National Park Service
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Natural Resource Stewardship and Science

Development of the Geomorphological Map for Gateway National Recreation Area (Post-Hurricane Sandy)

(1) Principal Characteristics and Components and (2) Metrics of Change

Natural Resource Report NPS/NRSS/GRD/NRR—2017/1416

ON THE COVER
Sandy Hook Visitors Center, Gateway National Recreation Area

Photo credit: USGS Marine Geology. November 5, 2012.

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April 2017

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

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Please cite this publication as:

Psuty, N. P., W. Schmelz, J. Greenberg, and A. Spahn. 2017. Development of the geomorphological map for Gateway National Recreation Area (post-Hurricane Sandy): (1) Principal characteristics and components and (2) metrics of change. Natural Resource Report NPS/NRSS/GRD/NRR—2017/1416. National Park Service, Fort Collins, Colorado.

NPS 646/137660, April 2017

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Executive Summary

This report incorporates the geomorphological map, its philosophical underpinnings, legend descriptions, and the GIS data layers for the three Units of Gateway National Recreation Area, Sandy Hook Unit (New Jersey), Staten Island Unit (New York), and Jamaica Bay Unit (New York) in the aftermath of Hurricane Sandy, October 2012. The theme of the map follows the current scientific organization of geomorphological mapping that includes morphometrics, causative processes, and evolutionary stages. Surface form was interpreted from a variety of data sources that include recent orthophotos, recent Light Detection and Ranging (LiDAR) data sets, and spatial information on soils and vegetation. The archival information was augmented with field visits.

The geomorphological features of the Gateway site include: 1) a portion of a glacial terminal moraine; 2) coastal topography that was created during an early phase of coastal barrier spit / barrier island development; 3) coastal topography that developed with the downdrift extension of the barrier spit / barrier island systems; 4) coastal topography associated with the estuarine margins of embayments situated inland of the developing barrier spits / barrier islands; 5) topographical modifications created by Hurricane Sandy; and 6) anthropogenic modifications to the natural topography, consisting of excavation as well as accumulation. The geomorphological maps of the Units and their subdivisions and the map legend portray the spatial and temporal association of the surface features created during the several stages of landscape development, as well as the broad anthropogenic modifications of the surface. These processes continue to influence development of the landscape and, as a result, this map will serve to identify a stage in the evolution of the geomorphology at Gateway National Recreation Area. Many of the geomorphological features incorporated on these maps were affected by processes and responses associated with Hurricane Sandy in October 2012, and a comparison with a map representation of the pre-storm geomorphological configuration (2010) is tabulated. Thus, this report is organized into two sections:

- Part 1: Post-Hurricane Sandy geomorphological maps of Gateway National Recreation Area.
- Part 2: Quantification of the dimensions of change in the magnitude and distribution of geomorphological features as a result of Hurricane Sandy.

The several geomorphological maps are viewable utilizing a GIS as a full compilation of all of the data layers as well as user specified combinations of the data. Each of the map layers contained in this report meets the standards of Federal Geographic Data Committee (FGDC) compliant metadata. The full set of organized data layers is available from the Geologic Resources Division, National Park Service, PO Box 25287, Denver, Colorado 80225 or via the Geologic Resources Inventory publications page http://go.nps.gov/gripubs.

Cartographic representations of the several geomorphological map datasets are presented within two appendices to Part 1 of this report. Appendix II contains page-sized portrayals of the Post-Hurricane Sandy Geomorphological Map datasets, whereas Appendix I contains the 2010 Geomorphological Map datasets that were used in combination with the post-storm datasets to derive the quantifications of change provided within Part 2.

Acknowledgments

Guidance and support for this project came from a host of Gateway personnel that were sources of information and enthusiasm. Mark Christiano, GIS Specialist, Gateway National Recreation Area, contributed throughout the project with counsel, data sets, and data layers. Bruce Heise of the Geological Resources Division of the NPS Natural Resource Stewardship and Science Directorate was instrumental in defining the final product. Irina Beal and Katy Ames of Sandy Hook Cooperative Research Programs helped improve the product through their active participation in the map review process. And, a special tribute is extended to Jason Kenworthy, NPS Geologic Resources Division, for his efforts in guiding this publication. We are very appreciative of the great team of NPS personnel and others that were part of the entire production and review process. We additionally thank the reviewers, Courtney Schupp and Charlie Finkl, for their comments that significantly improved the quality of this publication.

Part 1. Principal Characteristics and Components

Background

Gateway National Recreation Area (Gateway NRA) is one of 270 National Park System components designated to have a digital geological map and an accompanying geological resources inventory report. However, rather than a geological map, a geomorphological map was created that depicted the surface topography based on data sources from 2010 (Psuty et al., 2015). However, the occurrence of Hurricane Sandy at the end of October 2012 caused considerable modification of the topography and the distribution and extent of the geomorphological features. As a result, a new geomorphological map of Gateway NRA is produced to represent the conditions created by Hurricane Sandy in the geomorphological evolution of the area. The focus of this report, therefore, is the creation of a geomorphological map representing the landform characteristics following Hurricane Sandy and the subsequent identification and quantification of distribution and magnitude of the changes utilizing the pre-Sandy map as a reference.

Site and Situation

Gateway National Recreation Area (Fig. 1) is composed of three geographical areas that have a general similarity in geomorphological development because they occur in a coastal setting exposed to waves and currents operating on sediment in alongshore transit. The three areas are: 1) the Sandy Hook Unit, a barrier spit extending northward along the northern margin of coastal New Jersey; 2) the Staten Island Unit, consisting of a) the margin of a terminal moraine as well as three separate coastal sites under the influence of a southwesterly alongshore transport system that terminates at a barrier spit, and b) two artificial islands off of the Staten Island shore; and 3) the Jamaica Bay Unit that is composed of: a) the downdrift portion of the Rockaway barrier island, terminating at Breezy Point, b) Plumb Beach, an easterly remnant of the Coney Island barrier island, c) a group of flood tide delta islands leading into Jamaica Bay, and d) a scattered plethora of wetlands and artificial fill along the margins of Jamaica Bay. Much of the landscape has been altered by the anthropogenic manipulation that has flattened a large proportion of the topographical expression. Sandy Hook has the greatest expanse of original coastal topography, whereas the Fort Wadsworth portion of the Staten Island Unit has the only example of Late Wisconsinan glacial topography. Because of the exposure of these Units to the Atlantic Ocean, the storm surge and waves associated with Hurricane Sandy greatly affected the pre-storm topography, especially at Sandy Hook, Breezy Point, and the length of the Staten Island shoreline.

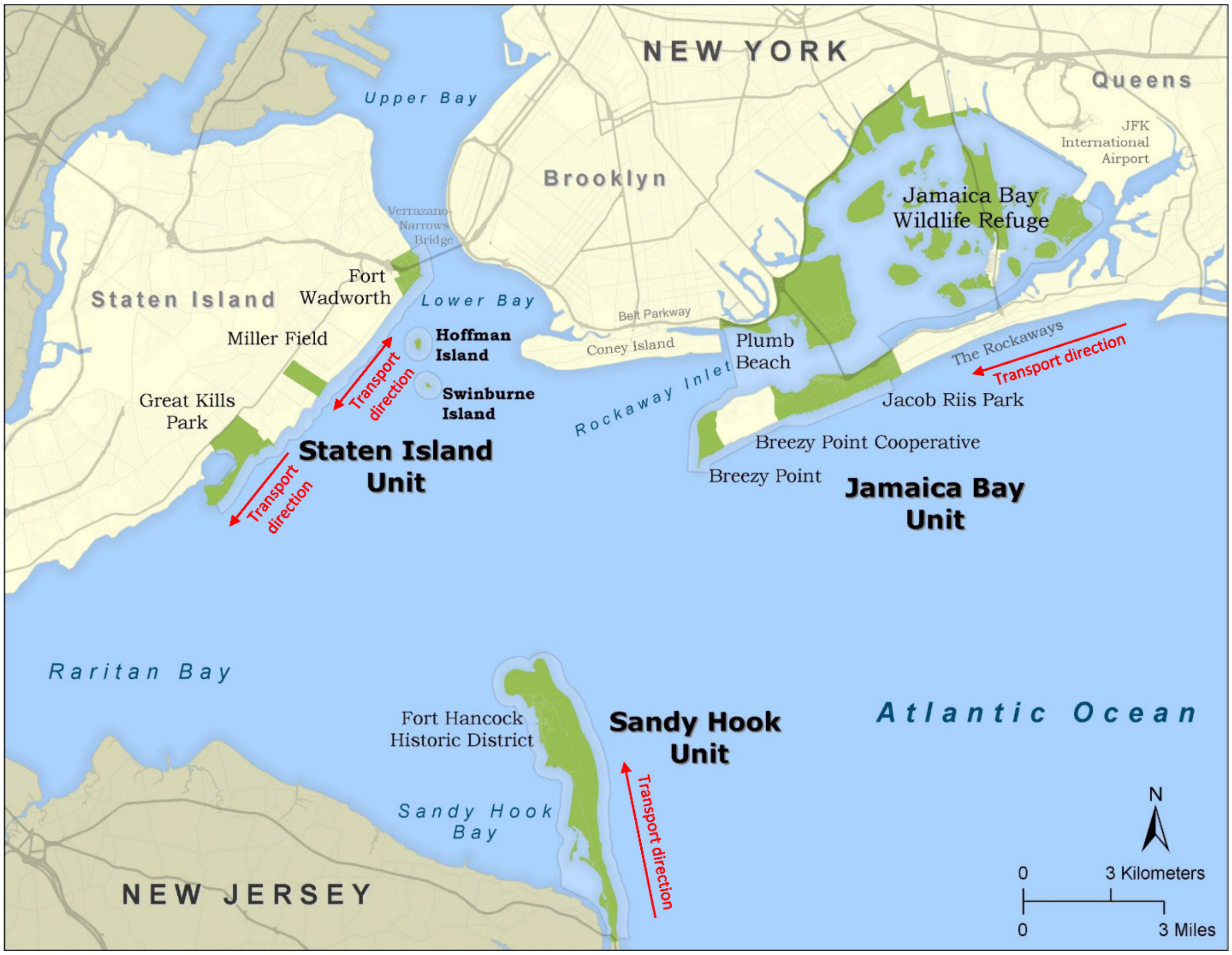

Figure 1. Location of Units comprising Gateway National Recreation Area. Red arrows depict the principal direction of alongshore sediment transport.

Geomorphological Evolution

The conceptual approach to describing, depicting, and mapping the geomorphological characteristics of Gateway is based on the components of morphometrics, causative processes, and temporal sequence of development of the surface. This tripartite organization is the essence of modern geomorphological maps (Dramis et al. 2011) that combine the processes and the surface expression of the sedimentary formations (either in their erosional or depositional form).

Further, the map legend (discussed later) is developed to track the evolution of the surface features and their associated causative processes, and to add the anthropogenic imprint on to the landscape.

The spatial separation of Gateway NRA into three primary units creates a condition whereby different suites of processes operating over different temporal periods combine to add geomorphological variety to the landscape (Psuty et al., 2010). The oldest topography is associated with a terminal moraine at Fort Wadsworth. The moraine and its adjacent outwash plain was deposited by a continental glacier about 16,0000 – 18,000 years ago during Wisconsinan time when sea level was more than 100 m lower than today. The remainder of Gateway NRA surface topography is associated with more recent coastal and estuarine processes operating at or near today's sea level position; it is these processes that have driven the formation of beaches and dunes during the last several thousand years. Located at the apex of the New York Bight where there is an abrupt change in orientation of the coast line, Gateway NRA is at or near the end of an alongshore sediment transport system that brings sand from south to north along coastal New Jersey, and from east to west along coastal Long Island. On Staten Island, the principal transport direction is from northeast to southwest.

Thus, glacial processes produced the oldest topography in Gateway, succeeded by coastal waves and currents that converged on Lower New York Harbor. Sediment transport in that converging scenario resulted in an elongation of spits and islands in a downdrift direction. The modifications created by Hurricane Sandy are the latest natural major event in the evolution of the coastal geomorphology at Gateway NRA.

Sandy Hook Unit (SHU)

Although all of Gateway NRA has had considerable manipulation of the surface topography by humans, the SHU retains the highest proportion of "natural landscape", in large part because of its status as a military base guarding part of the entrance into New York Harbor. That condition restricted access to much of Sandy Hook and preserved a significant proportion of the original topography. The dominant landform system on Sandy Hook is a series of accretionary foredune ridges that recount the extension of the spit northwesterly into Sandy Hook Bay. There is an active beach and foredune that extends along the entire ocean margin of the SHU. They are formed by the modern wave, current, and wind processes that transport sediment northerly. Inland of the active foredune are sequences of abandoned foredune ridges, each ridge representing the position of a former shoreline feature. The abandoned accretionary ridges vary in dimension and are classified as major (more than 4 m in crestal elevation), and minor (less than 4 m in crestal elevation). The major ridges tend to be coherent and consistent as they define the margin of Sandy Hook at some point in the geomorphological past. The minor ridges tend to be shorter and occupy a segment of Sandy Hook. It is likely that the major ridges defined the margin of Sandy Hook for a long period of time and that sediment accumulated at that shoreline position. The minor ridges also represent periods of accumulation to create the ridge form, but they were part of the shore position for shorter periods and may represent more rapid northerly extension of Sandy Hook.

The ridges are accompanied by inter-ridge swales, a topographical low area that was not filled with sand as the spit extended northerly. Occasionally, dune ridges of the spit extension closed off small embayments in the beach and caused the creation of isolated low-lying topography that are sites of ponds or wetlands among the accretionary foredune ridges today.

The bayside of Sandy Hook has a series of features that consist of: 1) narrow beaches and narrow dunes that formed on the low energy bay shorelines where there was ample sand for the waves and currents to transport and accumulate in a beach-dune combination (they are most often found on the northwest facing portion of the bay shoreline, facing the direction of greatest wave fetch); 2) back dune slope of the ocean-facing foredune system, usually in areas not exposed to the maximum wave directions on the bayside; and 3) wetlands that are to the lee of the northwest facing beaches on the bayside. The latter feature tends to be associated with former distal portions of Sandy Hook and locations where sediment transport around the end of the Hook created a small embayment.

A large portion of Sandy Hook has been leveled to accommodate a military base and its accompanying infrastructure. It is a planar surface that has little of the original topography. Other elements of the human alteration are: 1) roads; 2) gun batteries; 3) bulkheads; 4) a massive seawall that begins at the base of the Sandy Hook peninsula and continues for 2.5 km into and along the southern ocean-facing portion of the SHU.

Along portions of the Sandy Hook shoreline, Hurricane Sandy eroded and dissected or eliminated the active foredune ridge. In some areas, formerly abandoned foredunes replaced the active ridge in function, inherently becoming the new active foredune in a displaced spatial position. In other areas, washover deposits extended landward of the now eliminated foredune ridges. Additionally, erosion of the ocean shoreline and landward deposition of sediment impacted the built environment, as sheets of washover deposition covered a variety of roads and paved surfaces at Sandy Hook

Jamaica Bay Unit (JBU)

Similar to Sandy Hook, the geomorphological evolution of the JBU is related to alongshore sediment transport and downdrift extension of a coastal barrier into New York Harbor. An active beach extends the length of the ocean side of this park unit, and an active foredune occurs at the inland margin of the beach except at Riis Park and portions of the Breezy Point Cooperative.

In addition to the active foredune, there are occurrences of abandoned foredunes in restricted areas. In the past, the westerly progression of the Rockaway barrier island created a series of accretionary foredune ridge and swale topographical features that gave character to the barrier island. Much of the foredune landscape has been modified by human development to produce the present day planar surface. Some accretionary foredune ridge and swale topography at the western terminus of Breezy Point is related to the accumulation of sediment updrift of the Rockaway Inlet jetty, constructed in 1933. The geomorphological response of the Rockaway barrier to Hurricane Sandy was similar to that of Sandy Hook, wherein erosion impacted, dissected, and/or eliminated the active foredune ridge. The Fort Tilden and Breezy Point sites contained expanses of washover deposition that replaced foredune ridges, whereas the washover deposits in the Jacob Riis park portion of the park shoreline were produced on anthropogenically created surfaces.

Much of the topography within Jamaica Bay is related to the flood-tidal islands that formed on the inland margin of Rockaway Inlet as it migrated to the west. They are components of a flood tide delta that in the past received sand by a combination of tidal currents and wave action to build an extensive deltaic flat expanding into Jamaica Bay. At present, portions of the tidal deltaic islands are altered by human manipulation and have little of the original deltaic topography. Other portions of the islands are slowly disintegrating because of absence of sediment infusion by tidal action and because of the alterations caused by humans. The margin of Jamaica Bay has a few locations of wetlands and localized compartments of beach and dune topography. Most of the margin is landfill and is bulkheaded. East Pond and West Pond are fresh water components of the Jamaica Bay Wildlife Refuge created and maintained by constructed dikes. Portions of the dikes were breached by storm processes associated with Hurricane Sandy, producing inlet and deltaic features extending into the ponds.

The Plumb Beach area is an amalgam of natural and anthropogenic features. A large portion of the area is fill that formed the foundation for the Belt Parkway, but downdrift sediment transport to the east has created a natural beach-dune system backed by a relatively pristine wetland. This site is occupying the former location of the backmarsh of an eroded barrier island. In the weeks prior to the landfall of Hurricane Sandy, in the fall of 2012, the initial phase of a coastal engineering effort to stabilize the shoreline adjacent to the Belt Parkway commenced. This included the placement of ~90,000 m3 of sediment seaward of the highway, buffering it from the impact of the storm. A geotube groin was also installed to the east of the fill. The storm caused small washover deposits landward of the active foredune ridges at the site. In addition to the specific impacts of Hurricane Sandy, in the time between 2010 and 2012 (prior to Hurricane Sandy), there were a number of natural and anthropogenic modifications to the landscape, including the erosion of a small foredune east of the bath house/parking lot area, that contributed to the totality of changes.

Staten Island Unit (SIU)

Fort Wadsworth – The topography at this site is partially composed of the margin of the Wisconsinan terminal moraine. It is a high ridge of glacial till deposited at the margin of the maximum extent of glacial ice during the Wisconsinan epoch. The terminal moraine has an irregular hummocky surface mostly modified by anthropogenic activity, with steep slopes at its northeastern and east-facing margins. There is an outwash plain south of the terminal moraine and fill at the base of a scarp in the outwash plain. At the margin of the fill, there is a narrow zone of beach and very low dune topography. A variety of bulkhead structures associated with the remains of a dock occupy the northeast corner of the shoreline, whereas the beach margin fronting the Verrazano Narrows is strewn with stone and concrete rip-rap.

Miller Field

This is the site of an outwash plain emanating from the terminal moraine. It has been modified greatly. Most of it is a large planar surface, a former airfield, with a small wetland basin feature at the northern corner. The seaward margin is the site of a constructed sand barrier that currently has an active beach, and the barrier is bounded on its inland margin by a modest dune. There are groins constructed in the beach near both margins of the site. The alongshore transport is to the southwest, with a large offset in the shoreline beyond the groin on the downdrift margin. There were minor modifications to the foredune features at the northeastern margin of the site that occurred as a result of Hurricane Sandy, along with some washover deposition.

Great Kills Park

This site is largely an anthropogenic planar surface created by dredging of the marina in 1935-1948 and 1955. There is a narrow beach at the seaward margin that had fronted a low cliff in the vicinity of the large parking lot. This cliff was modified by erosion caused by Hurricane Sandy, leaving an inclined surface between the beach and the parking area. To the southwest of the former cliff area, washover deposition replaced a former low foredune feature. A thick sheet of sediment covered the shore parallel road providing access to the southern portion of the site. There are remnants of abandoned dunes in the downdrift portion of Great Kills Park (alongshore transport is to the southwest), in the remains of a former barrier spit, replete with accretionary foredune features. The seaward-most ridge was displaced landward during Hurricane Sandy, creating an active foredune ridge in a new location. There is a jetty at the downdrift end of the Park, with a navigation channel beyond the jetty leading from the harbor to the marina. The marina has a few small sections of beach at the margins of the fill, but most of the marina is lined by a bulkhead.

Legislative Boundary Areas

In the legislation establishing the extent of Gateway National Recreation Area, the beach portions between Fort Wadsworth, Miller Field, and Great Kills Park were designated as within Gateway NRA. Along most of this distance, the morphology consisted of an anthropogenically-created trapezoidal ridge fronted by a beach. Most of these ridges were completely eroded by Hurricane Sandy, resulting in the deposition of washover at inland positions. Between the Great Kills and Miller Field Park boundaries, toward the southwestern terminus of the constructed planar surface, there is a small natural beach and foredune area backed by a marsh that persists post-storm.

Swinburne Island and Hoffman Island

These two artificial islands are built from construction debris and are completely surrounded by stabilizing concrete walls. The surfaces of the islands are planar and are sites of buildings that served several purposes in their history before being incorporated into Gateway NRA. There was no geomorphological modification created by Hurricane Sandy.

Resources to Aid in the Spatial Recognition of Features

A geographic information system (GIS) was developed for the construction of the geomorphological map of Gateway NRA. The GIS includes orthophotos, light detection and ranging (LiDAR) data sets, and additional sources of geospatial information appropriate to the identification of the geomorphological features (Table 1).

Orthophotography

A total of 52 image tiles collected between November 1 and November 5, 2012, by the National Oceanic and Atmospheric Administration's (NOAA) National Geodetic Survey (NGS) with 0.35 m spatial resolution were accessed online from the NOAA Coastal Services Center (NOAA 2012).

LiDAR

The LiDAR data set covering Gateway National Recreation Area was collected on November 16, 2012 by the US Army Corps of Engineers (USACE), Joint Airborne Lidar Bathymetry Technical Center of eXpertise (JALBTCX) and made available online through the NOAA Coastal Services Center (USACE 2014). The data set incorporated topographic LiDAR data in Log ASCII Standard (LAS) format with the data points classified as either unclassified or ground.

Additional Sources

The primary additional source of spatially-organized data was the pre-Hurricane Sandy report and map produced by Psuty et al. (2015). Other sources included 3 image tiles covering Sandy Hook collected by Pictometry (Pictometry 2010) with 0.25 m spatial resolution and 382 image tiles collected by New York State over the Staten Island and Jamaica Bay units with 0.5 ft spatial resolution obtained from the New York City Department of Information Technology & Telecommunications (DoITT 2010). A LiDAR data set covering the Sandy Hook Unit collected between August 28 and September 9, 2010 by the US Army Corps of Engineers (USACE 2010), and a LiDAR data set covering the Jamaica Bay and Staten Island Units collected by the Sanborn Map Company between April 14 and May 1, 2010 (Sanborn 2010), were used to identify topographical change occurring between the pre-storm map and post-Hurricane Sandy. A vegetation map and report (Edinger et al. 2008) downloaded from the NPS Integrated Resource Management (IRMA) site, plus several geological reports (Gray Smith et al. 1999, Leatherman 1988, Psuty et al. 2005, and Psuty and Silveira 2008) were also referenced in the creation of the maps. Locations of buildings, infrastructure, and boundaries were accessed from a dataset provided by the NPS(NPS 2012). A roads data layer was provided by OpenStreetMap (2014), retrieved on March 31, 2014, and was modified as necessary from the orthophotos.

Table 1. Sources and quality of spatial data

Data	Year	Resolution	File Type	Source
Geomorphological map	2015	-	.gdb	NPS IRMA
Orthophotos	2010	0.25 m	.tif	Pictometry
Orthophotos	2011	0.5 ft	.jp2	DoITT – City of New York
Orthophotos	2012	0.35 m	.jp2	NOAA
LiDAR (bare earth)	2010	0.80 m (1.13 m)*	LAS	USACE
LiDAR (bare earth)	2010	0.38 m (0.46 m)*	LAS	Sanborn
LiDAR (bare earth)	2012	0.71 m (1.27 m)*	LAS	USACE
Vegetation	2008	-	.shp	NPS IRMA
Road/Walkways	2014	-	GIS Geodatabase	OpenStreetMap contributors

* = point spacing

Methodology of Topography Development

The initial approach of landform identification used November 2012 orthophotos of Gateway NRA (Fig. 2) to establish the geographical coordinates of the geomorphological units. The next phase utilized a 2012 bare earth LiDAR data set for Gateway NRA, provided by the USACE, to create a digital elevation model (DEM). However, the LiDAR bare earth DEM produced by this data set exhibited some noise in areas of dense vegetation. To minimize these surface perturbations, the raw LiDAR data points were filtered using the Reduce Point Density method via Airborne LiDAR Data Processing and Analysis Tools (ALDPAT) (Zhang and Cui 2007) software to create a new bare earth DEM. The Reduced Point Density method searches for and chooses the point of minimum elevation within a specified area, or window, to represent that location. One to three iterations of this filtering were applied to the bare earth LiDAR points, enlarging the window each time (three iterations [1m, 3m, and 5m windows] for Sandy Hook, but only one iteration [1 m window] for the rest of Gateway NRA). Each subsequent iteration was applied to the filtered data points of the previous iteration. The third iteration of this filtering process provided a bare earth LiDAR surface with sufficient relief to determine the spatial boundaries of the geomorphological features at Sandy Hook, while discarding most noise associated with non-ground points. For the other Gateway NRA Units, the first iteration provided this effect. The resulting reduced point density DEM layers were somewhat less detailed because the more minor variations were smoothed to emphasize the general trends in elevation (Fig. 3).

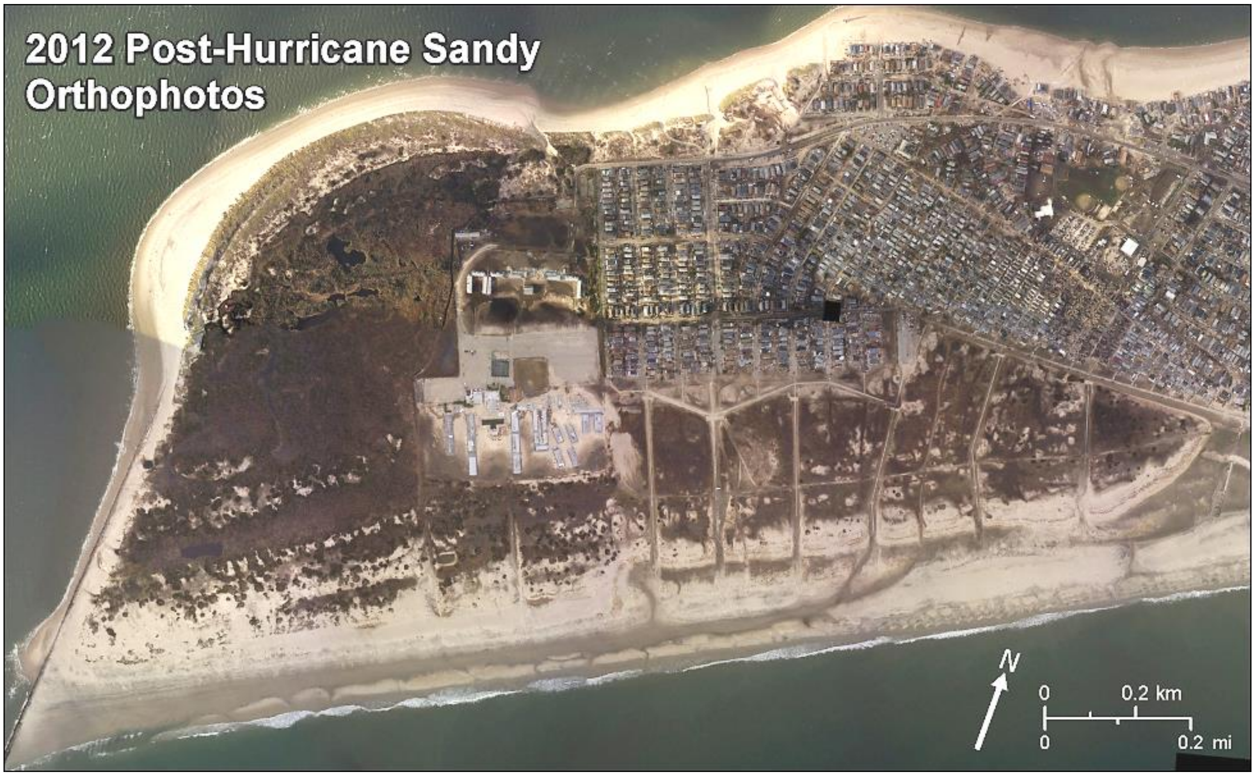

Figure 2. Orthophoto of the western tip of Breezy Point and the Rockaway Inlet shoreline, Jamaica Bay Unit, Gateway NRA.

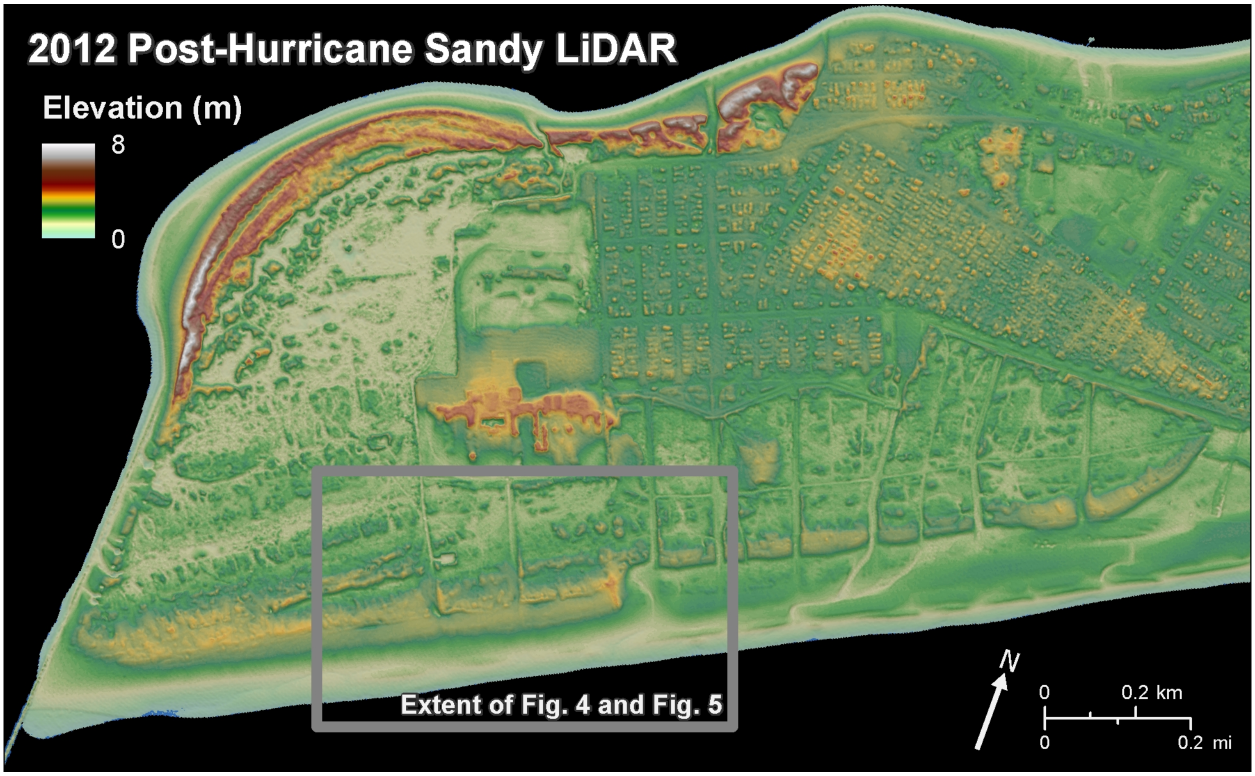

Figure 3. Digital elevation model (DEM) created from a 2012 LiDAR data set with reduced point density, Breezy Point, Jamaica Bay Unit, Gateway NRA. Area within the box indicates location of surface topography and geomorphological features incorporated in Figures 4 and 5.

A further refinement of the DEM incorporated the identification of changes in slope and dimensions of relief to help define the boundaries of the geomorphological categories and focus on the major changes. Thus, isolines of slope were plotted (Fig. 4) and changes in slope were selected to depict boundaries between ridges and swales, as well as the boundary of washover deposition. The result was a landform categorization into ridges, swales, and planar surfaces of various dimensions and continuity based on changes in slope and local relief. After the juxtaposition of topographical features was determined, their sequential evolution was interpreted using the fundamentals of sediment transport direction, sediment supply, and sediment budget. This process eventually outlined the distribution of beach, active and abandoned dune ridges, swales, and zones of washover deposition (Fig. 5). An additional enhancement of the elevation portrayal was performed by adding a shading effect generated by applying the hillshade tool in ArcGIS on the reduced point density DEM layers and incorporating that view in the geomorphological map (Fig. 6). The hillshade tool simulates illumination and shading of a 3-dimensional topographic surface, creating the appearance of relief on a 2-dimensional surface.

A vegetation map was used as supplemental information in the manual digitization of geomorphological features. Specifically, the 2008 vegetation map of Gateway NRA and 2012 orthophotos were used to identify the extent of marsh. In addition, orthophotos provided contextual information regarding the positioning of modification of the landscape, erosion-control structures, ponds, beaches on the oceanside and bayside, and other natural and anthropogenic features on the landscape. The topographical interpretations of areas of dense vegetation and low relief were verified through field visits.

Throughout the map generation process, all of the ancillary resources were consulted to help in the identification of the surface features, their characteristics, and their boundaries. Continuous feedback between site-specific landform designation and general categorization resulted in a consistent classification of landform features throughout Gateway NRA.

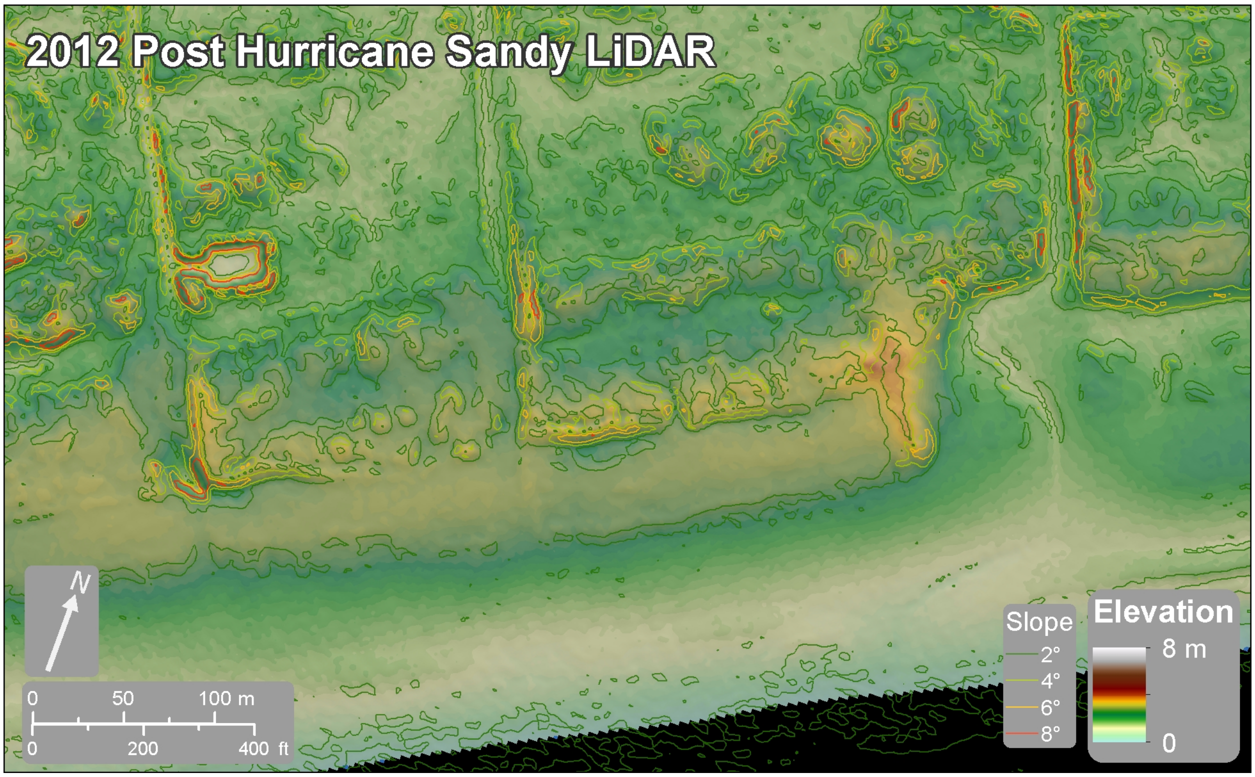

Figure 4. Incorporation of slope isolines to define landform boundaries within the DEM; site is shown on inset map area on Figure 3.

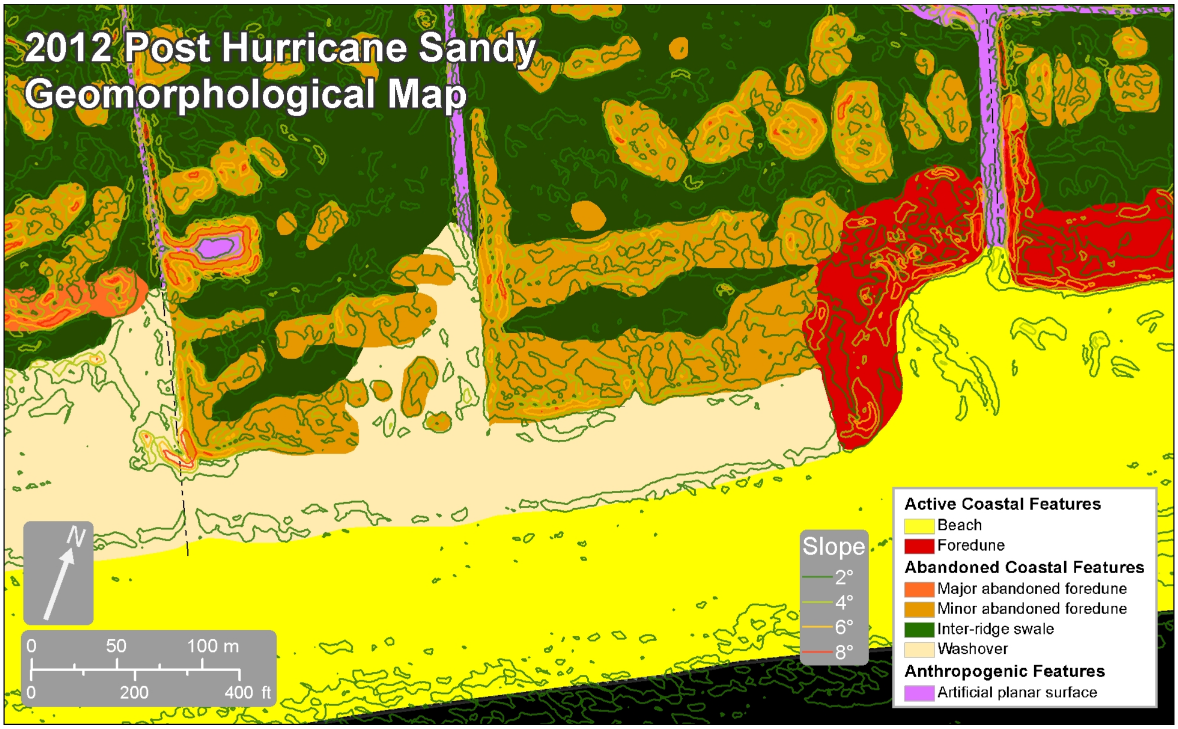

Figure 2. Distribution of geomorphological features, with boundaries created using elevation, relief, and slope criteria, plus supporting resources; site is shown on inset map area on Figure 3.

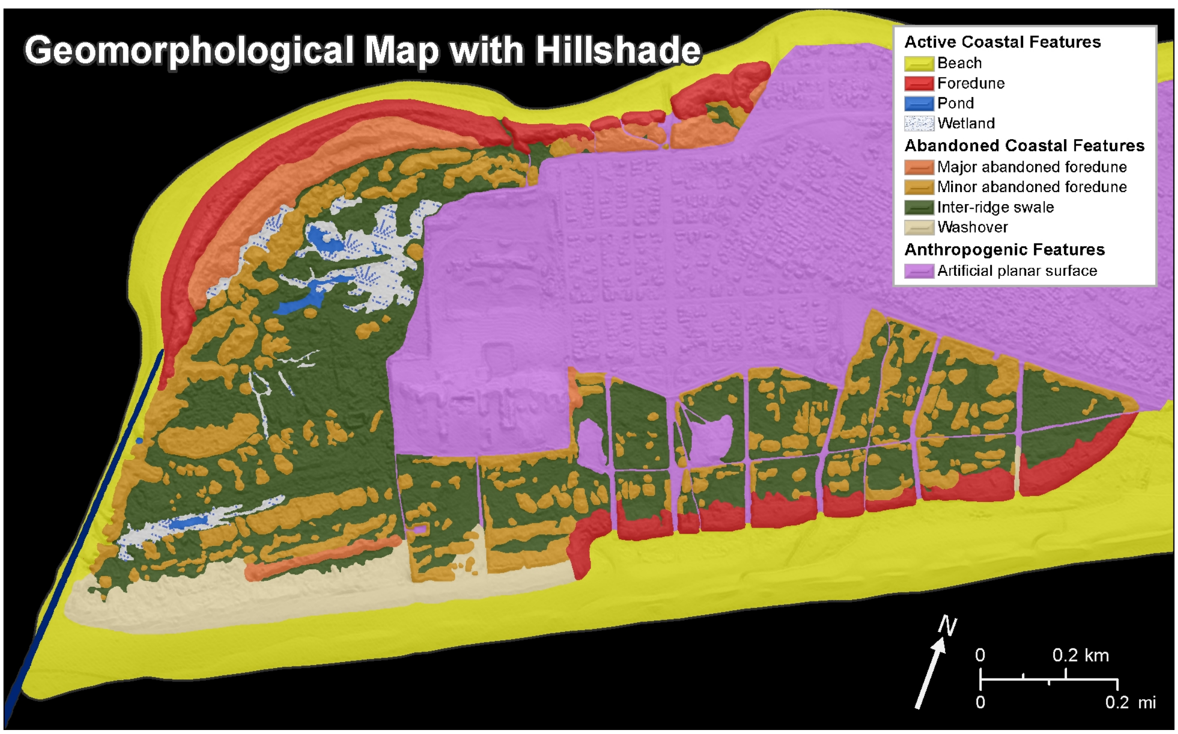

Figure 3. Distribution of geomorphological features, incorporating the active, abandoned, and anthropogenic characteristics of the post Hurricane Sandy topography with relief emphasized through the application of hillshade, Breezy Point, Jamaica Bay Unit, Gateway NRA.

Legend: Categories and Symbolization of Geomorphological Features

The legend is organized relative to the geomorphological evolution of the site, incorporating the relative sequence of coastal landform development from youngest to oldest (Fig. 7). The youngest features are those that are currently in active development, the beach and the associated dune ridge at its inland margin. Other active features include marshes/wetlands and ponds that are related to the modern sea level. Inland of the active foredunes are abandoned dune ridges that were formerly adjacent to an active beach. The abandoned dunes remain as ridges whereas the old beach features are now swales separating the dune features. In general, the abandoned dune ridges and swales constitute the majority of the landforms in these coastal accretionary systems. The oldest landforms in Gateway NRA are on Staten Island where parts of a large glacial terminal moraine and its associated outwash plain dominate the Fort Wadsworth topography. The landform features are thus composed of active coastal forms, abandoned coastal forms, and ancestral glacial forms. Superimposed on the variety of landforms are manipulations and constructions of anthropogenic origin that have altered the landscape and constitute a separate category.

Figure 7. Categories of geomorphological features, and surficial features created by anthropogenic activity.

Table 2. Geomorphological Features in the Gateway National Recreation Area.

Geomorphological classification	Conceptual Basis	Physical Description and Identification
Active Features		
Active Features: **Beach** 	Wave-deposited accumulation of sediment, specifically the seaward portion of a beach profile between the low tide line and the upper limit of storm wave action.	Area of low, nearly planar elevation exposed to waves on oceanside and bayside margins of the barrier spits. A very prominent feature that tends to be broad, continuous, and have sparse to no vegetation. The mapped feature extends from NAVD88 to the toe of the active foredune.
Active Features: **Foredune** 	Ridge formed by wind- and water-deposited sand at the inland margin of a beach, parallel to the coastline. It is vegetated by pioneer plant species that trap sediment. The foredune is actively participating in sediment exchange with the beach.	A continuous, linear feature of elevated topography (positive relief) that is parallel to the shoreline and immediately inland of the oceanside or bayside beach. Foredunes may be irregular in areas of dissection by wind and/or water.

Geomorphological classification	Conceptual Basis	Physical Description and Identification
Active Features: **Wetland**	A general term describing swamps and marshes in areas of very low elevation. Often found in areas sheltered from ocean waves such as the bayside of a barrier system or on isolated islands within a bay.	A flat surface in the intertidal zone characterized by wetland vegetation identified through the use of vegetation maps and aerial imagery. Drainage ditches were often excavated in wetland areas in an attempt to control mosquito populations.
Active Features: **Pond**	Area of open water within the boundaries of the barrier spit or adjacent to estuarine margins. Often occurs as small water bodies within wetlands.	Distinctly visible on orthophotos as dark sites among topography. Only water bodies identified at a 1:12000 map scale are delineated in this category.
Active Features: **Sand flat**	A relatively level, low relief and low elevation sandy area formed and modified by tidal flows in protected areas, often the inter-tidal extension of beaches.	Subtle, planar feature that is often narrow and discontinuous, in the vicinity of the beach, and has sparse to no vegetation. Usually occurring on the bayside of the barrier spit, often forming on the margin of a wetland.
Active Features: **Washover**	Feature caused by an episodic storm event that penetrated inland of the foredune ridge. A relatively flat blanket of sediment deposited in place of or on top of previously existing features or planar surfaces, often expressed in the landscape as fan-shaped deposit.	May be identified as an uncharacteristic break in continuous, shore-parallel linear features of positive relief such as the active foredune or abandoned foredune. It may be a fan-shaped positive elevation on a lower planar surface. Often visible on orthophotography as bare sand. The previously existing dunes may be retained adjacent to the washover fan as low, hummocky dune features.
	Abandoned Features	
Abandoned Features: **Major abandoned foredune**	A previously active foredune that is inland of the active foredune and is no longer in active sediment exchange with the beach. Often found parallel to or adjacent to an active foredune. May have been reworked by winds into parabolic, hummocky, or dissected features.	A former foredune ridge that may be generally linear and intact or dissected, depending on the age of the feature and the influence of wind, waves, and human activity. Usually in relatively close proximity to the active foredune ridge; i.e. ridges not separated by a major interdune swale. A dune is considered major if its ridge has an elevation above 4 meters.
Abandoned Features: **Minor abandoned foredune**	A previously active foredune that is no longer in active sediment exchange with the beach. Often found parallel or adjacent to active foredune. May have been reworked by winds into parabolic, hummocky, or dissected features. A minor abandoned dune either did not fully develop before being abandoned or has since lost elevation by the reworking of winds.	An inland sand ridge that may be linear and intact or dissected, depending on the age of the feature and the influence of wind and other natural and/or anthropogenic activities. Usually in relatively close proximity to the active foredune ridge; i.e. ridges not separated by a major interdune swale. A dune is considered minor if its ridge has an elevation below 4 meters.

Geomorphological classification	Conceptual Basis	Physical Description and Identification
Abandoned Features: **Inter-ridge swale**	A topographical low area between shore-parallel dune ridges that forms during time of abundant sediment supply (shoreline progradation), and occupies the space between the sequential, parallel foredune ridges.	Swales are the continuous and low areas that occur between the sequential, parallel foredune ridges, usually parallel to the active shoreline.
Abandoned Features: **Back dune slope**	Low area immediately inland of the leeward slope of the inlandmost dune ridge. It is related to the foundation of the dune-forming processes	Located on the inland margin of a dune ridge or series of dune ridges. Elevation and slope are generally low and tend to decrease toward the bayside, i.e., slopes away from the dune ridge toward the water.
Glacial Features		
Glacial Features: **Terminal moraine**	Glacial deposit at the margin of the extent of the glacial advance. Consists of unsorted till deposited on earlier landscape.	A large hummocky ridge, usually an abrupt change in topography, rising quickly to the greatest heights in the area.
Glacial Features: **Outwash plain**	A broad surface emanating from the terminal moraine. Created by meltwaters discharging beyond the terminal moraine and depositing sediment by glacio-fluvial processes.	A low planar surface sloping downward beyond the margins of the terminal moraine. It is frequently fan-shaped, leading from gaps or low areas in the terminal moraine. May have kettle holes caused by stranded blocks of ice.
Anthropogenic Features		
Anthropogenic Features: **Artificial planar surface**	A human-made flat or planar surface that has been leveled to site a structure such as a highway or building. Underlying topography is destroyed or covered.	Elevation of surface is nearly or completely homogeneous and level. Abrupt interruption of adjacent naturally occurring topography. Boundary of surface is often linear and clearly visible on the orthophotos.
Anthropogenic Features: **Elevated surface/ridge**	Area where the land has been intentionally elevated by humans for the construction of buildings or to assist in military operations. Such features include gun and mortar batteries built into dunes or disguised as dunes, as well as sites constructed to conceal missile locations.	Marked by variability in elevation, and often with the appearance of a dune or large topographic high. Specific sites can be identified from orthophotos and their boundaries determined based on LiDAR. They do not display the same homogeneity in elevation that is evident with artificial planar surfaces.
Anthropogenic Features: **Temporary surface feature**	A topographical feature created through a natural process driven deposition of sediment within the built environment that is likely to be removed.	Identifiable as a deposit of sediment on a formerly artificial planar surface. The character of the prior topography was based on older orthophotos and LiDAR. This feature consists of natural coastal topography such as washover deposition identifiable within in the contemporary data sources.

Geomorphological classification	Conceptual Basis	Physical Description and Identification
Anthropogenic Features: Erosion control structures **Jetty/Groin** **Bulkhead/Riprap** **Seawall**	An engineered structure built to stabilize the shoreline, reduce sediment erosion, and protect any existing development. These features include: **Jetty –** hard structure at an inlet or downdrift terminus of a beach, meant to prevent sediment from entering a navigation channel; **Groin** – hard structure of rock, wood, and/or concrete extending orthogonally from the shoreline into the water, typically reducing alongshore sediment transport; **Bulkhead** – vertical wall of wood, metal, or concrete, defining an edge in the landform feature; **Riprap –** stone or rubble piled along the margin of a landform feature; **Seawall** – a dike constructed to rise above the landform and prevent storm surge from penetrating inland.	Erosion control structures are primarily identified from orthophotographs. These structures, such as jetties, groins, bulkheads, and seawalls, have been constructed in many parts of the barrier spit over the course of its modern use. They are usually at the water's edge and are defining the margin of a landform or an anthropogenic feature. They are plotted in the report by Dallas et al. (2013), and this resource was utilized to identify locations of structures.
Anthropogenic Features: **Pier/dock/boardwalk**	A structure built into the water for the mooring of ships and boats, or over the land to accommodate pedestrians	Projections into the water, either as single units or in groups to constitute a marina or boat basin. Elevated walkways near the beach.

Final Product

The geomorphological map of Gateway National Recreation Area is the spatial portrayal of the evolution of the coastal, glacial, estuarine, and anthropogenic topography within the park, including the recent modifications that occurred as a result of Hurricane Sandy. A 1:12000 scale representation of the Gateway National Recreation Area geomorphological map consists of 26 page-sized panels, covering the extent of the three major units. The panels are incorporated herein as Appendix II, containing one set of panels without hillshade and a second set that incorporates hillshade.

Part 2. Metrics of Change

Geomorphological Metrics

The completion of the post-Hurricane Sandy geomorphological maps provided a representation of the geomorphological configuration at Gateway NRA directly related to the collection of its source datasets, particularly the LiDAR elevation data. The LiDAR datasets, collected on November 16, 2012, provided a snapshot of the surficial topographical expression resulting from the interaction of antecedent geomorphological architecture and the physical processes associated with the storm. Application of the methodology for the geomorphological categorization of topography detailed in Part 1 of this report resulted in a mapped representation of the geomorphological features with dimensions derived from the LiDAR DEM. Therefore, the post-Hurricane Sandy geomorphological maps were assigned the temporal value of November 2012, the date of the post-Hurricane Sandy LiDAR collection, and represented a stage in the development of Gateway's geomorphology. The 2010 geomorphological maps were completed utilizing the same methodology as the post-Hurricane Sandy maps. They were created utilizing LiDAR data collected between August 28 and September 11, 2010 for Sandy Hook and between April 14 and May 1, 2010 for Staten Island Unit and Jamaica Bay Unit. Therefore, these maps are assigned the temporal value of 2010. The creation of two geomorphological maps from temporally distinct topographical data sources provided an opportunity for the comparison of the geomorphological features depicted on them.

The metrics derived from this comparison are primarily grouped as areal or linear, describing the spatial dimensions required for their quantification. The two-dimensional areal comparisons represented the change in spatial distribution of discrete geomorphological features defined by the spatially-registered polygons that comprised each geomorphological map. The one-dimensional linear displacement metrics described both the cross-shore and alongshore shift of geomorphological features that lie at finite and readily identifiable positions on the profile. Because each map dataset was considered as a representation of the geomorphological configuration at a given time, quantifications derived from the comparisons of the maps represented net change over time. In this case, the dimensional change was related to the occurrence of the Hurricane Sandy storm event. The spatial distribution of the changes are placed into an alongshore context by assigning their occurrence within several components of the Gateway NRA. They consist of: 1. each of the 4 map "Areas" within the Sandy Hook Unit; 2. each of the 17 map "Areas" within the Jamaica Bay Unit, 3. each of the 5 map "Areas" within the Staten Island Unit; and 4. each of the three park Units within Gateway, Sandy Hook, Jamaica Bay, and Staten Island. The following geomorphological metrics were tabulated:

Areal

- The difference in spatial extent (area) for each geomorphological feature category.

Linear (for ocean facing shorelines)

- Displacement of the shoreline position.
- Displacement of the active foredune crest, defined as the highest elevation within the "Foredune" geomorphological feature category.

- Alongshore length of the shoreline and the “Foredune” geomorphological feature category present within each geomorphological map dataset.
- The net foredune alongshore length represented as a percentage change from 2010 to 2012.

Together, these metrics offer an insight into the vectors of topographical evolution that occurred in the temporal span between 2010 and November 2012, mostly as a result of Hurricane Sandy.

Methodology for the Derivation of Metrics

The methodology for the derivation of each metric of change involved the identification of a geomorphological feature’s areal extent or position of each temporally distinct map dataset, the calculation of change in area or position between those two quantities or points, and the representation of that change within an alongshore context listed in the tables of results.

Areal Change

The single areal quantification was the change in distribution of the planimetric area of geomorphological features between the two map datasets, 2010 and 2012 (post-Hurricane Sandy). At its base, each map dataset consisted of a group of polygons with digitized vertices registered in geographical coordinates of the spatial boundaries of the geomorphological features. Each of these polygons produced an areal dimension of a particular geomorphological feature. Once the calculation was achieved, the areas of polygons of a given classification were summed to provide the total area for that classification across the entire map.

The next step involved the division of the entirety of the Gateway geomorphological maps into smaller segments, and grouping them into: 1. each of the 4 map “Areas” within the Sandy Hook Unit; 2. each of the 17 map “Areas” within the Jamaica Bay Unit, 3. each of the 5 map “Areas” within the Staten Island Unit; and 4. each of the three park units within Gateway, Sandy Hook, Jamaica Bay, and Staten Island. In every one of these segments, the total area of individual polygons belonging to each of the geomorphological feature categories was calculated for both the pre- and post-storm maps (see Fig. 8 for an example of categories and comparative dimensions). Then the difference between the two maps was calculated for each individual category within that smaller segment. This procedure was repeated for the geomorphological features within each of the segments and collated to create the dimensional changes according to: 1. each of the 4 map “Areas” within the Sandy Hook Unit; 2. each of the 17 map “Areas” within the Jamaica Bay Unit, 3. each of the 5 map “Areas” within the Staten Island Unit; and 4. each of the three park units within Gateway, Sandy Hook, Jamaica Bay, and Staten Island. The results of the calculations are in Table 3, Table 4, Table 5, and Table 6, respectively.

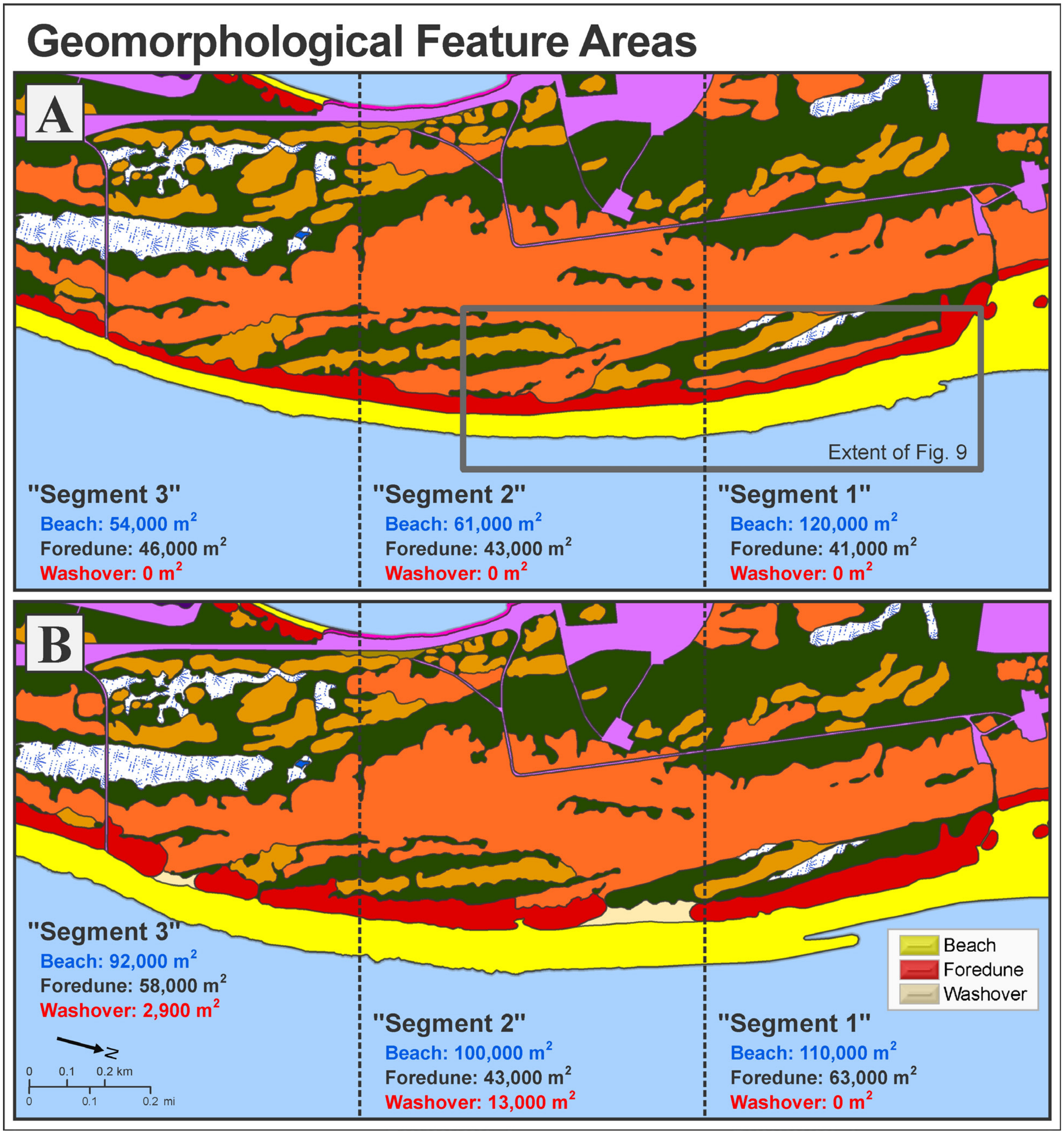

Figure 4. An example of the 2010 and Post-Hurricane Sandy distributions and metrics of geomorphological features for three selected segments along Sandy Hook. The planimetric area values for some geomorphological feature categories are represented and summed within alongshore segments for 2010 (Panel A) and post-Hurricane Sandy (Panel B), Sandy Hook Unit, Gateway National Recreation Area.

Linear Change

A number of metrics were developed to measure the cross-shore change of linear geomorphological features for ocean-facing shorelines within Gateway NRA, including the displacement of the shoreline, the displacement of the foredune crest, the alongshore length of the foredune, and the change in alongshore length of the foredune. Each of these metrics represented the linear displacement of positions identifiable using the geomorphological maps and LiDAR elevation datasets. With the exception of the foredune crest, these positions coincided with geomorphological feature boundaries represented in the maps. For example, the position of the shoreline was at the seaward boundary of the beach category, defined as the intersection of the beach face and NAVD88, whereas the foredune crest was located within the foredune's surface area. Each of these quantifications used a characteristic criterion for the identification of the geomorphological feature they describe and, as with the areal metric, were tabulated according to their occurrence within defined alongshore segments of Gateway NRA. In some instances, a mean value was required to describe the cross-shore change per alongshore component because the shoreline and foredune crest displacements were metrics depicting cross-shore displacement per some unit length along each segment. Whereas the alongshore length of the foredune could be measured and compared directly without the need for averaging, it did require the summation of individual foredune ridge lengths to provide a value appropriate to a given segment (Fig. 9).

The first linear metric, shoreline displacement, was defined as the cross-shore change in position of the seawardmost boundary of the "Beach" feature category, a position at NAVD88 on each geomorphological map dataset derived from LiDAR elevation data. Similar to the procedure utilized by the USGS Digital Shoreline Analysis System (Thieler et al. 2009), the shoreline position for each map dataset was quantified using the projected coordinates of the intersection of the NAVD88/Beach boundary line and cross-shore transects. For a given transect, the change in position was described by the vector that compared the intersection of the transect and the shoreline for each geomorphological map dataset. A standard interval of 12 m was applied between transects where they intersected the shoreline that created measurements of displacement of the position of the shoreline every 12 m. All of the shoreline change measurements within a given alongshore segment were averaged, representing the mean displacement for that length of shoreline. Mean shoreline displacement values were calculated for measurements within: 1. each of the 11 map "Areas" within Gateway containing ocean facing shorelines; and 2. each of the three park units within Gateway, Sandy Hook, Jamaica Bay, and Staten Island. The results of the calculations are in Table 7 and Table 8, respectively.

The foredune crest analysis was carried out utilizing a similar methodology to that used to derive the shoreline displacement metric. The same set of cross-shore transects used to sample the position of the shoreline was used to determine the position of the foredune crest, with mean displacement values calculated for the same alongshore segments. However, an additional step was required because the foredune crest did not lie on the boundary of a geomorphological feature polygon. First, the foredune crest was identified by utilizing the map and LiDAR datasets to determine the points of highest elevation within the boundary of the "Foredune" category. This was accomplished by constructing cross-sectional elevation profiles along each transect represented in each geomorphological map (pre- and post-Hurricane Sandy). Utilizing these profiles, the highest elevation within the "Foredune" category was extracted and its geographical coordinates were recorded. Similar to the shoreline analysis, the vector between this position for each set of temporal datasets on a given transect provided the displacement of the feature. The foredune crest change measurements were averaged to represent the mean displacement of the foredune crest for that a

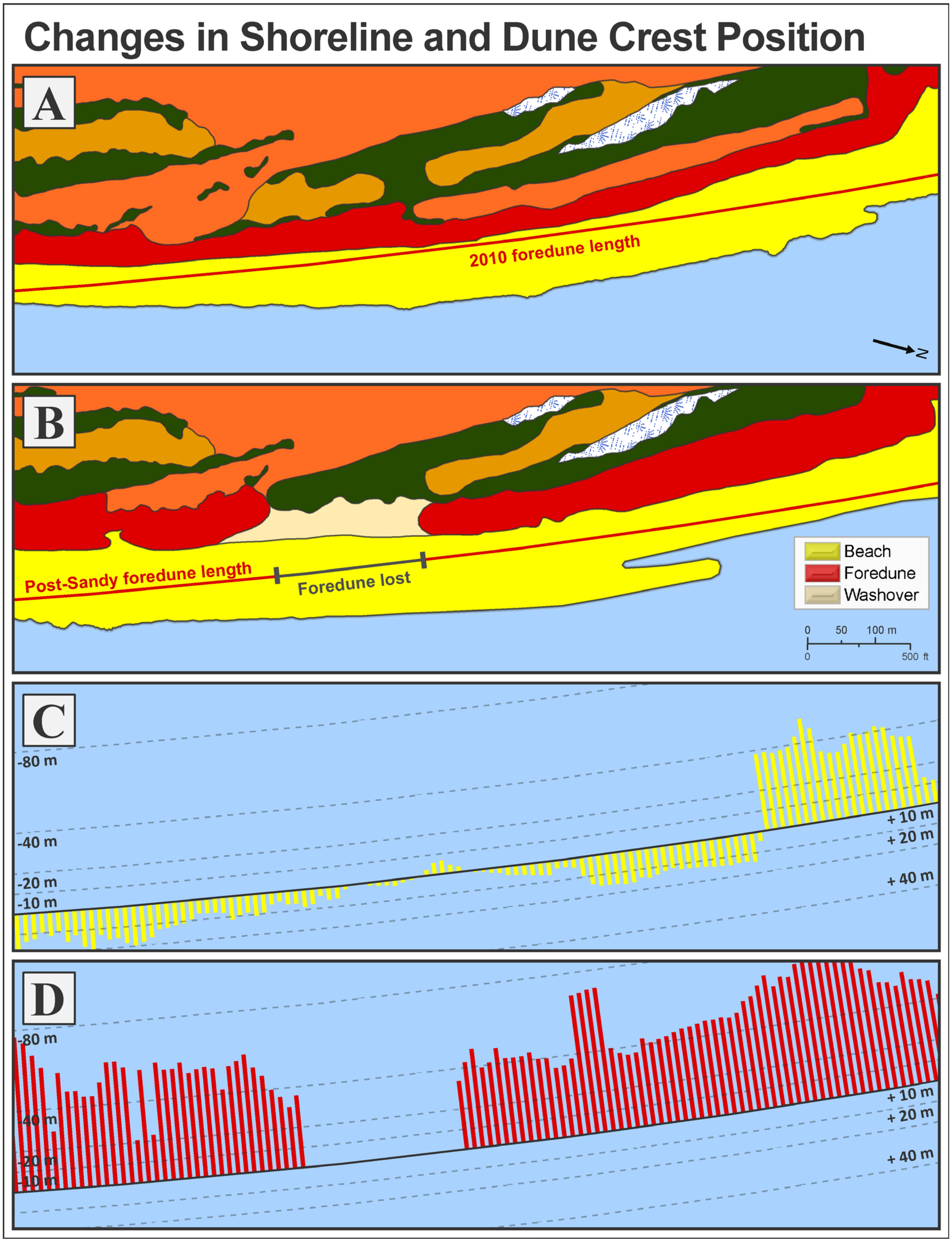

Figure 5. An example of the linear changes derived from the 2010 and Post-Hurricane Sandy geomorphological maps, incorporating a metric of alongshore foredune length by compartment (Panels A and B); a measure of shoreline displacement at 12 m intervals (Panel C); and a measure of foredune crest displacement at 12 m intervals, incorporating gaps where the foredune has been eroded (Panel D); Sandy Hook Unit, Gateway National Recreation Area.

given length of shoreline. Mean foredune crest displacement values were calculated for measurements within: 1. each of the 11 map “Areas” within Gateway containing ocean facing shorelines; and 2. each of the three park units within Gateway, Sandy Hook, Jamaica Bay, and Staten Island. The results of the calculations are in Table 7 and Table 8, respectively.

In addition to cross-shore foredune crest displacement, a second foredune displacement metric was required to adequately describe the linear change to the foredune feature. Because of severe erosion, there were differences in the alongshore length of the foredune feature in the two map datasets. Therefore, displacement of dune crest could not be calculated at every transect. Instead it could only be calculated at transects that intersected “Foredune” on both maps (Fig. 9). To quantify the variable alongshore distribution of the dune crest, the alongshore length of “Foredune” was tabulated for both maps, and the change in its alongshore length was presented as the percentage of the “Foredune” feature lost in the post-Hurricane Sandy maps. These metrics were calculated and spatially assigned by: 1. each of the 11 map “Areas” within Gateway containing ocean facing shorelines; and 2. each of the three park units within Gateway, Sandy Hook, Jamaica Bay, and Staten Island. The results of the calculations are in Table 7 and Table 8, respectively. For comparison, the alongshore length of the shoreline was added to these tables.

Results

Sandy Hook Unit

Table 3A. Areal change (m^2) of active coastal features sorted by map area within Sandy Hook Unit.

Area	Beach			Foredune			Sand flat			Wetland			Washover		
	2010	Post-S[1]	Dif.[2]	2010	Post-S	Dif.	2010	Post-S	Dif.	2010	Post-S	Dif.	2010	Post-S	Dif.
SHU 1	518,966	569,174	**50,208**	192,033	196,303	**4,270**	70,330	68,438	**-1,892**	169,449	169,431	**-18**	0	102,727	**102,727**
SHU 2	249,630	357,045	**107,415**	135,296	172,314	**37,017**	0	0	**0**	226,239	222,477	**-3,763**	0	19,546	**19,546**
SHU 3	384,931	415,483	**30,552**	169,412	99,453	**-69,959**	0	0	**0**	108,506	102,582	**-5,924**	0	162,303	**162,303**
SHU 4	58,460	72,322	**13,862**	26,390	0	**-26,390**	0	0	**0**	0	0	**0**	0	20,366	**20,366**

[1]Post-Hurricane Sandy; [2]Difference

Table 3B. Areal change (m^2) of abandoned coastal features sorted by map area within Sandy Hook Unit.

Area	Major abandoned foredune			Minor abandoned foredune			Inter-ridge swale			Back dune slope		
	2010	Post-S[1]	Dif.[2]	2010	Post-S	Dif.	2010	Post-S	Dif.	2010	Post-S	Dif.
SHU 1	559,425	543,453	**-15,972**	427,990	390,075	**-37,915**	691,794	652,750	**-39,044**	1,596	1,596	**0**
SHU 2	870,848	790,885	**-79,964**	386,263	361,513	**-24,749**	892,910	864,011	**-28,899**	5,600	5,600	**0**
SHU 3	90,656	67,761	**-22,895**	54,006	29,239	**-24,767**	112,113	86,202	**-25,911**	80,443	76,280	**-4,163**
SHU 4	11,158	9,348	**-1,810**	10,610	0	**-10,610**	6,671	1,261	**-5,410**	0	0	**0**

[1]Post-Hurricane Sandy; [2]Difference

Jamaica Bay Unit

Table 4A. Areal change (m^2) of active coastal features sorted by map area within Jamaica Bay Unit

Area	Beach			Foredune			Wetland			Washover		
	2010	Post-S[1]	Dif.[2]	2010	Post-S	Dif.	2010	Post-S	Dif.	2010	Post-S	Dif.
JBU 1	459,981	573,392	**113,410**	154,428	170,393	**15,964**	52,147	56,183	**4,035**	0	120,470	**120,470**
JBU 2	424,491	487,060	**62,570**	110,975	103,314	**-7,661**	10,155	8,821	**-1,334**	0	67,288	**67,288**
JBU 3	187,515	196,664	**9,149**	3,515	0	**-3,515**	0	0	**0**	0	57,373	**57,373**
JBU 4	50,541	68,158	**17,616**	22,551	42,310	**19,759**	53,284	53,094	**-189**	0	767	**767**
JBU 5	67,107	75,291	**8,183**	13,949	15,468	**1,519**	27,961	27,969	**7**	0	0	**0**
JBU 6	79,424	94,900	**15,476**	9,489	9,196	**-293**	117,580	113,136	**-4,444**	0	0	**0**
JBU 7	22,558	23,684	**1,126**	0	0	**0**	42,626	43,516	**891**	0	0	**0**
JBU 8	0	0	**0**	0	0	**0**	16,743	15,227	**-1,517**	0	0	**0**

[1]Post-Hurricane Sandy; [2]Difference

Table 4A (continued). Areal change (m^2) of active coastal features sorted by map area within Jamaica Bay Unit

Area	Beach			Foredune			Wetland			Washover		
	2010	Post-S[1]	Dif.[2]	2010	Post-S	Dif.	2010	Post-S	Dif.	2010	Post-S	Dif.
JBU 9	74,832	103,241	**28,409**	4,724	4,724	**0**	256,984	210,549	**-46,435**	0	0	**0**
JBU 10	26,562	34,442	**7,880**	4,894	4,894	**0**	587,309	582,843	**-4,466**	0	0	**0**
JBU 11	82,037	98,437	**16,400**	0	1,704	**1,704**	758,431	720,763	**-37,668**	0	0	**0**
JBU 12	34,104	45,147	**11,043**	1,759	1,759	**0**	731,843	755,751	**23,909**	0	0	**0**
JBU 13	58,595	80,663	**22,067**	0	0	**0**	988,340	1,033,030	**44,690**	0	0	**0**
JBU 14	125,737	130,794	**5,057**	399	399	**0**	234,307	228,992	**-5,315**	0	0	**0**
JBU 15	5,511	6,683	**1,172**	0	0	**0**	70,693	71,238	**544**	0	0	**0**
JBU 16	7,151	7,074	**-77**	0	0	**0**	303,844	294,503	**-9,341**	0	0	**0**
JBU 17	1,514	1,514	**0**	0	0	**0**	1,613,295	1,603,596	**-9,699**	0	0	**0**

[1]Post-Hurricane Sandy; [2]Difference

Table 4B. Areal change (m^2) of abandoned costal features sorted by map area within Jamaica Bay Unit

Area	Major abandoned foredune			Minor abandoned foredune			Inter-ridge swale			Back dune slope		
	2010	Post-S[1]	Dif.[2]	2010	Post-S	Dif.	2010	Post-S	Dif.	2010	Post-S	Dif.
JBU 1	149,162	91,756	**-57,406**	359,350	326,344	**-33,006**	628,054	555,831	**-72,223**	0	0	**0**
JBU 2	110,350	57,911	**-52,439**	45,991	34,317	**-11,674**	200,499	180,936	**-19,562**	0	0	**0**
JBU 3	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
JBU 4	16,605	1,382	**-15,224**	861	413	**-448**	3,669	525	**-3,144**	14,542	8,953	**-5,589**
JBU 5	0	0	**0**	4,129	4,602	**473**	677	276	**-401**	1,122	1,122	**0**
JBU 6	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
JBU 7	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
JBU 8	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
JBU 9	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
JBU 10	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
JBU 11	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
JBU 12	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
JBU 13	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
JBU 14	0	0	**0**	246	246	**0**	0	0	**0**	0	0	**0**
JBU 15	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
JBU 16	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
JBU 17	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**

[1]Post-Hurricane Sandy; [2]Difference

Staten Island Unit

Table 5A. Areal change (m^2) of active coastal features sorted by map area within Staten Island Unit.

Area	Beach			Foredune			Wetland			Washover		
	2010	Post-S[1]	Dif.[2]	2010	Post-S	Dif.	2010	Post-S	Dif.	2010	Post-S	Dif.
SIU 1	111,681	176,697	**65,017**	41,025	58,600	**17,575**	152,053	126,206	**-25,847**	0	37,844	**37,844**
SIU 2	112,800	137,762	**24,962**	38,331	11,269	**-27,062**	107,976	107,976	**0**	0	84,630	**84,630**
SIU 3	246,827	244,234	**-2,593**	17,737	0	**-17,737**	0	0	**0**	0	66,179	**66,179**
SIU 4	66,491	74,379	**7,888**	22,607	25,909	**3,302**	0	0	**0**	0	4,253	**4,253**
SIU 5	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**

[1]Post-Hurricane Sandy; [2]Difference

Table 5B. Areal change (m^2) of abandoned coastal features sorted by map area within Staten Island Unit.

Area	Major abandoned foredune			Minor abandoned foredune			Inter-ridge swale		
	2010	Post-S[1]	Dif.[2]	2010	Post-S	Dif.	2010	Post-S	Dif.
SIU 1	54,213	53,188	**-1,025**	56,127	32,079	**-24,049**	44,304	31,896	**-12,408**
SIU 2	335	335	**0**	4,956	386	**-4,569**	557	0	**-557**
SIU 3	0	0	**0**	0	0	**0**	30,587	10,493	**-20,094**
SIU 4	0	0	**0**	0	0	**0**	0	0	**0**
SIU 5	0	0	**0**	0	0	**0**	0	0	**0**

[1]Post-Hurricane Sandy; [2]Difference

By Park Unit

Table 6A. Areal change (m^2) of active coastal features sorted by Park Unit.

Area	Beach			Foredune			Sand flat			Wetland			Washover		
	2010	Post-S[1]	Dif.[2]	2010	Post-S	Dif.	2010	Post-S	Dif.	2010	Post-S	Dif.	2010	Post-S	Dif.
SHU	1,211,987	1,414,024	**202,037**	523,132	468,069	**-55,062**	70,330	68,438	**-1,892**	504,194	494,490	**-9,705**	0	304,942	**304,942**
JBU	1,707,660	2,027,142	**319,482**	326,683	354,160	**27,477**	0	0	**0**	5,865,542	5,819,210	**-46,333**	0	245,898	**245,898**
SIU	537,799	633,072	**95,274**	119,699	95,778	**-23,922**	0	0	**0**	260,029	234,182	**-25,847**	0	192,906	**192,906**

[1]Post-Hurricane Sandy; [2]Difference

Table 6B. Areal change (m^2) of abandoned coastal features sorted by Park Unit.

Area	Major abandoned foredune			Minor abandoned foredune			Inter-ridge swale			Back dune slope		
	2010	Post-S[1]	Dif.[2]	2010	Post-S	Dif.	2010	Post-S	Dif.	2010	Post-S	Dif.
SHU	1,532,087	1,411,447	**-120,640**	878,868	780,827	**-98,041**	1,703,489	1,604,225	**-99,264**	87,639	83,476	**-4,163**
JBU	276,118	151,048	**-125,069**	410,576	365,921	**-44,655**	832,899	737,568	**-95,331**	15,664	10,075	**-5,589**
SIU	54,548	53,523	**-1,025**	61,083	32,465	**-28,618**	75,448	42,389	**-33,059**	0	0	**0**

[1]Post-Hurricane Sandy; [2]Difference

Shoreline and Foredune Change by Map Area

Table 5. Metrics of shoreline and foredune change subdivided by Map Area.

Area	Shoreline Displacement (m)	Foredune Crest Displacement (m)	Shoreline Length (m)	2010 Foredune Length (m)	Post-S Foredune Length (m)	% of Foredune Lost
SHU 1	13.9	-5.3	3200	2600	2200	15%
SHU 2	4.1	-48.7	3200	2900	2600	10%
SHU 3	-8.8	-28.3	3100	3000	1600	47%
SHU 4	-9.7	-	1000	1000	0	100%
JBU 1	21.3	-15.4	2500	2400	1200	050%
JBU 2	-9.5	-38.1	3000	2500	1500	040%
JBU 3	-2.6	-	2000	0120	0000	100%
SIU 1	-2.1	-26.5	3000	1300	1300	0%
SIU 2	4.2	-25.0	3000	1400	350	75%
SIU 3	-2.2	-	3000	770	0	100%
SIU 4	0.7	-10.5	1500	850	860	-

Shoreline and Foredune Change by Park Unit

Table 8. Metrics of shoreline and foredune change subdivided by Park Unit.

Park Unit	Shoreline Displacement (m)	Foredune Crest Displacement (m)	Shoreline Length (m)	2010 Foredune Length (m)	Post-S Foredune Length (m)	% of Foredune Lost
Sandy Hook	2.0	-29.2	10500	9600	6400	33%
Jamaica Bay	4.0	-32.0	7500	5000	1300	74%
Staten Island	0.1	-20.6	11000	4200	2500	40%

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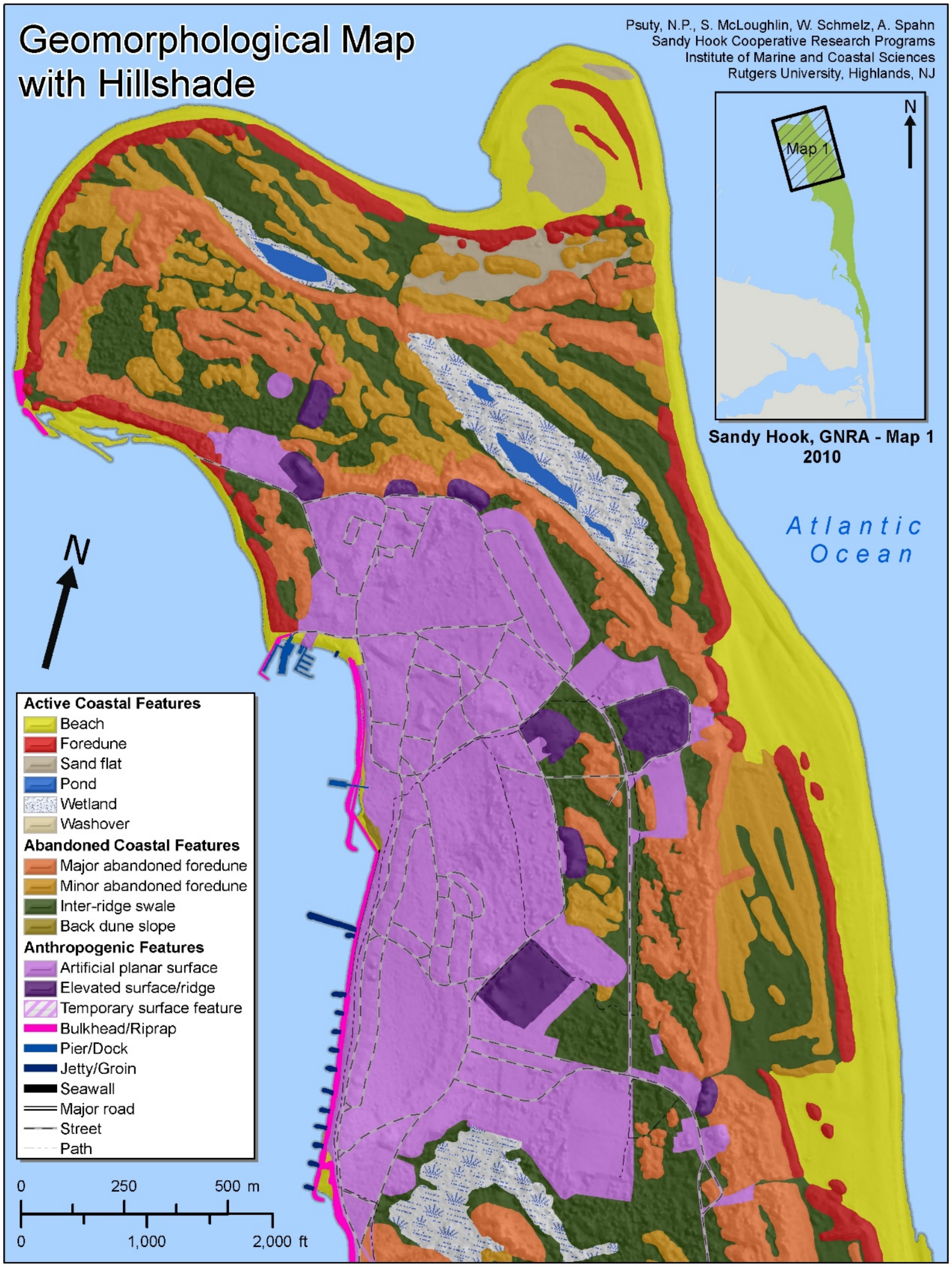
Appendix I: 2010 Maps of Gateway National Recreation Area Geomorphology, with and without Hillshade

The spatial datasets represented within these maps are the basis from which metrics of geomorphological change caused by Hurricane Sandy provided in Part 2 of this report are calculated.

Sandy Hook Unit (SHU)


Geomorphological Map
with Hillshade
Psuty, N.P., S. McLoughlin, W. Schmelz, A. Spahn
Sandy Hook Cooperative Research Programs
Institute of Marine and Coastal Sciences
Rutgers University, Highlands, NJ
N
Map 1
Sandy Hook, GNRA - Map 1
2010
Atlantic
Ocean
N
Active Coastal Features
Beach
Foredune
Sand flat
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Seawall
Major road
Street
Path
0
250
500 m
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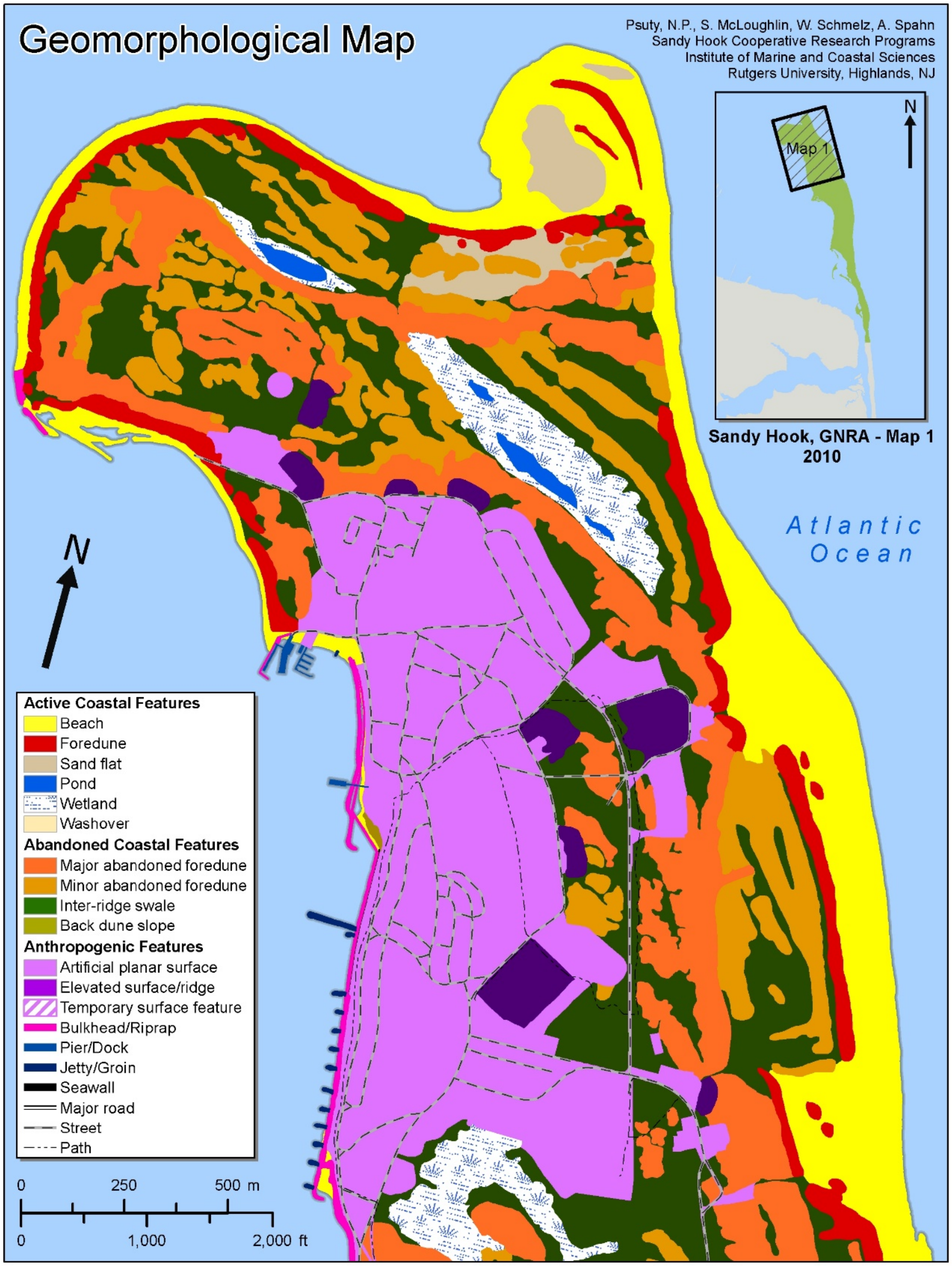
Geomorphological Map
Psuty, N.P., S. McLoughlin, W. Schmelz, A. Spahn
Sandy Hook Cooperative Research Programs
Institute of Marine and Coastal Sciences
Rutgers University, Highlands, NJ
N
Map 1
Sandy Hook, GNRA - Map 1
2010
Atlantic
Ocean
N
Active Coastal Features
Beach
Foredune
Sand flat
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Seawall
Major road
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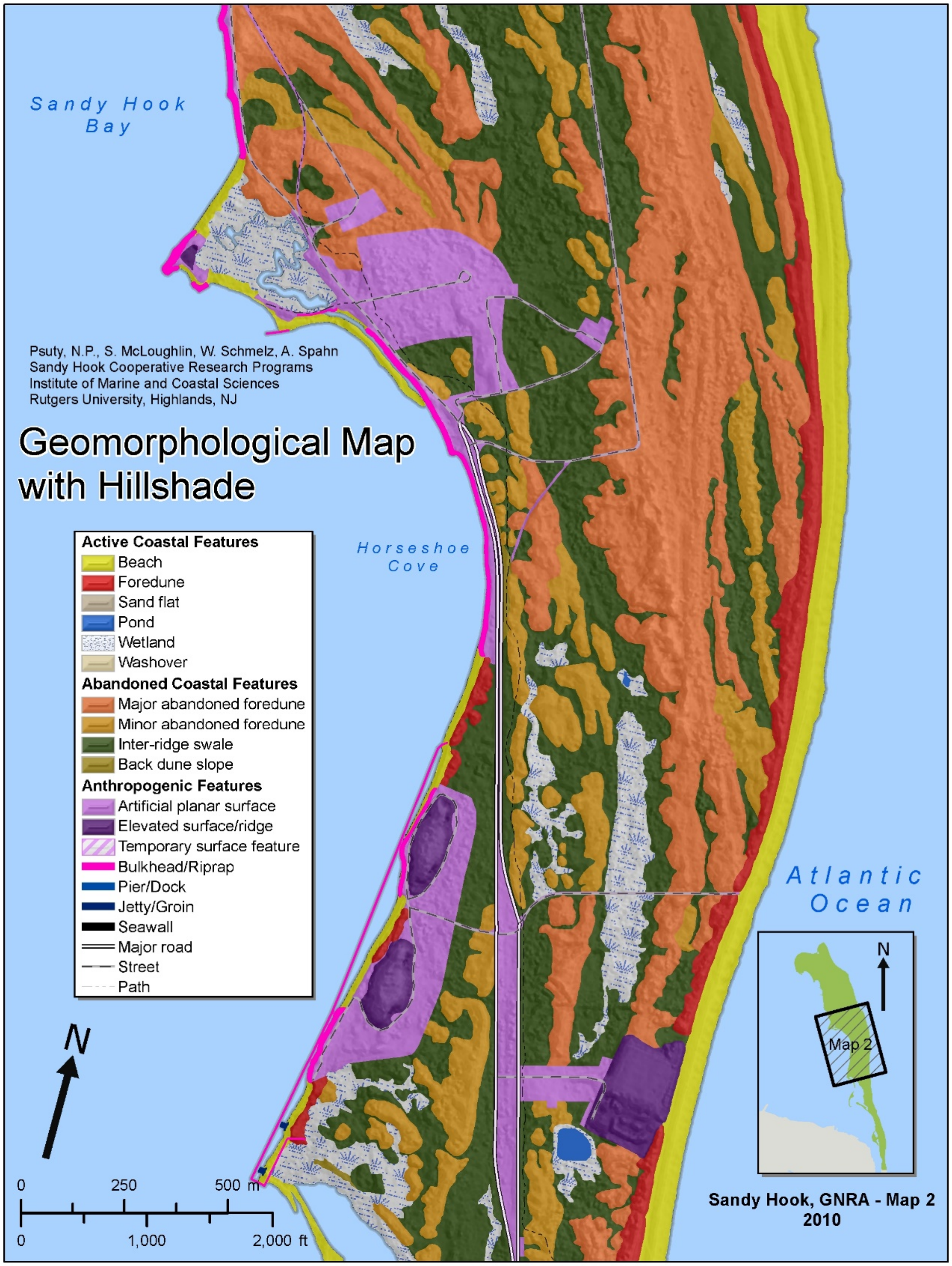
Sandy Hook Bay
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Sandy Hook Cooperative Research Programs
Institute of Marine and Coastal Sciences
Rutgers University, Highlands, NJ
Geomorphological Map with Hillshade
Horseshoe Cove
Active Coastal Features
Beach
Foredune
Sand flat
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Seawall
Major road
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Atlantic Ocean
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Map 2
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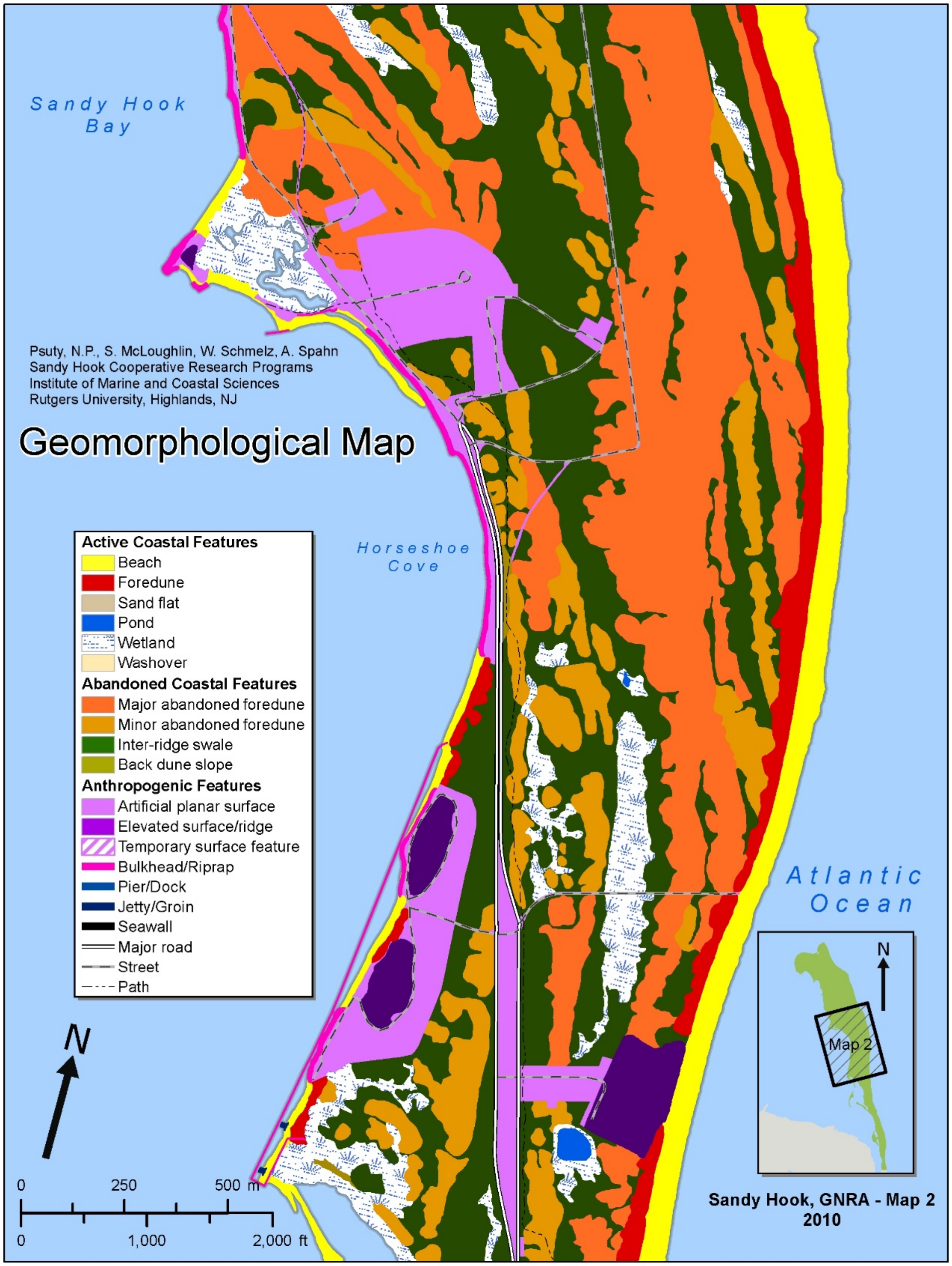
Sandy Hook, GNRA - Map 2
2010


Sandy Hook
Bay
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Sandy Hook Cooperative Research Programs
Institute of Marine and Coastal Sciences
Rutgers University, Highlands, NJ
Geomorphological Map
Horseshoe
Cove
Active Coastal Features
Beach
Foredune
Sand flat
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
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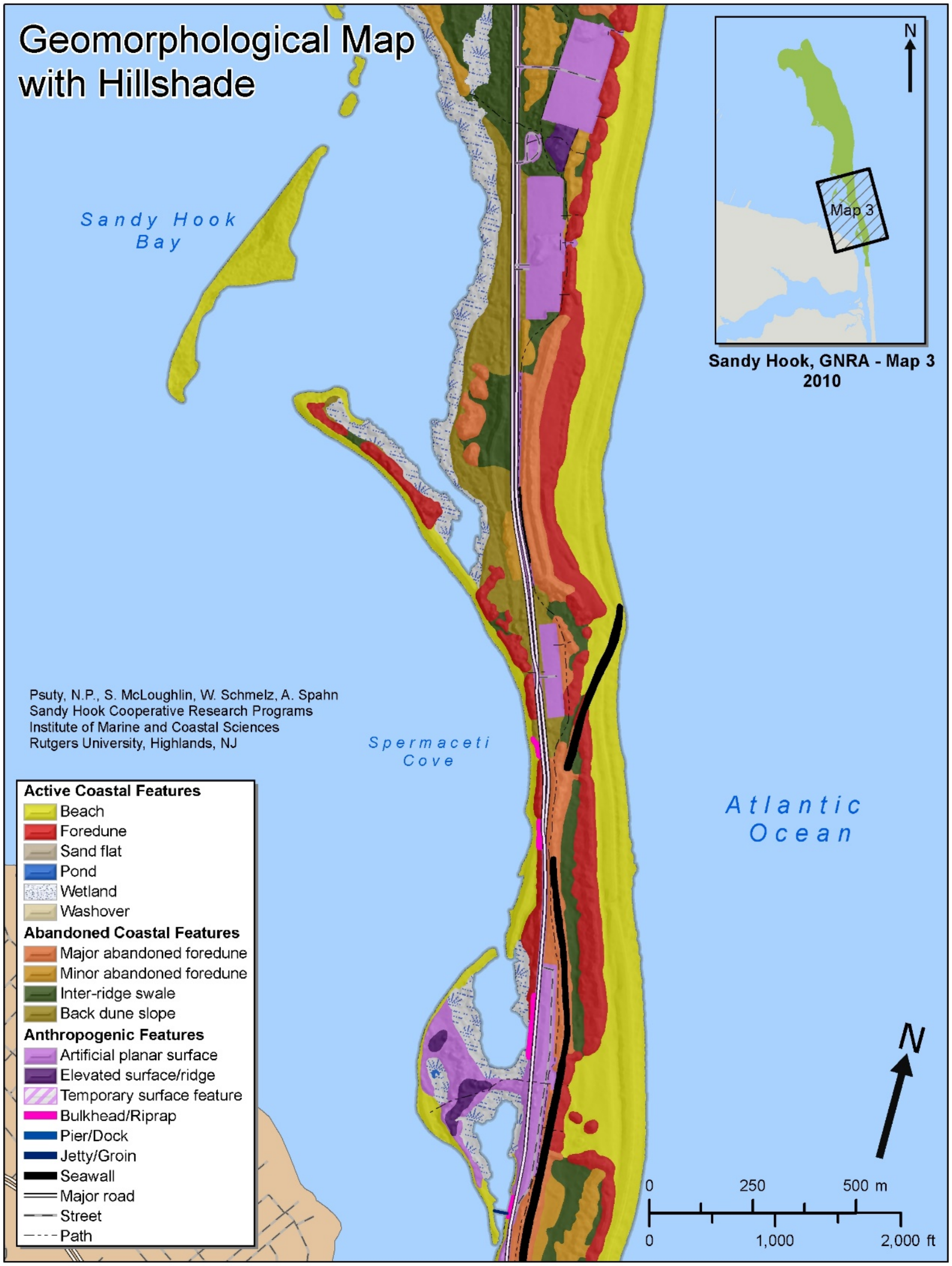
Map 2
Sandy Hook, GNRA - Map 2
2010


Geomorphological Map with Hillshade
Sandy Hook Bay
Spermaceti Cove
Atlantic Ocean
Psuty, N.P., S. McLoughlin, W. Schmelz, A. Spahn
Sandy Hook Cooperative Research Programs
Institute of Marine and Coastal Sciences
Rutgers University, Highlands, NJ
Sandy Hook, GNRA - Map 3
2010
Map 3
N
Active Coastal Features
Beach
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Sand flat
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Abandoned Coastal Features
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Inter-ridge swale
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Anthropogenic Features
Artificial planar surface
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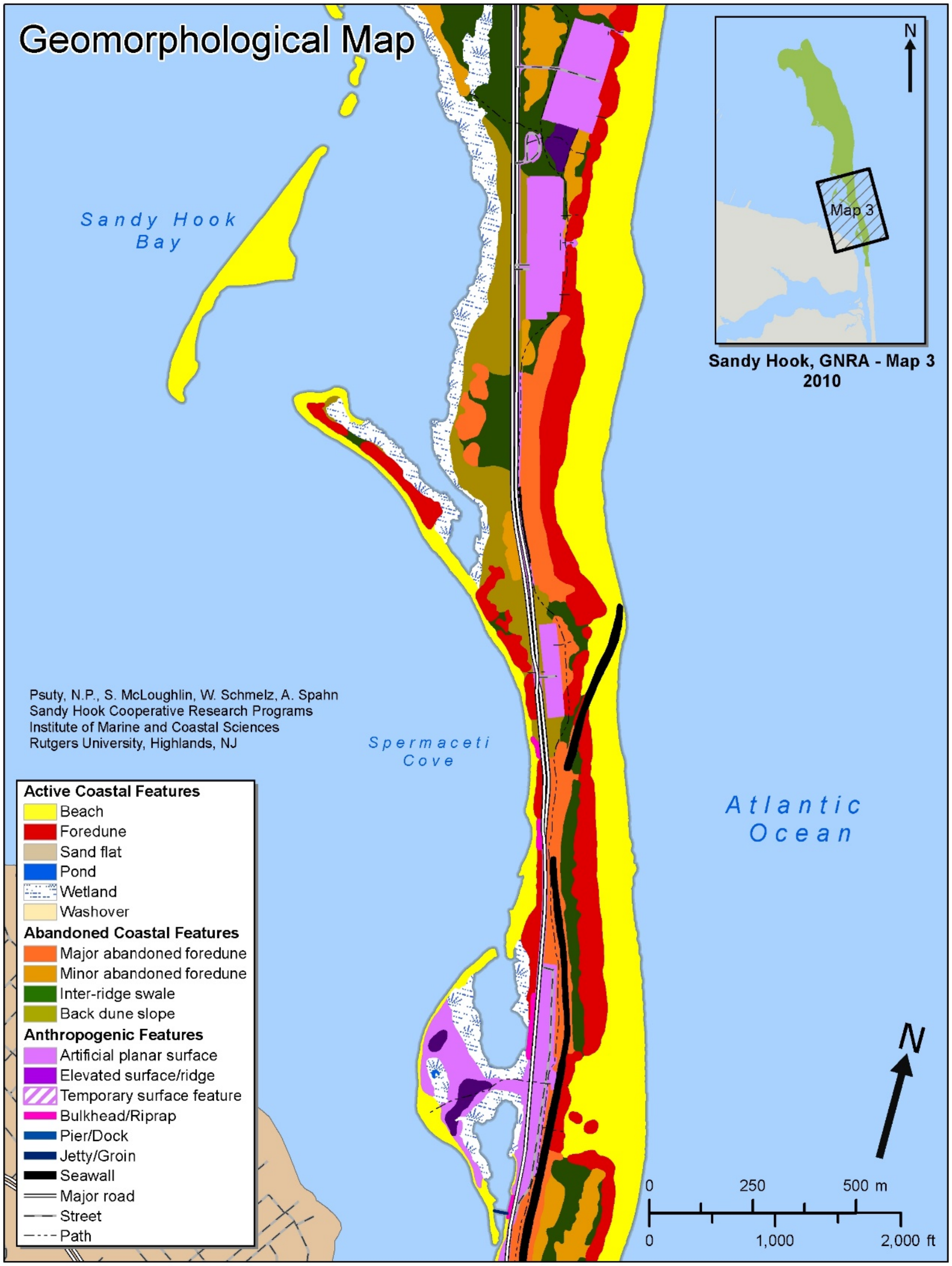
Geomorphological Map
Sandy Hook Bay
Spermaceti Cove
Atlantic Ocean
Psuty, N.P., S. McLoughlin, W. Schmelz, A. Spahn
Sandy Hook Cooperative Research Programs
Institute of Marine and Coastal Sciences
Rutgers University, Highlands, NJ
Map 3
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Sandy Hook, GNRA - Map 3
2010
Active Coastal Features
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Abandoned Coastal Features
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Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
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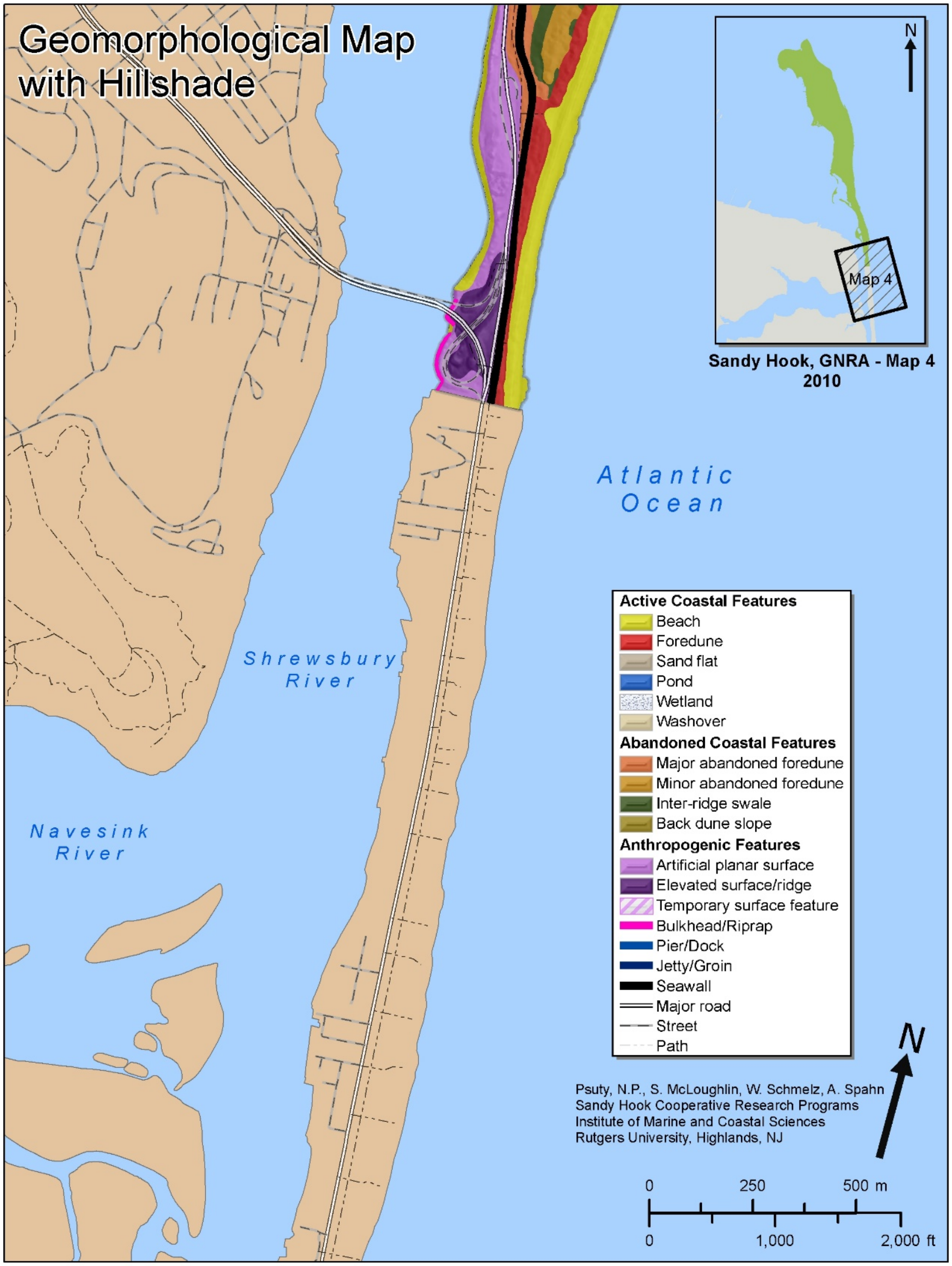
Geomorphological Map with Hillshade
Atlantic Ocean
Shrewsbury River
Navesink River
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Map 4
Sandy Hook, GNRA - Map 4
2010
Active Coastal Features
Beach
Foredune
Sand flat
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
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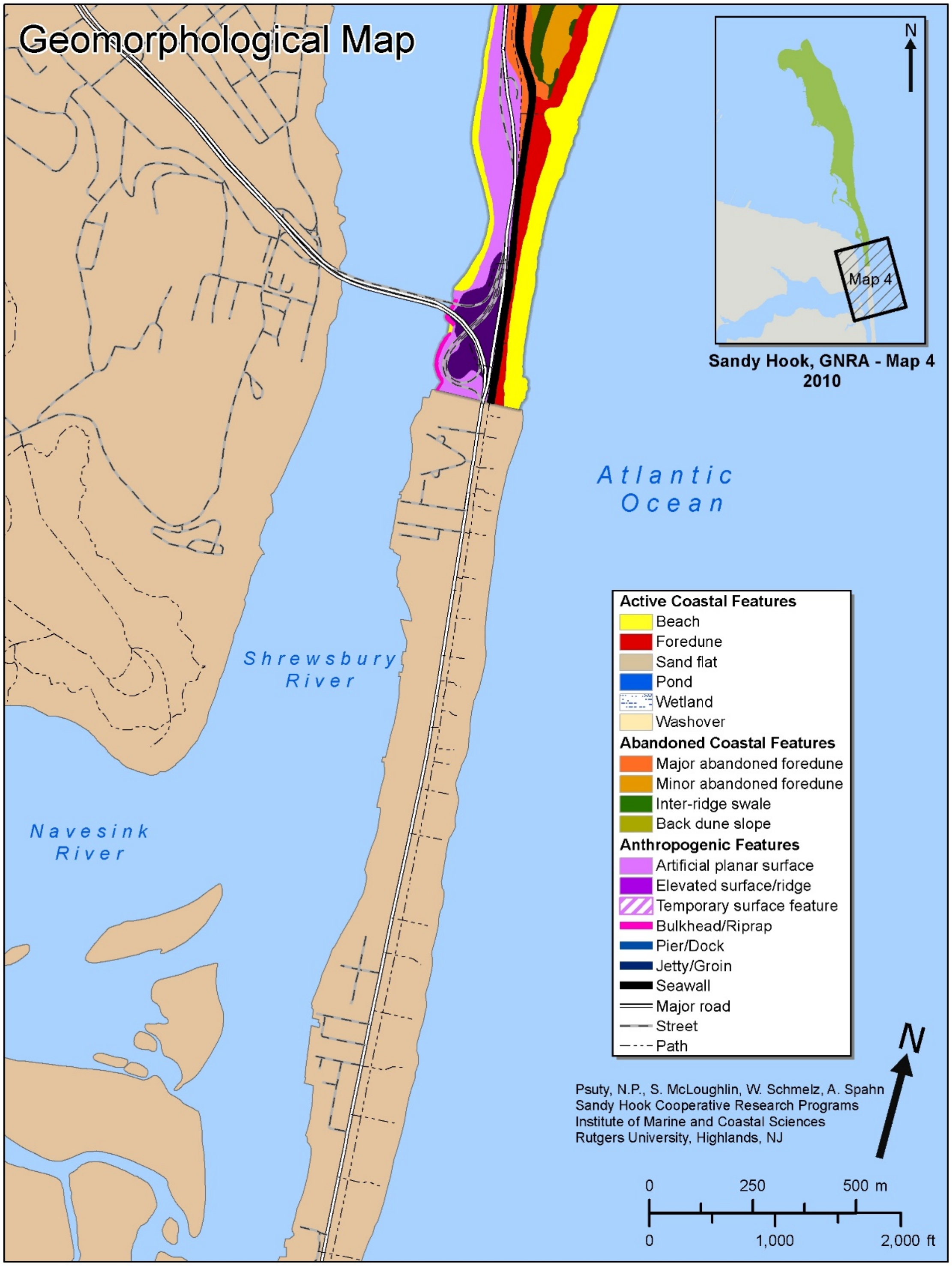
Geomorphological Map
Sandy Hook, GNRA - Map 4
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Abandoned Coastal Features
Major abandoned foredune
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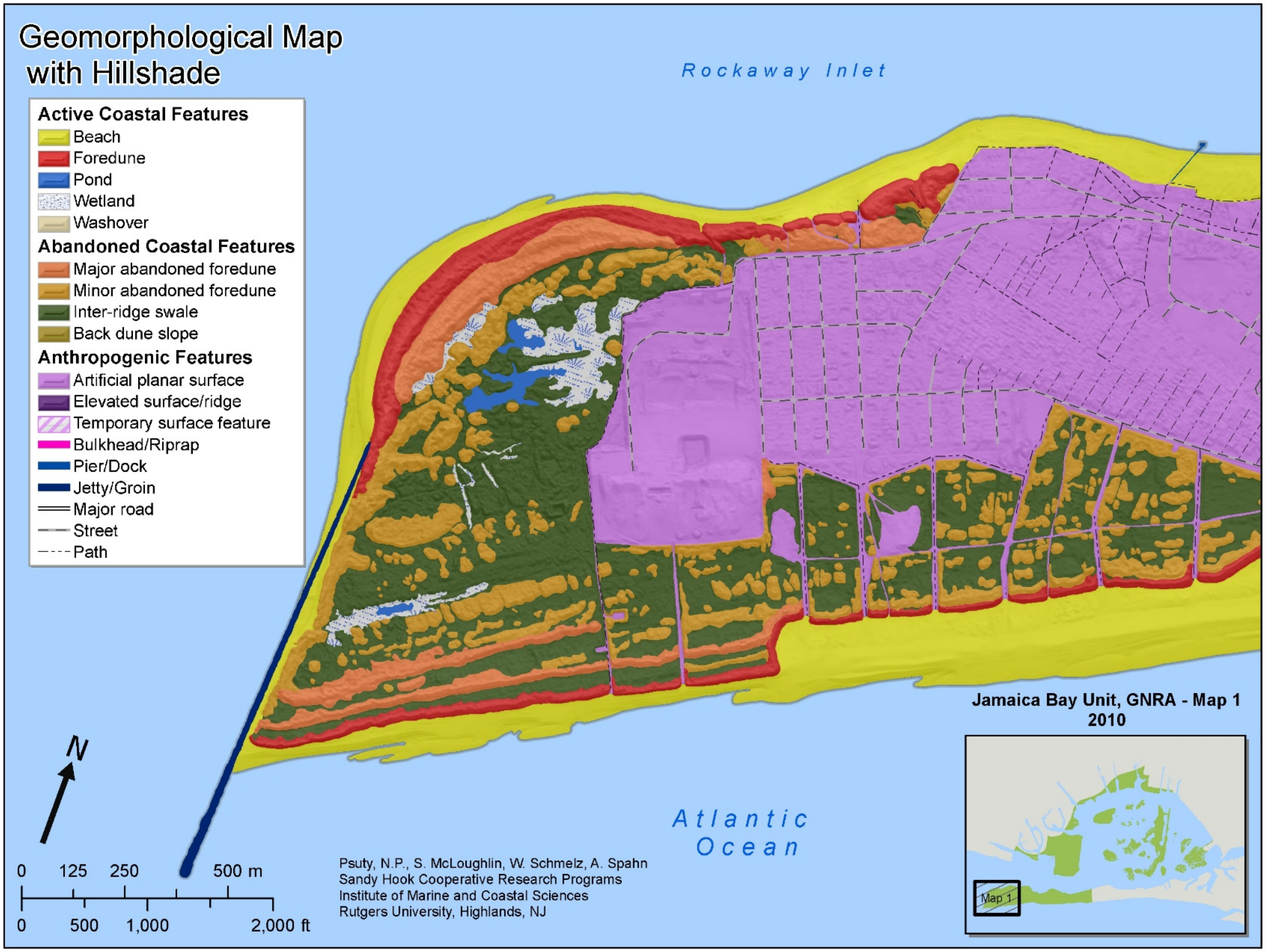
Jamaica Bay Unit (JBU)



Geomorphological Map with Hillshade
Rockaway Inlet
Active Coastal Features
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Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
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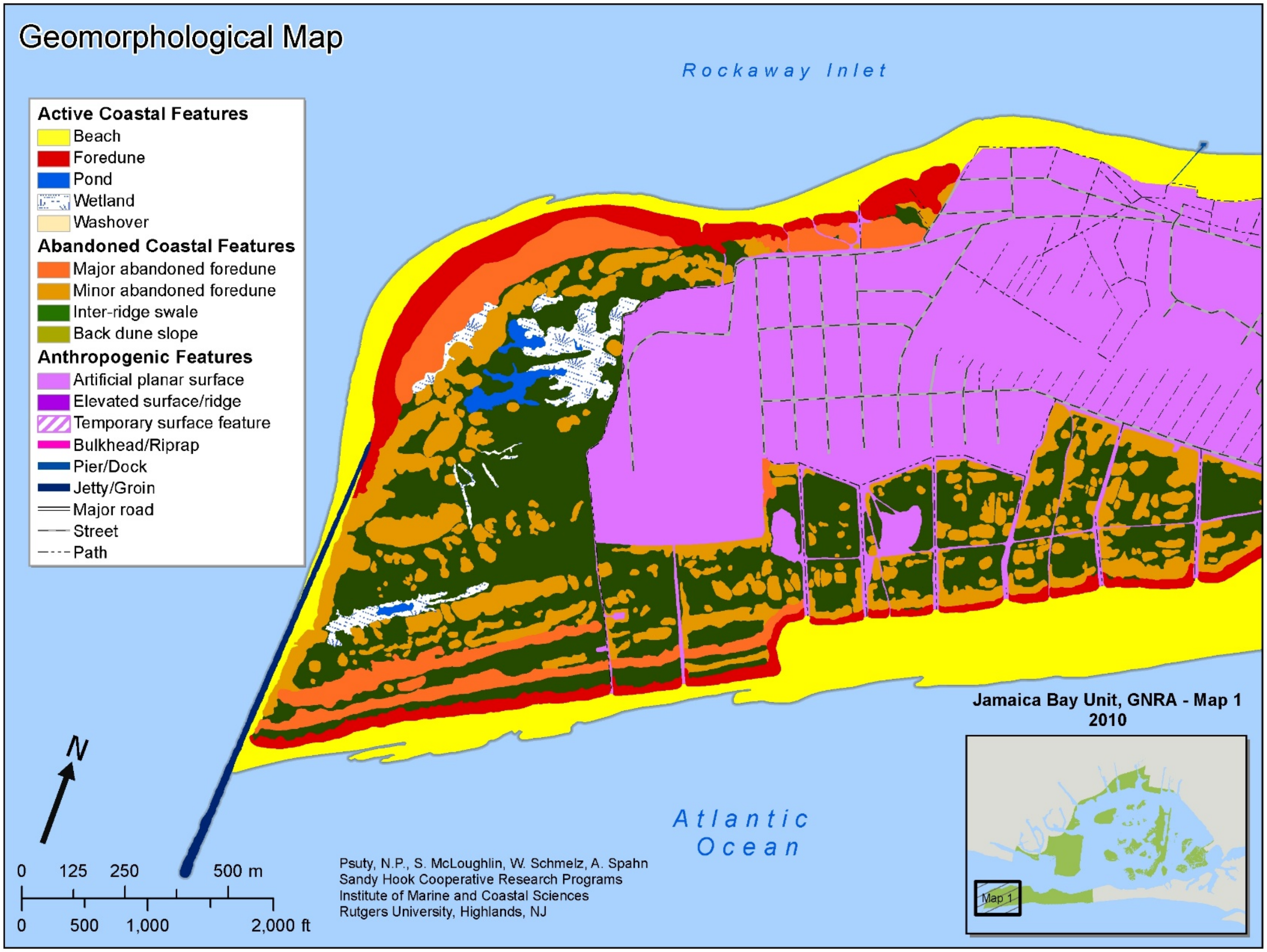
Sandy Hook Cooperative Research Programs
Institute of Marine and Coastal Sciences
Rutgers University, Highlands, NJ
Atlantic Ocean
Jamaica Bay Unit, GNRA - Map 1
2010
Map 1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Rockaway Inlet
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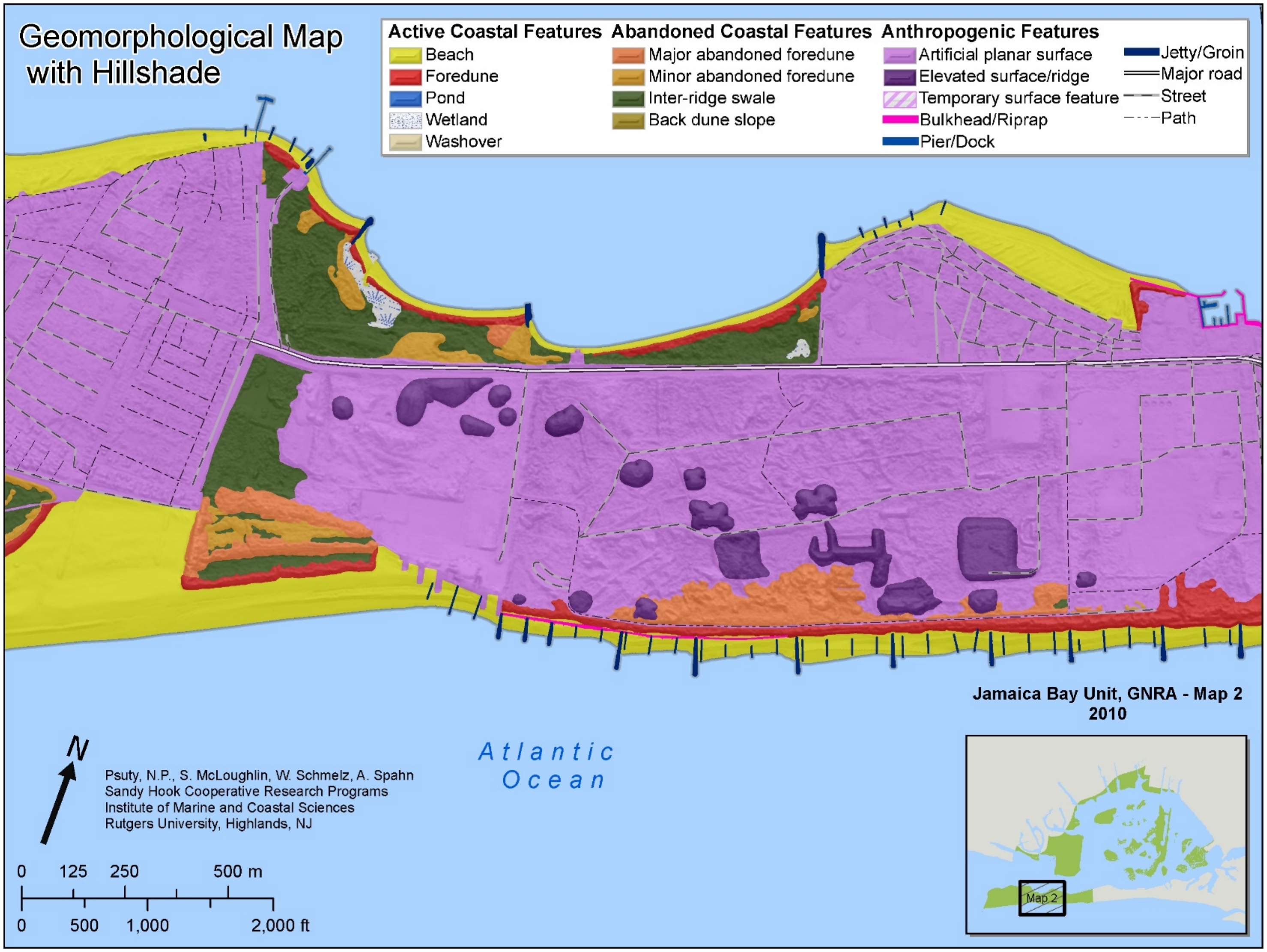
Institute of Marine and Coastal Sciences
Rutgers University, Highlands, NJ
Atlantic Ocean
Jamaica Bay Unit, GNRA - Map 1
2010
Map 1


Geomorphological Map with Hillshade
Active Coastal Features
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Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
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Jetty/Groin
Major road
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Jamaica Bay Unit, GNRA - Map 2
2010
Atlantic Ocean
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Psuty, N.P., S. McLoughlin, W. Schmelz, A. Spahn
Sandy Hook Cooperative Research Programs
Institute of Marine and Coastal Sciences
Rutgers University, Highlands, NJ
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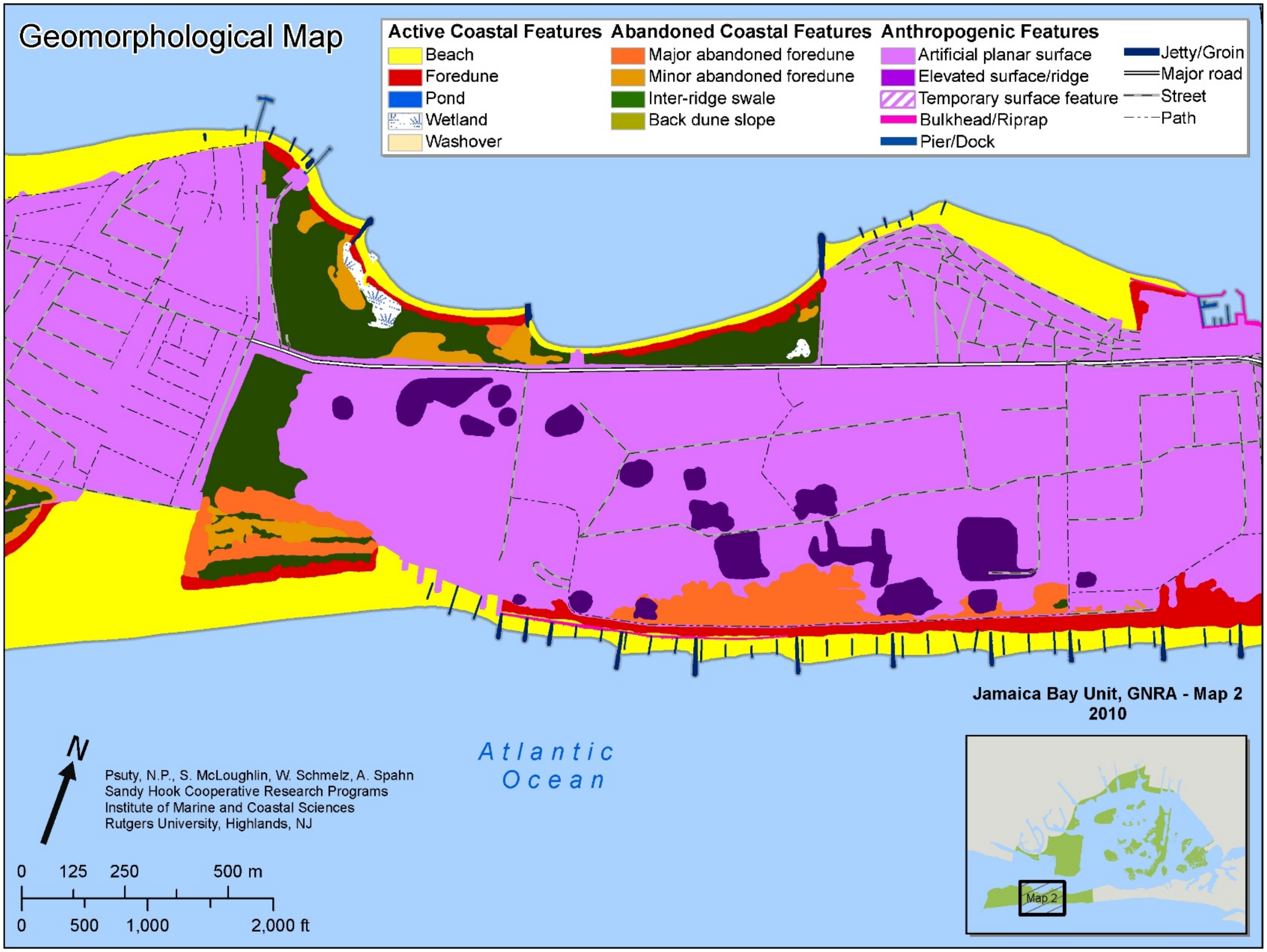
Map 2



Geomorphological Map
Active Coastal Features
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Wetland
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Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
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Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Major road
Street
Path
Jamaica Bay Unit, GNRA - Map 2
2010
Atlantic Ocean
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Psuty, N.P., S. McLoughlin, W. Schmelz, A. Spahn
Sandy Hook Cooperative Research Programs
Institute of Marine and Coastal Sciences
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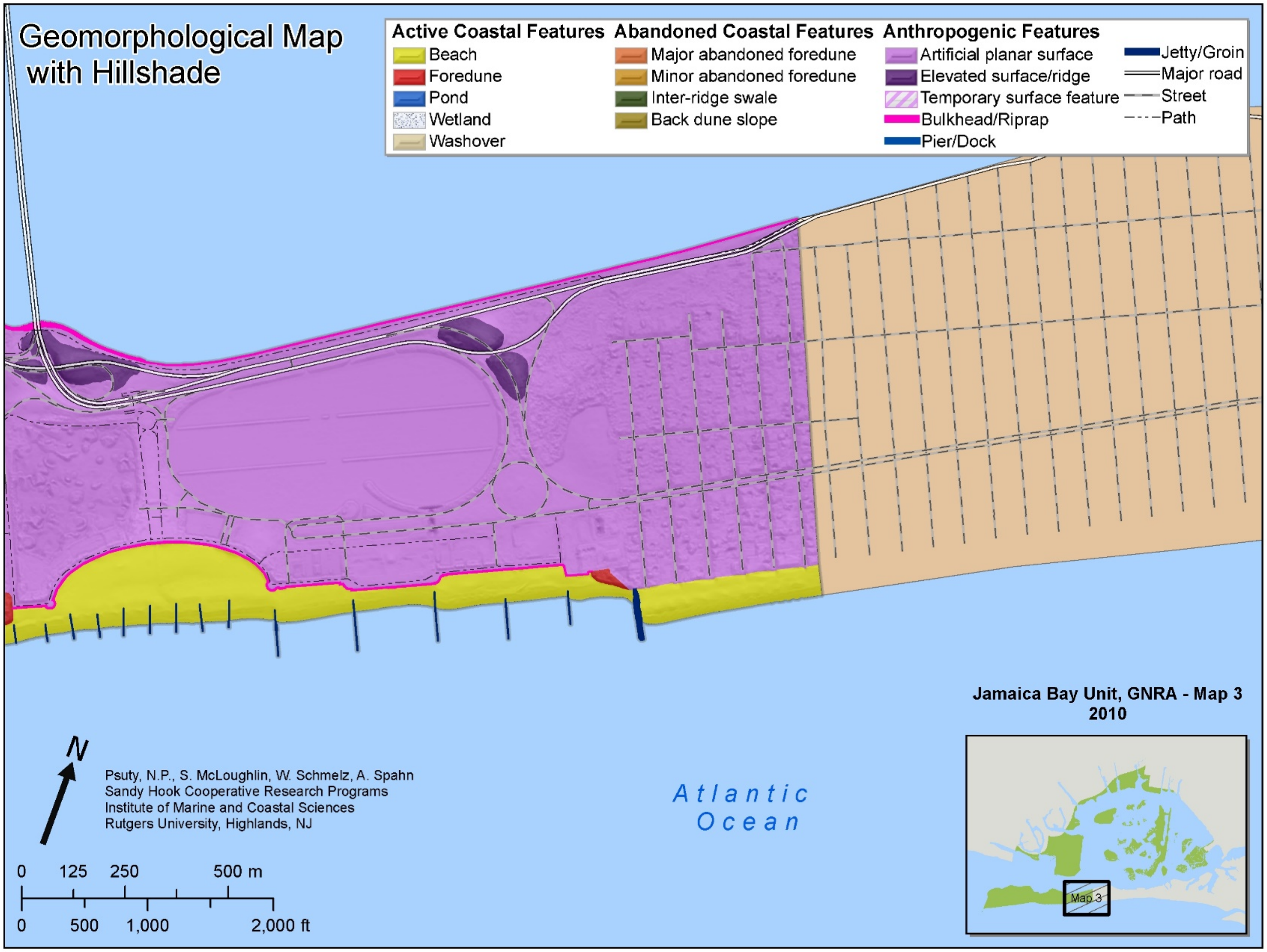
Map 2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Active Coastal Features
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Major abandoned foredune
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Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Major road
Street
Path
Jamaica Bay Unit, GNRA - Map 3
2010
Map 3
Atlantic Ocean
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Psuty, N.P., S. McLoughlin, W. Schmelz, A. Spahn
Sandy Hook Cooperative Research Programs
Institute of Marine and Coastal Sciences
Rutgers University, Highlands, NJ
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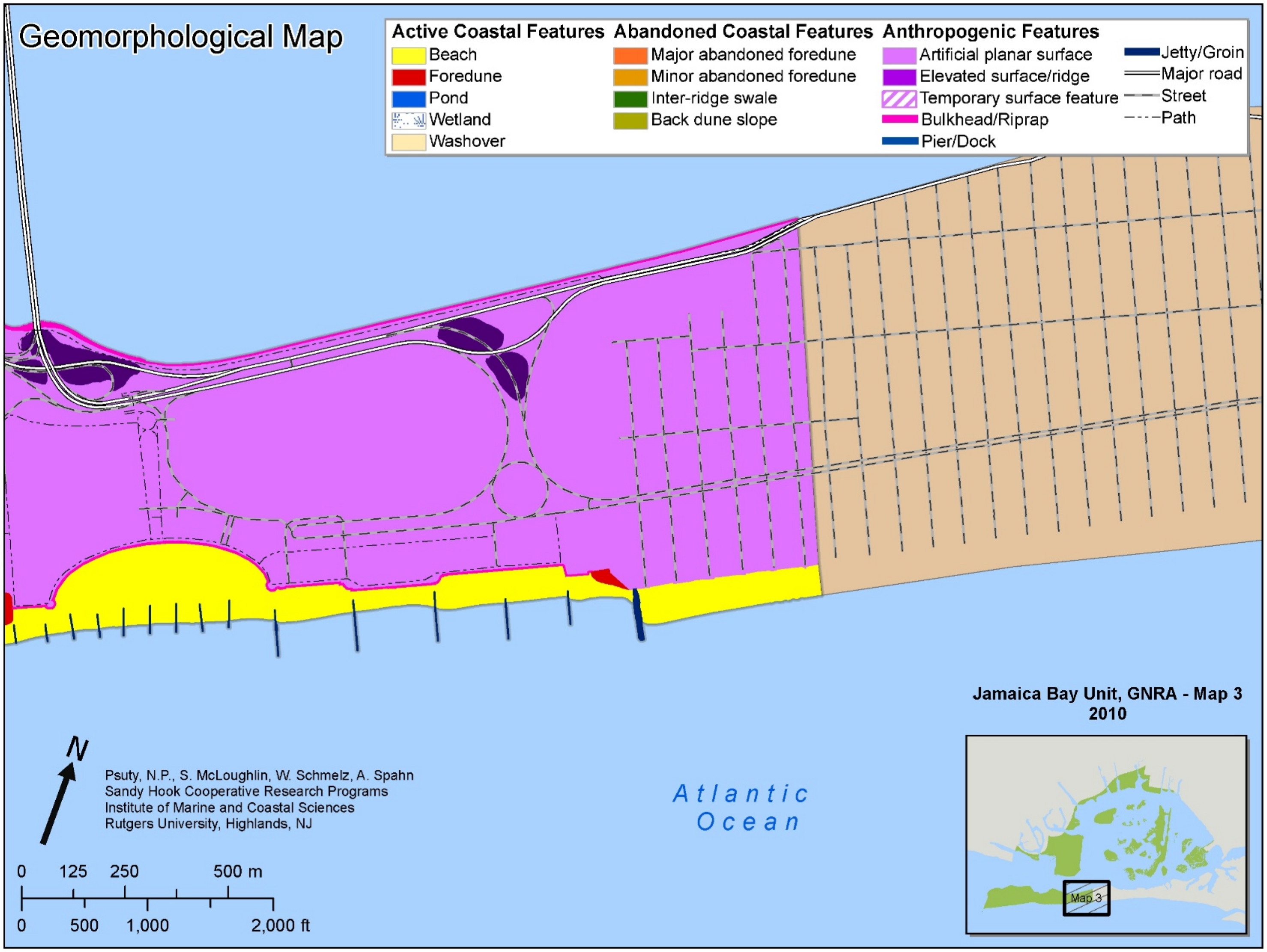
Geomorphological Map
Active Coastal Features
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Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Major road
Street
Path
Jamaica Bay Unit, GNRA - Map 3
2010
Map 3
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Psuty, N.P., S. McLoughlin, W. Schmelz, A. Spahn
Sandy Hook Cooperative Research Programs
Institute of Marine and Coastal Sciences
Rutgers University, Highlands, NJ
Atlantic Ocean
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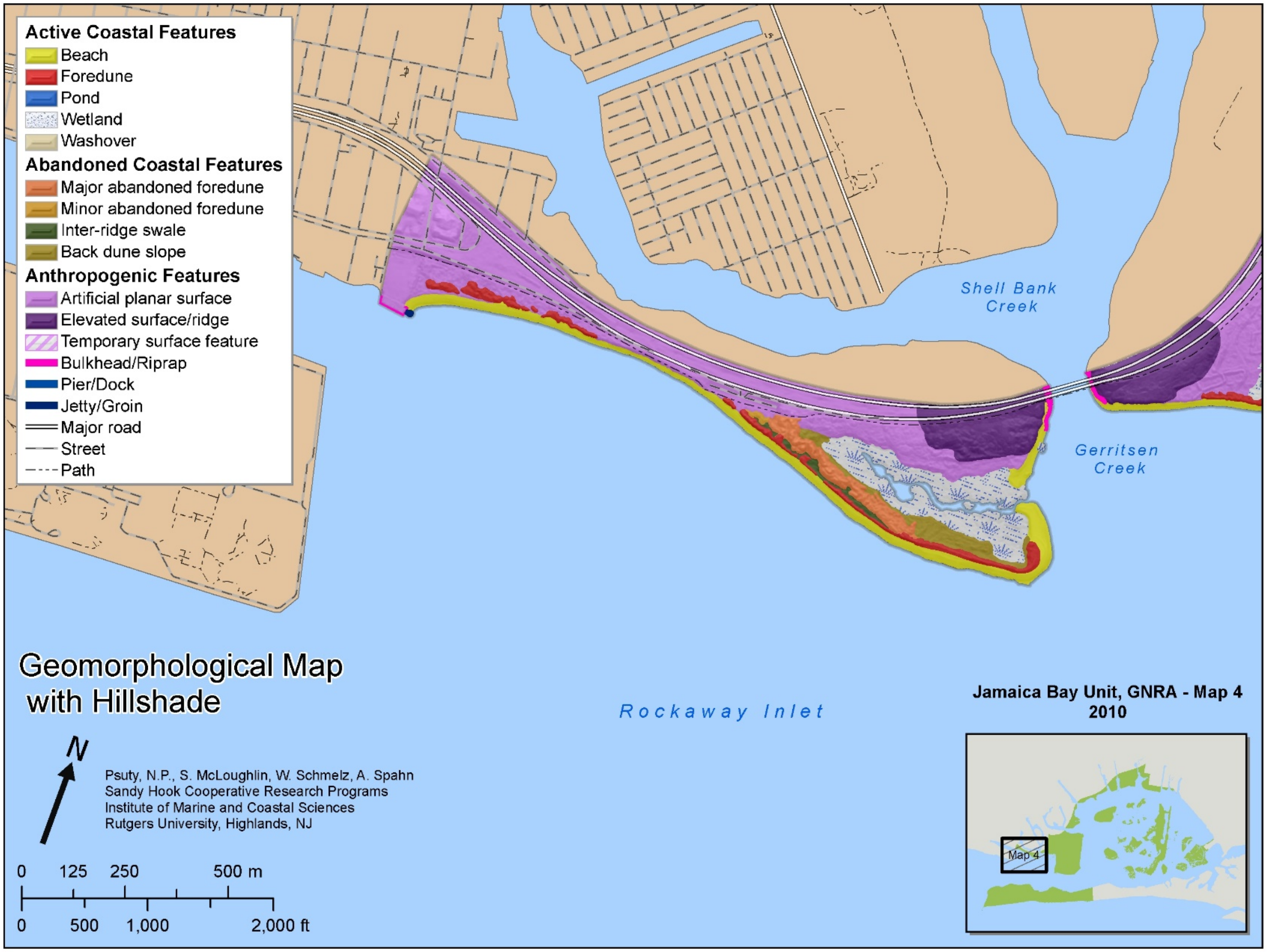

Active Coastal Features
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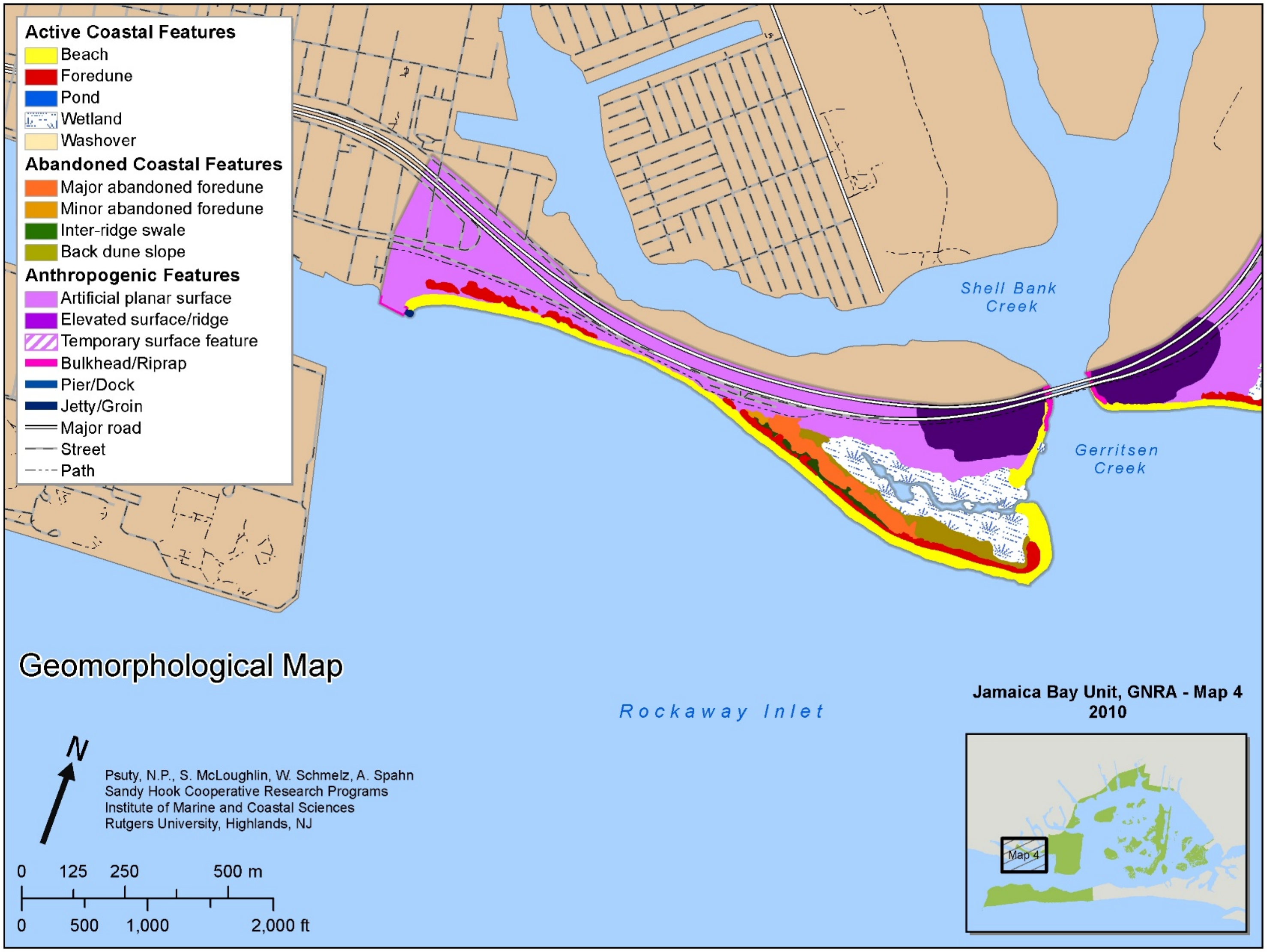
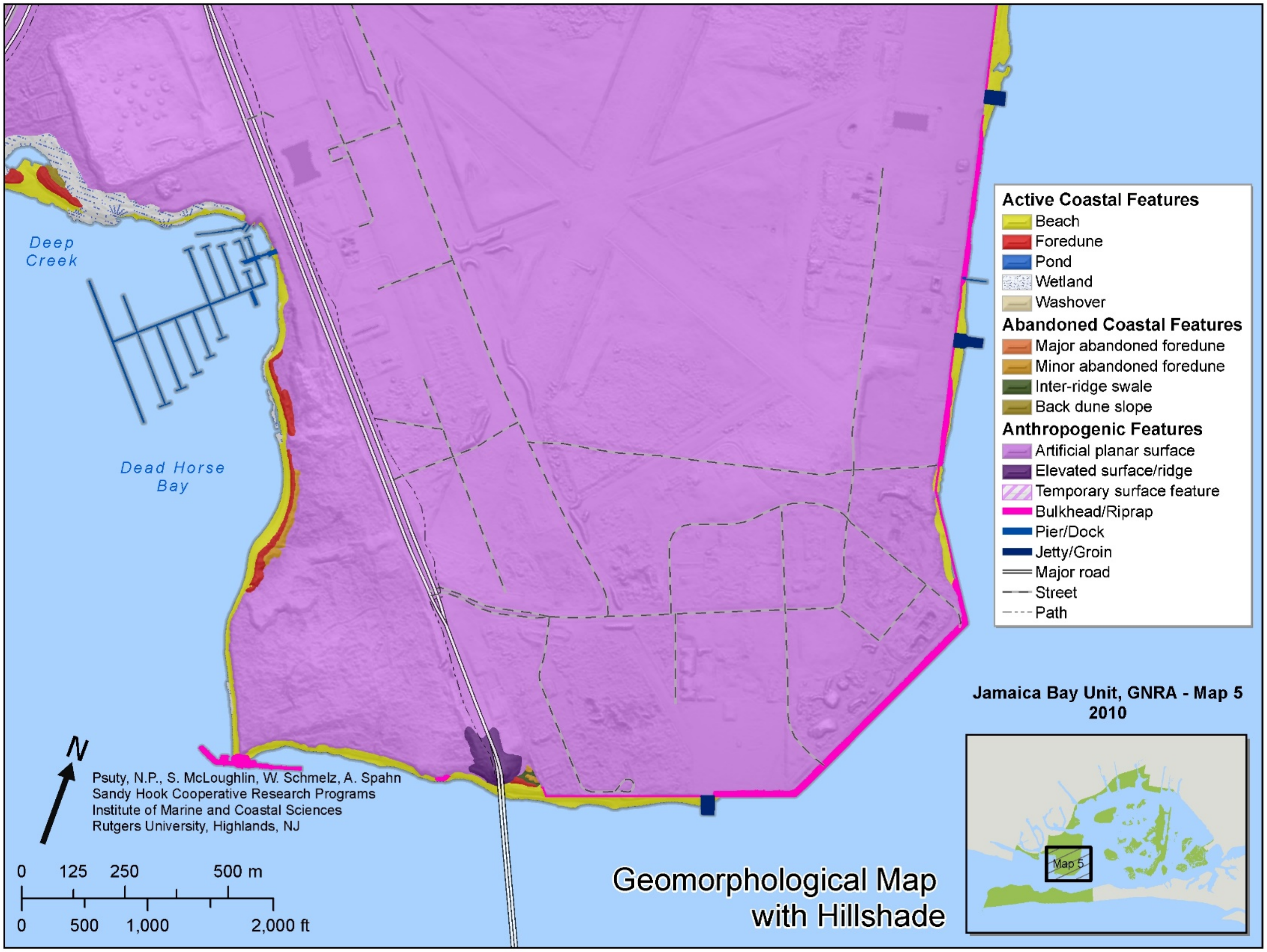
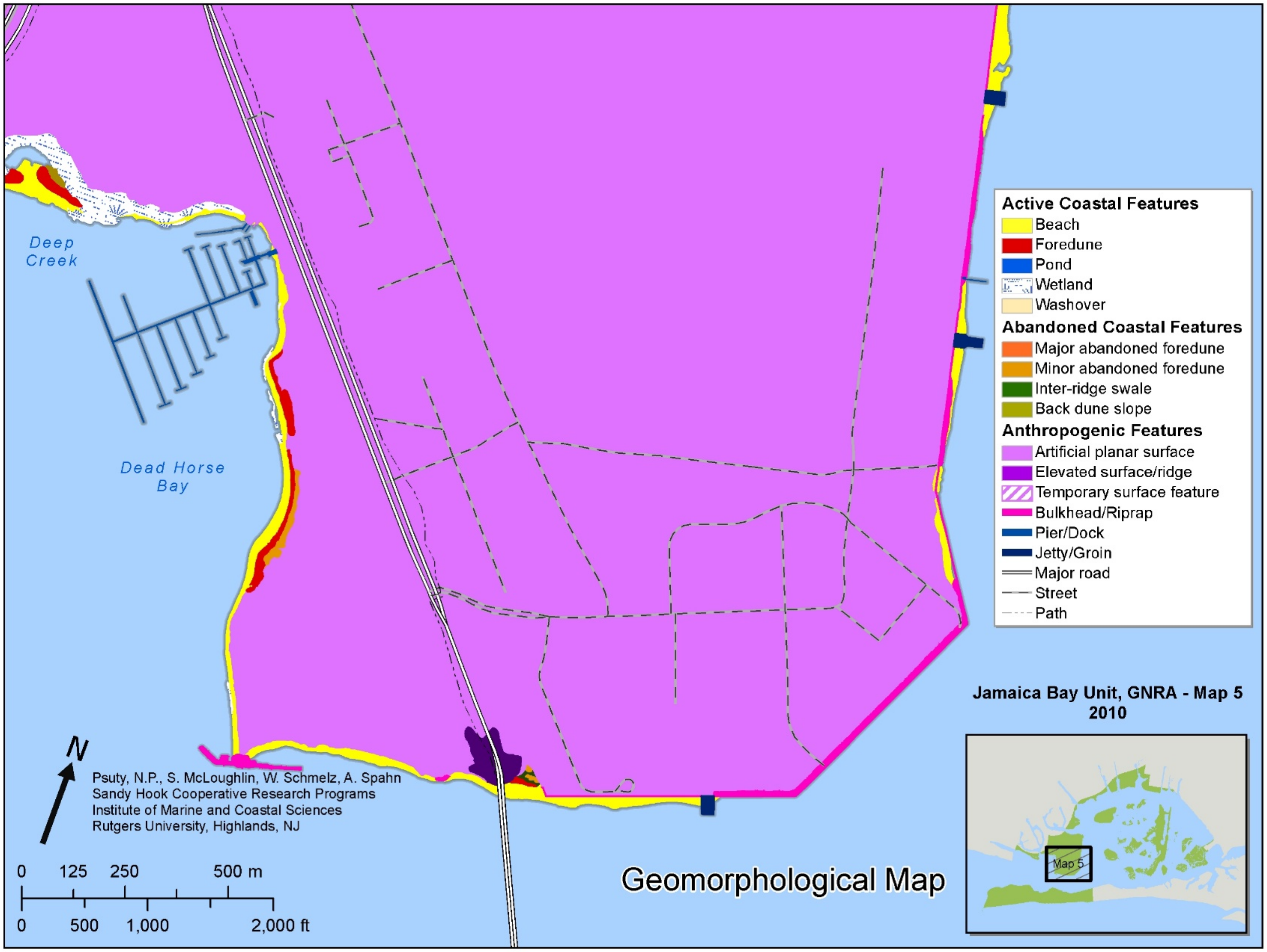
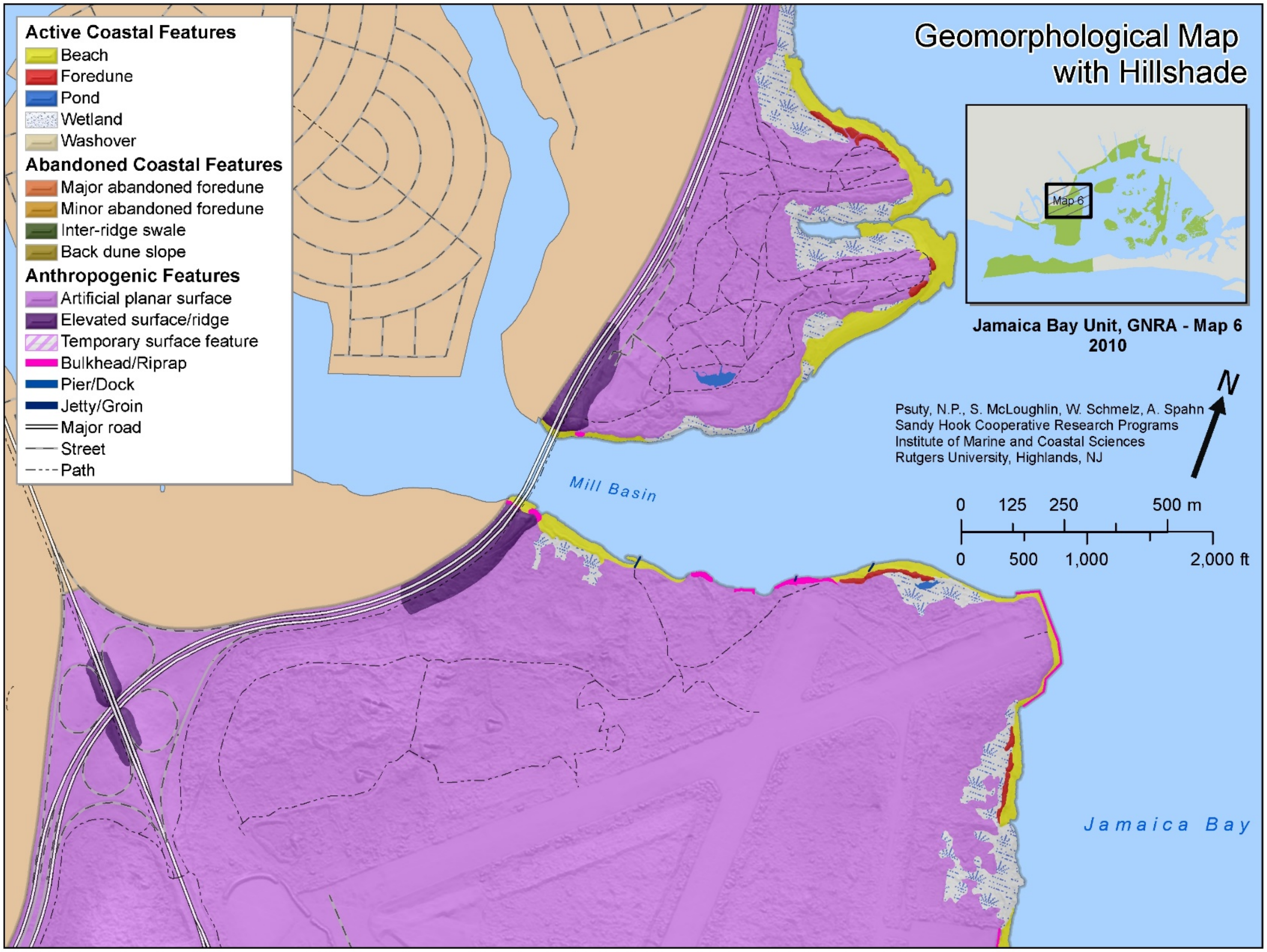
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Major road
Street
Path
Shell Bank Creek
Gerritsen Creek
Rockaway Inlet
Geomorphological Map
with Hillshade
Jamaica Bay Unit, GNRA - Map 4
2010
N
Psuty, N.P., S. McLoughlin, W. Schmelz, A. Spahn
Sandy Hook Cooperative Research Programs
Institute of Marine and Coastal Sciences
Rutgers University, Highlands, NJ
0 125 250 500 m
0 500 1,000 2,000 ft
Map 4

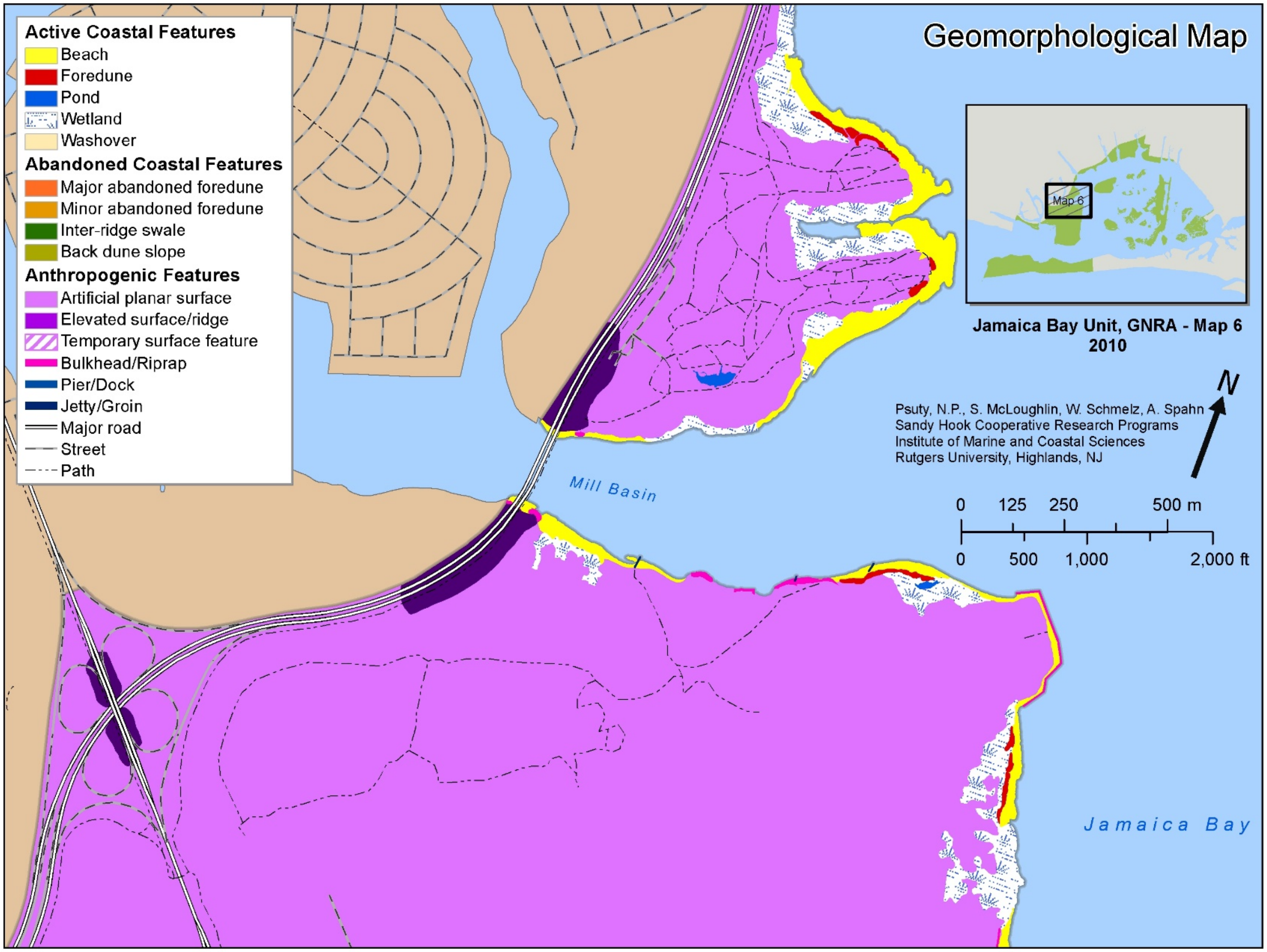

Active Coastal Features
Beach
Foredune
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Major road
Street
Path
Shell Bank Creek
Gerritsen Creek
Geomorphological Map
Rockaway Inlet
Jamaica Bay Unit, GNRA - Map 4
2010
N
Psuty, N.P., S. McLoughlin, W. Schmelz, A. Spahn
Sandy Hook Cooperative Research Programs
Institute of Marine and Coastal Sciences
Rutgers University, Highlands, NJ
0 125 250 500 m
0 500 1,000 2,000 ft
Map 4

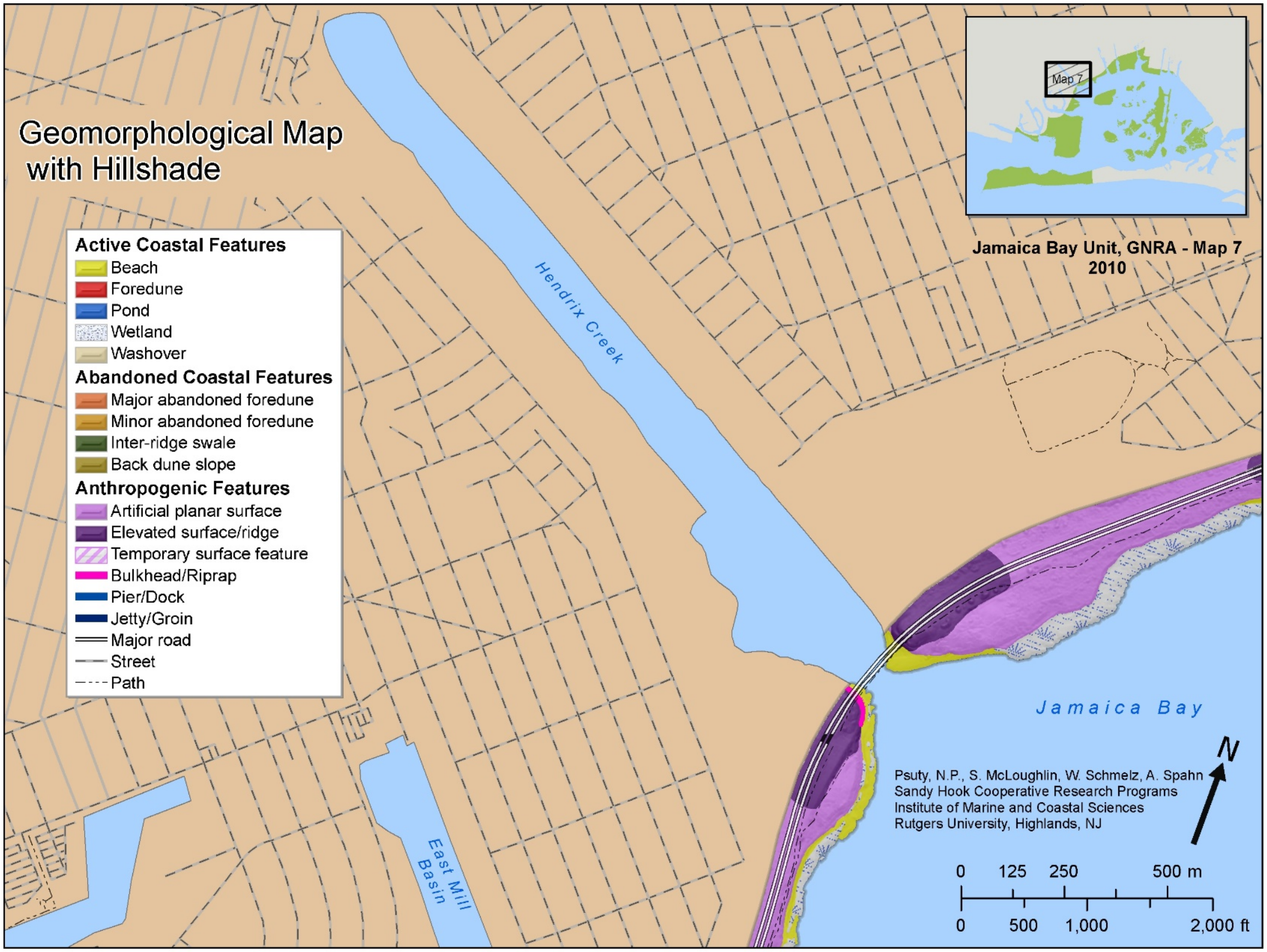

Deep Creek
Dead Horse Bay
Active Coastal Features
Beach
Foredune
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Major road
Street
Path
Jamaica Bay Unit, GNRA - Map 5
2010
Map 5
N
Psuty, N.P., S. McLoughlin, W. Schmelz, A. Spahn
Sandy Hook Cooperative Research Programs
Institute of Marine and Coastal Sciences
Rutgers University, Highlands, NJ
0 125 250 500 m
0 500 1,000 2,000 ft
Geomorphological Map
with Hillshade

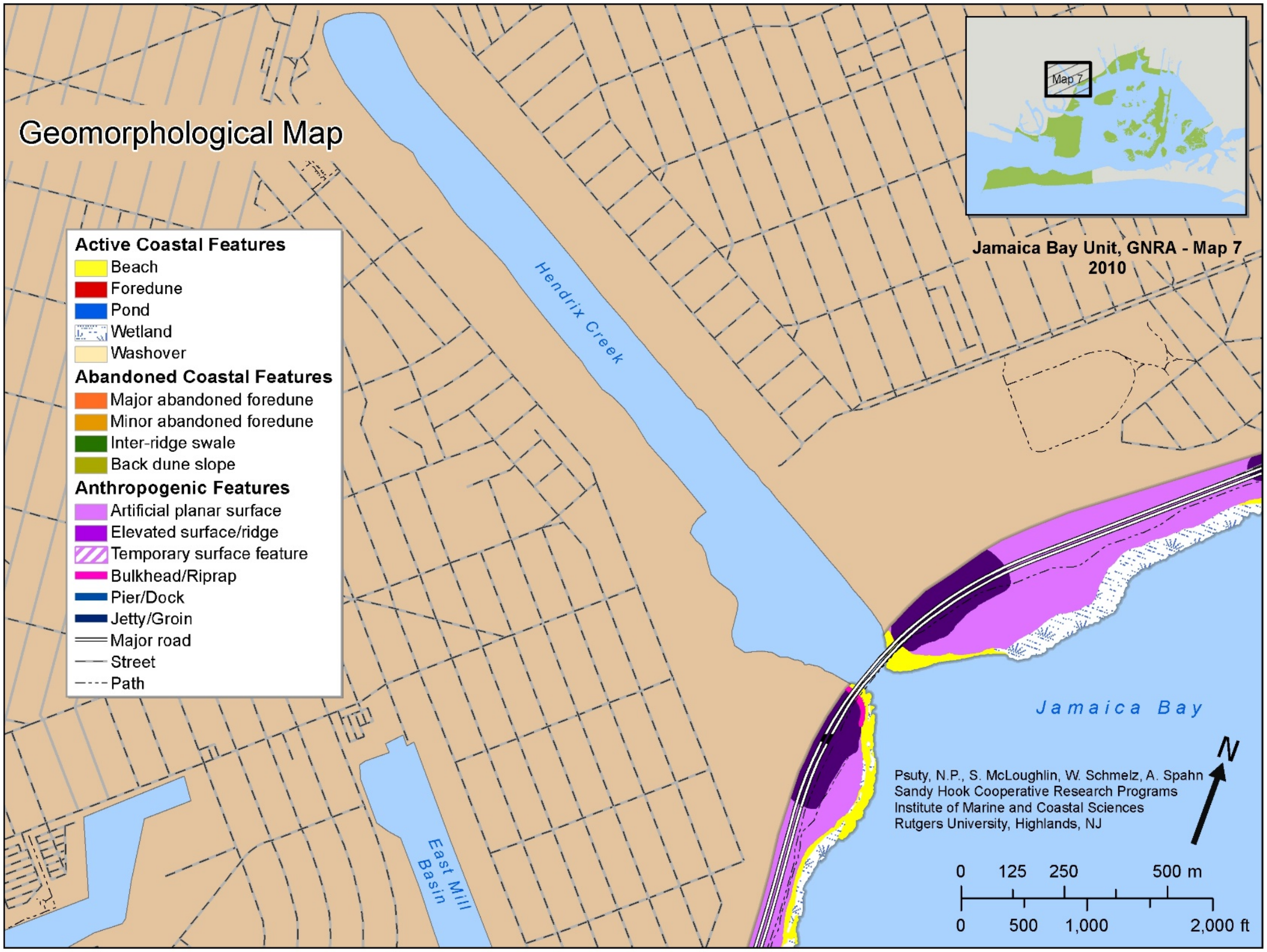


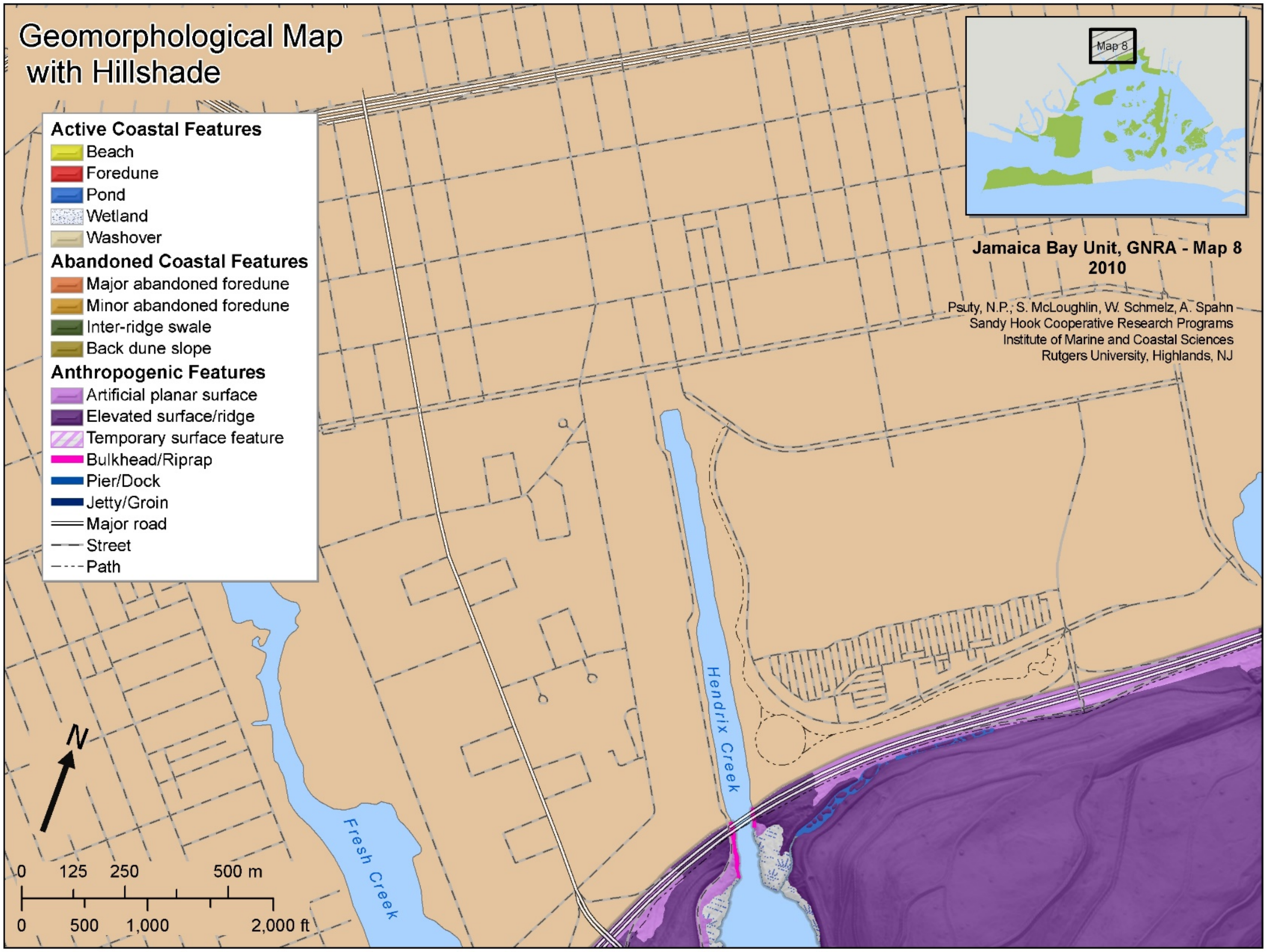
Deep Creek
Dead Horse Bay
Active Coastal Features
Beach
Foredune
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Major road
Street
Path
Jamaica Bay Unit, GNRA - Map 5
2010
Map 5
N
Psuty, N.P., S. McLoughlin, W. Schmelz, A. Spahn
Sandy Hook Cooperative Research Programs
Institute of Marine and Coastal Sciences
Rutgers University, Highlands, NJ
0 125 250 500 m
0 500 1,000 2,000 ft
Geomorphological Map

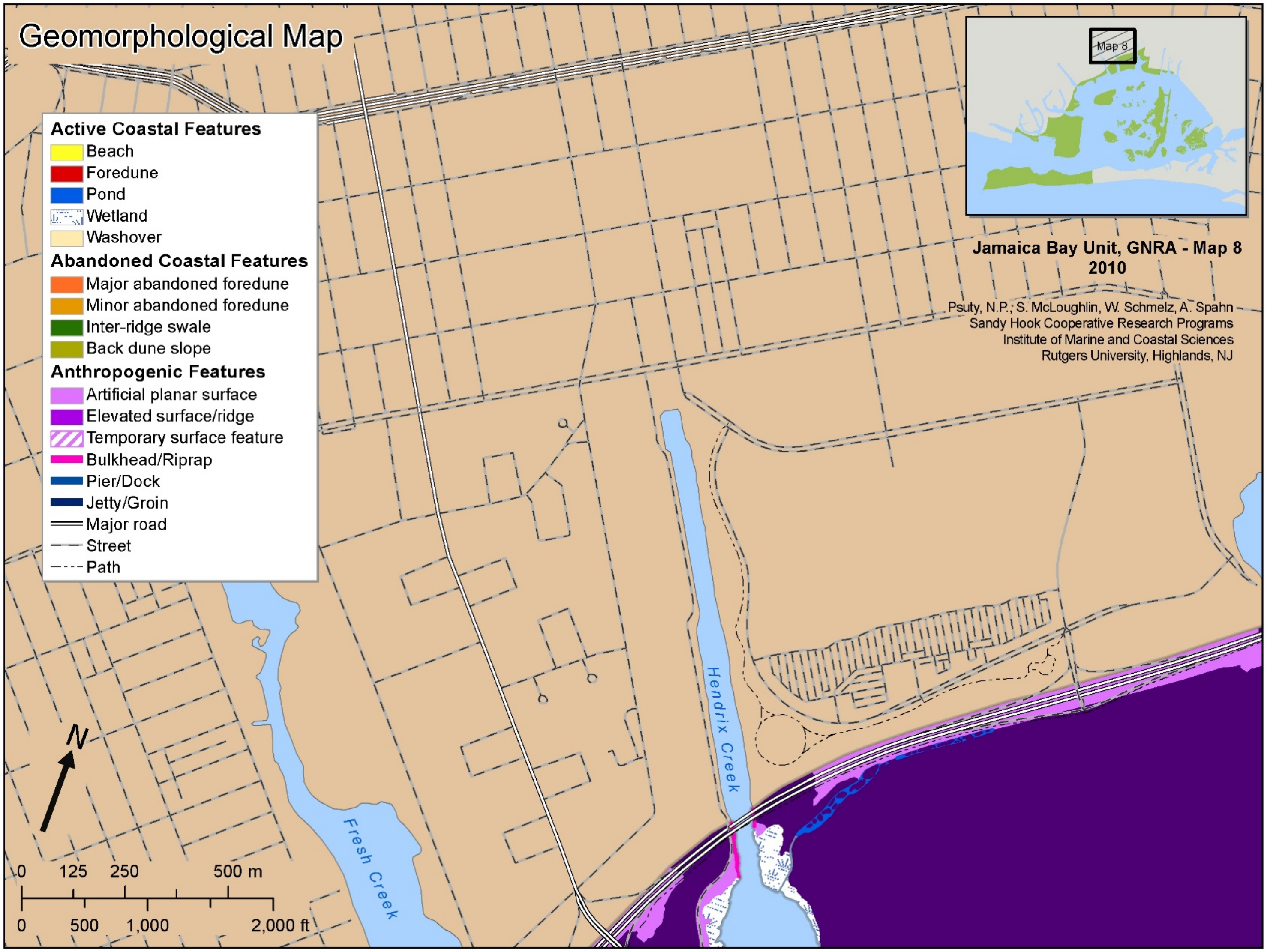

Geomorphological Map
with Hillshade
Active Coastal Features
Beach
Foredune
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Major road
Street
Path
Map 6
Jamaica Bay Unit, GNRA - Map 6
2010
N
Psuty, N.P., S. McLoughlin, W. Schmelz, A. Spahn
Sandy Hook Cooperative Research Programs
Institute of Marine and Coastal Sciences
Rutgers University, Highlands, NJ
Mill Basin
0 125 250 500 m
0 500 1,000 2,000 ft
Jamaica Bay


Geomorphological Map
Active Coastal Features
Beach
Foredune
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Major road
Street
Path
Map 6
Jamaica Bay Unit, GNRA - Map 6
2010
Psuty, N.P., S. McLoughlin, W. Schmelz, A. Spahn
Sandy Hook Cooperative Research Programs
Institute of Marine and Coastal Sciences
Rutgers University, Highlands, NJ
N
0 125 250 500 m
0 500 1,000 2,000 ft
Mill Basin
Jamaica Bay

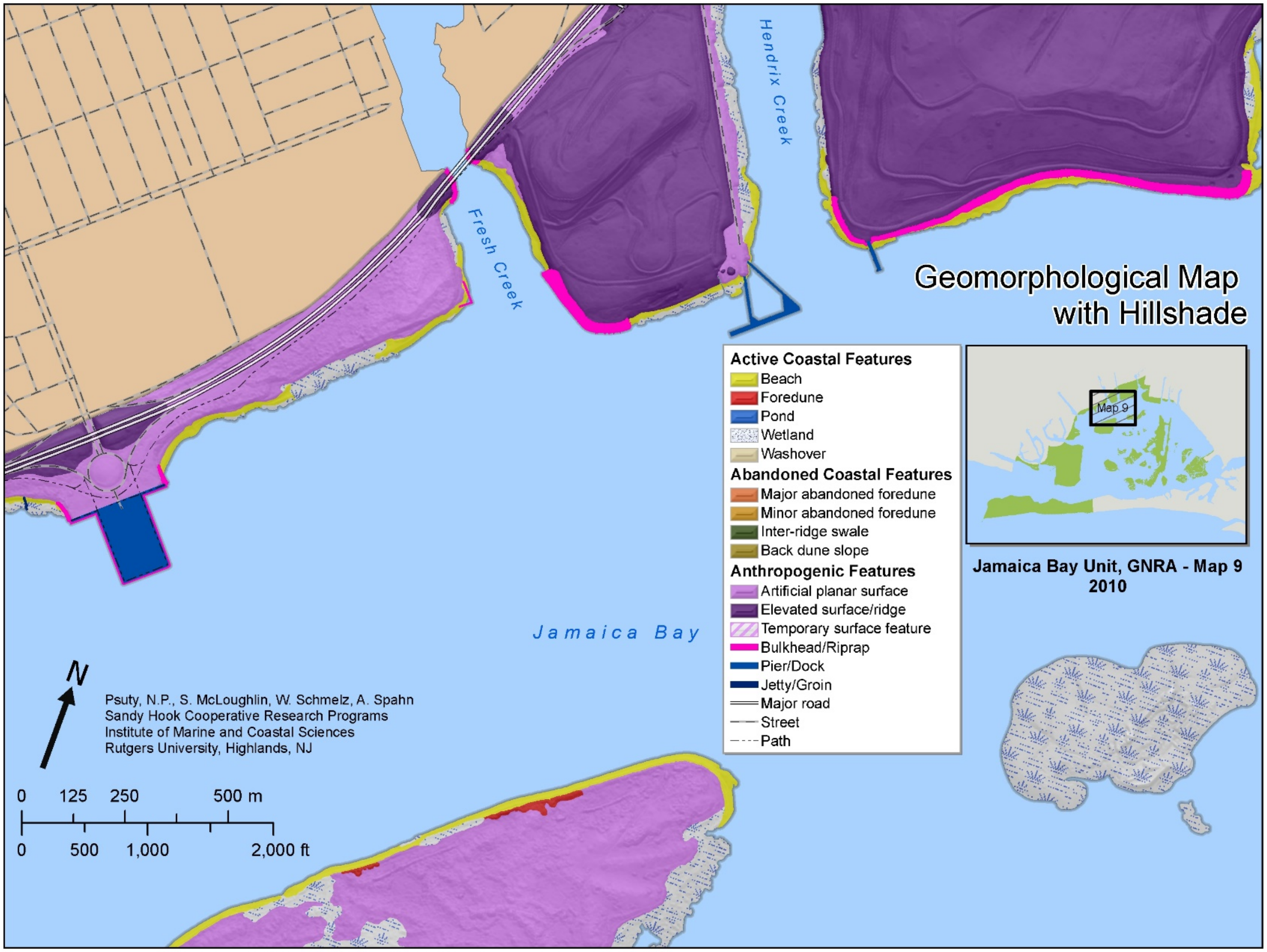

Geomorphological Map
with Hillshade
Active Coastal Features
Beach
Foredune
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Major road
Street
Path
Hendrix Creek
East Mill Basin
Jamaica Bay
Map 7
Jamaica Bay Unit, GNRA - Map 7
2010
N
Psuty, N.P., S. McLoughlin, W. Schmelz, A. Spahn
Sandy Hook Cooperative Research Programs
Institute of Marine and Coastal Sciences
Rutgers University, Highlands, NJ
0 125 250 500 m
0 500 1,000 2,000 ft


Geomorphological Map
Active Coastal Features
Beach
Foredune
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Major road
Street
Path
Hendrix Creek
East Mill Basin
Jamaica Bay
Map 7
Jamaica Bay Unit, GNRA - Map 7
2010
Psuty, N.P., S. McLoughlin, W. Schmelz, A. Spahn
Sandy Hook Cooperative Research Programs
Institute of Marine and Coastal Sciences
Rutgers University, Highlands, NJ
N
0 125 250 500 m
0 500 1,000 2,000 ft

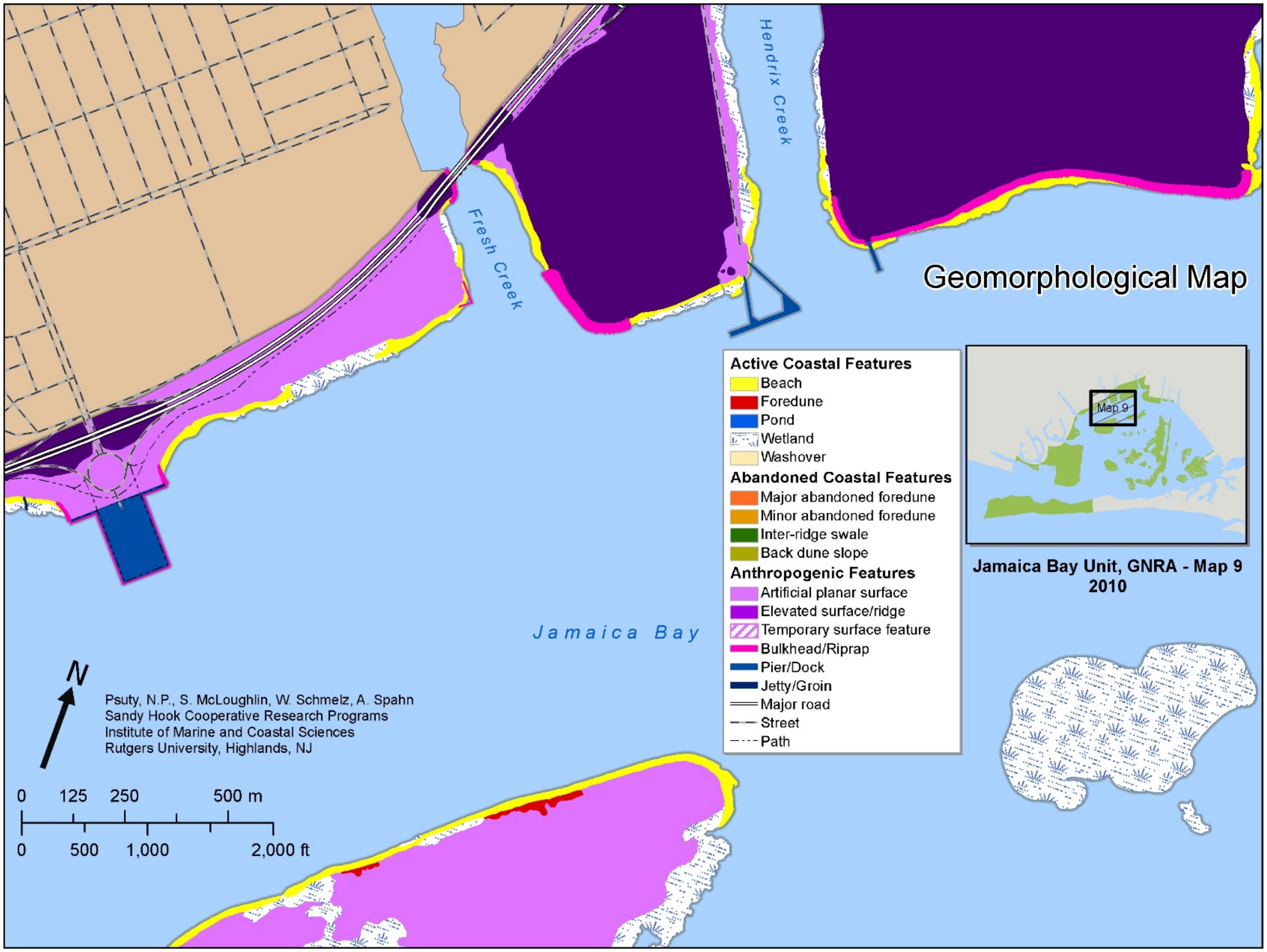

Geomorphological Map
with Hillshade
Active Coastal Features
Beach
Foredune
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Major road
Street
Path
Map 8
Jamaica Bay Unit, GNRA - Map 8
2010
Psuty, N.P., S. McLoughlin, W. Schmelz, A. Spahn
Sandy Hook Cooperative Research Programs
Institute of Marine and Coastal Sciences
Rutgers University, Highlands, NJ
Hendrix Creek
Fresh Creek
N
0 125 250 500 m
0 500 1,000 2,000 ft

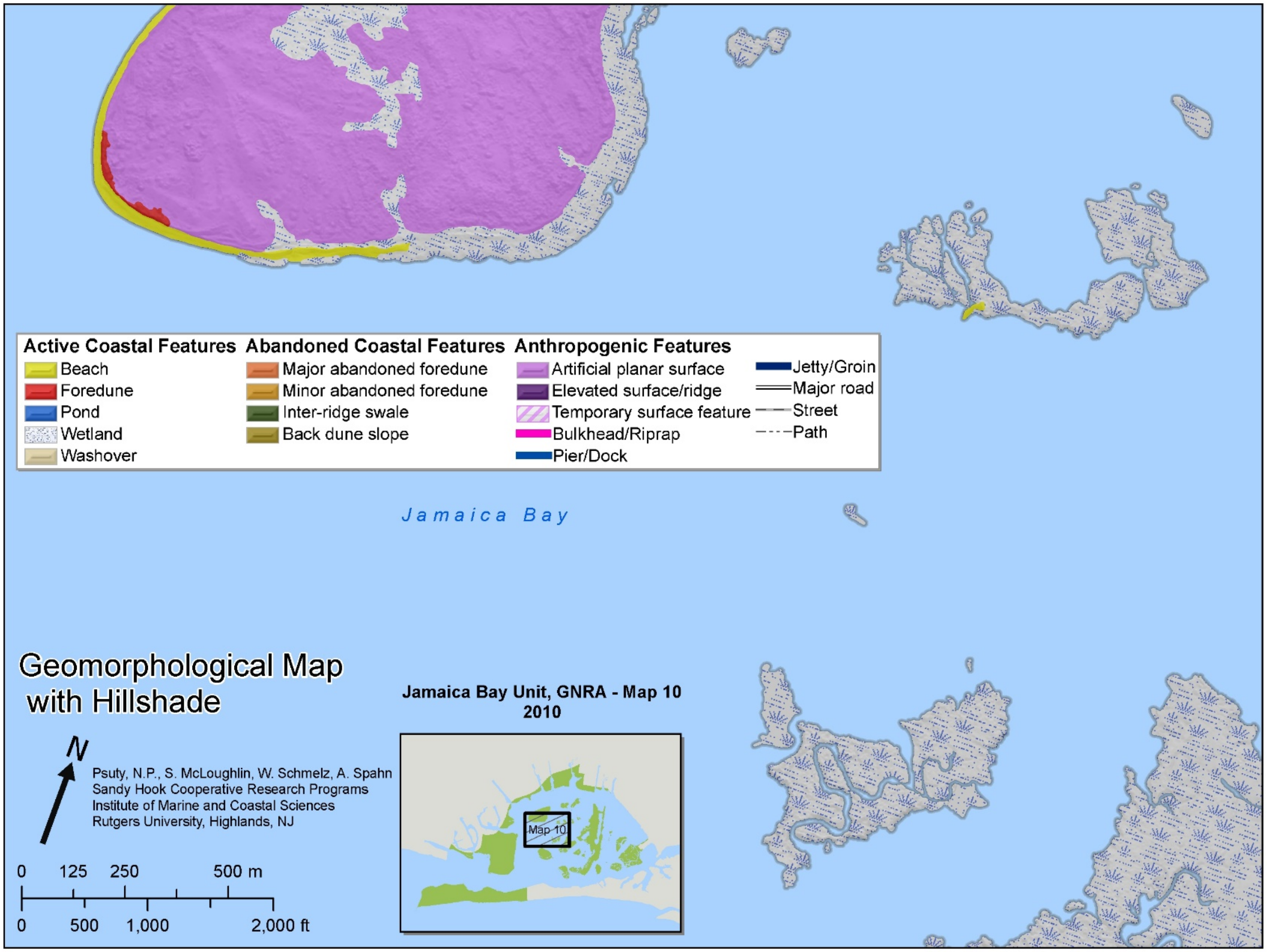


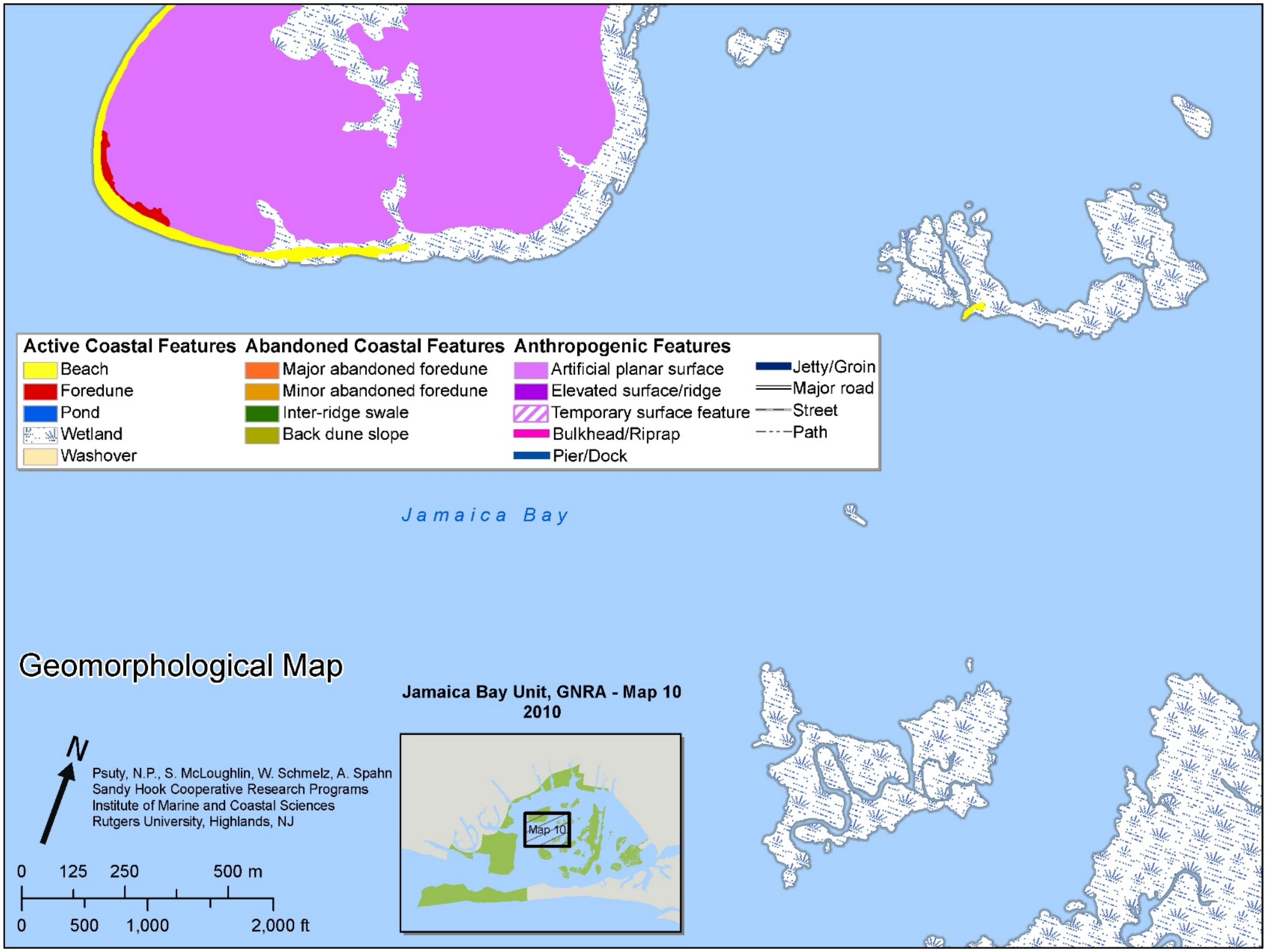
Geomorphological Map
Active Coastal Features
Beach
Foredune
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Major road
Street
Path
Map 8
Jamaica Bay Unit, GNRA - Map 8
2010
Psuty, N.P., S. McLoughlin, W. Schmelz, A. Spahn
Sandy Hook Cooperative Research Programs
Institute of Marine and Coastal Sciences
Rutgers University, Highlands, NJ
Hendrix Creek
Fresh Creek
N
0 125 250 500 m
0 500 1,000 2,000 ft

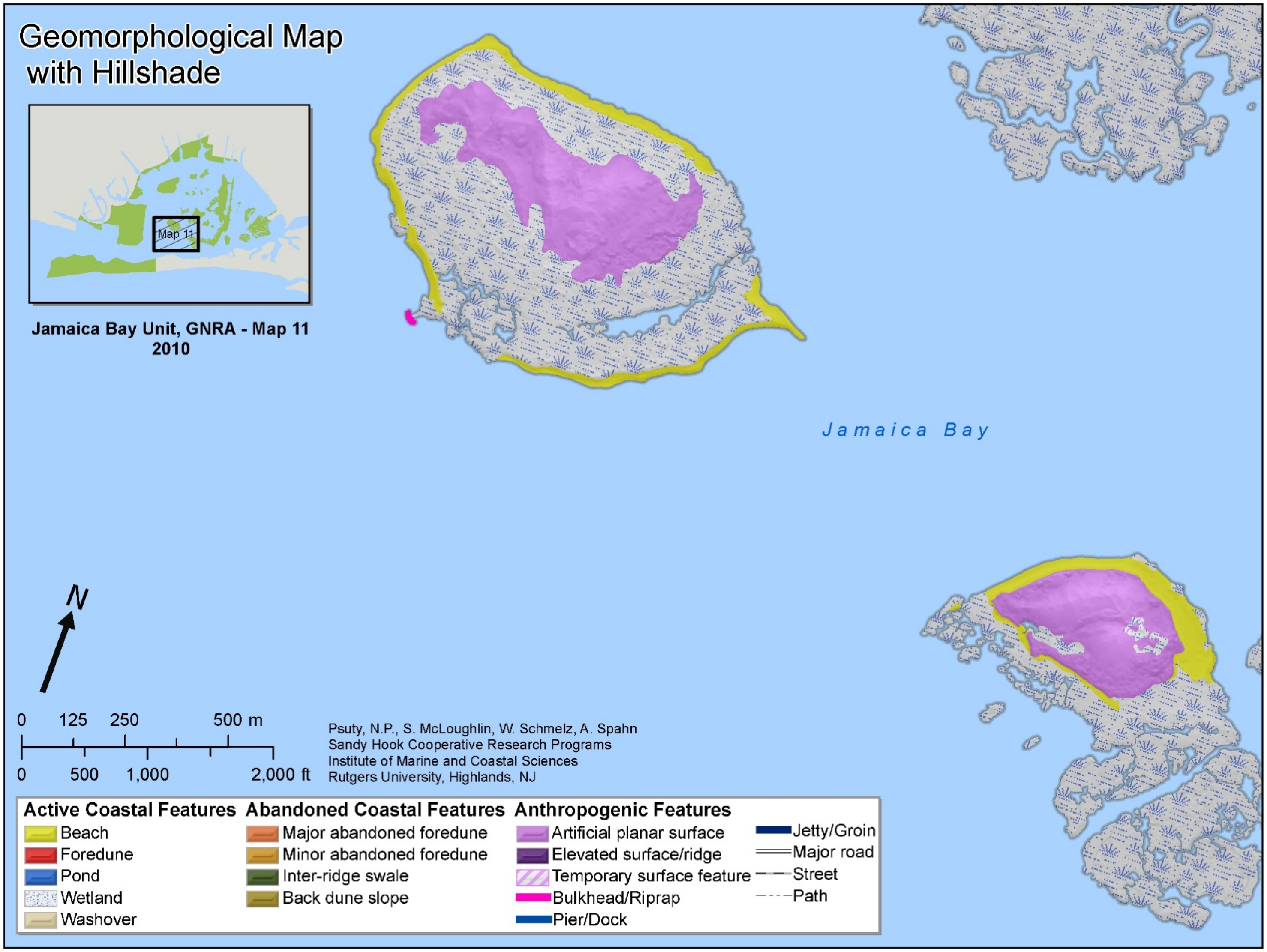


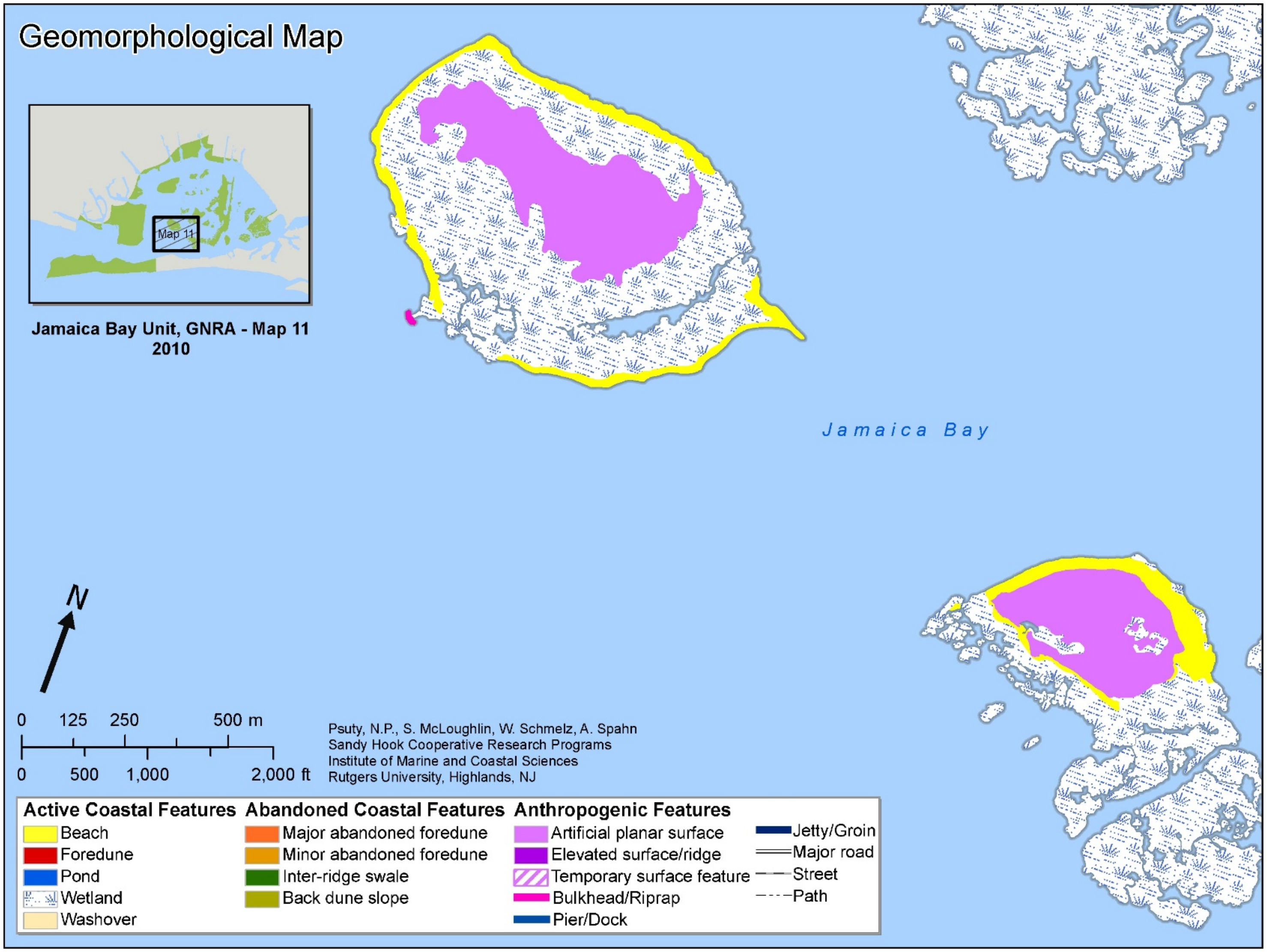
Hendrix Creek
Fresh Creek
Jamaica Bay
Geomorphological Map
with Hillshade
Active Coastal Features
Beach
Foredune
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Major road
Street
Path
Map 9
Jamaica Bay Unit, GNRA - Map 9
2010
N
Psuty, N.P., S. McLoughlin, W. Schmelz, A. Spahn
Sandy Hook Cooperative Research Programs
Institute of Marine and Coastal Sciences
Rutgers University, Highlands, NJ
0 125 250 500 m
0 500 1,000 2,000 ft

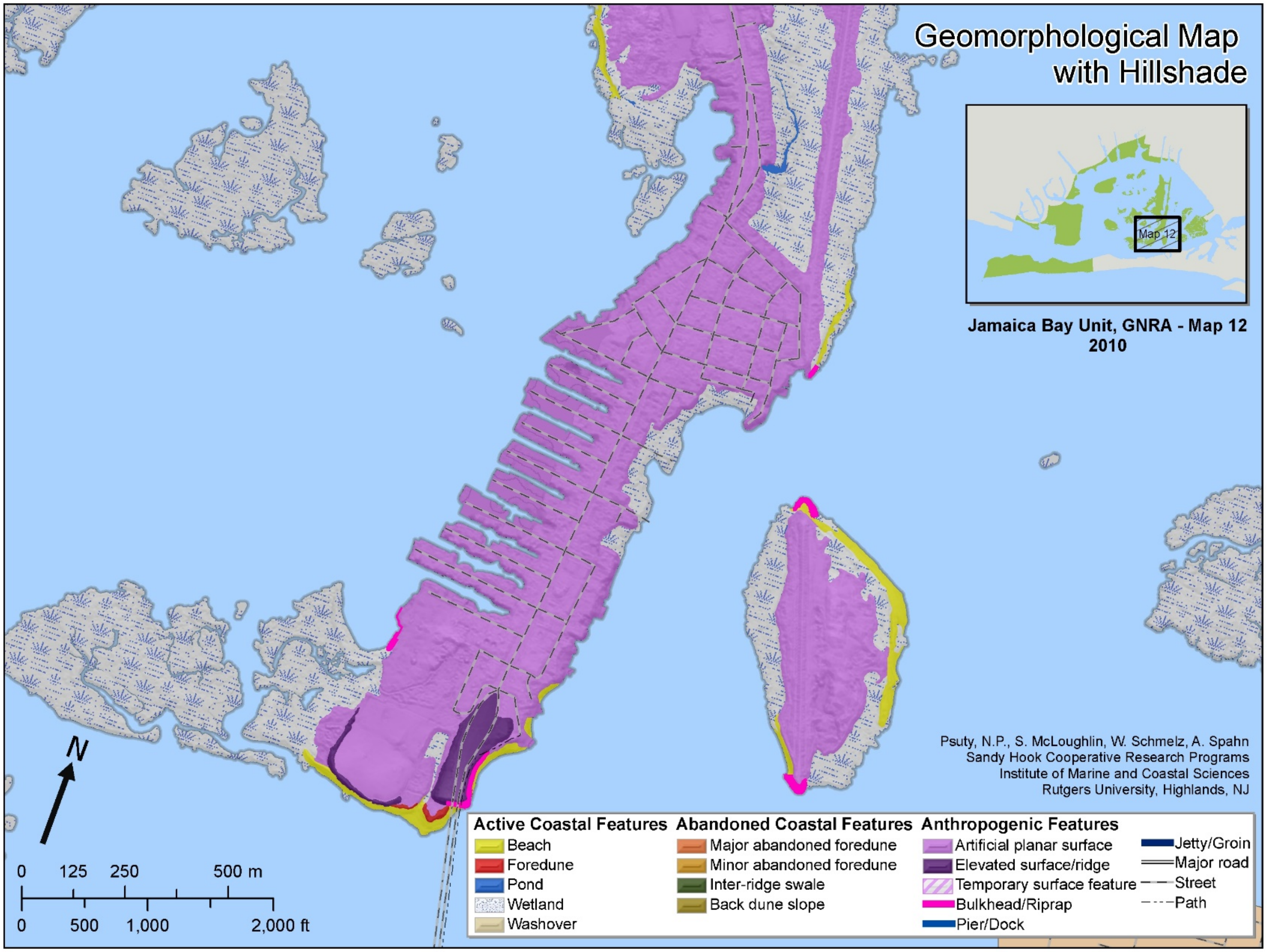

Hendrix Creek
Fresh Creek
Geomorphological Map
Active Coastal Features
Beach
Foredune
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Major road
Street
Path
Map 9
Jamaica Bay Unit, GNRA - Map 9
2010
Jamaica Bay
N
Psuty, N.P., S. McLoughlin, W. Schmelz, A. Spahn
Sandy Hook Cooperative Research Programs
Institute of Marine and Coastal Sciences
Rutgers University, Highlands, NJ
0 125 250 500 m
0 500 1,000 2,000 ft


Active Coastal Features
Beach
Foredune
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Major road
Street
Path
Jamaica Bay
Geomorphological Map with Hillshade
Jamaica Bay Unit, GNRA - Map 10
2010
N
Psuty, N.P., S. McLoughlin, W. Schmelz, A. Spahn
Sandy Hook Cooperative Research Programs
Institute of Marine and Coastal Sciences
Rutgers University, Highlands, NJ
0 125 250 500 m
0 500 1,000 2,000 ft
Map 10

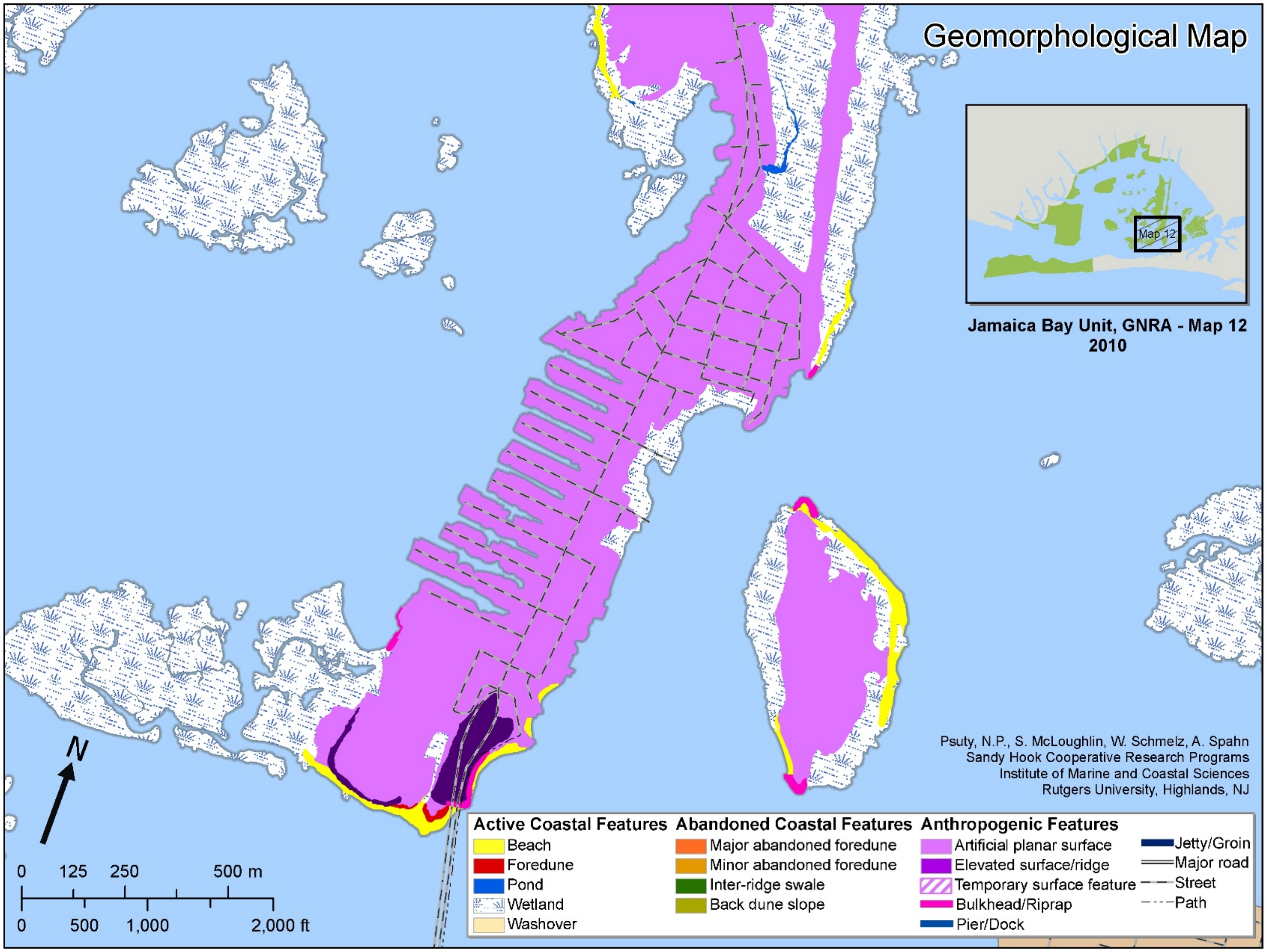

Active Coastal Features
Beach
Foredune
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Major road
Street
Path
Jamaica Bay
Geomorphological Map
Jamaica Bay Unit, GNRA - Map 10
2010
N
Psuty, N.P., S. McLoughlin, W. Schmelz, A. Spahn
Sandy Hook Cooperative Research Programs
Institute of Marine and Coastal Sciences
Rutgers University, Highlands, NJ
0 125 250 500 m
0 500 1,000 2,000 ft
Map 10

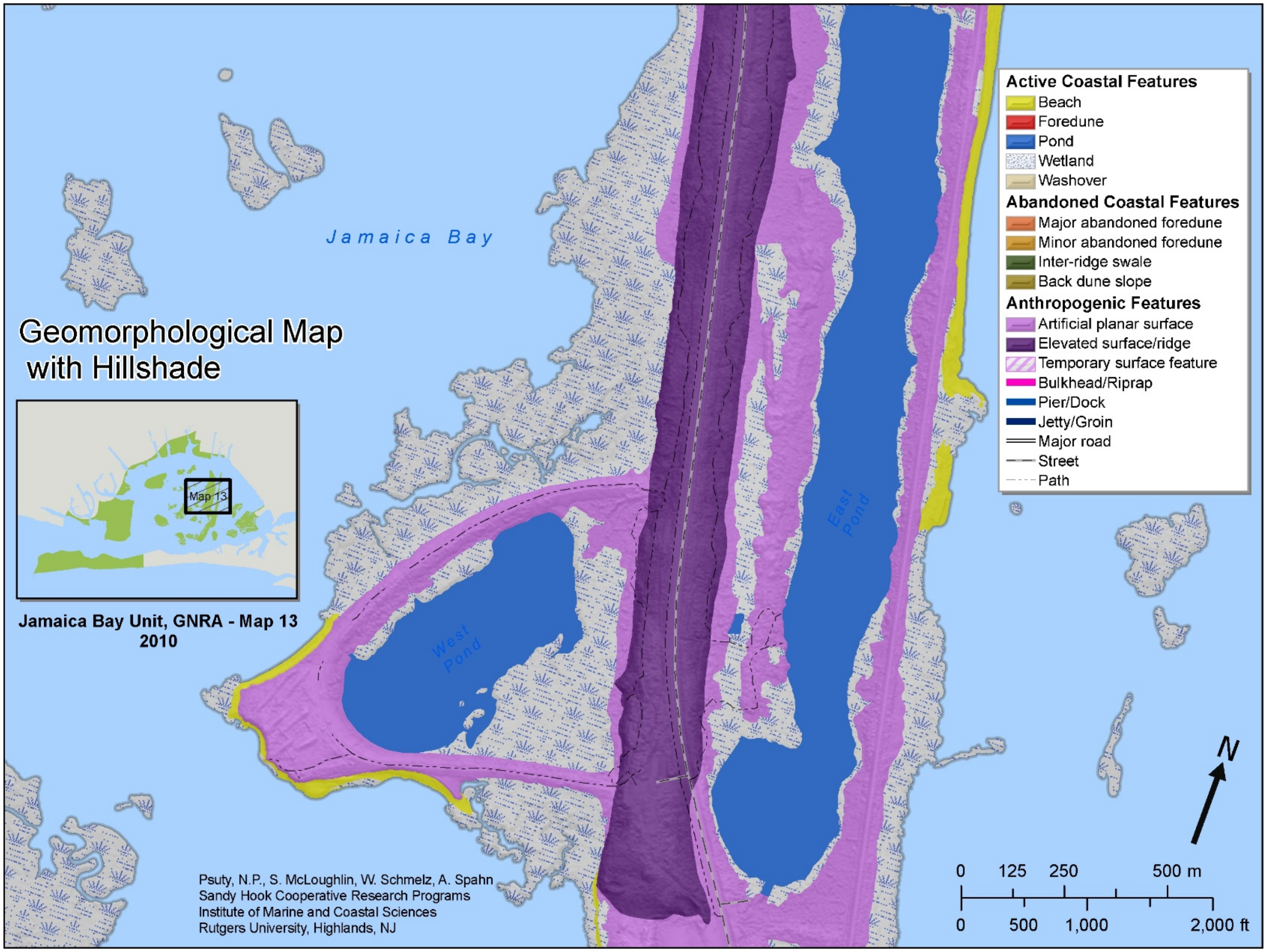

Geomorphological Map
with Hillshade
Map 11
Jamaica Bay Unit, GNRA - Map 11
2010
Jamaica Bay
N
0 125 250 500 m
0 500 1,000 2,000 ft
Psuty, N.P., S. McLoughlin, W. Schmelz, A. Spahn
Sandy Hook Cooperative Research Programs
Institute of Marine and Coastal Sciences
Rutgers University, Highlands, NJ
Active Coastal Features
Beach
Foredune
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Major road
Street
Path

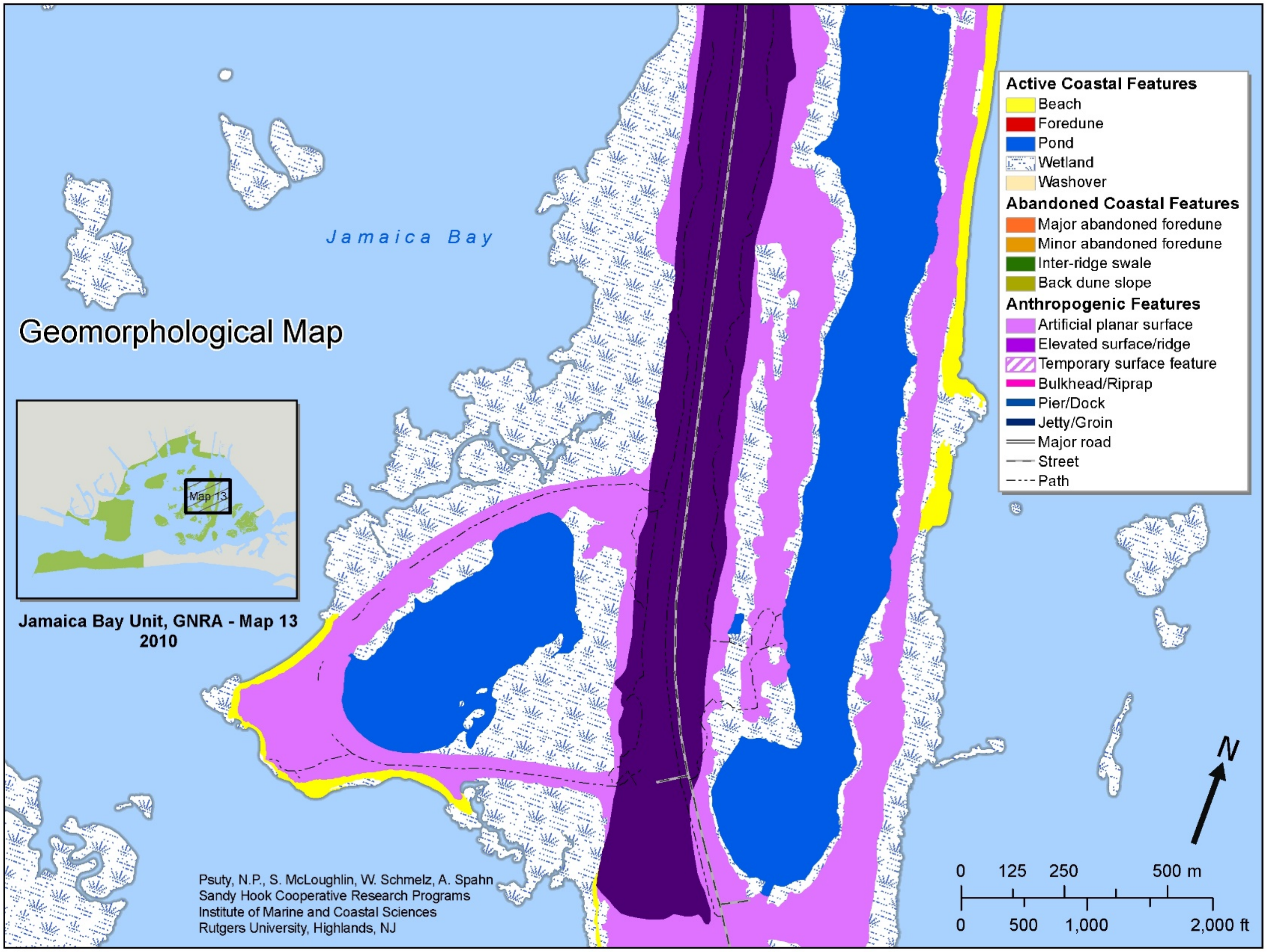

Geomorphological Map
Map 11
Jamaica Bay Unit, GNRA - Map 11
2010
Jamaica Bay
N
0 125 250 500 m
0 500 1,000 2,000 ft
Psuty, N.P., S. McLoughlin, W. Schmelz, A. Spahn
Sandy Hook Cooperative Research Programs
Institute of Marine and Coastal Sciences
Rutgers University, Highlands, NJ
Active Coastal Features
Beach
Foredune
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Major road
Street
Path

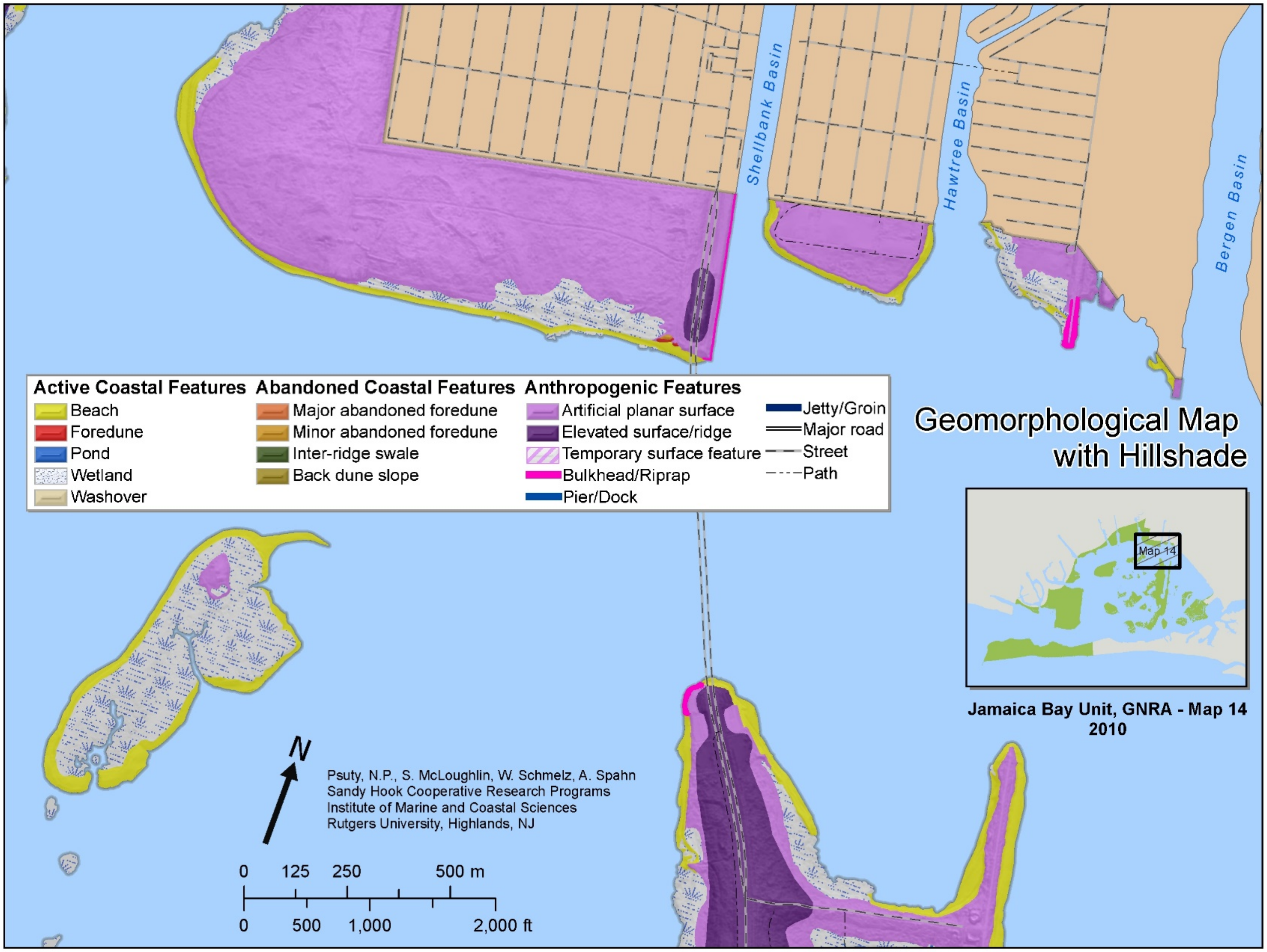


Geomorphological Map with Hillshade
Map 12
Jamaica Bay Unit, GNRA - Map 12
2010
N
0 125 250 500 m
0 500 1,000 2,000 ft
Psuty, N.P., S. McLoughlin, W. Schmelz, A. Spahn
Sandy Hook Cooperative Research Programs
Institute of Marine and Coastal Sciences
Rutgers University, Highlands, NJ
Active Coastal Features
Beach
Foredune
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Major road
Street
Path

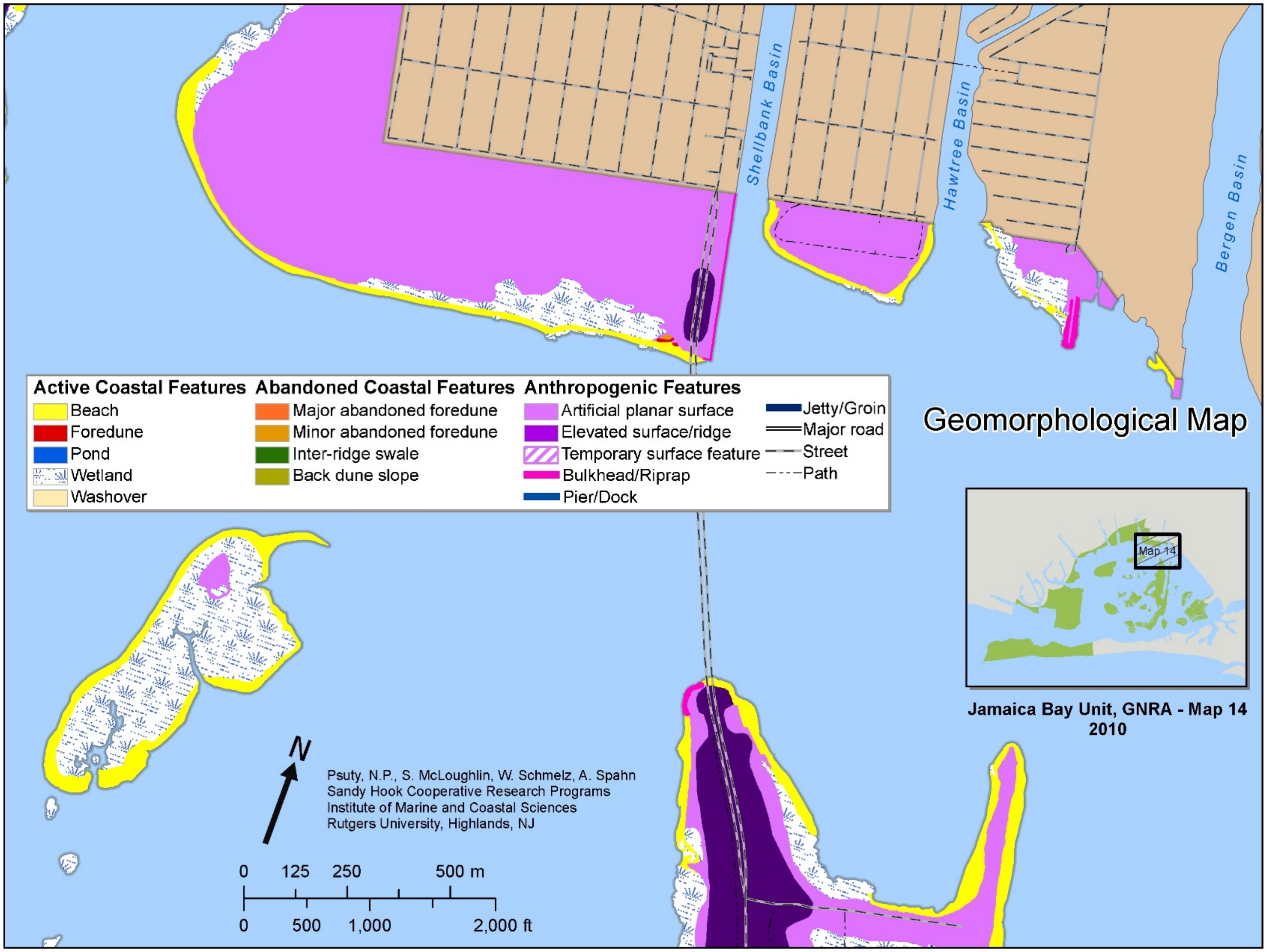

Geomorphological Map
Jamaica Bay Unit, GNRA - Map 12
2010
Map 12
N
0 125 250 500 m
0 500 1,000 2,000 ft
Psuty, N.P., S. McLoughlin, W. Schmelz, A. Spahn
Sandy Hook Cooperative Research Programs
Institute of Marine and Coastal Sciences
Rutgers University, Highlands, NJ
Active Coastal Features
Beach
Foredune
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Major road
Street
Path

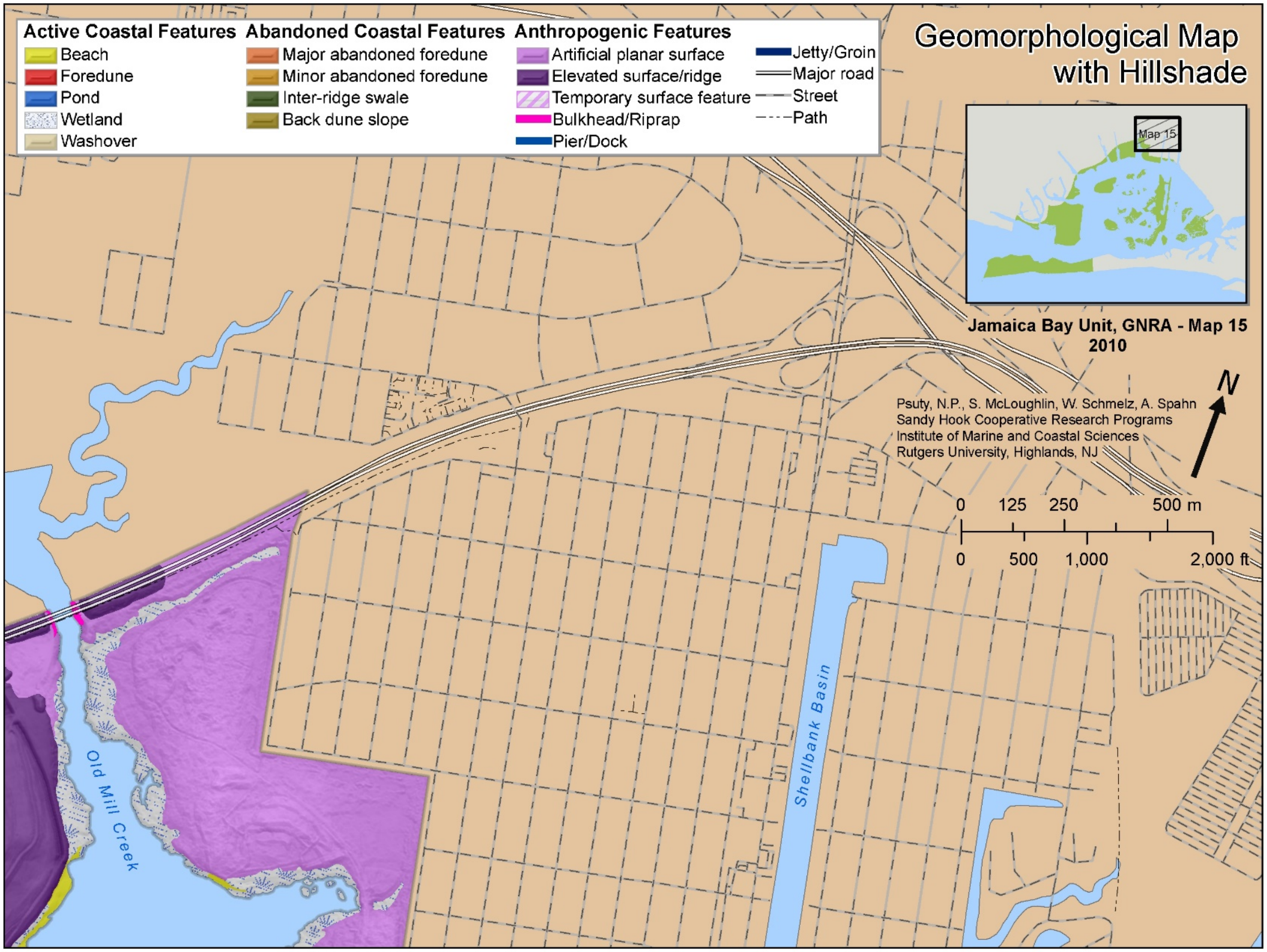

Geomorphological Map with Hillshade
Jamaica Bay
West Pond
East Pond
Map 13
Jamaica Bay Unit, GNRA - Map 13
2010
Active Coastal Features
Beach
Foredune
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Major road
Street
Path
N
0 125 250 500 m
0 500 1,000 2,000 ft
Psuty, N.P., S. McLoughlin, W. Schmelz, A. Spahn
Sandy Hook Cooperative Research Programs
Institute of Marine and Coastal Sciences
Rutgers University, Highlands, NJ


Active Coastal Features
Beach
Foredune
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Major road
Street
Path
Jamaica Bay
Geomorphological Map
Map 13
Jamaica Bay Unit, GNRA - Map 13
2010
Psuty, N.P., S. McLoughlin, W. Schmelz, A. Spahn
Sandy Hook Cooperative Research Programs
Institute of Marine and Coastal Sciences
Rutgers University, Highlands, NJ
N
0 125 250 500 m
0 500 1,000 2,000 ft

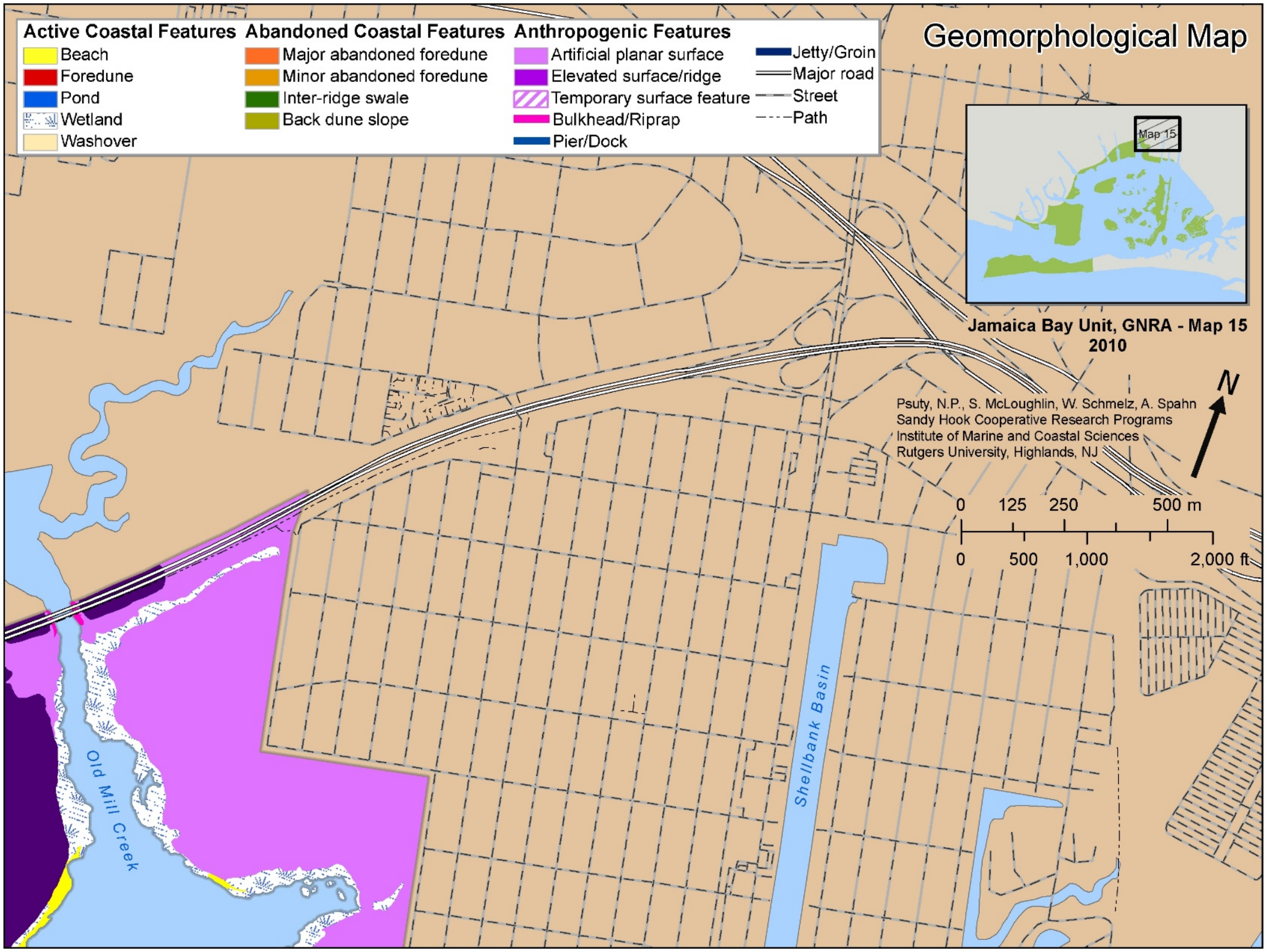


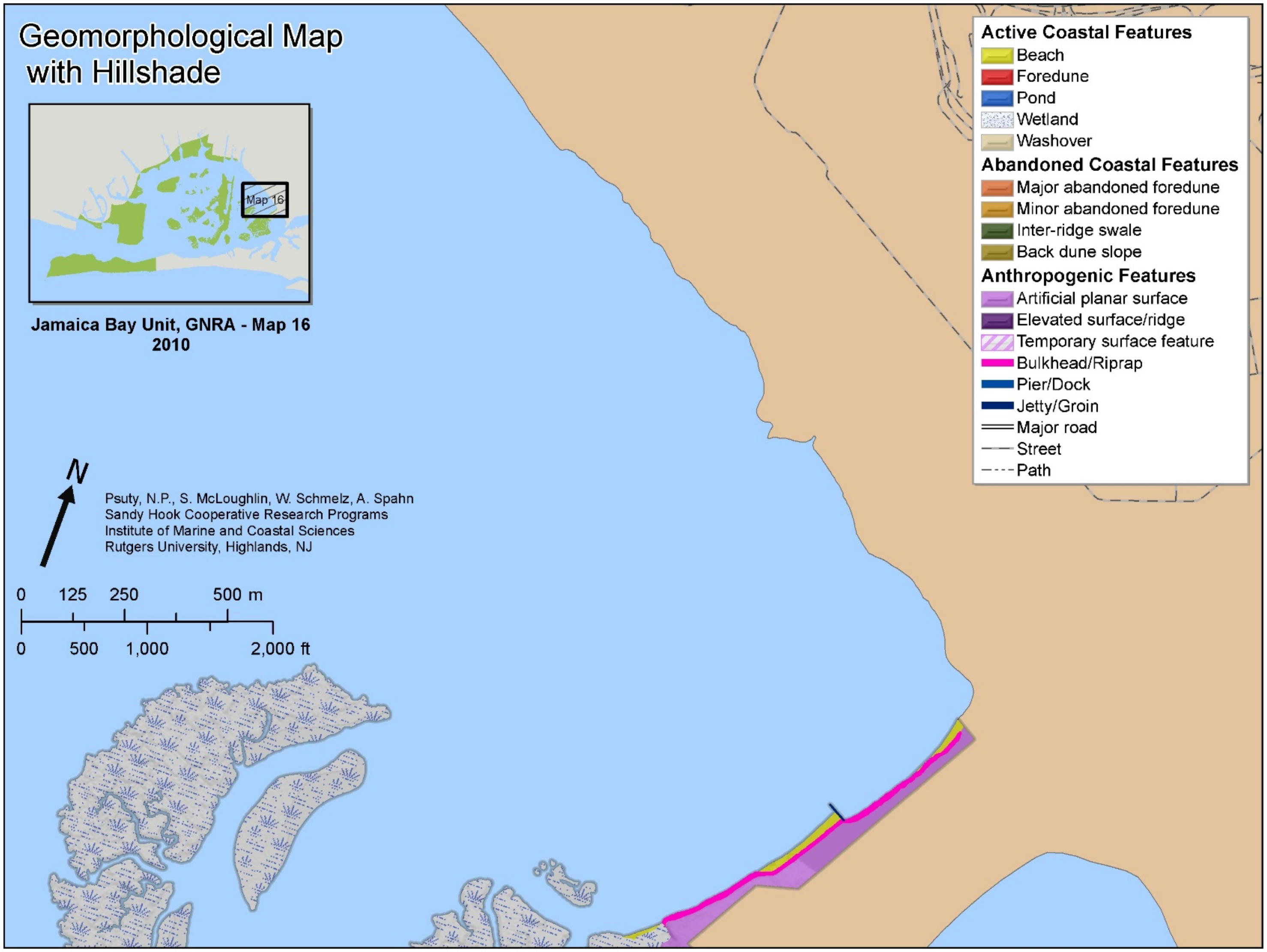
Shellbank Basin
Hawtree Basin
Bergen Basin
Active Coastal Features
Beach
Foredune
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Major road
Street
Path
Geomorphological Map
with Hillshade
Map 14
Jamaica Bay Unit, GNRA - Map 14
2010
N
Psuty, N.P., S. McLoughlin, W. Schmelz, A. Spahn
Sandy Hook Cooperative Research Programs
Institute of Marine and Coastal Sciences
Rutgers University, Highlands, NJ
0 125 250 500 m
0 500 1,000 2,000 ft


Shellbank Basin
Hawtree Basin
Bergen Basin
Active Coastal Features
Beach
Foredune
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Major road
Street
Path
Geomorphological Map
Map 14
Jamaica Bay Unit, GNRA - Map 14
2010
N
Psuty, N.P., S. McLoughlin, W. Schmelz, A. Spahn
Sandy Hook Cooperative Research Programs
Institute of Marine and Coastal Sciences
Rutgers University, Highlands, NJ
0 125 250 500 m
0 500 1,000 2,000 ft

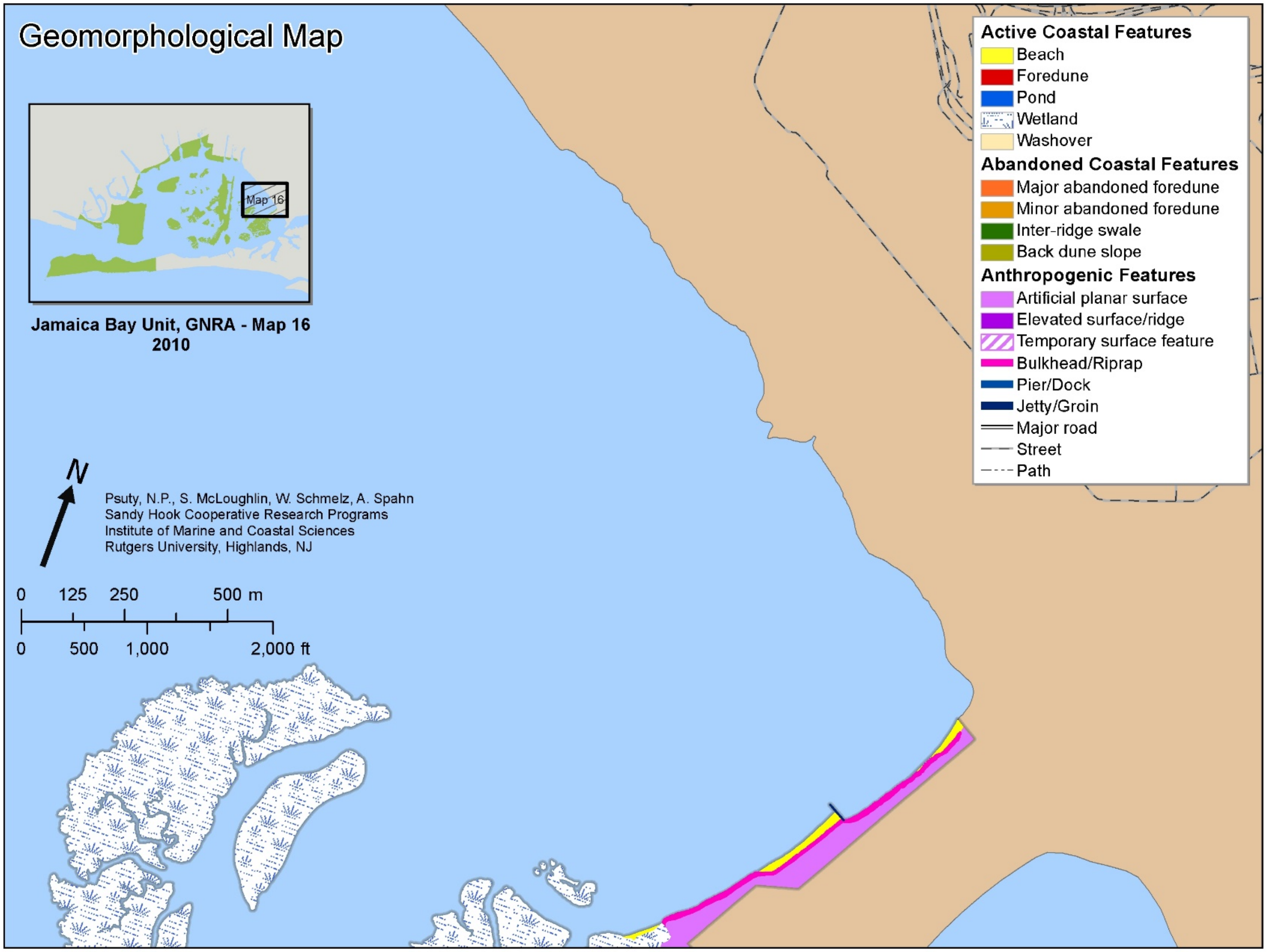


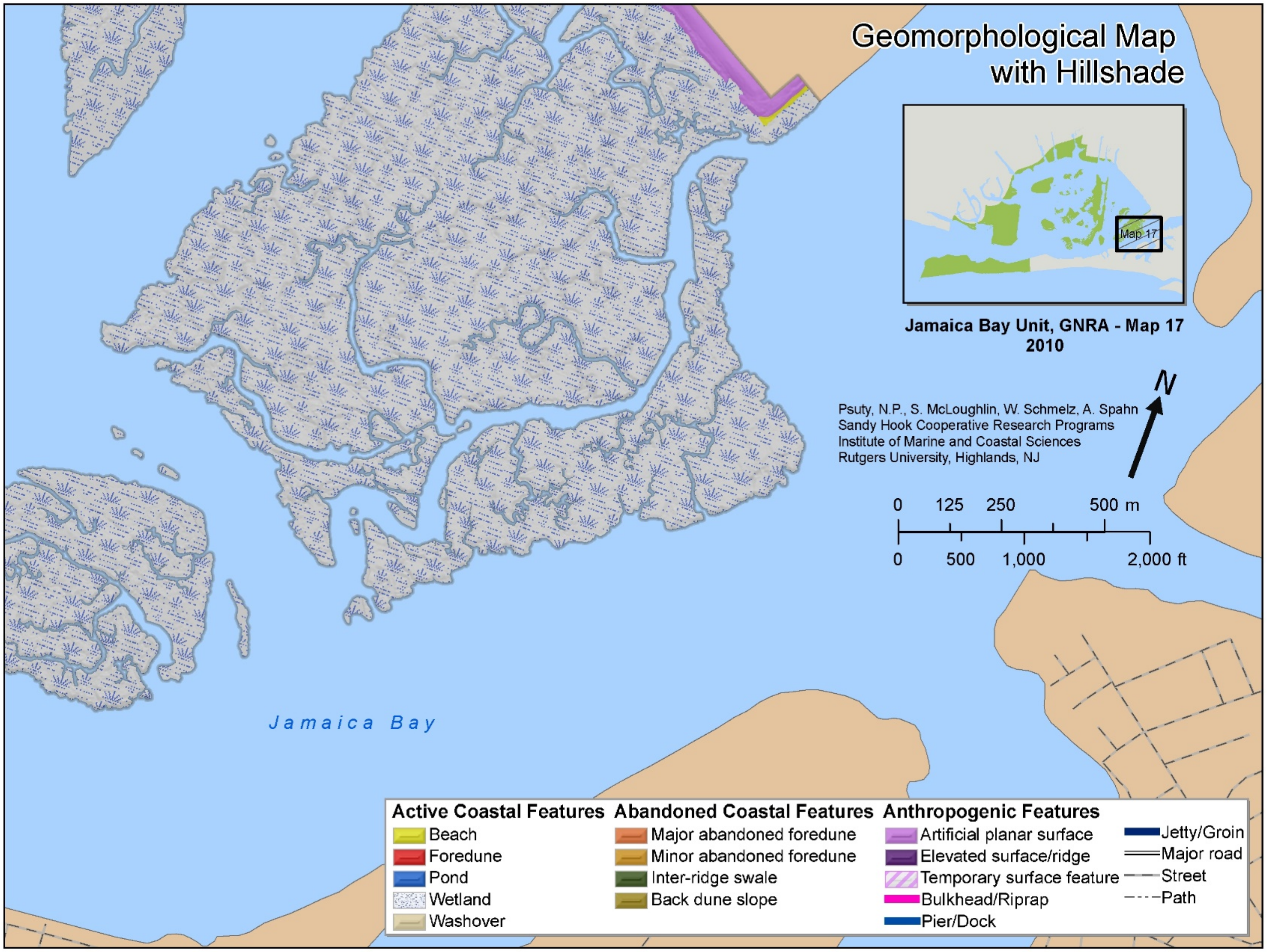
Active Coastal Features
Beach
Foredune
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Major road
Street
Path
Geomorphological Map with Hillshade
Map 15
Jamaica Bay Unit, GNRA - Map 15
2010
N
Psuty, N.P., S. McLoughlin, W. Schmelz, A. Spahn
Sandy Hook Cooperative Research Programs
Institute of Marine and Coastal Sciences
Rutgers University, Highlands, NJ
0 125 250 500 m
0 500 1,000 2,000 ft
Shellbank Basin
Old Mill Creek

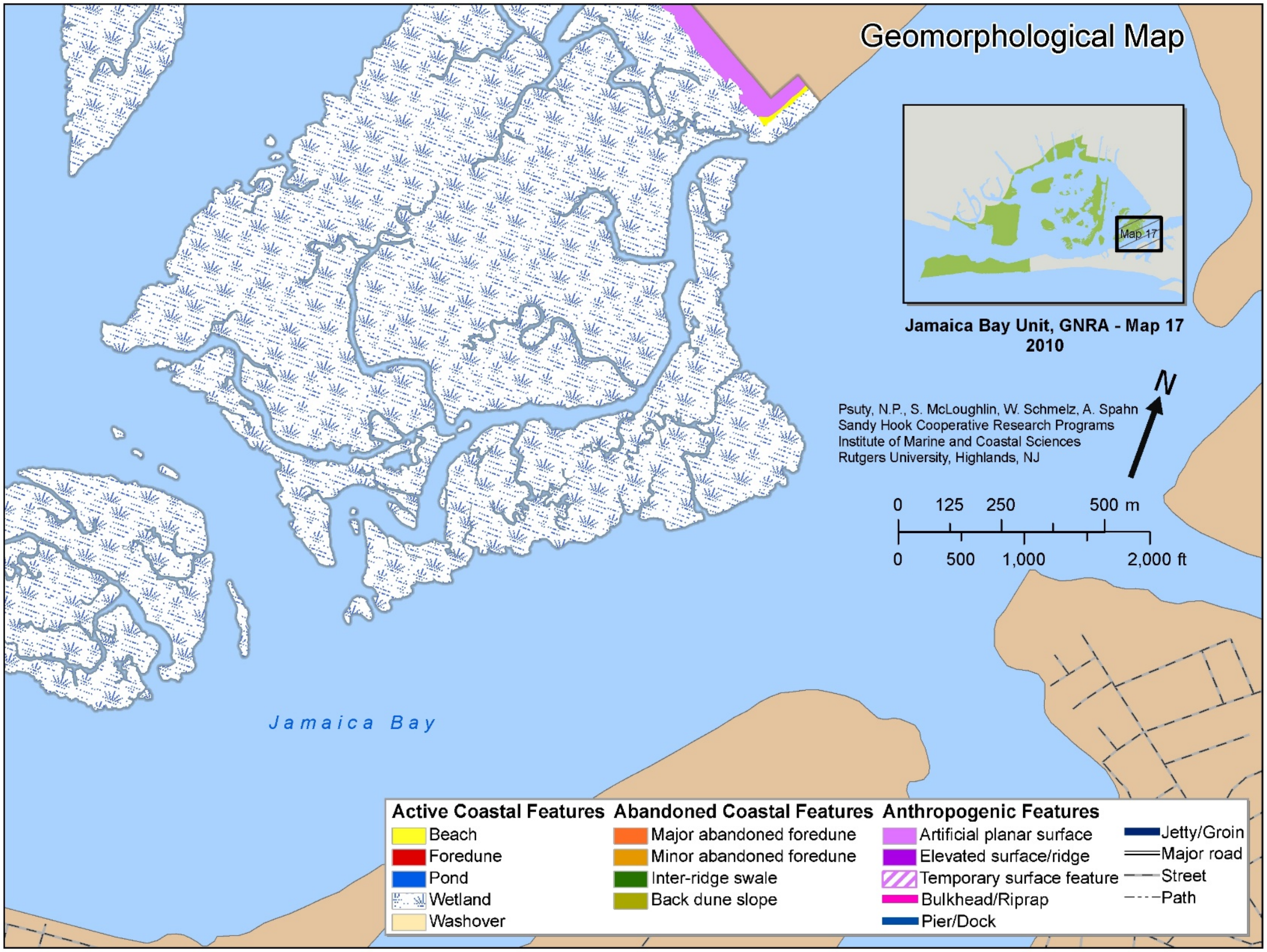

Active Coastal Features
Beach
Foredune
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Major road
Street
Path
Geomorphological Map
Map 15
Jamaica Bay Unit, GNRA - Map 15
2010
Psuty, N.P., S. McLoughlin, W. Schmelz, A. Spahn
Sandy Hook Cooperative Research Programs
Institute of Marine and Coastal Sciences
Rutgers University, Highlands, NJ
N
0 125 250 500 m
0 500 1,000 2,000 ft
Old Mill Creek
Shellbank Basin



Geomorphological Map
with Hillshade
Map 16
Jamaica Bay Unit, GNRA - Map 16
2010
N
Psuty, N.P., S. McLoughlin, W. Schmelz, A. Spahn
Sandy Hook Cooperative Research Programs
Institute of Marine and Coastal Sciences
Rutgers University, Highlands, NJ
0 125 250 500 m
0 500 1,000 2,000 ft
Active Coastal Features
Beach
Foredune
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Major road
Street
Path

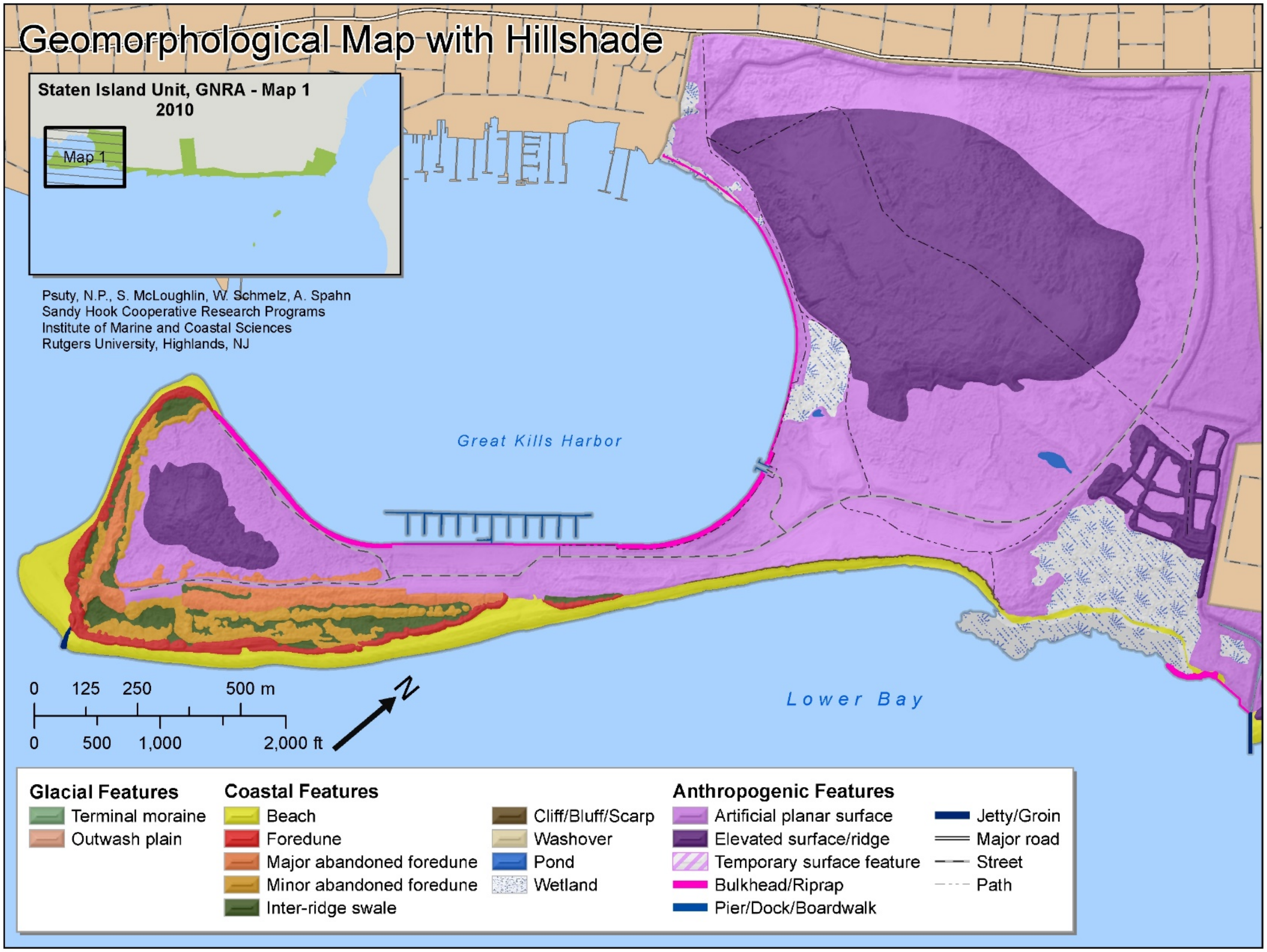

Geomorphological Map
Map 16
Jamaica Bay Unit, GNRA - Map 16
2010
N
Psuty, N.P., S. McLoughlin, W. Schmelz, A. Spahn
Sandy Hook Cooperative Research Programs
Institute of Marine and Coastal Sciences
Rutgers University, Highlands, NJ
0 125 250 500 m
0 500 1,000 2,000 ft
Active Coastal Features
Beach
Foredune
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Major road
Street
Path


Geomorphological Map
with Hillshade
Map 17
Jamaica Bay Unit, GNRA - Map 17
2010
N
Psuty, N.P., S. McLoughlin, W. Schmelz, A. Spahn
Sandy Hook Cooperative Research Programs
Institute of Marine and Coastal Sciences
Rutgers University, Highlands, NJ
0 125 250 500 m
0 500 1,000 2,000 ft
Jamaica Bay
Active Coastal Features
Beach
Foredune
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Major road
Street
Path

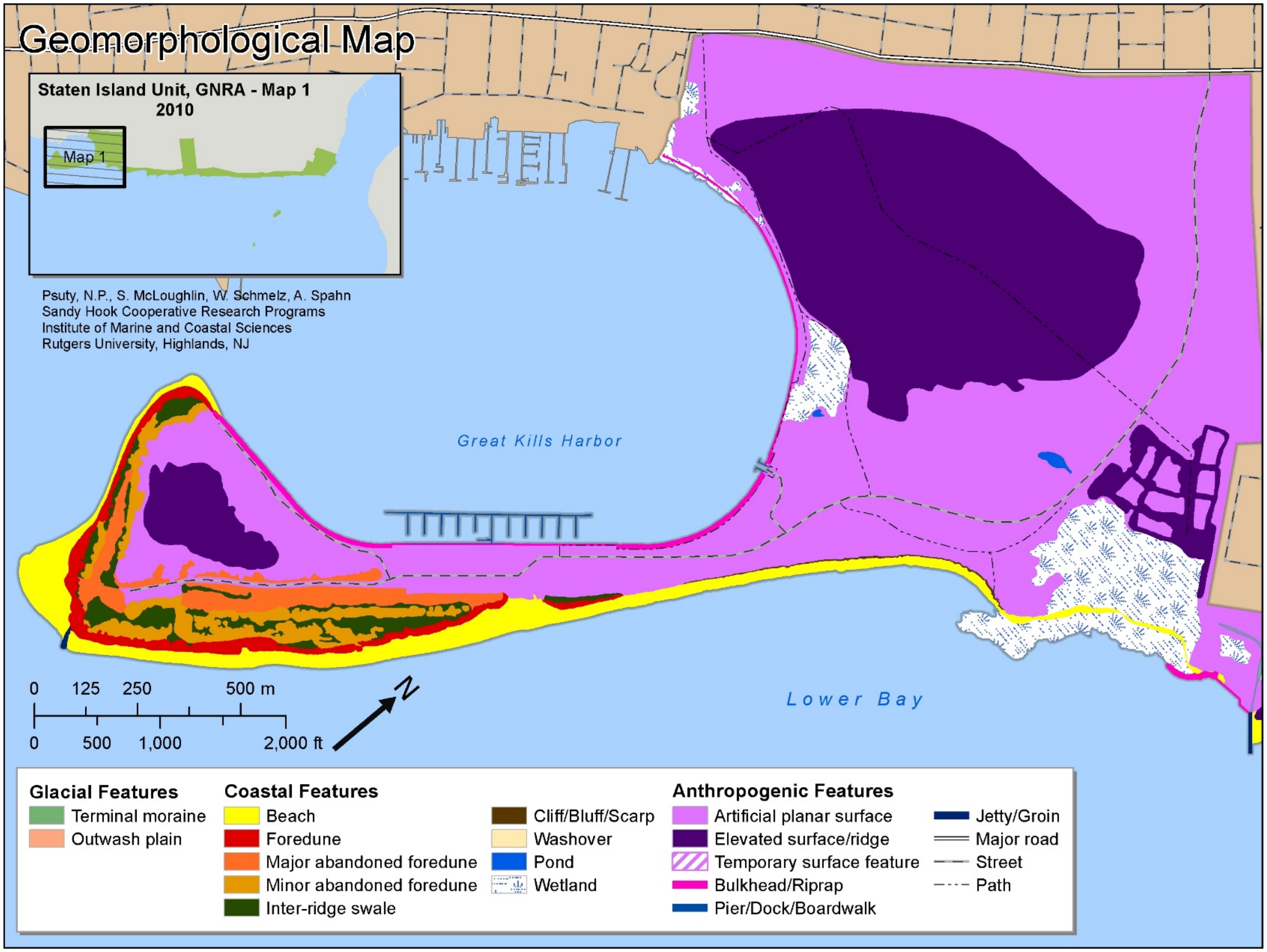


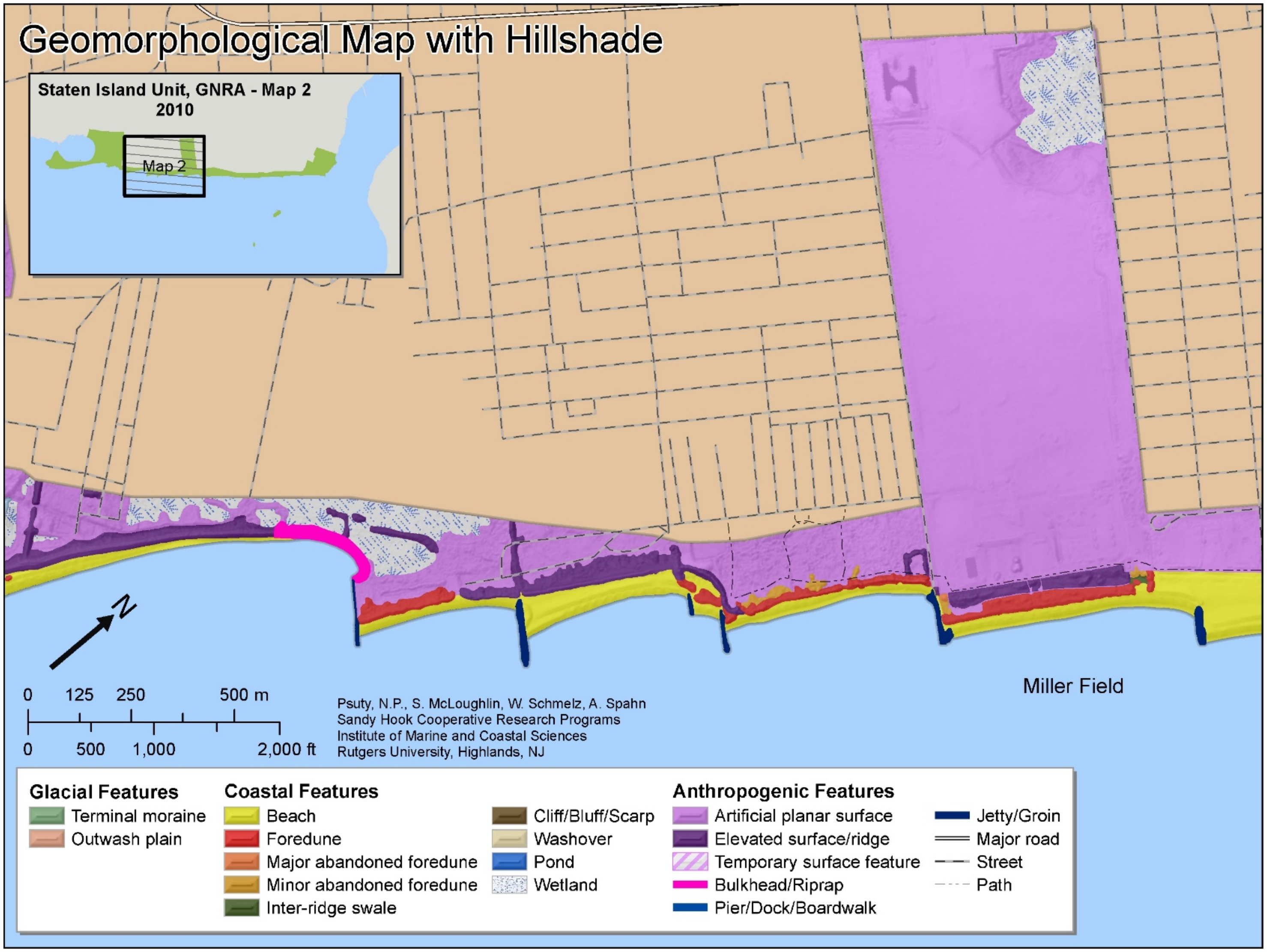
Geomorphological Map
Map 17
Jamaica Bay Unit, GNRA - Map 17
2010
N
Psuty, N.P., S. McLoughlin, W. Schmelz, A. Spahn
Sandy Hook Cooperative Research Programs
Institute of Marine and Coastal Sciences
Rutgers University, Highlands, NJ
0 125 250 500 m
0 500 1,000 2,000 ft
Jamaica Bay
Active Coastal Features
Beach
Foredune
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Major road
Street
Path

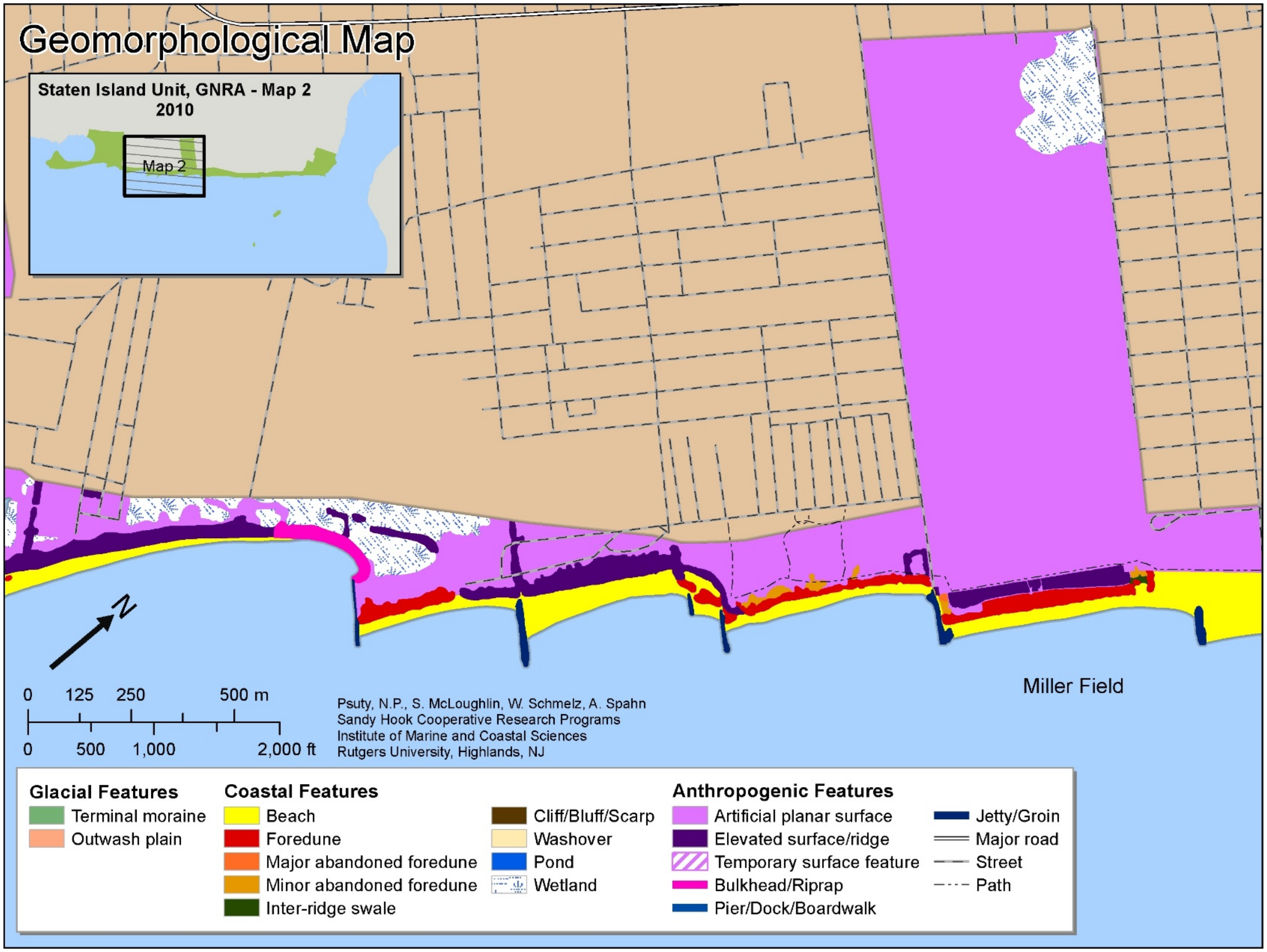
Staten Island Unit (SIU)

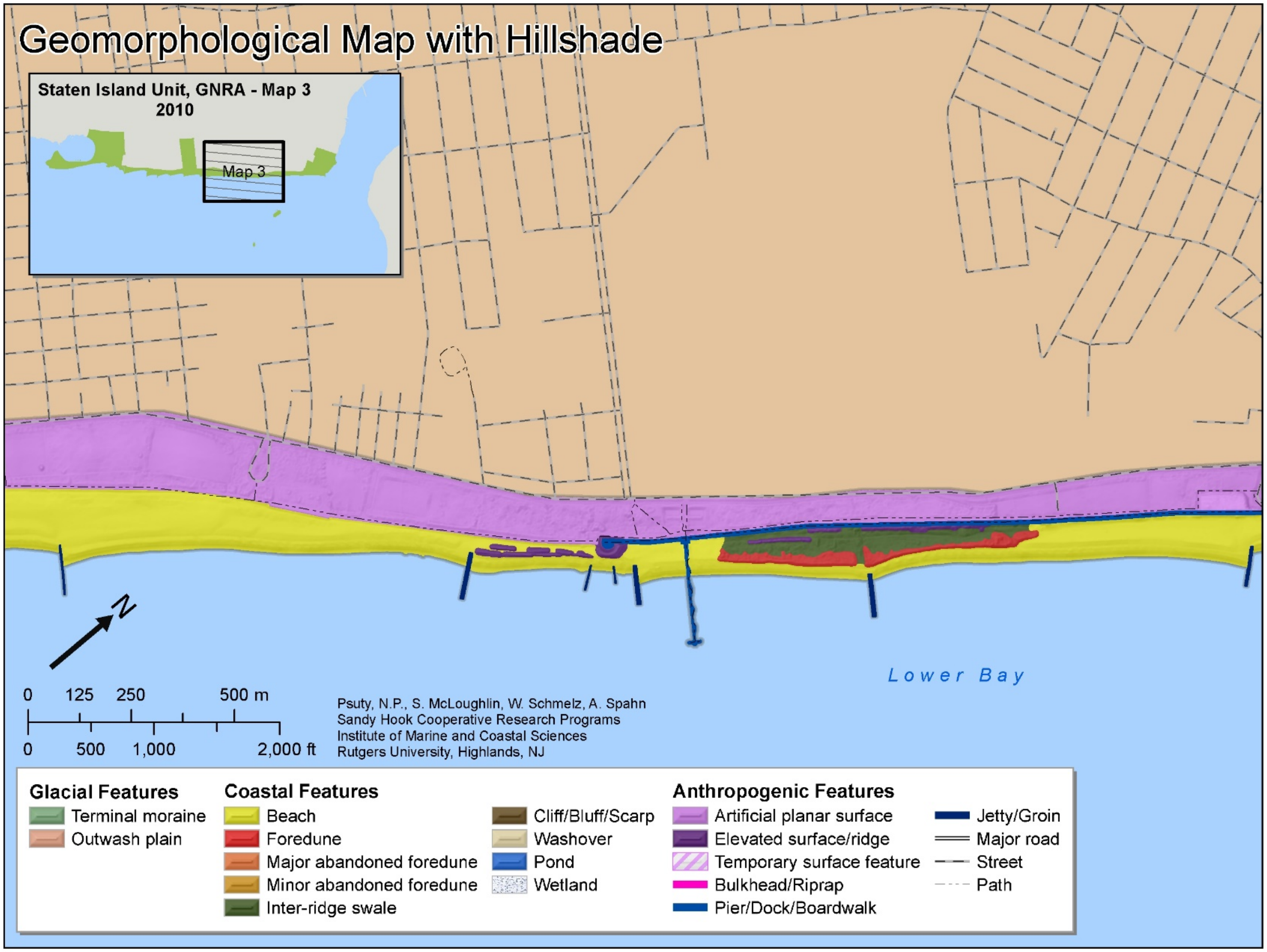


Geomorphological Map with Hillshade
Staten Island Unit, GNRA - Map 1
2010
Map 1
Psuty, N.P., S. McLoughlin, W. Schmelz, A. Spahn
Sandy Hook Cooperative Research Programs
Institute of Marine and Coastal Sciences
Rutgers University, Highlands, NJ
Great Kills Harbor
Lower Bay
0 125 250 500 m
0 500 1,000 2,000 ft
N
Glacial Features
Terminal moraine
Outwash plain
Coastal Features
Beach
Foredune
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Cliff/Bluff/Scarp
Washover
Pond
Wetland
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock/Boardwalk
Jetty/Groin
Major road
Street
Path

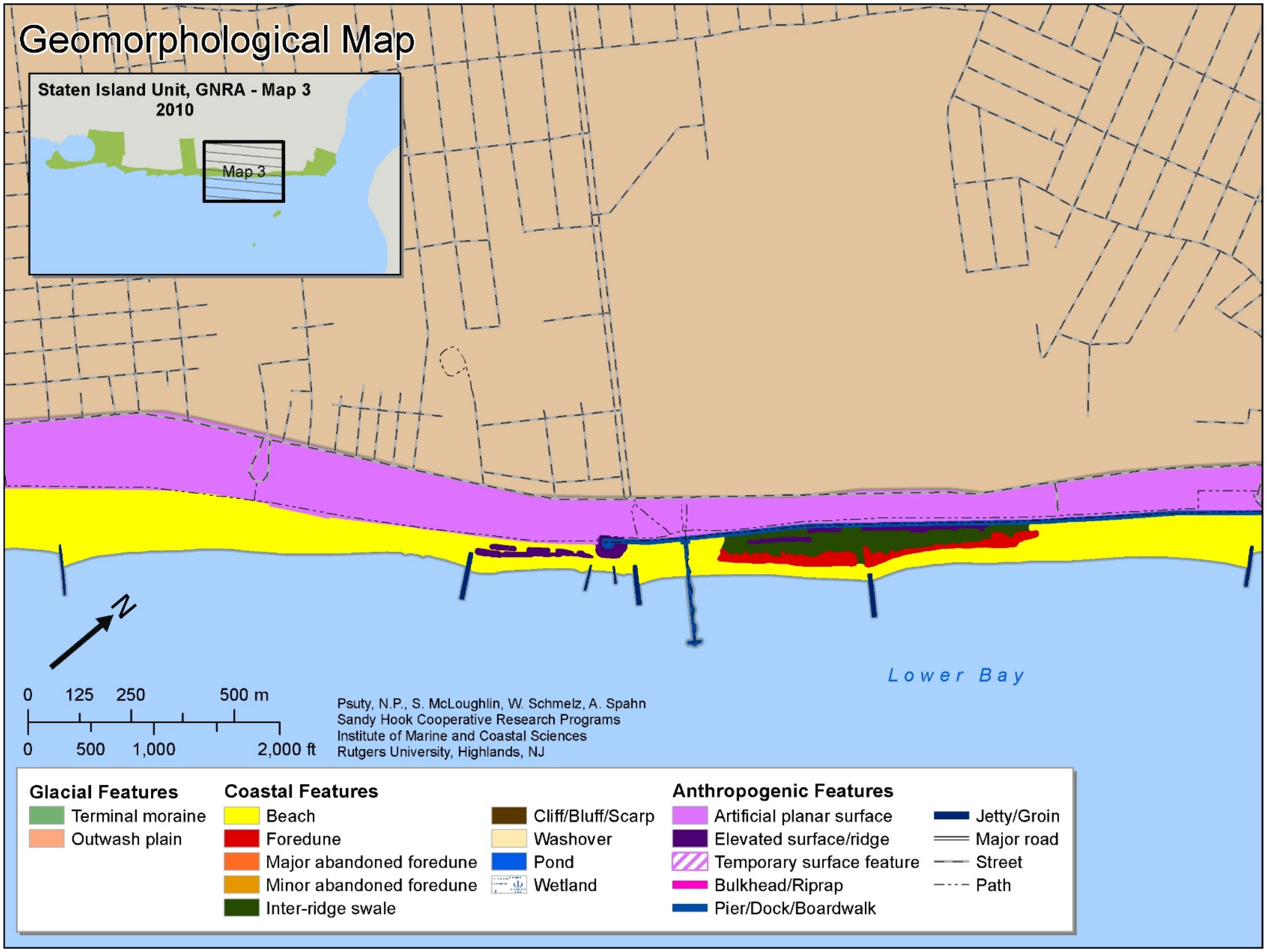

Geomorphological Map
Staten Island Unit, GNRA - Map 1
2010
Map 1
Psuty, N.P., S. McLoughlin, W. Schmelz, A. Spahn
Sandy Hook Cooperative Research Programs
Institute of Marine and Coastal Sciences
Rutgers University, Highlands, NJ
Great Kills Harbor
Lower Bay
0 125 250 500 m
0 500 1,000 2,000 ft
N
Glacial Features
Terminal moraine
Outwash plain
Coastal Features
Beach
Foredune
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Cliff/Bluff/Scarp
Washover
Pond
Wetland
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock/Boardwalk
Jetty/Groin
Major road
Street
Path

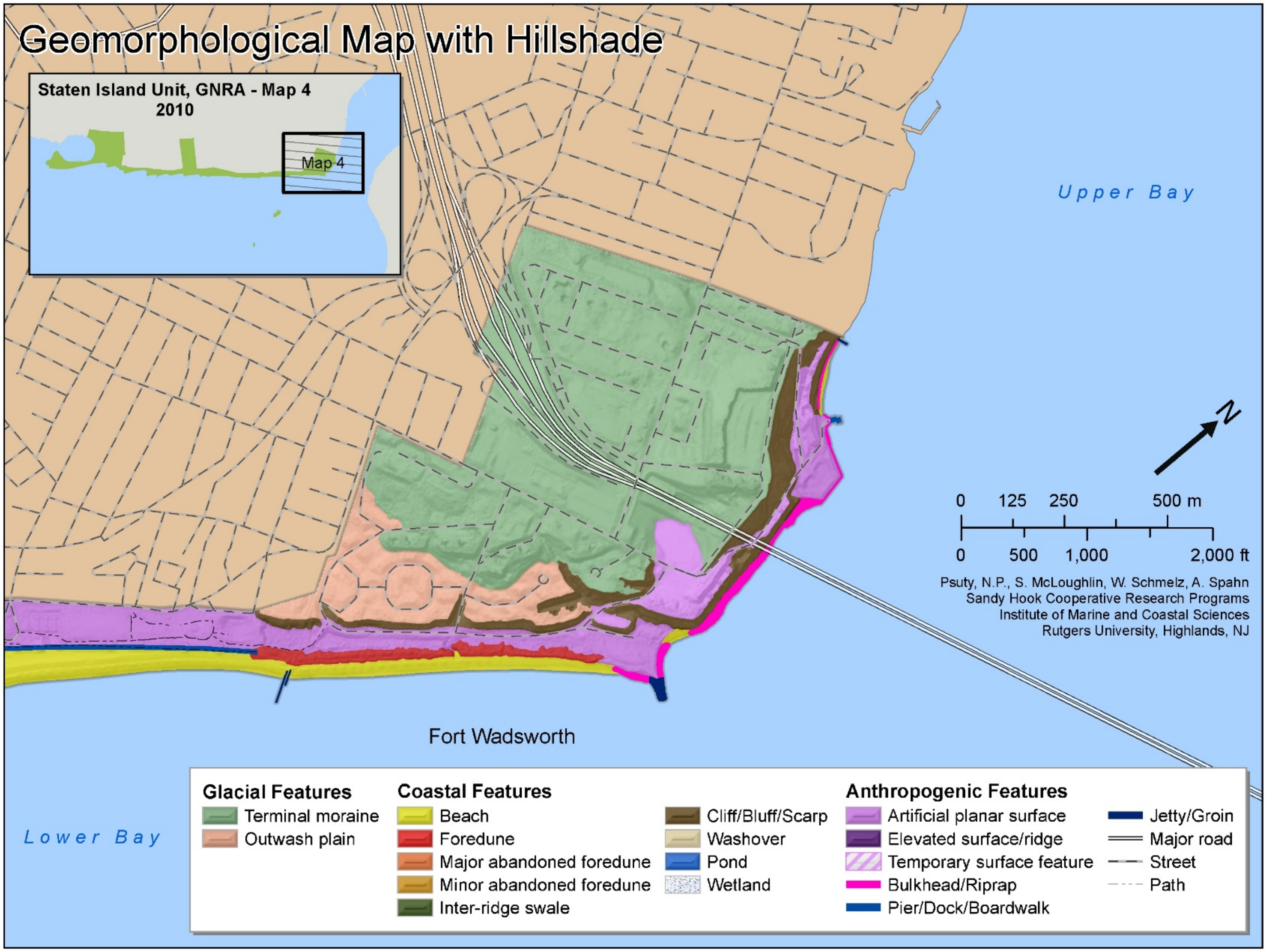

Geomorphological Map with Hillshade
Staten Island Unit, GNRA - Map 2
2010
Map 2
N
Miller Field
0 125 250 500 m
0 500 1,000 2,000 ft
Psuty, N.P., S. McLoughlin, W. Schmelz, A. Spahn
Sandy Hook Cooperative Research Programs
Institute of Marine and Coastal Sciences
Rutgers University, Highlands, NJ
Glacial Features
Terminal moraine
Outwash plain
Coastal Features
Beach
Foredune
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Cliff/Bluff/Scarp
Washover
Pond
Wetland
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock/Boardwalk
Jetty/Groin
Major road
Street
Path


Geomorphological Map
Staten Island Unit, GNRA - Map 2
2010
Map 2
Miller Field
0 125 250 500 m
0 500 1,000 2,000 ft
Psuty, N.P., S. McLoughlin, W. Schmelz, A. Spahn
Sandy Hook Cooperative Research Programs
Institute of Marine and Coastal Sciences
Rutgers University, Highlands, NJ
Glacial Features
Terminal moraine
Outwash plain
Coastal Features
Beach
Foredune
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Cliff/Bluff/Scarp
Washover
Pond
Wetland
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock/Boardwalk
Jetty/Groin
Major road
Street
Path

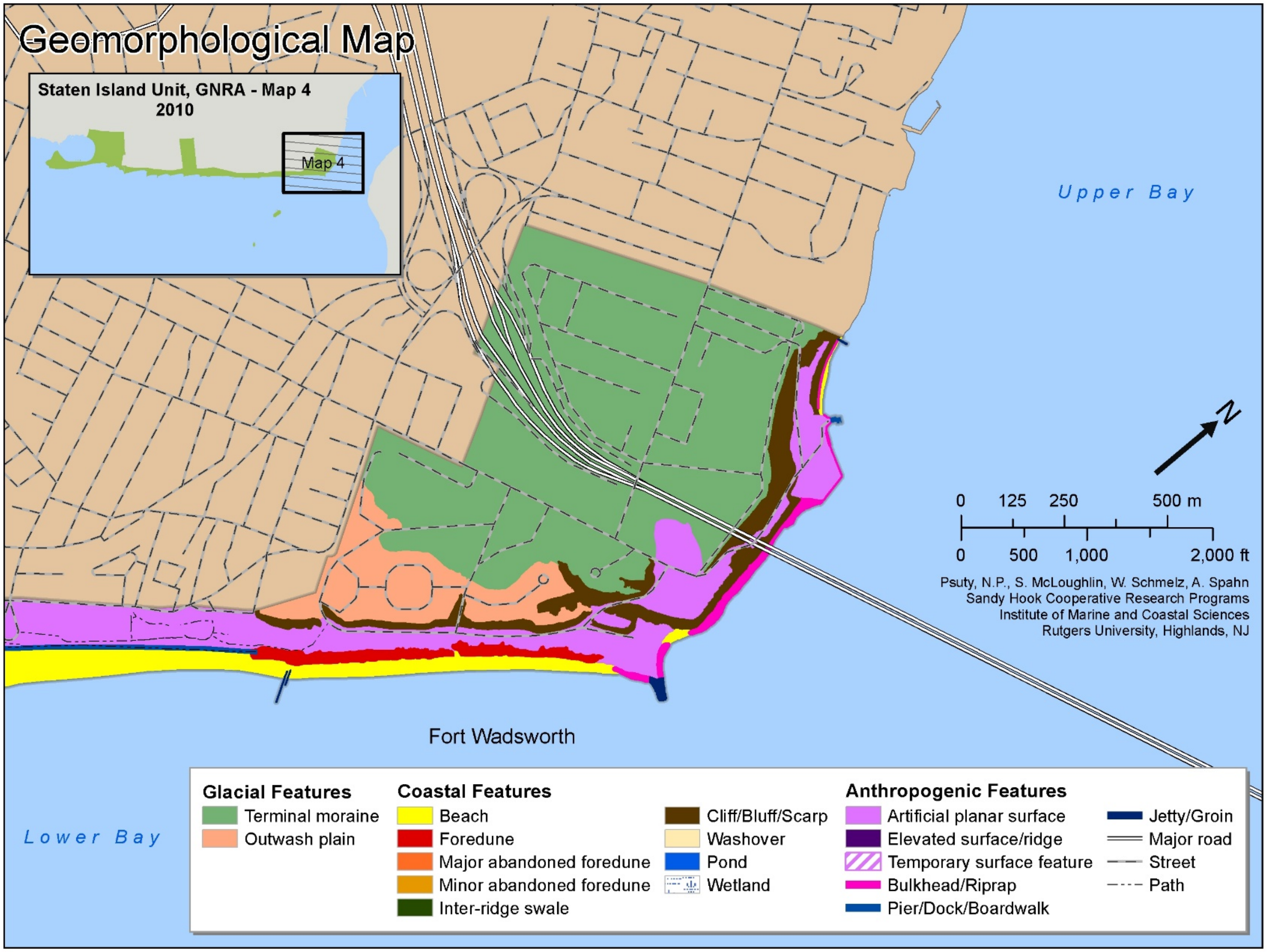


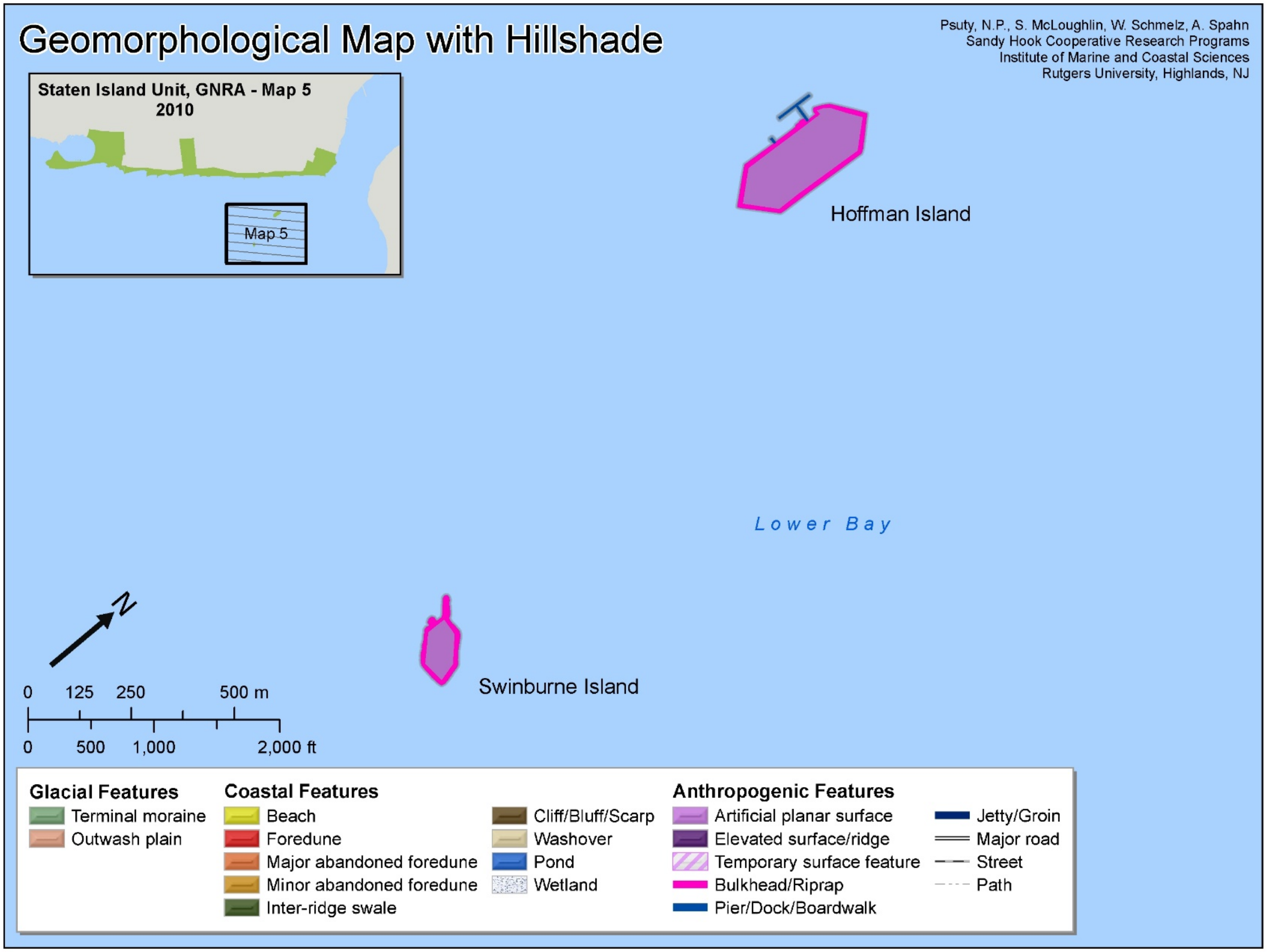
Geomorphological Map with Hillshade
Staten Island Unit, GNRA - Map 3
2010
Map 3
N
Lower Bay
0 125 250 500 m
0 500 1,000 2,000 ft
Psuty, N.P., S. McLoughlin, W. Schmelz, A. Spahn
Sandy Hook Cooperative Research Programs
Institute of Marine and Coastal Sciences
Rutgers University, Highlands, NJ
Glacial Features
Terminal moraine
Outwash plain
Coastal Features
Beach
Foredune
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Cliff/Bluff/Scarp
Washover
Pond
Wetland
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock/Boardwalk
Jetty/Groin
Major road
Street
Path

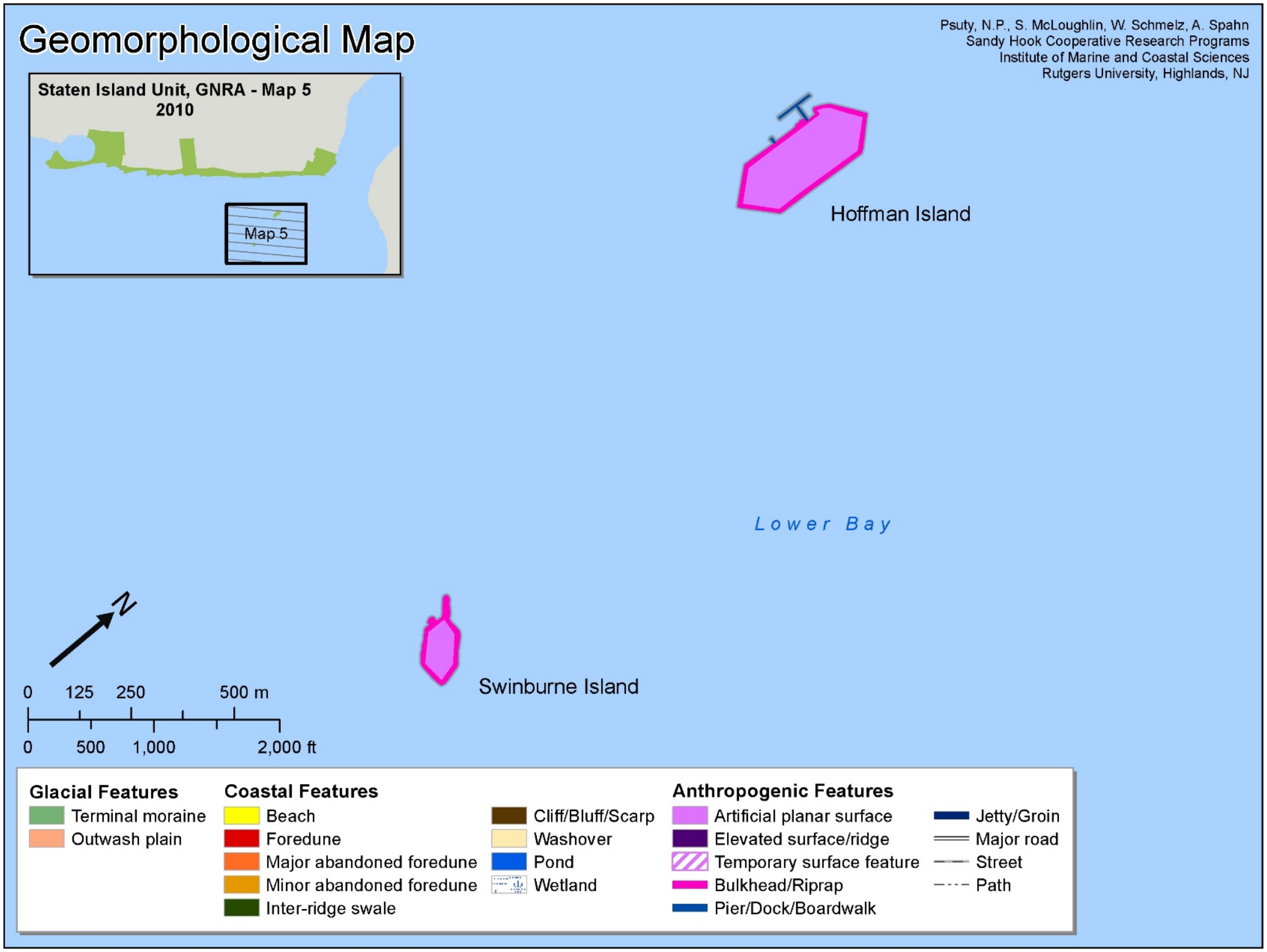

Geomorphological Map
Staten Island Unit, GNRA - Map 3
2010
Map 3
Lower Bay
N
0 125 250 500 m
0 500 1,000 2,000 ft
Psuty, N.P., S. McLoughlin, W. Schmelz, A. Spahn
Sandy Hook Cooperative Research Programs
Institute of Marine and Coastal Sciences
Rutgers University, Highlands, NJ
Glacial Features
Terminal moraine
Outwash plain
Coastal Features
Beach
Foredune
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Cliff/Bluff/Scarp
Washover
Pond
Wetland
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock/Boardwalk
Jetty/Groin
Major road
Street
Path



Geomorphological Map with Hillshade
Staten Island Unit, GNRA - Map 4
2010
Map 4
Upper Bay
Lower Bay
Fort Wadsworth
0 125 250 500 m
0 500 1,000 2,000 ft
N
Psuty, N.P., S. McLoughlin, W. Schmelz, A. Spahn
Sandy Hook Cooperative Research Programs
Institute of Marine and Coastal Sciences
Rutgers University, Highlands, NJ
Glacial Features
Terminal moraine
Outwash plain
Coastal Features
Beach
Foredune
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Cliff/Bluff/Scarp
Washover
Pond
Wetland
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock/Boardwalk
Jetty/Groin
Major road
Street
Path


Geomorphological Map
Staten Island Unit, GNRA - Map 4
2010
Map 4
Upper Bay
Lower Bay
Fort Wadsworth
N
0 125 250 500 m
0 500 1,000 2,000 ft
Psuty, N.P., S. McLoughlin, W. Schmelz, A. Spahn
Sandy Hook Cooperative Research Programs
Institute of Marine and Coastal Sciences
Rutgers University, Highlands, NJ
Glacial Features
Terminal moraine
Outwash plain
Coastal Features
Beach
Foredune
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Cliff/Bluff/Scarp
Washover
Pond
Wetland
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock/Boardwalk
Jetty/Groin
Major road
Street
Path


Geomorphological Map with Hillshade
Psuty, N.P., S. McLoughlin, W. Schmelz, A. Spahn
Sandy Hook Cooperative Research Programs
Institute of Marine and Coastal Sciences
Rutgers University, Highlands, NJ
Staten Island Unit, GNRA - Map 5
2010
Map 5
Hoffman Island
Lower Bay
Swinburne Island
N
0 125 250 500 m
0 500 1,000 2,000 ft
Glacial Features
Terminal moraine
Outwash plain
Coastal Features
Beach
Foredune
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Cliff/Bluff/Scarp
Washover
Pond
Wetland
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock/Boardwalk
Jetty/Groin
Major road
Street
Path


Geomorphological Map
Psuty, N.P., S. McLoughlin, W. Schmelz, A. Spahn
Sandy Hook Cooperative Research Programs
Institute of Marine and Coastal Sciences
Rutgers University, Highlands, NJ
Staten Island Unit, GNRA - Map 5
2010
Map 5
Hoffman Island
Lower Bay
Swinburne Island
N
0 125 250 500 m
0 500 1,000 2,000 ft
Glacial Features
Terminal moraine
Outwash plain
Coastal Features
Beach
Foredune
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Cliff/Bluff/Scarp
Washover
Pond
Wetland
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock/Boardwalk
Jetty/Groin
Major road
Street
Path

Appendix II: Post-Hurricane Sandy Maps of Gateway National Recreation Area Geomorphology, with and without Hillshade

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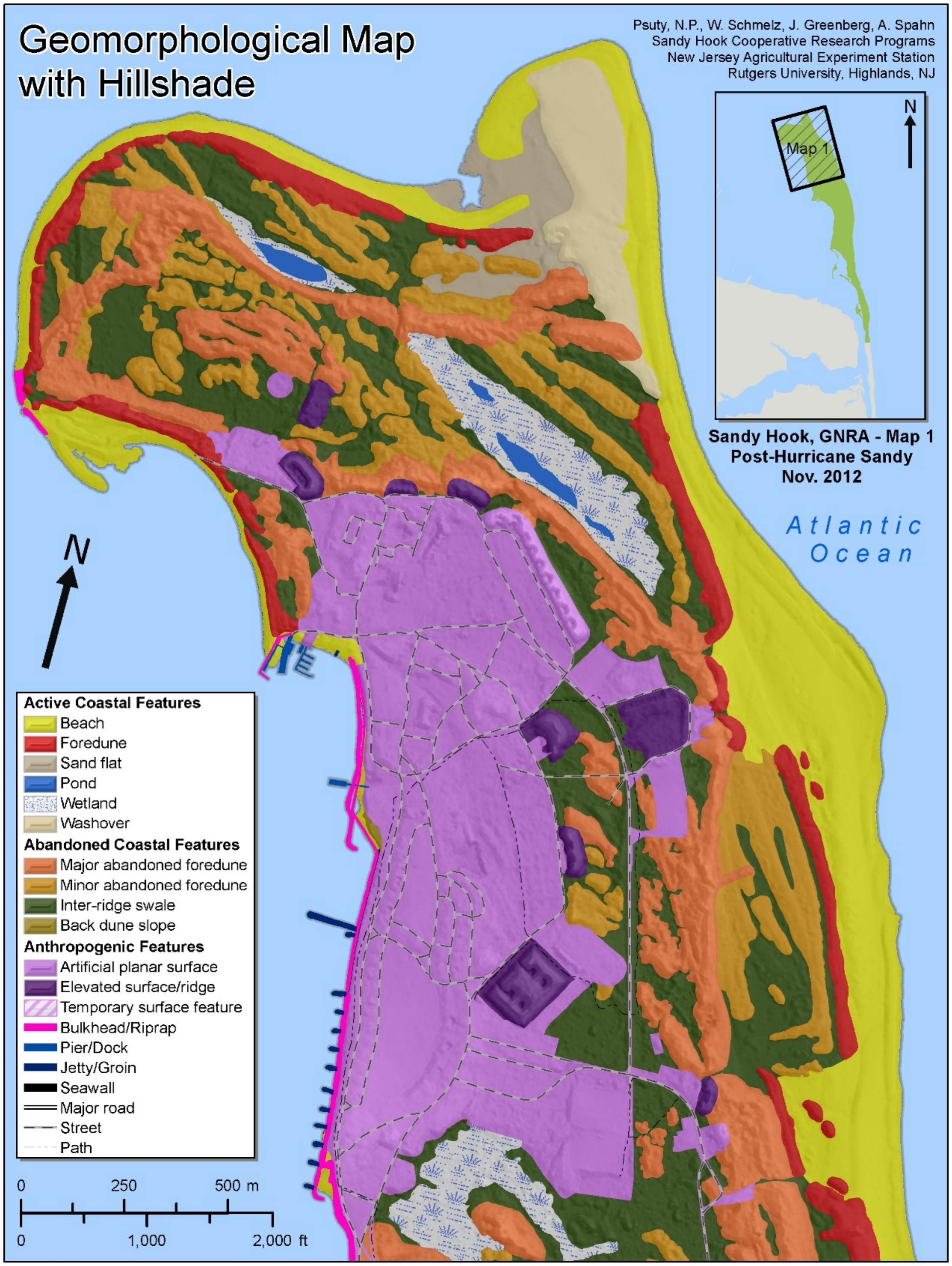
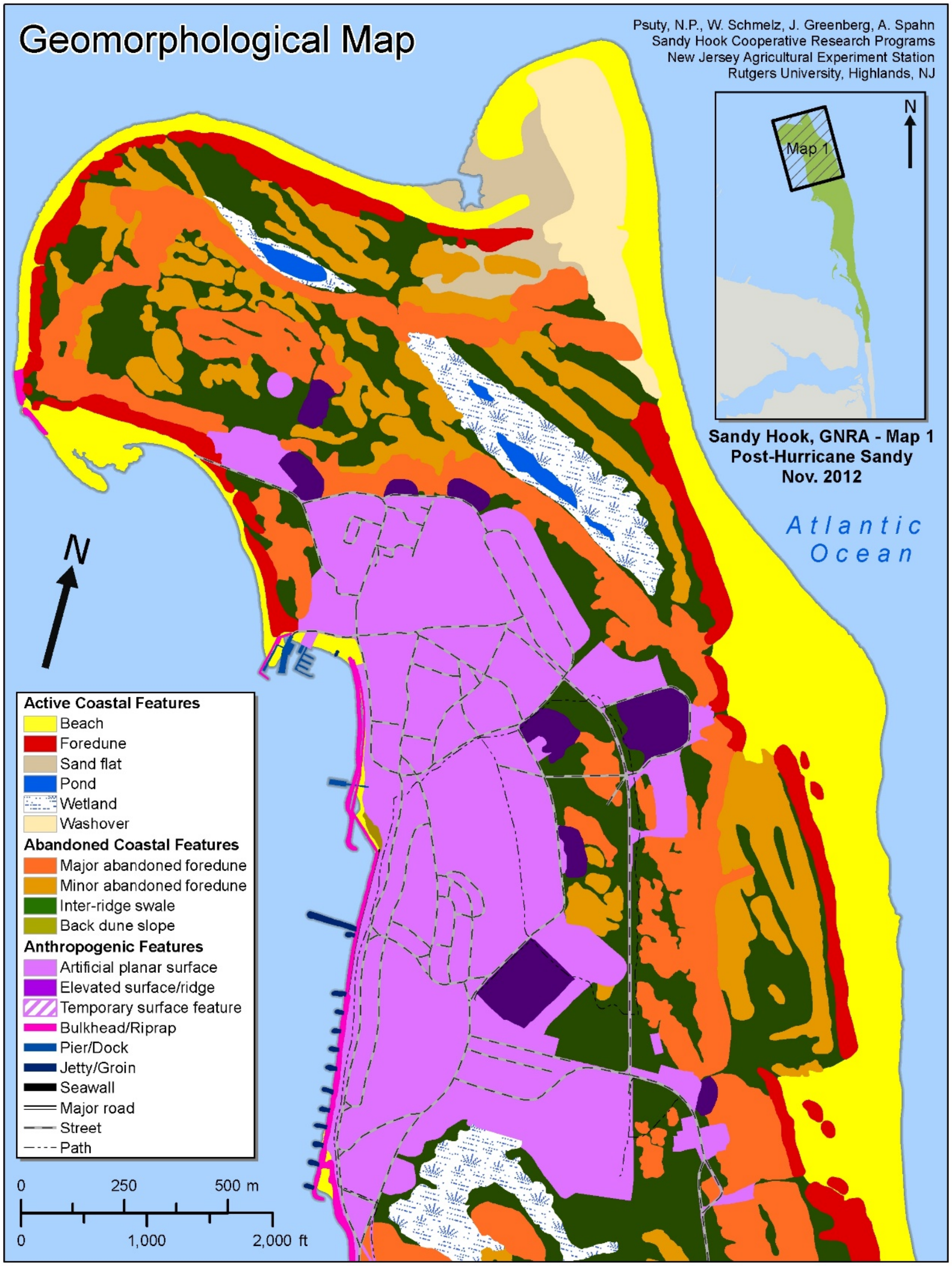
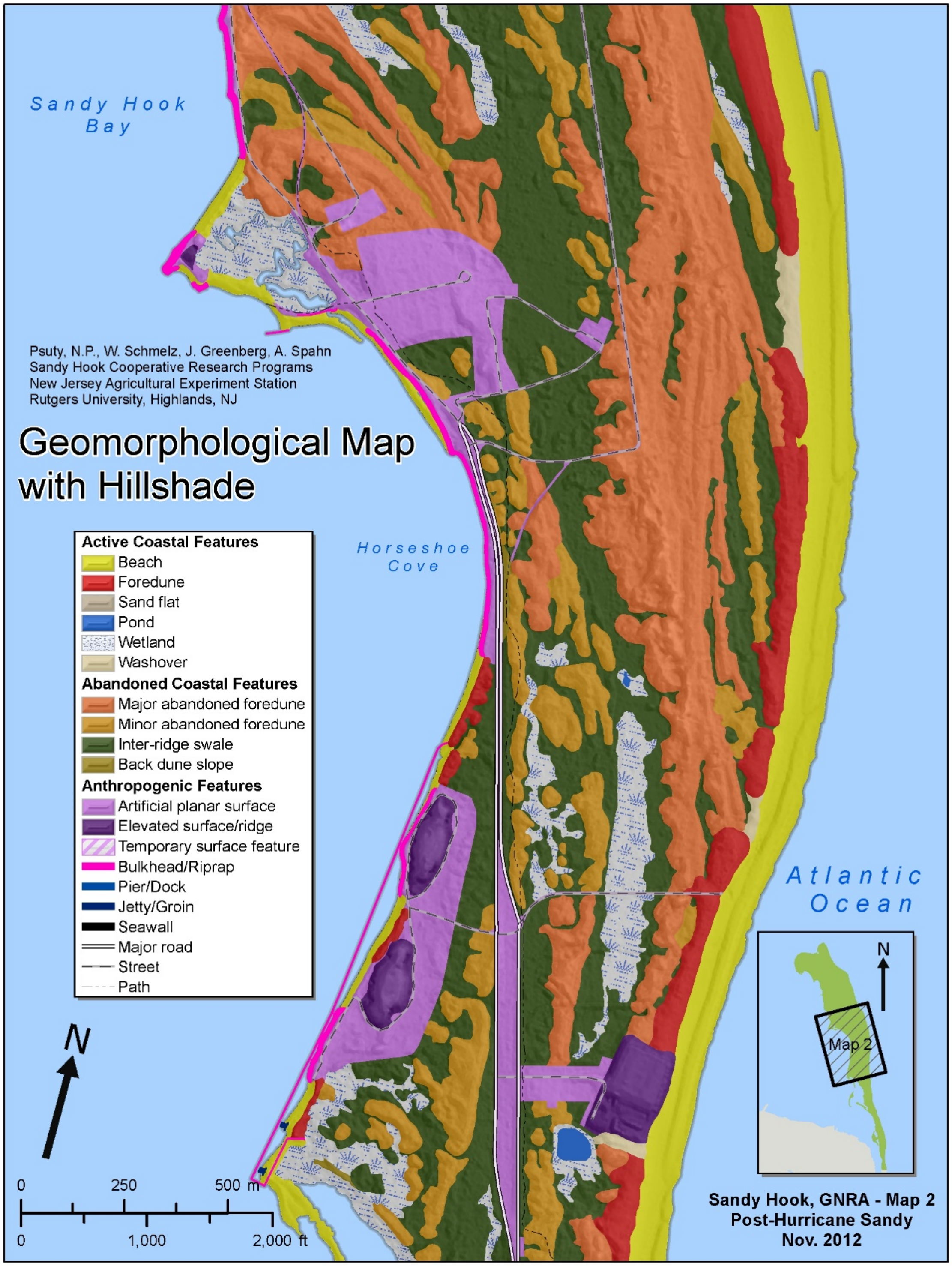
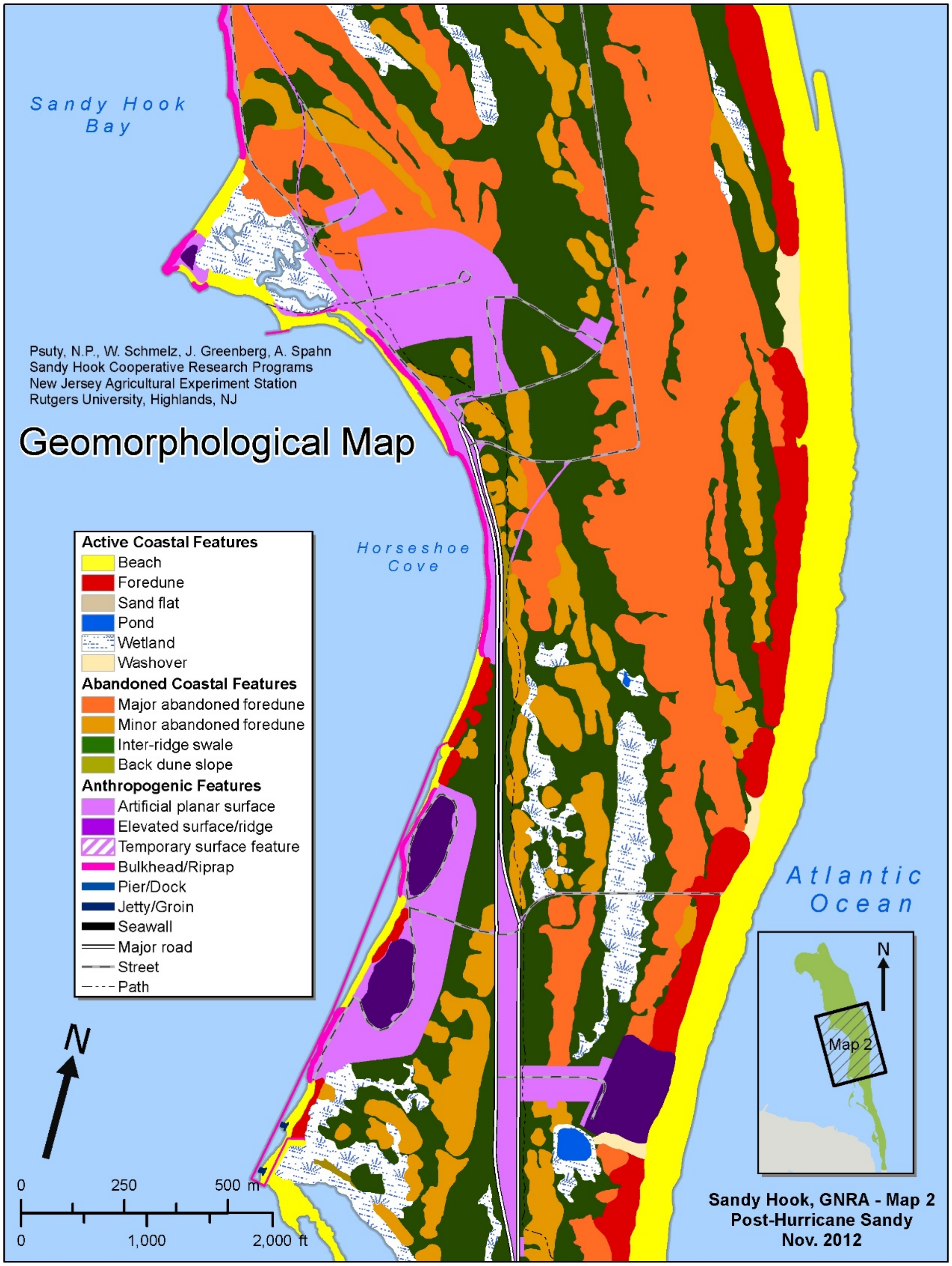
Sandy Hook Unit (SHU)

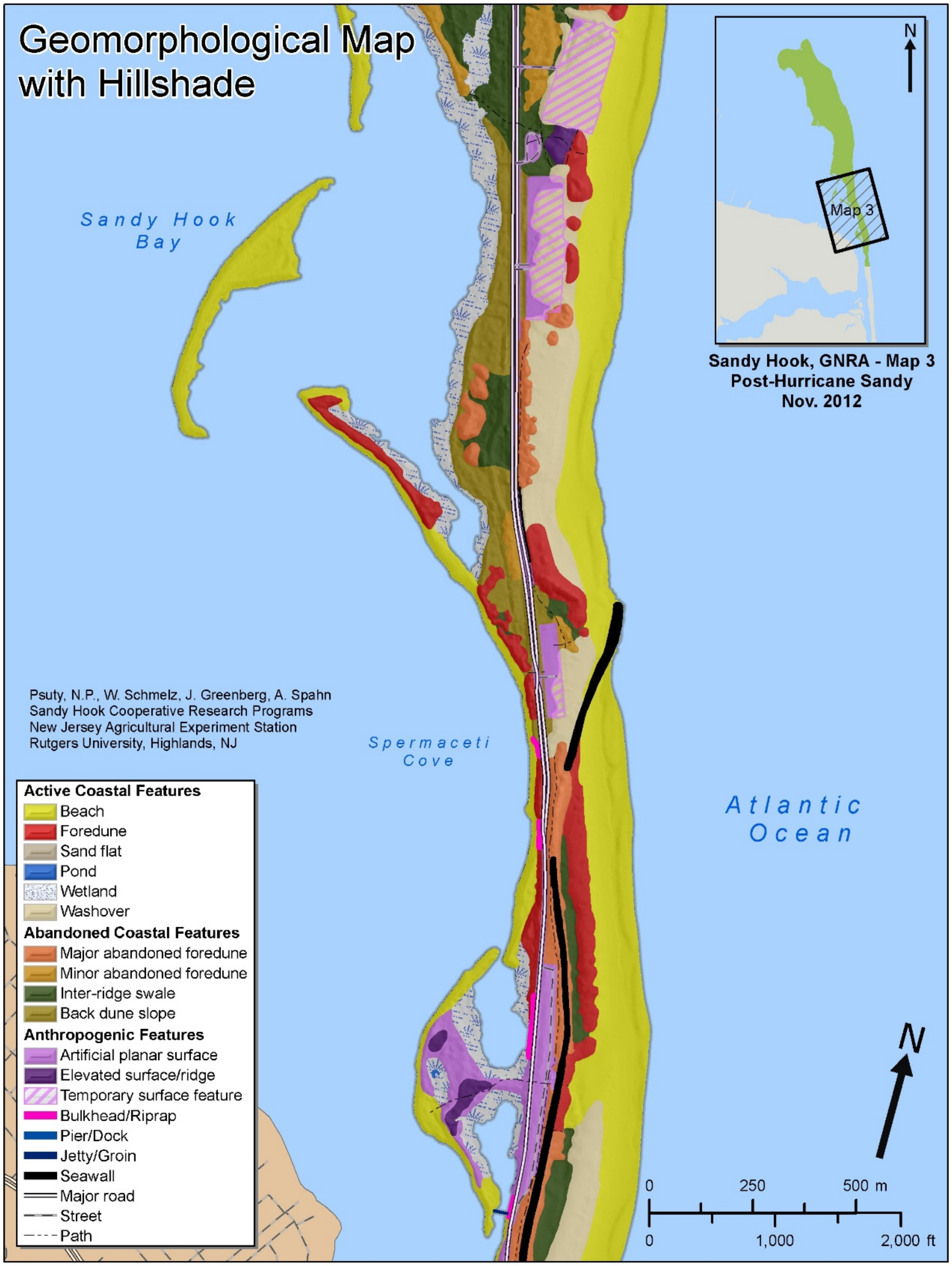

Geomorphological Map with Hillshade
Psuty, N.P., W. Schmelz, J. Greenberg, A. Spahn
Sandy Hook Cooperative Research Programs
New Jersey Agricultural Experiment Station
Rutgers University, Highlands, NJ
N
Map 1
Sandy Hook, GNRA - Map 1
Post-Hurricane Sandy
Nov. 2012
Atlantic Ocean
N
Active Coastal Features
Beach
Foredune
Sand flat
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Seawall
Major road
Street
Path
0 250 500 m
0 1,000 2,000 ft

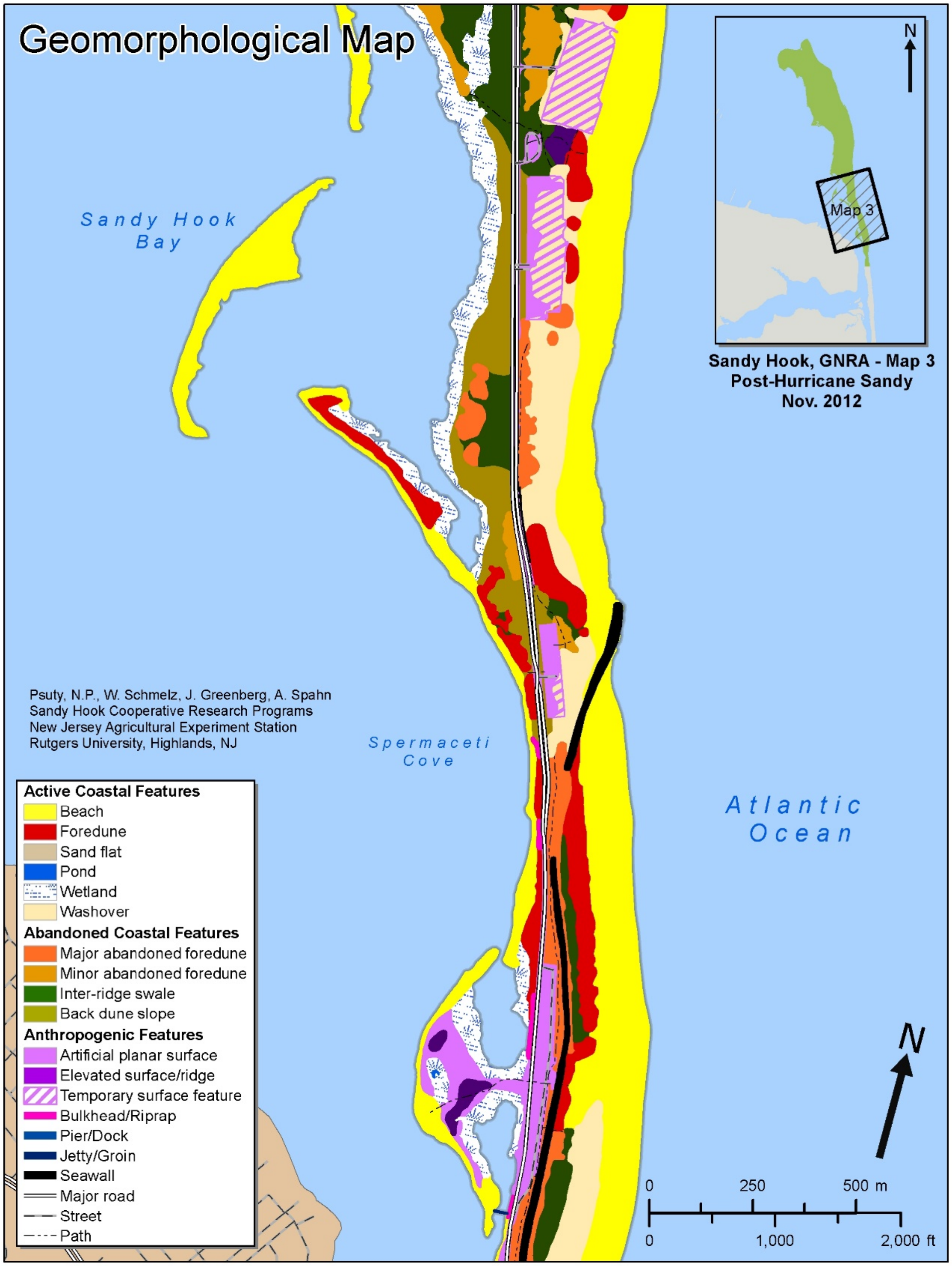


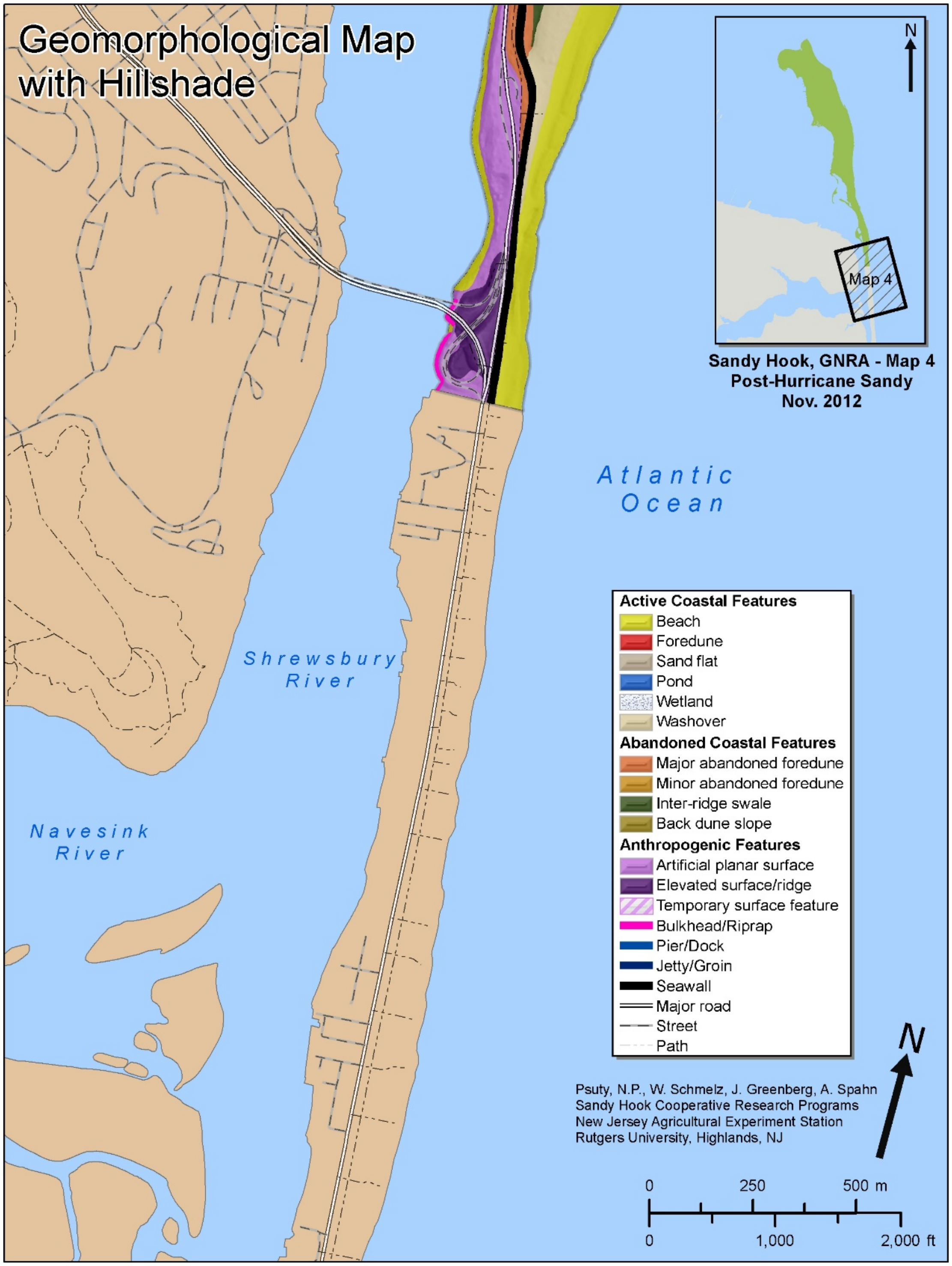
Geomorphological Map
Psuty, N.P., W. Schmelz, J. Greenberg, A. Spahn
Sandy Hook Cooperative Research Programs
New Jersey Agricultural Experiment Station
Rutgers University, Highlands, NJ
N
Map 1
Sandy Hook, GNRA - Map 1
Post-Hurricane Sandy
Nov. 2012
Atlantic
Ocean
N
Active Coastal Features
Beach
Foredune
Sand flat
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Seawall
Major road
Street
Path
0
250
500 m
0
1,000
2,000 ft

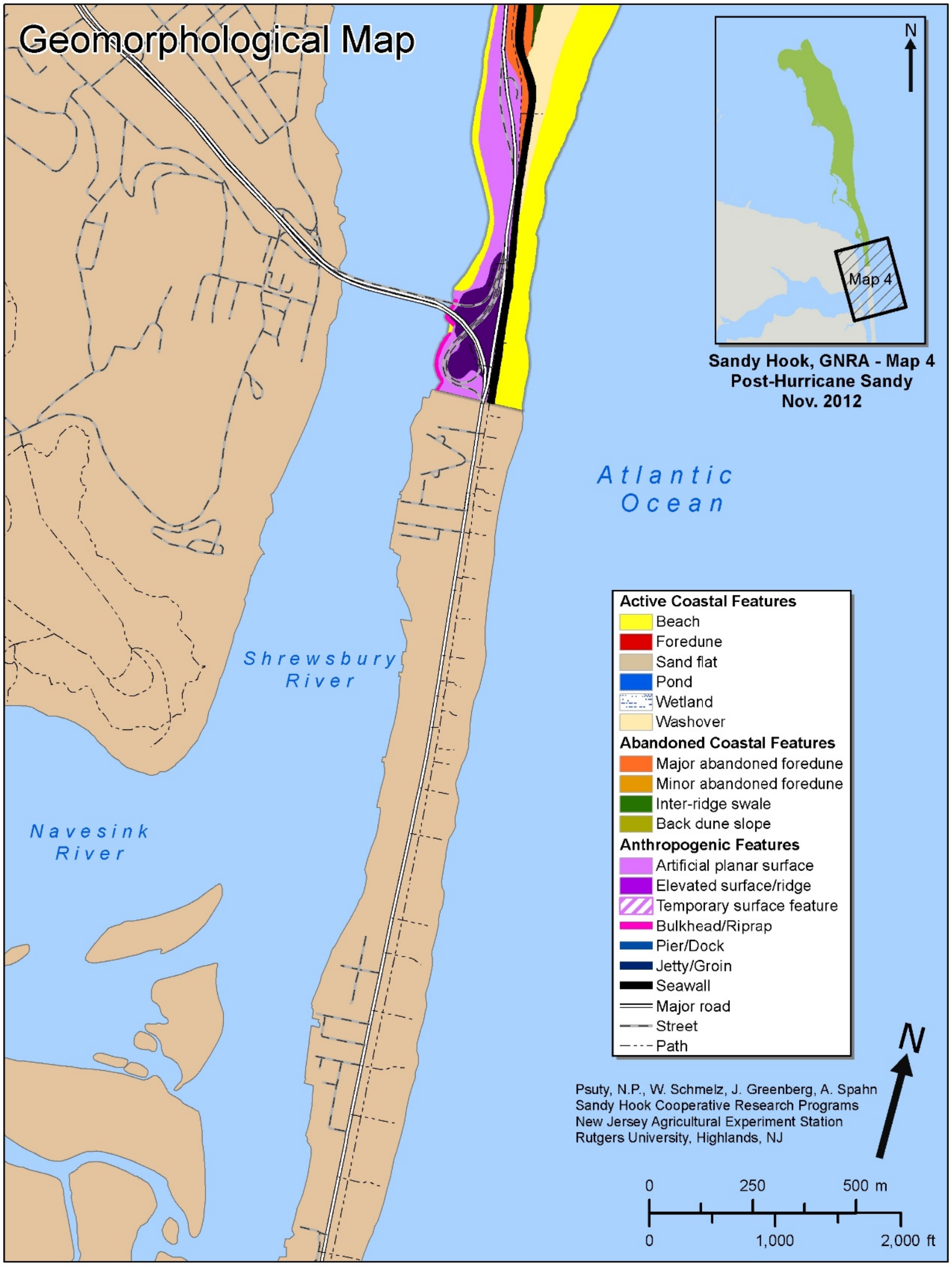

Sandy Hook
Bay
Psuty, N.P., W. Schmelz, J. Greenberg, A. Spahn
Sandy Hook Cooperative Research Programs
New Jersey Agricultural Experiment Station
Rutgers University, Highlands, NJ
Geomorphological Map
with Hillshade
Horseshoe
Cove
Active Coastal Features
Beach
Foredune
Sand flat
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Seawall
Major road
Street
Path
Atlantic
Ocean
N
Map 2
N
0
250
500 m
0
1,000
2,000 ft
Sandy Hook, GNRA - Map 2
Post-Hurricane Sandy
Nov. 2012


Sandy Hook
Bay
Psuty, N.P., W. Schmelz, J. Greenberg, A. Spahn
Sandy Hook Cooperative Research Programs
New Jersey Agricultural Experiment Station
Rutgers University, Highlands, NJ
Geomorphological Map
Horseshoe
Cove
Active Coastal Features
Beach
Foredune
Sand flat
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Seawall
Major road
Street
Path
N
0
250
500 m
0
1,000
2,000 ft
Atlantic
Ocean
N
Map 2
Sandy Hook, GNRA - Map 2
Post-Hurricane Sandy
Nov. 2012

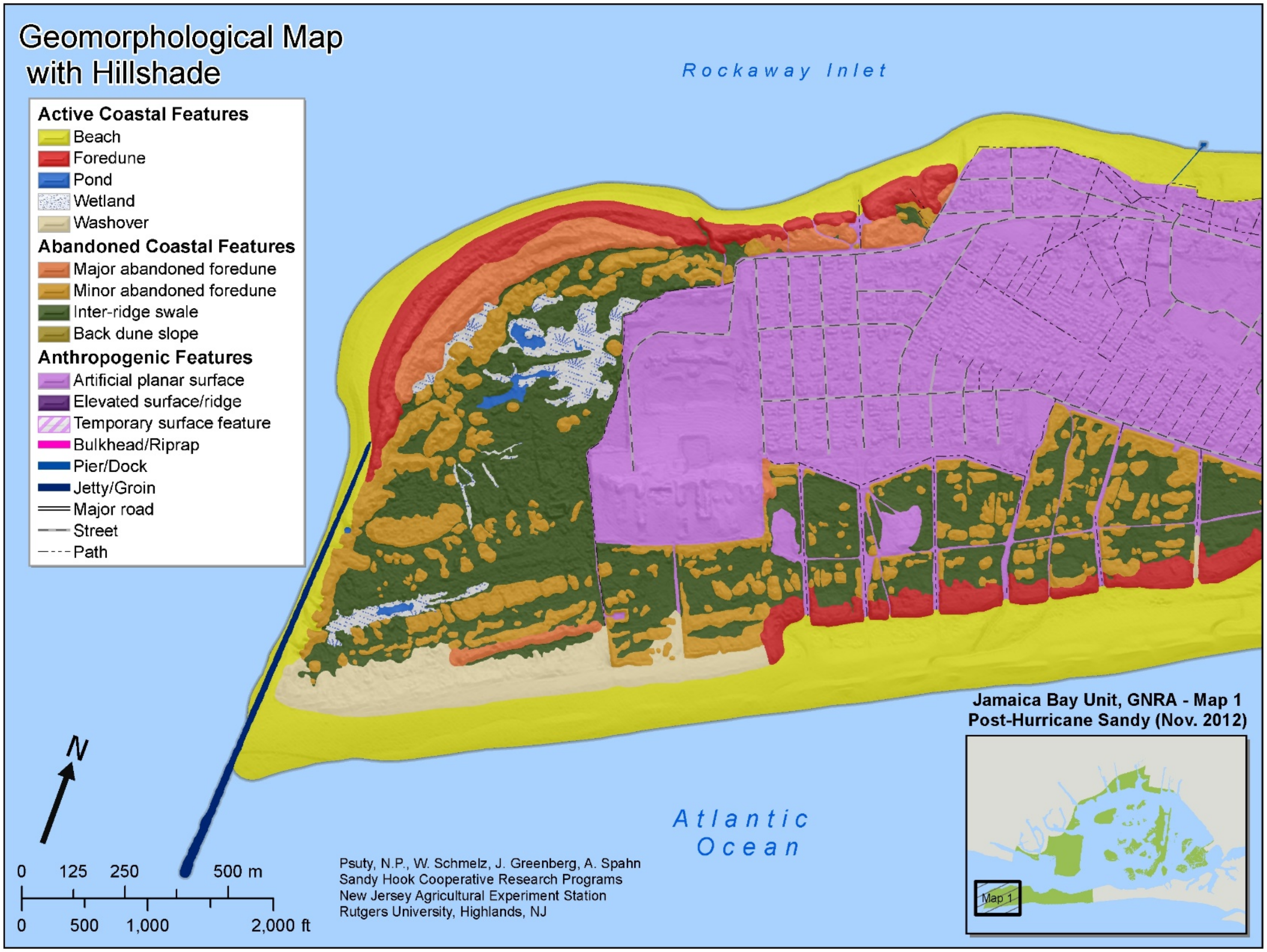

Geomorphological Map
with Hillshade
Sandy Hook
Bay
Spermaceti
Cove
Atlantic
Ocean
Psuty, N.P., W. Schmelz, J. Greenberg, A. Spahn
Sandy Hook Cooperative Research Programs
New Jersey Agricultural Experiment Station
Rutgers University, Highlands, NJ
Active Coastal Features
Beach
Foredune
Sand flat
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Seawall
Major road
Street
Path
Map 3
N
Sandy Hook, GNRA - Map 3
Post-Hurricane Sandy
Nov. 2012
N
0
250
500 m
0
1,000
2,000 ft

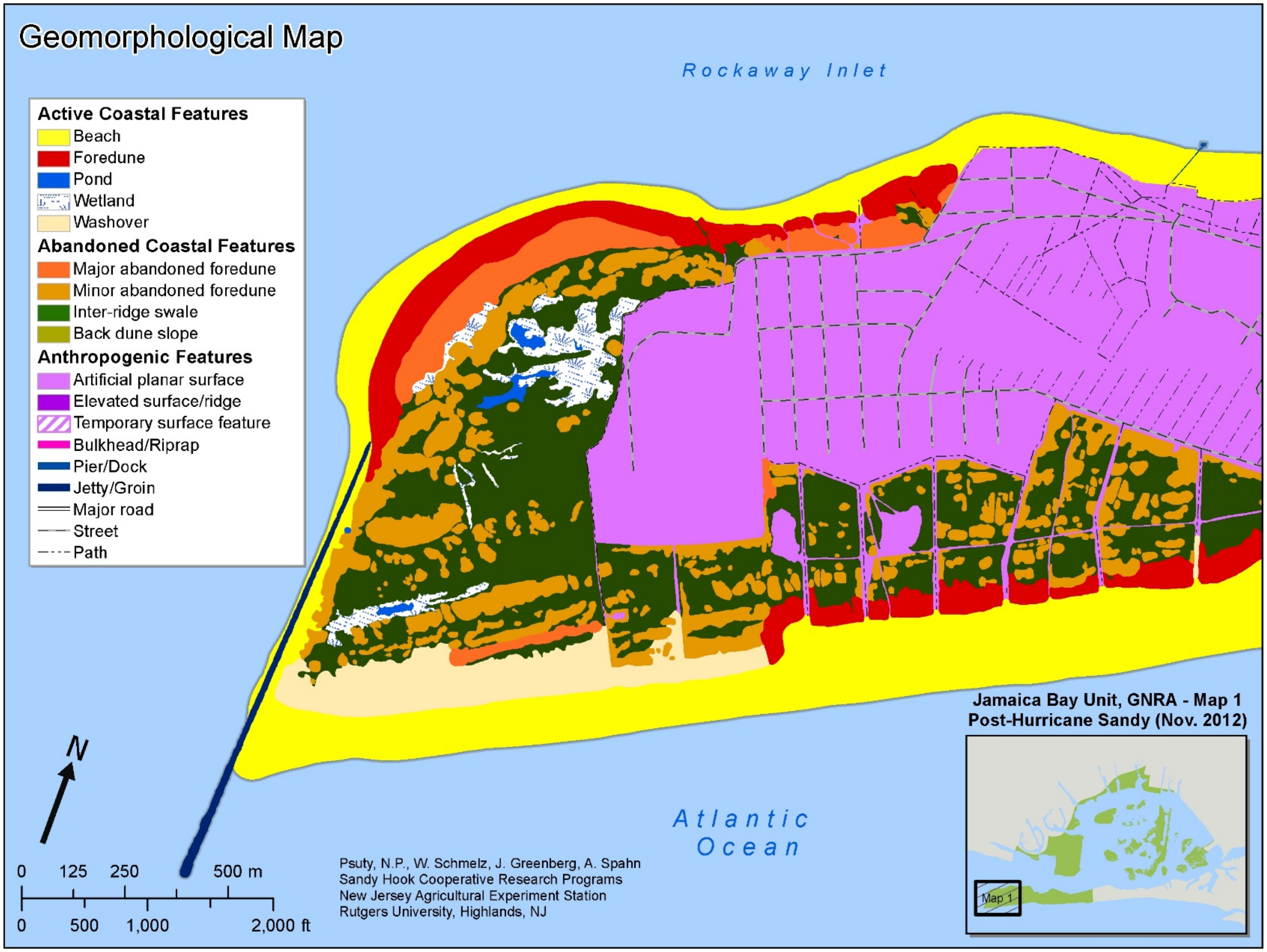

Geomorphological Map
Sandy Hook Bay
Spermaceti Cove
Atlantic Ocean
Sandy Hook, GNRA - Map 3
Post-Hurricane Sandy
Nov. 2012
Map 3
N
Psuty, N.P., W. Schmelz, J. Greenberg, A. Spahn
Sandy Hook Cooperative Research Programs
New Jersey Agricultural Experiment Station
Rutgers University, Highlands, NJ
Active Coastal Features
Beach
Foredune
Sand flat
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Seawall
Major road
Street
Path
0
250
500 m
0
1,000
2,000 ft

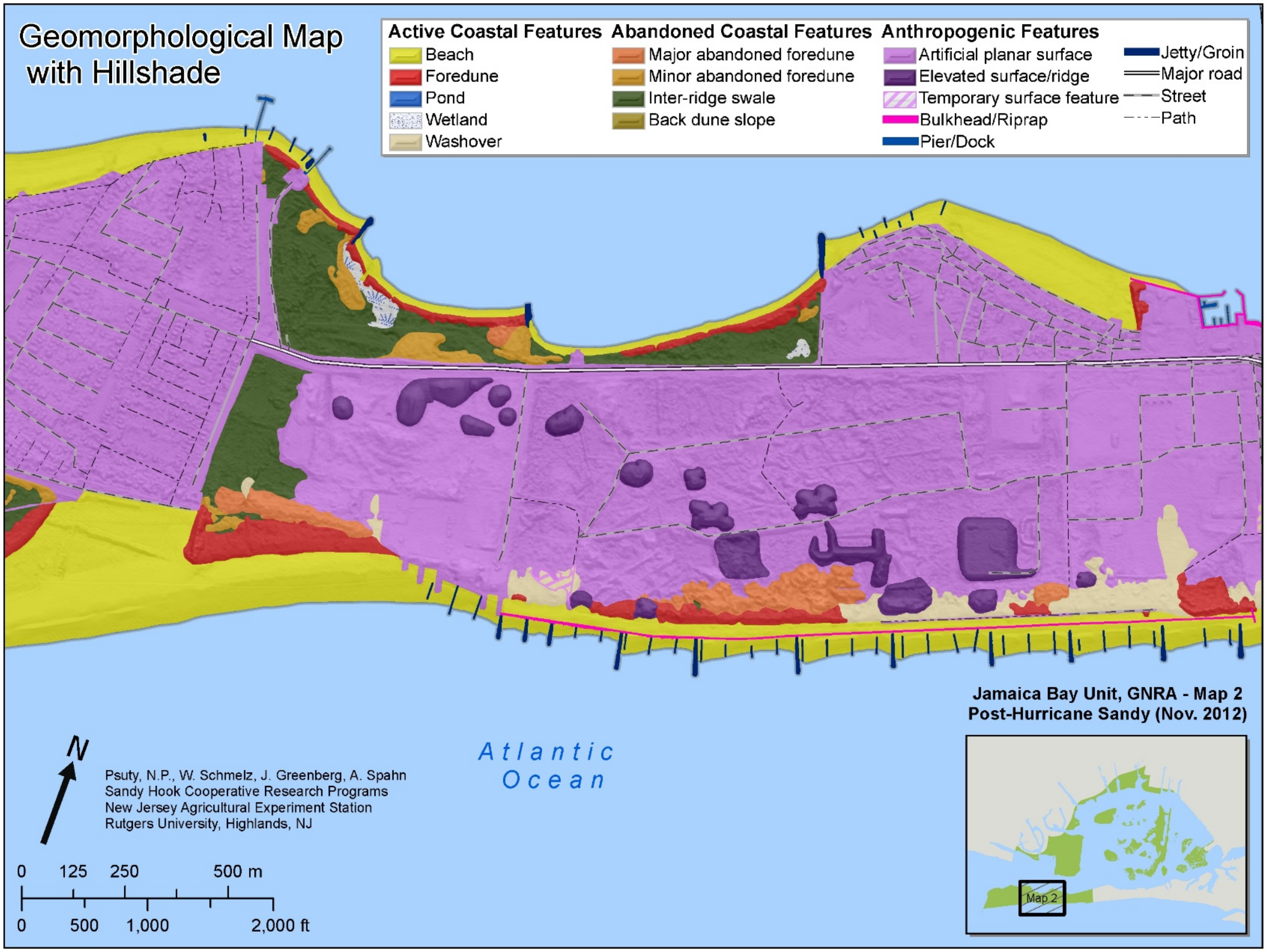

Geomorphological Map with Hillshade
Sandy Hook, GNRA - Map 4
Post-Hurricane Sandy
Nov. 2012
Map 4
N
Atlantic Ocean
Shrewsbury River
Navesink River
Active Coastal Features
Beach
Foredune
Sand flat
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Seawall
Major road
Street
Path
Psuty, N.P., W. Schmelz, J. Greenberg, A. Spahn
Sandy Hook Cooperative Research Programs
New Jersey Agricultural Experiment Station
Rutgers University, Highlands, NJ
N
0 250 500 m
0 1,000 2,000 ft

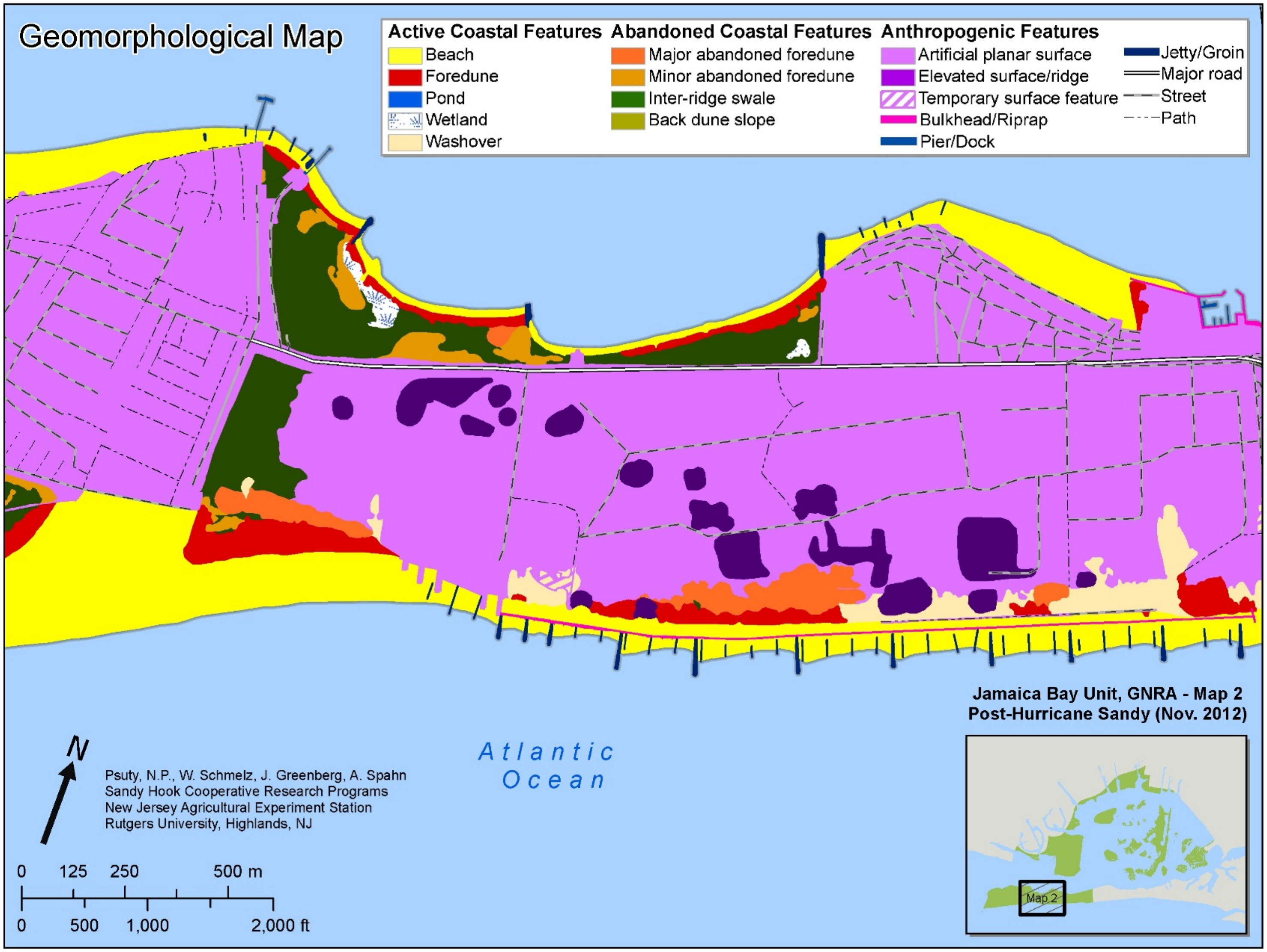

Geomorphological Map
Sandy Hook, GNRA - Map 4
Post-Hurricane Sandy
Nov. 2012
Map 4
N
Atlantic
Ocean
Shrewsbury
River
Navesink
River
Active Coastal Features
Beach
Foredune
Sand flat
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Seawall
Major road
Street
Path
Psuty, N.P., W. Schmelz, J. Greenberg, A. Spahn
Sandy Hook Cooperative Research Programs
New Jersey Agricultural Experiment Station
Rutgers University, Highlands, NJ
0 250 500 m
0 1,000 2,000 ft

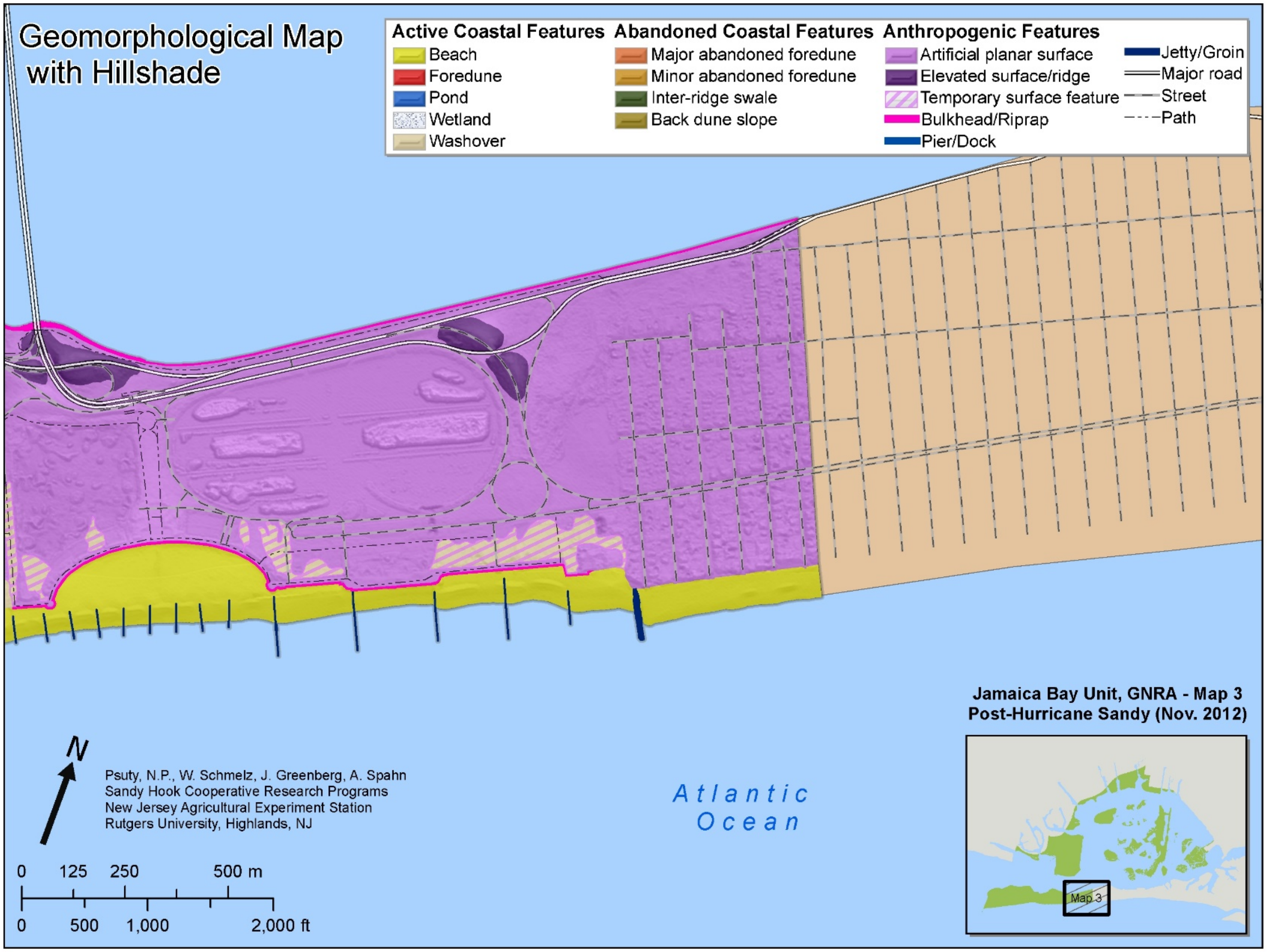
Jamaica Bay Unit (JBU)

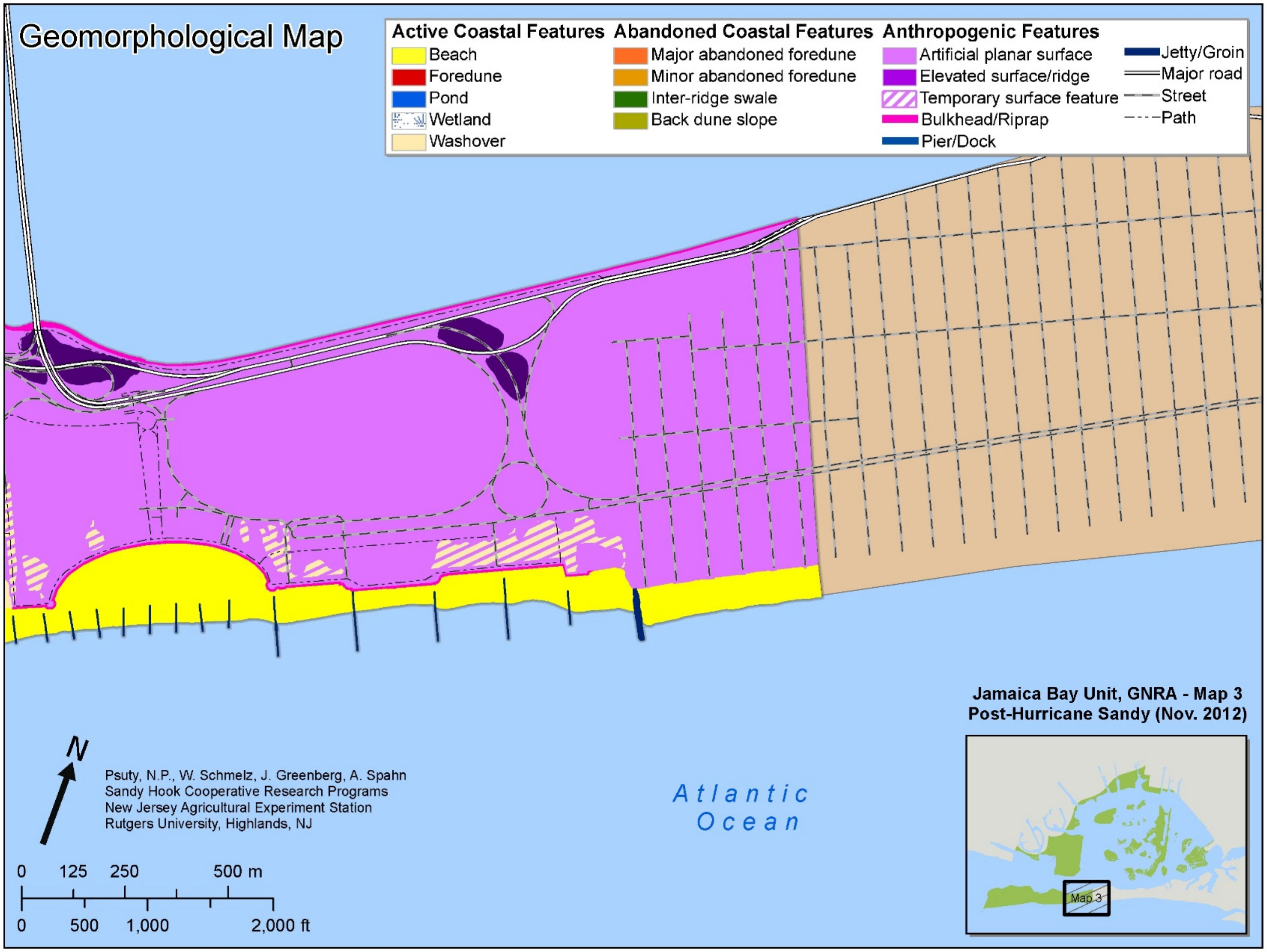

Geomorphological Map
with Hillshade
Rockaway Inlet
Active Coastal Features
Beach
Foredune
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Major road
Street
Path
N
0 125 250 500 m
0 500 1,000 2,000 ft
Psuty, N.P., W. Schmelz, J. Greenberg, A. Spahn
Sandy Hook Cooperative Research Programs
New Jersey Agricultural Experiment Station
Rutgers University, Highlands, NJ
Atlantic
Ocean
Jamaica Bay Unit, GNRA - Map 1
Post-Hurricane Sandy (Nov. 2012)
Map 1

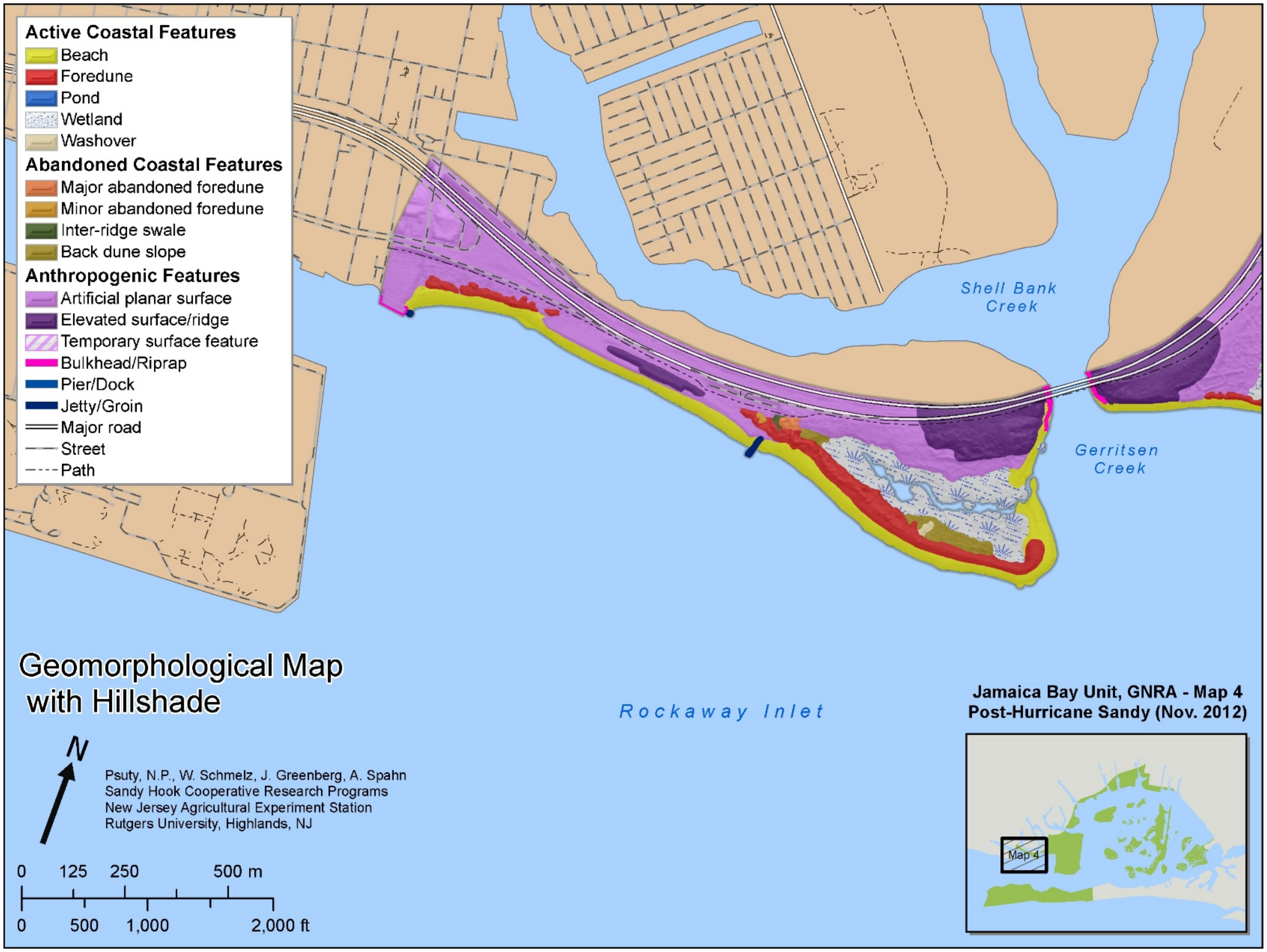

Geomorphological Map
Rockaway Inlet
Active Coastal Features
Beach
Foredune
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Major road
Street
Path
N
0 125 250 500 m
0 500 1,000 2,000 ft
Atlantic Ocean
Psuty, N.P., W. Schmelz, J. Greenberg, A. Spahn
Sandy Hook Cooperative Research Programs
New Jersey Agricultural Experiment Station
Rutgers University, Highlands, NJ
Jamaica Bay Unit, GNRA - Map 1
Post-Hurricane Sandy (Nov. 2012)
Map 1


Geomorphological Map with Hillshade
Active Coastal Features
Beach
Foredune
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Major road
Street
Path
Jamaica Bay Unit, GNRA - Map 2
Post-Hurricane Sandy (Nov. 2012)
Map 2
Atlantic Ocean
N
Psuty, N.P., W. Schmelz, J. Greenberg, A. Spahn
Sandy Hook Cooperative Research Programs
New Jersey Agricultural Experiment Station
Rutgers University, Highlands, NJ
0 125 250 500 m
0 500 1,000 2,000 ft

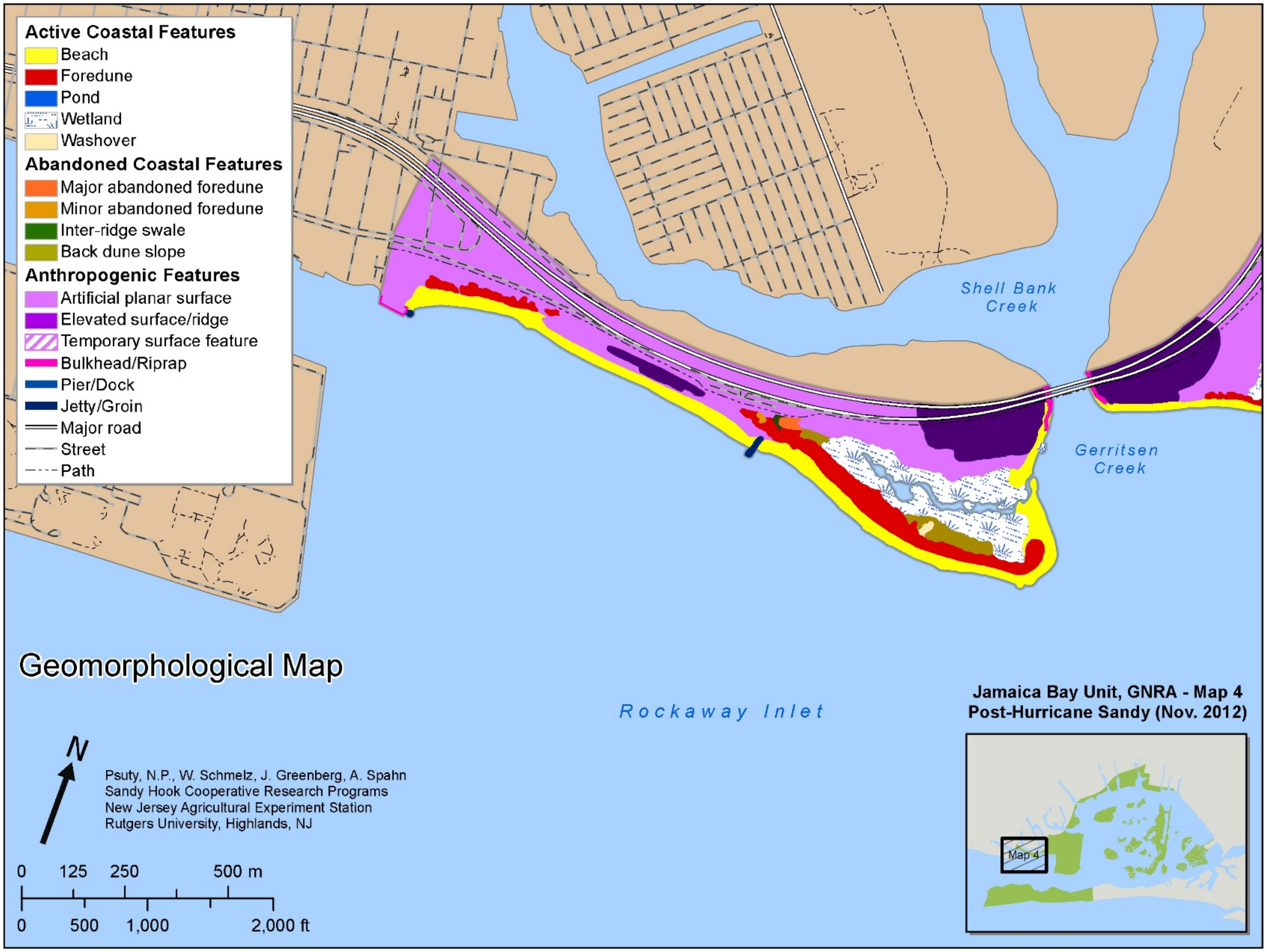

Geomorphological Map
Active Coastal Features
Beach
Foredune
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Major road
Street
Path
Atlantic Ocean
Jamaica Bay Unit, GNRA - Map 2
Post-Hurricane Sandy (Nov. 2012)
Map 2
N
Psuty, N.P., W. Schmelz, J. Greenberg, A. Spahn
Sandy Hook Cooperative Research Programs
New Jersey Agricultural Experiment Station
Rutgers University, Highlands, NJ
0 125 250 500 m
0 500 1,000 2,000 ft

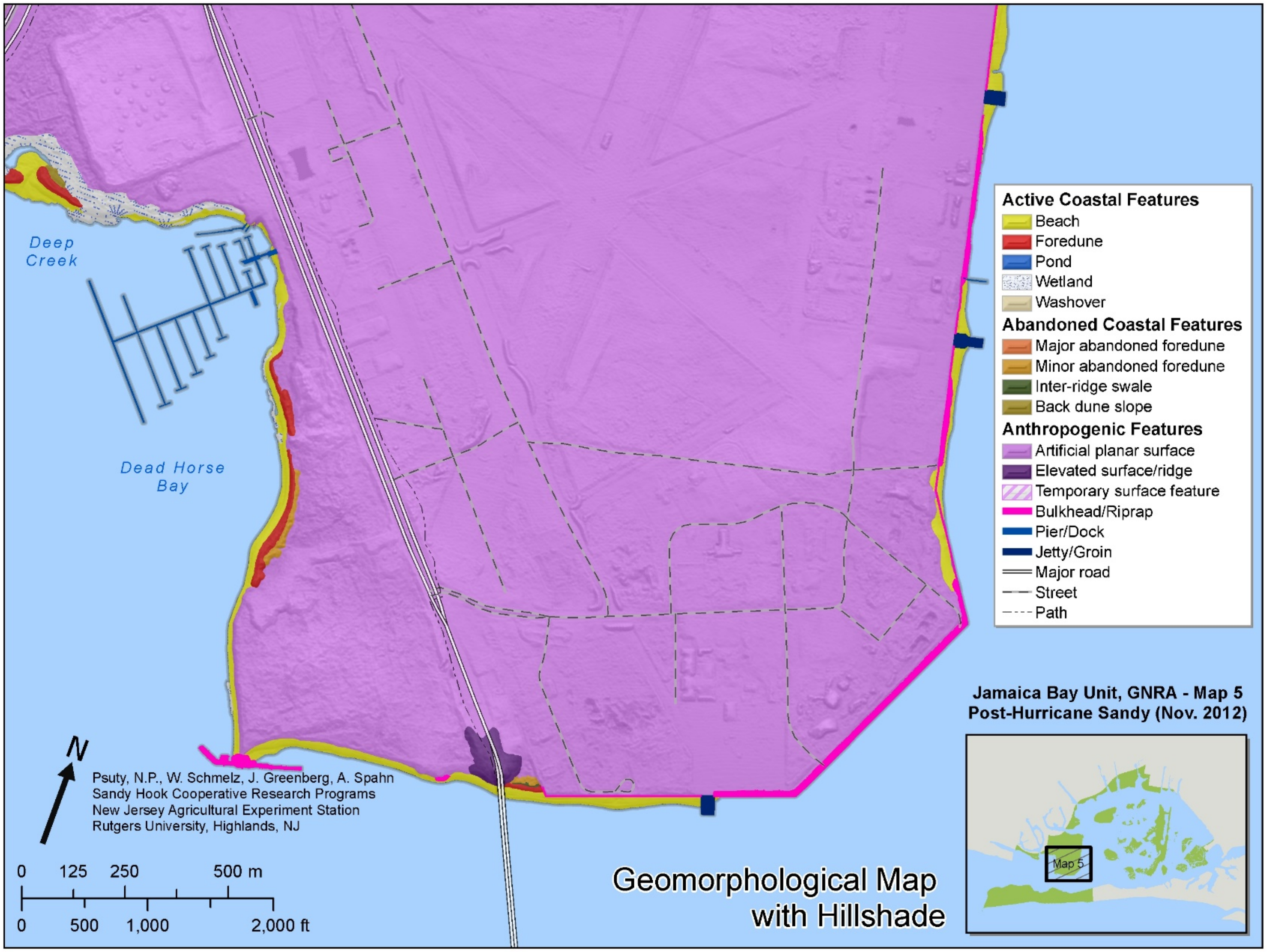

Geomorphological Map
with Hillshade
Active Coastal Features
Beach
Foredune
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Major road
Street
Path
Jamaica Bay Unit, GNRA - Map 3
Post-Hurricane Sandy (Nov. 2012)
Map 3
N
Psuty, N.P., W. Schmelz, J. Greenberg, A. Spahn
Sandy Hook Cooperative Research Programs
New Jersey Agricultural Experiment Station
Rutgers University, Highlands, NJ
Atlantic
Ocean
0 125 250 500 m
0 500 1,000 2,000 ft

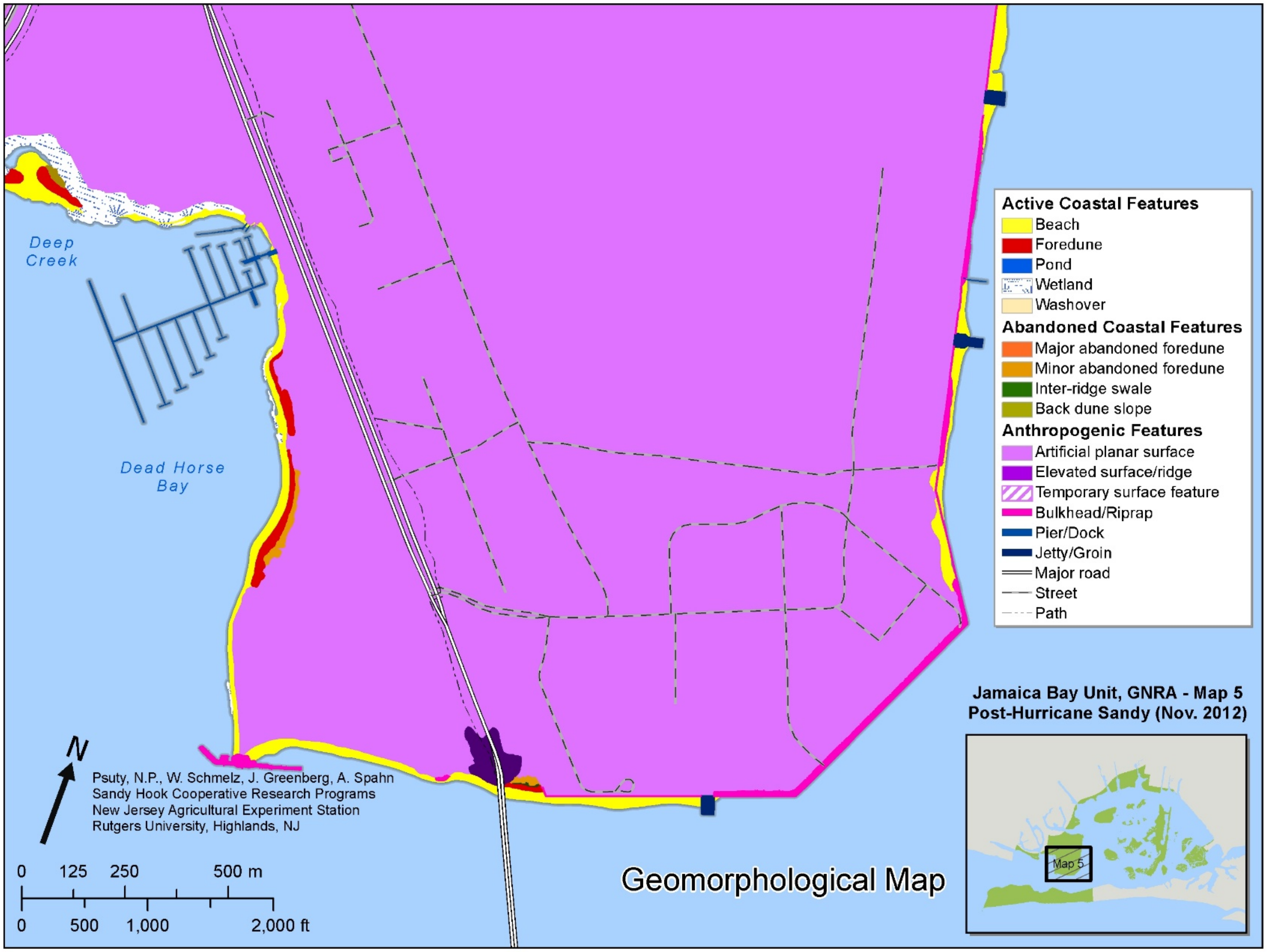

Geomorphological Map
Active Coastal Features
Beach
Foredune
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Major road
Street
Path
Jamaica Bay Unit, GNRA - Map 3
Post-Hurricane Sandy (Nov. 2012)
Map 3
Atlantic Ocean
N
Psuty, N.P., W. Schmelz, J. Greenberg, A. Spahn
Sandy Hook Cooperative Research Programs
New Jersey Agricultural Experiment Station
Rutgers University, Highlands, NJ
0 125 250 500 m
0 500 1,000 2,000 ft

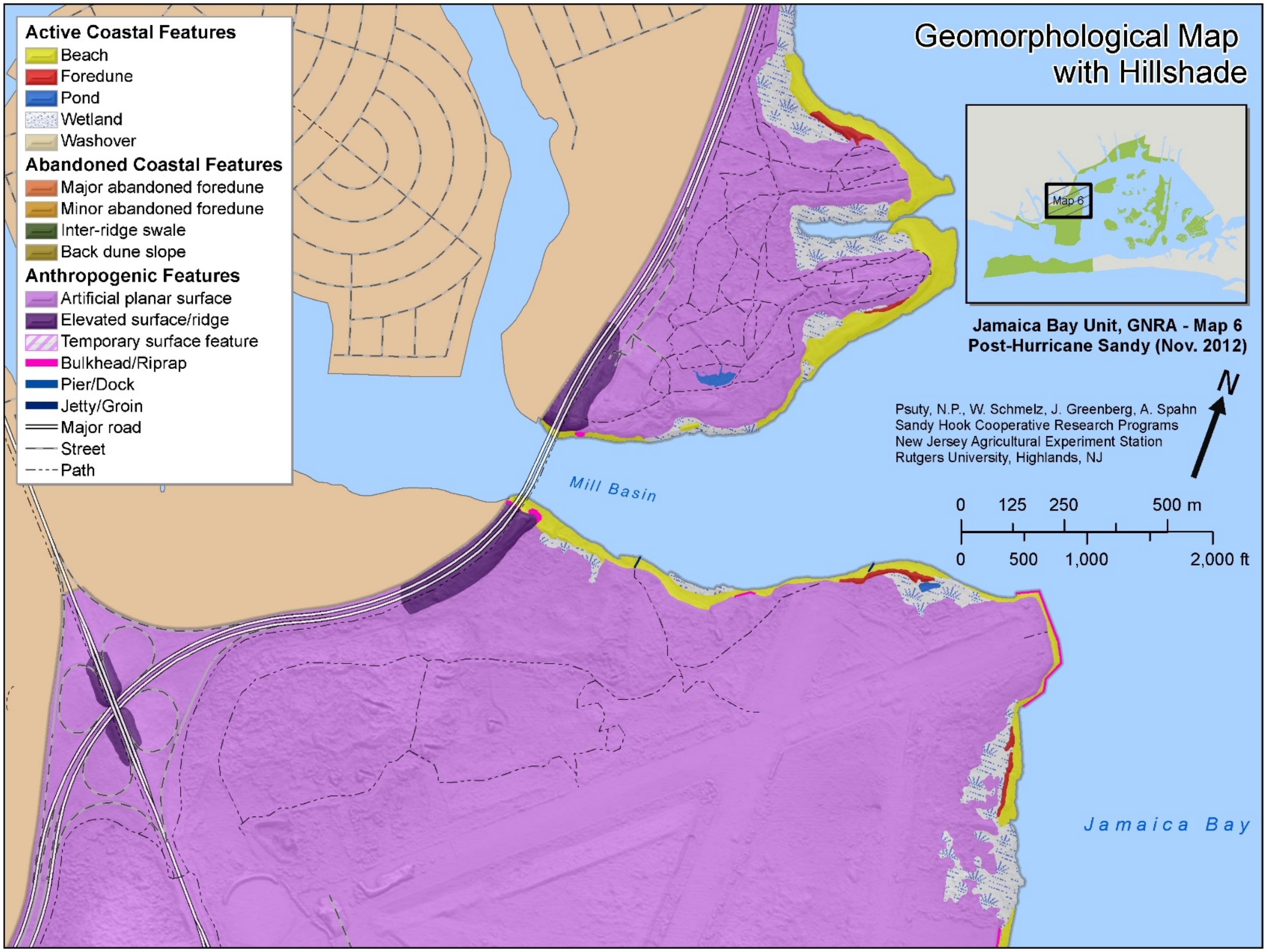


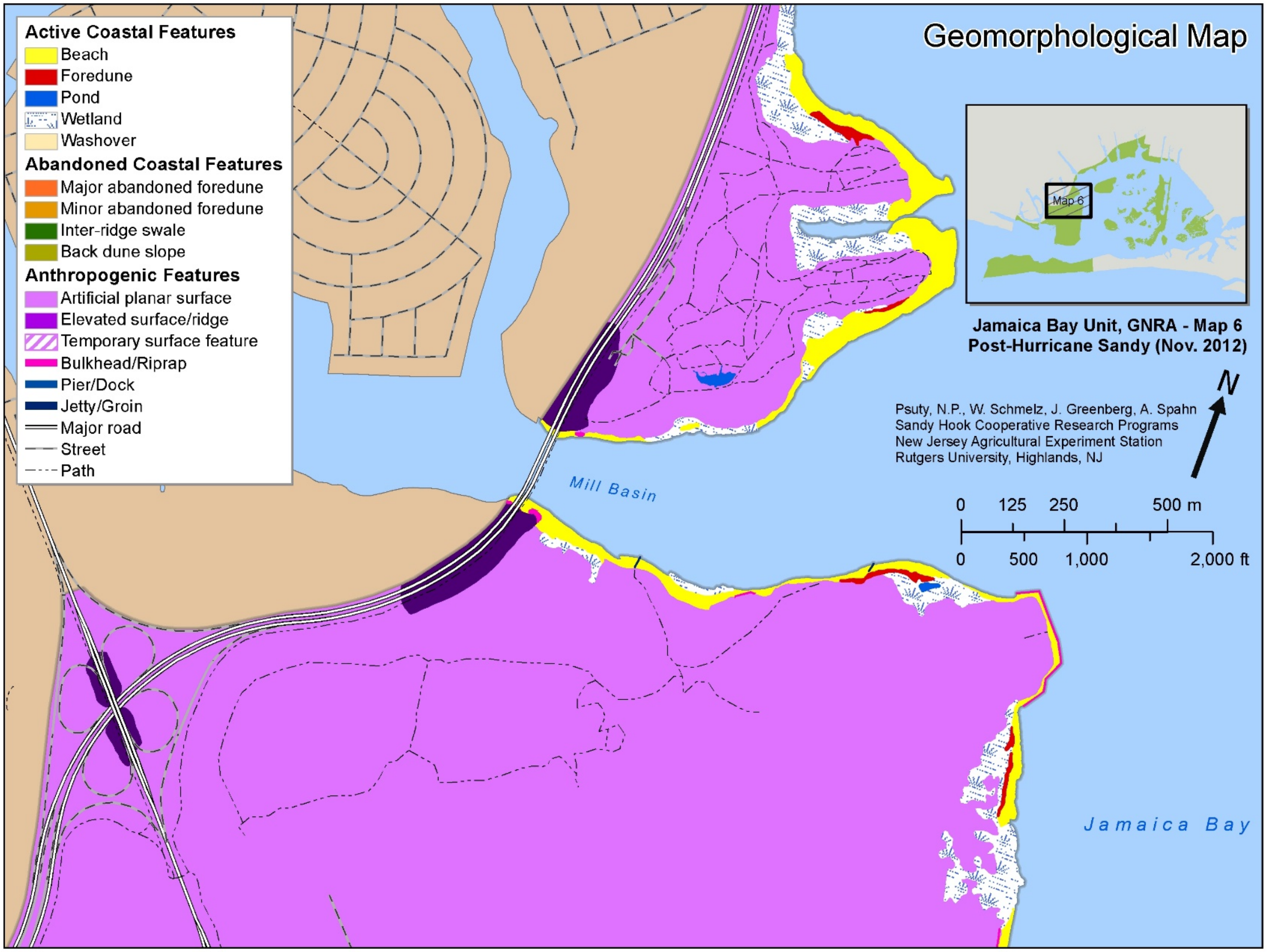
Active Coastal Features
Beach
Foredune
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Major road
Street
Path
Shell Bank Creek
Gerritsen Creek
Rockaway Inlet
Geomorphological Map with Hillshade
Jamaica Bay Unit, GNRA - Map 4
Post-Hurricane Sandy (Nov. 2012)
N
Psuty, N.P., W. Schmelz, J. Greenberg, A. Spahn
Sandy Hook Cooperative Research Programs
New Jersey Agricultural Experiment Station
Rutgers University, Highlands, NJ
0 125 250 500 m
0 500 1,000 2,000 ft
Map 4

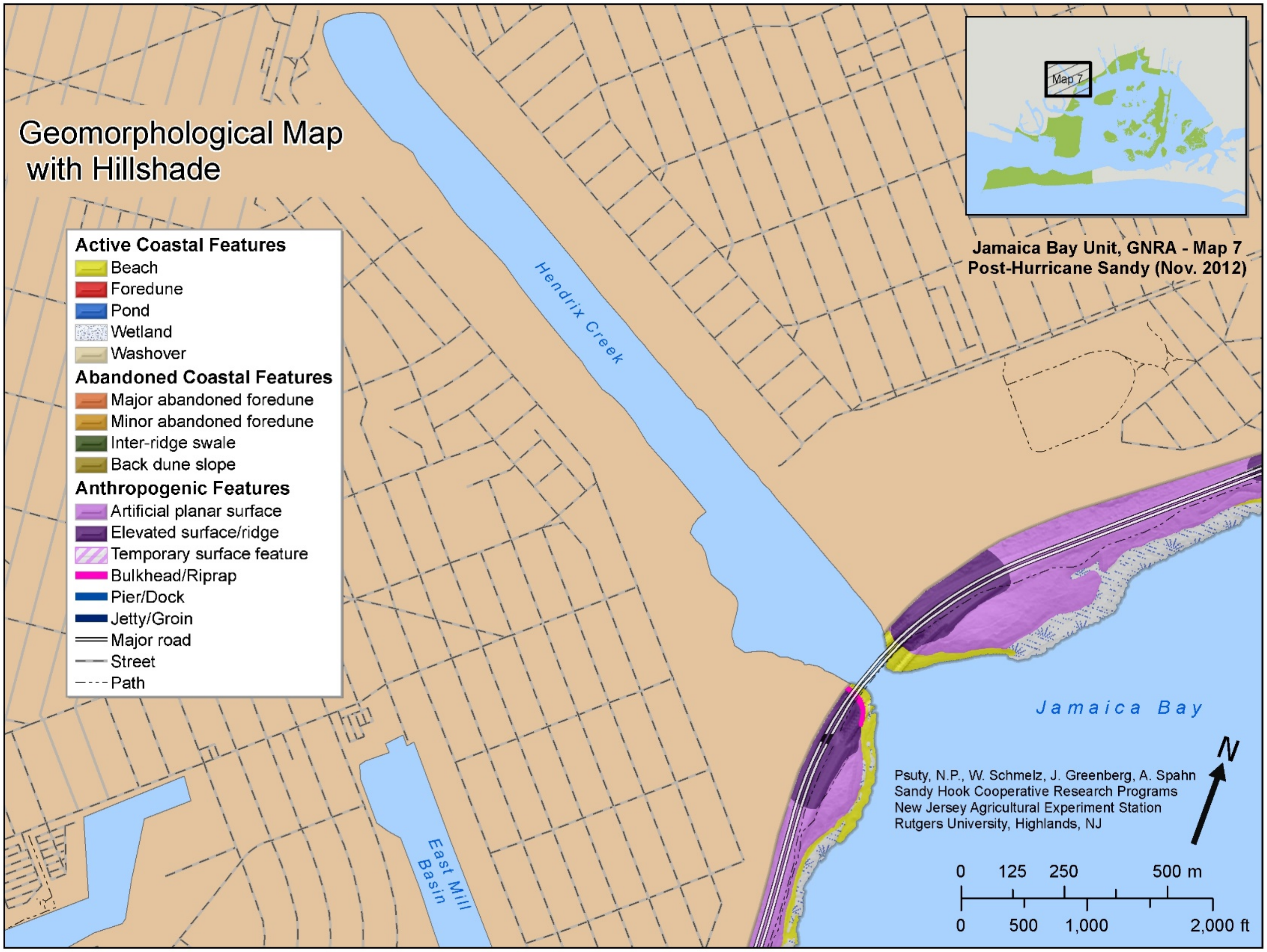

Active Coastal Features
Beach
Foredune
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Major road
Street
Path
Shell Bank Creek
Gerritsen Creek
Geomorphological Map
Rockaway Inlet
Jamaica Bay Unit, GNRA - Map 4
Post-Hurricane Sandy (Nov. 2012)
N
Psuty, N.P., W. Schmelz, J. Greenberg, A. Spahn
Sandy Hook Cooperative Research Programs
New Jersey Agricultural Experiment Station
Rutgers University, Highlands, NJ
0 125 250 500 m
0 500 1,000 2,000 ft
Map 4


Deep Creek
Dead Horse Bay
Active Coastal Features
Beach
Foredune
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Major road
Street
Path
Jamaica Bay Unit, GNRA - Map 5
Post-Hurricane Sandy (Nov. 2012)
Map 5
N
Psuty, N.P., W. Schmelz, J. Greenberg, A. Spahn
Sandy Hook Cooperative Research Programs
New Jersey Agricultural Experiment Station
Rutgers University, Highlands, NJ
0 125 250 500 m
0 500 1,000 2,000 ft
Geomorphological Map
with Hillshade

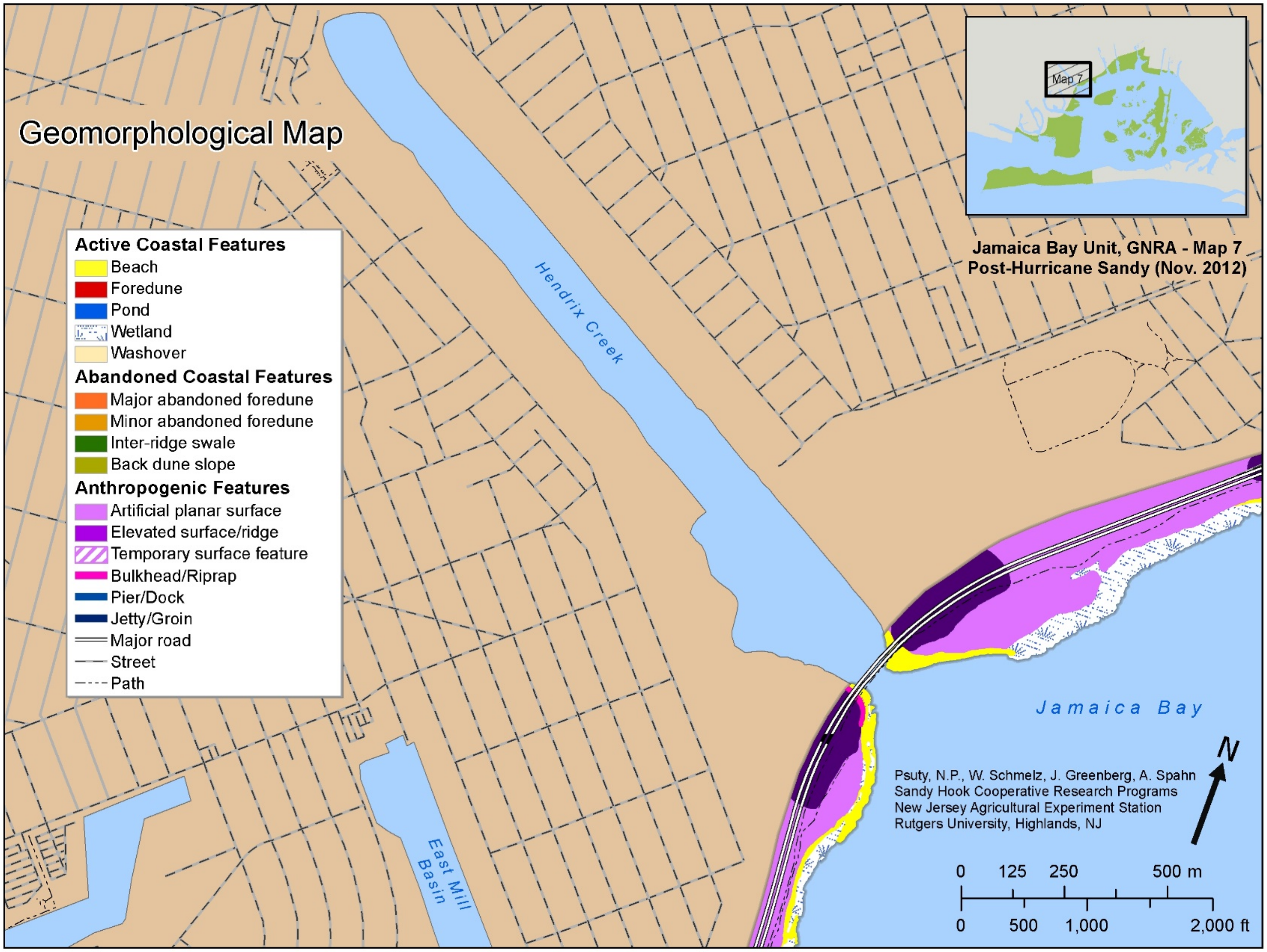

Active Coastal Features
Beach
Foredune
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Major road
Street
Path
Deep Creek
Dead Horse Bay
N
Psuty, N.P., W. Schmelz, J. Greenberg, A. Spahn
Sandy Hook Cooperative Research Programs
New Jersey Agricultural Experiment Station
Rutgers University, Highlands, NJ
0 125 250 500 m
0 500 1,000 2,000 ft
Geomorphological Map
Jamaica Bay Unit, GNRA - Map 5
Post-Hurricane Sandy (Nov. 2012)
Map 5


Active Coastal Features
Beach
Foredune
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Major road
Street
Path
Geomorphological Map
with Hillshade
Map 6
Jamaica Bay Unit, GNRA - Map 6
Post-Hurricane Sandy (Nov. 2012)
N
Psuty, N.P., W. Schmelz, J. Greenberg, A. Spahn
Sandy Hook Cooperative Research Programs
New Jersey Agricultural Experiment Station
Rutgers University, Highlands, NJ
0 125 250 500 m
0 500 1,000 2,000 ft
Mill Basin
Jamaica Bay

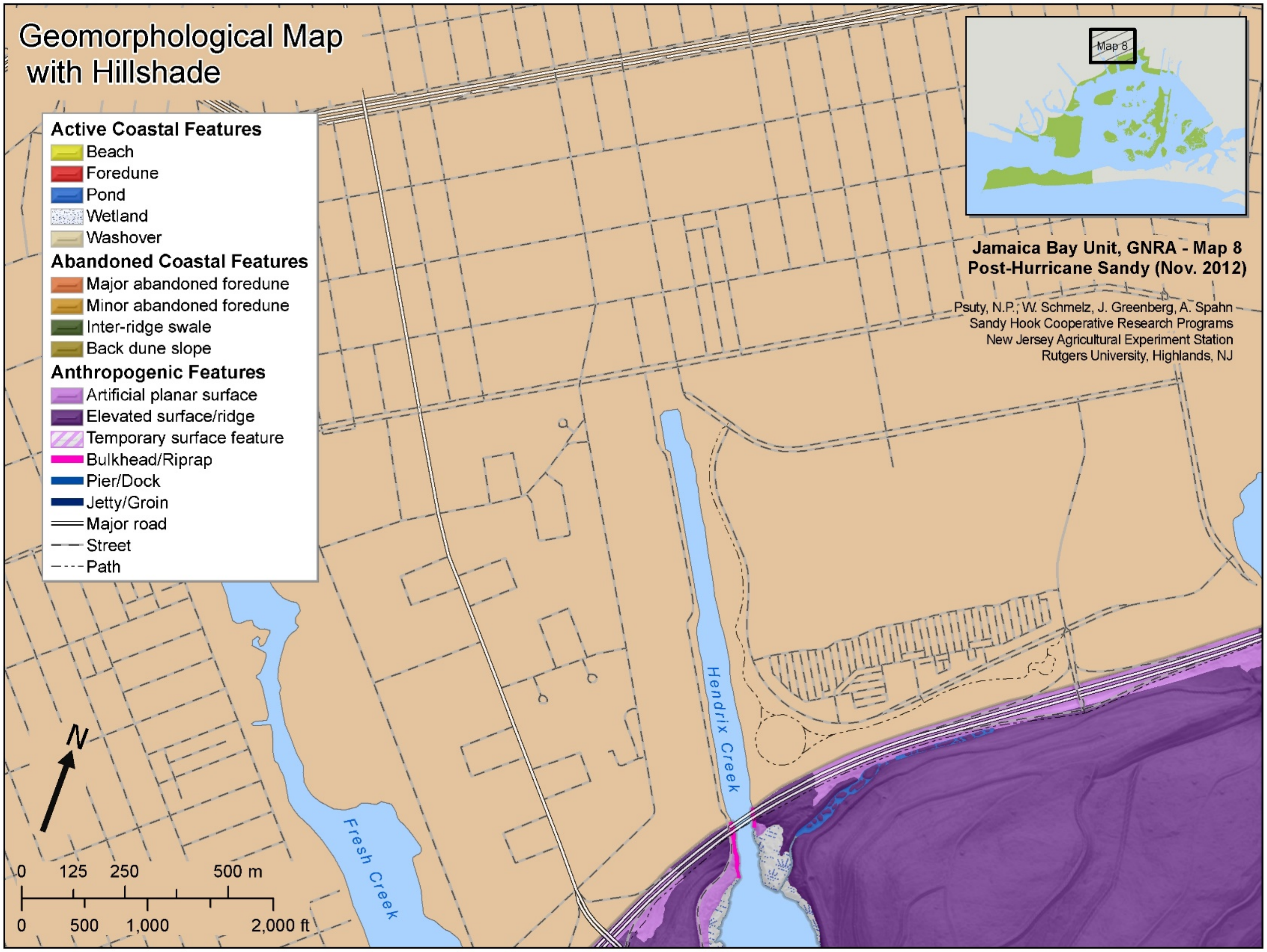

Geomorphological Map
Active Coastal Features
Beach
Foredune
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Major road
Street
Path
Map 6
Jamaica Bay Unit, GNRA - Map 6
Post-Hurricane Sandy (Nov. 2012)
N
Psuty, N.P., W. Schmelz, J. Greenberg, A. Spahn
Sandy Hook Cooperative Research Programs
New Jersey Agricultural Experiment Station
Rutgers University, Highlands, NJ
Mill Basin
0 125 250 500 m
0 500 1,000 2,000 ft
Jamaica Bay

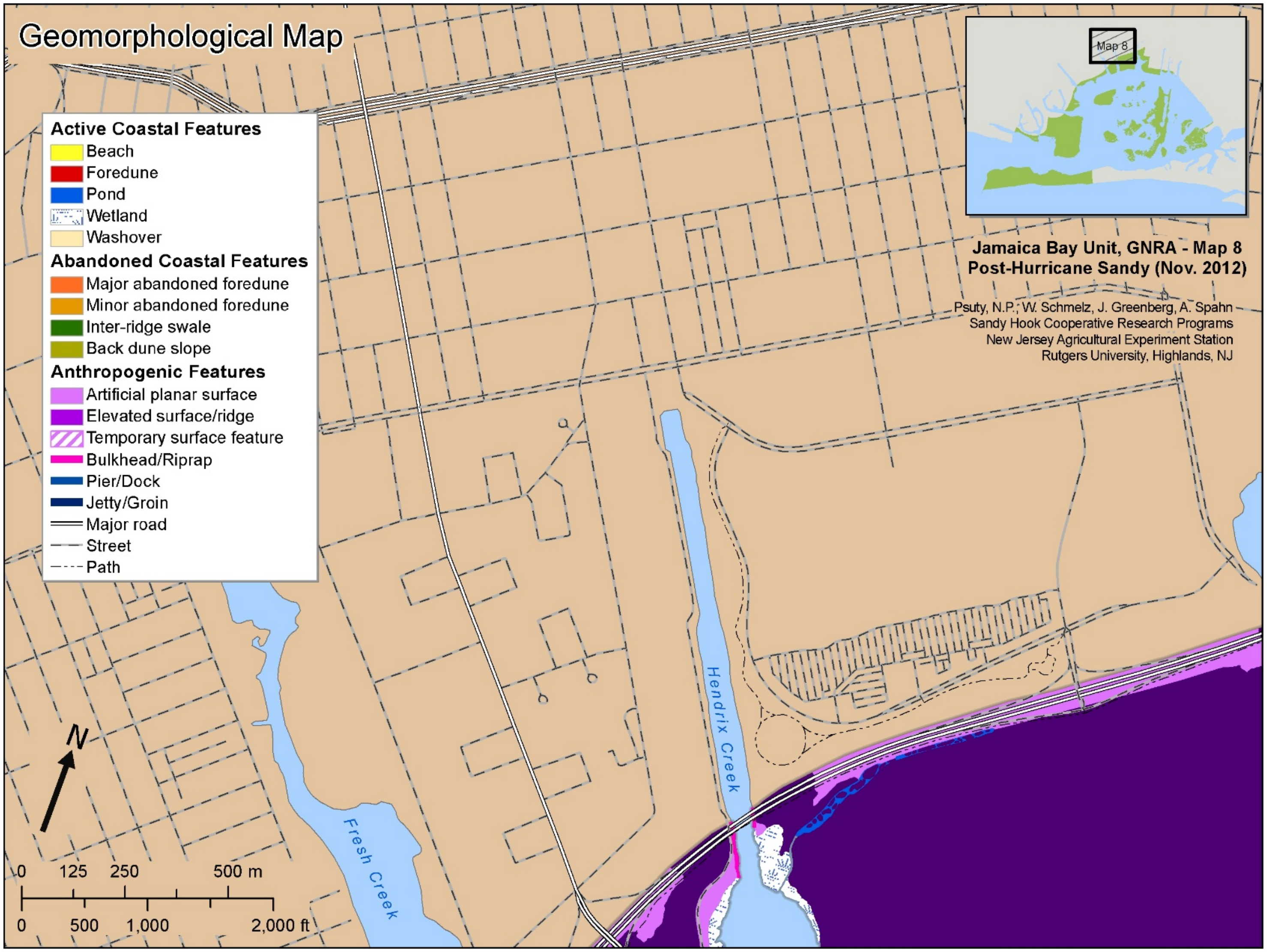


Geomorphological Map
with Hillshade
Active Coastal Features
Beach
Foredune
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Major road
Street
Path
Hendrix Creek
East Mill Basin
Map 7
Jamaica Bay Unit, GNRA - Map 7
Post-Hurricane Sandy (Nov. 2012)
Jamaica Bay
N
Psuty, N.P., W. Schmelz, J. Greenberg, A. Spahn
Sandy Hook Cooperative Research Programs
New Jersey Agricultural Experiment Station
Rutgers University, Highlands, NJ
0 125 250 500 m
0 500 1,000 2,000 ft

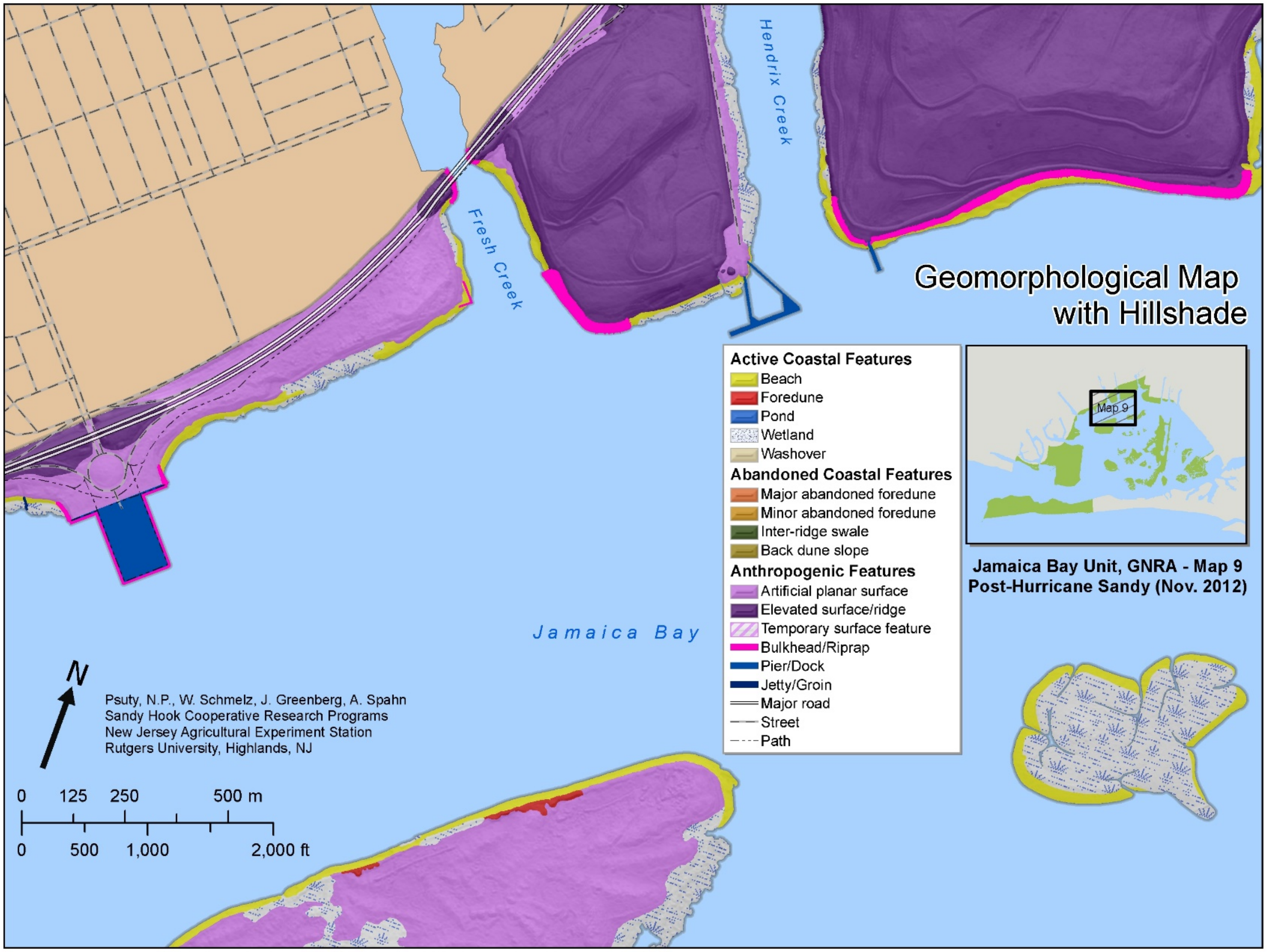


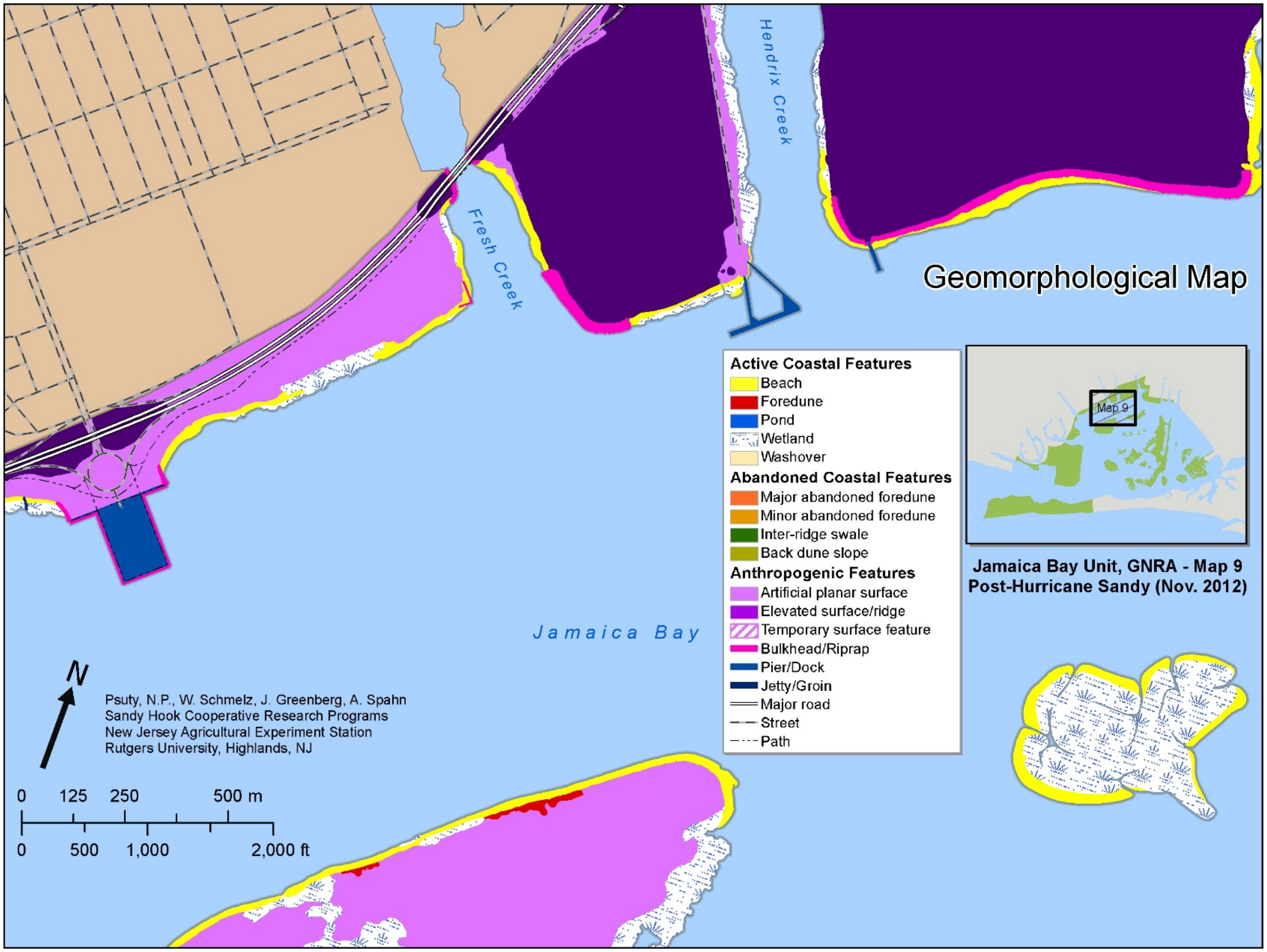
Geomorphological Map
Active Coastal Features
Beach
Foredune
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Major road
Street
Path
Hendrix Creek
East Mill Basin
Jamaica Bay
Map 7
Jamaica Bay Unit, GNRA - Map 7
Post-Hurricane Sandy (Nov. 2012)
Psuty, N.P., W. Schmelz, J. Greenberg, A. Spahn
Sandy Hook Cooperative Research Programs
New Jersey Agricultural Experiment Station
Rutgers University, Highlands, NJ
N
0 125 250 500 m
0 500 1,000 2,000 ft

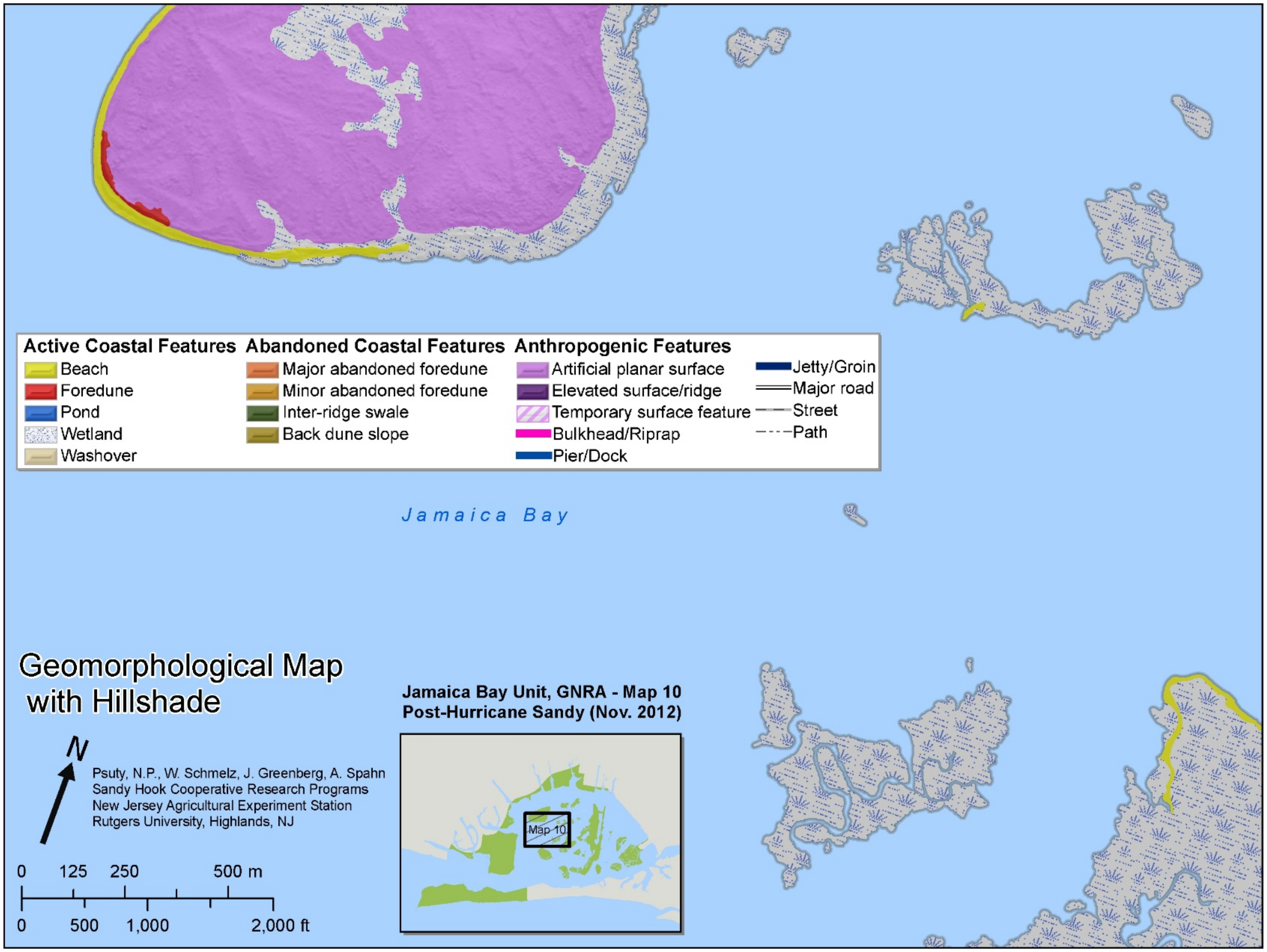

Geomorphological Map
with Hillshade
Active Coastal Features
Beach
Foredune
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Major road
Street
Path
Map 8
Jamaica Bay Unit, GNRA - Map 8
Post-Hurricane Sandy (Nov. 2012)
Psuty, N.P., W. Schmelz, J. Greenberg, A. Spahn
Sandy Hook Cooperative Research Programs
New Jersey Agricultural Experiment Station
Rutgers University, Highlands, NJ
Hendrix Creek
Fresh Creek
N
0 125 250 500 m
0 500 1,000 2,000 ft



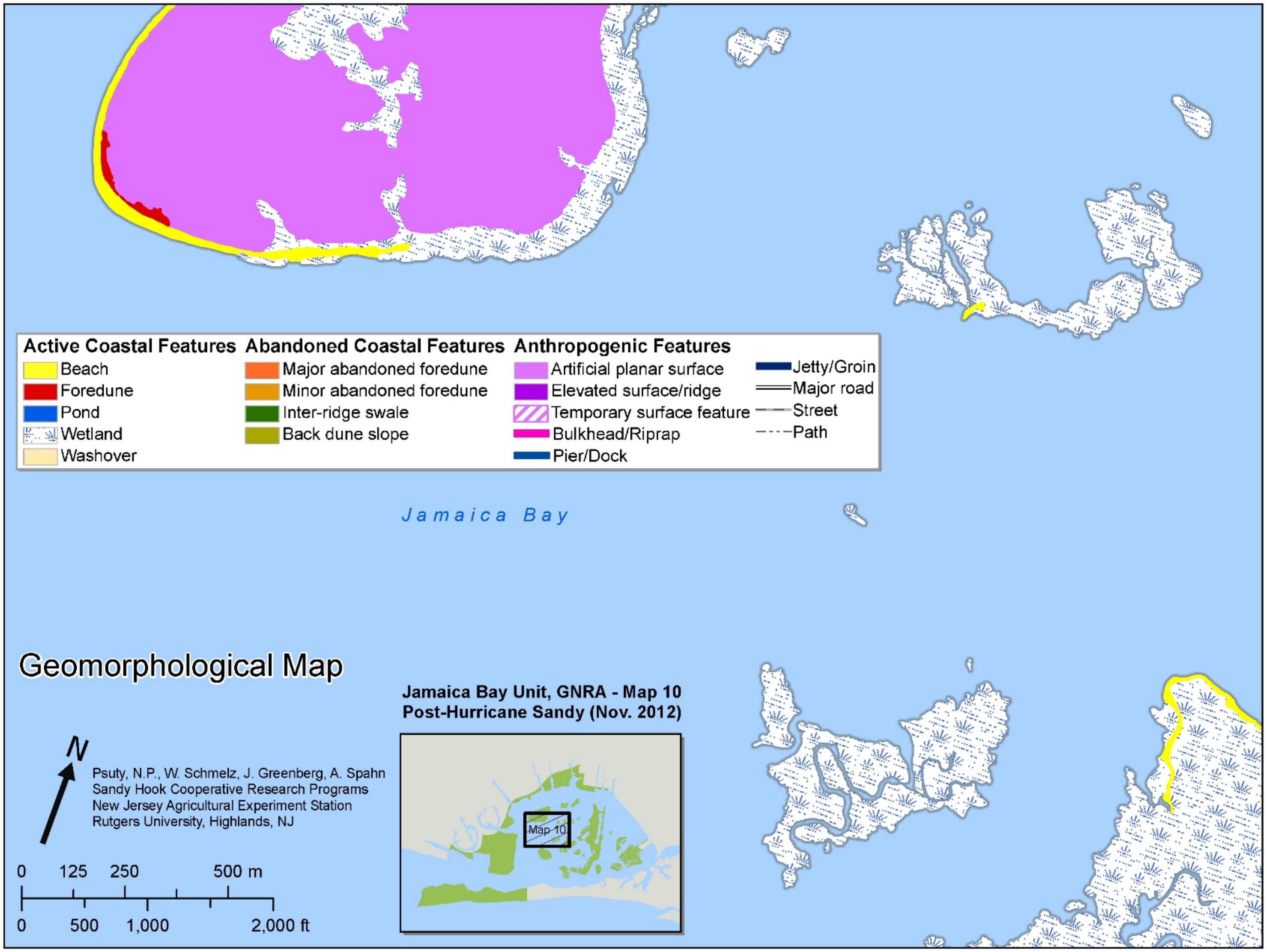
Geomorphological Map
Active Coastal Features
Beach
Foredune
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Major road
Street
Path
Map 8
Jamaica Bay Unit, GNRA - Map 8
Post-Hurricane Sandy (Nov. 2012)
Psuty, N.P., W. Schmelz, J. Greenberg, A. Spahn
Sandy Hook Cooperative Research Programs
New Jersey Agricultural Experiment Station
Rutgers University, Highlands, NJ
Hendrix Creek
Fresh Creek
N
0 125 250 500 m
0 500 1,000 2,000 ft


Geomorphological Map
with Hillshade
Hendrix Creek
Fresh Creek
Jamaica Bay
Active Coastal Features
Beach
Foredune
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Major road
Street
Path
Map 9
Jamaica Bay Unit, GNRA - Map 9
Post-Hurricane Sandy (Nov. 2012)
N
Psuty, N.P., W. Schmelz, J. Greenberg, A. Spahn
Sandy Hook Cooperative Research Programs
New Jersey Agricultural Experiment Station
Rutgers University, Highlands, NJ
0 125 250 500 m
0 500 1,000 2,000 ft

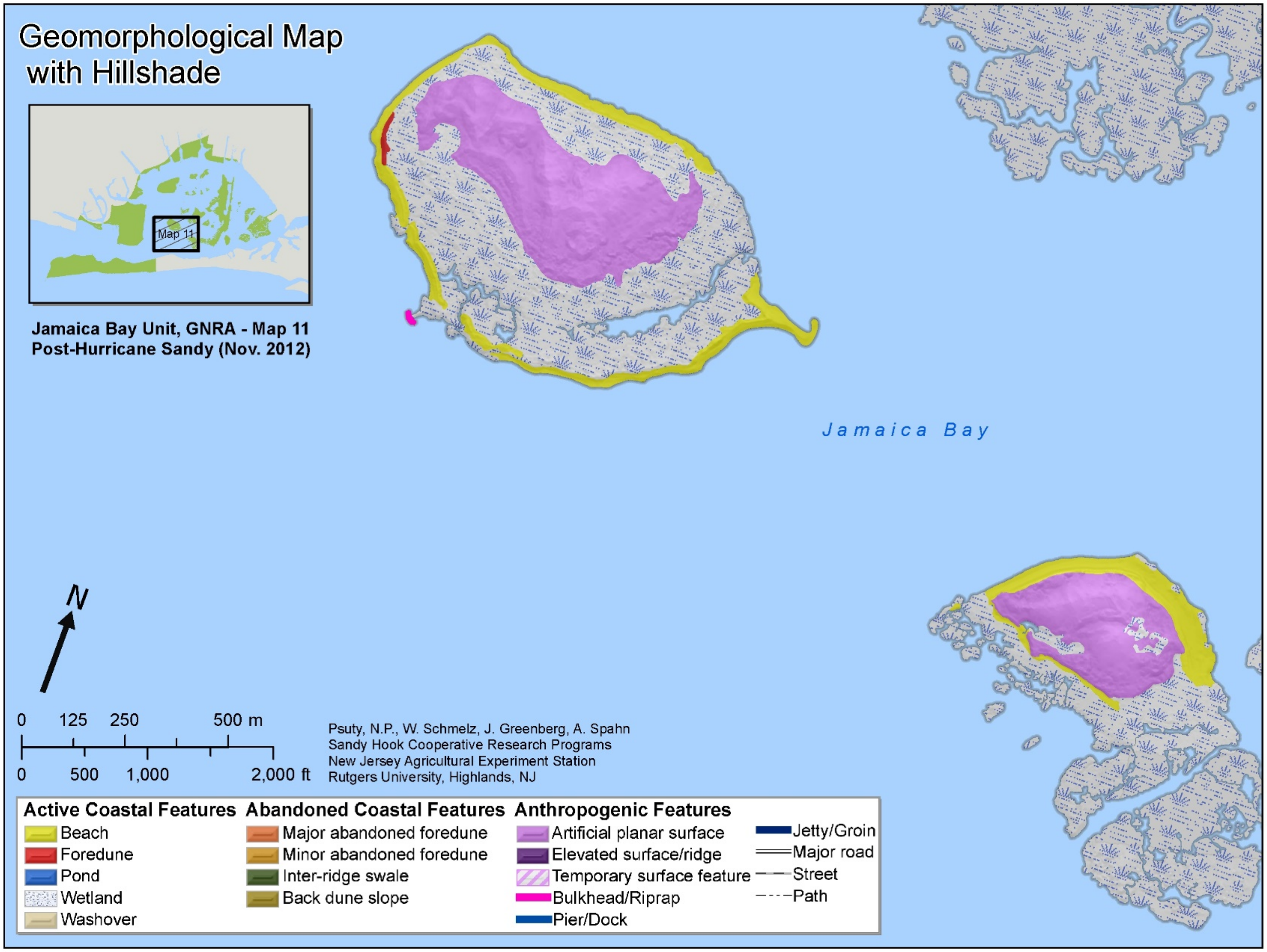

Geomorphological Map
Hendrix Creek
Fresh Creek
Jamaica Bay
Active Coastal Features
Beach
Foredune
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Major road
Street
Path
Map 9
Jamaica Bay Unit, GNRA - Map 9
Post-Hurricane Sandy (Nov. 2012)
N
Psuty, N.P., W. Schmelz, J. Greenberg, A. Spahn
Sandy Hook Cooperative Research Programs
New Jersey Agricultural Experiment Station
Rutgers University, Highlands, NJ
0 125 250 500 m
0 500 1,000 2,000 ft



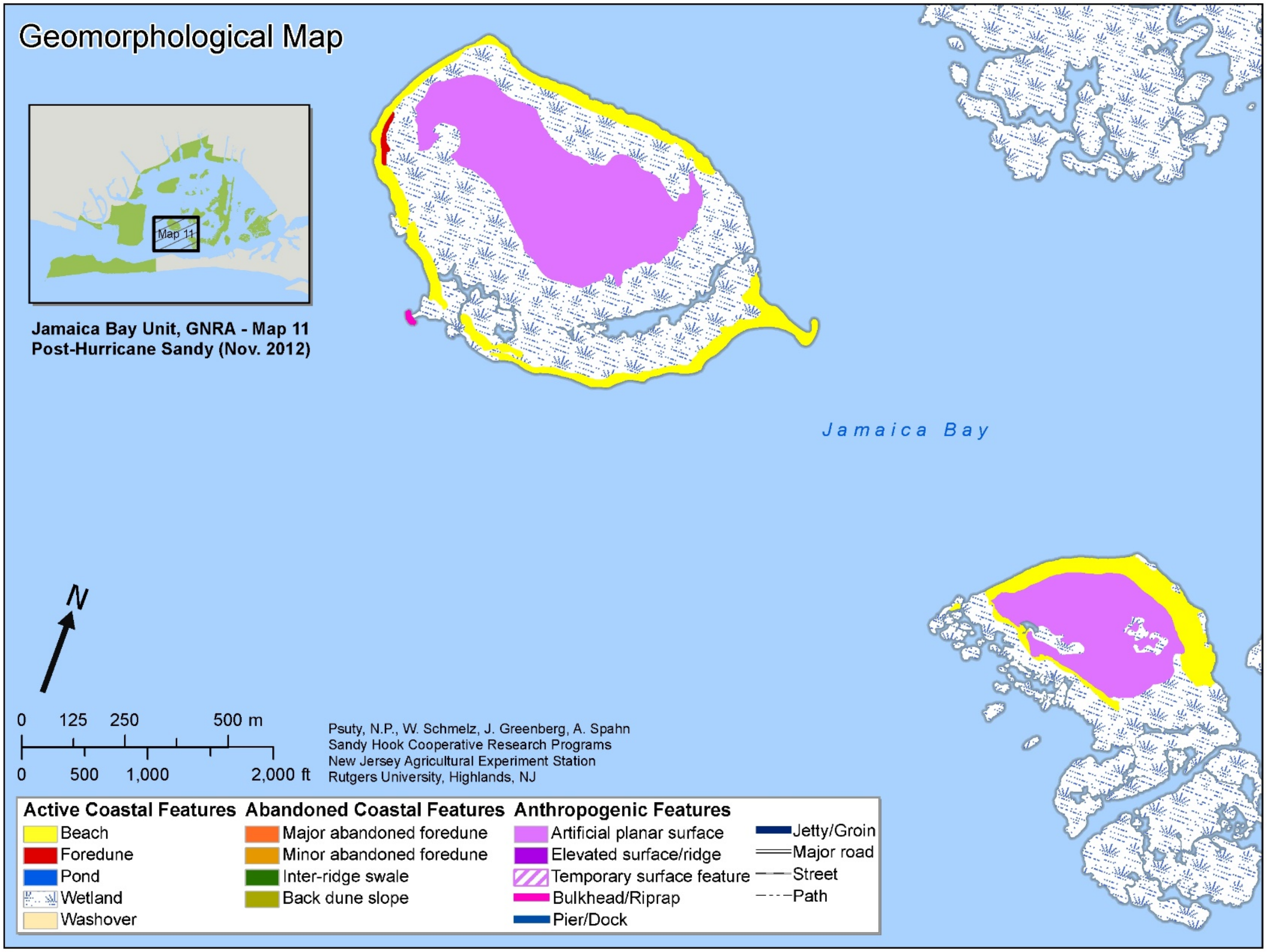
Active Coastal Features
Beach
Foredune
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Major road
Street
Path
Jamaica Bay
Geomorphological Map
with Hillshade
N
Psuty, N.P., W. Schmelz, J. Greenberg, A. Spahn
Sandy Hook Cooperative Research Programs
New Jersey Agricultural Experiment Station
Rutgers University, Highlands, NJ
0 125 250 500 m
0 500 1,000 2,000 ft
Jamaica Bay Unit, GNRA - Map 10
Post-Hurricane Sandy (Nov. 2012)
Map 10

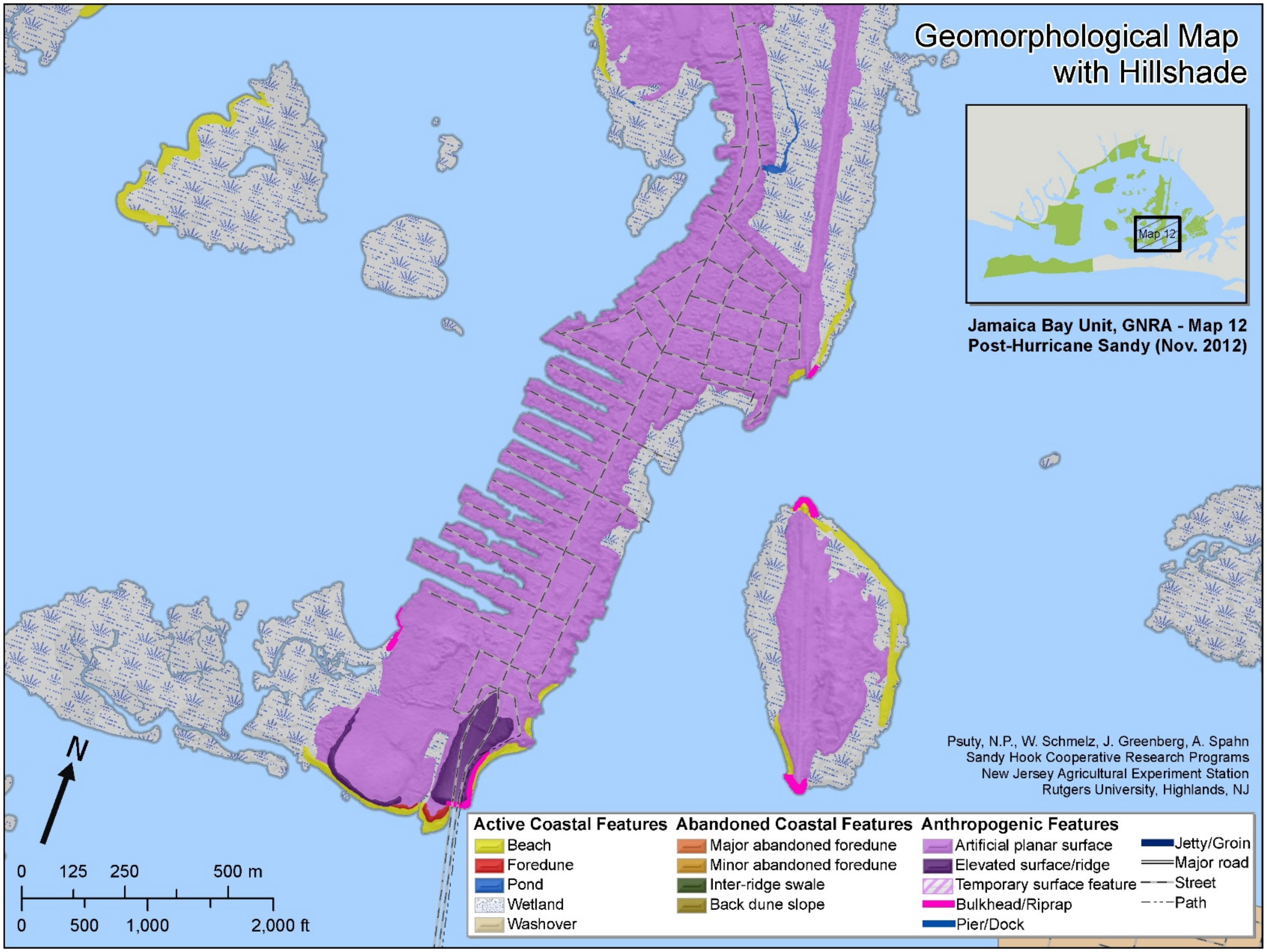


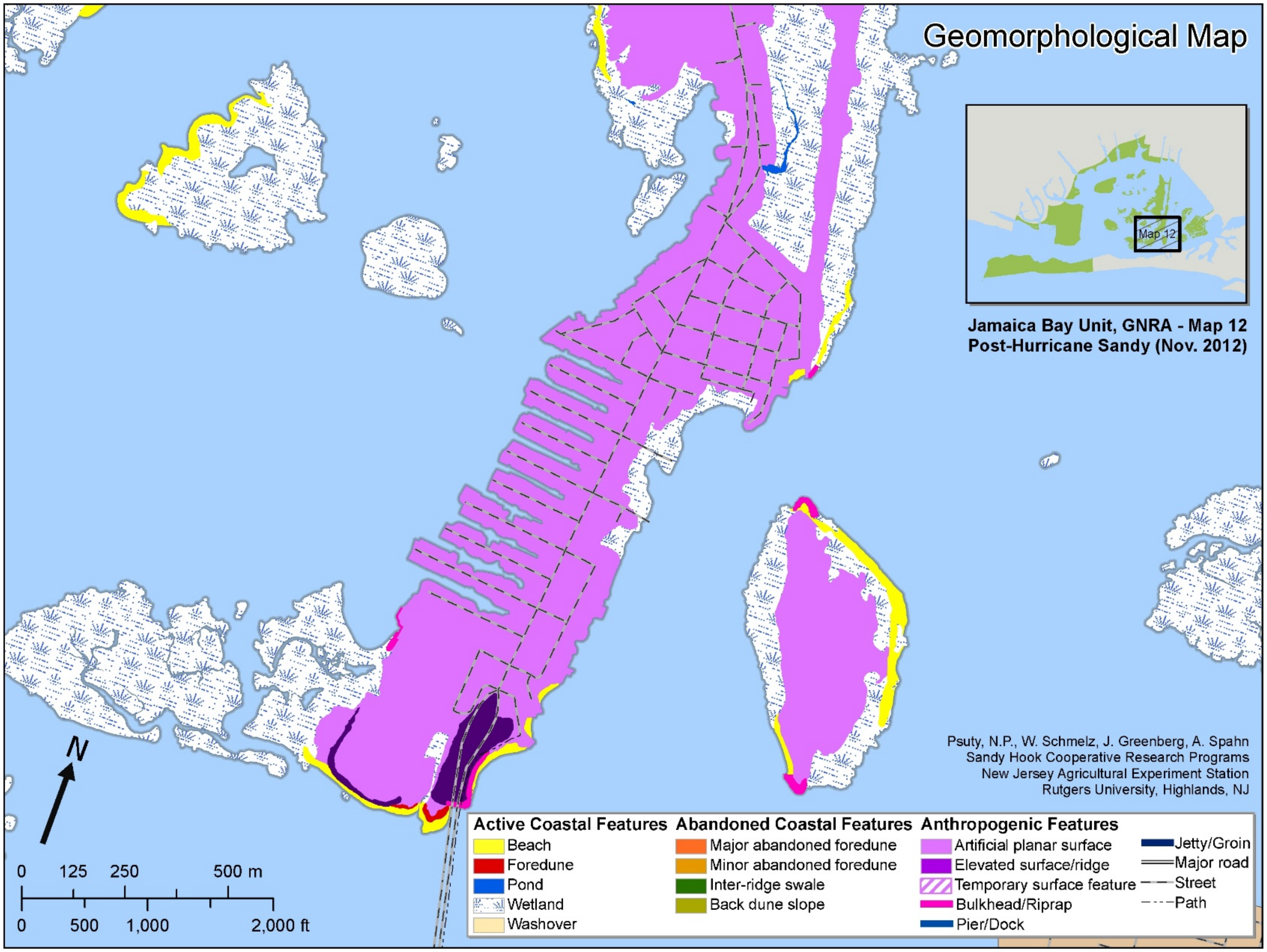
Active Coastal Features
Beach
Foredune
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Major road
Street
Path
Jamaica Bay
Geomorphological Map
Jamaica Bay Unit, GNRA - Map 10
Post-Hurricane Sandy (Nov. 2012)
Map 10
N
Psuty, N.P., W. Schmelz, J. Greenberg, A. Spahn
Sandy Hook Cooperative Research Programs
New Jersey Agricultural Experiment Station
Rutgers University, Highlands, NJ
0 125 250 500 m
0 500 1,000 2,000 ft



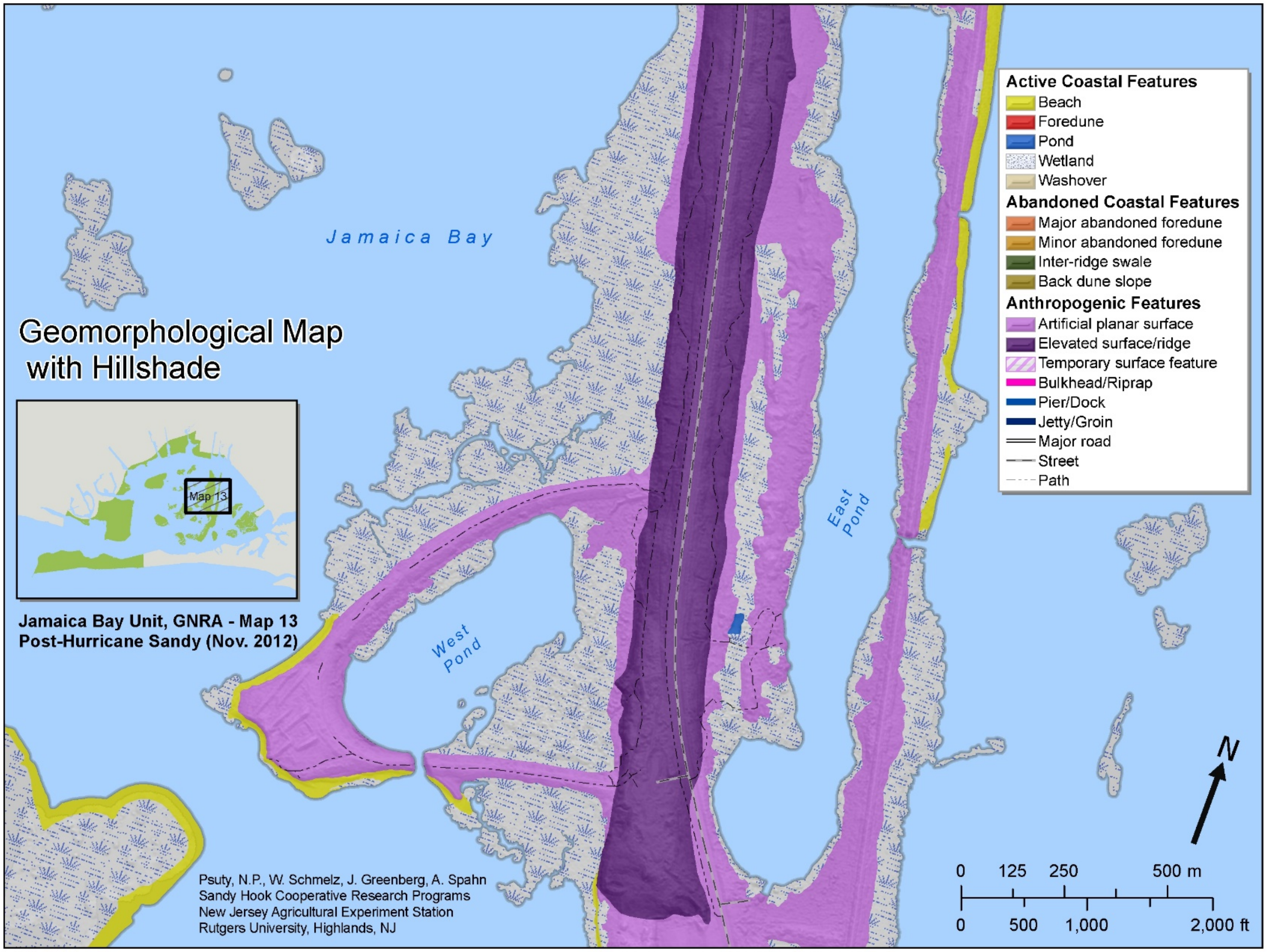
Geomorphological Map
with Hillshade
Map 11
Jamaica Bay Unit, GNRA - Map 11
Post-Hurricane Sandy (Nov. 2012)
Jamaica Bay
N
0
125
250
500 m
0
500
1,000
2,000 ft
Psuty, N.P., W. Schmelz, J. Greenberg, A. Spahn
Sandy Hook Cooperative Research Programs
New Jersey Agricultural Experiment Station
Rutgers University, Highlands, NJ
Active Coastal Features
Beach
Foredune
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Major road
Street
Path

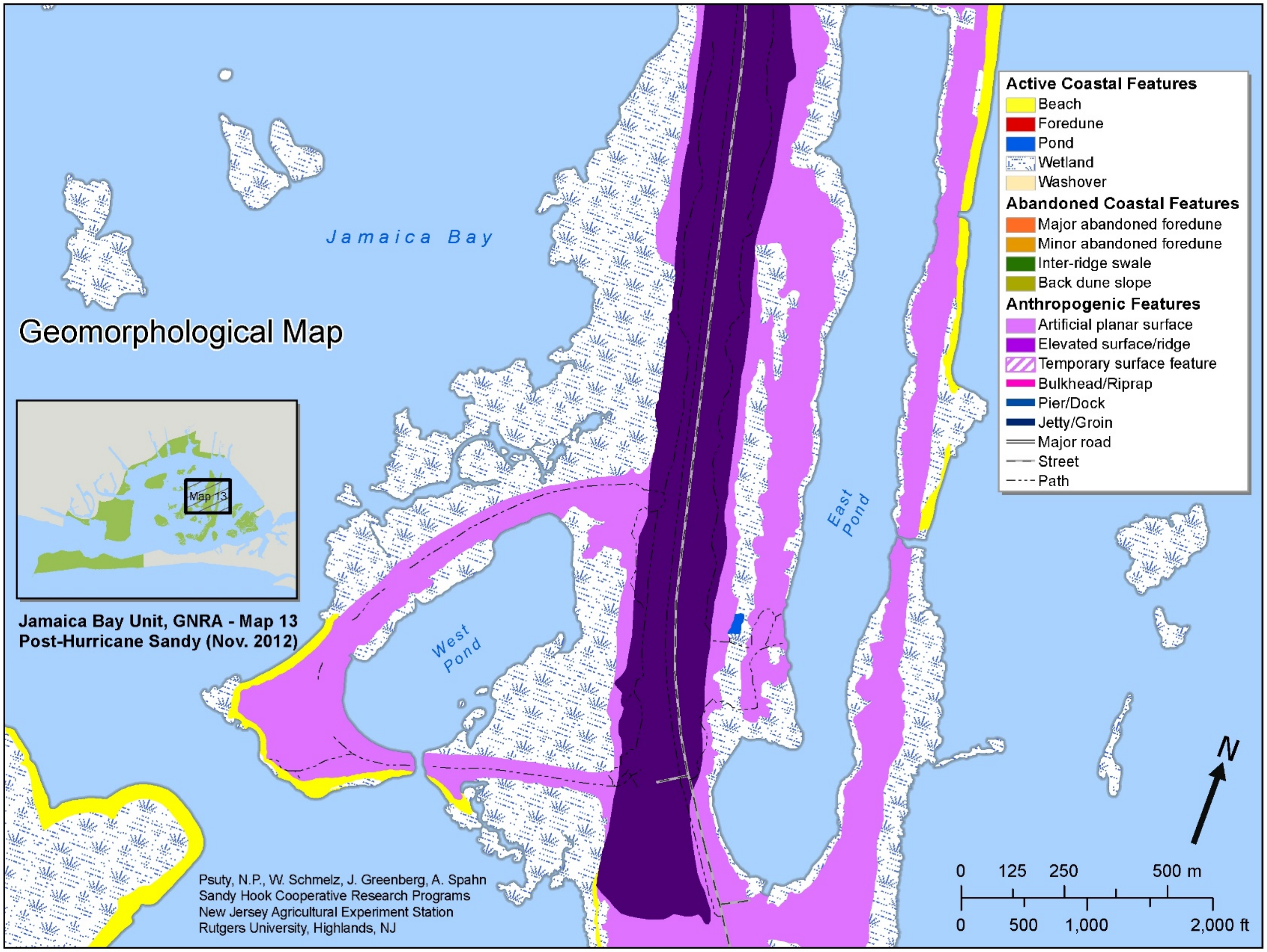

Geomorphological Map
Map 11
Jamaica Bay Unit, GNRA - Map 11
Post-Hurricane Sandy (Nov. 2012)
Jamaica Bay
N
0 125 250 500 m
0 500 1,000 2,000 ft
Psuty, N.P., W. Schmelz, J. Greenberg, A. Spahn
Sandy Hook Cooperative Research Programs
New Jersey Agricultural Experiment Station
Rutgers University, Highlands, NJ
Active Coastal Features
Beach
Foredune
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Major road
Street
Path

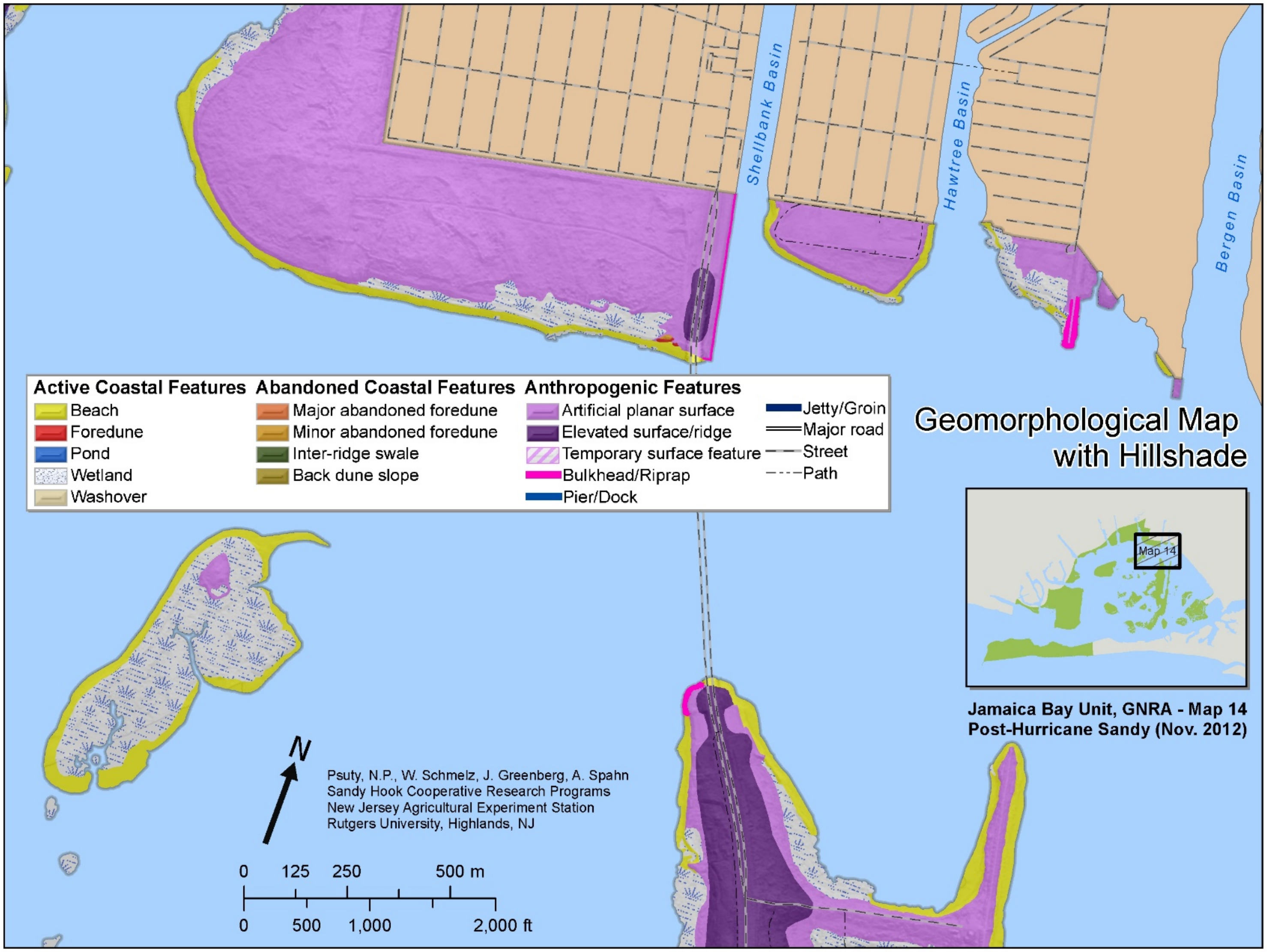

Geomorphological Map
with Hillshade
Map 12
Jamaica Bay Unit, GNRA - Map 12
Post-Hurricane Sandy (Nov. 2012)
Psuty, N.P., W. Schmelz, J. Greenberg, A. Spahn
Sandy Hook Cooperative Research Programs
New Jersey Agricultural Experiment Station
Rutgers University, Highlands, NJ
N
0 125 250 500 m
0 500 1,000 2,000 ft
Active Coastal Features
Beach
Foredune
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Major road
Street
Path

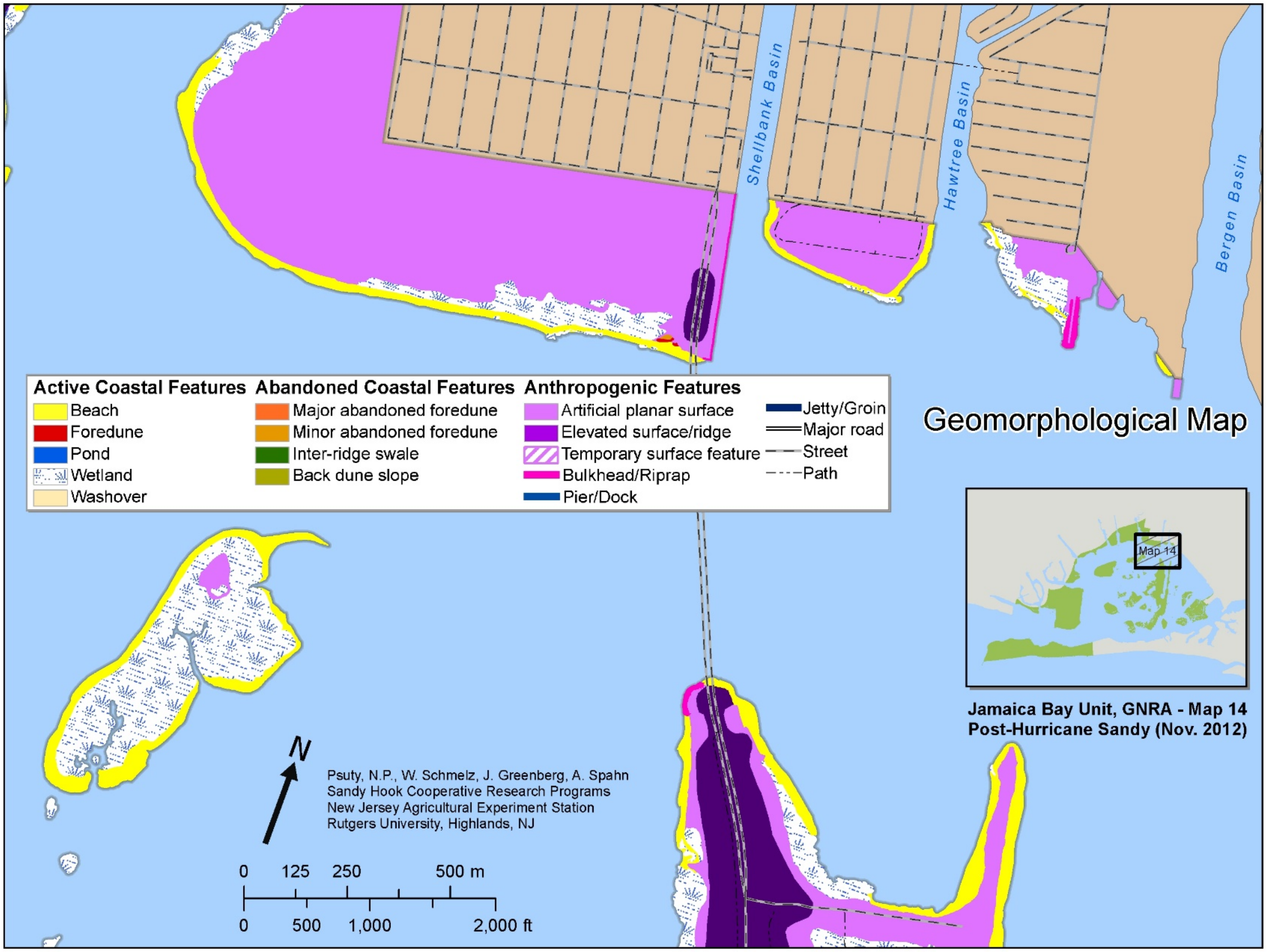


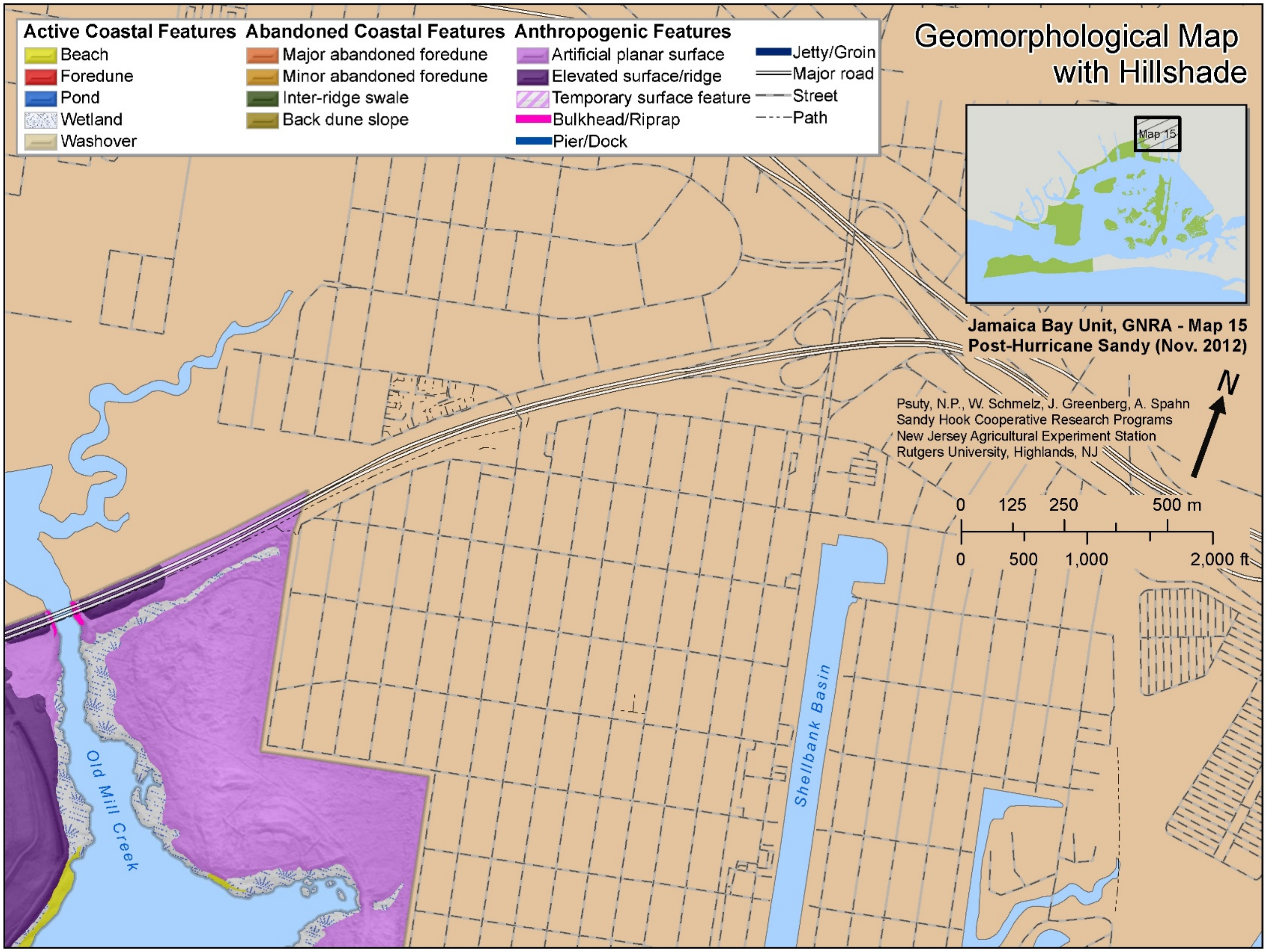
Geomorphological Map
Map 12
Jamaica Bay Unit, GNRA - Map 12
Post-Hurricane Sandy (Nov. 2012)
N
Psuty, N.P., W. Schmelz, J. Greenberg, A. Spahn
Sandy Hook Cooperative Research Programs
New Jersey Agricultural Experiment Station
Rutgers University, Highlands, NJ
0 125 250 500 m
0 500 1,000 2,000 ft
Active Coastal Features
Beach
Foredune
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Major road
Street
Path

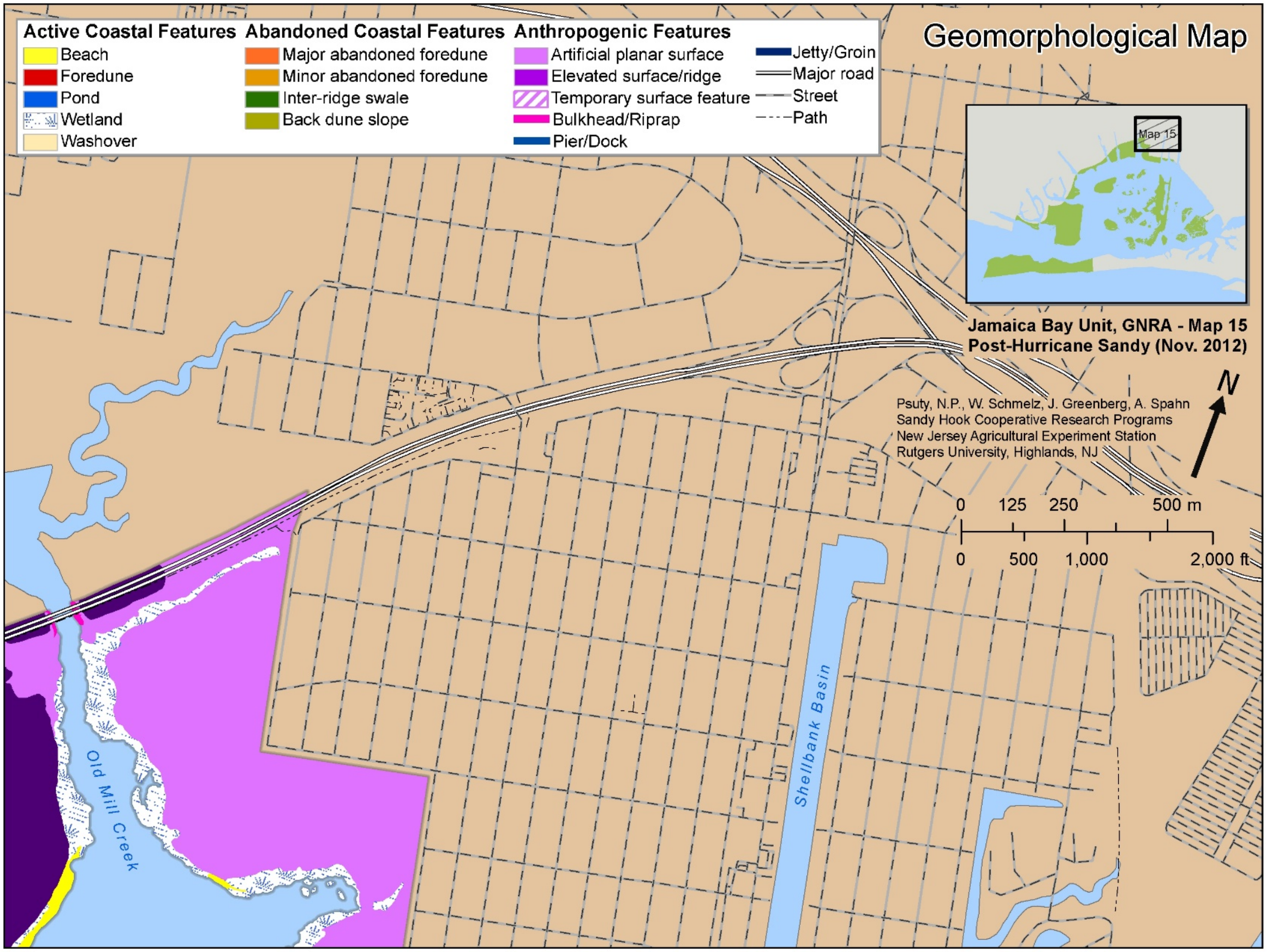

Geomorphological Map
with Hillshade
Map 13
Jamaica Bay Unit, GNRA - Map 13
Post-Hurricane Sandy (Nov. 2012)
Jamaica Bay
West Pond
East Pond
Active Coastal Features
Beach
Foredune
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Major road
Street
Path
N
0 125 250 500 m
0 500 1,000 2,000 ft
Psuty, N.P., W. Schmelz, J. Greenberg, A. Spahn
Sandy Hook Cooperative Research Programs
New Jersey Agricultural Experiment Station
Rutgers University, Highlands, NJ


Geomorphological Map
Jamaica Bay
West Pond
East Pond
Map 13
Jamaica Bay Unit, GNRA - Map 13
Post-Hurricane Sandy (Nov. 2012)
Active Coastal Features
Beach
Foredune
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Major road
Street
Path
N
0 125 250 500 m
0 500 1,000 2,000 ft
Psuty, N.P., W. Schmelz, J. Greenberg, A. Spahn
Sandy Hook Cooperative Research Programs
New Jersey Agricultural Experiment Station
Rutgers University, Highlands, NJ

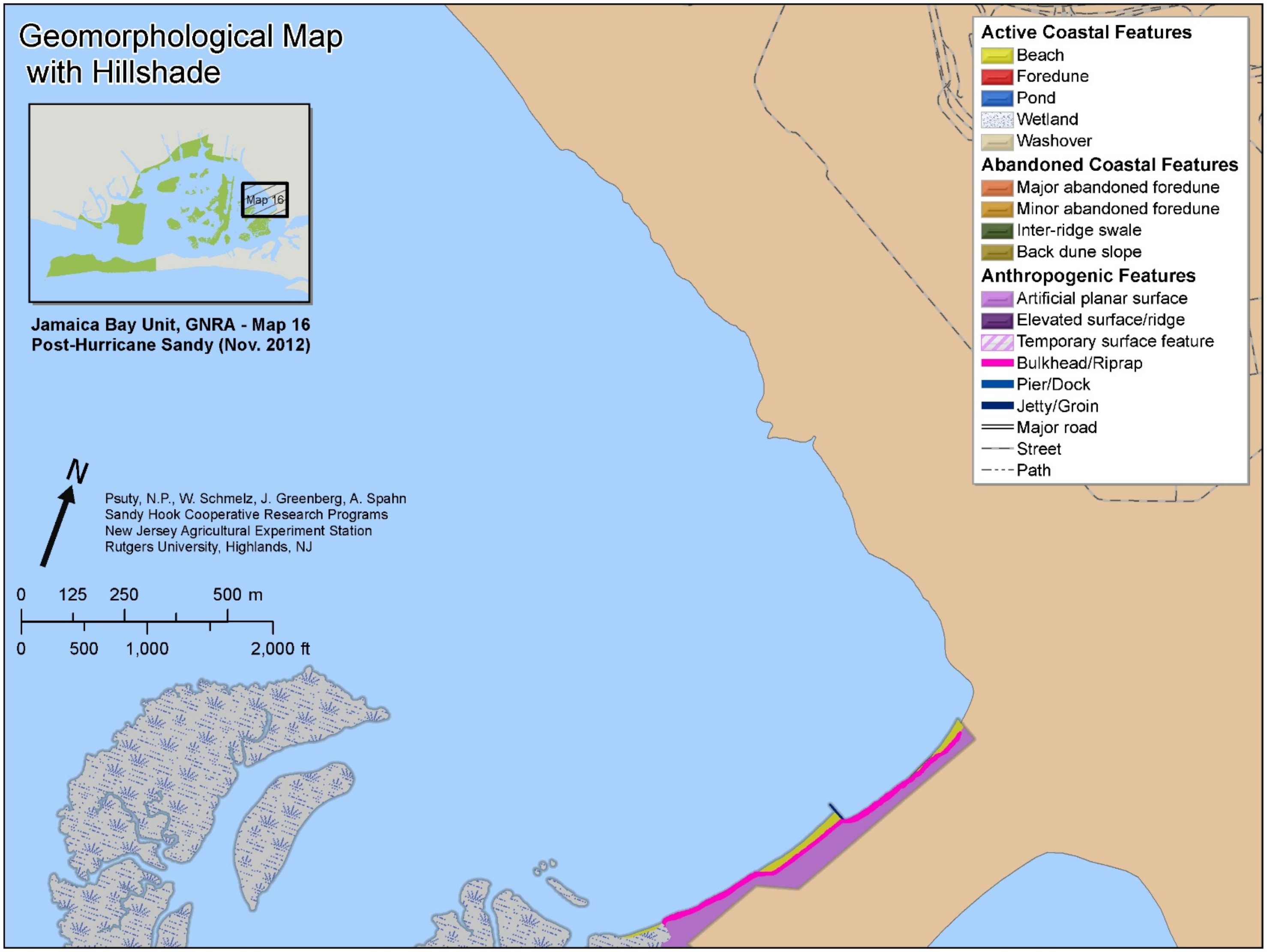

Shellbank Basin
Hawtree Basin
Bergen Basin
Active Coastal Features
Beach
Foredune
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Major road
Street
Path
Geomorphological Map
with Hillshade
Map 14
Jamaica Bay Unit, GNRA - Map 14
Post-Hurricane Sandy (Nov. 2012)
N
Psuty, N.P., W. Schmelz, J. Greenberg, A. Spahn
Sandy Hook Cooperative Research Programs
New Jersey Agricultural Experiment Station
Rutgers University, Highlands, NJ
0 125 250 500 m
0 500 1,000 2,000 ft


Shellbank Basin
Hawtree Basin
Bergen Basin
Active Coastal Features
Beach
Foredune
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Major road
Street
Path
Geomorphological Map
Map 14
Jamaica Bay Unit, GNRA - Map 14
Post-Hurricane Sandy (Nov. 2012)
N
Psuty, N.P., W. Schmelz, J. Greenberg, A. Spahn
Sandy Hook Cooperative Research Programs
New Jersey Agricultural Experiment Station
Rutgers University, Highlands, NJ
0 125 250 500 m
0 500 1,000 2,000 ft

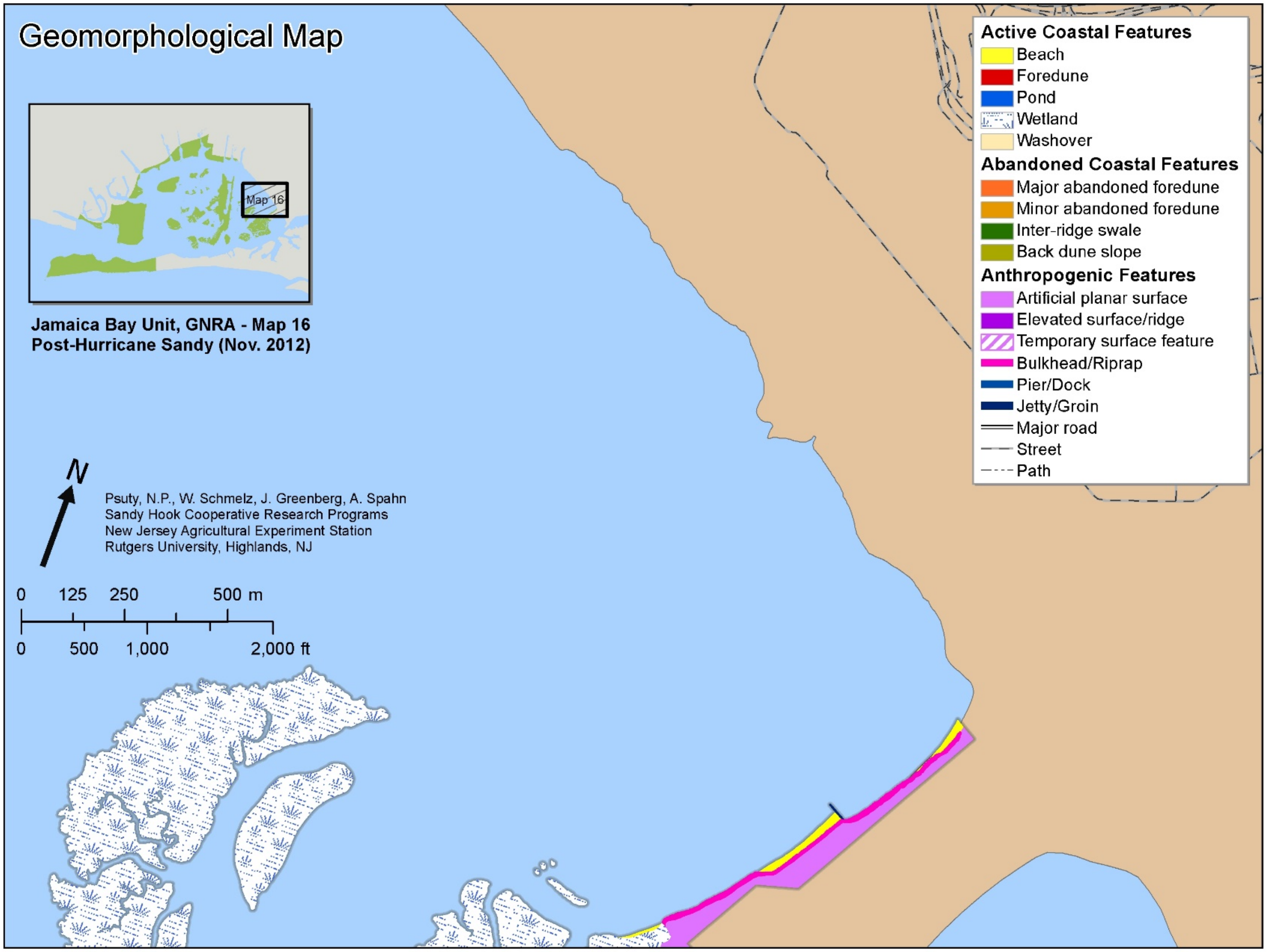

Active Coastal Features
Beach
Foredune
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Major road
Street
Path
Geomorphological Map with Hillshade
Map 15
Jamaica Bay Unit, GNRA - Map 15
Post-Hurricane Sandy (Nov. 2012)
N
Psuty, N.P., W. Schmelz, J. Greenberg, A. Spahn
Sandy Hook Cooperative Research Programs
New Jersey Agricultural Experiment Station
Rutgers University, Highlands, NJ
0 125 250 500 m
0 500 1,000 2,000 ft
Shellbank Basin
Old Mill Creek



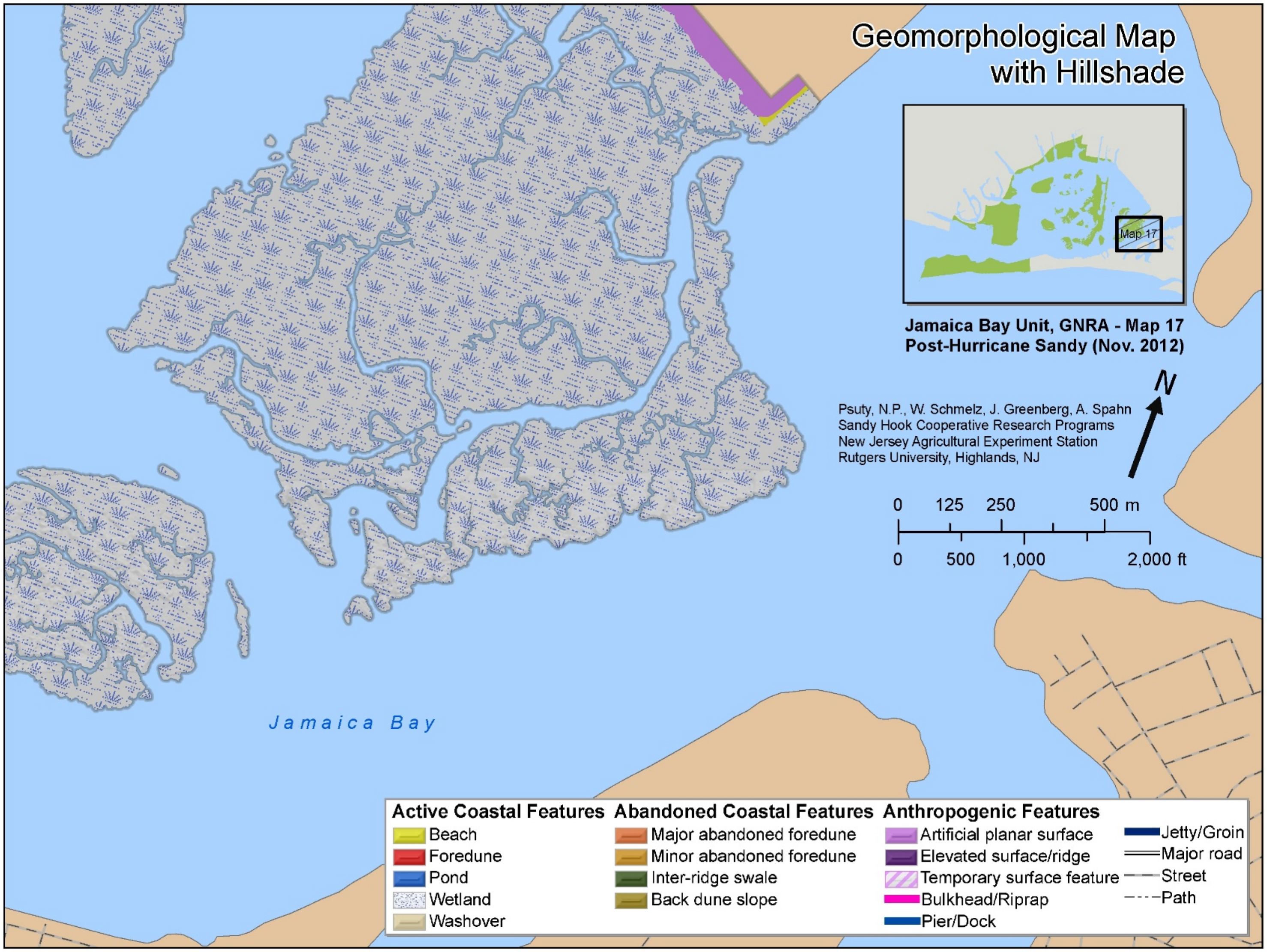
Active Coastal Features
Beach
Foredune
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Major road
Street
Path
Geomorphological Map
Map 15
Jamaica Bay Unit, GNRA - Map 15
Post-Hurricane Sandy (Nov. 2012)
N
Psuty, N.P., W. Schmelz, J. Greenberg, A. Spahn
Sandy Hook Cooperative Research Programs
New Jersey Agricultural Experiment Station
Rutgers University, Highlands, NJ
0 125 250 500 m
0 500 1,000 2,000 ft
Old Mill Creek
Shellbank Basin

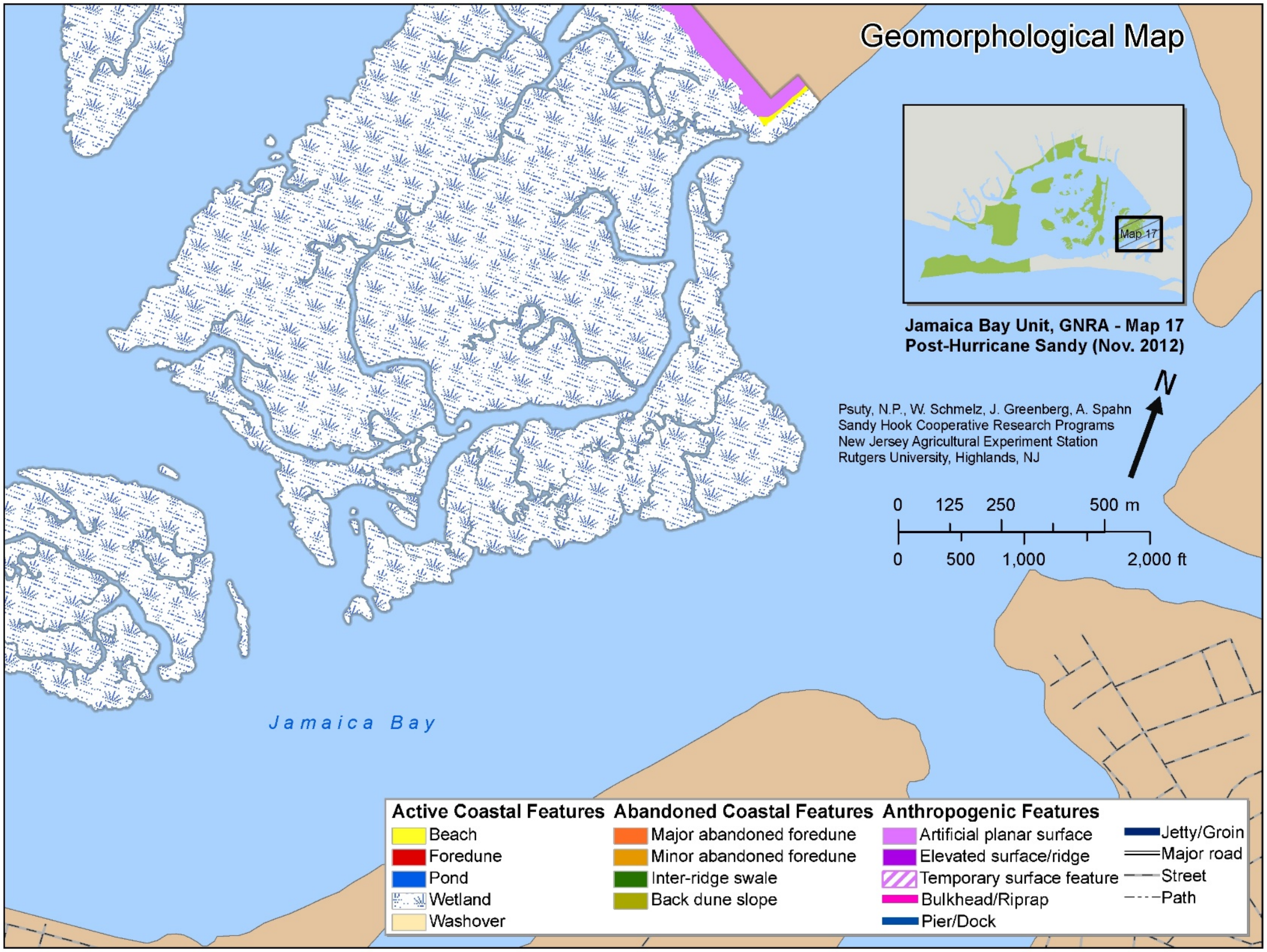


Geomorphological Map
with Hillshade
Map 16
Jamaica Bay Unit, GNRA - Map 16
Post-Hurricane Sandy (Nov. 2012)
N
Psuty, N.P., W. Schmelz, J. Greenberg, A. Spahn
Sandy Hook Cooperative Research Programs
New Jersey Agricultural Experiment Station
Rutgers University, Highlands, NJ
0 125 250 500 m
0 500 1,000 2,000 ft
Active Coastal Features
Beach
Foredune
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Major road
Street
Path

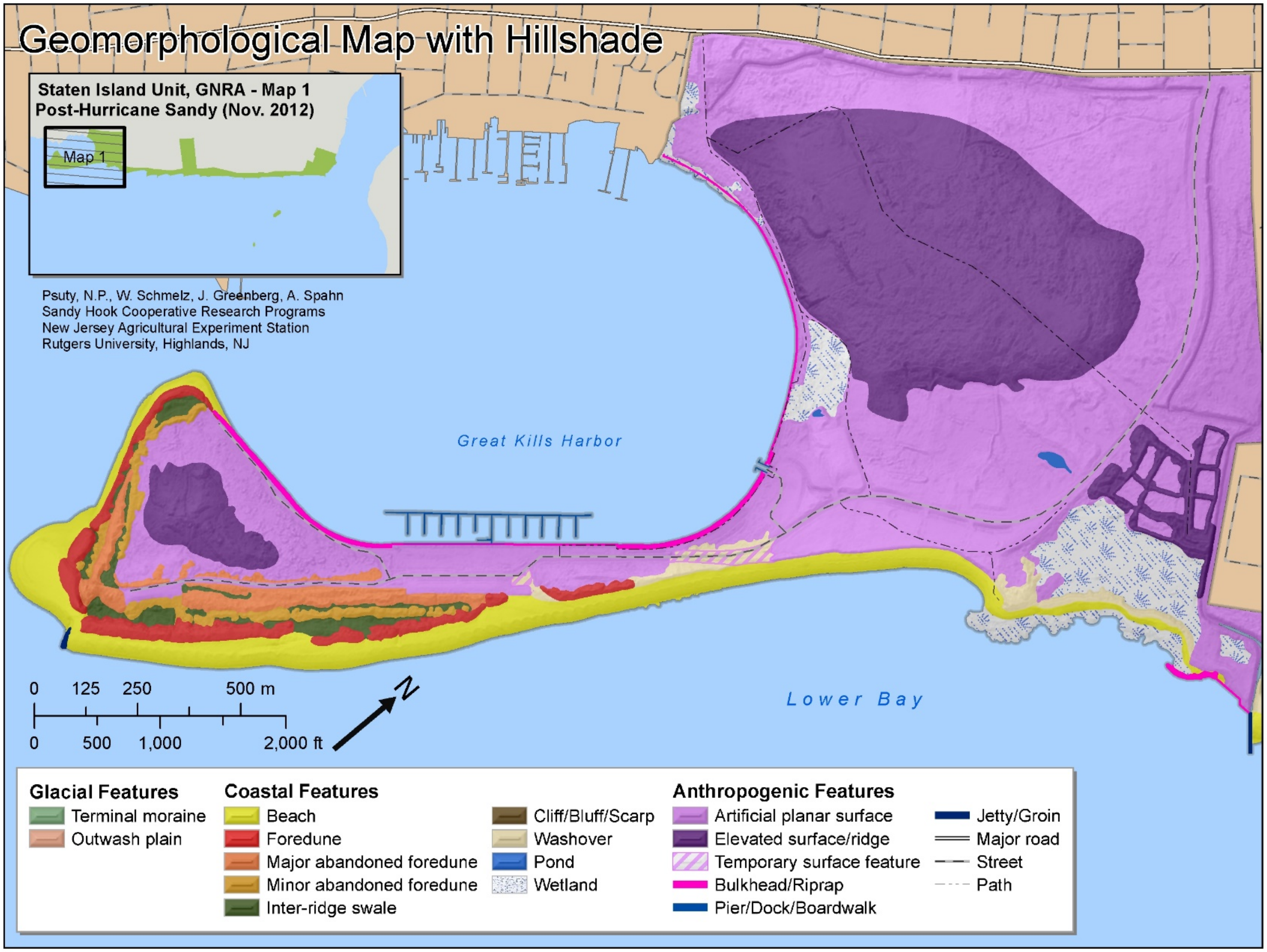


Geomorphological Map
Map 16
Jamaica Bay Unit, GNRA - Map 16
Post-Hurricane Sandy (Nov. 2012)
N
Psuty, N.P., W. Schmelz, J. Greenberg, A. Spahn
Sandy Hook Cooperative Research Programs
New Jersey Agricultural Experiment Station
Rutgers University, Highlands, NJ
0 125 250 500 m
0 500 1,000 2,000 ft
Active Coastal Features
Beach
Foredune
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Major road
Street
Path

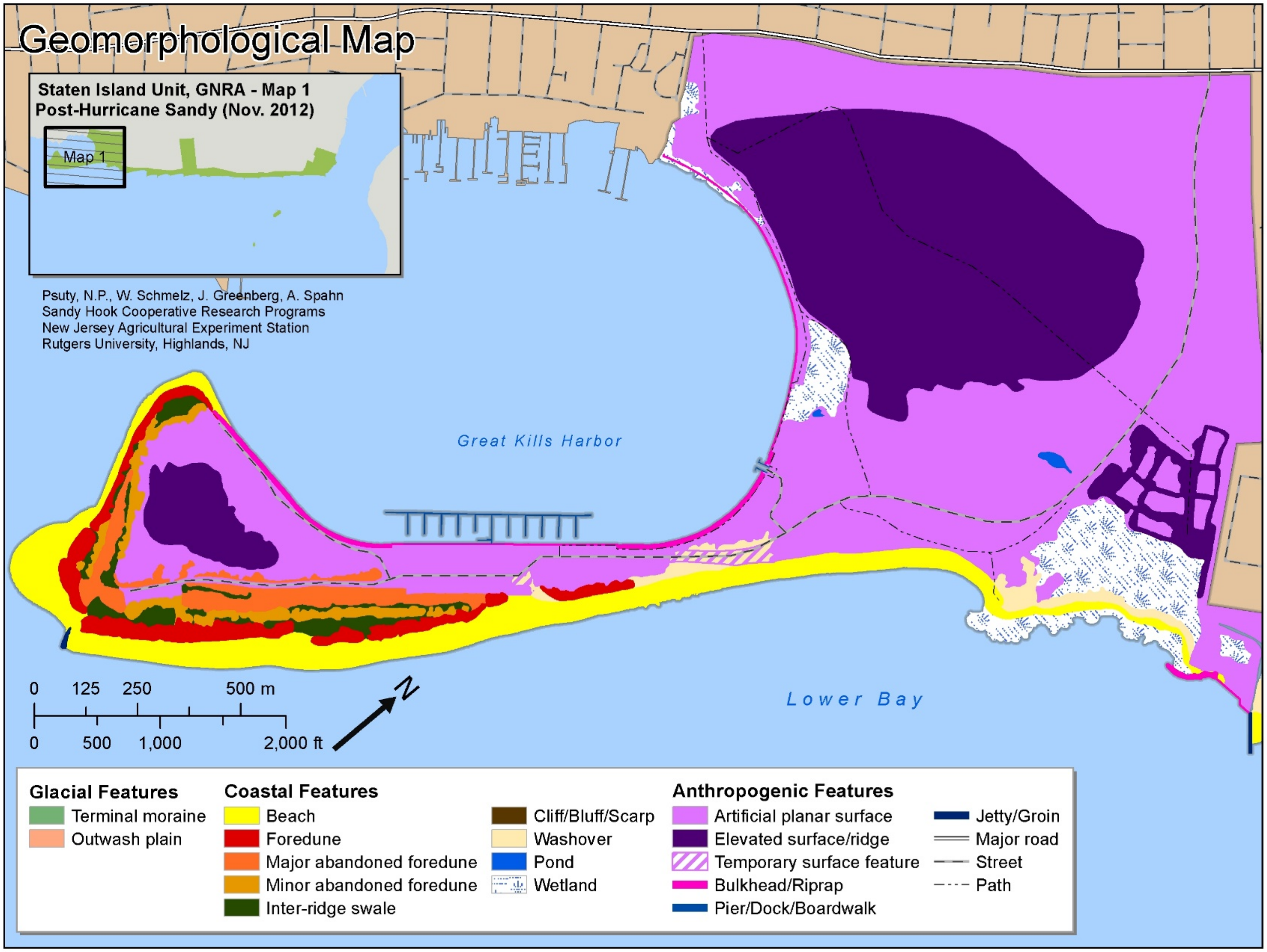

Geomorphological Map
with Hillshade
Map 17
Jamaica Bay Unit, GNRA - Map 17
Post-Hurricane Sandy (Nov. 2012)
N
Psuty, N.P., W. Schmelz, J. Greenberg, A. Spahn
Sandy Hook Cooperative Research Programs
New Jersey Agricultural Experiment Station
Rutgers University, Highlands, NJ
0 125 250 500 m
0 500 1,000 2,000 ft
Jamaica Bay
Active Coastal Features
Beach
Foredune
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Major road
Street
Path


Geomorphological Map
Map 17
Jamaica Bay Unit, GNRA - Map 17
Post-Hurricane Sandy (Nov. 2012)
N
Psuty, N.P., W. Schmelz, J. Greenberg, A. Spahn
Sandy Hook Cooperative Research Programs
New Jersey Agricultural Experiment Station
Rutgers University, Highlands, NJ
0 125 250 500 m
0 500 1,000 2,000 ft
Jamaica Bay
Active Coastal Features
Beach
Foredune
Pond
Wetland
Washover
Abandoned Coastal Features
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Back dune slope
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock
Jetty/Groin
Major road
Street
Path

Staten Island Unit (SIU)



Geomorphological Map with Hillshade
Staten Island Unit, GNRA - Map 1
Post-Hurricane Sandy (Nov. 2012)
Map 1
Psuty, N.P., W. Schmelz, J. Greenberg, A. Spahn
Sandy Hook Cooperative Research Programs
New Jersey Agricultural Experiment Station
Rutgers University, Highlands, NJ
Great Kills Harbor
Lower Bay
0 125 250 500 m
0 500 1,000 2,000 ft
N
Glacial Features
Terminal moraine
Outwash plain
Coastal Features
Beach
Foredune
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Cliff/Bluff/Scarp
Washover
Pond
Wetland
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock/Boardwalk
Jetty/Groin
Major road
Street
Path


Geomorphological Map
Staten Island Unit, GNRA - Map 1
Post-Hurricane Sandy (Nov. 2012)
Map 1
Psuty, N.P., W. Schmelz, J. Greenberg, A. Spahn
Sandy Hook Cooperative Research Programs
New Jersey Agricultural Experiment Station
Rutgers University, Highlands, NJ
Great Kills Harbor
Lower Bay
0 125 250 500 m
0 500 1,000 2,000 ft
N
Glacial Features
Terminal moraine
Outwash plain
Coastal Features
Beach
Foredune
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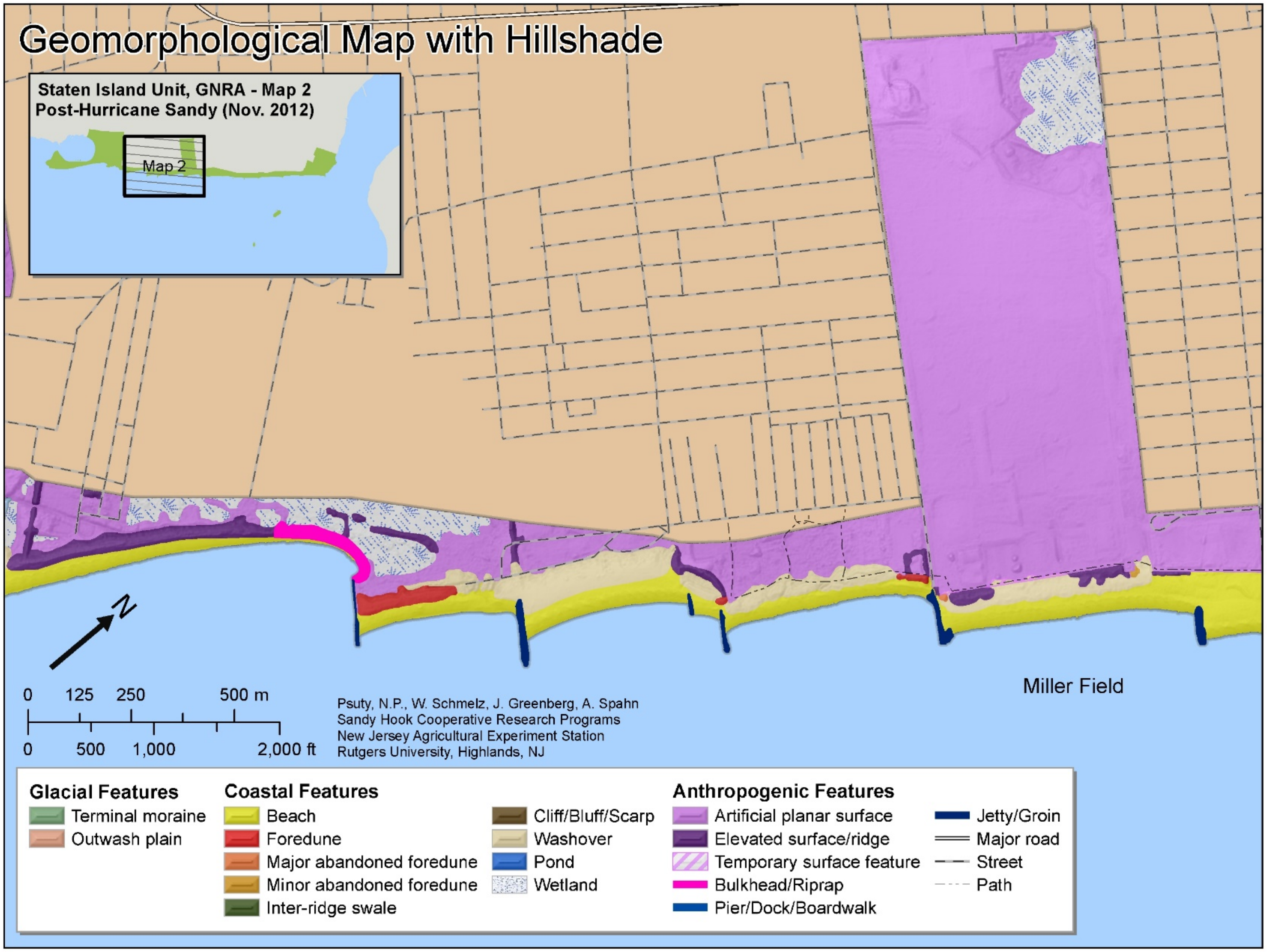
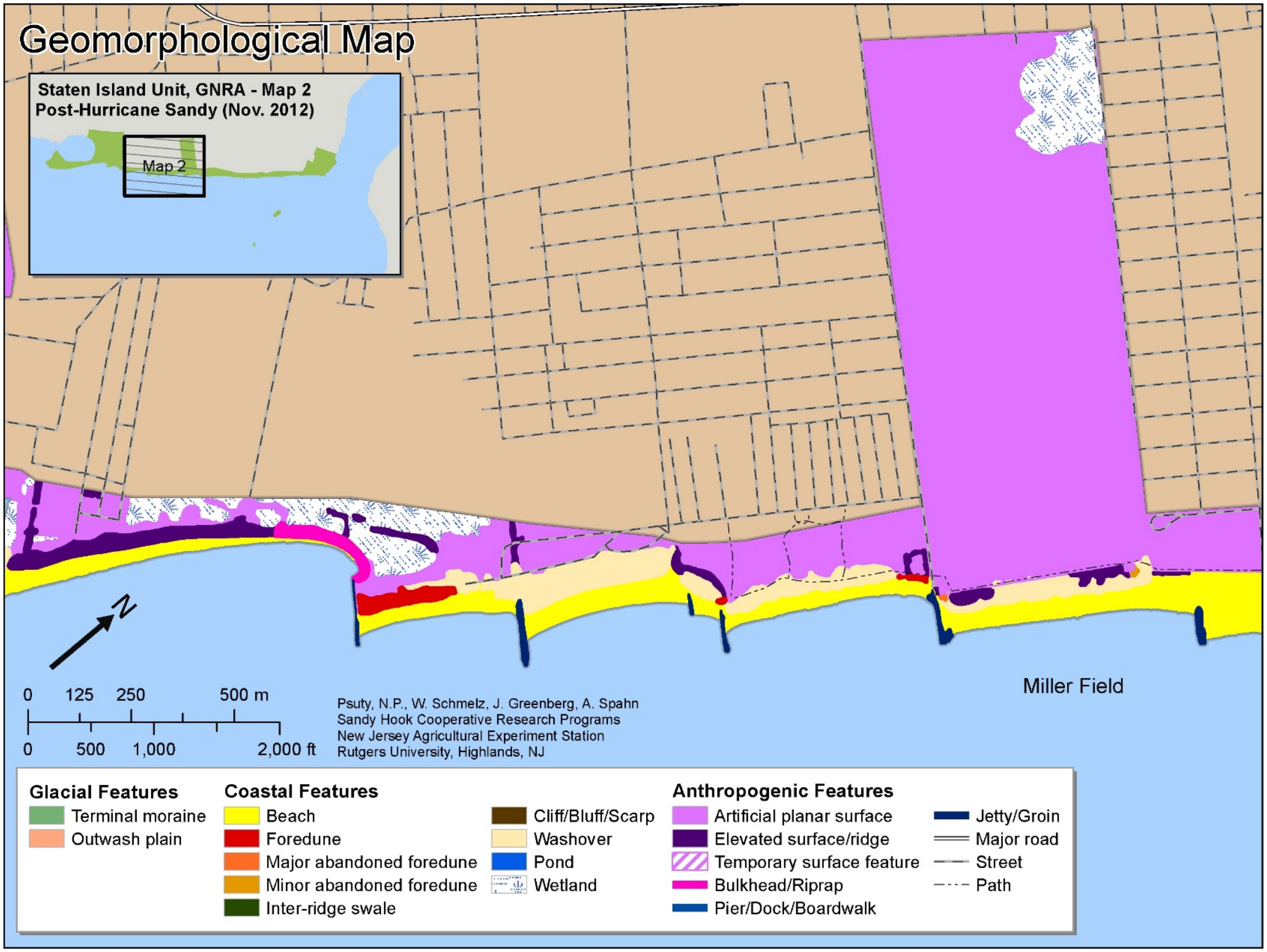
Temporary surface feature
Bulkhead/Riprap
Pier/Dock/Boardwalk
Jetty/Groin
Major road
Street
Path


Geomorphological Map with Hillshade
Staten Island Unit, GNRA - Map 2
Post-Hurricane Sandy (Nov. 2012)
Map 2
N
Miller Field
0 125 250 500 m
0 500 1,000 2,000 ft
Psuty, N.P., W. Schmelz, J. Greenberg, A. Spahn
Sandy Hook Cooperative Research Programs
New Jersey Agricultural Experiment Station
Rutgers University, Highlands, NJ
Glacial Features
Terminal moraine
Outwash plain
Coastal Features
Beach
Foredune
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Cliff/Bluff/Scarp
Washover
Pond
Wetland
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock/Boardwalk
Jetty/Groin
Major road
Street
Path



Geomorphological Map
Staten Island Unit, GNRA - Map 2
Post-Hurricane Sandy (Nov. 2012)
Map 2
N
0 125 250 500 m
0 500 1,000 2,000 ft
Psuty, N.P., W. Schmelz, J. Greenberg, A. Spahn
Sandy Hook Cooperative Research Programs
New Jersey Agricultural Experiment Station
Rutgers University, Highlands, NJ
Miller Field
Glacial Features
Terminal moraine
Outwash plain
Coastal Features
Beach
Foredune
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Cliff/Bluff/Scarp
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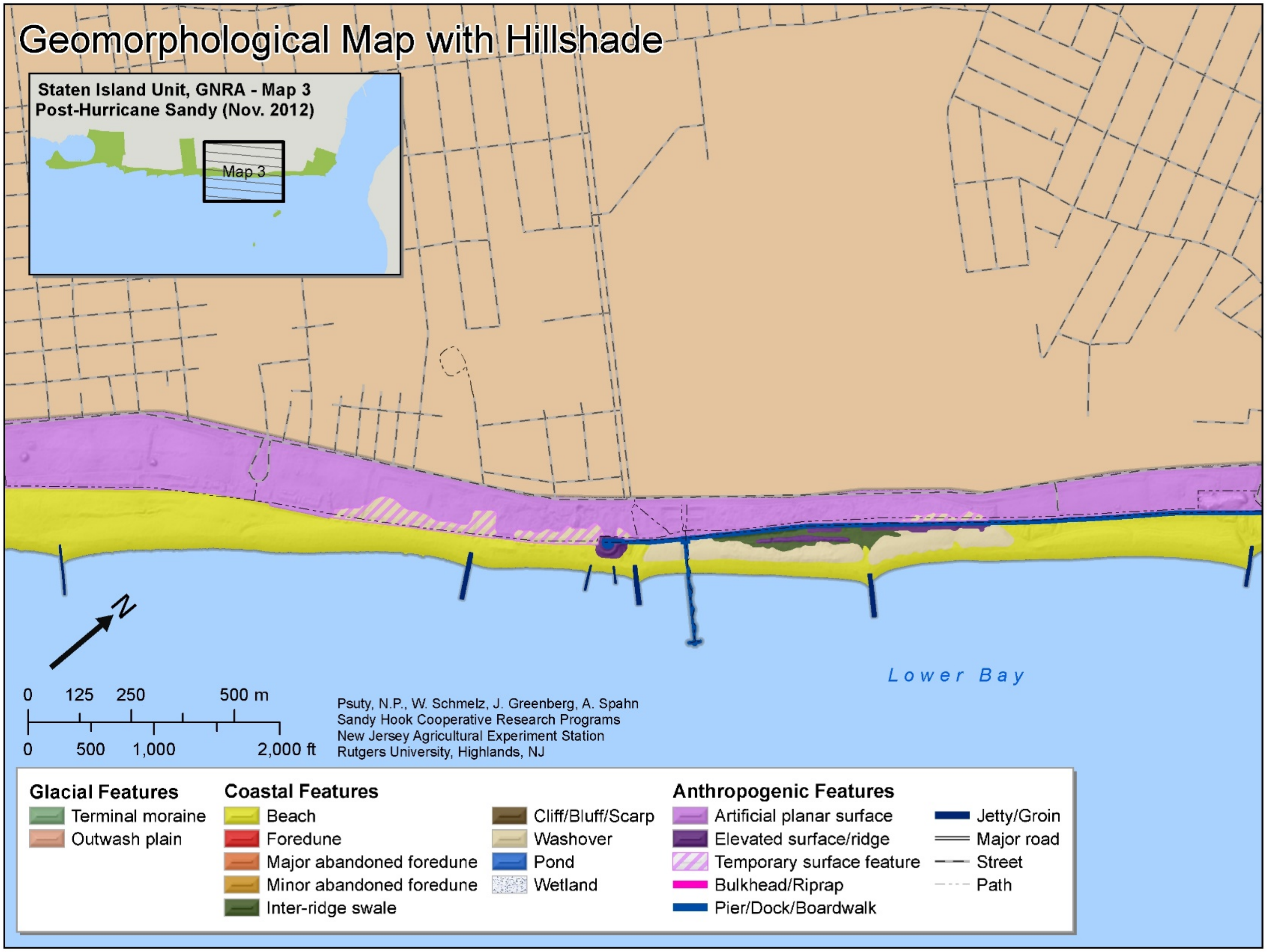
Wetland
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock/Boardwalk
Jetty/Groin
Major road
Street
Path


Geomorphological Map with Hillshade
Staten Island Unit, GNRA - Map 3
Post-Hurricane Sandy (Nov. 2012)
Map 3
Lower Bay
N
0 125 250 500 m
0 500 1,000 2,000 ft
Psuty, N.P., W. Schmelz, J. Greenberg, A. Spahn
Sandy Hook Cooperative Research Programs
New Jersey Agricultural Experiment Station
Rutgers University, Highlands, NJ
Glacial Features
Terminal moraine
Outwash plain
Coastal Features
Beach
Foredune
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Cliff/Bluff/Scarp
Washover
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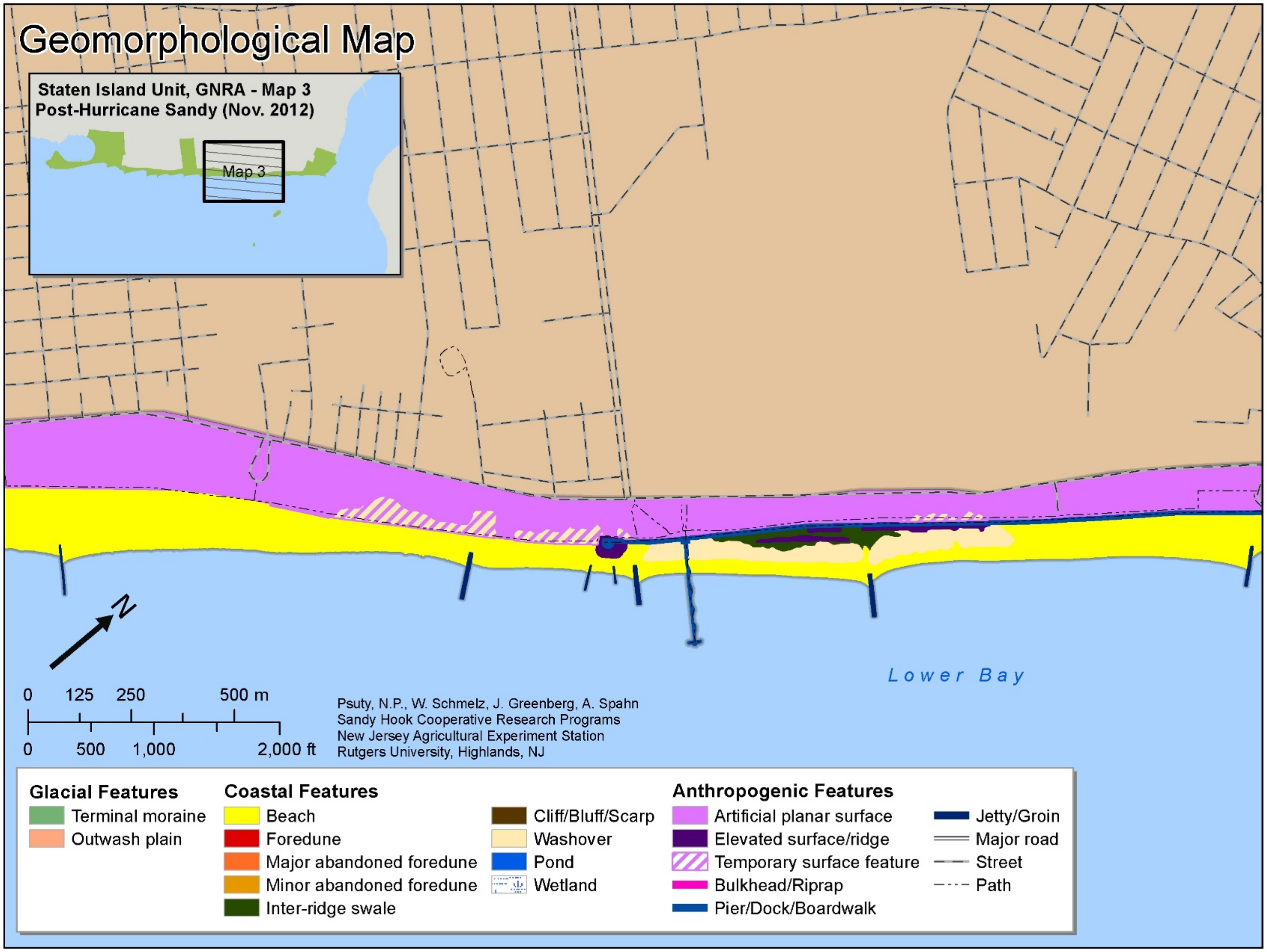
Wetland
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock/Boardwalk
Jetty/Groin
Major road
Street
Path



Geomorphological Map
Staten Island Unit, GNRA - Map 3
Post-Hurricane Sandy (Nov. 2012)
Map 3
Lower Bay
N
0 125 250 500 m
0 500 1,000 2,000 ft
Psuty, N.P., W. Schmelz, J. Greenberg, A. Spahn
Sandy Hook Cooperative Research Programs
New Jersey Agricultural Experiment Station
Rutgers University, Highlands, NJ
Glacial Features
Terminal moraine
Outwash plain
Coastal Features
Beach
Foredune
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Cliff/Bluff/Scarp
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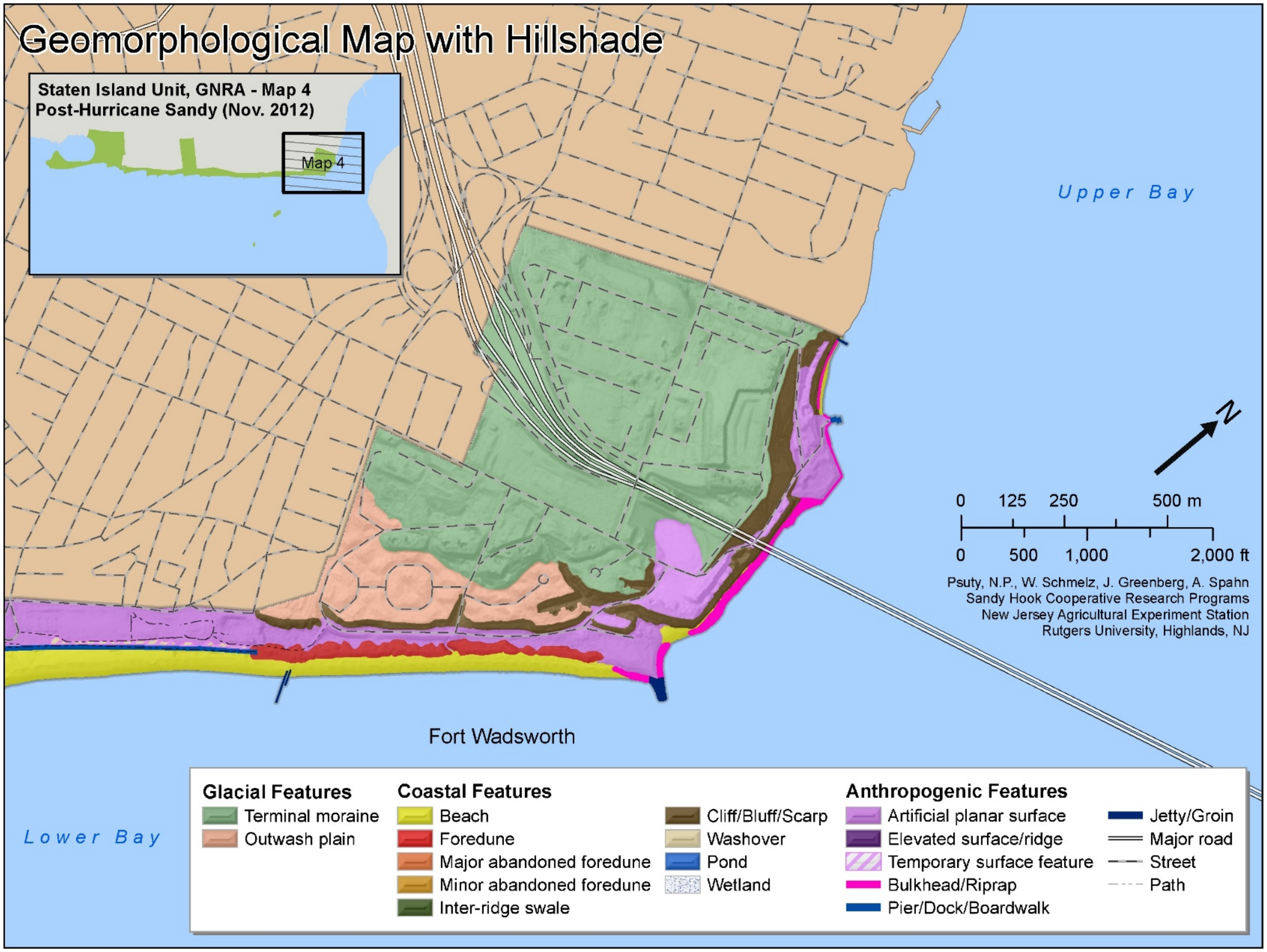
Wetland
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock/Boardwalk
Jetty/Groin
Major road
Street
Path



Geomorphological Map with Hillshade
Staten Island Unit, GNRA - Map 4
Post-Hurricane Sandy (Nov. 2012)
Map 4
Upper Bay
Lower Bay
Fort Wadsworth
N
0 125 250 500 m
0 500 1,000 2,000 ft
Psuty, N.P., W. Schmelz, J. Greenberg, A. Spahn
Sandy Hook Cooperative Research Programs
New Jersey Agricultural Experiment Station
Rutgers University, Highlands, NJ
Glacial Features
Terminal moraine
Outwash plain
Coastal Features
Beach
Foredune
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Cliff/Bluff/Scarp
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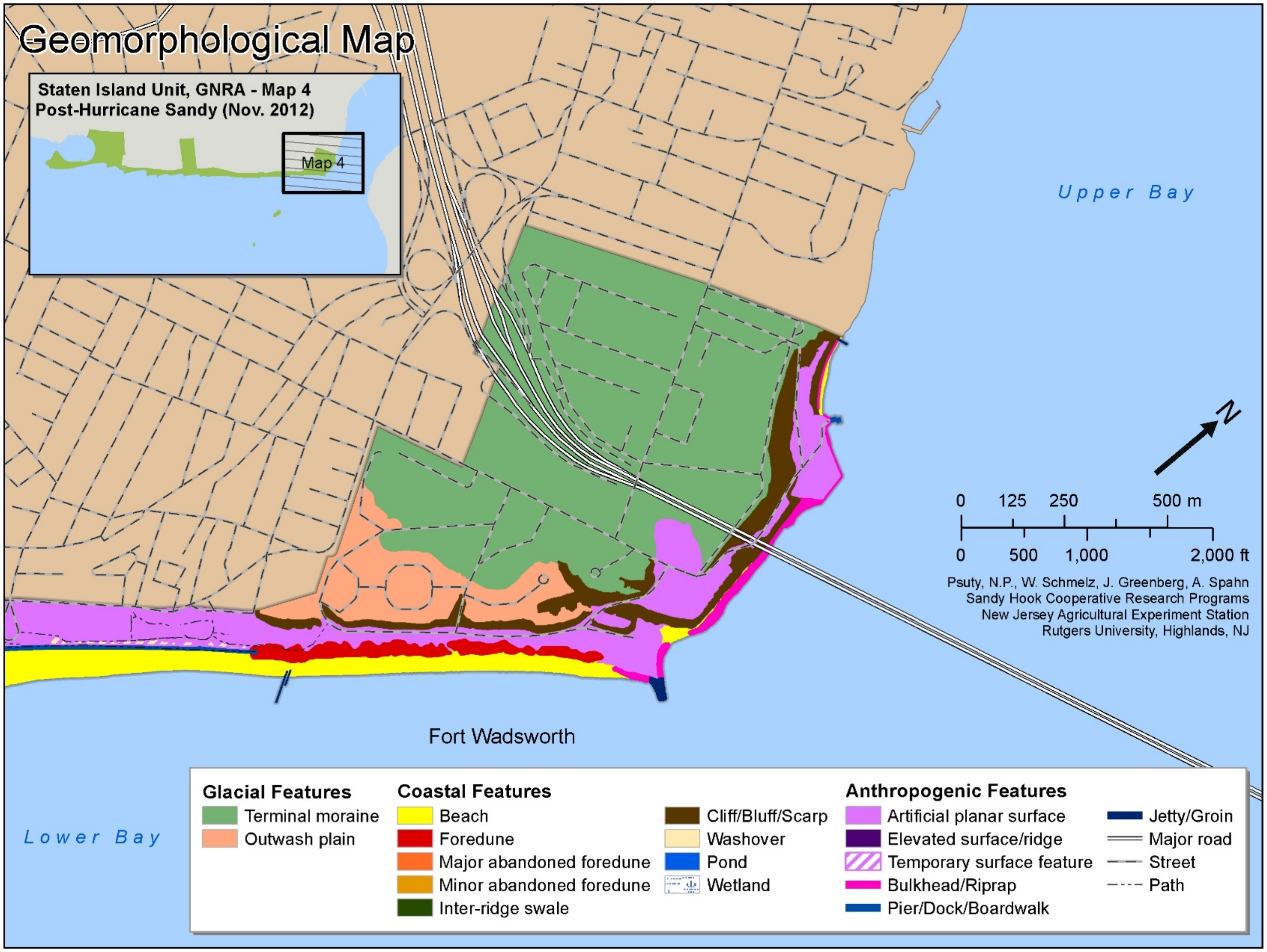
Wetland
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock/Boardwalk
Jetty/Groin
Major road
Street
Path


Geomorphological Map
Staten Island Unit, GNRA - Map 4
Post-Hurricane Sandy (Nov. 2012)
Map 4
Upper Bay
Lower Bay
Fort Wadsworth
N
0 125 250 500 m
0 500 1,000 2,000 ft
Psuty, N.P., W. Schmelz, J. Greenberg, A. Spahn
Sandy Hook Cooperative Research Programs
New Jersey Agricultural Experiment Station
Rutgers University, Highlands, NJ
Glacial Features
Terminal moraine
Outwash plain
Coastal Features
Beach
Foredune
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Cliff/Bluff/Scarp
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Anthropogenic Features
Artificial planar surface
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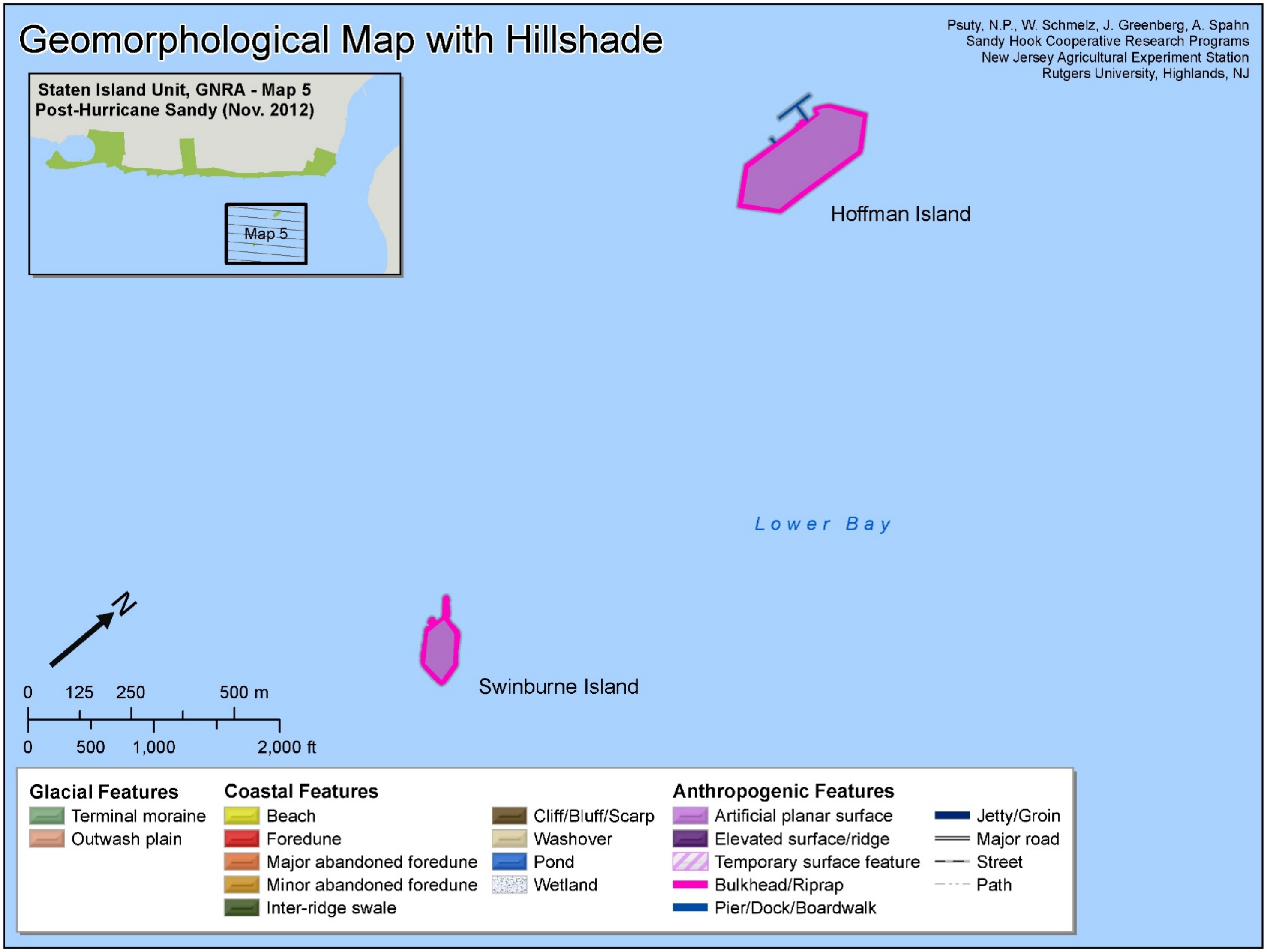
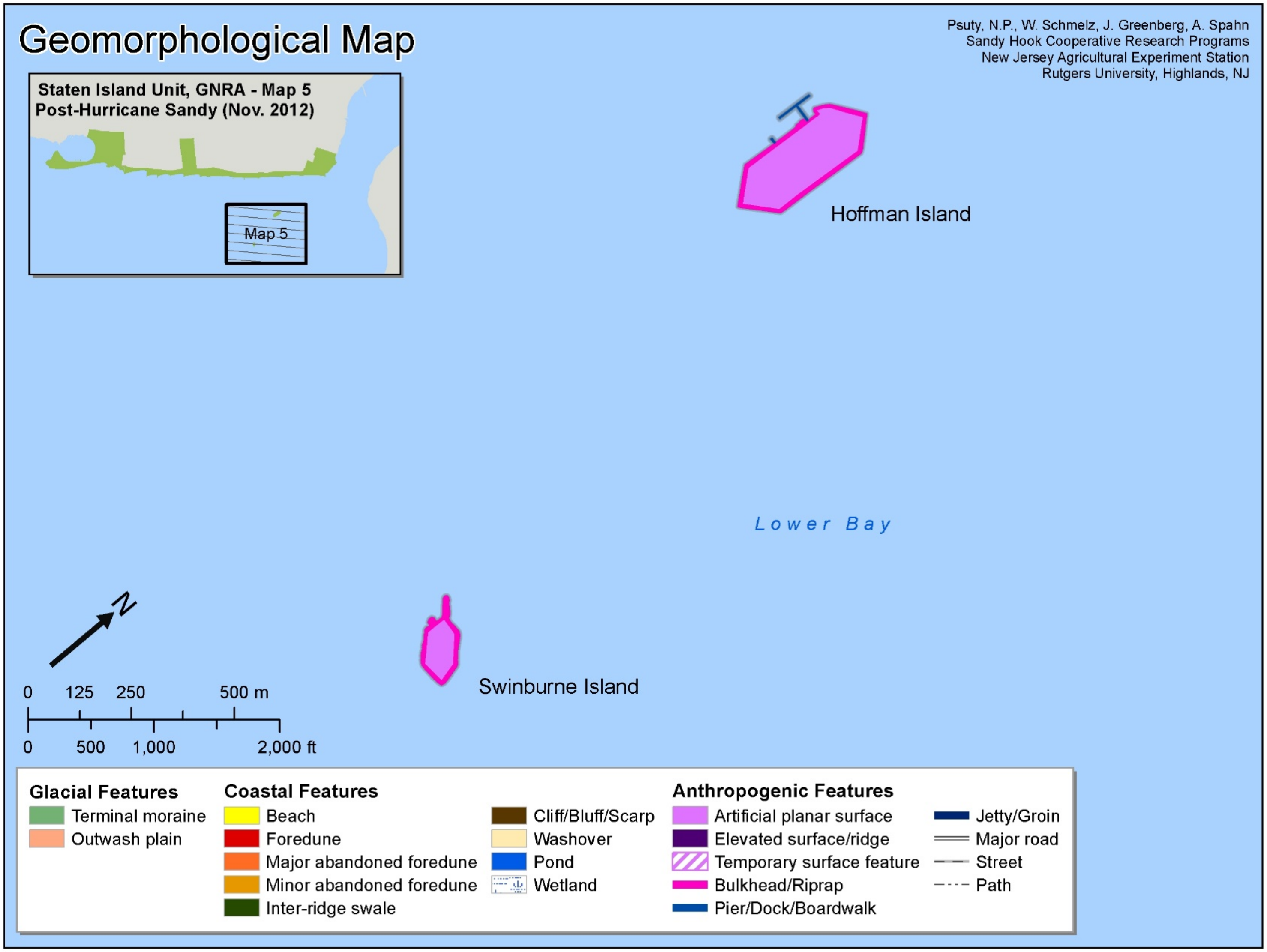
Major road
Street
Path



Geomorphological Map with Hillshade
Psuty, N.P., W. Schmelz, J. Greenberg, A. Spahn
Sandy Hook Cooperative Research Programs
New Jersey Agricultural Experiment Station
Rutgers University, Highlands, NJ
Staten Island Unit, GNRA - Map 5
Post-Hurricane Sandy (Nov. 2012)
Map 5
Hoffman Island
Lower Bay
Swinburne Island
N
0 125 250 500 m
0 500 1,000 2,000 ft
Glacial Features
Terminal moraine
Outwash plain
Coastal Features
Beach
Foredune
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Cliff/Bluff/Scarp
Washover
Pond
Wetland
Anthropogenic Features
Artificial planar surface
Elevated surface/ridge
Temporary surface feature
Bulkhead/Riprap
Pier/Dock/Boardwalk
Jetty/Groin
Major road
Street
Path


Geomorphological Map
Psuty, N.P., W. Schmelz, J. Greenberg, A. Spahn
Sandy Hook Cooperative Research Programs
New Jersey Agricultural Experiment Station
Rutgers University, Highlands, NJ
Staten Island Unit, GNRA - Map 5
Post-Hurricane Sandy (Nov. 2012)
Map 5
Hoffman Island
Lower Bay
Swinburne Island
N
0 125 250 500 m
0 500 1,000 2,000 ft
Glacial Features
Terminal moraine
Outwash plain
Coastal Features
Beach
Foredune
Major abandoned foredune
Minor abandoned foredune
Inter-ridge swale
Cliff/Bluff/Scarp
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Jetty/Groin
Major road
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Path

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National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science
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