W00344

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Ocean Survey

DESCRIPTIVE REPORT

Type of Survey:	External Source Data
Registry Number:	W00344

LOCALITY

State(s):	Georgia
General Locality:	Savannah, GA
Sub-locality:	Wassaw Sound

2014

Georgia Department of Natural Resources

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Date:

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

REGISTRY NUMBER:

HYDROGRAPHIC TITLE SHEET

W00344

INSTRUCTIONS: The Hydrographic Sheet should be accompanied by this form, filled in as completely as possible, when the sheet is forwarded to the Office.

State(s):	**Georgia**
General Locality:	**Savannah, GA**
Sub-Locality:	**Wassaw Sound**
Scale:	**10,000**
Dates of Survey:	**April 2014 to August 2014**
Project Number:	**OSD-AHB-17**
Data Source:	**Georgia Department of Natural**
Chief of Party:	**Resources Clark Alexander**
Soundings by:	**single beam, interferometric**
Imagery by:	**side scan sonar**
Verification by:	**Atlantic Hydrographic Branch**
Soundings Acquired in:	**Meters at Mean Lower Low Water**

Remarks: ***The purpose of this survey is to provide contemporary surveys to update National Ocean Service (NOS) nautical charts. All separates are filed with the hydrographic data. Any revisions to the Descriptive Report (DR) generated during office processing are shown in bold red italic text. The processing branch maintains the DR as a field unit product, therefore, all information and recommendations within the body of the DR are considered preliminary unless otherwise noted. The final disposition of surveyed features is represented in the OCS nautical chart update products. All pertinent records for this survey, including the DR, are archived at the National Centers for Environmental Information (NCEI) and can be retrieved via https://www.ncei.noaa.gov/.***

DESCRIPTIVE REPORT MEMO

April 02, 2018

MEMORANDUM FOR: Atlantic Hydrographic Branch

FROM: Dr. Clark Alexander, Skidaway Institute of Oceanography
Chief of Party, Georgia Department of Natural Resources

SUBJECT: Submission of Survey W00344

This survey was conducted for sea floor mapping purposes. This report was generated by AHB on behalf of the Chief Scientist, as this document will be published and available at NCEI.

Vertical beam echo sounder data, interferometric data, and horizontal laser scanner data was submitted as XYZ data and imported creating point cloud data. All point cloud data sets were referenced in creating the source bathymetric grids for chart update. No raw data was submitted.

Soundings were reduced to Mean Lower Low Water (MLLW) using VDATUM models.

The survey deliverables as submitted did not include data acquisition and processing information. The submitted academic report lists the methods for corrector application. Based on the report, all data were corrected with all applicable methods.

There were no DTONs created for this survey.

This report was prepared by Dr. Clark Alexander, Skidaway Institute of Oceanography, under grant award # NA13NOS4190114 to the Georgia Department of Natural Resources from the Office of Ocean and Coastal Resource Management, National Oceanic and Atmospheric Administration.

This survey will be used to update NOAA navigational products where possible.

The survey is partially adequate to supersede previous data. This survey will be used to update NOAA navigational products where possible.

Metadata for Survey W00344	
Project	OSD-AHB-17
Survey	W00344
State	Georgia
Locality	Savannah, GA
Sub-Locality	Wassaw Sound
Scale of Survey	1:10000
Sonars Used	EdgeTech 4600 (Interferometric) Ohmex Sonarmite (SBES) Riegl VZ-1000 (Lidar)
Horizontal Datum	North American Datum of 1983 (NAD83)
Vertical Datum	Mean Lower Low Water
Vertical Datum Correction	VDatum
Projection	Projected UTM 17
Field Unit	Georgia Department of Natural Resources
Survey Dates	04/01/2014 - 08/31/2014
Chief of Party	Clark Alexander, Skidaway Institute of Oceanography
Submission Date	09/21/2017

Final Report to the Georgia Department of Natural Resources
Coastal Incentive Grant Program

Improving Habitat Classification, Hazard Mitigation and Navigation in Coastal Georgia with a State-of-the-Art Bathymetric Sonar System

November 4, 2014

This report was prepared by Dr. Clark Alexander, Skidaway Institute of Oceanography, under grant award # NA13NOS4190114 to the Georgia Department of Natural Resources from the Office of Ocean and Coastal Resource Management, National Oceanic and Atmospheric Administration. The statements, findings, conclusions, and recommendations are those of the author(s) and do not necessarily reflect the views of DNR, OCRM or NOAA.

Background and Approach

The bathymetry, or underwater depth, throughout a coastal region is a critical dataset that impacts many facets of coastal environmental and hazard management. Without a knowledge of depth, the US Army Corps of engineers cannot accurately model hurricane storm inundation, coastal fisheries biologists cannot effectively identify and manage essential fish habitat as required by the Magnuson-Stevens Act, and boaters cannot safely transit our State's recreational waters. The need for managers to identify and manage essential fish habitat is particularly critical, and almost impossible to do without the sort of site-specific data that will be provided by this study. This importance has manifested itself in a government-funded series of mapping campaigns that have produced bathymetric data for coastal regions throughout the United States. The last time the bathymetry of coastal Georgia was mapped comprehensively was in the 1930s. These old datasets for most of the sounds in Georgia have been converted to digital datasets. Given the energetic physical environment and anthropogenic activities over the past 80 years, it is unreasonable to assume that any of the bathymetric data for the Georgia coast, outside of that for the Brunswick and Savannah harbors, is reasonably accurate.

This project focused on addressing this critical need for up-to-date bathymetry in coastal Georgia by taking a state-of-the-art, Edgetech 4600 bathymetric sonar system recently acquired by the Skidaway Institute of Oceanography for use on the 90' RV Savannah, and developing its use in estuaries and sounds. One of the advantages to this system is that it collects both bathymetry and sidescan (bottom roughness and character) data simultaneously. Together, these datasources are a powerful combination for evaluating benthic habitats. The goals of this project were to successfully deploy the system from the RV Jack Blanton, a 28' research vessel owned by Skidaway Institute, by constructing an appropriate sonar mount for the vessel and to use it to collect a comprehensive bathymetric dataset for Wassaw Sound, as a proof-of-concept for the technique, which can be applied to other estuaries and sounds to update bathymetry in coming years.

Once the new mount was installed and the system was tested successfully, bathymetric data were collected throughout Wassaw Sound. Mapping included Wassaw Sound, Wilmington River, Romerly Marsh Creek, Tybee Cut, Half Moon River and Bull River. Mosaics of bathymetry, bottom character and benthic habitat were created for use in GIS software by DNR and other stakeholders, and for delivery to the public through the Georgia Coastal Hazards Portal (GCHP). These new data were compared to older work in Wassaw Sound (Alexander et al., 1995, 1997) to leverage earlier insights in support of better habitat mapping. In addition, recently available digital sounding data from a 1994 NOAA survey of Wassaw Sound provided the opportunity to assess sediment dynamics and sediment volumetric changes over the past 20 years in a very dynamic coastal environment, by comparison with the data collected in this current assessment of bathymetry, bottom character and benthic habitat in Wassaw Sound.

Generalized Wassaw Sound Survey Methods

Bathymetric soundings, sidescan sonar imaging, and sediment grain size data collection were conducted for Wassaw Sound, Wilmington River, Bull River, Tybee Cut, Half Moon River, and Romerly Marsh Creek in Chatham County, Georgia to accurately map bottom topography and habitat type (Figure 1). The project area covers 36 km^2. Three methods of field data collection and one existing dataset were utilized to efficiently acquire bathymetric data across a range of depth conditions and environments within the study area (Figure 2). Swath bathymetry was collected using a 230 kHz Edgetech 4600 interferometric sonar on over 30 survey missions (completed in April 2014) for all major channels and areas where water depths exceeded 2-3 meters MLLW. Single beam echosounder data were collected using a 200 kHz Ohmex Sonarmite echosounder over 13 survey missions (July-August 2014) in shallow areas where water depth was less than 2-3 meters MLLW. Topographic laser (i.e., LiDAR) data were collected using a Reigl terrestrial laser scanner over 2 survey missions (April 2014) for expansive shallow shoals that were exposed at spring low tides. Existing digital elevation model (DEM) data from Chatham County, Georgia, derived from airborne LiDAR data acquisition and supplied by Chatham County SAGIS, was incorporated along the flanks of the intertidal region for creating final bathymetric maps. All swath bathymetric data were processed in Hypack/Hysweep software. Single beam, terrestrial lidar and airborne lidar datasets were combined with the swath bathymetric data in ARCGIS 10.1 to create the final bathymetric surface (Figure 3; see Appendix 1 for detail maps).

Co-registered sidescan sonar data were collected contemporaneously with swath bathymetry data (Figure 4). Because the sidescan sonar data are collected during the swath bathymetry campaigns using the same instrument, no sidescan data were collected in areas too shallow for swath bathymetry surveys. Sediment data from grain size samples collected during this project were merged with existing grain size datasets from previous studies within the project area (Figure 5, Table 1; Alexander et al., 1995, 1997; National Ocean Service, 2013). These grain size data were integrated with sidescan backscatter mosaics to develop the bottom character map of Wassaw Sound (Figure 6). Regions of similar reflectivity observed in the sonar imagery dataset were auto-extracted using Geocoder, a bottom classification program within Hypack, and ground-truthed using the physical sample data.

Description of Field Instrumentation

Swath Bathymetry and Sidescan Imaging

Swath bathymetry and sidescan sonar data were collected with a 230 kHz Edgetech 4600 interferometric sidescan sonar and topside processor, providing co-registered simultaneous side scan and bathymetric data. To achieve high quality hydrographic survey data from a small vessel, the sonar transducer array and equipment must have a solid and precise mounting platform that provides significant stability for the equipment as well as the capacity for

Figure 1: Map of Wassaw Sound Survey area.

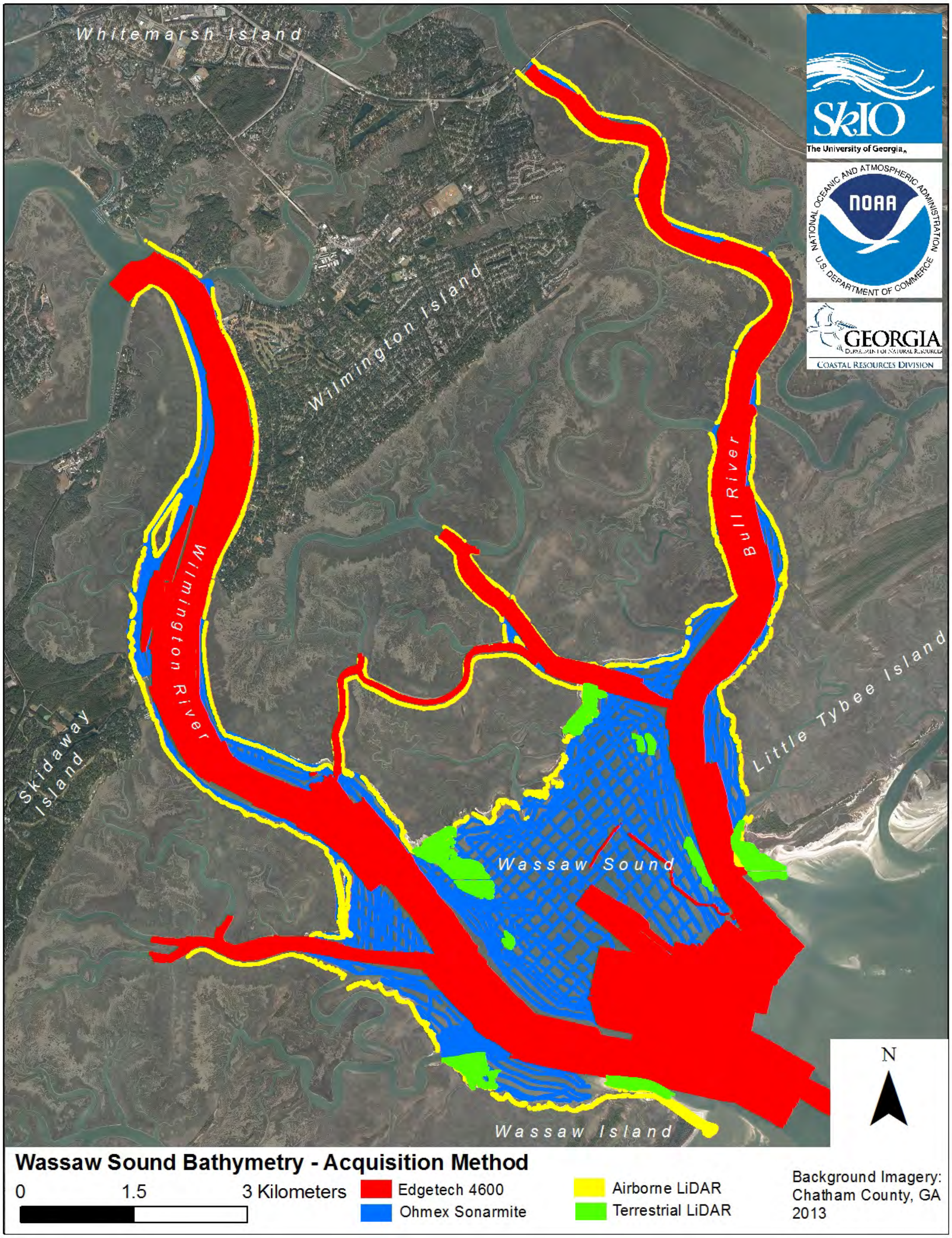

Figure 2: Map depicting the areas covered by different mapping methods in Wassaw Sound survey area.

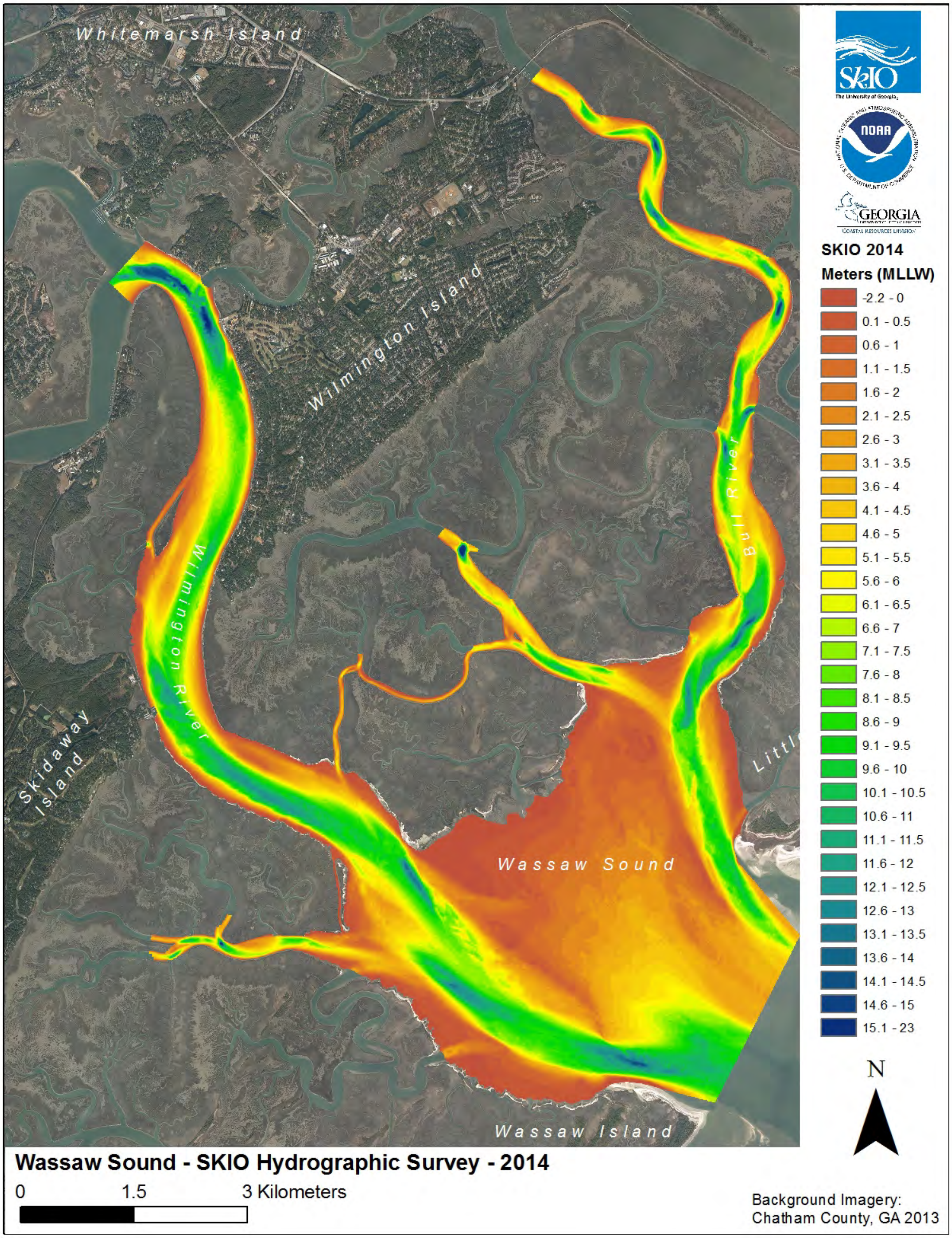

Figure 3: Final composite bathymetric surface for the Wassaw Sound survey area.

Figure 4: Sidescan sonar mosaic for Wassaw Sound survey area.

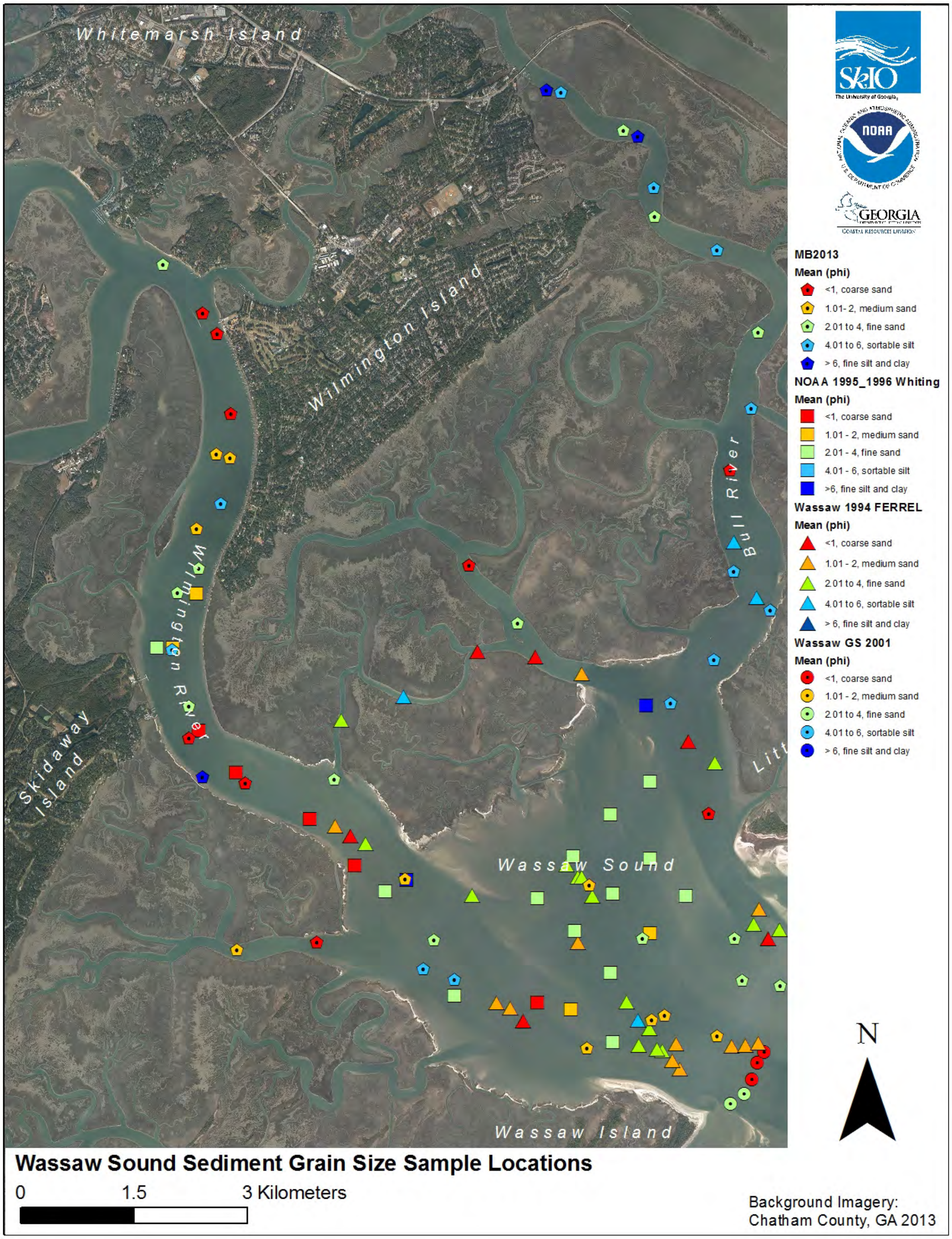

Figure 5: Location and grain size results for sediment samples used to develop bottom character map of the Wassaw Sound survey area. Note that samples include those from the Alexander et al. (1995, 1997) Wassaw Sound benthic habitat mapping studies.

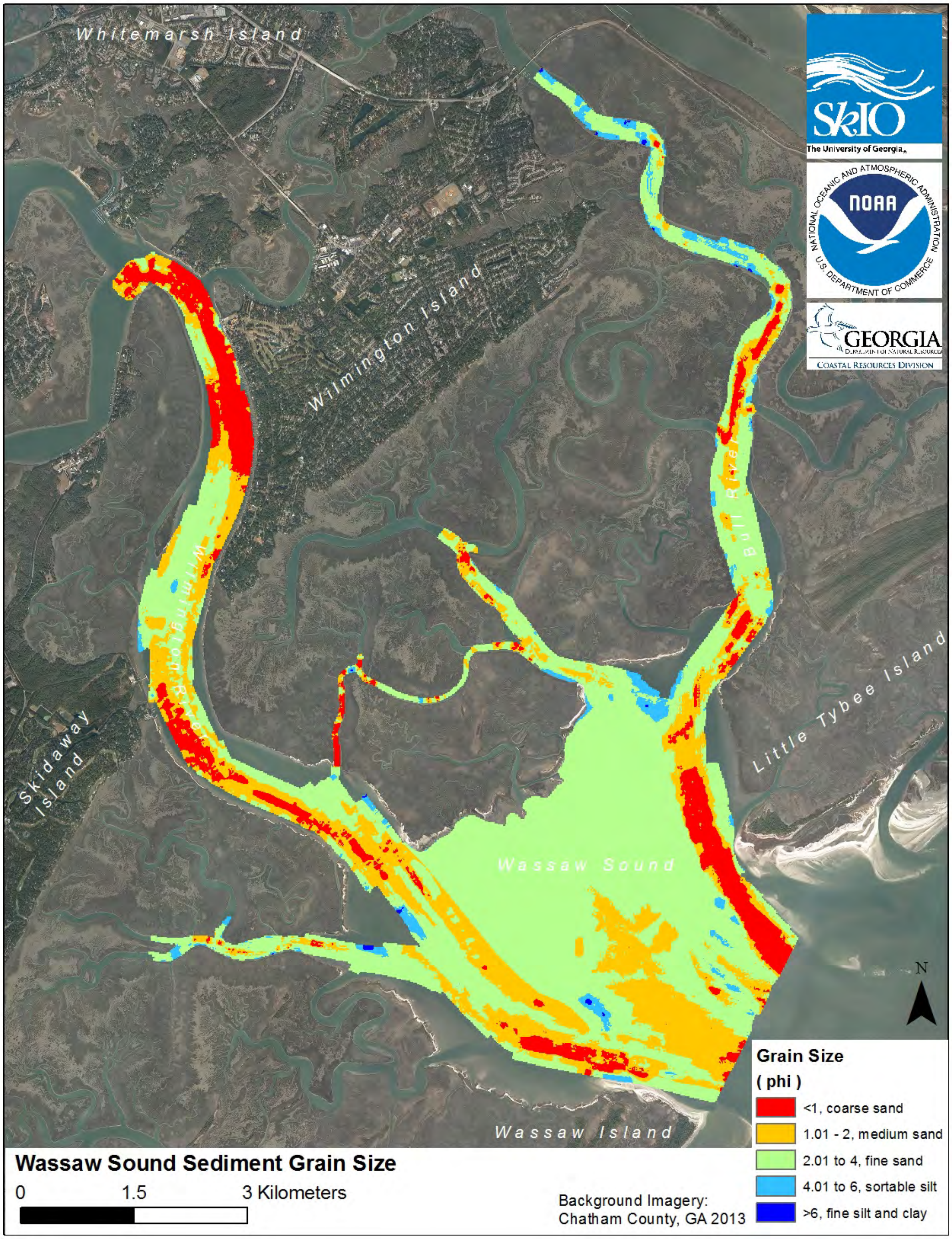

Figure 6: Bottom character map of Wassaw Sound survey area. Coarser sediments are observed in major channels and open sound areas. Note that Bull River exhibits finer bottom sediments in its upper reaches when compared to the larger Wilmington River.

adjustment in the field. Because every vessel is unique in layout and configuration, custom design and fabrication was necessary to create an appropriate mounting platform for the survey mission. The Skidaway Institute machine shop fabricated a stainless steel pedestal, even with the gunwale, on the port side of the Skidaway Institute of Oceanography's 28 foot Parker, the R/V Jack Blanton (Figure 7A). The pedestal supported the mounting plate for an adjustable depth, fixed pole, which could be rotated fore and aft to stow the sonar when transiting between survey areas. The 4-m pole and associated adjustable mounting plate was purchased from Applied Marine Systems and was customized to accommodate the Edgetech 4600 mounting bracket and the combination power/data cable connecting the sonar to the topside computer. Skidaway Marine Operations provided and installed a manual davit on the aft port quarter of the vessel to assist in rotating the sonar and fixed pole between horizontal and vertical positions.

Bathymetric surveying requires multiple screens to display the many data streams monitored by the survey crew and pilot to assure data quality. The Edgetech 4600 topside computer and multiple monitors were installed along the port side of the vessel cabin on a custom-designed survey station designed and built by Mike Robinson. Accurate hydrographic surveys require multiple positioning data streams in order to process the correct spatial location of sounding data. A dual antenna, Trimble SPS 461 RTK GPS receiver was used to provide both position and vessel heading data streams. The cabin-top mount for the dual antenna system was designed and installed on the RV Blanton by the Skidaway Institute machine shop. A cell phone modem connected the RTK-GPS receiver to a subscription-based, real-time Virtual Reference Network (eGPS, Inc.) to provide real time kinematic (RTK) correction data to the GPS receiver. The RTK correction data allows sub-decimeter horizontal and vertical antenna precision and allowing for real-time tide-height corrections to be measured and integrated into the data as it was collected. A motion reference unit (MRU) is a critical part of a swath bathymetric data collection system because it removes the negative effects of ship heave, pitch, and roll from the sensor readings. Vessel motion data was provided by a SMC IMU-8 MRU and was mounted inside the cabin near the vessel centerline on a custom-fabricated base plate. An AML Minos-X sound velocity profiler collected data for correcting acoustic ray refraction during surveys because of velocity differences within the water column.

Single Beam Bathymetry

Single beam echosounder data was collected using a 200 kHz Ohmex Sonarmite echosounder, side mounted on the Skidaway Institute of Oceanography's 20 ft. Carolina Skiff, the R/V Sandpiper, and a 16 ft. Carolina Skiff, the R/V Sandflea. Positioning for the single beam data was provided by a Trimble R6 RTK-GPS using the eGPS VRS for real time kinematic positioning and tide height correction data (Figure 7B). The sonarmite is a portable system that connects the transducer, RTK-GPS sensor and survey controller via Bluetooth communications protocols.

Figure 7. A) The Skidaway Institute of Oceanography's R/V Jack Blanton shown with the Edgetech 4600 sonar system mounted on the port side. B) Ohmex Sonarmite echosounder deployed on port side of Skidaway Institute of Oceanography's R/V Sandflea. Note RTK-GPS antenna on pole for real-time tide corrections and position.

LiDAR

Terrestrial LiDAR surveys were conducted using a Riegl VZ-1000 3D terrestrial laser scanner and a Trimble R8 RTK-GPS. The Reigl scanner utilizes a near infrared laser to construct high resolution 3D morphology based on XYZ measurements recorded by the sensor and is capable of mm to cm accuracy between repeat scans. The XYZ point cloud from a typical scan contains millions of data points, providing high resolution scanning products. The advantage of using the terrestrial LiDAR scanner is that repeat scans over time can provide data for determining 2D and 3D (volumetric) changes, although that is not currently planned for Wassaw Sound.

Data Collection Methods

Swath Bathymetry and Sidescan Surveys

Surveys were planned using target matrix boxes and planned track lines created using Hypack, Inc.'s Hypack 2013 hydrographic software (Figure 2). Matrix boxes were approximately 1.5 km in length and were designed to allow straight segments for the planned lines as much as possible. Planned-line spacing varied between 15 m and 40 m to provide 50-100% bathymetric swath overlap and was determined based on the existing charted depths of the survey area. Sound velocity casts were collected at the start of each survey mission and approximately every 2 hours thereafter or whenever the survey changed matrix location. The Edgetech 4600 sonar was controlled using Edgetech Discover software interfaced with Hypack Hysweep software. To ensure complete bottom coverage without compromising resolution, side scan data was collected with a 100 m swath width. In a few instances in shallow water, a side scan swath width of 25 m was used.

Project geodesy was configured within the Hypack software. The survey data were collected with distance and depth units in meters, coordinate system UTM Zone 17 North, vertical datum NAVD88 using Geoid Model 2012au0, and ellipsoid WGS 84. RTK-GPS was used within Hypack to calculate and incorporate real-time tide values. Charted depths were adjusted to mean lower low water (MLLW) using NOAA VDatum 3.3 where available (National Oceanic and Atmospheric Administration, 2014a) and displayed as soundings (i.e., with positive numbers indicating increasing water depth). The majority of the survey area was within a VDatum zone. Survey areas outside the boundary of the VDatum zone were adjusted to MLLW with a user defined value of 1.1m, following data trends in adjacent VDatum zones.

The width of the bathymetry data swath is dependent on water depth (i.e., the deeper the water the wider the swath). Survey missions were planned for days when high tide was predicted during the middle of the day to maximize survey efforts. Areas of shoals were surveyed during the higher range of the tide and deeper channels were surveyed at lower tide stages. The bathymetry swath was monitored and evaluated in real time during the survey to maintain adequate overlap between survey lines and to identify any potential problems in the data. Because of wave heights and sea conditions outside the operational parameters of our motion reference unit, we were unable to collect good data during much of the period between October to February. Where ship motion artifacts were observed in survey data either while on the ship or in post-processing, the survey lines were run again on a day with better sea conditions.

Single Beam Bathymetric Surveys

Planned lines for single beam surveys were produced using ArcGIS10.1 software and loaded as ESRI shapefiles into a Trimble TSC2 survey controller datalogger. The areas for single beam echosounding were the shallow shoals and channel flanks outside the operational range of the swath bathymetry system. Data were collected as depth applied elevations in meters relative to NAVD88 in the survey controller software and converted to soundings relative to MLLW in post-processing.

LiDAR Surveys

The terrestrial LiDAR scanner was deployed during two hour intervals bracketing low tide. Laser surveys were conducted when predicted astronomical low (negative) spring tides subaerially exposed as much of the shoals as possible (Figure 2). Both the laser's frame and line resolutions were set to 0.04 degrees creating an XYZ point spacing of approximately 7 cm at 100 m distance. Data was collected up to 1.4 km from the scanner based on a laser pulse repetition rate of 70 kHz. Additionally, atmospheric corrections were made to compensate for temperature and humidity conditions present each day of scanning. For each scan, five-cm cylinder reflector targets were placed around the scanner and georeferenced with either a Trimble R6 or R8 RTK-GPS system to enable merging sequential laser scans. Data were collected as elevations in meters relative to NAVD88 and converted to soundings relative to MLLW in post-processing.

Sediment Sampling

Samples for grain size analysis and benthic character were collected during several cruises using a ponar grab sampler (Figure 5). Pre-existing samples used in this study were collected in 1994 (NOAA ship Whiting), 1995-1996 (NOAA ship FERREL) and 2001 (Skidaway Institute RV Blue Fin). A final set of samples were collected specifically for this project in 2014 (Skidaway Institute RV Sand Piper) to ensure complete sample coverage of the surveyed area. A total of 125 stations were analyzed for this study. Observations of sediment type, obvious biota and distinctive characteristics were noted during sample collection.

Data Processing Methods

Swath Bathymetry and Sidescan

The swath bathymetry and sidescan data were processed with HYPACK hydrographic software, which creates [.hsx] files that contain both data sets. Bathymetry data collected with the Edgetech 4600 sonar was edited and processed by matrix area using Hypack Hysweep 64-bit editor software. Sound velocity profiles, vessel device offsets, patch test adjustments, and geodetic parameters were automatically incorporated with associated survey line files during editing. Each line was evaluated by sweep profile and gridded surface to manually edit the data and trim obviously noisy outer beam soundings. Co-registered side-scan sonar imagery was used to aid in sounding evaluation. Edited matrix areas were exported as .xyz files with point spacing between 1-3 meters. The Hypack TIN Editor was used to generate matrix surfaces to further evaluate the data and highlight areas of interest.

Sidescan data processing was performed using a combination of HYPACK sidescan targeting and mosaicing (SSTM), a module provided within HYPACK, and GEOCODER (64 bit, version 13.0.2.0), a software product that was developed at the University of New Hampshire and that is now licensed, maintained and provided by HYPACK. SSTM provides better tools for bottom tracking; each line was first inspected and processed in SSTM. Each line was then saved as an [.hs2] file before being loaded into GEOCODER. Before processing the data in GEOCODER, a digital terrain model (DTM) was created from bathymetry data for use in analyzing the sonar data. With the DTM a more precise analysis of sidescan backscatter is possible. Without a DTM, GEOCODER will assume that the bottom is flat; with a DTM, however, the influence of bottom morphology can be taken into account. Time variable gain (TVG) and slant range corrections are automatically applied by GEOCODER. Angle varied gain (AVG), a method that considers beam angle rather than range or across-track offset, was set to "Trend" to make use of the DTM; all other default options, including filters, remained at default values. Finally the sidescan sonar data were mosaicked at 0.10 m resolution and exported as a georeferenced [.TIF] image (Figure 4). All georeferenced sidescan [.TIF] images were imported into ArcGIS 10.1 and visually analyzed for bedforms or other significant features. A zoom level between 1:500 and 1:2500 was maintained to ensure a consistent image interpretation. Measurement tools provided within ArcGIS were used to determine length and width of bedforms and other features.

GEOCODER not only generates mosaics of side scan data, it also characterizes the sea floor in terms of mean grain size using angular response analysis (ARA) (Figure 6). For this process, unedited [.hsx] files were added to the DTM and mosaicked at 0.10 m resolution. Characteristic patch areas about 50 m in length, where sediment grain size data were also available, were identified in each matrix. Subsequently, the beam pattern, the sonar's signature in the backscatter that is used to calibrate the bottom type for a selected patch, was extracted and the beam patterns were calibrated to the known mean grain sizes. Finally an ARA analysis was performed on the mosaic for each matrix using the calibrated beam pattern. Data were exported as XYZID files, converted into [.txt] files in a text editor, and imported into ArcGIS 10.1. In ArcGIS, projected classifications were compared to the known grain size from the sample stations. The ARA analysis was repeated using different patch areas and representative grain sizes to get the best fit to the whole dataset. The final GEOCODER grain size benthic character map for each survey matrix was exported as a [.shp] file. All [.shp] files were merged and converted to a single raster with a 15 m resolution.

Single Beam Bathymetry

Data collected with the Ohmex Sonarmite echosounder was downloaded daily from the data collector and imported into ArcGIS 10.1 software as individual survey mission point shapefiles. The elevation values were converted to sounding values relative to MLLW (i.e., with positive numbers indicating increasing water depth). The datum adjustment for the points used the same VDatum zones and user defined offsets as the swath bathymetry data. After all surveys were complete, daily survey mission files were merged to generate a comprehensive single-beam survey point shapefile.

LiDAR

Individual XZY point clouds from separate laser scans were imported and processed within RiSCAN Pro (v.1.7.8) to create a final XYZ georeferenced point cloud that contains all of the point clouds merged together.

Point elevation data for the marsh border surrounding the project area was extracted from a LiDAR-derived DEM of Chatham County, Georgia provided by the County. The elevations were converted from feet to meters and adjusted to the MLLW vertical datum.

Combined Bathymetric Data

Soundings data from the three survey methods and from the marsh perimeter LiDAR was combined using ArcGIS 10.1 software. The [.xyz] files from the Edgetech sonar, Ohmex sonar, terrestrial LIDAR scanner, and aerial LiDAR were converted to point shapefiles. A 3 m x 3 m cell-size, gridded surface of the project area was generated using the ArcGIS 3D Analyst Topo to Raster function, a gridding program designed for creating hydrographic surfaces. A polygon shapefile representing the perimeter of the project area was used as an analysis boundary for the gridding application.

Sediment Samples

All sediment samples were wet-sieved through a 63 µm sieve to separate the coarse fraction, (sand and gravel; larger than 63 µm), from the mud fraction (silt and clay; smaller than 63 µm). The mud fraction was captured in a graduated cylinder for further analysis. The coarse fraction was then dried and sieved through stacked sieves starting at -1 phi (2 mm) to separate gravel (larger than 2 mm) from sand (2 mm - 63 µm) at 0.5 phi (NOAA samples) and 0.25 phi (Skidaway Institute samples) intervals. The percentage of mud in the total sample was quantified by taking an aliquot from the graduated cylinder, which was subsequently dried. If sufficient quantities of mud existed (>10% by weight), the silt and clay grain-size distributions were determined with a Micromeritics Sedigraph 5100. If the sample contained <10 % mud, an additional aliquot was taken to quantify the percent silt and clay in the sample. Grain size frequency distribution, mean grain size and modal diameter were derived from these data.

Results

Wassaw Sound Bathymetric Map

The three survey data sources were integrated into a 3 m x 3 m gridded surface map representing the bathymetry of the project area (Figure 3). Sounding values (i.e., values get larger as water gets deeper) range from -2.2 m to 23 m referenced to MLLW with a mean sounding value for the survey area of 4.3 m. General bathymetry of the project area exhibits deeper scours and depressions along the outside bends of channels and at intersections with converging channels. In major channels (e.g., Wilmington and Bull Rivers) deeper channel thalwegs are partitioned by shallow cross-channel shoals, creating a "chutes and pools" morphology. Shallow shoals are also typically located along channel flanks, inside the bends of channels, and across the broad ramp forming the center of Wassaw Sound. The Wilmington River area exhibits a very complex bottom topography in the reach adjacent to Turners Creek (Figure 8). The deepest regions within the project area are located in channel confluence scour depressions in Wilmington River near Turners Creek, Half Moon River (Figure 9), and Romerly Marsh Creek. The shallowest regions of the survey area are located along the western edge of Wassaw Sound adjacent to Cabbage Island, along the southern flank of the Bull River as it crosses the sound, and along the northern flank of the Wilmington River as it crosses the sound. Bathymetric data were prepared as an ESRI GRID file and as an RGB Geotiff file as project deliverables. A tiled map containing ten higher-resolution images of the Wassaw Sound bathymetric map are provided in Appendix 1.

The main channel of the Wilmington River averages 8 to 9 meters in depth with deeper scours down to 12-13 meters. A slight channel constriction where the Wilmington River enters into Wassaw Sound shoals slightly to approximately 7 meters. The deepest area surveyed in the Wilmington River, near the entrance to Turners Creek, has maximum depths of 16 meters with complex bottom topography and structural features between 7-9 meters water depth (Figure 8). These changes in bathymetry are abrupt, often indicating that apparently vertical scarps exist in this area, having been eroded into resistant geologic materials.

The main channel of the Bull River between the US80 Bridge and Wassaw Sound exhibits channel scour depressions down to 16 meters water depth. Separating the depressions, cross-channel bars shoal to between 4-5 meters water depth. The confluence of Bull River, Lazaretto Creek, and Shad River has created channel scours as deep as 12 meters.

The deepest area surveyed during this project was a 23 meter deep depression near the confluence of Half Moon River and Beards Creek (Figure 9). This depression is tightly constrained in the area of the confluence and is steepest on the upstream side of the Half Moon River, and rapidly shoals to depths between 3 and 4 meters. A similar 18 meter deep depression was documented in Romerly Marsh Creek at the confluence with another tidal creek.

The shallowest region of the survey area, with exception to intertidal flats along channel flanks, is the western edge of Wassaw Sound and two linear shoals that frame the northern and southern edges of a broad sand ramp in the middle of the sound. Several areas on and near these shoals are subaerially exposed on every spring low tide.

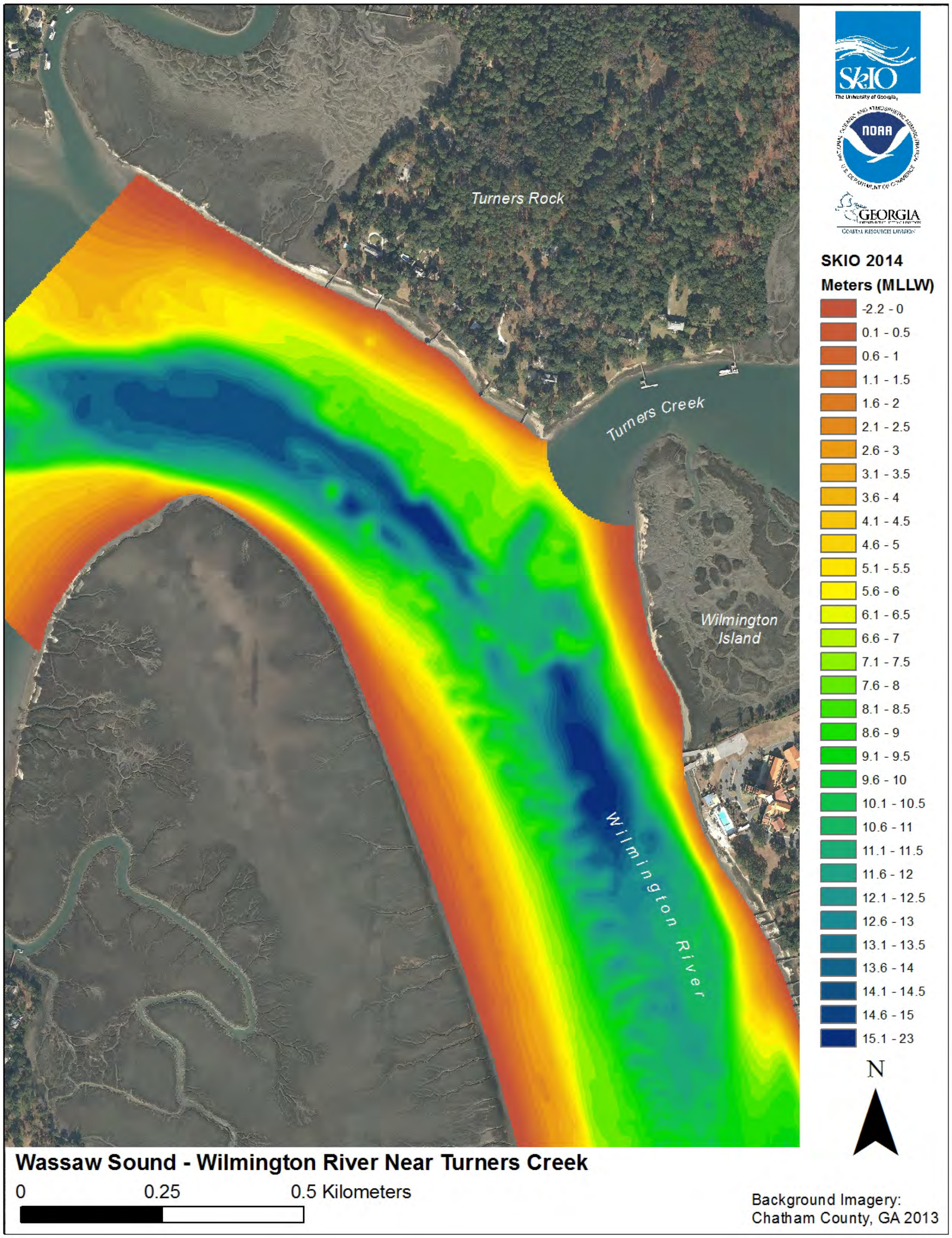

Figure 8: Detailed bathymetry of the Wilmington River near Turners Creek. Note the rough bottom morphology with abrupt changes in depth.

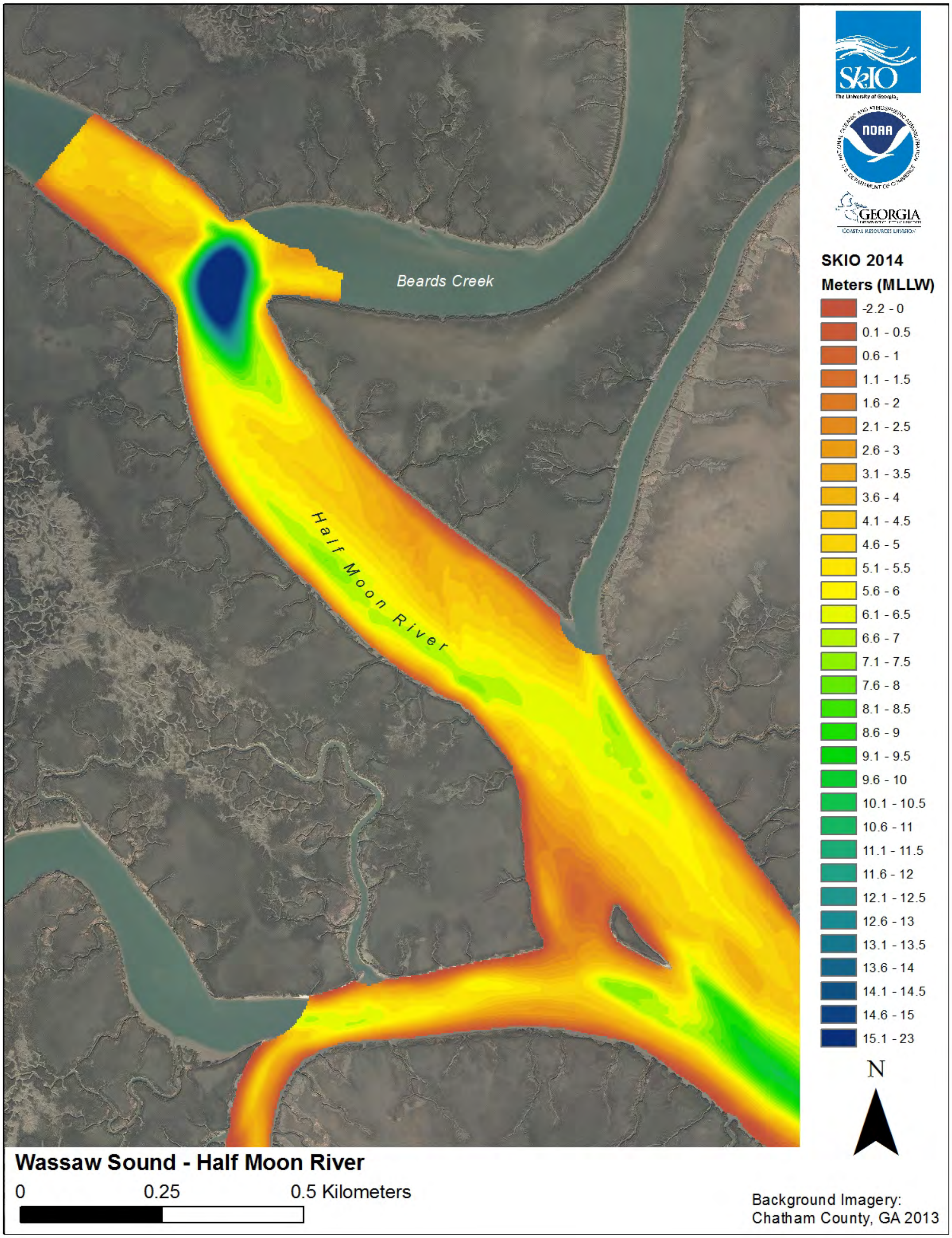

Figure 9: Detailed bathymetry of the Half Moon River. Note the deep scour depression at the confluence with Beards Creek.

Sediment Grain Size Analysis

Sediments in Wassaw Sound are dominated by sands (Figures 5, 6 and Table 1). The typical sediment (representing 70% of samples examined) is composed of 90-100% sand and gravel (particles greater than 63 μm), 0-3% silt (particles 63-4 μm) and 0-8% clay (particles smaller than 4 μm), and. These sediments are representative of the lower reaches of the Wilmington and Bull Rivers, and of the extensive sand flats fronting Cabbage Island. In the upper reaches of the Bull and Half Moon Rivers, in Romerly Marsh Creek and in Tybee Cut, sediments contain more mud (clay: 7-69% and silt: 1-25%), and sand and gravel are less dominant (6-89%).

When examined by sieving, the sediments exhibit characteristic grain size distributions. Sediments from the Cabbage Island Flats all display good sorting and a strong mode at 3 phi, indicating the well-winnowed nature of these sediments. Sediments from farther seaward and in the middle of the large river channels have modal diameters that are coarser (1-2 phi), reflecting the higher physical energy to which they are subjected. Samples from these channel thalweg areas also have a large component of shells or shell fragments. Sediment grain size distribution analyses allow distinction between sediments that appear similar on the basis of percent sand in a sample. Thus, such analyses are useful in determining changes in bed texture in response to disturbance or environmental changes.

Measurement of mean grain sizes for the sand fraction demonstrates that the coarsest sands and areas of shell hash are associated with areas of highest physical energy (mouths of rivers and areas of constricted tidal flow, e.g., channel "narrows" and confluence of streams). The distributions for these major subenvironments in the Sound are distinct. The fact that distributions are different in these environments that derive much of their material from similar sources suggests that changes in physical processes (i.e., disturbance) would lead to changes in the distributions themselves. The question that remains to be answered is whether these distinct distributions are sensitive enough to disturbance to reveal changes caused by natural or anthropogenic activities, and what effect seasonal variations in physical energy may have on bed sediments.

Sediment grain size samples collected during this project were joined with an existing database of grain size samples collected on 3 previous projects to generate a surface grain size map for the study area. This map supports the inferences made from the point data, suggesting that the textural bottom character extrapolations made by the GEOCODER software are reasonable and can be used to interpret bottom characteristics. All grain size data from this project are reported in Table 1. Extrapolated bottom character data were prepared as an ESRI GRID file and as an RGB Geotiff file as project deliverables.

<u>Wassaw Sound Area Bottom Classification Map</u>

Sidescan images aid in the interpretation of bottom type, structure identification, and for targeting areas of interest. Sidescan imagery of the study area was used to identify unique features and regions throughout the project area. The features were broadly classified into 3 major bottom types: 1) sand waves (wavelength 10's of meters, height ≥1 meter; Figure 10); 2) megaripples (wavelength ≥ 60 cm, height ≥ 6 cm; Figure 11); and 3) other (anthropogenic materials, slump blocks, marsh outcrops; Figure 12). Bedforms were dominantly observed in the channels and on the shallow ramp in the middle of Wassaw Sound. Megaripples were the most common features, representing 12% of the project area, whereas sand waves represent 6% of the project area. These classifications were used to create a map showing regions of bedforms, indicating sufficient energy to mobilize and/or scour the seafloor (Figure 13). Areas that are not identified as having bedforms or classified as "other" exhibited a flat, featureless bottom.

The "other" classification represents less than 1% of the project area. Some of these isolated features, which we interpret as marsh slump blocks, are located along Wilmington Island in the Wilmington River, and at a channel confluence in Romerly Marsh Creek. The abrupt, irregular topography of the upper Wilmington River is also classified as "other", given its unique character within the study area. Anthropogenic features, classified as "other", are found distributed throughout the study area (Figure 14). Thirteen man-made targets were identified during the sidescan sonar analysis and are detailed in Appendix 2. Three targets were identified as sunken vessels. One target was identified as a derelict piling associated with a channel marker. Eight targets were unidentified and classified as unknown. One target identified was not an anthropogenic physical structure, but was rather the remnants of trawl marks made by the doors on trawl nets operating within the sound limits (Appendix 2).

<u>Wassaw Sound Area 1994-2014 Comparisons</u>

Faunal Diversity

Previous studies examined the distribution of taxa in the outer parts of Wassaw Sound (Alexander et al., 1995, 1997). As a broad generalization, environments located nearest the mouth of Wassaw Sound typically were either depauperate or contained few taxa. This is especially true of environments located in the deeper, flanking channels that provide for the primary flood and drainage of the Wilmington and Bull Rivers, and the shallowest areas most fully exposed to the mouth of the Sound on the intertidal flats seaward of Cabbage Island. In contrast, environments further from the Sound's mouth tended to be more taxa rich, contain more habitat types, or have greater abundances of infauna and epifauna. Sediments near the mouth of the Sound are more often or more intensely disturbed by shoaling waves, tidal currents and bottom trawling, which was noted on the sidescan records inside the mouth of the sound. In these environments, the most common and abundant taxa are two that characteristically respond rapidly and effectively to disturbance (spionid polychaetes and oligochaete worms).

Although rare in the sediment-dominated environments of Wassaw Sound and its associated rivers and creeks, occasional outcroppings of "hard bottom" are found. These are often comprised of shell bars, limestone cobble, or scarps scoured into resistant geologic units (i.e.,

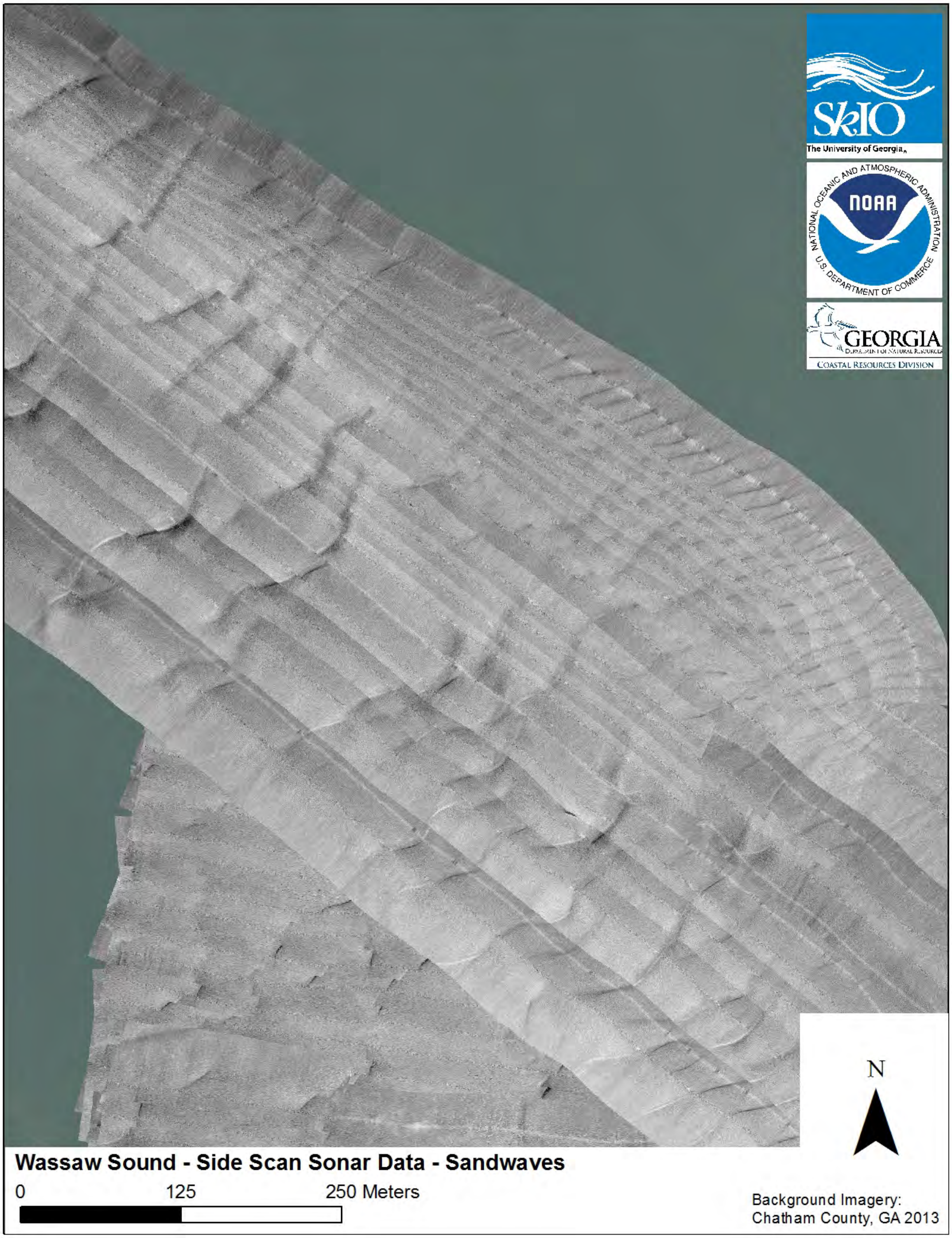

Figure 10: Sidescan sonar image showing characteristics of sand waves in Wassaw Sound.

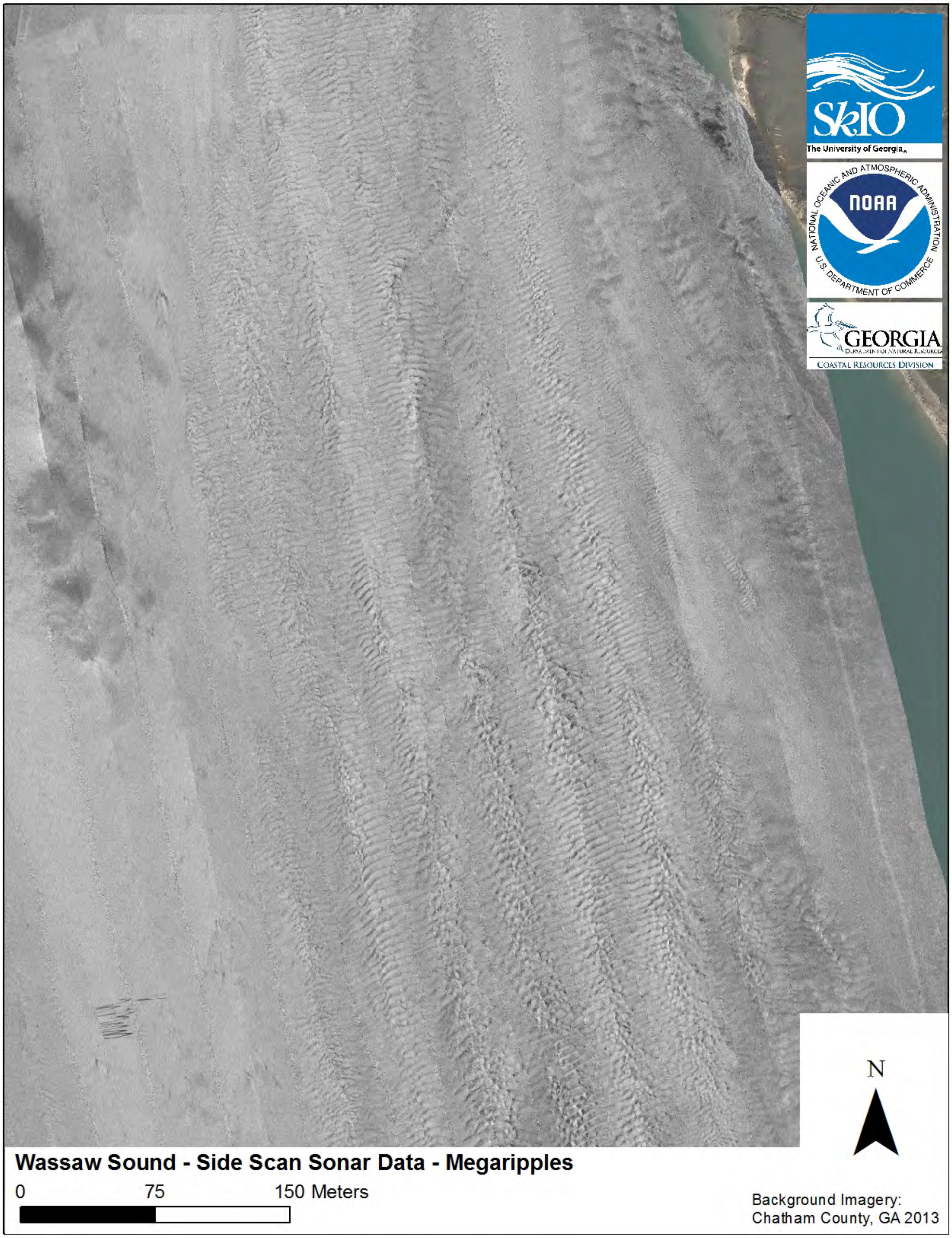

Figure 11: Sidescan sonar image showing characteristics of megaripples in Wassaw Sound.

Figure 12: Sidescan sonar mosaic showing an example of the "other" category. This image shows channel-margin, marsh slump blocks along Wilmington Island in the upper Wilmington River. See Figure 14 and Appendix 2 for additional examples of "other" classified objects.

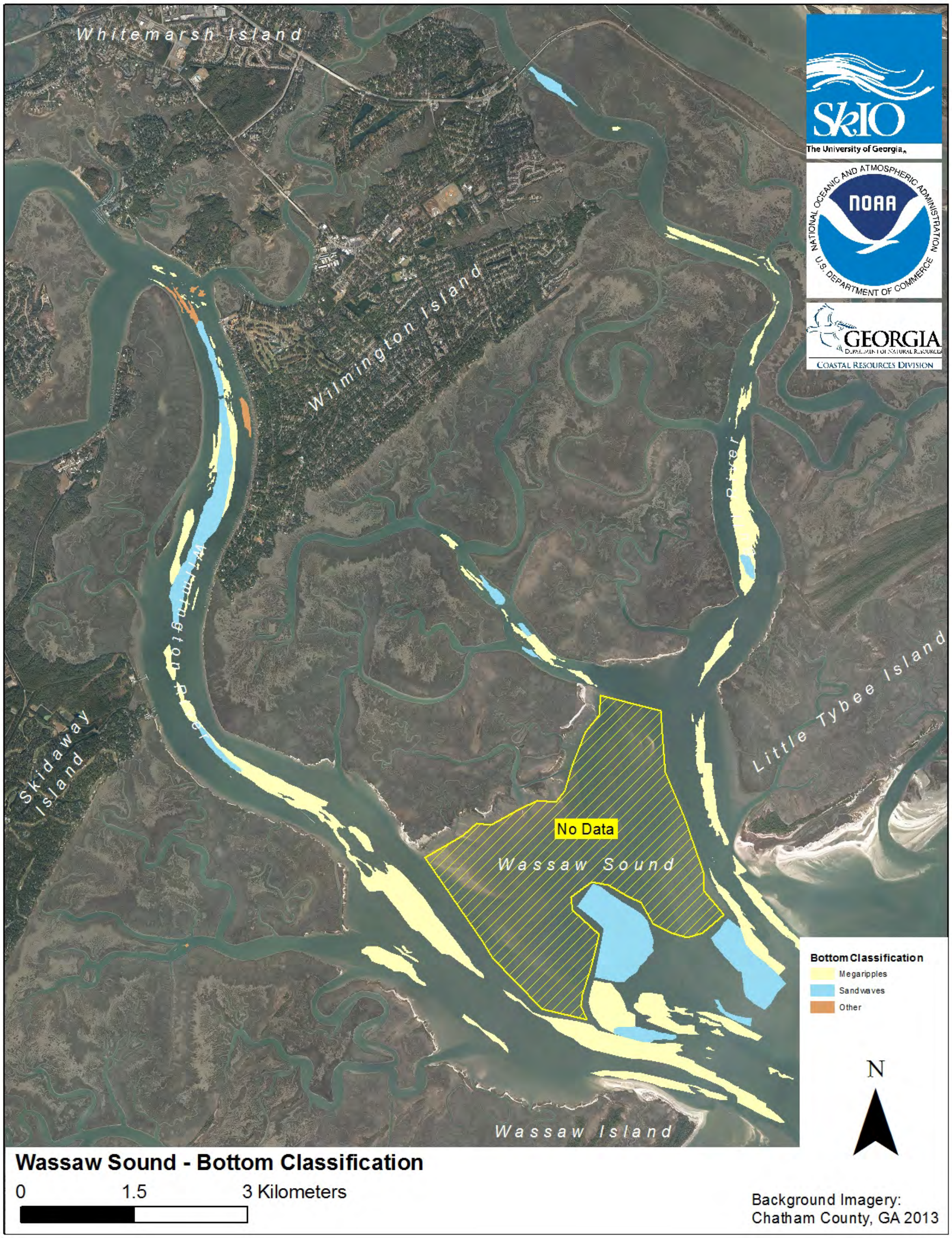

Figure 13: Bottom classification of Wassaw Sound study area based on sidescan sonar observations. Note that areas of sand waves (the larger of the two bedforms identified) generally correspond to regions of coarser sediment shown in Figure 6. No sidescan data was collected in the shallow, central region of Wassaw Sound (see text).

Figure 14: Example of an anthropogenic structure observed in Wassaw Sound surveys. Target shown (barge) is located in the upper Wilmington River (see Appendix 2).

Wilmington River). It is in these types of patchy environments that the presence of live-bottoms can be expected. Alexander et al. (1997) reported that exposed portions of these substrates host an assemblage of animals and some algae that are incapable of inhabiting more mobile sediments. The most common fauna include the sea whip (*Leptogorgia virgulata*, an octocoral), encrusting bryozoans, and several species of sponge. Ulva (a green seaweed, also known as sea lettuce) and branching red seaweeds are also common inhabitants. The erect, branching fauna (primarily *Leptogorgia*) themselves serve as hosts to a diverse assemblage of animals that either utilize the refuge of the host, feed upon or encrust it. These animals include most commonly solitary ascidians (sea squirts), sponges, caprellid and gammarid amphipods, nereid polychaetes, mud crabs, and barnacles. The invasive seaweed species *Gracilaria vermiculophylla,* which was not a common species identified in the Alexander et al. (1997) study, is now commonly found in finer-grained, shallow and intertidal areas flanking the major channels.

Based on these generalizations from previous studies and from new observations of sediment and bottom character from this study, we are able to extend the boundaries of our benthic classification (Figure 15). The taxa-rich regions can be extended up the Wilmington River, Bull River, Half Moon River and into Romerly Marsh Creek. The large region of complex topography in the upper Wilmington River is classified as taxa-rich because of the presence of hard bottom substrate throughout the region, which would provide habitat diversity and hard bottom for a diverse biota. However, it is possible that the western side of this area is taxa-poor, given that very large-scale, ebb-oriented bedforms are observed in this area in both the bathymetry (Figure 3) and sidescan (Figure 4) data in this area, indicating a sandy, mobile bed, which may be more similar to that nearer to the mouth of the sound.

Because of additional sampling in the shallow areas seaward of Cabbage Island, we are able to extend the taxa-poor region closer to shore in that area. One small region shows a change from a taxa-rich to a taxa-poor designation between the 1997 and 2014 sampling (i.e., the region near the confluence of Half Moon River and Bull River). This change does not result from a change in habitat or dynamic environmental conditions, but rather results from better sampling and examination of derived parameters for the area.

Those areas with small numbers of individuals, few taxa or low diversity that are frequently mobilized and disturbed (i.e., near the mouth of the sound and on broad, shallow intertidal flats) are colonized by pioneering species that respond rapidly to disturbance. In contrast, those areas with large numbers of individuals, many taxa or high diversity (i.e., major channels and creeks farther inland from the mouth of the Sound) would be significantly more susceptible to environmental disturbances. To further generalize these observations, taxa-poor regions of high energy and habitat homogeneity are frequently reworked and retain winnowed, coarse-grained sediments, whereas taxa-rich regions of lower energy and habitat diversity are more stable, contain both coarse and fine sediments, and are more sensitive to disturbance. It is important to note that these more sensitive areas are the same as those in which we found evidence for live bottom communities ((i.e., *Leptigorgia* in Half Moon River).

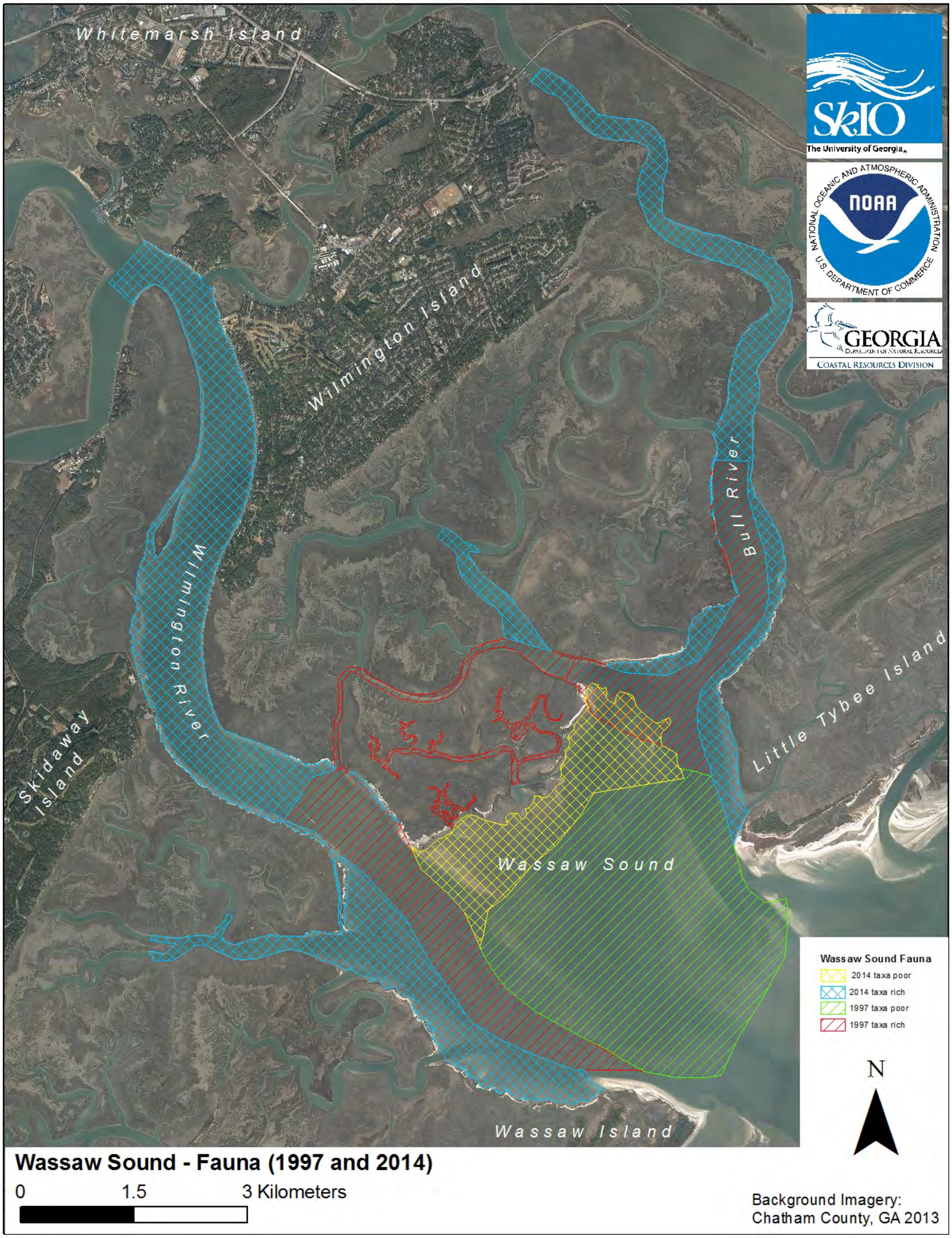

Figure 15: Composite benthic habitat map for Wassaw Sound incorporating insights from earlier studies and new data collected for the current study of Wassaw Sound.

Bathymetry

NOAA very recently released hydrographic sounding data for Wassaw Sound acquired in 1994 on NOAA Survey H10581 (National Oceanic and Atmospheric Administration, 2014b). Although not a part of the promised deliverables, these newly available data allow us to compare bathymetric change between the two surveys and highlight regions of change over this 20-year period (Figure 16). The 1994 data were used to generate an ESRI GRID file for a preliminary change analysis with the 2014 Skidaway Institute bathymetric data. For this comparison the 1994 bathymetry data were gridded using the same parameters as the 2014 Skidaway Institute bathymetry data set. Areas where there was bathymetric change of more than 1 m between the 1994 to 2014 surfaces were identified as zones of significant change. Zones where the bathymetry has become deeper tend to be located near the major channels and zones where the bathymetry has become more shoal tend to be located on the prominent sandbars flanking the shallow center of Wassaw Sound (Cabbage Spit, Wassaw Breaker). Significant shoaling was also identified along the channel flanks of the Wilmington River.

A preliminary analysis examining shoals in the outer sound was conducted to estimate the average vertical change for these dynamic features. Wassaw Breaker, a sandbar that extends seaward along the southern edge of the Bull River channel across the sound, has become more shoal between the two surveys with a mean change of +1.6 m, with maximum change of +2.7 m. The area adjacent to, and southwest of, Wassaw Breaker has deepened and exhibits a mean change of -1.2 m with a maximum change of -2.1 m. Cabbage Spit, a sandbar that extends seaward along the northern edge of the Wilmington River across the sound, has become more shoal between the two surveys, exhibiting a mean change of +1.6 m with a maximum change of +3.0 m. The area adjacent to, and northwest west of, Cabbage Spit has deepened and exhibits a mean change of -1.6 m with maximum change of -2.8 m. Further analysis comparing these two bathymetric datasets is planned. Although there has been significant change in the areas discussed above, little impact on benthic habitat and faunal diversity is expected, given that these dynamic areas are already classified as taxa-poor.

Dissemination of Results

The bathymetric dataset for Wassaw Sound is provided as an ESRI GRID and as a RGB Geotiff to DNR-CRD and the Coastal Management Program. Other stakeholders who can use the data (DNR-HPD, Chatham Co., NOAA Hydrography, US Army Corps of Engineers) have been approached through one-on-one meetings with colleagues at those agencies, and we are in negotiations concerning formats and metadata standards for data acceptance. Alexander spoke before the NOAA Hydrographic Services Review Panel, which met in Charleston, SC on Sept. 16th, 2014, where he was asked to discuss his Wassaw and estuarine mapping efforts. He has also provided these data to the public under the Coastal DEM tab on the Georgia Coastal Hazards Portal (GCHP), a recent outreach project funded by the Georgia Coastal Management Program, where the public can examine depths in relation to a variety of other parameters.

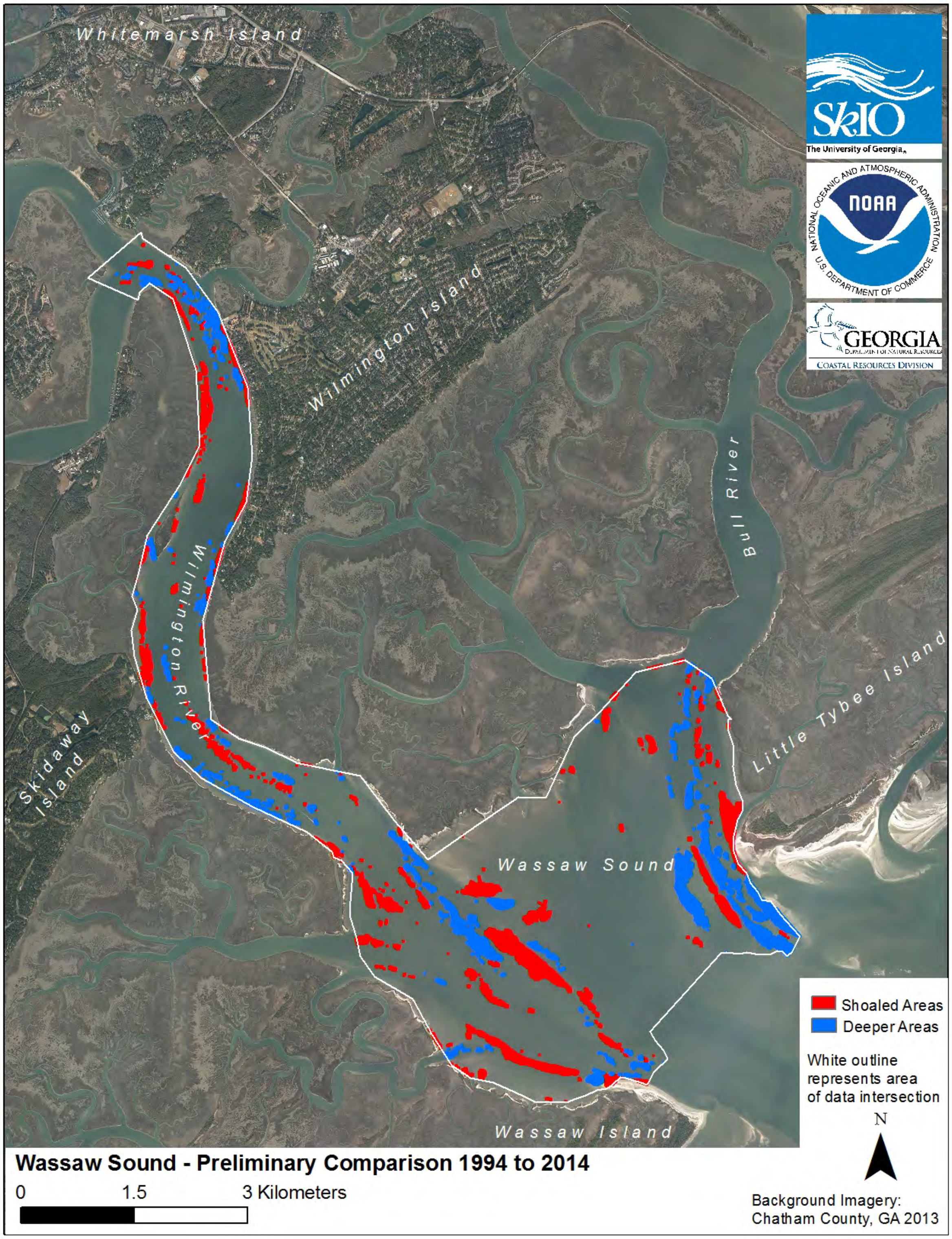

Figure 16: Preliminary comparison between the swath-bathymetric data developed in the current survey of Wassaw Sound and a 1994 NOAA survey. Red areas have shoaled by a meter or more, whereas blue areas have deepened by a meter or more in this 20 year period.

Acknowledgements

We gratefully acknowledge the Skidaway machine shop for fabrication help with the mount, Skidaway marine operations for their support of our vessel needs throughout this project, and Dr. Chester Jackson, Georgia Southern University, for the loan of his terrestrial lidar unit.

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Table 1

Grain Size Ground-Truth Data for Wassaw Sound Benthic Character Mapping

Note: grain size and sediment sorting are in phi units where:

$$phi = \log_2(mm)$$

and

$$2^{-(phi)} = (mm)$$

Cruise	Station	Latitude	Longitude	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	Mean Size (phi)	Sorting (phi)
Ferrel 1994	1	31.9184	-80.9300	12.00	80.83	0.70	6.47	1.68	2.59
Ferrel 1994	2	31.9185	-80.9281	15.66	78.88	0.81	4.65	1.42	2.42
Ferrel 1994	3	31.9188	-80.9263	14.87	79.72	0.65	4.76	1.52	2.45
Ferrel 1994	4	31.9157	-80.9373	4.10	89.15	0.49	6.26	1.53	2.38
Ferrel 1994	5	31.9167	-80.9383	0.73	93.19	0.03	6.04	1.92	2.16
Ferrel 1994	6	31.9179	-80.9397	0.04	94.21	0.32	5.42	2.93	1.78
Ferrel 1994	7	31.9205	-80.9415	0.44	86.44	3.28	9.84	3.05	2.57
Ferrel 1994	8	31.9215	-80.9431	0.03	67.79	9.83	22.35	4.64	3.14
Ferrel 1994	9	31.9237	-80.9447	4.77	87.41	0.57	7.25	2.32	2.47
Ferrel 1994	10	31.9365	-80.9664	0.83	93.76	0.15	5.27	2.68	1.91
Ferrel 1994	11	31.9387	-80.9515	0.00	94.06	0.07	5.88	2.85	1.92
Ferrel 1994	12	31.9401	-80.9531	0.00	94.00	0.34	5.68	2.98	1.85
Ferrel 1994	13	31.9308	-80.9515	1.79	91.94	0.27	6.00	1.93	2.37
Ferrel 1994	14	31.9364	-80.9495	0.48	93.61	0.31	5.60	2.82	1.89
Ferrel 1994	15	31.9387	-80.9510	0.00	94.39	0.70	4.91	2.88	1.75
Ferrel 1994	16	31.9236	-80.9630	33.77	59.59	1.04	5.55	1.20	2.88
Ferrel 1994	17	31.9230	-80.9611	25.96	65.72	2.97	5.34	1.71	2.79
Ferrel 1994	18	31.9215	-80.9592	51.36	42.43	0.54	5.68	0.92	2.94
Ferrel 1994	19	31.9185	-80.9430	0.49	90.11	1.75	7.64	2.92	2.25
Ferrel 1994	20	31.9181	-80.9405	6.37	91.96	0.77	0.90	2.03	1.45
Ferrel 1994	21	31.9187	-80.9378	2.50	90.77	0.80	5.93	1.89	2.30

Cruise	Station	Latitude	Longitude	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	Mean Size (phi)	Sorting (phi)
Ferrel 1994	22	31.9313	-80.9249	80.24	11.53	0.54	7.69	-0.05	3.10
Ferrel 1994	23	31.9324	-80.9233	6.82	86.17	0.52	7.69	2.43	2.55
Ferrel 1994	24	31.9348	-80.9261	10.11	83.21	0.55	6.13	1.52	2.52
Ferrel 1994	25	31.9330	-80.9269	18.28	68.38	1.44	11.90	2.09	3.25
Ferrel 1994	26	31.9523	-80.9323	0.00	83.78	8.15	8.07	3.64	2.18
Ferrel 1994	27	31.9546	-80.9340	18.49	74.30	0.22	6.99	0.97	2.73
Ferrel 1994	28	31.9721	-80.9264	2.14	75.91	6.86	15.10	4.07	2.80
Ferrel 1994	29	31.9787	-80.9296	1.25	60.35	11.86	26.53	4.53	3.71
Ferrel 1994	30	31.9630	-80.9510	29.39	61.81	1.64	7.16	1.43	2.91
Ferrel 1994	31	31.9650	-80.9575	38.32	54.01	1.20	6.47	0.95	2.90
Ferrel 1994	32	31.9656	-80.9656	52.46	38.31	2.46	6.78	0.50	3.05
Ferrel 1994	33	31.9602	-80.9760	2.29	62.22	9.59	25.90	4.80	3.40
Ferrel 1994	34	31.9574	-80.9847	2.76	89.62	0.97	6.65	2.14	2.33
Ferrel 1994	35	31.9427	-80.9813	2.26	90.13	0.53	7.08	2.69	2.28
Ferrel 1994	36	31.9436	-80.9835	31.17	62.96	0.10	5.77	0.88	2.65
Ferrel 1994	37	31.9448	-80.9856	10.45	83.94	0.03	5.58	1.30	2.35
Whiting 1995/6	7865	31.9189	-80.9467	2.54	93.78	0.86	2.82	2.30	1.64
Whiting 1995/6	7864	31.9228	-80.9525	6.37	93.63	0.00	0.00	1.20	1.27
Whiting 1995/6	7863	31.9236	-80.9572	64.87	35.13	0.00	0.00	-0.07	1.69
Whiting 1995/6	7860	31.9244	-80.9689	0.08	80.93	5.24	13.74	3.92	2.61
Whiting 1995/6	6991	31.9511	-80.9994	83.61	9.58	0.04	6.77	-0.34	2.86

Cruise	Station	Latitude	Longitude	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	Mean Size (phi)	Sorting (phi)
Whiting 1995/6	6990	31.9561	-81.0047	87.47	10.70	0.32	1.52	-0.91	1.52
Whiting 1995/6	6989	31.9661	-81.0083	15.17	81.82	0.16	2.85	1.26	2.10
Whiting 1995/6	6988	31.9661	-81.0106	2.79	88.89	0.98	7.35	2.11	2.50
Whiting 1995/6	6986	31.9725	-81.0050	7.86	89.89	0.38	1.87	1.25	1.65
Whiting 1995/6	2518	31.9500	-80.9414	0.00	96.96	0.49	2.55	2.95	1.26
Whiting 1995/6	2517	31.9461	-80.9469	0.01	98.17	0.20	1.61	2.27	1.26
Whiting 1995/6	2514	31.9319	-80.9414	7.60	88.44	1.14	2.82	1.91	2.02
Whiting 1995/6	2513	31.9367	-80.9467	1.45	96.37	0.30	1.87	2.34	1.38
Whiting 1995/6	2512	31.9411	-80.9522	0.00	98.18	0.16	1.66	2.67	1.15
Whiting 1995/6	2511	31.9361	-80.9572	0.01	97.48	0.41	2.10	3.05	1.14
Whiting 1995/6	2510	31.9322	-80.9519	3.89	92.94	0.49	2.68	2.09	1.72
Whiting 1995/6	2509	31.9272	-80.9469	14.56	67.57	4.94	12.93	2.85	3.30
Whiting 1995/6	2421	31.9592	-80.9419	0.54	27.53	18.78	53.15	7.65	4.00
Whiting 1995/6	1190	31.9369	-80.9786	1.49	95.39	0.49	2.63	2.52	1.43
Whiting 1995/6	1189	31.9383	-80.9756	2.38	22.79	21.09	53.75	7.12	3.60
Whiting 1995/6	1188	31.9400	-80.9828	90.91	6.94	0.43	1.72	-0.86	1.68
Whiting 1995/6	1187	31.9456	-80.9892	56.59	38.63	1.39	3.39	-0.02	2.32
Whiting 1995/6	2516	31.9408	-80.9414	2.67	91.56	1.54	4.22	2.68	1.94
Whiting 1995/6	2515	31.9364	-80.9364	2.90	96.16	0.07	0.88	2.43	1.20
Blue Fin 2001	1	31.9115	-80.9301	0.06	85.19	3.76	10.99	3.34	2.94
Blue Fin 2001	2	31.9127	-80.9282	16.57	74.10	2.21	7.12	2.10	2.97

Cruise	Station	Latitude	Longitude	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	Mean Size (phi)	Sorting (phi)
Blue Fin 2001	3	31.9144	-80.9271	57.65	36.67	2.16	3.52	0.21	2.61
Blue Fin 2001	4	31.9165	-80.9264	26.94	71.31	0.36	1.39	0.70	1.92
Blue Fin 2001	5	31.9177	-80.9254	50.51	47.36	0.46	1.68	0.22	2.11
Blue Fin 2001	6	31.9122	-80.9146	0.00	97.98	0.46	1.57	3.07	1.20
Blue Fin 2001	7	31.9116	-80.9154	1.06	83.58	5.74	9.62	3.82	2.61
Blue Fin 2001	8	31.9110	-80.9166	19.21	75.28	2.06	3.45	1.62	2.49
Blue Fin 2001	9	31.9101	-80.9172	44.65	51.20	1.16	2.99	0.44	2.46
Blue Fin 2001	10	31.9090	-80.9182	48.38	49.26	0.74	1.61	0.30	2.09
Blue Fin 2001	11	31.9076	-80.9197	22.48	75.70	0.29	1.53	0.47	1.83
Blue Fin 2001	12	31.9036	-80.9029	30.31	62.87	1.77	5.05	1.62	2.89
Blue Fin 2001	13	31.9030	-80.9045	63.30	32.98	0.78	2.93	-0.05	2.44
Blue Fin 2001	14	31.9021	-80.9061	6.78	92.45	0.16	0.61	1.23	1.20
Blue Fin 2001	15	31.9011	-80.9072	2.54	96.88	0.15	0.43	1.93	1.03
Blue Fin 2001	16	31.9105	-80.9156	22.38	67.60	3.31	6.71	1.99	3.05
Skidaway Institute 2014	1	31.9804	-81.0050	0.28	98.49	0.05	1.18	1.78	1.06
Skidaway Institute 2014	2	31.9222	-80.9393	7.56	90.91	0.25	1.29	1.39	1.54
Skidaway Institute 2014	3	31.9197	-80.9320	0.33	98.19	0.21	1.27	1.31	1.47
Skidaway Institute 2014	4	31.9217	-80.9412	2.83	95.98	0.07	1.12	1.49	1.25

Cruise	Station	Latitude	Longitude	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	Mean Size (phi)	Sorting (phi)
Skidaway Institute 2014	5	31.9314	-80.9425	1.14	96.15	0.52	2.19	2.14	1.54
Skidaway Institute 2014	6	31.9377	-80.9499	3.57	94.82	0.13	1.47	1.87	1.42
Skidaway Institute 2014	7	31.9257	-80.9232	0.10	97.37	0.35	2.17	2.71	1.20
Skidaway Institute 2014	8	31.9314	-80.9296	0.79	97.55	0.03	1.62	2.54	1.12
Skidaway Institute 2014	9	32.0120	-81.0097	5.04	91.24	0.78	2.94	2.28	1.89
Skidaway Institute 2014	10	32.0061	-81.0042	49.47	47.46	0.90	2.17	0.17	2.01
Skidaway Institute 2014	11	32.0037	-81.0022	4.52	93.23	0.43	1.82	0.75	1.48
Skidaway Institute 2014	12	31.9941	-81.0002	11.41	87.36	0.38	0.85	0.44	1.33
Skidaway Institute 2014	13	31.9893	-81.0023	7.50	83.06	1.85	7.59	1.58	2.69
Skidaway Institute 2014	14	31.9888	-81.0003	0.85	98.13	0.19	0.83	1.20	1.09
Skidaway Institute 2014	15	31.9834	-81.0016	0.52	67.13	7.01	25.34	4.34	3.55
Skidaway Institute 2014	16	31.9757	-81.0048	4.15	72.92	5.33	17.61	3.09	3.51
Skidaway Institute 2014	17	31.9727	-81.0077	0.09	97.96	0.19	1.76	2.66	1.08

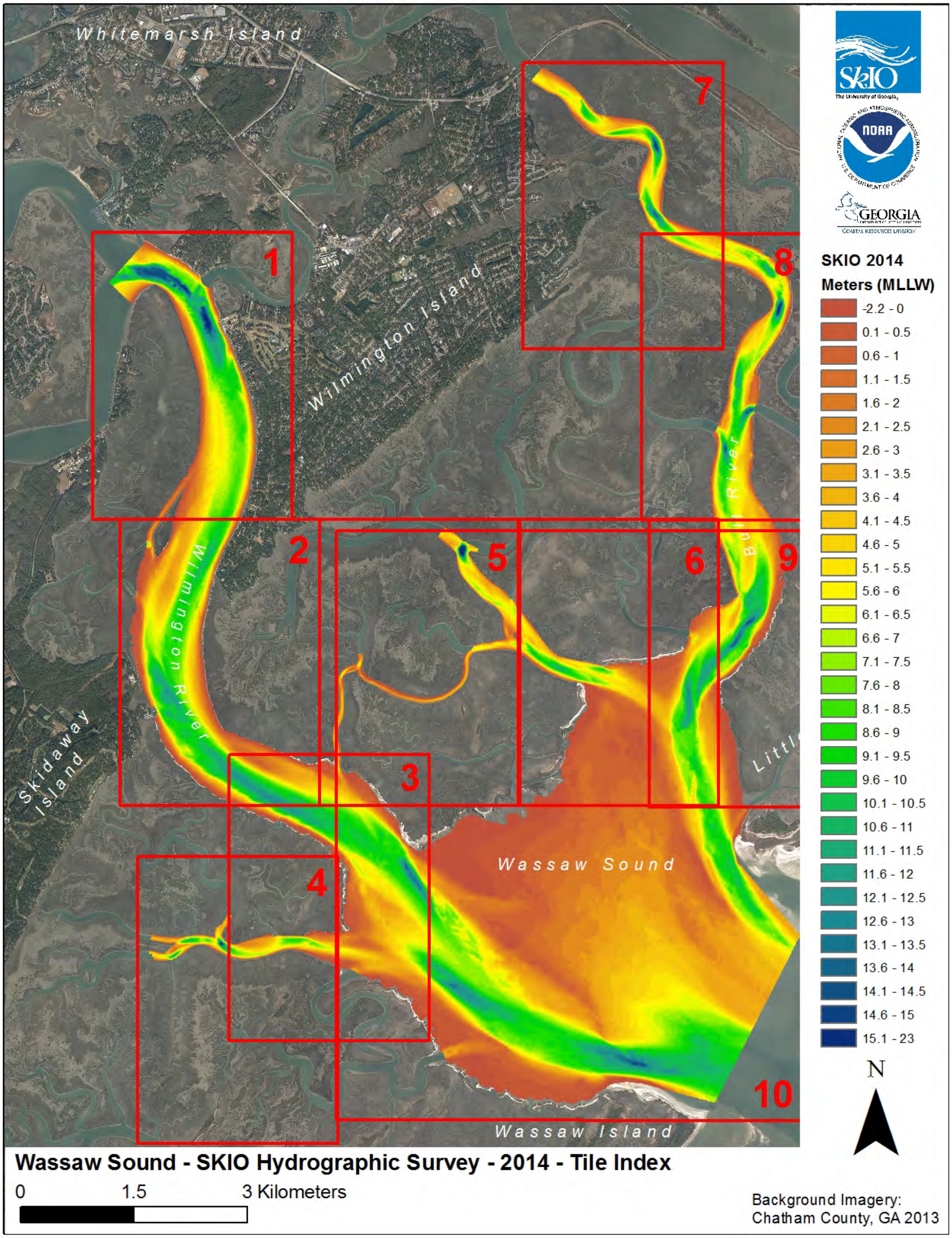
Cruise	Station	Latitude	Longitude	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	Mean Size (phi)	Sorting (phi)
Skidaway Institute 2014	18	31.9659	-81.0085	0.24	62.91	8.75	28.10	4.79	3.52
Skidaway Institute 2014	19	31.9591	-81.0061	1.91	86.93	2.41	8.75	2.51	2.62
Skidaway Institute 2014	20	31.9553	-81.0061	37.96	60.44	0.39	1.21	0.31	1.74
Skidaway Institute 2014	21	31.9507	-81.0042	0.08	33.15	22.16	44.61	6.68	3.37
Skidaway Institute 2014	22	31.9499	-80.9982	44.63	54.32	0.21	0.84	-0.05	1.52
Skidaway Institute 2014	23	31.9504	-80.9857	0.90	88.07	3.22	7.81	3.32	2.14
Skidaway Institute 2014	24	31.9385	-80.9758	5.08	87.75	2.25	4.92	1.67	2.37
Skidaway Institute 2014	25	31.9312	-80.9718	0.01	98.25	0.31	1.43	2.79	0.96
Skidaway Institute 2014	26	31.9310	-80.9882	69.66	19.78	3.08	7.48	0.53	3.21
Skidaway Institute 2014	27	31.9265	-80.9689	0.15	79.96	5.79	14.10	4.07	2.60
Skidaway Institute 2014	28	31.9183	-80.9503	10.31	88.41	0.48	0.80	1.11	1.50
Skidaway Institute 2014	29	31.9263	-80.9285	9.67	89.04	0.19	1.10	2.06	1.53
Skidaway Institute 2014	30	31.9463	-80.9332	23.14	75.44	0.36	1.07	0.59	1.58

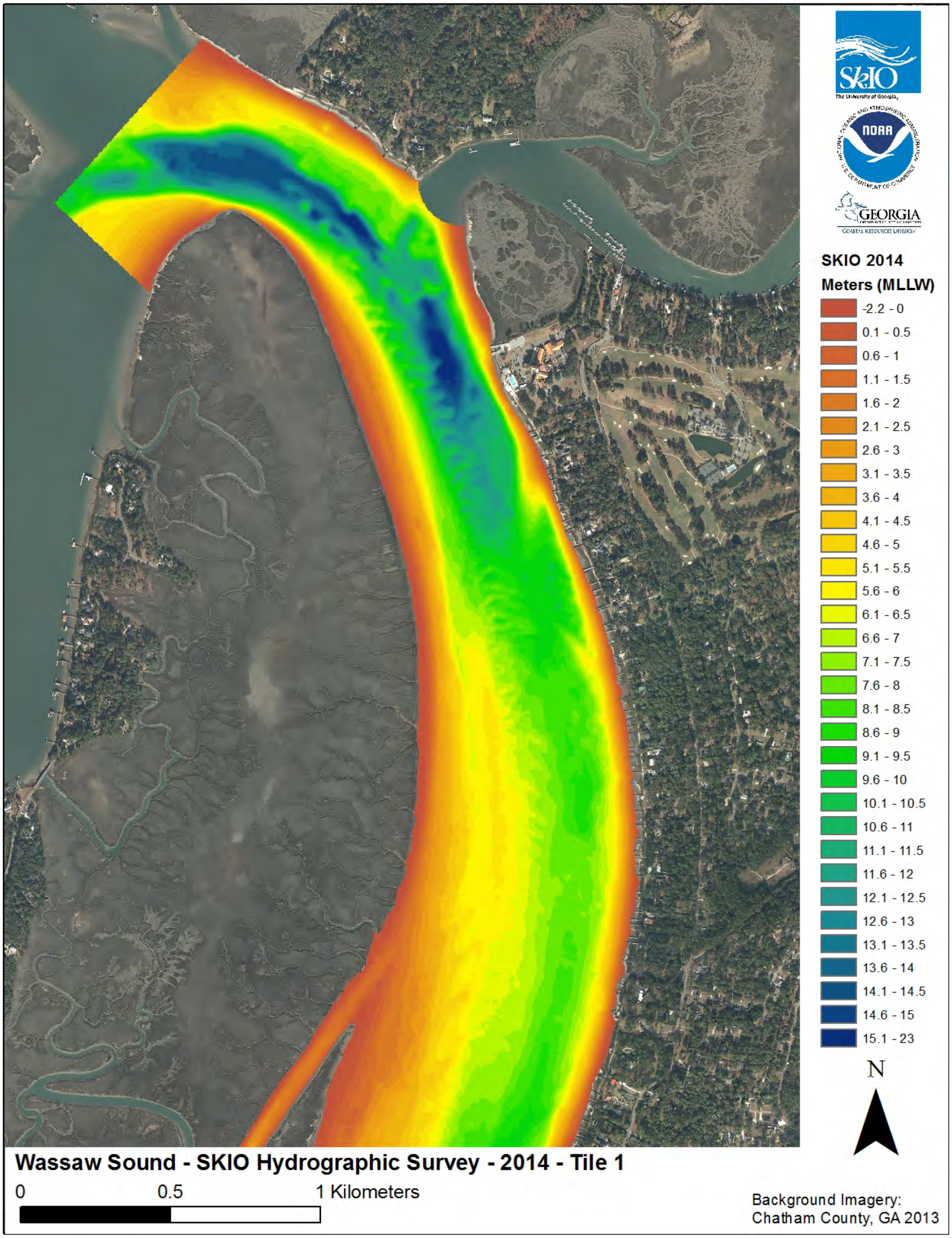
Cruise	Station	Latitude	Longitude	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	Mean Size (phi)	Sorting (phi)
Skidaway Institute 2014	31	31.9595	-80.9386	0.32	66.20	18.13	15.35	4.78	2.59
Skidaway Institute 2014	32	31.9647	-80.9324	0.00	68.31	18.79	12.90	4.11	2.75
Skidaway Institute 2014	33	31.9706	-80.9245	0.08	76.01	9.71	14.20	4.13	2.66
Skidaway Institute 2014	34	31.9752	-80.9296	5.10	35.75	26.54	32.62	5.52	3.79
Skidaway Institute 2014	35	31.9874	-80.9302	26.42	70.86	0.72	2.01	0.86	1.95
Skidaway Institute 2014	36	31.9947	-80.9272	8.90	49.06	21.19	20.85	4.03	3.85
Skidaway Institute 2014	37	32.0038	-80.9262	0.39	93.94	1.26	4.41	2.83	1.68
Skidaway Institute 2014	38	32.0137	-80.9320	0.21	55.60	12.40	31.78	5.09	3.70
Skidaway Institute 2014	39	32.0177	-80.9407	16.88	53.52	8.39	21.21	3.47	3.92
Skidaway Institute 2014	40	32.0211	-80.9408	0.08	44.89	16.42	38.60	5.73	3.83
Skidaway Institute 2014	41	32.0273	-80.9431	0.00	6.49	24.58	68.93	8.54	2.56
Skidaway Institute 2014	42	32.0280	-80.9451	0.23	81.99	4.92	12.86	3.93	2.52
Skidaway Institute 2014	43	32.0326	-80.9538	0.72	41.94	16.36	40.99	5.89	3.85

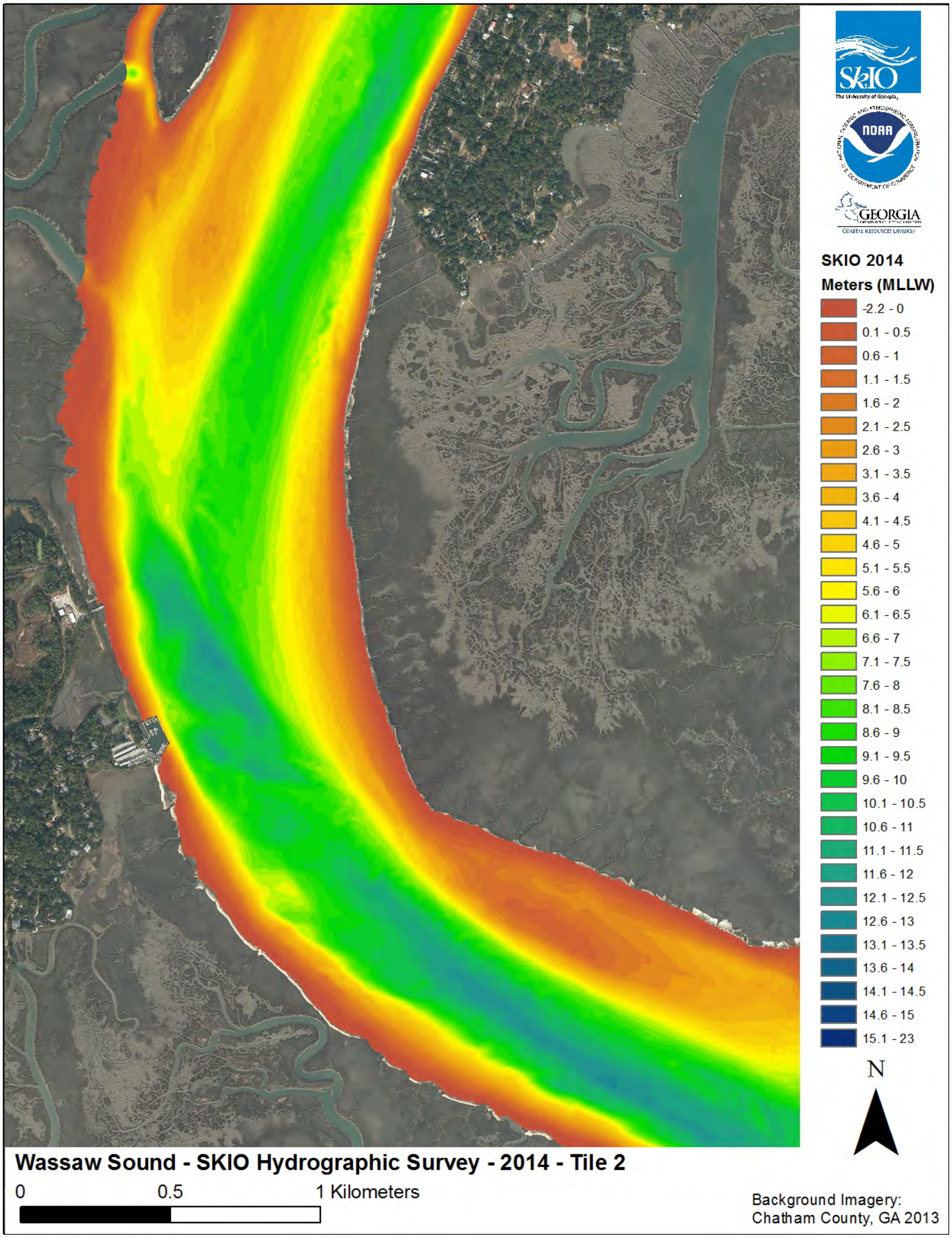
Cruise	Station	Latitude	Longitude	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	Mean Size (phi)	Sorting (phi)
Skidaway Institute 2014	44	32.0328	-80.9559	0.37	22.69	21.33	55.61	7.43	3.28
Skidaway Institute 2014	45	31.9277	-80.9732	0.47	60.56	10.67	28.31	4.66	3.70
Skidaway Institute 2014	46	31.9300	-80.9994	5.91	92.12	0.18	1.79	1.86	1.70
Skidaway Institute 2014	47	31.9691	-80.9600	14.23	71.17	3.96	10.64	2.51	3.08
Skidaway Institute 2014	48	31.9760	-80.9668	32.28	61.97	1.96	3.80	0.85	2.37

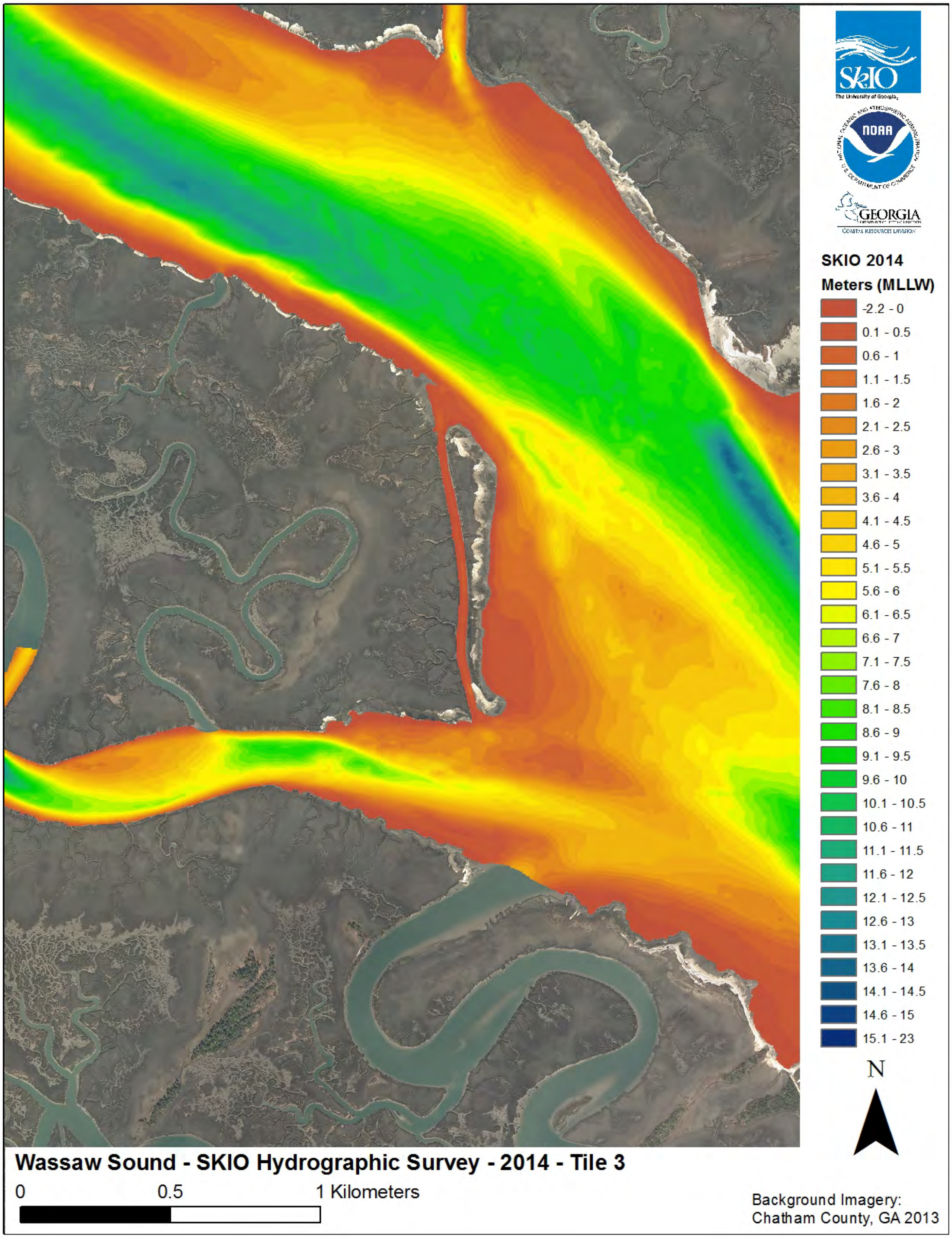
Appendix 1

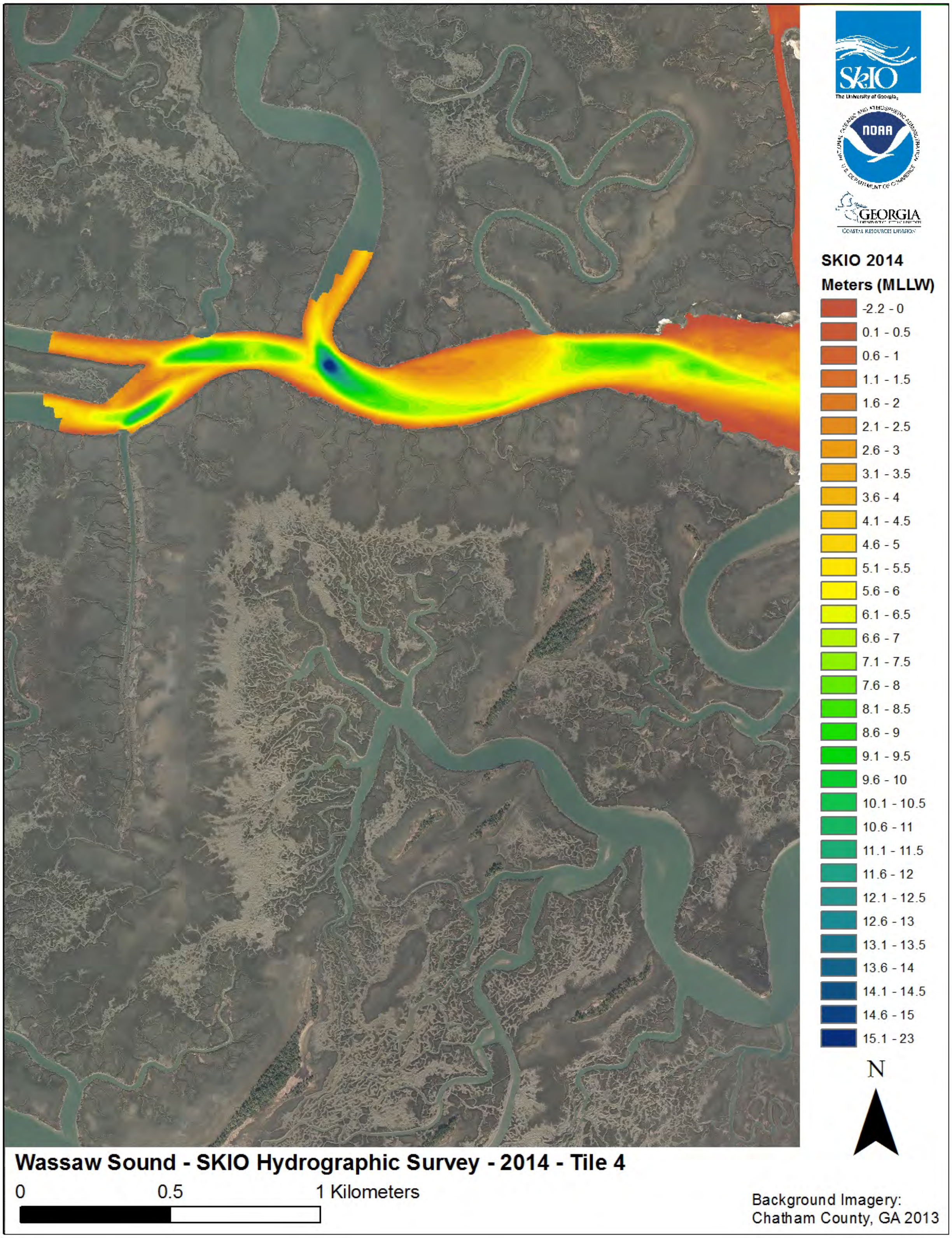
Detail maps showing the bathymetry of Wassaw Sound

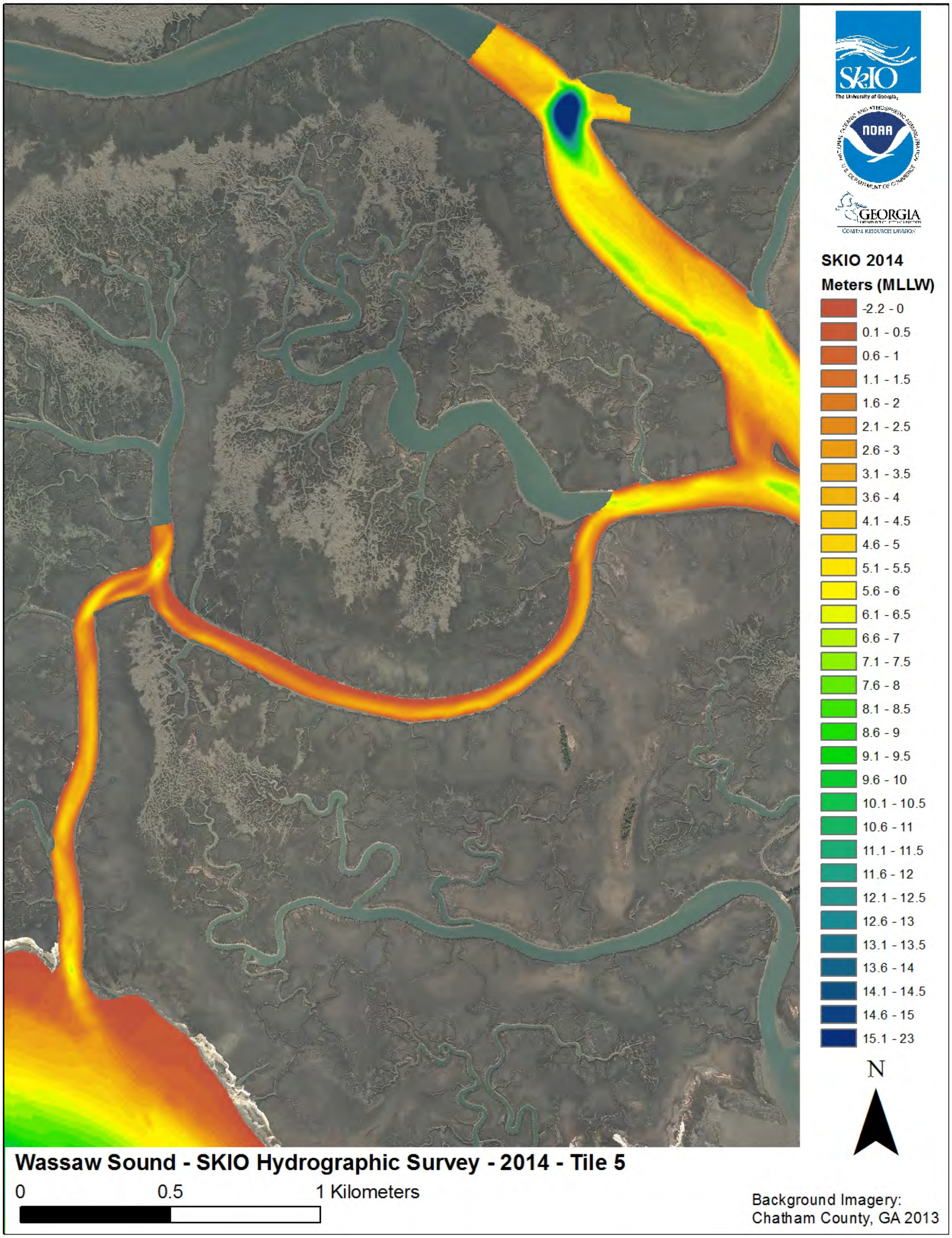

Whitemarsh Island
Wilmington Island
Wilmington River
Skidaway Island
Wassaw Sound
Wassaw Island
Bull River
1
2
3
4
5
6
7
8
9
10
GEORGIA
SKIO 2014
Meters (MLLW)
-2.2 - 0
0.1 - 0.5
0.6 - 1
1.1 - 1.5
1.6 - 2
2.1 - 2.5
2.6 - 3
3.1 - 3.5
3.6 - 4
4.1 - 4.5
4.6 - 5
5.1 - 5.5
5.6 - 6
6.1 - 6.5
6.6 - 7
7.1 - 7.5
7.6 - 8
8.1 - 8.5
8.6 - 9
9.1 - 9.5
9.6 - 10
10.1 - 10.5
10.6 - 11
11.1 - 11.5
11.6 - 12
12.1 - 12.5
12.6 - 13
13.1 - 13.5
13.6 - 14
14.1 - 14.5
14.6 - 15
15.1 - 23
N
Wassaw Sound - SKIO Hydrographic Survey - 2014 - Tile Index
0
1.5
3 Kilometers
Background Imagery:
Chatham County, GA 2013

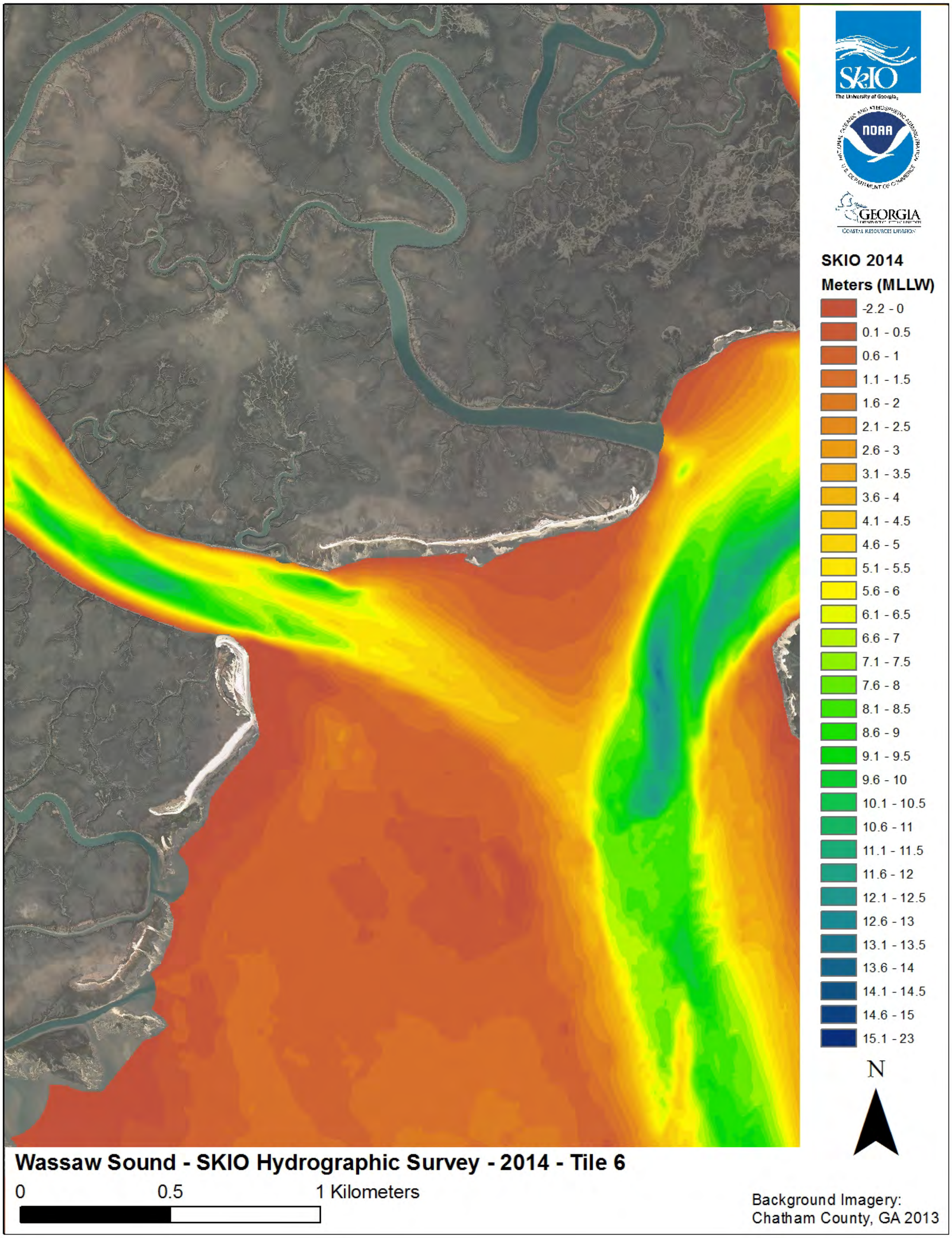

The University of Georgia
SKIO 2014
Meters (MLLW)
-2.2 - 0
0.1 - 0.5
0.6 - 1
1.1 - 1.5
1.6 - 2
2.1 - 2.5
2.6 - 3
3.1 - 3.5
3.6 - 4
4.1 - 4.5
4.6 - 5
5.1 - 5.5
5.6 - 6
6.1 - 6.5
6.6 - 7
7.1 - 7.5
7.6 - 8
8.1 - 8.5
8.6 - 9
9.1 - 9.5
9.6 - 10
10.1 - 10.5
10.6 - 11
11.1 - 11.5
11.6 - 12
12.1 - 12.5
12.6 - 13
13.1 - 13.5
13.6 - 14
14.1 - 14.5
14.6 - 15
15.1 - 23
N
Wassaw Sound - SKIO Hydrographic Survey - 2014 - Tile 1
0
0.5
1 Kilometers
Background Imagery:
Chatham County, GA 2013

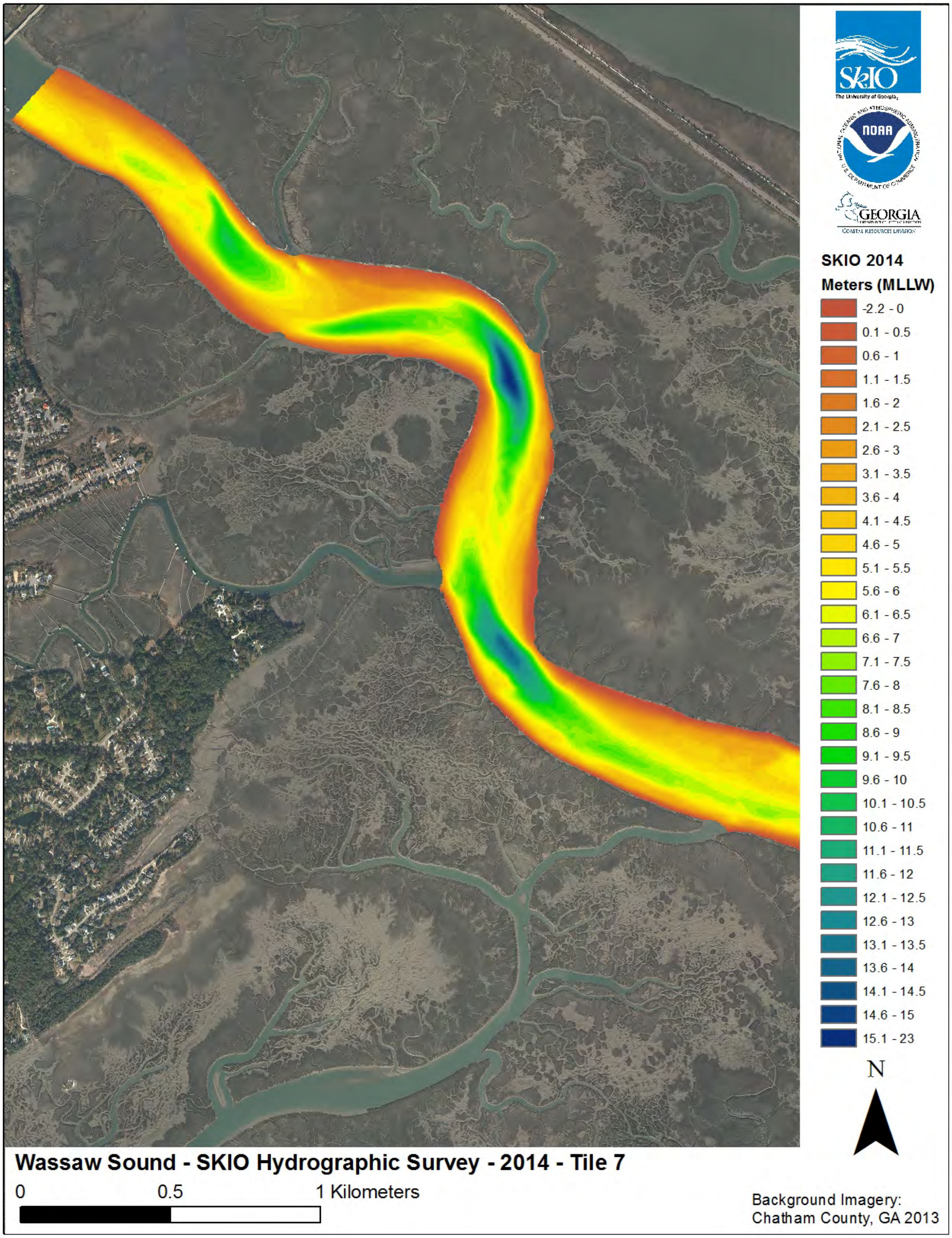

SKIO 2014
Meters (MLLW)
-2.2 - 0
0.1 - 0.5
0.6 - 1
1.1 - 1.5
1.6 - 2
2.1 - 2.5
2.6 - 3
3.1 - 3.5
3.6 - 4
4.1 - 4.5
4.6 - 5
5.1 - 5.5
5.6 - 6
6.1 - 6.5
6.6 - 7
7.1 - 7.5
7.6 - 8
8.1 - 8.5
8.6 - 9
9.1 - 9.5
9.6 - 10
10.1 - 10.5
10.6 - 11
11.1 - 11.5
11.6 - 12
12.1 - 12.5
12.6 - 13
13.1 - 13.5
13.6 - 14
14.1 - 14.5
14.6 - 15
15.1 - 23
N
Wassaw Sound - SKIO Hydrographic Survey - 2014 - Tile 2
0
0.5
1 Kilometers
Background Imagery:
Chatham County, GA 2013

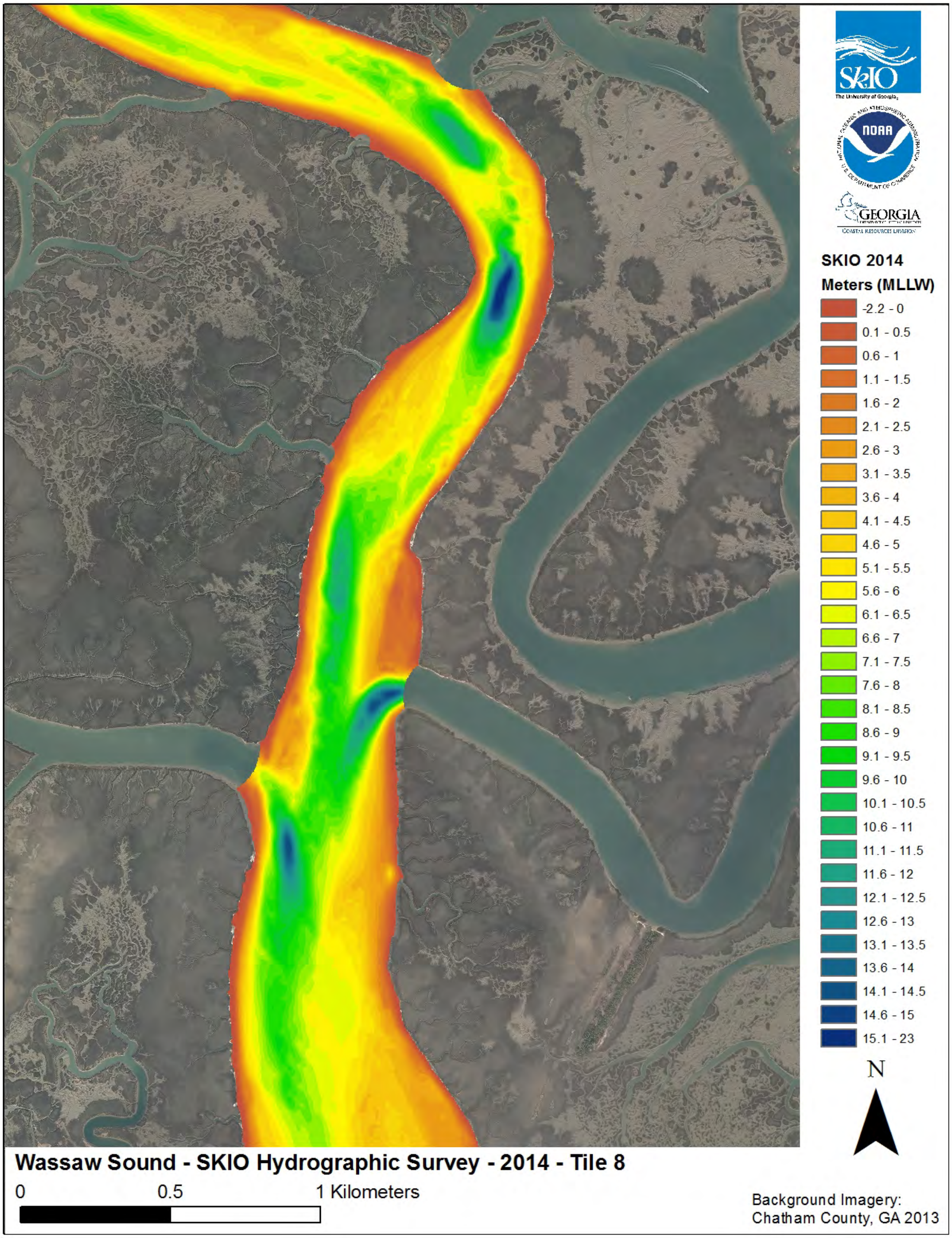

SKIO 2014
Meters (MLLW)
-2.2 - 0
0.1 - 0.5
0.6 - 1
1.1 - 1.5
1.6 - 2
2.1 - 2.5
2.6 - 3
3.1 - 3.5
3.6 - 4
4.1 - 4.5
4.6 - 5
5.1 - 5.5
5.6 - 6
6.1 - 6.5
6.6 - 7
7.1 - 7.5
7.6 - 8
8.1 - 8.5
8.6 - 9
9.1 - 9.5
9.6 - 10
10.1 - 10.5
10.6 - 11
11.1 - 11.5
11.6 - 12
12.1 - 12.5
12.6 - 13
13.1 - 13.5
13.6 - 14
14.1 - 14.5
14.6 - 15
15.1 - 23
N
Wassaw Sound - SKIO Hydrographic Survey - 2014 - Tile 3
0
0.5
1 Kilometers
Background Imagery:
Chatham County, GA 2013


The University of Georgia
NOAA
GEORGIA
COASTAL RESOURCES DIVISION
SKIO 2014
Meters (MLLW)
-2.2 - 0
0.1 - 0.5
0.6 - 1
1.1 - 1.5
1.6 - 2
2.1 - 2.5
2.6 - 3
3.1 - 3.5
3.6 - 4
4.1 - 4.5
4.6 - 5
5.1 - 5.5
5.6 - 6
6.1 - 6.5
6.6 - 7
7.1 - 7.5
7.6 - 8
8.1 - 8.5
8.6 - 9
9.1 - 9.5
9.6 - 10
10.1 - 10.5
10.6 - 11
11.1 - 11.5
11.6 - 12
12.1 - 12.5
12.6 - 13
13.1 - 13.5
13.6 - 14
14.1 - 14.5
14.6 - 15
15.1 - 23
N
Wassaw Sound - SKIO Hydrographic Survey - 2014 - Tile 4
0
0.5
1 Kilometers
Background Imagery:
Chatham County, GA 2013

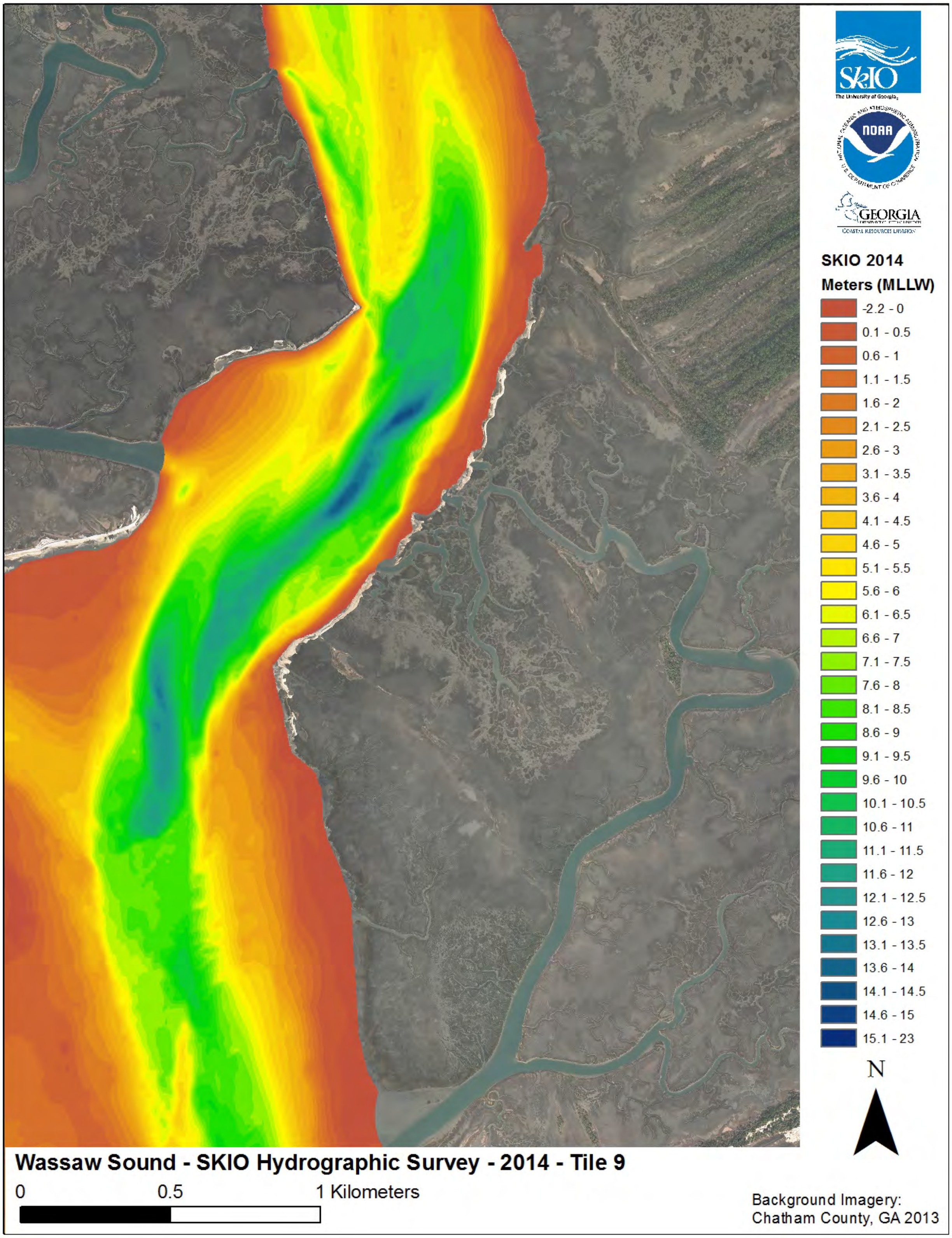

SKIO 2014
Meters (MLLW)
-2.2 - 0
0.1 - 0.5
0.6 - 1
1.1 - 1.5
1.6 - 2
2.1 - 2.5
2.6 - 3
3.1 - 3.5
3.6 - 4
4.1 - 4.5
4.6 - 5
5.1 - 5.5
5.6 - 6
6.1 - 6.5
6.6 - 7
7.1 - 7.5
7.6 - 8
8.1 - 8.5
8.6 - 9
9.1 - 9.5
9.6 - 10
10.1 - 10.5
10.6 - 11
11.1 - 11.5
11.6 - 12
12.1 - 12.5
12.6 - 13
13.1 - 13.5
13.6 - 14
14.1 - 14.5
14.6 - 15
15.1 - 23
N
Wassaw Sound - SKIO Hydrographic Survey - 2014 - Tile 5
0
0.5
1 Kilometers
Background Imagery:
Chatham County, GA 2013

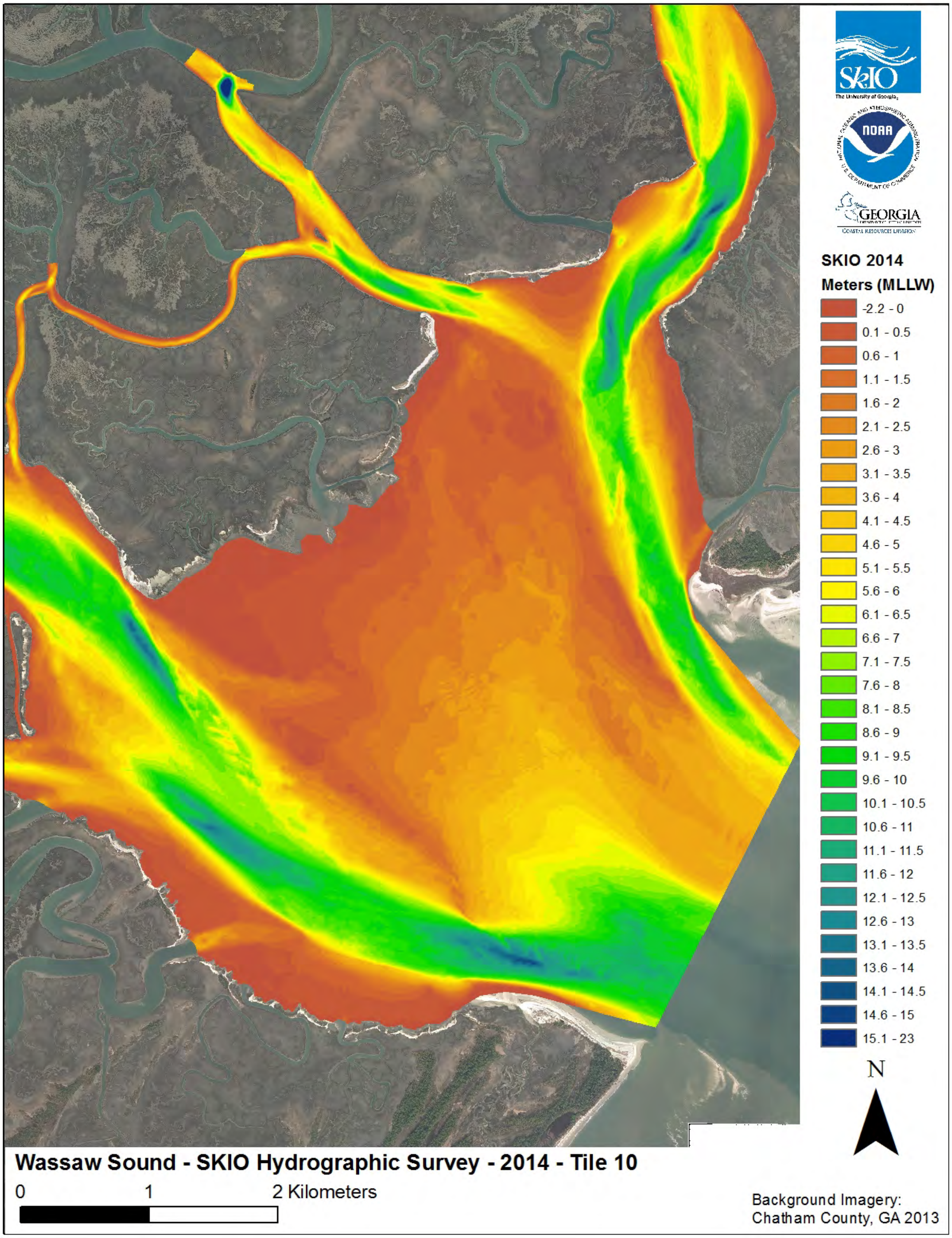

The University of Georgia
SKIO 2014
Meters (MLLW)
-2.2 - 0
0.1 - 0.5
0.6 - 1
1.1 - 1.5
1.6 - 2
2.1 - 2.5
2.6 - 3
3.1 - 3.5
3.6 - 4
4.1 - 4.5
4.6 - 5
5.1 - 5.5
5.6 - 6
6.1 - 6.5
6.6 - 7
7.1 - 7.5
7.6 - 8
8.1 - 8.5
8.6 - 9
9.1 - 9.5
9.6 - 10
10.1 - 10.5
10.6 - 11
11.1 - 11.5
11.6 - 12
12.1 - 12.5
12.6 - 13
13.1 - 13.5
13.6 - 14
14.1 - 14.5
14.6 - 15
15.1 - 23
N
Wassaw Sound - SKIO Hydrographic Survey - 2014 - Tile 6
0
0.5
1 Kilometers
Background Imagery:
Chatham County, GA 2013


SKIO 2014
Meters (MLLW)
-2.2 - 0
0.1 - 0.5
0.6 - 1
1.1 - 1.5
1.6 - 2
2.1 - 2.5
2.6 - 3
3.1 - 3.5
3.6 - 4
4.1 - 4.5
4.6 - 5
5.1 - 5.5
5.6 - 6
6.1 - 6.5
6.6 - 7
7.1 - 7.5
7.6 - 8
8.1 - 8.5
8.6 - 9
9.1 - 9.5
9.6 - 10
10.1 - 10.5
10.6 - 11
11.1 - 11.5
11.6 - 12
12.1 - 12.5
12.6 - 13
13.1 - 13.5
13.6 - 14
14.1 - 14.5
14.6 - 15
15.1 - 23
N
Wassaw Sound - SKIO Hydrographic Survey - 2014 - Tile 7
0
0.5
1 Kilometers
Background Imagery:
Chatham County, GA 2013



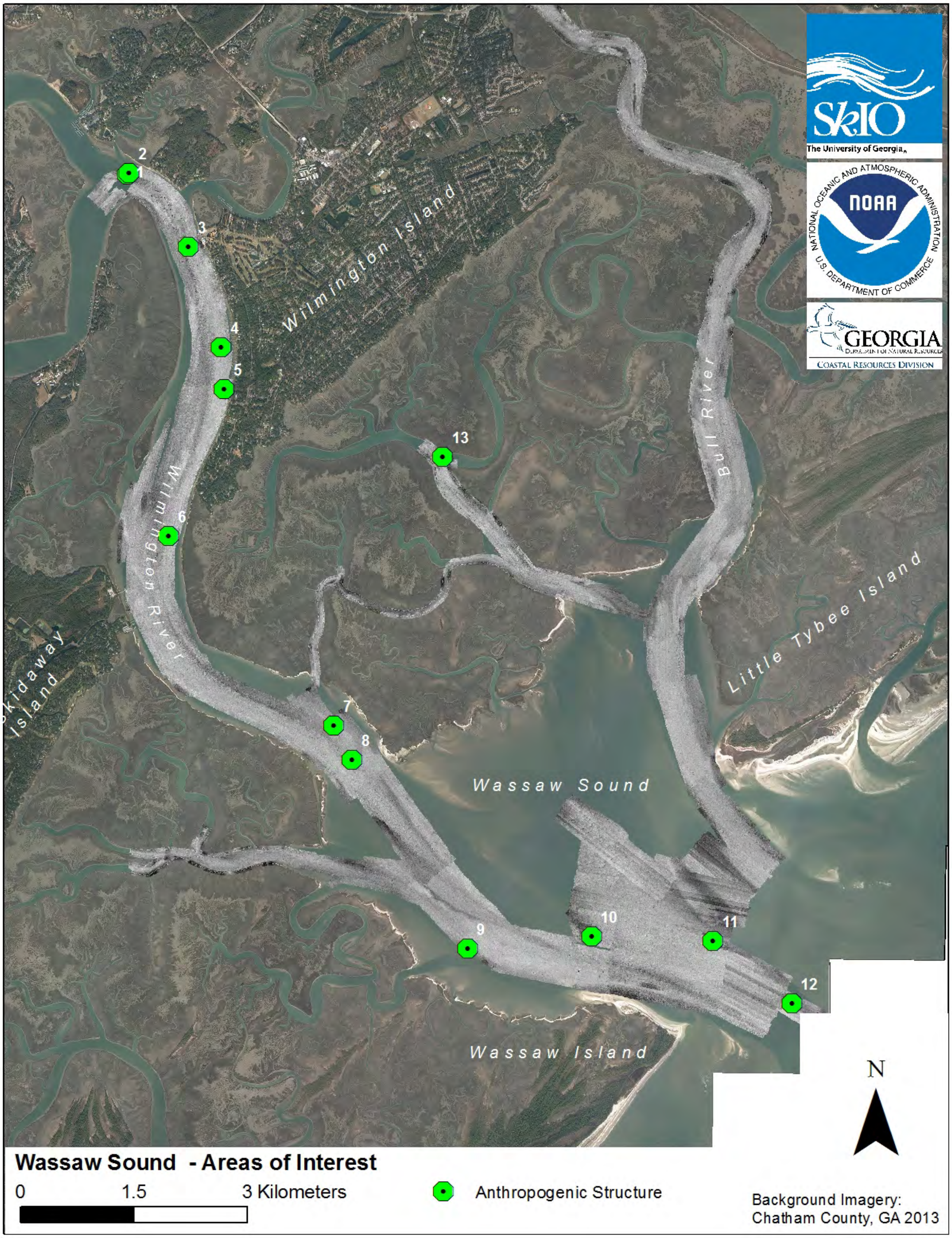
Wassaw Sound - SKIO Hydrographic Survey - 2014 - Tile 8


SkIO
The University of Georgia
NOAA
GEORGIA
COASTAL RESOURCES DIVISION
SKIO 2014
Meters (MLLW)
-2.2 - 0
0.1 - 0.5
0.6 - 1
1.1 - 1.5
1.6 - 2
2.1 - 2.5
2.6 - 3
3.1 - 3.5
3.6 - 4
4.1 - 4.5
4.6 - 5
5.1 - 5.5
5.6 - 6
6.1 - 6.5
6.6 - 7
7.1 - 7.5
7.6 - 8
8.1 - 8.5
8.6 - 9
9.1 - 9.5
9.6 - 10
10.1 - 10.5
10.6 - 11
11.1 - 11.5
11.6 - 12
12.1 - 12.5
12.6 - 13
13.1 - 13.5
13.6 - 14
14.1 - 14.5
14.6 - 15
15.1 - 23
N
Wassaw Sound - SKIO Hydrographic Survey - 2014 - Tile 9
0
0.5
1 Kilometers
Background Imagery:
Chatham County, GA 2013

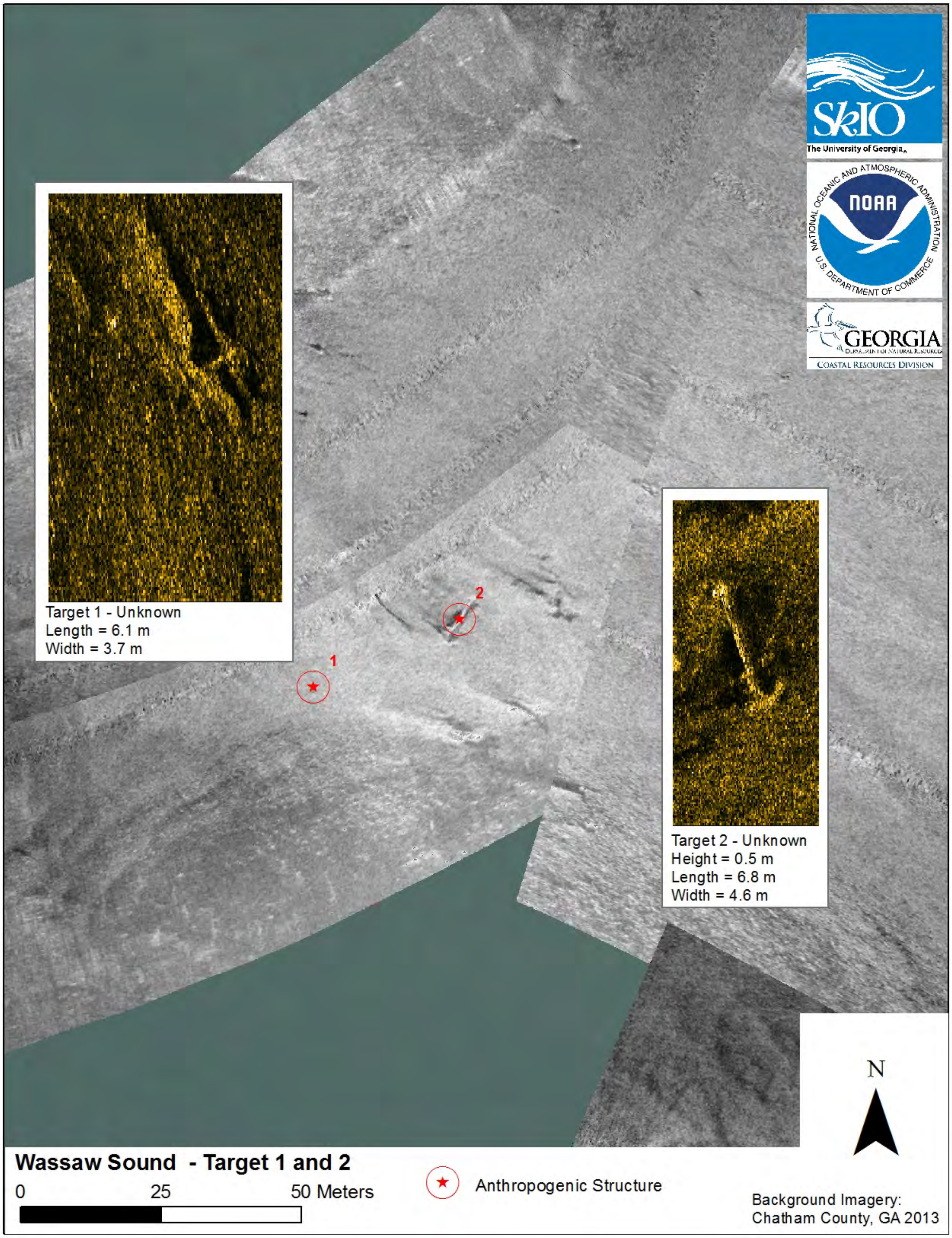

SkIO
The University of Georgia
NOAA
GEORGIA
COASTAL RESOURCES DIVISION
SKIO 2014
Meters (MLLW)
-2.2 - 0
0.1 - 0.5
0.6 - 1
1.1 - 1.5
1.6 - 2
2.1 - 2.5
2.6 - 3
3.1 - 3.5
3.6 - 4
4.1 - 4.5
4.6 - 5
5.1 - 5.5
5.6 - 6
6.1 - 6.5
6.6 - 7
7.1 - 7.5
7.6 - 8
8.1 - 8.5
8.6 - 9
9.1 - 9.5
9.6 - 10
10.1 - 10.5
10.6 - 11
11.1 - 11.5
11.6 - 12
12.1 - 12.5
12.6 - 13
13.1 - 13.5
13.6 - 14
14.1 - 14.5
14.6 - 15
15.1 - 23
N
Wassaw Sound - SKIO Hydrographic Survey - 2014 - Tile 10
0
1
2 Kilometers
Background Imagery:
Chatham County, GA 2013

Appendix 2

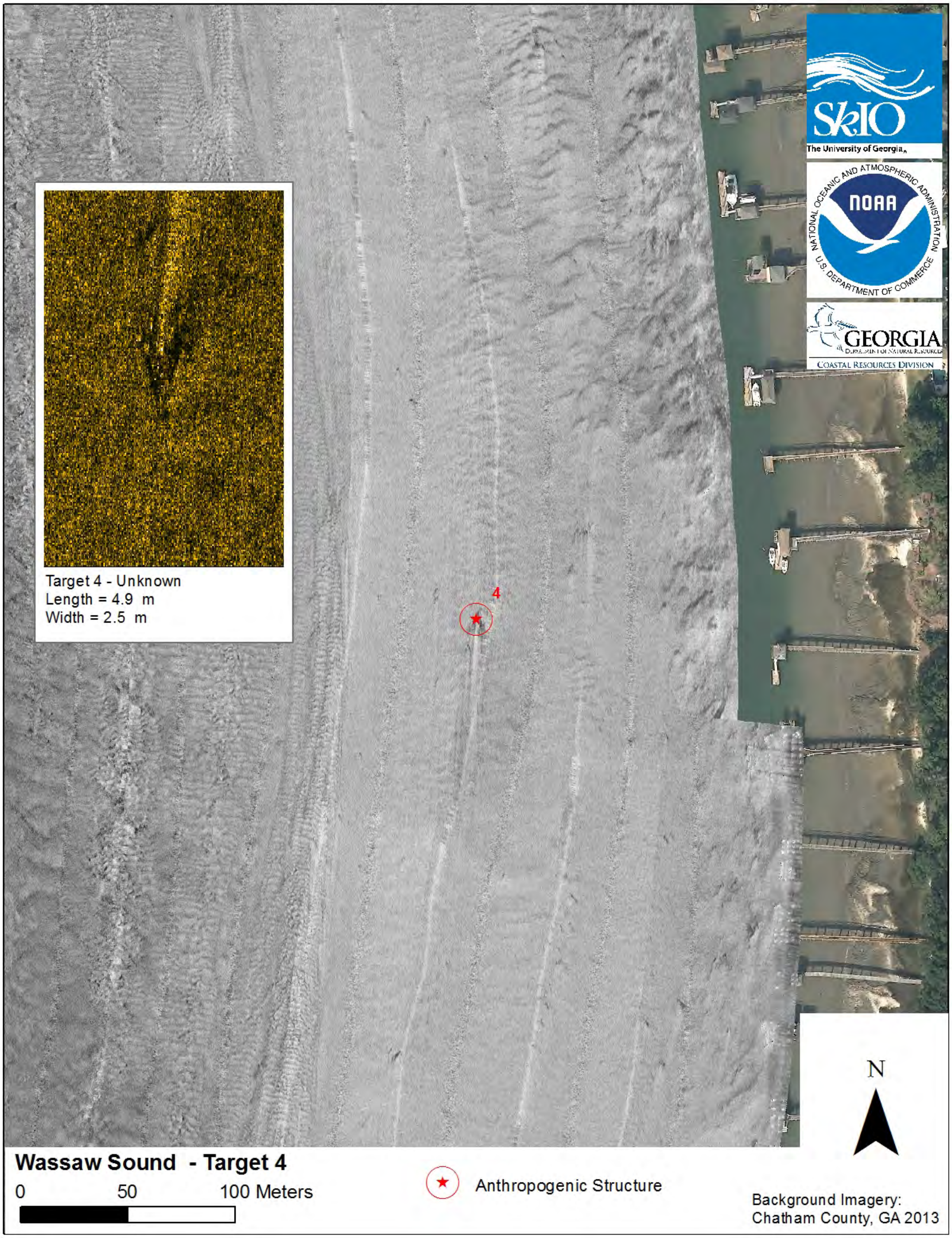
Anthropogenic targets identified with side scan sonar within the project area



Wassaw Sound - Areas of Interest
0
1.5
3 Kilometers
Anthropogenic Structure
Background Imagery:
Chatham County, GA 2013
Wilmington Island
Wilmington River
Bull River
Little Tybee Island
Wassaw Sound
Wassaw Island
Island
N
1
2
3
4
5
6
7
8
9
10
11
12
13
SkIO
The University of Georgia
NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE
GEORGIA
COASTAL RESOURCES DIVISION


Target 1 - Unknown
Length = 6.1 m
Width = 3.7 m
Target 2 - Unknown
Height = 0.5 m
Length = 6.8 m
Width = 4.6 m
1
2
SkIO
The University of Georgia
NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE
GEORGIA
COASTAL RESOURCES DIVISION
N
Wassaw Sound - Target 1 and 2
0
25
50 Meters
Anthropogenic Structure
Background Imagery:
Chatham County, GA 2013

SkIO
The University of Georgia
NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE
GEORGIA
COASTAL RESOURCES DIVISION
Target 3 - Barge
Height = 1.0 m
Length = 15.0 m
Width = 8.0 m
3
N
Wassaw Sound - Target 3
0
50
100 Meters
Anthropogenic Structure
Background Imagery:
Chatham County, GA 2013



Target 4 - Unknown
Length = 4.9 m
Width = 2.5 m
4
Wassaw Sound - Target 4
0
50
100 Meters
Anthropogenic Structure
N
Background Imagery:
Chatham County, GA 2013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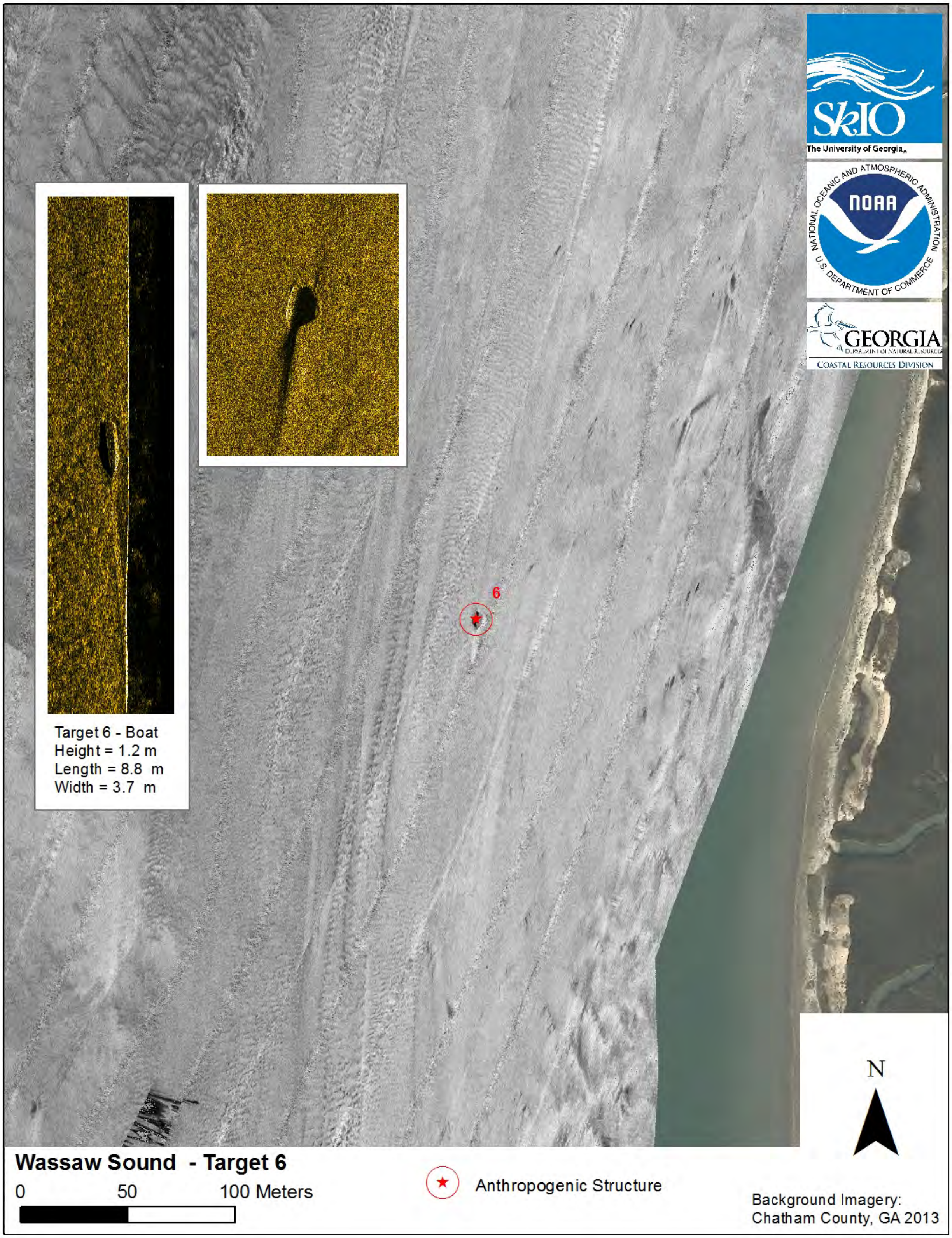
NOAA
U.S. DEPARTMENT OF COMMERCE
GEORGIA
COASTAL RESOURCES DIVISION
Target 5 - Unknown
Height = 0.4 m
Length = 4.0 m
Width = 1.7 m
5
N
Wassaw Sound - Target 5
0 50 100 Meters
Anthropogenic Structure
Background Imagery:
Chatham County, GA 2013



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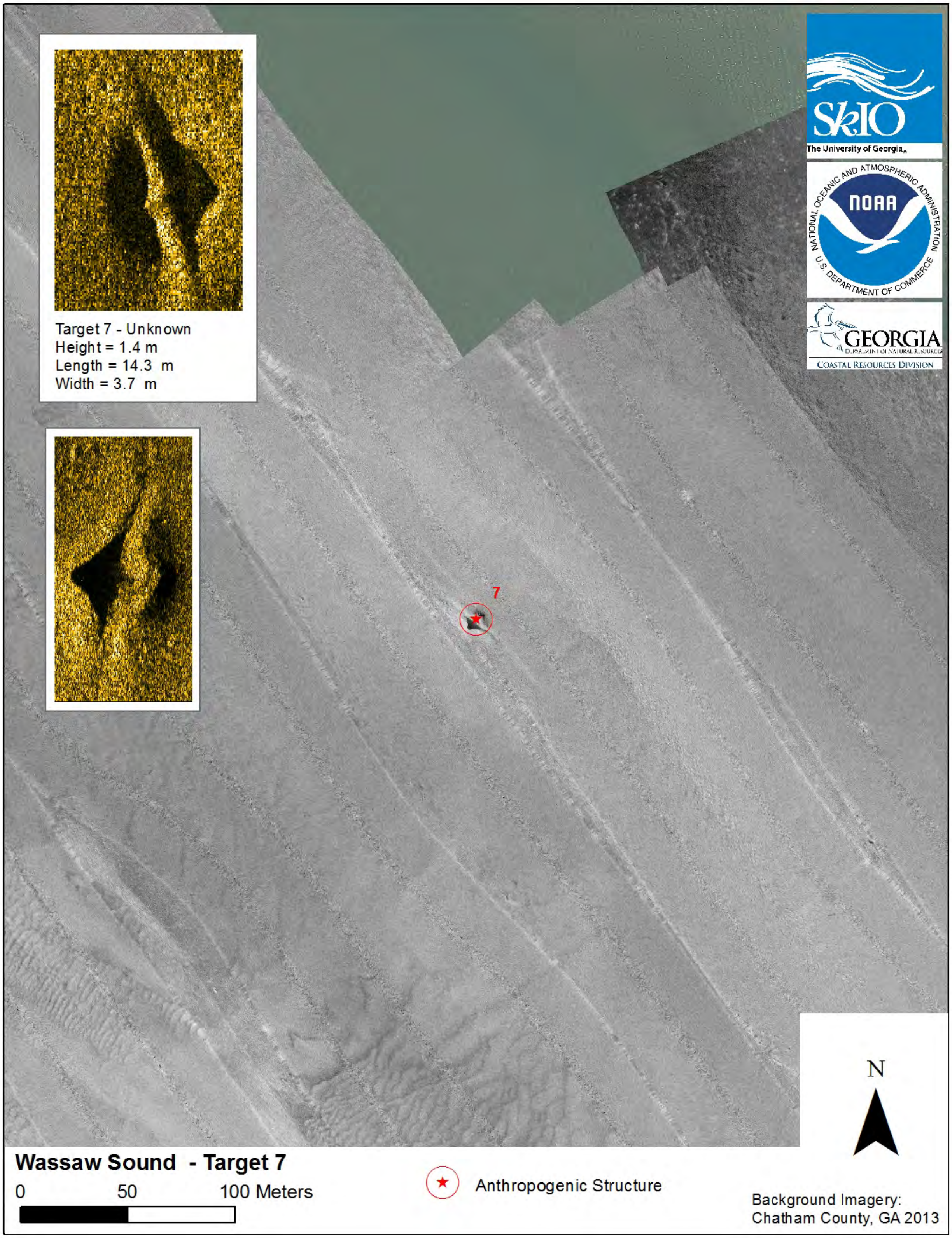
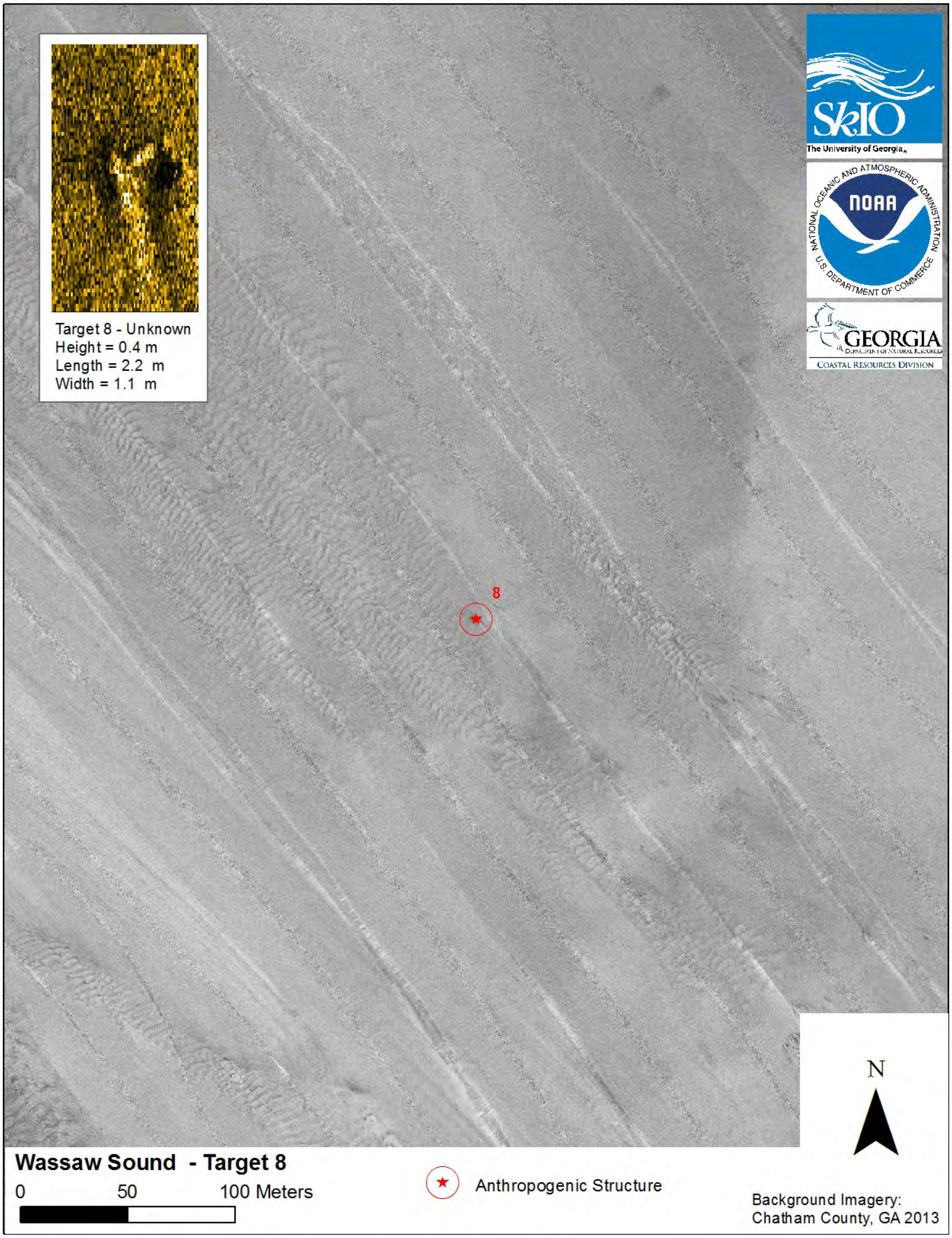
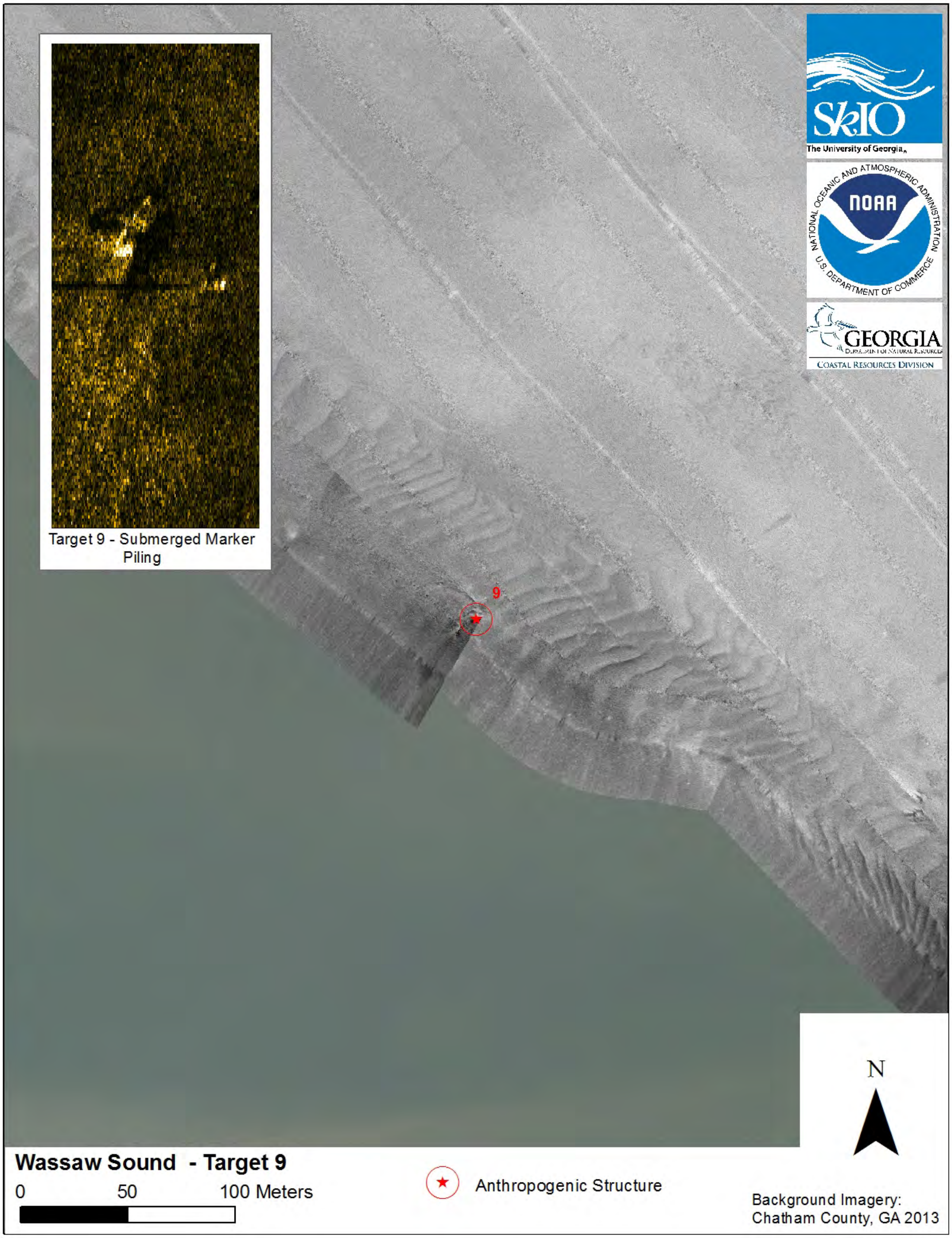
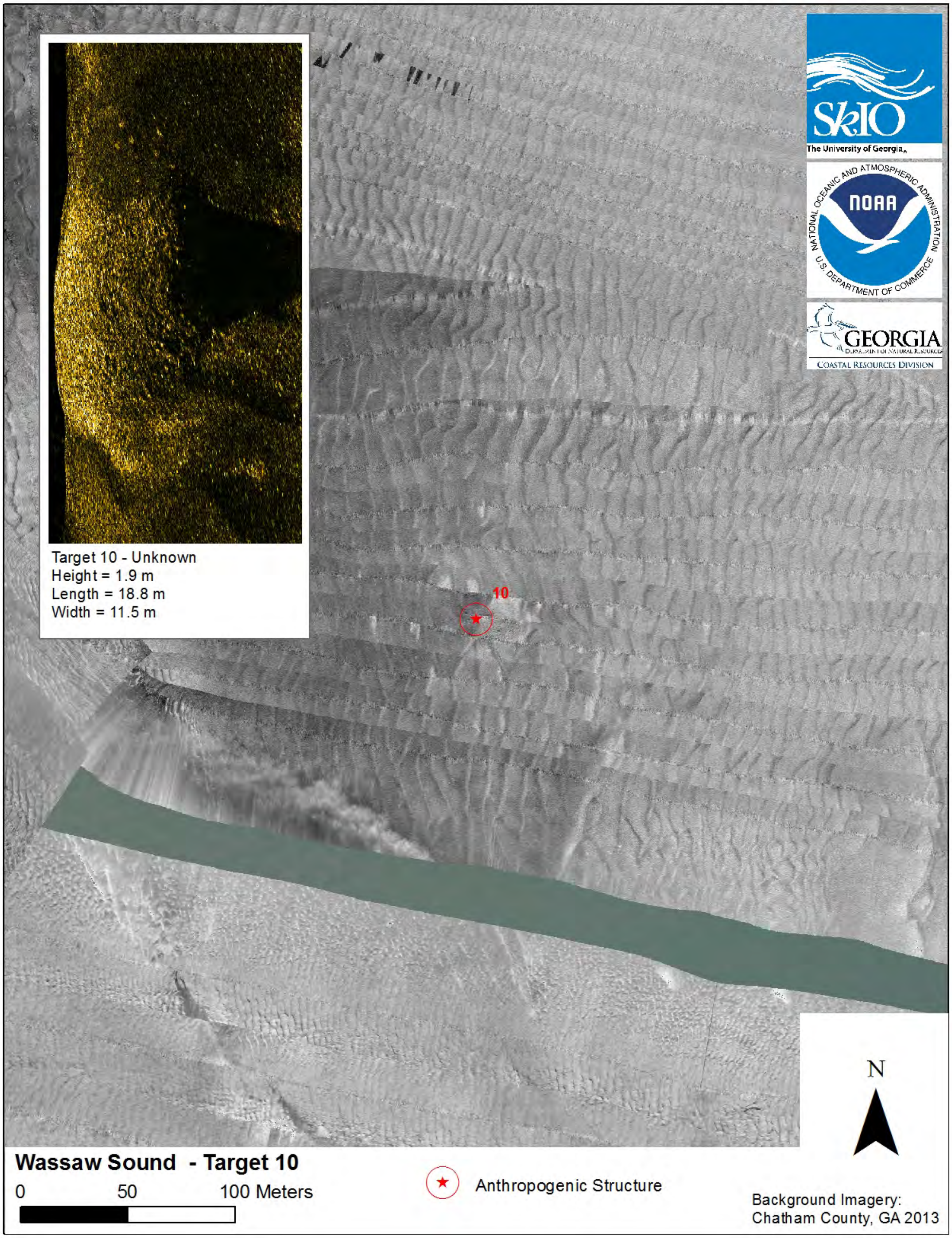
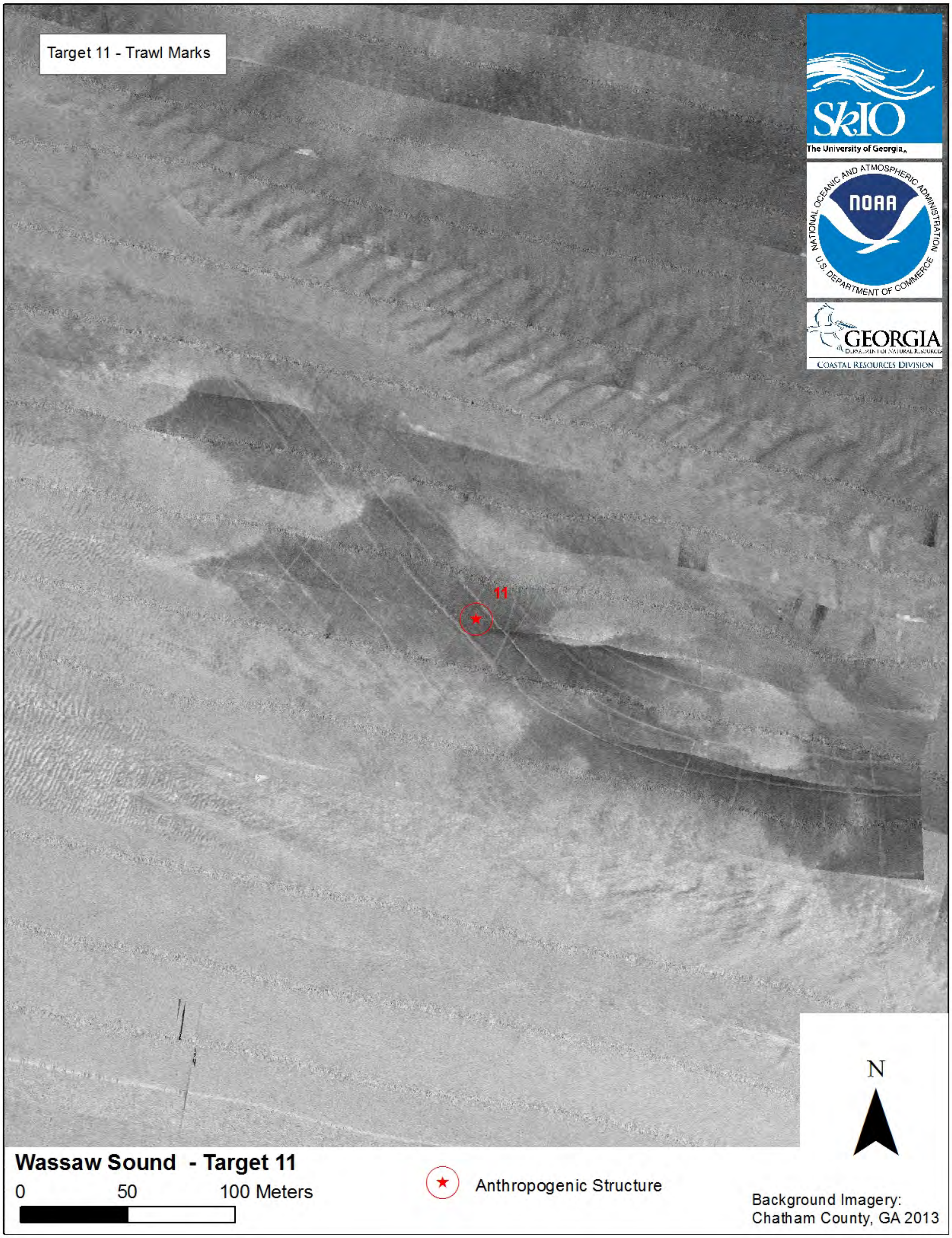
NOAA
U.S. DEPARTMENT OF COMMERCE
GEORGIA
COASTAL RESOURCES DIVISION
Target 6 - Boat
Height = 1.2 m
Length = 8.8 m
Width = 3.7 m
6
N
Wassaw Sound - Target 6
0
50
100 Meters
Anthropogenic Structure
Background Imagery:
Chatham County, GA 2013

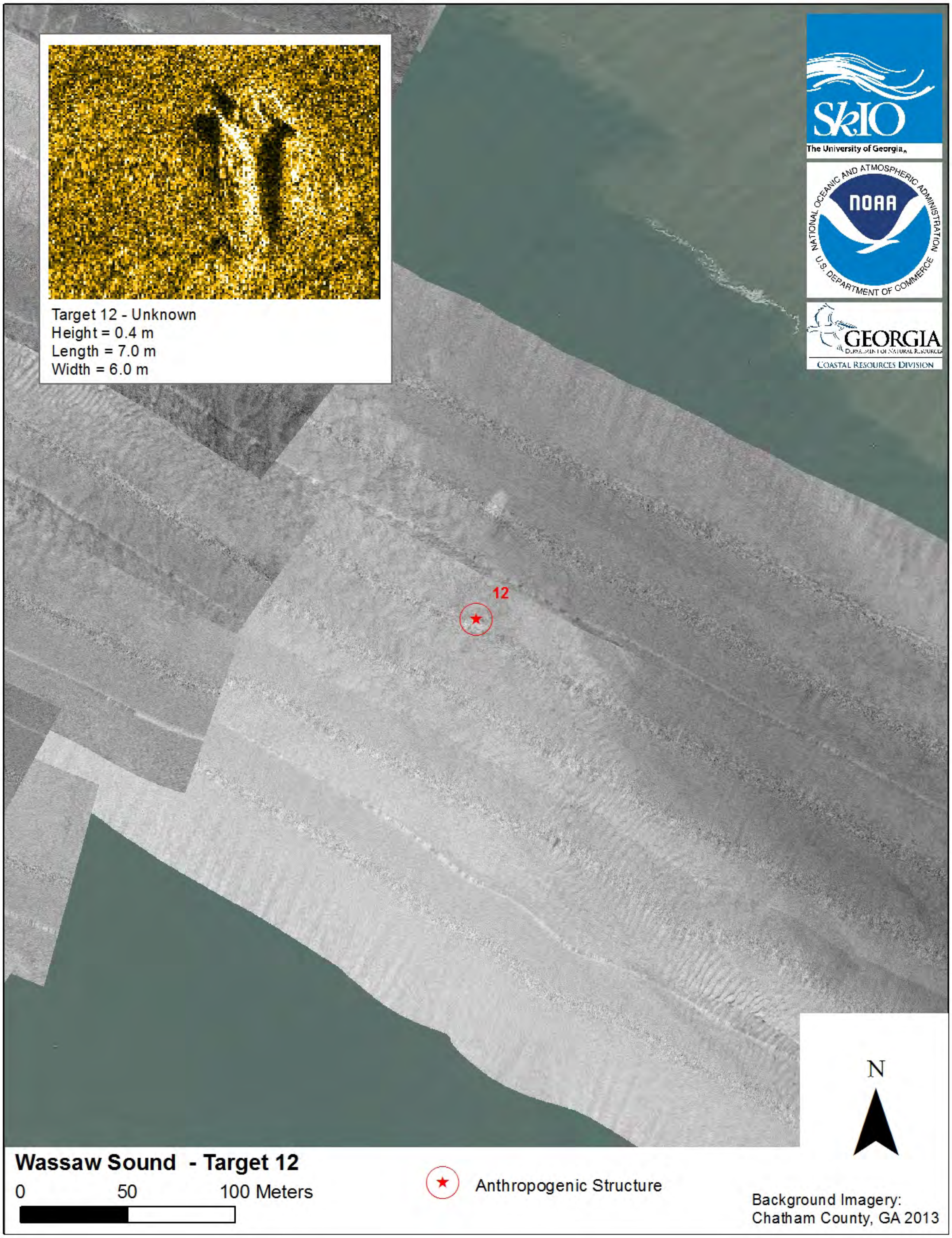

Target 7 - Unknown
Height = 1.4 m
Length = 14.3 m
Width = 3.7 m
7
SkIO
The University of Georgia
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NOAA
U.S. DEPARTMENT OF COMMERCE
GEORGIA
COASTAL RESOURCES DIVISION
N
Wassaw Sound - Target 7
0
50
100 Meters
Anthropogenic Structure
Background Imagery:
Chatham County, GA 2013

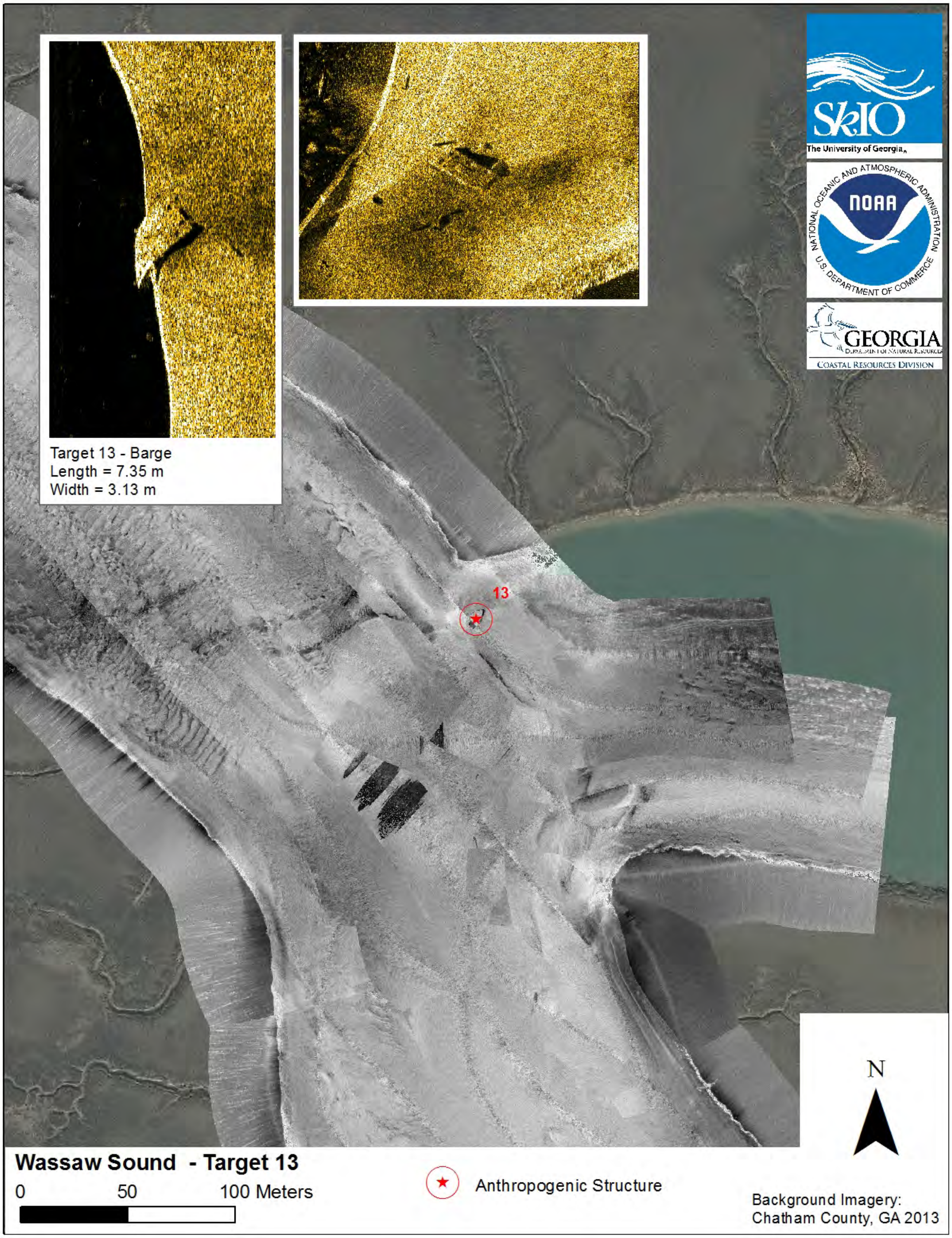

Target 8 - Unknown
Height = 0.4 m
Length = 2.2 m
Width = 1.1 m
8
N
Wassaw Sound - Target 8
0
50
100 Meters
Anthropogenic Structure
Background Imagery:
Chatham County, GA 2013


Target 9 - Submerged Marker Piling
9
The University of Georgia
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NOAA
U.S. DEPARTMENT OF COMMERCE
GEORGIA
COASTAL RESOURCES DIVISION
N
Wassaw Sound - Target 9
0
50
100 Meters
Anthropogenic Structure
Background Imagery:
Chatham County, GA 2013


Target 10 - Unknown
Height = 1.9 m
Length = 18.8 m
Width = 11.5 m
10
N
Wassaw Sound - Target 10
0
50
100 Meters
Anthropogenic Structure
Background Imagery:
Chatham County, GA 2013


Target 11 - Trawl Marks
11
N
Wassaw Sound - Target 11
0
50
100 Meters
Anthropogenic Structure
Background Imagery:
Chatham County, GA 2013


Target 12 - Unknown
Height = 0.4 m
Length = 7.0 m
Width = 6.0 m
SkIO
The University of Georgia
NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE
GEORGIA
COASTAL RESOURCES DIVISION
12
N
Wassaw Sound - Target 12
0
50
100 Meters
Anthropogenic Structure
Background Imagery:
Chatham County, GA 2013


Target 13 - Barge
Length = 7.35 m
Width = 3.13 m
13
N
Wassaw Sound - Target 13
0
50
100 Meters
Anthropogenic Structure
Background Imagery:
Chatham County, GA 2013

APPENDIX I

TIDES AND WATER LEVELS

W00344 Does not include any tide and water level documentation

APPENDIX II

SUPPLEMENTAL SURVEY RECORDS AND CORRESPONDENCE

W00344 Does not include any supplemental survey records or correspondence.

APPROVAL PAGE

W00344

Data meet or exceed current specifications as certified by the OCS survey acceptance review process. Descriptive Report and survey data except where noted are adequate to supersede prior surveys and nautical charts in the common area.

The following products will be sent to NCEI for archive

- Descriptive Report
- Collection of Bathymetric Attributed Grids (BAGs)
- Processed survey data and records
- GeoPDF of survey products

The survey evaluation and verification has been conducted according current OCS Specifications, and the survey has been approved for dissemination and usage of updating NOAA's suite of nautical charts.

Approved: Digitally signed by WARTICK.RYAN.AUGUSTUS.1100903608 Date: 2019.05.02 12:33:06 -04'00'

Lieutenant Commander Ryan Wartick, NOAA
Chief, Atlantic Hydrographic Branch