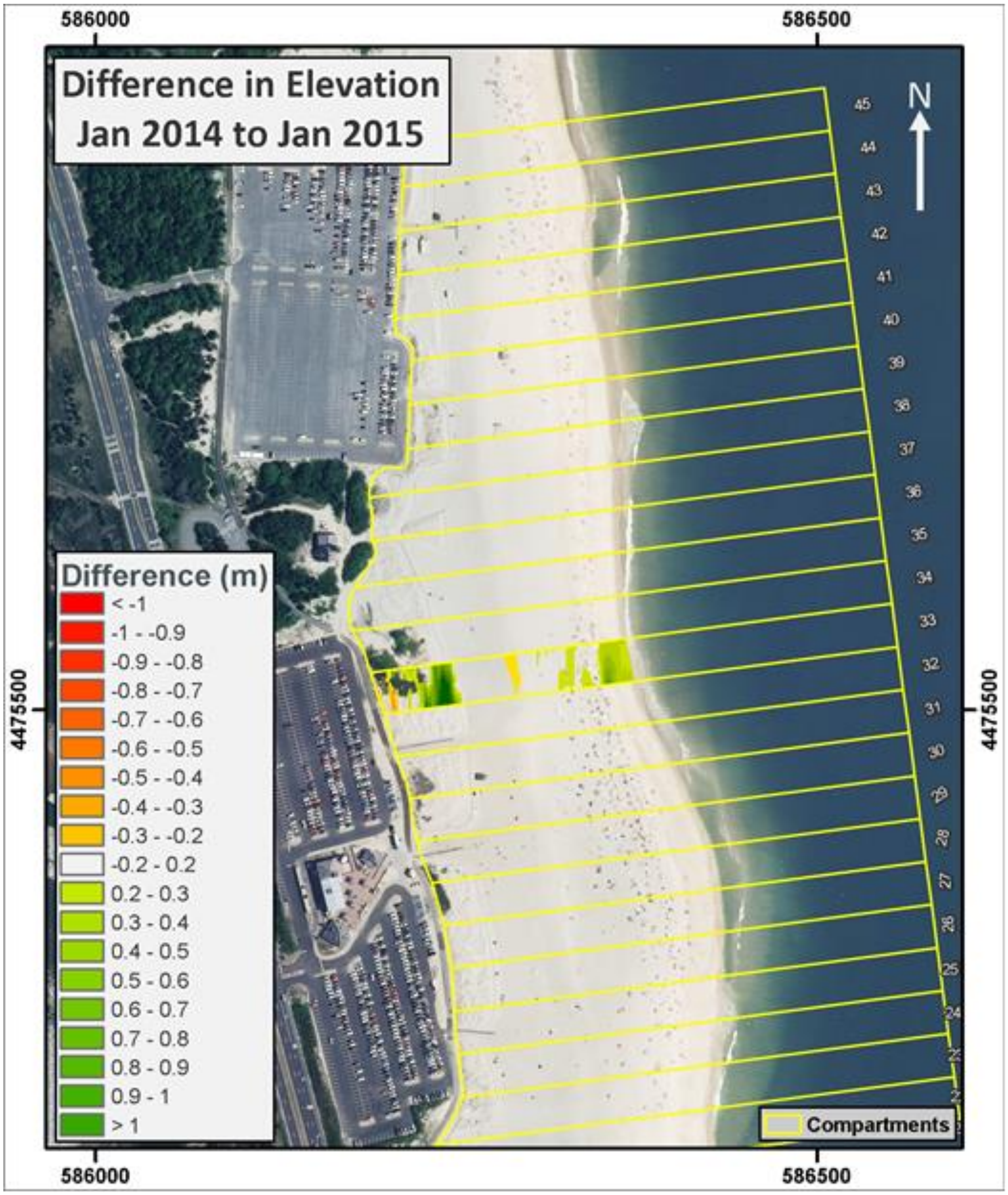


Figure S7.11. Difference in Elevation raster clipped to a targeted compartment for calculating volumetric change.

7.3.6 Storage of Calculated Volumetric Changes

Applying this procedure of calculating volumetric changes between multiple surveys and to individual compartments within the Area of Special Interest generates a significant amount of data. It is suggested that three matrices are generated to store the quantified volumetric erosion, volumetric deposition, and total volumetric change. For a site with *n* surveys and *i* compartments, each matrix can be arranged spatially and temporally following the example provided in Table S7.1.

Table S7.2. Matrix constructed to store calculated volumetric changes in spatial and temporal dimensions.

Compartment	**Survey 1 to 2**	**Survey 2 to 3**	**…**	**Survey *n*-1 to *n***
1	___ m^3	___ m^3	___ m^3	___ m^3
2	___ m^3	___ m^3	___ m^3	___ m^3
…	___ m^3	___ m^3	___ m^3	___ m^3
i	___ m^3	___ m^3	___ m^3	___ m^3
Total				

Table note XXXXXX

7.4 Generation of Spatial and Temporal Metrics of Volumetric Change

Having derived the values of erosion, deposition, and volumetric change for surveys within a site following the procedures in SOP #7.1, there are a number of statistical and graphical portrayals of the data that can be generated. These portrayals can be divided into two groups, absolute changes and trend analyses.

7.4.1 Absolute Changes

The absolute changes between surveys are the values stored within the matrices generated in SOP #7.3.6. Individual temporal comparisons within these matrices can be presented in graphical form and can include spatial summary statistics (Fig. S7.12). For example, the mean volumetric change per compartment for the totality of the Area of Special Interest, or groups of individual compartments within it, provides a means to compare the condition of a site as a whole to subareas within it. This metric can illuminate spatial significance to the dimensions of geomorphological change within a site. The standard deviation of change is a measure of the variability of difference values within individual compartments about the mean change per compartment for the entire Area of Special Interest. Other statistical measurements may be calculated, such as maximum and minimum change, and median and mode, to describe and display the distributional characteristics of the dataset.

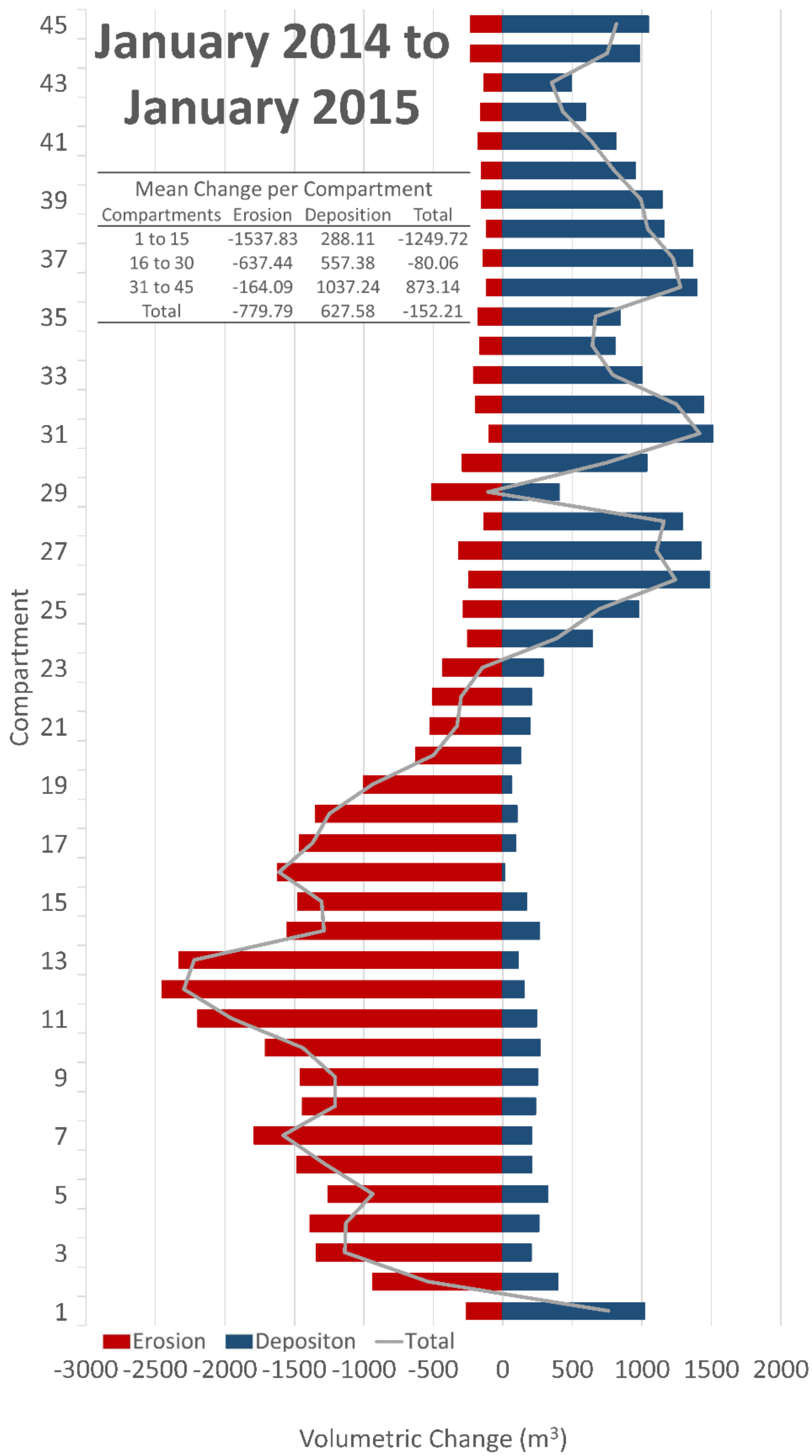


Figure S7.12. Graphical portrayal of absolute volumetric changes in Compartments within the Critical Zone with spatially divided summary statistics change. The raster of differences between surveys can also be utilized to create an image of the cross-shore and alongshore patterns of volumetric erosion and deposition. (Fig S7.13)

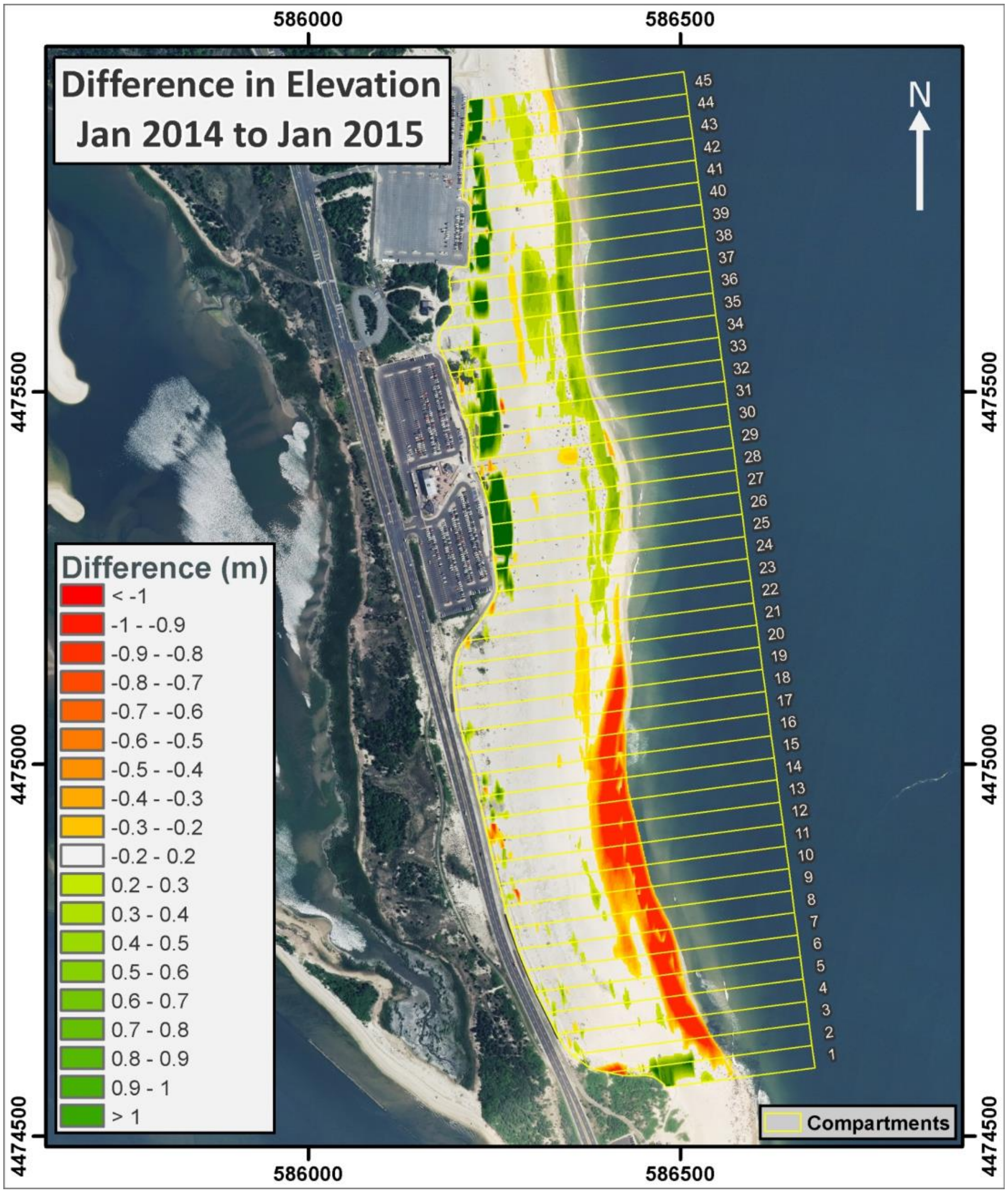


Figure S7.13. Image portraying the spatial distribution of erosion and deposition at the Critical Zone Area of Special Interest from January 2014 to January 2015.

7.4.2 Trend Analyses

The trend in volumetric change may be derived utilizing a regression analysis of all surveys collected within a given time period. The direction and rate of volumetric change can be estimated by calculating a regression of difference measurements through time. Moreover, a regression of differences can be applied to the Area of Special Interest as a whole, or to individual compartments within the study area. Utilizing individual compartments identifies any spatial variations in sediment transport and storage within an Area of Special Interest. The trend analysis becomes more meaningful with a longer record of volumetric change, and with more measurements within a given period of time. Therefore, a site with monthly measurements will be better suited to generate trends of change than a site with annual measurements. A minimum of five years should be used to begin to depict trends of change. An example of a spatial trend analysis is provided for data collected between 2008 and 2013 at Great Kills Park, Gateway National Recreation Area in Staten Island, NY (Fig. S7.14).

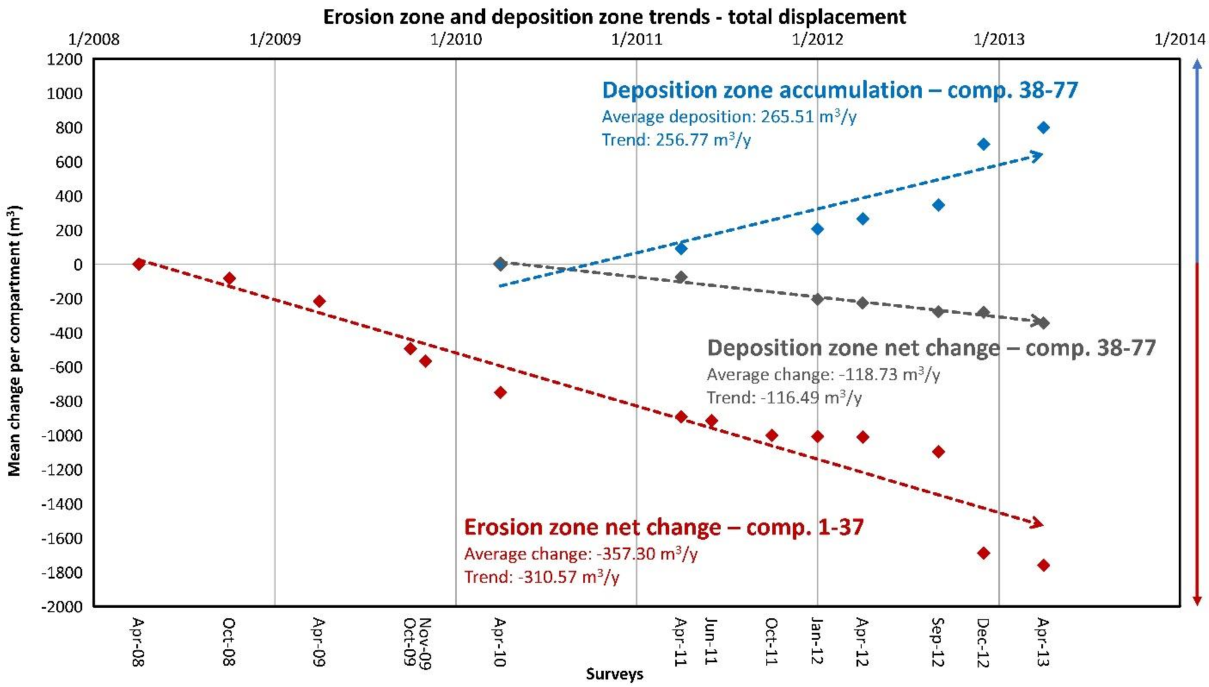


Figure S7.14. Spatial distribution of trends in erosion, deposition, and net volumetric change for portions of the Great Kills Park shoreline from 2008 to 2013. (Psuty et al., 2016)

7.5 Production of Reports

7.5.1 Annual Project Report

The Annual Project Report is a summary of the geomorphological change data over the period of one year (number of surveys dependent on survey frequency, e.g., five surveys for seasonal frequency). General statistics will be included for the seasonal changes as well as the annual change. The Annual Project Report is organized into sections to present the data in narrative, tabular, and graphical form. The sections are as follows:

1. Introduction
2. Site and situation
3. Timing of coastal topography surveys
4. Natural and cultural events affecting the geomorphology
5. Areas of special interest
6. Changes to the protocol

7. Landform Elevation Model surveys data sets, summary statistics, and portrayal of change
8. Information for management and recommendations
9. Problems/concerns
10. Appendices
11. Bibliography

7.5.2 Project Trend Report

The Project Trend Report is a summary of the full database of coastal topography, with an emphasis on the previous five years. It is a comprehensive complement of analyses that synthesize the geomorphological change data, and provide scientific interpretation of the trends revealed in the numerical analyses. The sections of the report are as follows:

1. Introduction
2. Site and situation
3. Timing of coastal topography surveys
4. Natural and cultural events affecting the geomorphology
5. Areas of special interest
6. Changes to the protocol
7. Landform Elevation Model surveys data sets, summary statistics, and portrayal of change
8. Trend analysis, description and interpretation
9. Information for management and recommendations
10. Problems/concerns
11. Appendices
12. Bibliography

Standard Operating Procedure (SOP) # 8 - Data Management

Version 1.0 (May 2018)

The following table lists all changes that have been made to this Standard Operating Procedure since the original publication date. Any recommended or required changes added to the log must be complete and concise and promptly brought to the attention of the Project Leader. The project leader will review and incorporate all changes, officially complete the revision history log, and change the date and version number on the title page. For complete instructions, please refer to SOP#9 – Revising the Protocol.

Revision History Log:

New Version #	Previous Version #	Revision Date	Author (full name, title, affiliation)	Location in Document and Description of Change	Reason for Change

Proper data management and standardization are essential to the effective utilization of information gained through long-term geomorphological monitoring activities. This SOP provides guidelines for the development, storage, and distribution of monitoring data associated with the Network's Coastal Landform Elevation Monitoring Protocol. It describes how information and data generated at various points during the data-collection, analysis, and reporting processes are to be organized, stored, and disseminated. This SOP describes the file management system used for this protocol, and details how monitoring data are stored in the NCBN Coastal Topography Monitoring database. The SOP also outlines the procedures for performing data QA/QC, archiving both spatial and tabular datasets, and making the data publicly accessible via National Park Service information clearinghouses.

A formal information management plan for all NCBN monitoring protocols is available at http://science.nature.nps.gov/im/units/ncbn/products/Data_manage/NCBN_DM_Plan_2004Dec15v2.pdf and should be consulted for more detailed policy information.

8.1 Definition of the Coastal Topography Dataset

The Coastal Landform Elevation Model Monitoring program will produce a number of electronic and paper data files that will include raw and post-processed spatial datasets, a Microsoft Access relational database, and scanned field forms. The large number and variety of files will require conscientious and formal attention to their management. It is the responsibility of the Network Data Manager and Project Leader to assemble, maintain, and make available the various components of the Coastal Landform Elevation Model dataset described here.

8.1.1 Baseline Data
Prior to data collection at a given park, an extensive array of survey benchmarks are located and/or created, and areas of interest and transect lines are established. For each park (or park unit, in the case of Gateway National Recreation Area), the following “baseline” datasets have been created for use by survey personnel to guide data collection in the field and for quality control purposes once the data have been downloaded from the GPS equipment:

1. One ESRI point-feature shapefile (.shp) containing all survey benchmark locations
2. One ESRI polyline shapefile (.shp) containing the set of Survey Transect Lines that will constrain where the GPS survey data are collected
3. One ESRI polygon shapefile (.shp) containing the set of Survey Photo Locations
4. One ESRI polygon shapefile (shp)containing the set of Survey Transect Buffer Lines that brackets the Survey Transect Lines
5. One ESRI polyline shapefile (.shp) containing the location of the QA/QC Transect
6. One or more field datasheets containing location information and other metadata regarding the above benchmarks and transect lines. Stored in Adobe Portable Document File (.pdf) format.

8.1.2 Survey Data
Once initial post-processing and export procedures have been completed by survey personnel (see SOP#6 – Initial Post-Survey Processing), the following datasets will be delivered for each park, twice per year, to the NCBN Data Manger or Project Leader. Files will be delivered in digital format by mail via CD/DVD or as compressed archive files via email or FTP.

1. All raw RTK-GPS data files, including Trimble data collector (.dc format) and job (.job format) files downloaded from the GPS unit
2. All processed RTK-GPS coordinates derived from the above Trimble job files and exported in comma-delimited (.csv) format
3. Scanned versions of all field data forms (Adobe .pdf format) associated with each Trimble job file
4. One Trimble Business Center (TBC) project file (.vce format)
5. One ESRI shapefile (.shp format) containing all profile points having undergone quality control procedures as outlined in SOP#6 – Initial Post-Survey Processing.
6. A metadata file for the above shapefile that complies with Federal Geographic Data Committee (FGDC) standards and the NCBN spatial metadata template (available from the NCBN Data Manager)
7. All digital photographs taken at each profile location during the survey.

8.1.3 Analysis and Reports
In addition to the collection and initial processing of shoreline positional data, Network personnel or contracted investigators will periodically conduct analyses of topographic change using the

Landform Elevation Models. These investigators will also produce annual and long-term (five-year) reports summarizing and interpreting the results from the above analyses. Copies of these reports will be delivered to the NCBN project leader and stored primarily in Adobe .pdf format.

8.2 The Microsoft Access Database

All raw data collected annually as part of the Coastal Landform Elevation Model Monitoring Protocol will be entered into the NCBN Coastal Topography Monitoring database, a Microsoft Access relational database that is compliant with the NPS Inventory and Monitoring Division Database Standards (https://irma.nps.gov/DataStore/Reference/Profile/222420).

Key aspects of the database design include:

- Ease of data entry, mirroring as closely as possible the processes for recording data on Protocol field sheets;
- Built-in quality assurance features (e.g., primary keys, cascading edits though multiple tables, lookup tables, numeric range limits, etc.); and
- Standardized formatting allowing for ease of data sharing and cross dataset analyses.

8.2.1 File Management and Documentation

It is the responsibility of the NCBN Data Manager or designated Project Leader to assemble and maintain the various components of the Coastal Landform Elevation Model Dataset described above. The monitoring protocol generates a number of raw data products and reports that are not suitable for direct storage within a relational database, including raw and post-processed RTK GPS data files, Trimble Business Center project files, ESRI shapefiles, scanned field sheets (.pdf), and digital photographs. In order to ensure proper functioning of the Coastal Landform Elevation Model Monitoring Database and to generally ease the data retrieval process, the Database User's Guide identifies a coherent, consistent directory structure to store data files.

The master (i.e., most current) version of the Coastal Landform Elevation Model Monitoring Database will reside on the Network file server under the main drive in the file structure outlined in Figure S8.1.

In order for hyperlinks within the database to work properly, the main folder 'CoastalTopo3D_Monitoring_Datasets' should be placed at the same directory level as the Microsoft Access monitoring database itself (Fig. S8.1) and within the structure of the main 'CoastalTopo3D_Monitoring_Datasets' folder (Fig. S8.2). This directory structure, along with naming conventions for the various file types, is outlined in detail in the Database User's Guide.

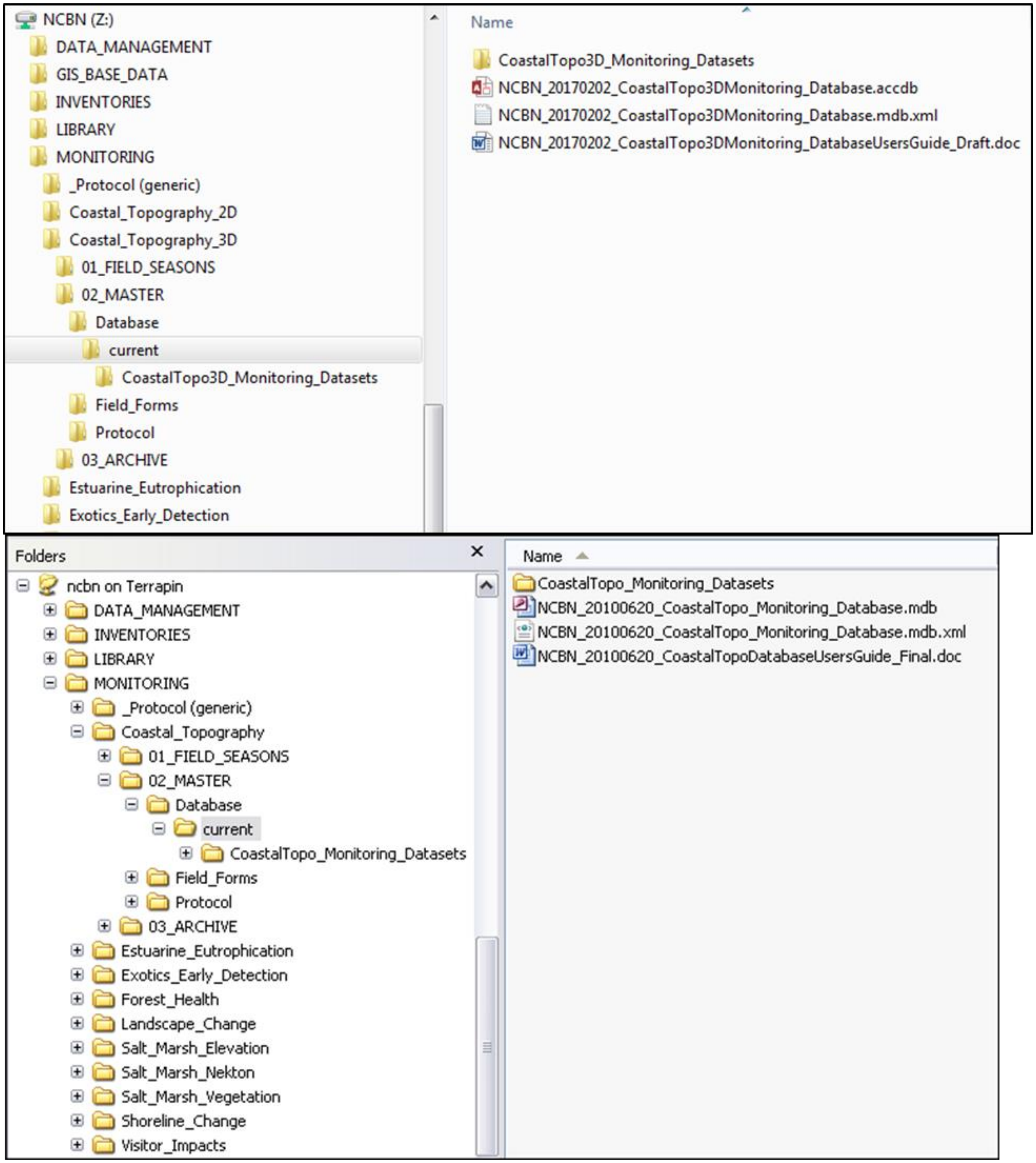


Figure S8.1. Location of Access database within the Network file server directory structure.

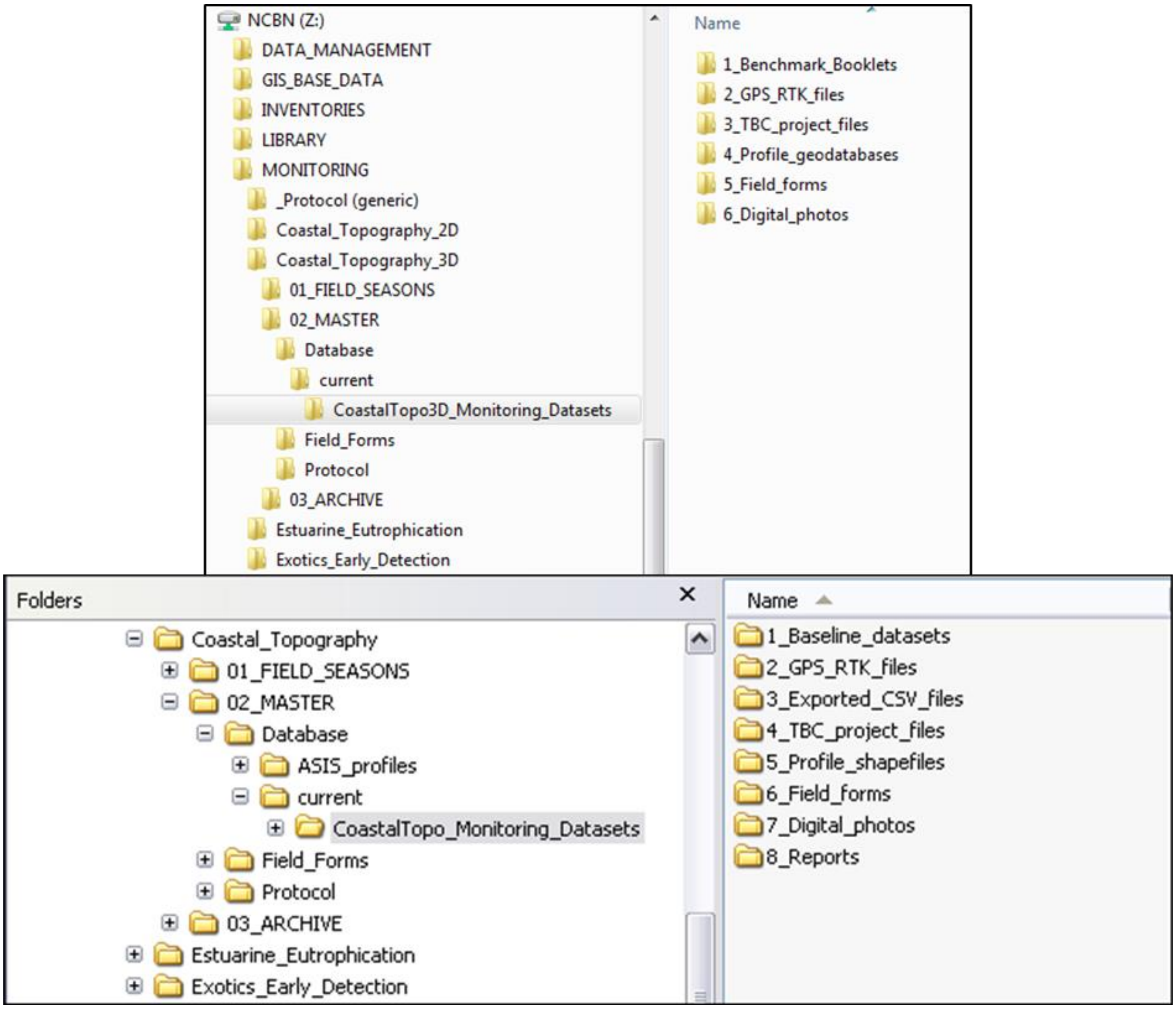


Figure S8.2. Directory structure for data files associated with the Coastal Landform Elevation Model Monitoring Database.

8.2.2 Data Entry

The NCBN Data Manager or designated Project Leader will be responsible for entering all data into the Access database. Data collected using paper field sheets should be entered as soon as possible following data collection when field technicians' memories are fresh and discrepancies in the data are more easily resolved. The *NCBN Coastal Landform Elevation Monitoring Database User's Guide*, provides comprehensive instructions on entering raw data into the Microsoft Access application.

1. **Baseline datasets.** For each area of interest, investigators have developed and surveyed benchmark locations and permanent transects against that subsequent RTK GPS data will be compared. Benchmark features are stored in ESRI shapefiles (one per park or park unit, when applicable), as are the transects. These files, as well as their accompanying metadata are generated once and should be placed in the "Baseline_datasets" folder as indicated above.

2. **RTK-GPS files.** The original GPS data points are an integral component of the coastal topography dataset, allowing for the recreation and replication of any subsequent calculations or derivations. The raw data files that are directly downloaded from the GPS data collector contains information beyond the horizontal vertical point positions, including information concerning the precision and accuracy of the position, time and date of collection, equipment used, number of satellites, signal to noise ratio, etc. If Trimble GPS data collectors such as the R8, R10, or 5700 are used, these data will be in proprietary data collector (.dc) and job (.job) formats.

   If there is any question as to whether prescribed GPS data collection parameters have been exceeded (see SOP #4), the NCBN Data Manager or Project Leader should refer to these files to determine that GPS unit settings for data collection have been correctly applied.

   Because these files are typically in non-tabular and proprietary formats, their content are not entered directly into the database. Rather the files themselves are linked in the database via a stored, relative directory path. Step-by-step procedures for linking these files to the database are found in the Database User's Guide.

   All exported RTK-GPS coordinates derived from the above Trimble job files are exported in complementary comma-delimited (.csv) files. These files are stored in the "3_Exported_CSV_files" folder and are also linked to the database via stored relative path information. A single Trimble Business Center project (.vce) file is similarly stored in the folder "4_TBC_project_files" and is linked within the database.

   Finally, a single ERSI shapefile (.shp) per survey season per park is generated from the above comma-delimited (.csv) files and is likewise stored in the folder "5_Profile_shapefiles" and linked within the database.

3. **GPS coordinates.** The RTK-GPS coordinates (horizontal positions plus elevations) are the core data of the Coastal Landform Elevation Model Monitoring Protocol and compose the basis for all subsequent analyses. In order to store these data in a manner that facilitates their ability to be searched, filtered, and exported for analysis, these coordinates are extracted from the database (.dbf) files of each of the above-mentioned ESRI shapefiles (.shp) and are subsequently appended to a single data table within the Access database. The Database User's Guide outlines the process for importing these data from the deliverables in #2 above.

4. **Field data forms.** The Field Data Forms collected in conjunction with the individual RTK-GPS surveys (one form per day per surveyor) provide information essential to the usability and verification of the dataset. If not already converted, the NCBN Data Manager or Project Leader will scan hard-copy field data forms and export them as Adobe .pdf files. These files are then stored in the folder "6_Field_forms" and linked within the database according to the steps outlined in the Database User's Guide.

5. **Digital photographs.** Digital photographs are taken to document the condition of the area of interest during RTK-GPS data collection. Additional photos may also be taken to document any unusual features encountered during data collection (e.g., the presence of a large scarp,

overwash areas, etc.). These files are stored in the folder “7_Digital_photos” and linked within the database according to the steps outlined in the Database User’s Guide.

6. **Reports.** Copies of all annual and long-term trend reports are stored in the folder “8_Reports.”

8.2.3 Spatial Data Validation

All features within the benchmark (point) and transect (line) shapefiles undergo initial QA/QC before being delivered to the NCBN (see SOP#6). Upon receipt, the Data Manager or a designated technician familiar with GIS software will also validate these spatial features using the following procedures:

1. In a GIS, overlay all features on available, well documented GIS vector data and imagery for the park unit. The NCBN Data Manager will provide the appropriate spatial datasets, such as:
   - DOQQ’s or other orthophotography
   - Georeferenced park visitor maps
   - Best available park boundary coverages
   - Wetlands
   - Hydrography
   - Roads
2. Label and visually inspect the location of all station features. Note any apparent discrepancies, such as:
   - Features located partially or wholly outside of the park boundary
   - Features associated with habitat types other than the beach-dune-cliff system
   - Two or more sampling stations sharing the same coordinates
3. Check all benchmark and transect features against their corresponding quality control buffer features described above. Any features falling outside of their respective buffers should be brought to the attention of the survey team.

For all noted discrepancies, it is advisable to first consult the original .csv files to rule out possible errors resulting from manipulating the original coordinate data in Microsoft Excel, text editors, etc. Such potential errors would include those arising from the improper transcription of coordinates or incorrect projection information. Remaining questions should be resolved by first consulting the associated field sheets and/or contacting the survey team who collected the data. If the problem cannot be corrected, the feature will be removed from the final dataset and the survey team will collect a new feature as soon as possible. All changes should be indicated and initialed on the field sheet and noted in the protocol database.

8.2.4 Data Verification

In order to minimize transcription errors, each line of data will be verified against the original field data sheets by a second person. If no staff members are available, the Project Leader or Data

Manager should verify 100% of the data entry. Fields indicating the verification of records (date verified, reviewer's name, etc.) are included within the database. In addition, 10% of records will be reviewed a second time by the Project Leader. The Project Leader will convey the results of this comparison to the Data Manager, who will incorporate the information into the database's metadata file during the final review / archiving process.

The Coastal Landform Elevation Model Monitoring Database contains features designed to aid the Project Leader in the data verification process. These features can be found from the database Main Menu by clicking 'Analysis and Reports' → 'Export Data to Excel.' (These Excel files summarize data that are otherwise stored or displayed in multiple tables and forms within the database, greatly facilitating visual inspection of the records.)

Once all field data for a season have been entered into the database, the Project Leader should export the *Profile Verification* Excel file and check that coordinates exist for each profile with a given park and year.

Finally, in order to ensure that all records have indeed been verified for a field season, the Project Leader should export the *Data Verification* Excel file and determine that the *Last_Name* and *Verified_Date* fields are complete.

8.3 Data Backup

8.3.1 Local Data Backup

Backups of the Coastal Landform Elevation Model Monitoring project directory (including the protocol and database) are made daily per an arrangement with the University of Rhode Island Field Technical Support Center (URI FTSC). Incremental (daily) backups of NCBN data drives are maintained on a weekly basis, culminating in a full backup at the end of each week. Weekly backup tapes are retained for six months. Semi-annual full backups are retained in perpetuity at an off-site data archive.

8.3.2 Export to ASCII for Backup:

As software and hardware evolve, datasets must be consistently migrated to new platforms, or they must be saved in formats that are independent of specific platforms or software (e.g., ASCII delimited files). NCBN archiving procedures include saving datasets in both their native format (typically MS-Access or Excel spreadsheet format) and as sets of ASCII text files. As a platform- and software-independent format, ASCII text files ensure future usability of the data in a wide range of applications and platforms.

As part of the annual archiving of the Coastal Landform Elevation Model Monitoring Database, the Network Data Manager will produce such ASCII text files for all tabular data within the database. A Microsoft Access utility designed for this task called "Exportdb" is available via the NPS I&M Intranet (http://www1.nrintra.nps.gov/im/datamgmt/dtbases/links_sources/data_tools/exportdb.zip), or on the NCBN main data server at \DATA_MANAGEMENT\Tools\NRDTv3\add_ons. Exportdb will write the following ASCII comma-delimited text files for each database:

- TABLEDEF.txt - This file will contain one record for every table in the selected database. Fields in the file include Table_Name, Table_Description, Table_Format, Number of Fields, Export_Date.
- FIELDDEF.txt - This file will contain one record for every column in every table in the selected database. Fields in the file include Table_Name, Field_Name, Field_Description, Field_Type, Field_Width.
- One comma-delimited ASCII text file containing all the data rows in each table in the selected database.

Exportdb displays a single form containing three function buttons (Fig. S8.3):

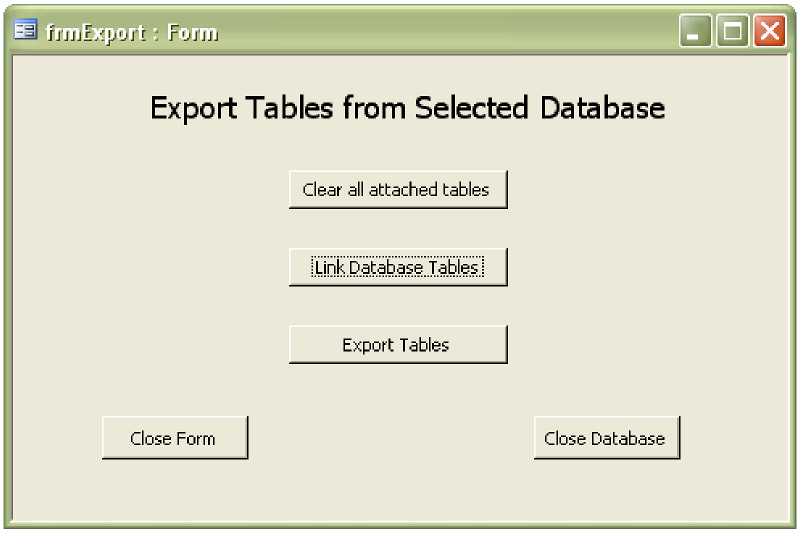


Figure S8.3. Screenshot of the Exportdb Microsoft Access utility displaying a single form containing three function buttons.

The "Clear all attached tables" button will clear all tables linked from previous sessions. The "Link Database Tables" button will open a browse window to allow the selection of the Microsoft Access database for export. (Note: the utility will not export tables that are linked to a back-end database.)

The "Export Tables" button will open a browse window to allow selection of the destination directory for the text files. Once a directory is selected, the export will be performed.

Alternatively, the following procedure can be used to export tables directly from the Monitoring Database:

1. In the Database window, click the name of the table, and then on the File menu, click Export
2. In the Save as type box, click Text Files (*.txt; *.csv; *.tab; *asc)
3. Click the arrow to the right of the Save in box, and select the drive or folder to export to
4. In the File Name box, enter a name for the file (or use the suggested name), and then click Export

8.4 Archiving

Datasets associated with the Coastal Landform Elevation Model Monitoring Protocol will be archived on an annual basis, both in their native formats as well as ASCII text files. Archived datasets will include both tabular data in MS-Access format as well as spatial data. Network staff are responsible for preparing tabular data from the protocol for archival following completion of standard QA/QC procedures. The Network Data Manager then prepares the tabular data for archiving by creating:

- A set of ASCII comma-delimited text files for the tabular data files and tables comprising the dataset
- An XML file that preserves relationships between tables for each MS-Access database
- A readme.txt file that explains the contents of each ASCII file, file relationships, and field definitions

Quality control checks are then performed on these ASCII files to ensure that the numbers of records and fields correspond to the source dataset and that conversion has not created errors or data loss. If possible, a second reviewer, preferably a program scientist, checks the ASCII files and documentation to verify that tables, fields, and relations are fully explained and presented in a way that is useful to secondary users.

Following each field season, the Data Manger will archive a dataset consisting of the following elements:

1. A copy of the Coastal Topography Landform Elevation Model database containing all data from the current field season (with accompanying FGDC-compliant metadata)
2. Spatial datasets and FGDC-compliant metadata for all station locations visited during the past year
3. ASCII text file versions of the data products mentioned above
4. Digital (.pdf) copies of the field forms from each survey for that year
5. A digital (.pdf) copy of the final Annual Report
6. Once every five years, a copy of the Long-term Report

When a project dataset is ready to be archived, the Data Manger will package all relevant files into a compressed archive file (e.g., ZIP or RAR file format), that will adhere to the following naming convention:

NCBN_[Date]_[Author]_CoastalTopo3DMonData_Archive_Final.rar

The archive will be placed on the NCBN data server in the appropriate directory location, i.e.:

\\MONITORING\Coastal_Topography_3D\03_ARCHIVE\[Year]

Archives, along with all data files residing on the NCBN data server, are backed up daily by the URI Environmental Data Center, and archived off-site with the NPS Boston Support Office twice per year.

8.5 Database Revision Control

Because the Coastal Landform Elevation Model Monitoring Database follows the IMD database design guidance, a table describing database revision history (tbl_Db_Revisions) and linking to the database metadata (tbl_Db_Meta) is included as a core table in each component database file (i.e., front end and back end Access files). Revisions will be performed periodically by or in conjunction with NCBN staff as the need arises and should be documented fully in the above tables, as well as in the database metadata.

On an annual basis, the Data Manager or Project Leader is responsible for identifying and documenting any changes needed for the Coastal Landform Elevation Model Monitoring Database. The Data Manager is then responsible for making these changes to the database, the accompanying Database User's Guide, and this Data Management SOP (See SOP #9 - Revising the Protocol).

8.6 Data Distribution

Access to NCBN data products will be facilitated via a variety of information systems that allow users to browse, search, and acquire Network data and supporting documents. All annual and long-term reports will be posted on the NCBN website (https://science.nature.nps.gov/im/units/ncbn/) and accessible through the Data Store application via the NPS Integrated Resource Management Applications (IRMA) portal (https://irma.nps.gov/Portal). Metadata associated with all spatial and tabular datasets will be posted on the NPS Data Store requests for the actual data can be made by contacting the NCBN Data Manager:

Northeast Coastal & Barrier Inventory & Monitoring Network
Data Manager
University of Rhode Island
Room 105 Coastal Institute
1 Greenhouse Road
Kingston, RI 02881
Fax: 401-874-4561

Standard Operating Procedure (SOP) # 9 - Revising the Protocol

Version 1.0 (May 2018)

The following table lists all changes that have been made to this Standard Operating Procedure since the original publication date. Any recommended or required changes added to the log must be complete and concise and promptly brought to the attention of the Project Leader. The project leader will review and incorporate all changes, officially complete the revision history log, and change the date and version number on the title page. For complete instructions, please refer to SOP#9 – Revising the Protocol.

Revision History Log:

New Version #	Previous Version #	Revision Date	Author (full name, title, affiliation)	Location in Document and Description of Change	Reason for Change

Due to the long-term nature of the NCBN monitoring program, revisions to the Protocol Narrative and to individual Standard Operating Procedures (SOPs) will be necessary from time to time (O'Ney 2005). Careful documentation of changes to the Narrative and its related SOPs, along with a library of previous versions, are essential for maintaining consistency in the collection, summary, analysis, and reporting of data.

The Revision History Logs found at the beginning of the narrative and each protocol SOP list all edits to that section since the original publication date. Information entered in these logs should be complete and concise. The logs track the previous version date and number, date of revision and new version number, author(s) of revision, location of changes within the document, description of change, and the reason the change was made. Author information must include full name, title, and affiliation.

The Master Version Table found immediately after the Protocol Narrative's Revision History Log tracks the relationships between the Narrative and the associated SOP's. The use of this table is discussed in detail below.

9.1 Instructions for Recording Revisions

Protocol users must promptly notify the Project Leader about recommended and/or required changes. The Project Leader will then review and incorporate all changes, update the Revision History Log and Master Version Table, and change the date and version number on the title page.

9.1.1 Minor Revisions

Minor revisions are those that do not represent a change in the underlying methods or procedures used to generate data values for the protocol's existing data set. Minor revisions include small changes in, or clarification of, procedures. Version numbers for minor revisions increase incrementally by hundredths (1.01, 1.02 . . .).

9.1.2 Major Revisions

Major revisions are those that involve changes in methodology that could influence the resulting data values and the ability to compare newly collected data with data collected using a previous version, such as:

- Addition of monitoring objectives
- Changes to the sampling design
- Changes to reporting requirements
- Addition of new variables

Major revisions are designated with the next whole number in the sequence (2.0, 3.0, 4.0...).

9.1.3 Coordinating Narrative and SOP Versions

In order to track the most current version numbers of all SOPs associated with a particular protocol version, the Project Leader will also maintain the Master Version Table, which immediately precedes the Narrative's Revision History Log. A new entry must be made each time the Narrative and/or any SOPs are modified. In cases where the Narrative and/or one or more SOPs have undergone only minor revisions, the overall protocol version number will itself increase incrementally by hundredths. In cases where the Narrative and/or one or more SOPs have undergone a major revision (whether or not other sections have undergone minor revisions), the overall protocol version number will increase incrementally by whole numbers. The Master Version Table tracks the relationships between the protocol narrative and the associated Standard Operating Procedures (Table S9.1).

Table S9.1. Example of Master Version Table reflecting possible revision scenarios and associated numbering of the protocol.

Master Version Table: Coastal Topography Monitoring Protocol and Standard Operating Procedures												
Date of Revision	**Protocol**	**Narrative**	**SOP #1**	**SOP #2**	**SOP #3**	**SOP #4**	**SOP #5**	**SOP #6**	**SOP #7**	**SOP #8**	**SOP #9**	**SOP #10**
1/1/2010	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
6/1/2010	1.01	1.01	1.01	1.00	1.00	1.00	1.01	1.00	1.00	1.00	1.01	1.01
8/2/2010	2.00	1.01	1.01	1.00	1.00	2.00	1.01	1.00	1.00	1.00	1.01	1.01
1/10/2011	3.00	2.00	1.01	1.00	1.01	2.01	1.02	1.00	1.00	1.01	1.02	1.01

The Project Leader will also update all associated field forms to reflect the change in protocol version. Users noting discrepancies in versions between the protocol, SOPs, data values, and field forms should notify the Project Leader so that corrections can be made and documentation kept current.

9.2 Reviewing Suggested Protocol Revisions

All suggested edits require review by the Project Leader for clarity and technical soundness. Small changes or additions to existing methods will be reviewed by NCBN staff. However, if a significant change in methods is recommended, additional expert review may be required.

9.3 Communicating Changes to Investigators / Users

Once changes have been made, the updated document is posted on the NCBN web site (http://www.nature.nps.gov/im/units/ncbn/) and is added to the National Vital Signs Monitoring Protocol Database (http://science.nature.nps.gov/im/monitor/VitalSigns/BrowseProtocol.aspx). All previous versions are archived in the NCBN information system and can be obtained by contacting the Data Manager. Each time an SOP is revised, the Project Leader ensures that all known users obtain a current copy of the SOP and receive the necessary briefing material and/or training to understand and incorporate the change(s). Users are encouraged to visit the network web site and/or contact the Project Leader at least once per season to check for updates associated with the monitoring protocol.

Standard Operating Procedure (SOP) # 10 - Field Safety

Version 1.0 (May 2018)

The following table lists all changes that have been made to this Standard Operating Procedure since the original publication date. Any recommended or required changes added to the log must be complete and concise and promptly brought to the attention of the Project Leader. The Project Leader will review and incorporate all changes, officially complete the revision history log, and change the date and version number on the title page. For complete instructions, please refer to SOP 9: Revising the Protocol or SOPs.

Revision History Log:

New Version #	Previous Version #	Revision Date	Author (full name, title, affiliation)	Location in Document and Description of Change	Reason for Change
1.00	none	April 12, 2013	Dennis Skidds Data Manager, Northeast Coastal and Barrier Network	Initial SOP	Initial SOP

10.1 Introduction

Whereas it is the goal of the Northeast Coastal and Barrier Network to ensure a safe working environment for all employees, cooperators, contractors, and volunteers ("staff"), each individual is responsible for ensuring his or her own safety in the field. Safety concerns should be brought to the attention of either the NCBN Program Manager or the NCBN Shoreline Project Leader as soon as possible. Because shoreline position change is monitored in several parks each spring and fall, it is critical that individual park policies regarding safety are respected and followed.

This SOP was designed to provide an overview of safety issues that should be covered during pre-season training and to serve as a first reference in case of an incident. Topics covered include emergency procedures and contacts, incident reporting, field preparation, safe field procedures, and vehicle safety. A Green-Amber Red Risk Assessment (GAR) has been conducted for this protocol, as has a Job Safety Analysis (JSA), that documents hazards associated with this protocol and recommends approaches to mitigate these hazards. These documents are available on the NCBN website. The JSA must be read and signed by all staff members who conduct field work for this protocol. This SOP does not cover first aid procedures.

10.2 Responding to an Incident

10.2.1 Life-Threatening Medical Emergency

1. **Call 9-1-1 or park emergency number. If available, use an NPS radio to contact dispatch.** It is the responsibility of the Project Lead to obtain and provide to monitoring staff

current park emergency contact information prior to conducting the shoreline survey. The Project Lead will verify this information on an annual basis.

2. Administer first aid to the best of your knowledge, ability, and training. If appropriate, transport to emergency room
3. As soon as it is practical to do so, inform your supervisor and the park emergency contact. If your supervisor is not an NPS employee, the supervisor must contact the NCBN Program Manager as soon as it is practical to do so.
4. For NPS staff and volunteers, work with the Project Lead and Program Manager to complete Worker's Compensation paperwork (must be done within 48 hours of incident). For contractors and cooperators, follow your organization's procedures for documenting accidents, and notify the NCBN Program Manager with details of the incident.

10.2.2 Non-Emergency Incidents

1. Contact your supervisor immediately after the incident. If your supervisor is not an NPS employee, the supervisor must contact the NCBN Program Manager as soon as it is practical to do so.
2. For NPS staff and volunteers, work with the Project Lead and NCBN Program Manager to complete Worker's Compensation paperwork (must be done within 48 hours of incident). For contractors and cooperators, follow your organization's procedures for documenting accidents, and notify the NCBN Program Manager with details of the incident.
3. Seek medical attention, if needed.

NOTE: Never discard original paperwork related to workers compensation claims (including information from doctor's visits, and CA-1, CA-2, CA-16 or CA-17 forms).

10.3 Safety Equipment Carried in the Field

The following is a list of safety materials and personal items that are commonly used when conducting salt marsh monitoring:

- Cellular phone (required)
- 2-way radio (available at FIIS, SAHI, and other parks if requested)
- Helmet, goggles, gloves (if using an ATV)
- Collapsible shovel, boards, extra fuel can (if using an ATV)
- First aid kit
- Insect repellant
- Drinking water and snacks / lunch
- Hat, sunscreen, and sunglasses

If a particular park requires the use of a two-way radio, it will be provided. A cellular phone is required regardless of whether or not a 2-way radio is used. A first aid kit for use during data collection will be provided by the Network. A first aid kit must always be brought into the field. Staff members are responsible for providing and packing their own boots, food and drinking water, bug repellant, sunscreen and other personal items needed for each field day.

10.4 Working as a Team

Although the shoreline position monitoring is generally conducted by a single field technician, there are circumstances when working in a team becomes necessary (e.g., the shoreline has become hazardous or difficult to navigate due to a recent a storm event). To ensure safe and successful field data collection, it is important that staff members recognize their roles as part of the monitoring team and that all individuals take steps to be informed about potential hazards and park policies. The Project Leader will review the equipment each technician is expected to have with them at all times (e.g., GPS unit, batteries, cell phone or radio, water, sunscreen, insect repellant). In addition to equipment used for shoreline position change monitoring, staff members are responsible for packing any personal items needed for working in the field.

10.5 Job Safety

An important tool used to promote safe conduct is the Job Safety Analysis (JSA; sometimes called a Job Hazard Analysis or JHA). This approach is consistent with NPS Directors Order 50 and Reference Manual 50B for Occupational Health and Safety. The JSA process is to (1) identify hazards associated with field and laboratory settings, as appropriate, and (2) develop approaches to mitigate those hazards. All monitoring staff for this protocol (including individuals who are observing or only participating for a short time) must read and sign the JSA for this protocol. In addition, monitoring staff must read the entire Safety SOP before deploying to the field.

10.6 First Aid Kits and Training

A first aid kit should be with monitoring staff members at all times while in the field. An inventory of first aid kits should be performed prior to each field season to ensure that all medical supplies are in sufficient quantity and haven't expired. Each first aid kit will have an inventory list of the supplies it should contain. Items in first aid kits that are used should be promptly replaced.

10.7 Maintaining Communication

Staff are expected to carry a mode of communication at all times while in the field. Unless they are water proof, these items should be stored in a water resistant or water proof container (e.g. Ziploc bag). At some parks (e.g., FIIS, SAHI), a radio will be provided upon request, but a cell phone should be used as a secondary mode of communication.

In cases where data will be collected by monitoring staff not directly employed by the relevant park unit (e.g., personnel who are duty stationed at the NCBN offices, university cooperators, volunteers, etc.), the Program Manager and the Project Lead will establish a Memorandum of Understanding (MOU) between the NCBN and the park, designating someone at the park to serve as an official point of contact (POC) for the monitoring staff. It is the responsibility of the Project Lead to obtain and provide to monitoring staff the name and contact information for the POC before deployment to the field. (The Project Lead will verify this information on an annual basis.)

Monitoring staff must notify the appropriate park POC with expected dates of field work. The POC will also be provided with the location(s) where sampling will be conducted, estimated departure and return time, a description of the vehicle used for transportation to the field site, a description of the vehicle used for conducting field work (if applicable), and monitoring staff contact information (e.g., cellular phone numbers). The POC must be instructed to not take failure to check in lightly; if the staff member fails to check-in on or before 1) the planned, hourly check-in times, or 2) the completion of field work, the POC will immediately try to reach the team by all available methods. If the crew has not been reached within 30 minutes, the POC must notify emergency services and initiate a search. If the trip is cancelled or if the plan changes while in the field, staff must notify the POC immediately.

All crew members are responsible for being aware of the time and ensuring that hourly and end of day check-ins occur on schedule; the POC will call emergency services if the crew misses their check in and cannot be located within 30 minutes of the check-in time.

10.8 Allergies / Medical Conditions

All allergies or special conditions must be brought to the attention of the Project Lead and other monitoring staff prior to the beginning of field work. Individuals are required to carry any necessary medications (i.e., EpiPens, inhalers) and medical alert tags on their person at all times.

10.9 All-Terrain Vehicle (ATV) Safety

Any staff member who will be operating an all-terrain vehicle (ATV), utility terrain vehicle (UTV), or other off-road vehicle (ORV) during the course of data collection must complete the safety training required by the park unit in which the field work will be conducted. Each park may implement specific operating requirements, and staff are responsible for following individual park protocols. Park-specific ORV operation SOPs will be available through the Project Lead. It is the responsibility of the Project Lead to obtain any updates to such SOPs on an annual basis.

10.10 Vehicle Safety

Staff are responsible for inspecting their government vehicles before every use to ensure the vehicles are in safe working condition. This includes visually checking tire pressure, adjusting mirrors, and making sure equipment is secure. Monitoring staff utilizing government vehicles must perform preventative maintenance in a timely manner (e.g., having oil changed by a qualified mechanic), and report any potential hazards or needed repairs to their supervisor.

Rules that must be followed when operating a vehicle:

- Everyone in a government vehicle is required to wear a seat belt, and when using other vehicles seat belts are mandatory where required by law, and strongly recommended in all situations.
- Texting or any other cell phone use is strictly prohibited while driving a government vehicle and it is strongly recommended that staff avoid use of cell phones while driving any vehicle.
- Only federal employees or authorized volunteers, cooperators and contractors are allowed to operate a government vehicle.

- Passengers who are not federal employees, volunteers, or authorized cooperators and contractors are forbidden from riding in a government vehicle.
- Drivers must adhere to all federal and state vehicle regulations, including all posted speed limits.

Because government vehicles are self-insured, damage resulting from government vehicle accidents are generally paid by the driver's program (e.g., NCBN). However, in cases of severe negligence, the driver found at fault for the accident may be personally liable.

Procedures for reporting a motor vehicle accident:

1. Seek medical attention if needed.
2. If the incident involves a government vehicle, follow the Northeast Region accident/incident reporting guidelines. A copy of these guidelines and the corresponding forms (SF 91 and SF94) should be located in the glove compartment of every federal vehicle at all times. If the incident involves a contractor or cooperator vehicle, follow your organization's procedures for documenting accidents, and notify the NCBN program manager with details of the incident.

10.11 Recognizing the Potential Hazards of the Shore

10.11.1 Plants, Insects, and Wildlife

Monitoring staff should be acquainted with potential wildlife/plant and marine organism hazards encountered during fieldwork, including ticks, mosquitoes, stinging insects, snakes, and poison ivy. Staff should be able to identify and be alert to the presence of noxious plants (e.g., poison ivy, poison oak) so contact may be avoided whenever possible. Individuals should be aware of their individual sensitivity to noxious plants, pre-treat with a skin barrier product, and wash thoroughly at the end of the day. (Washing with liquid dish detergent helps to remove noxious plant oils from the skin). Warning labels on insect repellants should be read thoroughly, and only the minimum amount of repellant needed for protection should be applied. Insect repellant is only applied to clothing and not under clothing.

Guidelines for preventing tick borne illness:

- A good source of information regarding Lyme Disease and other tick borne illnesses is the Center for Disease Control website, available at http://www.cdc.gov/ncidod/dvbid/lyme/index.htm.
- If sampling is conducted in areas where ticks are present, precautions (e.g., light colored clothing, long sleeves and pants) should be taken to minimize exposure to tick bites. Pants should be tucked into socks and taped. Shirts should be tucked into pants.
- Apply insect repellant containing DEET (20-30% concentration) to your clothing for further protection. Permethrin kills ticks on contact. If using Permethrin, do not apply to clothes while they are being worn. Clothing should be treated and allowed to dry prior to wearing. Permethrin should be applied to clothing only—when applied to skin it loses effectiveness within 20 minutes.

- Check field clothes for ticks before entering living space or vehicles.
- Conduct daily self-checks for ticks immediately upon returning from the field. Pay particular attention to armpits, navel, ears, and groin, and use a mirror when doing self-checks.
- If a tick is found, remove it from the skin as soon as possible. Use fine-tipped tweezers to firmly grasp the tick very close to the skin. With a steady motion, pull the tick's body away from the skin. Clean the area with alcohol or soap and water. Avoid crushing the tick's body. Prior to removal, do not attempt to burn or smother the tick as this will increase the chances of it regurgitating fluids and increase the risk of disease transmission. The tick's mouthparts may remain in the skin after the tick is removed. As long as the tick's head and body are removed from the skin, it can no longer transmit disease.
- Document the tick bite; include the date and time of discovery as well as the location of fieldwork over the last two to four days.
- If a tick bite is found, monitor yourself closely for signs and symptoms of tick borne diseases for up to 30 days. Symptoms of tick-borne illnesses typically take several days to weeks to develop. Most people develop a single itchy red welt at the site of a tick bite. This welt can be up to the size of a quarter and may last for several weeks. This welt does not indicate infection with a tick borne illness. More severe rashes and rashes that spread, or cover a large area will require medical evaluation.
- Seek medical attention if symptoms of tick borne illnesses develop within 30 days of removing an attached tick. These symptoms may include a large bull's eye rash around the tick bite, a pronounced spotted rash on extremities, high fever, headaches, or unexplained joint aches. When seeking medical attention, select a doctor who is familiar with tick borne illnesses.

Guidelines for preventing mosquito-borne illnesses—West Nile Virus, encephalitis:

- A good source of information regarding West Nile Virus and encephalitis is the Center for Disease Control website:
- http://www.cdc.gov/ncidod/dvbid/westnile/index.htm , and http://www.cdc.gov/ncidod/dvbid/arbor/eeefact.htm
- Stay informed about the presence of West Nile or encephalitis at or near monitoring sites.
- To reduce mosquito bites, wear long pants and head-nets, consider wearing long sleeves. Tuck pants into socks and tuck shirts into pants. Reinforce thin areas of clothing (such as pockets) with duct tape.
- Spray clothing with insect repellent as a barrier, or use clothing made of repellent-impregnated fabric.

10.11.2 Other Environmental Hazards

In addition to wildlife and plant hazards, staff should be prepared to work in uneven or steep terrain. Some shoreline features, such as bluff tops, can be steep and potentially unstable. Monitoring staff should utilize field methods (e.g., offsets or laser range finders) that allow them to collect data at a safe distance from unstable or dangerous features.

Shoreline features are generally in the open, without significant sources of shade. Therefore, steps must be taken to prevent heat injuries such as dehydration and heat exhaustion. Stay informed about the weather, and be prepared for sudden changes.

Heat - dehydration, heat exhaustion

- Be alert for early signs of heat-related illness, such as thirst, headache, confusion, crankiness, muscle weakness, or excessive or unusual fatigue. Monitor yourself and others.
- If you do notice signs of heat illness, take immediate steps to remediate the problem, such as drinking more water and resting in the shade for ½ to 1 hour. If symptoms do not lessen, seek medical assistance.

Cold - hypothermia

- Be aware of the risks of hypothermia. Hypothermia can occur in mild temperatures especially if it is windy or if clothing is wet. Dress in layers.
- Be alert for early signs of cold-related illness, such as chills, shivering, stiffening or whitening of extremities, confusion, slurred speech, muscle weakness, or excessive or unusual fatigue. Monitor yourself and others.
- If symptoms of cold illness occur, take immediate steps to remediate the problem, such as putting on more layers, moving to a warm place, drinking a warm beverage, and engaging in increased physical activity. If symptoms do not lessen, seek medical assistance.

Uneven terrain on foot - tripping, loose footing

- Particularly when collecting data on tops or toes of bluffs, be aware of steep drops or potentially unstable overhangs. Utilize offsets or laser range finders to collect data at a safe distance if necessary.
- Note the presence of recent sloughs, fallen trees or shrubs, and rocks.
- When possible, do not climb over fallen trees or other obstacles, but rather pause the survey, circumvent the obstructions, and re-initiate data collection once the obstacles has been passed.
- Look for and test secure footing.
- Take slow and cautious steps when crossing tidal creeks or inlets—the sediment is often unconsolidated.
- Maintain good communication with co-workers when working in teams.

Uneven terrain on a vehicle

- Be aware of steep beach-faces and scarps when collecting shoreline position data on an ATV or other vehicle in order to avoid rollovers. Utilize offsets or laser range finders to collect data at a safe distance if necessary.

- Be aware of the presence of drift wood, fishing gear, and other debris, particularly following storm events.
- Familiarize yourself with all jetties, groin fields, and other structures on the beach, particularly those which may become partially obscured by sand.

Adverse weather

Weather conditions can be hazardous and can change quickly. Monitoring staff are responsible for planning their day according to the local weather forecast and for being aware of their surroundings and changing conditions.

- Be acquainted with park policies regarding safety during adverse weather (i.e., high wind, rough seas, thunderstorms). You may be required to return from the field early.
- Re-schedule or shorten field days accordingly if thunderstorms are likely.
- Cover is generally limited on beaches, dunes, and bluffs, and you are usually the tallest point increasing the risk of a lightning strike. You are in danger from lightning if you hear thunder.
- If caught in a lightning storm, call the emergency contact to inform them you will be out of radio / phone contact until the lightning storm passes. Call back in after the storm has passed. If you cannot get inside and if you feel your hair stand on end, lightning is about to strike: Make yourself the smallest target possible and minimize contact with the ground (do not lie flat on the ground). Crouch down on the balls of your feet and keep your feet close together. Place your hands on your knees and lower your head. Members of a party should stay separated by at least ten feet. Information regarding lightning safety is available at http://www.lightningsafety.noaa.gov/

Tides

- Plan your field work and be alert for rising tides that may inundate depleted beaches, cutting off foot or vehicle access.
- ATVs and other vehicles should never be driven through inundated areas. When waves have reached the level of dunes or the toe of bluffs, you should turn around, return the vehicle to the nearest park maintenance facility or ranger station, and reschedule the survey.

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