

Gulf Coast Network

National Park Service
Inventory and Monitoring Division



Standard Operating Procedure SHR07

Change Calculation, Data Analysis, and Reporting— Version 1.0

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Summary

This standard operating procedure (SOP) details the comparison of GPS shoreline positions and the quantification of their differences. To compare surveys between years and calculate change, each GPS shoreline survey should be a continuous line feature from which distances to a pre-established offshore baseline are made. Distances from each GPS shoreline feature to the baseline are measured using pre-established transects at regular intervals. The results of these comparisons are exported into a distance matrix. Creation of the data matrix provides the means to characterize the entire shoreline (as a whole) as well as subsets of the shoreline (smaller areas of interest). This SOP introduces:

- The Digital Shoreline Analysis System as the recommended tool for measuring and reporting the changes in shoreline position.
- A suite of summary statistics and trend analyses that can be used in describing and comparing the spatial measures of change.
- Content and structure for the biennial report and the project trend report.

Revision Log

Revision Date	Author	Changes Made	Reason for Change	New Version #

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Objectives of this SOP

Unlike previous SOPs that describe an activity to be accomplished as a means to collect, download, and transmit the collected shoreline position data, this SOP describes the approach used to transform the GIS line feature from the shoreline survey into measurements that will be exported into the data matrix. The data matrix table serves as the basis for calculations of dimensional change. In addition to generating the data matrix of measurements, the SOP presents a series of guidelines that describe the biennial report and the project trend report.

Procedural Background Steps

The procedures described in this SOP utilize a program developed by the United States Geological Survey (USGS) entitled Digital Shoreline Analysis System (DSAS) developed to measure, calculate, and statistically analyze changes in shoreline position (Thieler et al. 2009). DSAS is an open source extension to ESRI ArcMap 10.x software. The latest version, along with installation instructions, a detailed user's manual, and additional background information, can be found at:

https://woodshole.er.usgs.gov/project-pages/DSAS/version4/images/pdf/DSASv4_2.pdf

(Himmelstross 2009).

A series of preliminary steps is required to run the shoreline change calculation in DSAS. These steps include the development of a trendline (a generalized shoreline), a corresponding offshore baseline, and the generation of transects that are equally spaced along the shoreline and extend inland from the offshore baseline. The trendline, baseline, and transects will be created for the initial survey and reused to measure shoreline change in each subsequent shoreline survey. The following section describes the steps to generate shoreline trendline, baseline, and transects.

Creation of the Trendline and the Baseline

The trendline represents the general trend of the shoreline (Figure 1) as determined using current orthophotography for each park. It is created by drawing a smoothed line along the entire length of the ocean beach shoreline. The trendline is digitized using ESRI ArcMap software and saved in a geodatabase as a polyline feature. The geodatabase serves as the storage and initial analytical container for the main GIS components of this project. The trendline is used to generate the offshore baseline from which distances to the surveyed GPS shorelines are measured. The baseline is developed by re-creating the trendline approximately 200 meters (656 feet [ft]) seaward and parallel to the smoothed shoreline (Figure 1) using the buffer function in ArcMap. This offset reference is necessary so future positions of the eroding or accreting shoreline will not intercept the baseline and thereby complicate the mathematical calculations. The trendline and baseline are created once for each park and will only need to be modified if they no longer represent the general trend of the shoreline; for example, if there is a major change such as the introduction of jetties, creating a permanent breach.

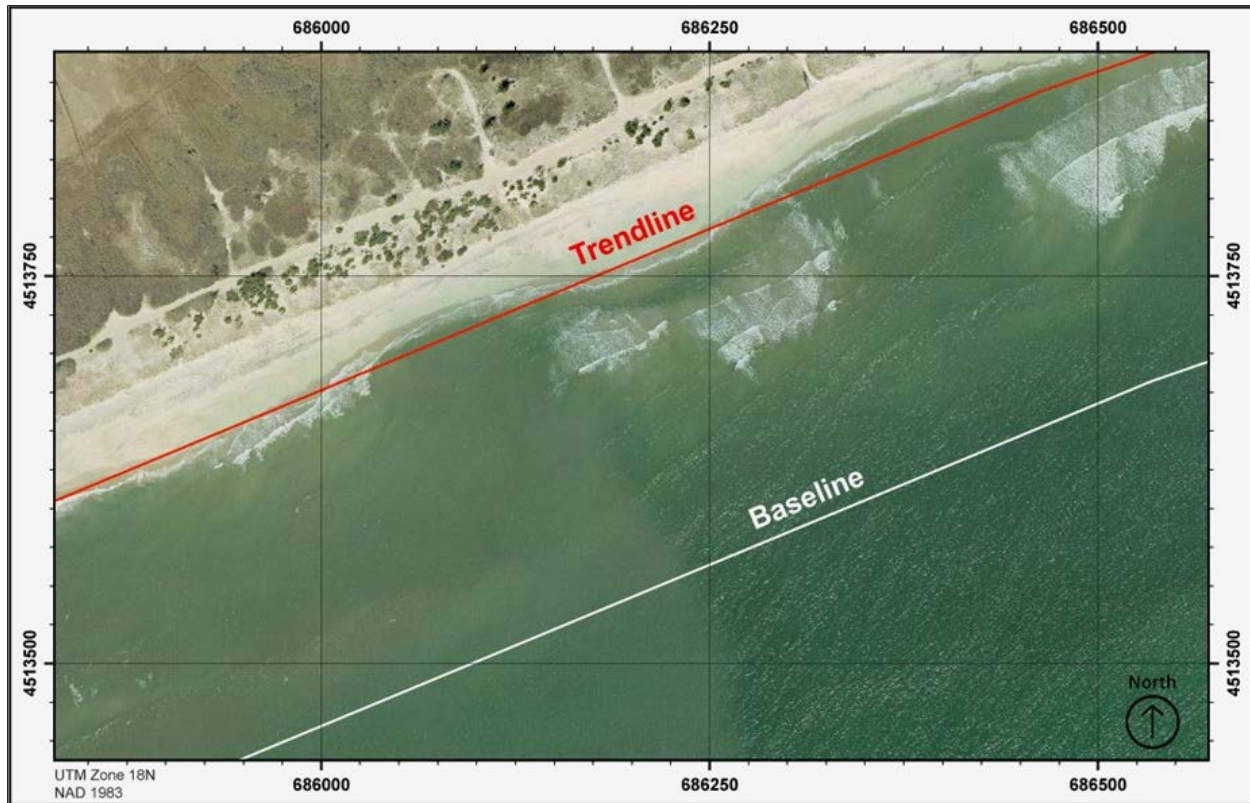


Figure 1. The trendline is a smoothed representation of the general trend of the shoreline that removes the minor features caused by local conditions. The baseline is positioned 200 meters offshore, parallel to the trendline. Figure and caption from Psuty et al. (2010).

Creation of Transects

Once the baseline is created, transects are generated using the DSAS toolbar in ArcMap. The even spacing of transects along the trendline supports the unbiased and systematic calculation of descriptive statistics, such as the mean and standard deviation, as well as calculation of trends in shoreline change. The process for creating transects is demonstrated in the user guide, Section 6, available on the DSAS website <http://woodshole.er.usgs.gov/project-pages/DSAS/version4/> (Himmelstross 2009). Details of how to correctly format files for import and use in the DSAS extension are also provided in the DSAS tutorial and user guide. DSAS allows the user to generate transects at equally spaced locations originating at the baseline. The initially-cast transects may be subsequently adjusted using DSAS and ArcGIS so that they intersect the trendline at approximately 10-meter (32.8-ft) intervals and are approximately perpendicular to the trendline (Figure 2). This final set of transects will be used in DSAS to measure distances between each GPS-measured shoreline and the baseline.

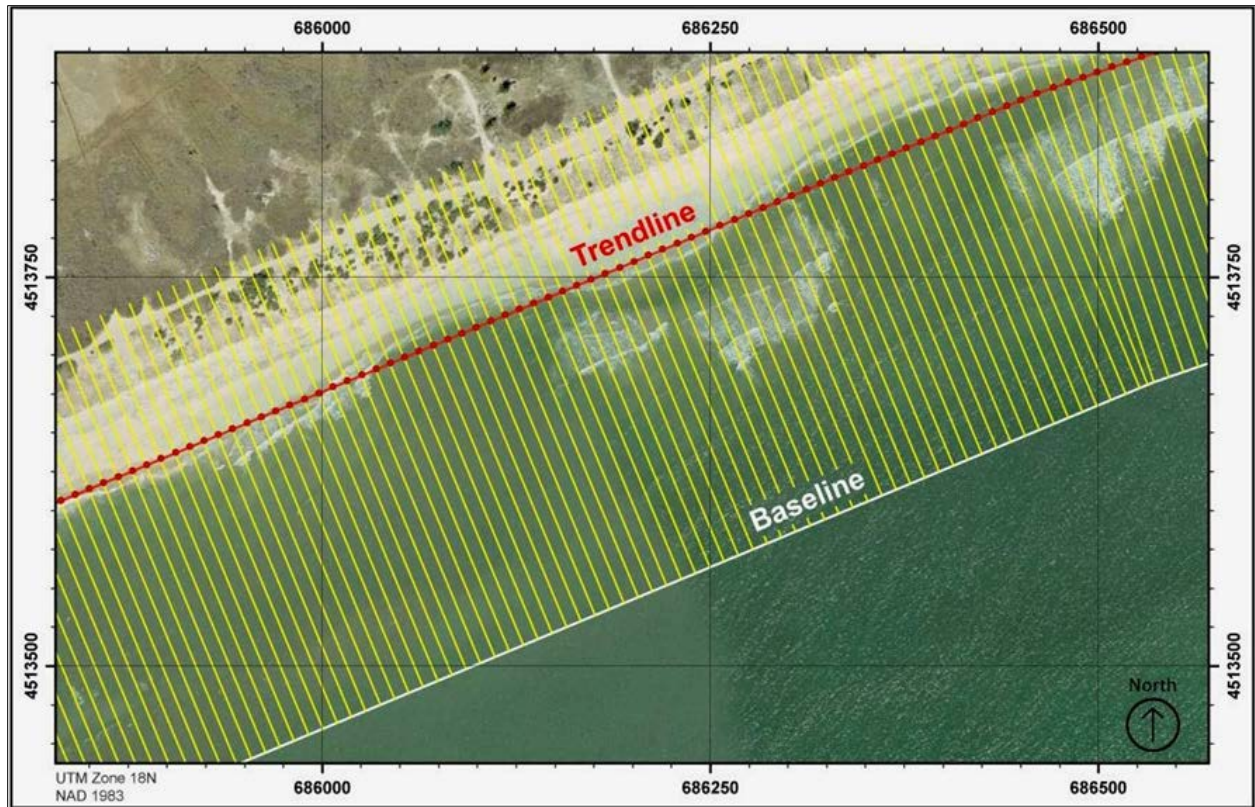


Figure 2. The yellow lines originating at the baseline are the transects created by DSAS that will be used to measure distances from the baseline to the surveyed shoreline position at each of the intercepts. Figure and caption from Psuty et al. (2010).

Adjustment of Transects

Transects that cross relatively straight sections of shoreline will need little if any adjustment. However, transects crossing the trendline in more curvilinear sections will need to be adjusted, e.g. added, deleted, or moved, so that all transects intersect the trendline perpendicularly at roughly 10-meter (32.8-ft) intervals (Figure 3). These adjustments can be accomplished using the smoothing function when casting transects in DSAS and/or utilizing the feature editing capabilities of GIS software packages such as ArcMap.

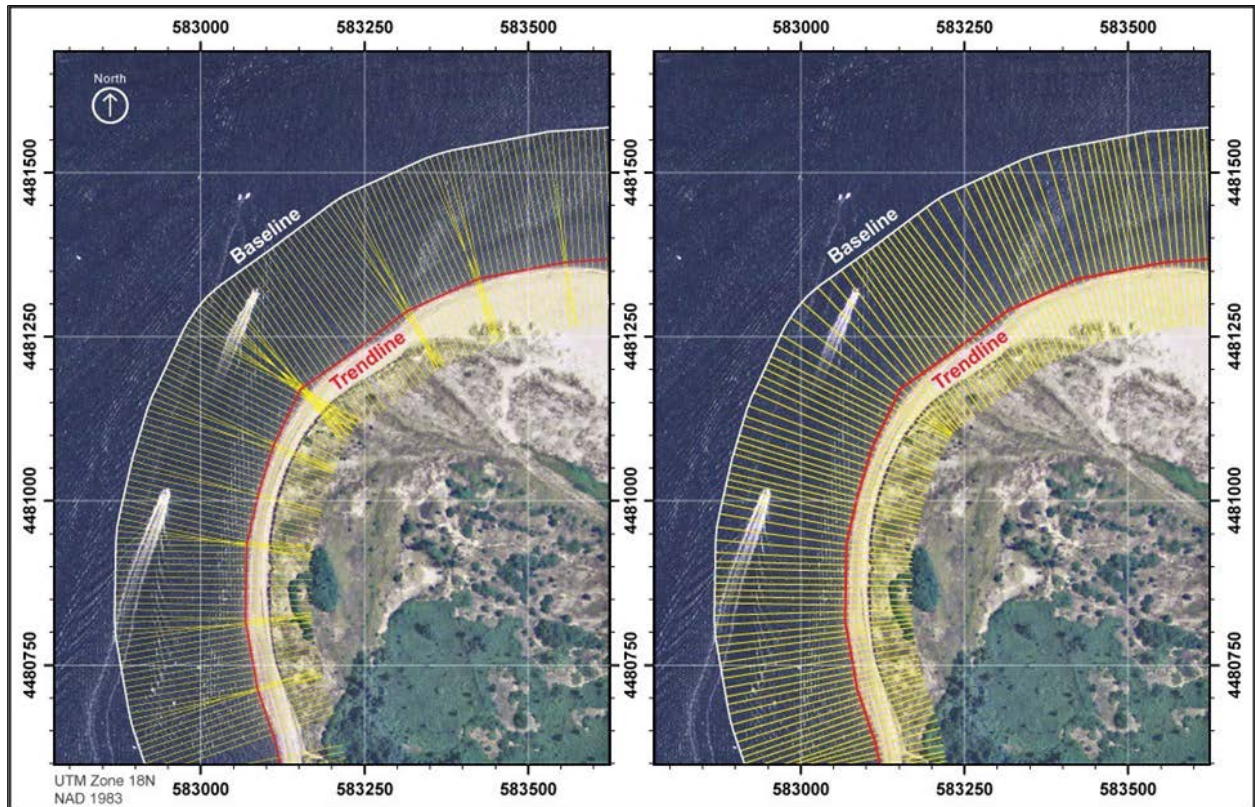


Figure 3. Example of transects created automatically by DSAS for a curved portion of the Sandy Hook shoreline (left panel) and those same transects after manual adjustment (right panel). Transects are shown in yellow in both panels. Figure and caption from Psuty et al. (2010).

In summary, the following steps must be completed before shoreline change can be calculated:

1. Create a smoothed shoreline (trendline) and an offshore baseline.
2. Create a series of evenly-spaced transects originating from the offshore baseline in DSAS.
3. Adjust transects using DSAS and/or ArcGIS so each transect intersects the trendline perpendicularly at approximately 10-meter (32.8-ft) intervals.

The most current versions of the baseline and transects reside as line feature classes in the project geodatabases—Z:\gis\guis\mon\geomorph\guisDsasFrame.gdb and Z:\gis\pais\mon\geomorph\guisDsasFrame.gdb.

Calculating and Comparing Shoreline Position

Each GPS-shoreline will be used to generate a series of distance measurements from the offshore baseline at each of the transects (Figure 4). These measurements are automatically calculated in DSAS and exported in tabular format for summary and analyses purposes (Figure 5). The distance output from DSAS is formatted so the shoreline position data are represented by a matrix of sequential shoreline distance measurements. The product of multiple surveys will be a matrix of

comparable distance values (Table 1). The matrix approach supports the generation of comparisons among any of the shoreline positions and requires that each shoreline be processed only once.

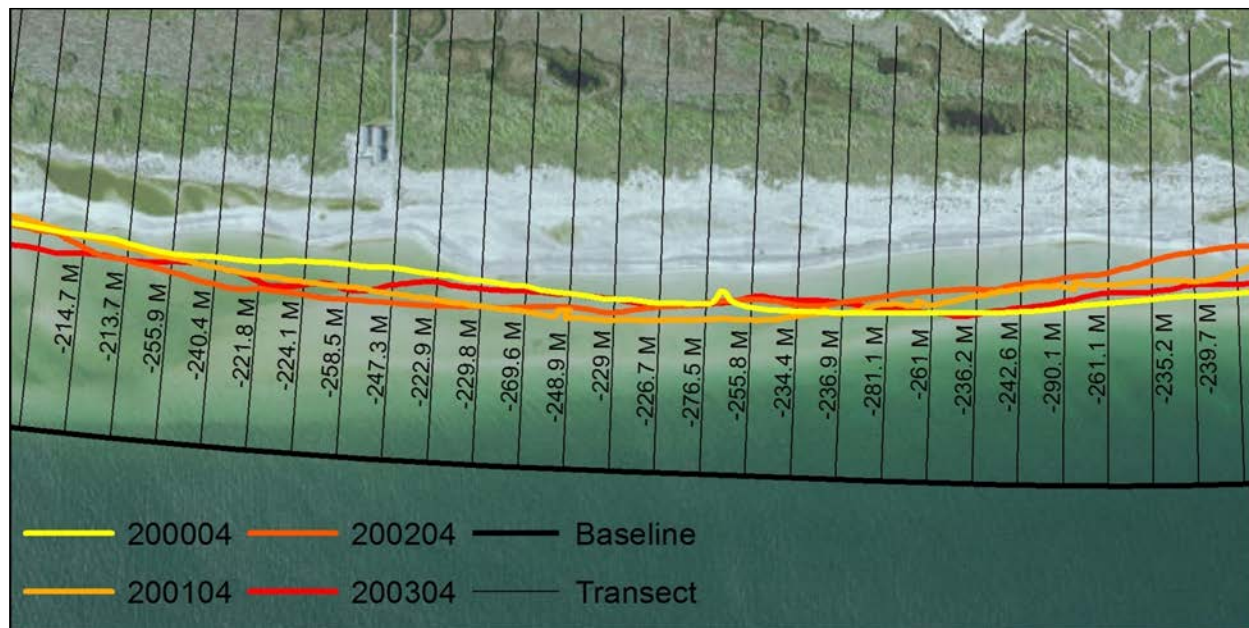


Figure 4. Transects are used to measure distances from the baseline to multiple GPS-surveyed shorelines. This figure shows four shoreline positions recorded in the spring.

Table							
guisWshipTransGulf_intersect_20150521_124551_spring							
object id	TransectId	Baselined	Shorelined		Distance	IntersectX	IntersectY
1	8	4	04/15/2000		-246.595197	313493.9096	3344614.053525
2	8	4	04/15/2001		-250.709526	313491.0239	3344616.98626
3	8	4	04/15/2002		-287.490977	313465.2270	3344643.204447
4	9	4	04/15/2000		-239.06029	313465.1929	3344575.581862
5	9	4	04/15/2001		-228.731514	313472.3582	3344568.142638
6	9	4	04/15/2002		-261.856896	313449.3784	3344592.000947
7	10	4	04/15/2000		-225.813421	313439.9348	3344533.214571
8	10	4	04/15/2001		-218.252482	313445.1214	3344527.713056
9	10	4	04/15/2002		-239.929592	313430.2514	3344543.485826
10	10	4	04/15/2003		-283.393901	313400.4359	3344575.111468
11	11	4	04/15/2000		-211.884799	313414.5891	3344490.528793
12	11	4	04/15/2001		-203.859326	313420.0314	3344484.630486
13	11	4	04/15/2002		-226.309877	313404.8071	3344501.130476

Figure 5. Screenshot of matrix of distance measurements generated with DSAS, incorporating distance measurements along a selection of transects from different survey dates. A full description of each of the columns in this table is in the DSAS User Guide and Tutorial (Himmelstoss 2009).

Table 1. Distance output from DSAS reformatted into Distance Matrix format. This matrix represents distance from baseline for each monitoring date from 2000–2003.

Transect ID	15 April 2000	15 April 2001	15 April 2002	15 April 2003
8	-246.6	-250.7	-287.5	--
9	-239.1	-228.7	-261.9	--
10	-225.8	-218.3	-239.9	-283.4
11	-211.9	-203.9	-226.3	-280.7
12	-217.9	-208.2	-227.6	-261.3
13	-236.4	-219.2	-221.6	-254.6
14	-246.4	-230.1	-237.1	-262.3
15	-253.9	-238.5	-253.3	-273.3
16	-265.0	-243.3	-257.6	-286.0
17	-258.7	-248.2	-262.1	-295.1

Quantifying Change by Comparison of Shoreline Positions

A comparison of shoreline positions is produced through a calculation of the differences in the distances from the baseline to any pair or combination of shorelines. The result is a table of the measured alongshore-displacement of the shoreline for a specific span of time (temporal variation). However, any comparison of shoreline position needs to acknowledge the shoreline position uncertainty (5 meters [16.4 ft]) and use this limitation to create the equivalent of error bars with any measure of displacement. This measure of uncertainty will apply in the comparison of change at any individual transect as well as the collation of measurements along the shoreline. They will also apply as these numerical data are processed further to produce summary statistics, such as a mean value of change and a standard deviation from the mean. Short-term comparisons will be produced biennially whereas long-term trend reports will be produced after a period of five surveys, or once every 10 years (Table 2).

Table 2. Measurements and comparisons of differences in shoreline position between similar seasons quantify the annual change.

Monitoring Year	1	2	3	4	5	6	7	8	9	10	11	12
Park Surveyed	GUIS	PAIS	GUIS	PAIS	GUIS	PAIS	GUIS	PAIS	GUIS	PAIS	GUIS	PAIS
Annual Report	GUIS	PAIS	GUIS	PAIS	GUIS	PAIS	GUIS	PAIS	--	--	GUIS	PAIS
Long-Term Report	--	--	--	--	--	--	--	--	GUIS	PAIS	--	--

Biennial Comparisons

A temporal comparison is the calculation of the change in the surveyed shoreline position over some time period. Some shoreline monitoring projects include comparisons of seasonal changes that occur

within a year's time. The Gulf Coast Network's focus is on calculating long-term change and measuring shoreline position on a biennial scale, comparing the position of the surveyed shoreline in the same season over a span of 24 months or more (Table 3). The comparisons of shoreline positions, surveyed at repeated intervals and in the same season, begin to reveal trends in the direction and magnitude of change. Because the seasonal variation is absent from this comparison, the change reflects the short-term balance of sediment supply (loss of sediment should produce a net inland displacement of the shoreline, whereas gain of sediment should produce a net seaward displacement). Although the displacement represents the positive or negative sediment budget, it may also represent the contrast in storm frequency and severity. Thus, biennial comparisons are valuable, but they are short-term measures that might reflect stochastic events and not longer-term trends. Accordingly, biennial comparisons may be most important to park managers in characterizing event-based changes. In addition to the spatial comparisons described later in this document, central tendency and measures of dispersion should be calculated to characterize biennial changes (Figure 6). The positional uncertainty of the calculated difference between shorelines is about 7 meters (22.9 ft; *positional uncertainty of shoreline difference* = $\sqrt{5^2 + 5^2}$, where 5 meters [16.4 ft] is the positional uncertainty associated with each shoreline survey).

Table 3. Difference of Distance-to-shoreline measurements is calculated DSAS and presented in the data matrix. This matrix represents distance from baseline data for monitoring dates in 2001 and 2003. In the Difference field, negative numbers indicate erosion and a positive number would indicate accretion.

Transect ID	2001	2003	Difference (2003 minus 2001)
11	-203.9	-280.7	-76.8
13	-219.2	-254.6	-35.4
15	-238.5	-273.3	-34.9
17	-248.2	-295.1	-46.9
19	-248.7	-314.7	-66.0
21	-248.2	-308.6	-60.4
23	-244.1	-301.0	-56.8
25	-235.2	-290.1	-54.9

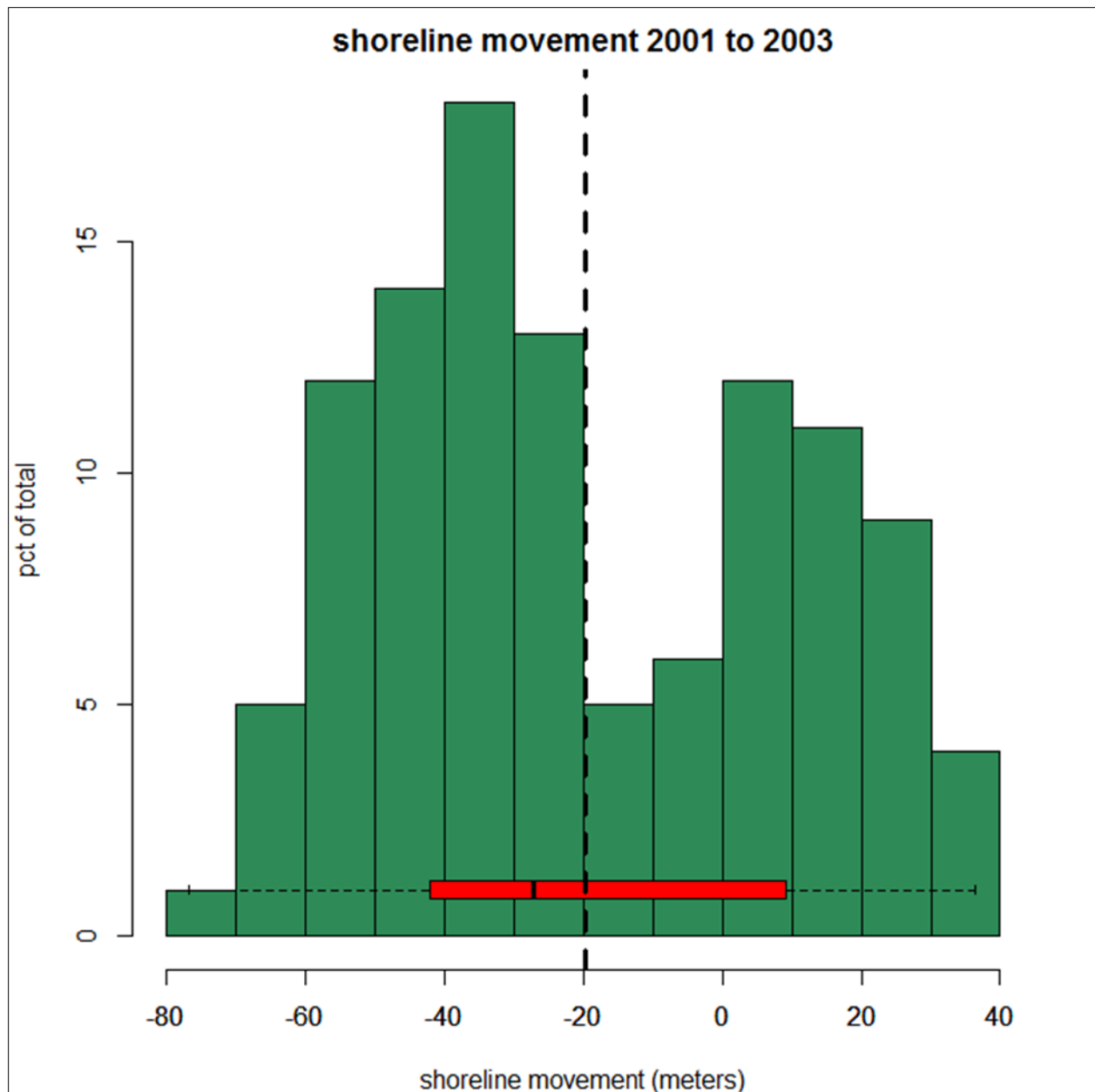


Figure 6. Histogram showing distribution of the difference in shoreline position between two spring seasons. Mean of -19.7 meters shown with vertical dashed line. Boxplot, shown horizontally, illustrates quartile distribution.

Long-term Comparisons

Long-term change in shoreline position is the change over a period of several years. The use of only two shorelines separated by more than one year is referred to as an End Point Rate (EPR) calculation. This calculation focuses on net change of shoreline position over the period of comparison (Figure 7). Whereas this value is straightforward and only requires information about the two data endpoints, it ignores all of the intermediate data points that are also useful in describing cycles and trends in the shoreline movement behavior. A more meaningful calculation in determining rate of change is the

Linear Regression Rate (LRR) model. The LRR is the slope of the regression line fit to distance (y-variable) and time (x-variable). The change rate, or slope, estimates the average change in shoreline location per year for each transect location.

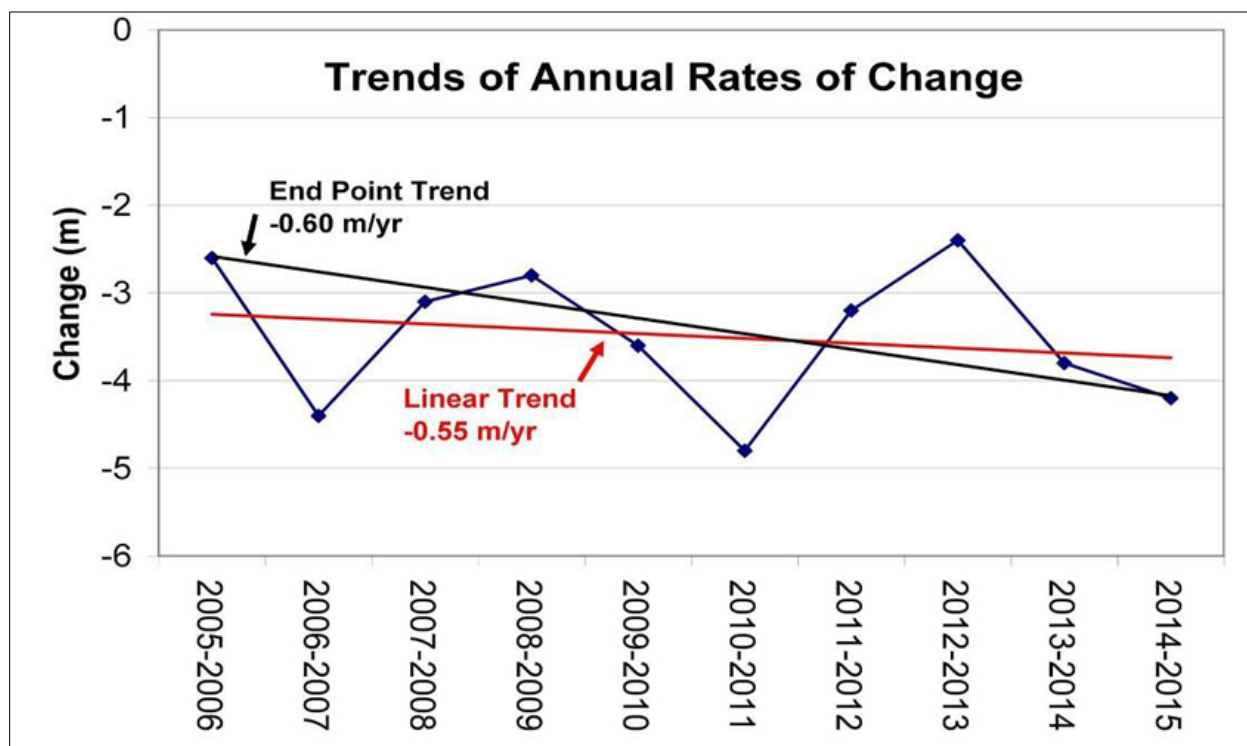


Figure 7. The array of mean differences from successive GPS surveys. Comparisons may be made of end-point positions as well as the sequence of shorter-term changes, or trends in the direction and magnitude of the changes. Figure and caption from Psuty et al. (2010).

Longer-term trends can be plotted alongside an annual change line graph, thus identifying a trend and shorter-term variation (Figure 7). This approach illustrates the internal variation in shoreline position in reaching its final location. EPR and LRR calculations are built into DSAS. These measures of change will generate a suite of numbers that more sophisticated statistical analysis may be used to summarize the trend of the change. Trend analysis becomes more meaningful with a longer record of shoreline change. A minimum of five sampling events should be used to begin to depict trends of change.

Spatial Comparisons

Changes in the shoreline position will likely vary in both magnitude and direction along the ocean shoreline of the park. Transect change coefficients can be pooled on many spatial scales to adapt to a variety of considerations and concerns (e.g., whole island, whole park, area of interest [AOI]). This alongshore variation constitutes the spatial component of the comparisons across biennial or long-term time periods. Spatial comparisons will be depicted in a map view to display the juxtaposition of the measures of change for the ocean shoreline (Figure 8).

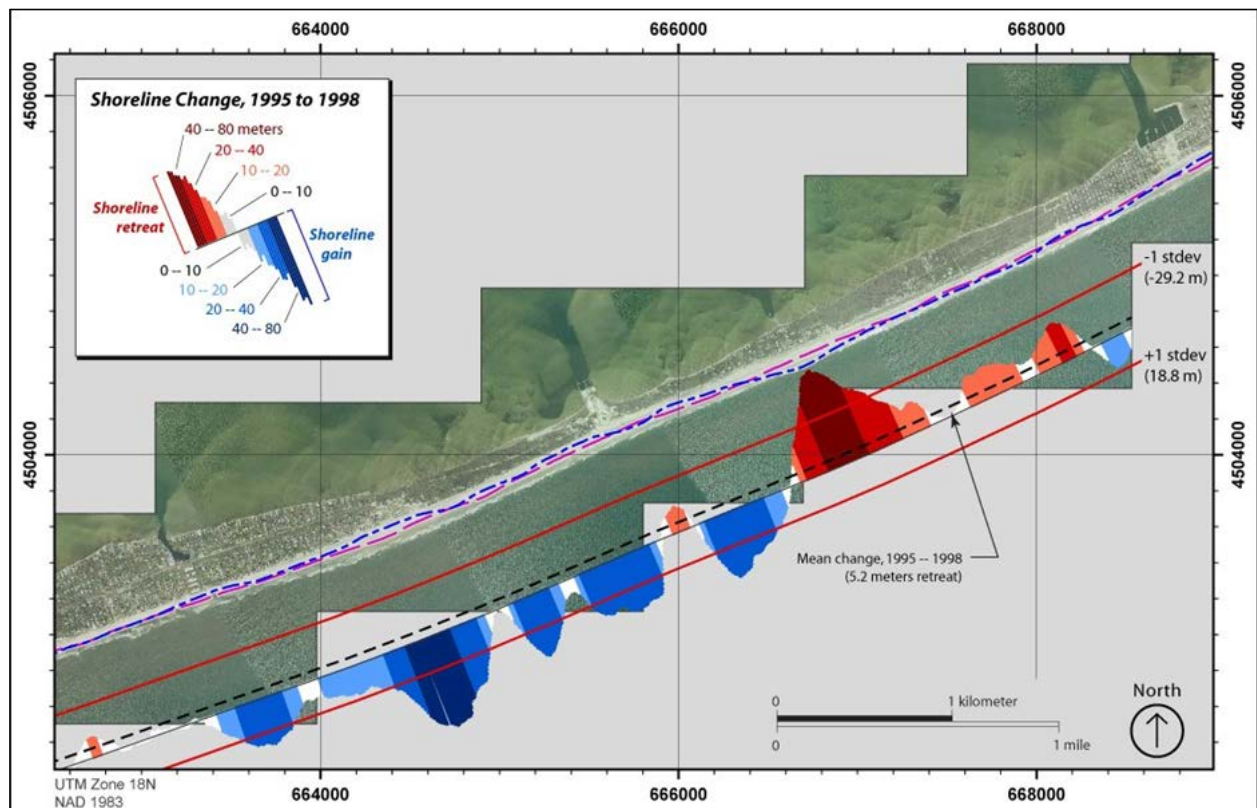


Figure 8. Alongshore distribution of differences in shoreline position depicting the spatial association of change, incorporating the value of mean change for the entire data set and the measure of one standard deviation for the data set. The scale of change includes color as well as length of the bars for easier recognition of the comparative values. Figure and caption from Psuty et al. (2010).

The generation of the maps depicting the magnitude of shoreline change between two dates is accomplished by using the Shoreline Change Mapper (SCM) application, an ESRI ArcGIS extension. SCM was developed by Rutgers University for the Northeast Coastal and Barrier Network protocol (Psuty et. al. 2010) and adapted by the Gulf Coast Network. The SCM includes a short user guide describing the process for creating maps. The application generates a new geographical data set that represents the actual, or exaggerated, distance of change as a bar-graph-type series of lines that correspond to the location of a sampling transect; these can be overlaid on existing base maps. The length of each line represents the magnitude and direction of change between two chosen dates.

The measures of change may be the net differences in shoreline position in an alongshore view, or the mean of the incorporated differences, or the rates of change. In any of the portrayals of the numerical differences of shoreline position, the statistical values of mean and standard deviation may be superimposed on the alongshore plots of the data. In long-term comparisons of changes, an alongshore plot of standard deviation emphasizes areas of major change.

Focus on Special Areas of Interest

In addition to summaries of the entire shoreline, there may be areas of interest to management that would benefit from a more focused analysis. Therefore, spatial subsets of the distance matrix may be identified to summarize change in smaller, local areas or at specific points of interest, such as an element of infrastructure. Areas or points of interest are identified by the GULN project leader with park staff so specific measures can be taken to address the concern. Individual transects can be defined as belonging to one or more spatial subsets within the entire data matrix of distances. By simply defining transects as belonging to an AOI, a single database can be maintained while allowing for summarization to occur on multiple spatial scales.

In addition to general summary statistics, AOIs may be monitored for specific change. Threshold values may be determined by park management or may be based on a previous analysis to signal or “flag” critical dimensions. For example, the distance matrix may be used to identify if and when the position of a shoreline approached a minimum threshold distance to the infrastructure element.

Production of Reports on Shoreline Change

The GULN project leader will periodically produce reports that portray the measured changes in shoreline position in narrative, tabular, and graphical formats. There are two types of products: a Biennial Project Report and a Project Trend Report. The Biennial Project Report summarizes the data from the current survey while putting it in context with the previous survey. The biennial project report is graphical in nature, primarily reporting a series of maps, graphs, and tables. The graphical reporting process is also a key part of data quality assurance as unexpected values are more likely to be identified in summaries and graphs and can be addressed promptly.

The project trend report covers five sampling events and includes information on trends and interpretations of the observations. These reports are submitted to park management and included in the protocol database. The project trend report is written in consultation with a locally knowledgeable coastal geomorphologist.

Biennial Project Report

The Biennial Project Report is a summary of the shoreline change data over the period of two surveys. General statistics (mean and standard deviation) will be included for this short-term change.

The Biennial 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 Shoreline Position Surveys
4. Natural and Cultural Events Affecting Shoreline Position
5. Areas of Special Interest
6. Changes to the Protocol
7. Shoreline Position Data Sets
8. Summary Statistics and Tables of Change
9. Information for Management
10. Problems/Concerns
11. Appendices
12. Bibliography

Project Trend Report

The Project Trend Report is a summary of the full database of shorelines, with an emphasis on the previous five samples. It is a comprehensive complement of analyses that synthesize the shoreline change data and provides scientific interpretation of the trends revealed in the numerical analyses. There are two additional sections to the information described above for the biennial report:

1. Introduction
2. Site and Situation
3. Timing of Shoreline Position Surveys
4. Natural and Cultural Events Affecting Shoreline Position
5. Areas of Special Interest
6. Changes to the Protocol
7. Shoreline Position Data Sets
8. Summary Statistics and Tables of Change
9. Presentation and Description of Trend Analysis
10. Interpretation of Trends
11. Information for Management and Recommendations
12. Problems/Concerns
13. Appendices
14. Bibliography

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