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FINAL REPORT

BIRD-LONG ISLAND MANAGEMENT STUDY PHASE 1A: THE APPLICATION OF GEOSPATIAL TOOLS TO QUANTIFY SHORELINE CHANGE AND THE THREAT TO CULTURAL AND NATURAL RESOURCES ON BIRD-LONG ISLAND

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The objectives of this study were to evaluate the rates of shoreline change on Bird-Long Island, the threat to historic resources on the island, evaluate the potential for a living shoreline, and delineate the plant alliances currently present. The pertinent conclusions from this study are:

1. The shoreline database for Bird and Long island contains 16 digitized shorelines; live oysters, oyster shell ridges and low marsh scarps dominate the southern shore of the islands, whereas more significant eroding upland scarps and erosional features characterize the more energetic northern shoreline.
2. Change rates are rapid (1.4-3.3 m/y) on the north shore of Bird-Long Island and are relatively slow on the south channel shoreline (0.20-0.51 m/y) reflecting prevailing environmental energy.
3. Battery Hamilton, a civil war gun emplacement and historic structure, will begin undergoing erosion in approximately 23 years, and will be completely eroded away in approximately 186 years.
4. Oysters and other reef forming organisms would likely colonize a living shoreline or other intervention that would promote habitat and minimize excessive erosion.

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Final Report

BIRD-LONG ISLAND MANAGEMENT STUDY PHASE 1A: THE APPLICATION OF GEOSPATIAL TOOLS TO QUANTIFY SHORELINE CHANGE AND THE THREAT TO CULTURAL AND NATURAL RESOURCES ON BIRD-LONG ISLAND

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EXECUTIVE SUMMARY

The Georgia Department of Transportation has a long-standing interest in the history and fate of Bird-Long Island in the Savannah River, because this island functions as a mitigation bank to compensate for the Department's activities in other areas of the state, and there are civil-war historic resources located on the island. Further, this island represents a significant financial investment by the Department, and current rates of change are unknown. This study evaluates the current character of shorelines on Bird-Long Island, determines rates of shoreline change on Bird-Long Island, determines the threat to historic resources on the island (Battery Hamilton, a civil-war era gun emplacement, important in the bombardment of Ft. Pulaski), evaluates the potential for living shoreline stabilization, and delineates the plant alliances currently present. These studies are important in determining future paths for preservation of the island and its physical, biological, and historic resources. This study will provide information that is critical for planning for stabilization of shorelines, boosting the resiliency of island biological communities, and determining the threat to erosional loss of historic resources on the island.

The shoreline database for Bird-Long Island contains 16 digitized shorelines; live oysters, oyster shell ridges, and low marsh scarps dominate the southern shore of the islands, whereas more significant eroding upland scarps and erosional features characterize the more energetic northern shoreline. Along those shorelines, change rates are rapid (1.4-3.3 m/y) on the north shore of Bird-Long Island and are relatively slow on the south channel shoreline (0.20-

0.51 m/y) reflecting prevailing environmental energy. Battery Hamilton, where rates are similarly slow (0.1-0.4 m/y), given its location on the south shore of Bird and Long Island, will begin undergoing erosion in approximately 23 years, and will be completely eroded away in approximately 186 years. Spat-stick studies document that oysters and other reef forming organisms would likely colonize a living shoreline or other intervention that would promote habitat and minimize excessive erosion. A variety of plant alliances were documented on the island, most were indigenous vegetation with exotic species that require control if the area is used as a mitigation site. Salinity dieback of several woody species suggests an opportunity to proceed with vegetative management planning for this area.

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1.0 INTRODUCTION

Bird-Long Island is a dredge-spoil island located between the north and south channels of the Savannah River. This island contains cultural and natural resources important to the State of Georgia, and functions as a mitigation bank for Georgia Department of Transportation activities throughout the state. However, these natural and cultural resources are under threat from documented and ongoing sea level rise, shoreline change (i.e., erosion and accretion) from natural and anthropogenic causes, and land subsidence. Within a geospatial and geographic information system (GIS) context, this project sought to assess both physical and biological characteristics of Bird-Long Island. Physical parameters to be documented include physical character of the current shoreline, location of modern and historic shorelines, magnitude of historic shoreline changes. Based on this data we predict future changes of the shoreline and quantify the threat to natural and cultural resources from shoreline change. Other goals included an initial assessment of the potential for using living shorelines (i.e., oyster-based stabilization) and existing plant alliances to assess the potential for managing island ecosystems for future conditions. Further, we collaborated with physical oceanographers to understand the dynamic physical setting of Bird-Long Island, and with economic geographers and restoration practitioners to document the status of, and prepare recommendations for, protection of natural and cultural resources, and the island as a whole.

Based on a review of the existing databases, no peer-reviewed literature citations were returned specifically pertaining to the site. However, several references are pertinent to determining the impact of sea level rise and shoreline change on coastal areas to protect cultural and natural resources. Shoreline change data for the island is available in the Georgia Coastal Hazards Portal (gchp.skio.usg.edu; created by PI Alexander) but those data are only current to 2002. Alexander has performed numerous studies that assessed shoreline change in coastal Georgia at, for example, Ft. Pulaski (Alexander, 2008), Wassaw and Jekyll Islands (Langley et al., 2003), Cumberland Island (Jackson et al., 2007), along the AIWW (Alexander et al., 2011), in the rivers and salt marsh estuaries of Georgia (Alexander and Hladik, 2015; Alexander, 2016) and at various archaeological sites throughout the Georgia coastal zone (Alexander et al., 2008, 2011; Robinson et al., 2010). This last cited study, completed through extensive collaboration with the Georgia DNR Historic Preservation Division, examined the rates of shoreline change adjacent to cultural resource sites, to create a prioritized list for site documentation based on site life-span (Alexander et al., 2008, 2011). Some vegetative coverage information was available from Alexander and Hladik (2015), but no assessments of oyster recruitment had ever been conducted for this area.

Georgia's coast is generally presumed to be spat rich, however, a number of factors impact spat recruitment necessary for any proposed coastal intervention, such as a living shoreline. Water quality, salinity, velocity, erosion, deposition, and ground water are some of the factors that impact oyster recruitment and these factors are highly variable in the Savannah River at Bird-Long Island. However, scattered oyster reefs are present in the vicinity of the site and spat collection confirmed the availability of reef-forming organisms, such as oyster spat, at Bird-Long Island.

The major objectives of this project are as follows:

Objective 1: “Map the modern shoreline and shoreline character of Bird-Long Island”.

Objective 2: “Determine the historic character of shoreline change of Bird-Long Island.”

Objective 3: “Determine the detailed past and modeled future shoreline behavior, and archaeological life-span, of Battery Hamilton.”

Objective 4: “Provide vegetative mapping, including spatially representing plant alliances, and an assessment of oyster recruitment potential.”

2.0 METHODOLOGIES

2.1 Imagery

Historic imagery for this study was acquired for time periods from 1933 to 2016. Imagery includes National Ocean Survey (NOS) T-sheets, United States Geological Survey digital orthophoto quarter quadrangles (DOQQs), controlled aerial photography, IKONOS satellite images, and post-Hurricane Matthew (October, 2016) imagery acquired by the National Oceanographic and Atmospheric Administration (NOAA) Remote Sensing Division.

Additional historic aerial photographs were located using a coastal aerial imagery archive located at the Skidaway Institute of Oceanography (Skidaway). The scanned aerial images from 1970, 1972, 1983, and 1993 were registered and rectified using ArcGIS 10.1. Each scanned image was georectified using the

Chatham County compressed mosaic (IKONOS) imagery taken in 2008 as control. Between eleven and thirteen ground control points (GCPs) were selected from the 2008 imagery and root mean-square (RMS) values calculated and recorded to estimate horizontal accuracy.

2.2 Shoreline Determination

Three different methods were utilized to define shorelines (see Table 1). The National Ocean Survey (NOS) provided a 1933 digitized shoreline for the Georgia Coast through the NOS T-sheet archives. Shorelines from 1970 to 2016 were digitized onscreen in ArcGIS 10.1 using georectified images. During the process of digitizing shorelines from historical imagery, the high water line (HWL) or swash terminus, bluff toe, or marsh edge were selected as the primary indicators of shoreline position. The shoreline for each image was digitized at a scale of 1:1000 or larger and converted into an ESRI shapefile. The 2017 shoreline position (HWL, eroding bluffs, marsh scarps or marsh edge) was mapped with 50-cm accuracy using a Trimble Geo-XT equipped with a remote, high-sensitivity antenna. The north shore of Bird-Long Island consists mostly of sandy beach, firm marsh or upland and can be surveyed by walking along the shore at low tide. The South shore differs from the northern shoreline. It is a complex muddy marsh system interrupted by multiple small creeks that excludes a survey by foot. Therefore a tandem kayak was deployed to survey the South shore. The Geo-XT was affixed to the kayak and guided along the marsh edge at high tide. The remote antenna was perpendicularly offset about a meter on the starboard side of the kayak to enable following the shoreline without going aground. The Geo-XT data were converted into an ESRI shapefile. All shorelines were merged into a single shapefiles to enable AMBUR analysis of the data.

2.3 AMBUR Analyses

The AMBUR program (Analyzing Moving Boundaries Using R; Jackson et al., 2012) was employed to calculate shoreline changes and produce a variety of statistical data on shoreline change rates and variability. The program calculates shoreline change by measuring the positional differences between two or more digitized shorelines. These measurements were taken at transects cast perpendicular to the shore from a baseline at a spacing interval ranging from 2 to 20 m depending on the area of interest. For the analysis, the shoreline of Bird and Long was divided into south, north, and east shores. In order to capture shoreline change representative for Battery Hamilton, a separate fine-scale analysis was performed. Data output from AMBUR presented in this report details various parameters of shoreline change, e.g., the mean erosion and accretion rates, and number of erosional and accretional transects along each shoreline. It is extremely important to compare the calculated change rates with the change rate error for each analysis (see columns 3 and 4 in Table 2). Longer time periods have much lower error, because of the time elapsed between shoreline visualizations, whereas rates determined between two shorelines close in time have much higher errors (i.e., around Hurricane Matthew).

2.4 Reef-Forming Organisms

Oyster spat was collected on spat sticks placed in the South Channel of the Savannah River to collect spat from the first spawn, which usually occurs in April. Spat sticks are placed in the intertidal marsh zone at the same elevation as existing reefs to determine whether spat recruitment is occurring at that site. Specifically, three ¾" diameter one meter long sanded PVC pipes were inserted 40 cm into the marsh substrate prior to the April spawn and collected and replaced with fresh spat sticks at even intervals until October. The collected spat sticks were examined for visible spat.

2.5 Existing Vegetation

Soil moisture, conductivity, and temperature were measured using electroconductivity (EC, in mS per cm), recorded on Bird Long Island, near the extant magazine, and at other sites that were more easily accessible on Cockspur Island, also a dredge-formed island. Vegetation can only tolerate certain ranges of salinity, and species will decline and change if salinity increases. The NDVI (normalized difference vegetation index) from the ESRI (Environmental Systems Research Institute) ChangeMatters interface within ArcGIS was used to assess vegetative change. Remote sensing of the vegetation was conducted on Bird-Long Island for the marsh, based on previous classifications by Alexander and Hladik (2015). Additionally, eight points were accessed from boat to characterize plant communities in upland areas. These sites were selected based on signatures and textures present in the aerial imagery of the site.

3.0 FINDINGS

3.1 Modern shoreline and shoreline character

The shoreline database for Bird and Long island contains 15 historic shorelines derived from historic maps and charts, satellite imagery, and aerial photography, and one current shoreline, collected on the ground in 2017 (Figure 1; Table 1). These shorelines represent almost a century of change on this island and allow us to determine the changes over time on the island. Shoreline character has been mapped for the whole island and was described flowing the methodology of Alexander et al. (2011), which highlights the major components of the shoreline while indicating the biological and/or physical characteristics (Figure 2). Live oysters, oyster shell ridges, and low marsh scarps dominate the southern shore of the islands, whereas more significant eroding upland scarps and erosional features characterize the more energetic northern shoreline. Geospatial datasets of these shorelines will be provided as deliverables with this report.

3.2 Historic and future shoreline change of Bird-Long Island

AMBUR analyses show that 100 year rates are generally consistent over time, and shoreline processes are less energetic on the south channel of the Savannah River (Table 2). Shoreline character reflects the amount of energy inherent in each segment of the system and is similar to observations made throughout the AIWW and local tidal systems. The general nature of shoreline processes (i.e., erosion vs accretion) is illustrated in Figure 3. Shoreline change rates were assessed on long-term (1933-2017), mid-term (1972-2013), and short-term periods. The 2013 shoreline was used as the modern shoreline in our mid-term analysis to limit the effect of hurricane impacts on average rates. For short-term periods, we chose 2015-2016, a period that spans Hurricane Matthew to illustrate the impacts of a single major event, and chose 2015-2017, a period spanning Matthew but pre-Irma to illustrate recovery of the system. In general, rates on all these timescales are consistent. Change rates are rapid (1.4-3.3 m/y) on the north shore of Bird-Long Island and are relatively slow on the south channel shoreline (0.20-0.51 m/y) reflecting prevailing environmental energy. Rates are also very rapid on the eastern end of the island, which has traditionally been a rapidly eroding connection to Cockspur Island. A breach formed there in 2008 and continues to widen at rates of 2.4-2.8 m/y. In most cases, annualized rates were 2-3 times more rapid in the year spanning the impact of Hurricane Matthew, illustrating that single events can produce rates of retreat larger than normal rates within a region. Average rates for larger shoreline sections have returned to slower, long-term rates in the subsequent year after that event. However, the rate of retreat of erosional shoreline sections only has remained elevated for almost two years, suggesting that further work is necessary to determine how long these elevated rates persist. Future shorelines, created by projecting long-term shoreline change rates into the future using the AMBUR tool, are shown for 25 and 50 year projections in Figure 4. Geospatial datasets of these shorelines will be provided as deliverables with this report.

3.3 Detailed past and modeled future shoreline behavior, and archaeological life-span, of Battery Hamilton

Battery Hamilton was examined in detail (2-m spacing of transects) to generate a more detailed knowledge of the future for this historic site (Figure 5 and Table 2). As on the south shoreline in general, change rates are relatively slow (0.07-0.51

m/y) reflecting low prevailing environmental energy. Average rates for the shoreline section directly adjacent to the battery did not change a statistically significant amount over the Hurricane Matthew period and have been relatively consistent over time. In general, the rates are more erosional in the NW and SE sections of the assessed shoreline and lowest in the middle of the section assessed. Future shorelines, created by projecting long-term shoreline change rates into the future, are shown for 25 and 50 years projections in Figure 6. Currently, the channelward boundary of the site is 10 m from the shoreline, and the inshore boundary is 82 m from the shoreline. Using the long-term erosion rate for the site (-0.44 m/y), it will begin undergoing erosion in approximately 23 years and will be completely eroded away in approximately 186 years. If we use the somewhat faster erosion rate that characterizes just the erosional transects since the hurricane (-0.63 m/y, Table 2), those times would be 16 and 130 years, respectively, for beginning erosion and total loss of the site. Geospatial datasets of these shorelines will be provided as deliverables with the final report.

3.4 Broadly characterizing reef-forming organism source availability

Although the spat sticks were washed out during Hurricane Irma, evidence from early in the summer pointed toward spat establishment at Bird-Long Island's southern shore and suggests a living shoreline is feasible. The spat sticks placed in the south channel showed spat settlement ranging from 2-20 per stick, which is low and consistent with other findings by others during this time period (Wisner, 2018). Recovered spat sticks showed oyster settlement at Battery Hamilton (Site 2) and further east near Cockspur (Site 1), but not on the western end of the island (Site 3) as indicated below in 2017 (Table 3).

Scattered oyster reefs and oyster spat recruitment were documented in the vicinity of Bird-Long Island. Oysters and other reef forming organisms would likely colonize a living shoreline or other intervention that would promote habitat and minimize excessive erosion. Permitting of these activities is required and almost no structures have been permitted in the marshland area below the line of jurisdiction in Georgia, while thousands of projects occur in the states adjacent to Georgia. Investigating if a King's Grant rights were conveyed with the purchase of Bird-Long would be useful in the permitting process.

3.5 Characterizing existing vegetation with existing and new data

Historic vegetation analysis illustrated the upland vegetation is decreasing on the north shore of the island while the remainder of the island was static based on changes in NDVI (Figure 7). A variety of plant alliances were documented on the island, most were indigenous vegetation with a few exotic species that require control if the area is used as a mitigation site. Notable indigenous species included a large Black Cherry (*Prunus serotina*) and large Live Oak (*Quercus virginiana*) that presumably have occupied the site for a long time. Salinity dieback of several woody species, such as Live Oak, exists in several areas and a soil sample from the site confirmed high soil salinity, which suggests an opportunity to proceed with vegetative management planning for this area.

The management plan needs to account for factors and responses to extreme climatic events and subsidence. Possible interventions should be reviewed to increase the resiliency of Bird-Long Island and may include vegetative management, placement of thin layering (or at least experiment with beneficial dredge material), and interventions to minimize excessive erosion based on existing research (See complementary study of Haas, GDOT Project 16-34, for details of physical energetics of the Bird-Long Island site).

An ESRI shapefile with metadata providing an inventory of preliminary plant alliances based on recently collected, remotely sensed photogrammetry for Bird-Long Island is available online at the Georgia Wetlands Restoration Access Portal:
(http://geospat.gatech.edu/arcgis/rest/services/Wetlands/Marsh_Cover/MapServer).

Marshland vegetation classification was completed based on work by others and verified in the field. Upland vegetation was categorized into alliances based on eight data points along ~3.5 miles of coastline. Convenience sampling of upland vegetation was performed based on aerial signatures. The island is mostly anthropogenic and many indigenous species colonized the island. A few exotic species are present and require maintenance to suppress and remove if the site is proposed for mitigation.

Two vegetative transects were taken at Battery Hamilton and registered with LiDAR to better understand plant species distribution and communicate findings (Figures 10, 11). These transects provided a survey of the plant communities growing atop and surrounding the remains of Battery Hamilton. Several 4x8” timbers are buried under the salt marsh surface, left from a powder magazine. Transect 1 was located by the monitoring wells, which demarcate them. The brackish water covers the timbers most of the time (see mean sea level), creating an anaerobic environment where decomposition time is much longer. Transect 1 crossed the front left corner of the ruins, and the midpoint of the magazine. Transect 2 lies several meters southeast. Though it does not traverse Battery Hamilton, it represents the surrounding vegetation types. The cross sections, taken from a 2009 LiDAR survey as a DEM in ArcMap, are exaggerated five times vertically to better represent the slight changes in topography that could be causing the gradient of dominant plants seen through the transect. As with most salt marsh communities, Spartina is the dominant genus. Spartina alterniflora grows in patches of low, medium, and high heights, while Spartina patens—typically a high marsh species—also appears. A few patches of Baccharis halimifolia are present among Iva fructescens, and an area of bare ground/wrack indicates especially high salinity.

Illegal dumping, trash collection, and removal of inert material that has been deposited is also required. Examples include several hundred 12 volt batteries deposited near the extant pier on the eastern end of the island on the North Channel, pressure treated wood and other marine debris. These items require removal and monitoring in the impacted areas.

Preservation of the island and its cultural and natural resources will require a management plan that seeks to create a resilient system based on the many external factors that may impact the island. Factors include, but are not limited to, sea level rise, increased variability in climatic events, longer dry periods, subsidence, and increased erosion in unprotected areas.

4.0 CONCLUSIONS

1) Shoreline change rates along Bird-Long Island shorelines are rapid (1.4-3.3 m/y) on the north shore and are relatively slow on the south channel shoreline (0.20-0.51 m/y) reflecting prevailing environmental energy. Episodic events (i.e., hurricanes; Hurricane Matthew was captured in our study window) dramatically alter the steady-state system and increase change rates, on both the north and south shores. Change rates remain elevated for at least two years (the duration of our dataset, ended prior to Hurricane Irma). Within that time frame, shoreline change rates do not show a tendency to return to long-term averages.

2) Using AMBUR forecasting tools, we predict that Battery Hamilton, where shoreline change rates are low (0.1-0.4 m/y), in line with its location on the south shore of Bird-Long Island, will begin undergoing erosion in approximately 23 years, and will be completely eroded away in approximately 186 years.

3) Spat-stick studies document that oysters and other reef forming organisms would likely colonize a living shoreline or other intervention that would promote habitat and minimize excessive erosion.

4) A variety of plant alliances exist on the island. Most were indigenous vegetation with exotic species that require control if the area is to be used as a mitigation site. Salinity dieback of several woody species suggests an opportunity to proceed with vegetative management planning for this area.

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Appendix 1

Tables

Table 1: Sources of shoreline data used in this analysis and accuracy of each source.

Year	Method	Accuracy (m)
1933	NOS T-Sheet Shoreline	6.1
1970	Digitized using Aerial Photography	1.51
1972	Digitized using Aerial Photography	1.57
1976	Digitized using Aerial Photography	5
1983	Digitized using Aerial Photography	1.50
1984	Digitized using Aerial Photography	5
1987	Digitized using Aerial Photography	6.1
1993	Digitized using Aerial Photography	1.25
1999	Digitized using Aerial Photography	5
2002	Digitized using Aerial Photography	5
2004	Digitized using Aerial Photography	5
2008	Digitized using Aerial Photography	5
2013	Digitized using Aerial Photography	5
2015	Digitized using Aerial Photography	5
2016	Digitized using Aerial Photography	5
2017	Trimble GPS (Geo-XT)	0.50

Table 2: Summary table of shoreline change rates for Bird-Long Island and Battery Hamilton. N.D. indicates "no data" because no accretion transects were present along the shoreline being considered.

Shoreline	Time Period	Mean Shoreline Change Rate (m/yr)	Shoreline Change Rate Error (m/yr)	Overall Mean Change (m)	Number of Transects	Erosion Transects	Accretion Transects	Erosion Transects (%)	Accretion Transects (%)	Mean Erosion Rate (m/yr)	Mean Accretion Rate (m/yr)
Bird/Long - N. shore	1933 to 2017	-1.39	0.07	-111.84	333	333	0	100.0	0.0	-1.39	N.D.
Bird/Long - N. shore	1972 to 2013	-1.93	0.13	-79.16	333	333	0	100.0	0.0	-1.93	N.D.
Bird/Long - N. shore	2015 to 2016 (post-Matthew)	-1.92	3.99	-3.40	333	242	91	72.7	27.3	-3.38	1.97
Bird/Long - N. shore	2015 to 2017 (post-Matthew/pre-Irma)	-3.29	1.96	-8.57	333	301	32	90.4	9.6	-3.74	0.94
Bird/Long - S. shore	1933 to 2017	-0.20	0.07	-16.59	312	216	96	69.2	30.8	-0.35	0.13
Bird/Long - S. shore	1972 to 2013	-0.41	0.13	-16.90	312	309	3	99.0	1.0	-0.42	0.07
Bird/Long - S. shore	2015 to 2016 (post-Matthew)	-0.51	3.99	-0.91	312	195	117	62.5	37.5	-1.41	0.99
Bird/Long - S. shore	2015 to 2017 (post-Matthew/pre-Irma)	-0.48	1.96	-1.25	312	221	91	70.8	29.2	-0.90	0.53
Bird/Long - E. shore	1933 to 2017	-2.62	0.07	-102.77	59	59	0	100.0	0.0	-2.62	N.D.
Bird/Long - E. shore	1972 to 2013	-2.40	0.13	-62.76	59	59	0	100.0	0.0	-2.40	N.D.
Bird/Long - E. shore	2008 to 2017	-2.80	0.53	-26.89	59	59	0	100.0	0.0	-3.79	N.D.
Bird/Long - E. shore	2015 to 2016 (post-Matthew)	-3.77	3.99	-6.69	59	45	14	76.3	23.7	-5.52	1.85
Bird/Long - E. shore	2015 to 2017 (post Matthew pre Irma)	-2.57	1.96	-6.67	59	44	15	74.6	25.4	-3.66	0.64
Battery Hamilton	1933 to 2017	-0.07	0.07	-5.60	42	42	0	100.0	0.0	-0.07	N.D.
Battery Hamilton	1972 to 2013	-0.44	0.13	-17.94	42	42	0	100.0	0.0	-0.44	N.D.
Battery Hamilton	2015 to 2016 (post-Matthew)	-1.03	3.99	-1.83	42	39	3	92.9	7.1	-1.12	N.D.
Battery Hamilton	2015 to 2017 (post-Matthew/pre-Irma)	-0.44	1.96	-1.15	42	31	11	73.8	26.2	-0.63	N.D.

Table 3: Summary table of with average spat number and density at three sites detailed in narrative. Site 2 is Battery Hamilton and illustrates a living shoreline may be colonized by reef forming organisms.

Date and Site	Average of # spat	Average of density m^2 (low)	Average of density m^2 (high)
6-Jun 2017			
1	0.00	0.00	0
2	0.25	3.05	3.57
3	30.00	366.00	428.4
13-Jul 2017			
1	0.00	0.00	0
2	11.67	142.33	166.6
3	87.50	1067.50	1249.5

Appendix 2

Figures

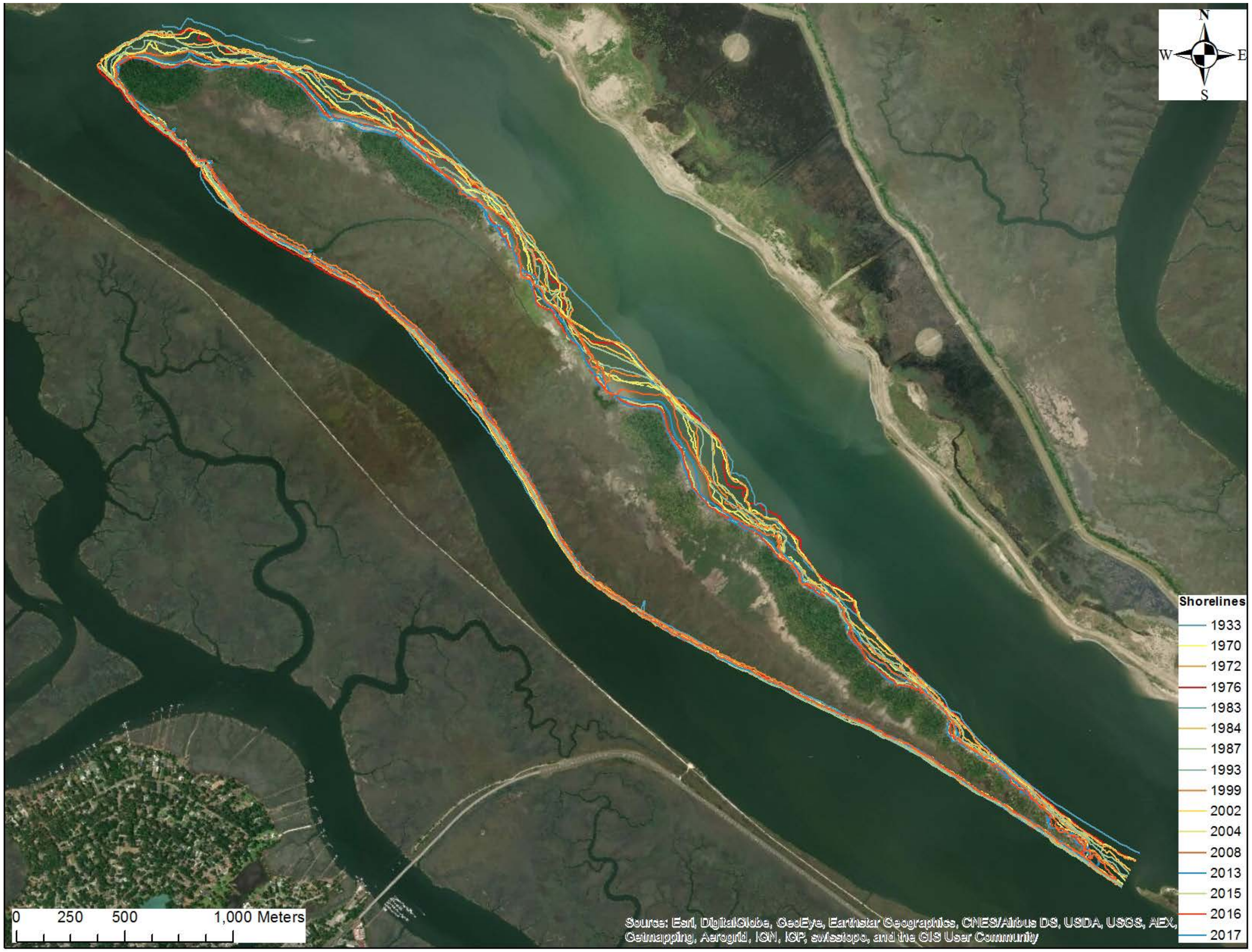

Figure 1: All shorelines for Bird-Long Island used in this study.

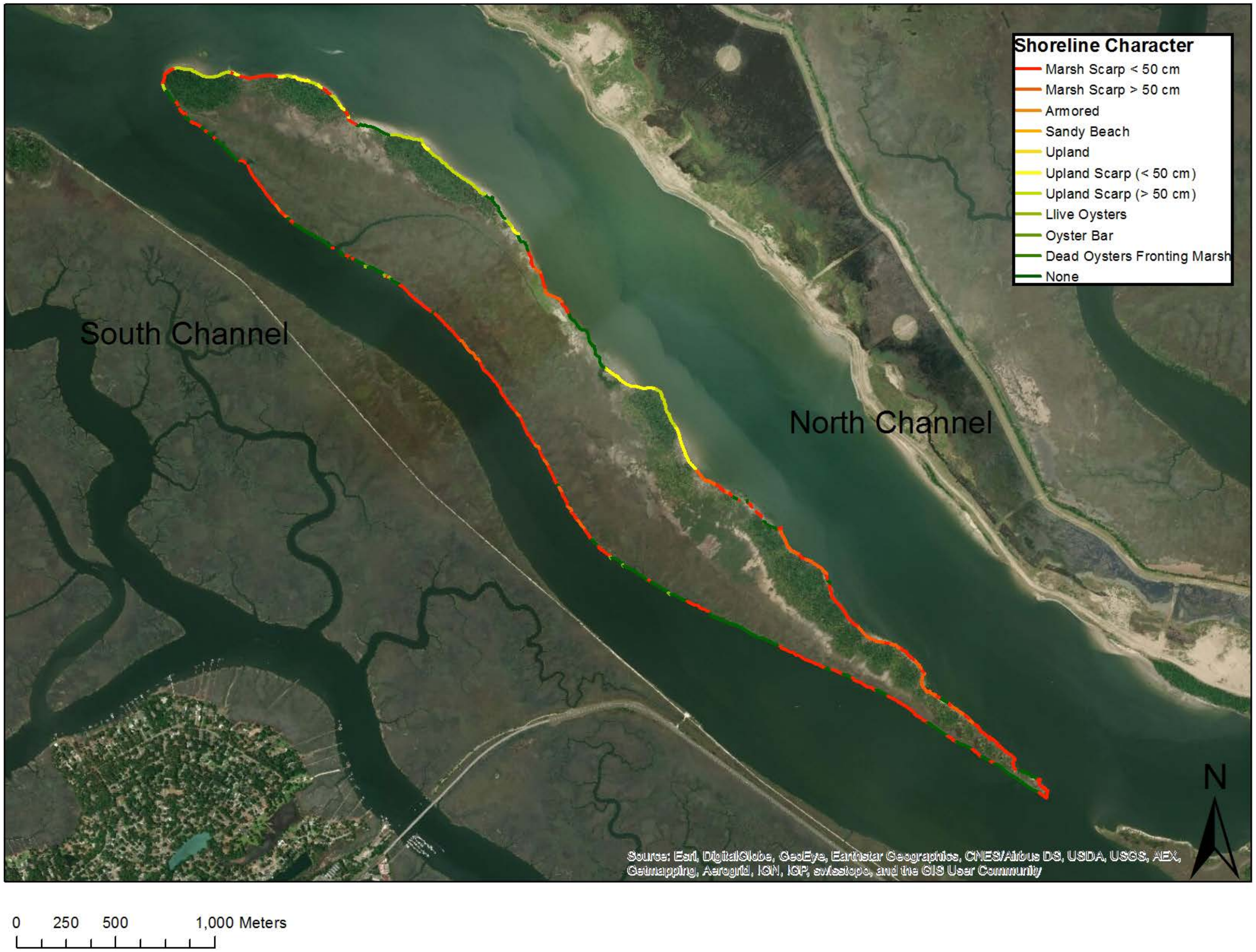

Figure 2: Shoreline characterization of current conditions on Bird-Long Island from video surveys.

Figure 3: General character of shoreline change on Bird-Long Island. Red indicates erosion and blue indicates accretion. Length of line shows distance of shoreline movement from 1933 to 2013 and is a proxy for shoreline change rate.

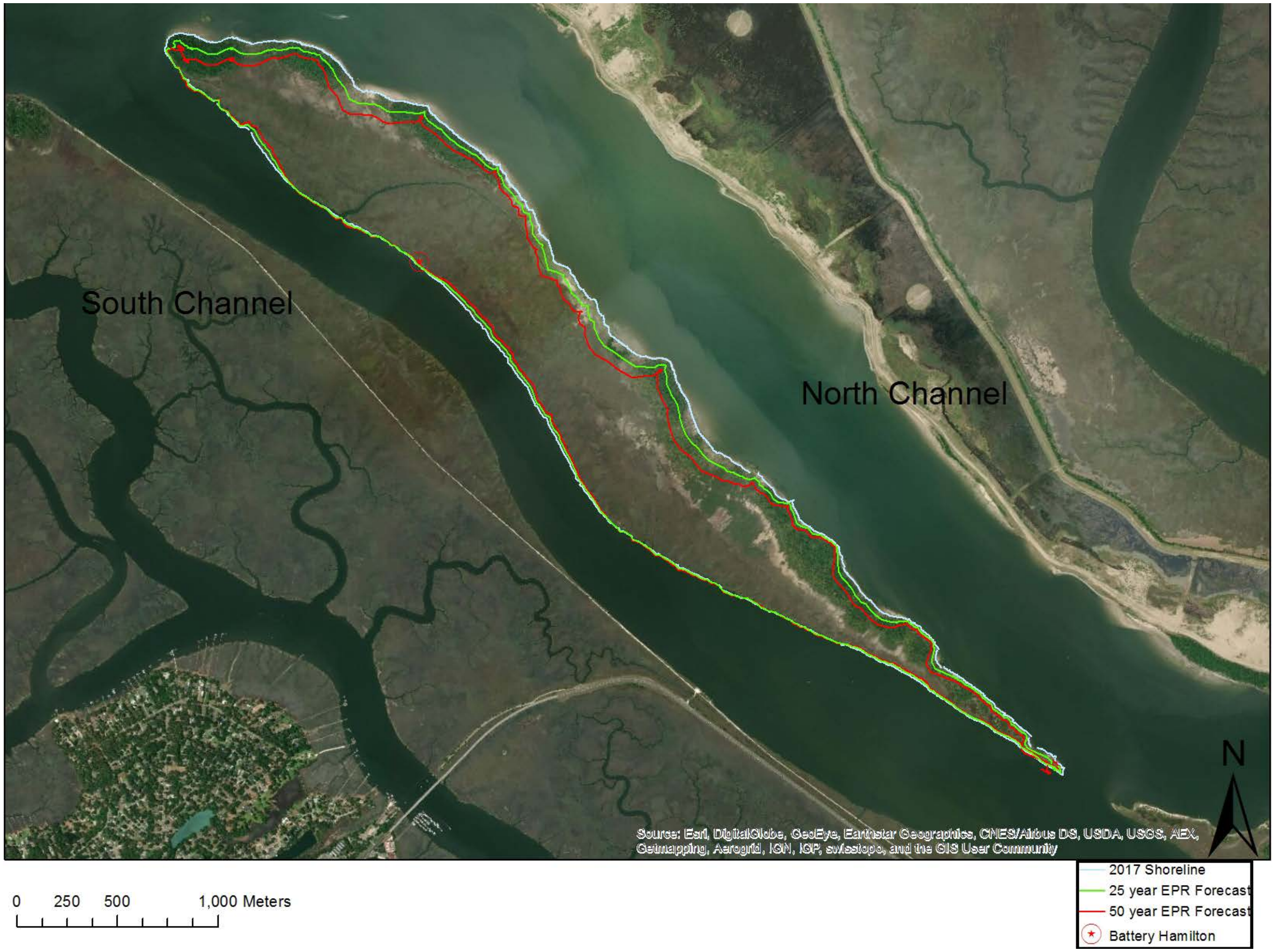

Figure 4: Projected 25 and 50 year future shorelines for Bird-Long Island.

Figure 5: Character of shoreline change at Battery Hamilton. Red indicates erosion and blue indicates accretion. Length of line shows distance of shoreline movement from 1933 to 2013.

Figure 6: Projected 25 and 50 year future shorelines for Battery Hamilton.

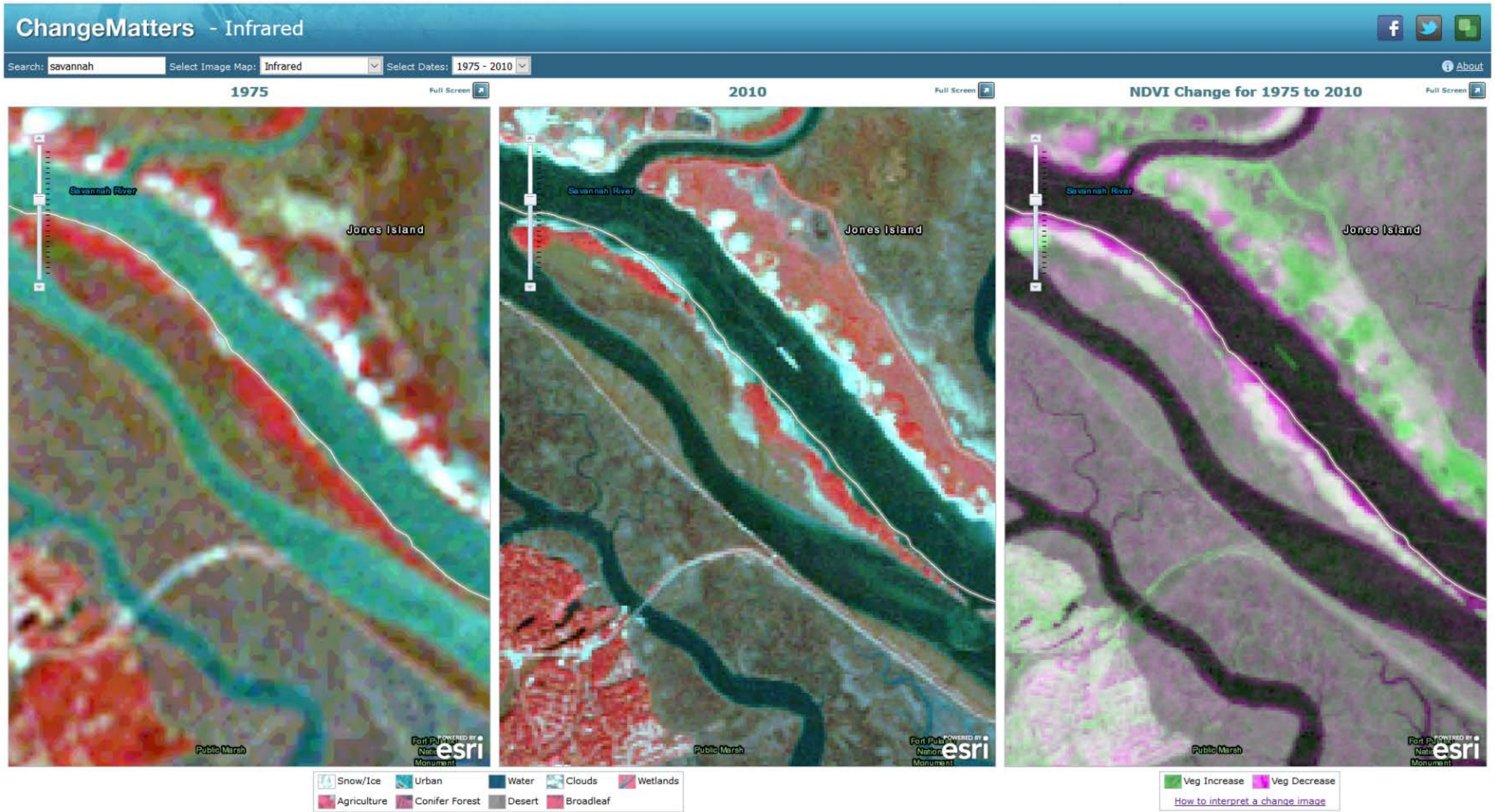

Figure 7: NDVI Change from 1975 to 2010. Notes: Vegetative loss is exhibited on north shore of Bird-Long Island with little appreciable vegetative gain on majority of island. Source: ESRI Change Matters.

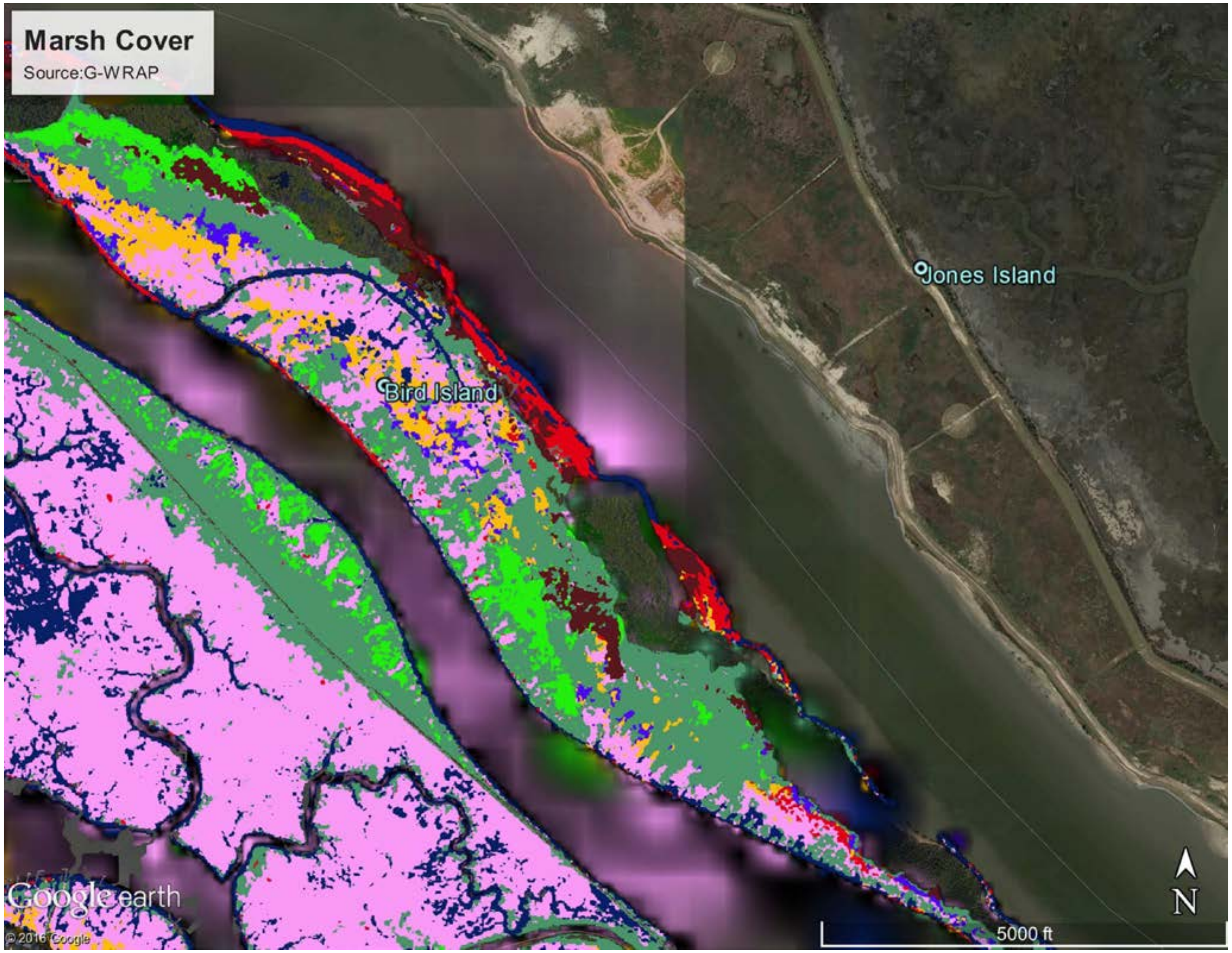

Figure 8: Classification of marsh alliances. Notes: Vegetative alliances were mapped using remote sensing. (Source: Hladik et al., 2012)

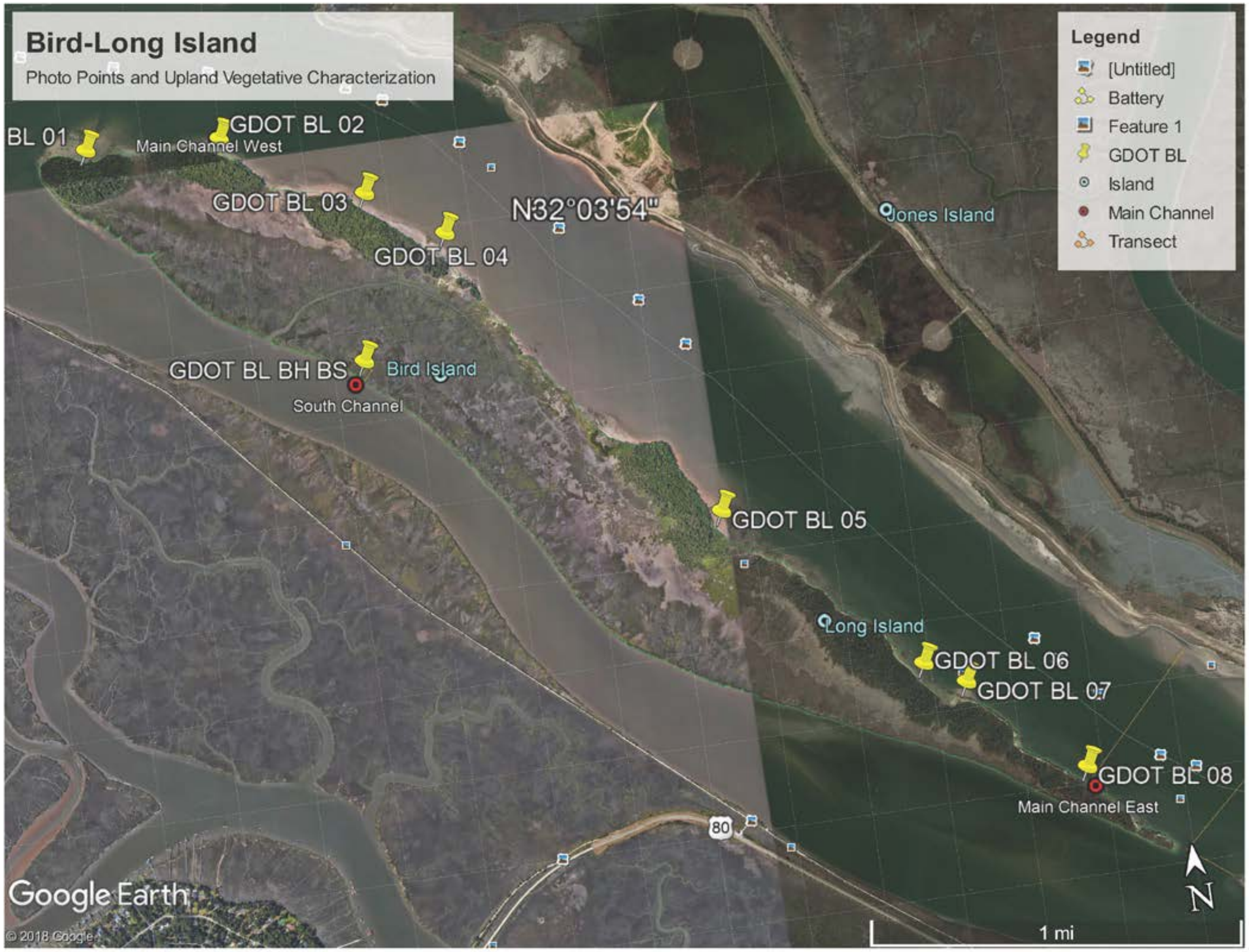

Figure 9: Bird Long Island Upland Vegetation Characterization Points. Notes: Upland vegetative alliances points based on imagery signatures. Source: Google EarthPro and G-WRAP Portal.

Figure 10: Bird Long Island Upland Vegetation Transects locations at Battery Hamilton.

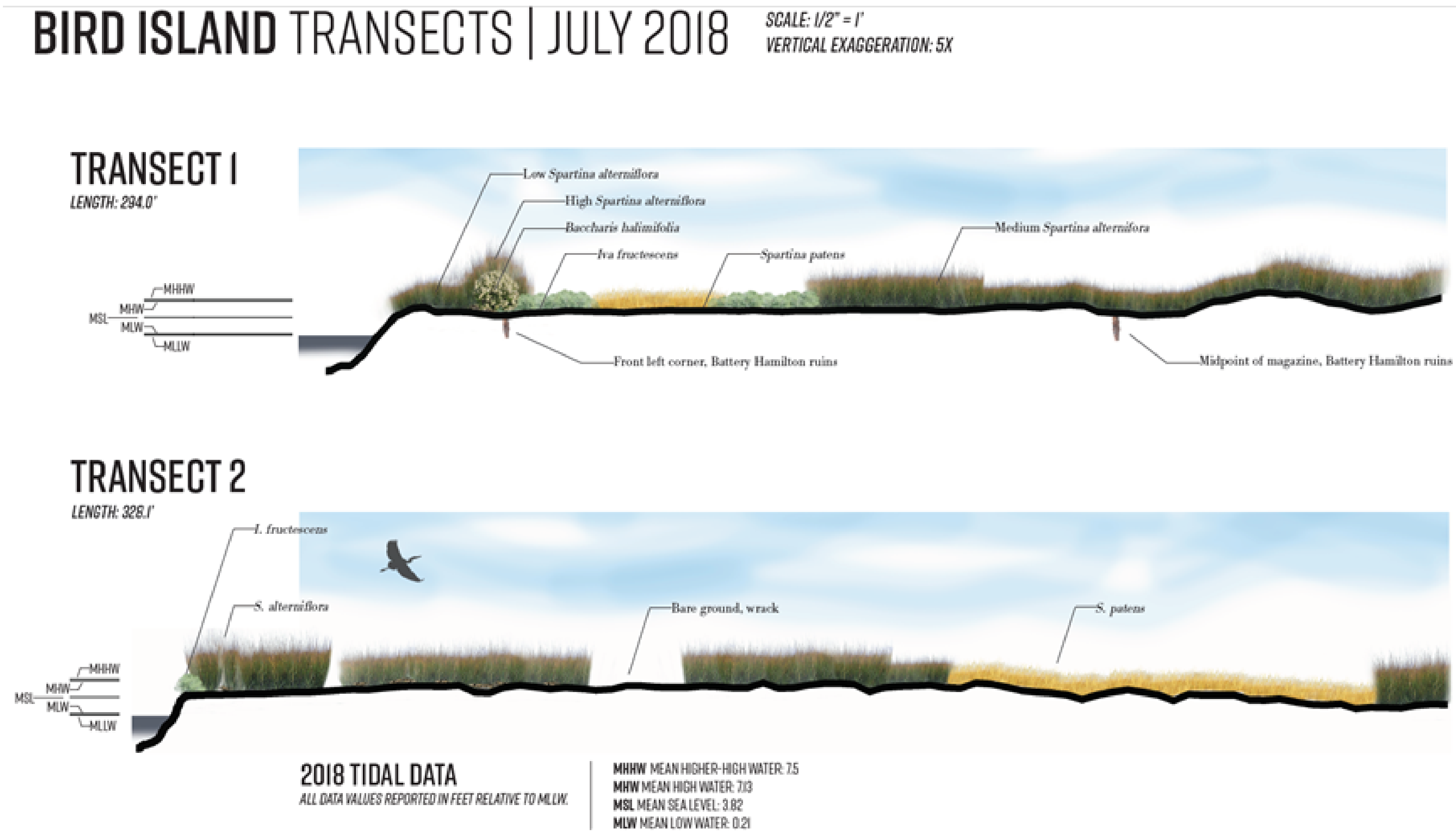

Figure 11: Bird Long Island Upland Vegetation Transects showing south channel of the Savannah River to the left.