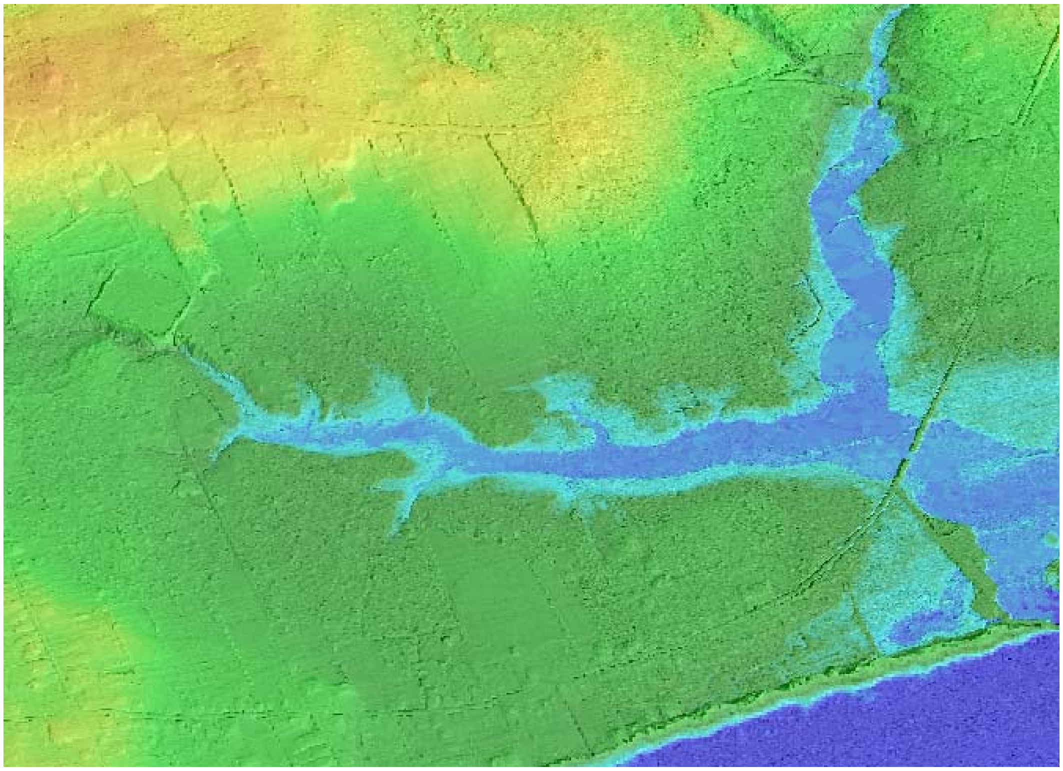
Sea- Level Rise and Climate Change on the Coastal Zone of southeastern New Brunswick



Applied Geomatics Research Group

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Background

Coastal sensitivity to sea level rise has become a major issue in Canada and a nation wide overview published by the Geological Survey of Canada in 1998 demonstrates that there are low, moderate, and high sensitivity regions. Some of the most severely threatened coastal areas in Canada are parts of the Atlantic coast, demonstrated by the map in figure 1, including most sections of southeastern New Brunswick. Factors contributing to this coastal sensitivity include soft sandstone bedrock, a sandy and dynamic shore zone, an indented shoreline with extensive salt marsh, low terrain behind the shore with significant flooding potential, documented high rates of shore retreat, and ongoing submergence of the coast (Webster et al., 2003).

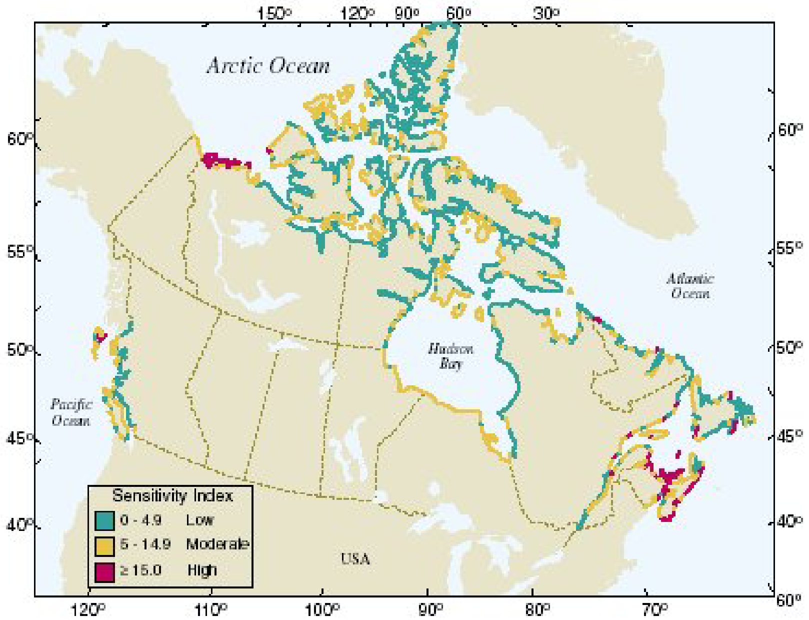

Figure 1 – Schematic map representing regions of the Canadian coast that are sensitive to sea level rise, based on a nation wide overview published by the Geological Survey of Canada in 1998 (Shaw, 1998).

Impacts of sea level rise vary from location to location and often lead to many physical changes to the coastal environment. These changes, in turn, affect human uses such as settlement, tourism, fishing, agriculture, as well as wildlife uses of the coast. The most serious physical impacts of sea level rise on coastal zones are inundation and displacement of wetlands and lowlands; coastal erosion; increased vulnerability to coastal storm damage and flooding; and salinization of surface water and ground water. The Intergovernmental Panel on Climate Change predicts that global average sea level may increase by 0.09-0.088 meter by the year 2100, placing the lives and property of 46 million people at risk (Houghton et al., 2001).

Accelerated sea level rise due to global warming can intensify these coastal impacts that already occur in these sensitive regions. Storm surges are the meteorological effects on sea level and can be defined at the coast as the difference between the observed water level and the predicted astronomical tide (Environment Canada Website, 2001).

Coastal inundation and extensive damage result when large storm surges occur during times of high tides. The combined effects of sea level rise and climate change will lead to higher and more frequent flooding of the existing coastal areas and an increase in erosion of coastal features such as dines (Webster et al., 2003).

Figure 2 – Coastal areas of southeastern New Brunswick incorporate a wide range of different environments such as urban (left) and estuarial tidal flats (right).

An airborne LIDAR system can obtain high-resolution data that can be processed to produce an accurate representation of the topography, perfect for predicting areas that are at risk to coastal flooding associated with sea level rise and storm surge events. The LIDAR sensor emits a series of near-infrared laser pulses toward the surface and records the time difference between the contact with the surface and the return to the sensor after reflection. The aircraft uses a high precision global positioning system (GPS) and an inertial measurement unit (IMU) to determine the location and measure the attitude so that the ground location of the return laser pulse can be determined.

Figure 3 – Terra Remote Sensing LIDAR setup showing the aircraft (left), the sensor mount (middle) and the equipment inside of the aircraft (right).

The LIDAR data consists of a series of point measurements that consists of geographic location and height of both natural and man-made features, and can be processed to produce several different products and can be integrated into a geographic information system (GIS). The point data can be separated into a file containing only points that interact with the surface and a file that contains all of the rest of the points.

This separation of data allows for the construction of a digital surface model with the forests and other features (non ground related) removed, providing a true ground digital elevation model (DEM). A DEM is a representation or a visual description of the general land surface. Traditional DEMs are typically derived from photogrammetry, and do not have the vertical accuracy or resolution suitable for most scales of regional floodplain mapping (e.g. 1:10,000). Good flood simulation must be simulated on a surface that best represents the actual ground elevation.

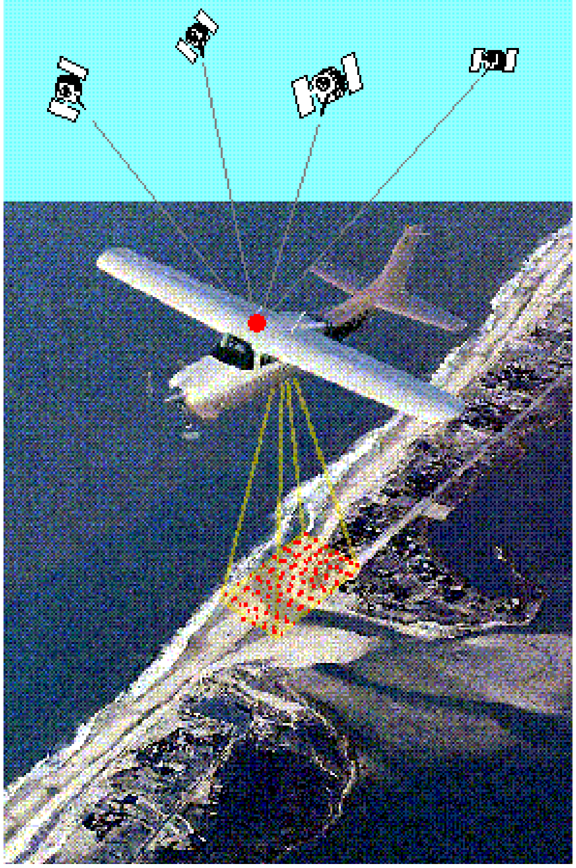

Figure 4 – Schematic of airborne LIDAR mapping technology (Carter, 2000). Global Positioning System and an Inertial Measurement Unit determine the location of the aircraft when the laser pulse is sent and returns.

LIDAR data for this project was collected by Terra Remote Sensing during the spring of 2003 and will conclude during the spring of 2004, as part of the Canada Climate Change Action Fund (CCAF) proposal # A591 requirements. Terra's sensor is a first return sensor (Mark-I) with a diode pumped YAG scanning laser operating in a wavelength of 1047 nanometers, and has a swath scan of 56 degrees. Its pulse repetition frequency is typically up to 10 kHz and results in relative accuracies in the horizontal and vertical axes at normal flying altitudes of up to 30 cm depending on nature of the ground cover.

The resultant LIDAR is split into files representing ground hits, and non-ground hits, by the vendor. The data arrives in the form of ASCII text files, all hits, non-ground and ground hits. The data will need to be imported and processed with GIS and image processing software to generate the accurate DEM products. The high accuracy and high data point density achieved by LIDAR has improved the accuracy of flood hazard mapping (Christian, 2001).

Objectives

The overall goals of this project are to:

1) Develop an in-depth technical understanding of using LIDAR data to create accurate 3D surface models suitable to create flood risk maps

2) Make a significant contribution to the CCAF project

The main objectives of this project are to:

1) Establish ground control in support of the Terra LIDAR mission and validate the LIDAR data provided using a high precision global positioning system

2) Build accurate Digital Elevation Models and Digital Surface Models from the high resolution LIDAR data of the coastal zone of southeastern New Brunswick

3) Create three dimensional visualizations of the coastal topography

4) Provide flood risk maps for three different sea level rise scenarios of the study areas that Terra flown in the spring of 2003. Sea level and storm surge data to be provided by the Storm Surge and Meteor Modeling sub projects.

5) Share resultant data with partners of the CCAF project

Study Area

The entire study area consists of the coastal region of southeastern New Brunswick from Kouchibouguac National Park to Jourimain Island. The study area is split into ten smaller polygons, based on sub-project requirements of the CCAF project team. The polygons, (shown in the map of figure 5) have been given the following general names: Kouchibouguac National Park, Cap-Lumiere, laDune, Bouctouche, Cormierville, Ille Cocagne, Cap-Pele, Shemogue Harbour, Little Shemogue, and Cape Jourimain.

Note: Four polygons were excluded (Kouchibouguac National Park, Shemogue Harbour, Little Shemogue, and Cape Jourimain) from this project due to technical difficulties that Terra experienced with their new LIDAR Mark II system. These polygons will be flown in the spring of 2004 and the LIDAR data will be processed by the AGRG.

Figure 5 –LandSat image of southeastern New Brunswick to show geographically where each LIDAR study area is located.

Data Sources and Analytical Tools

LIDAR

Terra Remote Sensing provided the LIDAR data in an ASCII (American Standard Code for Information Interchange) file format. The LIDAR data was split into two types; a ground only hits file and a non-ground only hits file, and each file contains the following data: GPS Week, GPS time, Flight Line Number, Easting, Northing, orthometric height, and Ellipsoidal height.

Reference System: WGS 84
Projection: UTM Zone 20 N
Resolution (XY): 0.6 metre
Relative Accuracy: ± 0.3 metres
Absolute Accuracy ± 0.3 metres

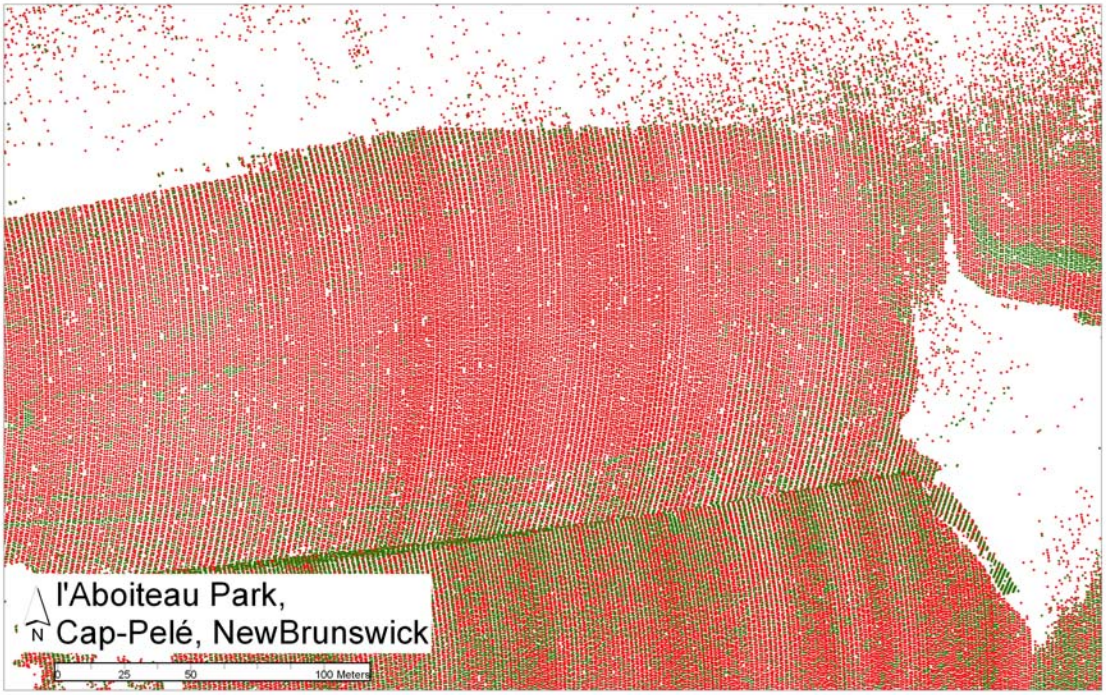

Figure 6 –LIDAR point data separated into ground (red) and non ground (green) points of l'Aboiteau Provincial Park in the Cap Pele area.

GPS Validation data

GPS data was collected by members of the AGRG with a Leica RTK GPS System and sometimes with a Leica Total Station. Data was collected in the fall of 2002, spring of 2003 (while Terra was flying), and the fall of 2003. The data was processed and exported into ESRI shapefile format. The GPS data contained the following data: easting, northing, orthometric height, geoid separation, GPS time, Standard deviations and field work related attributes such as photos numbers, and ground details. GPS data for LIDAR validation has been collected for the whole region.

Reference System: WGS 84
Geoid model: HT1-01
Projection: UTM Zone 20 N
Accuracy: ± 0.02 metres

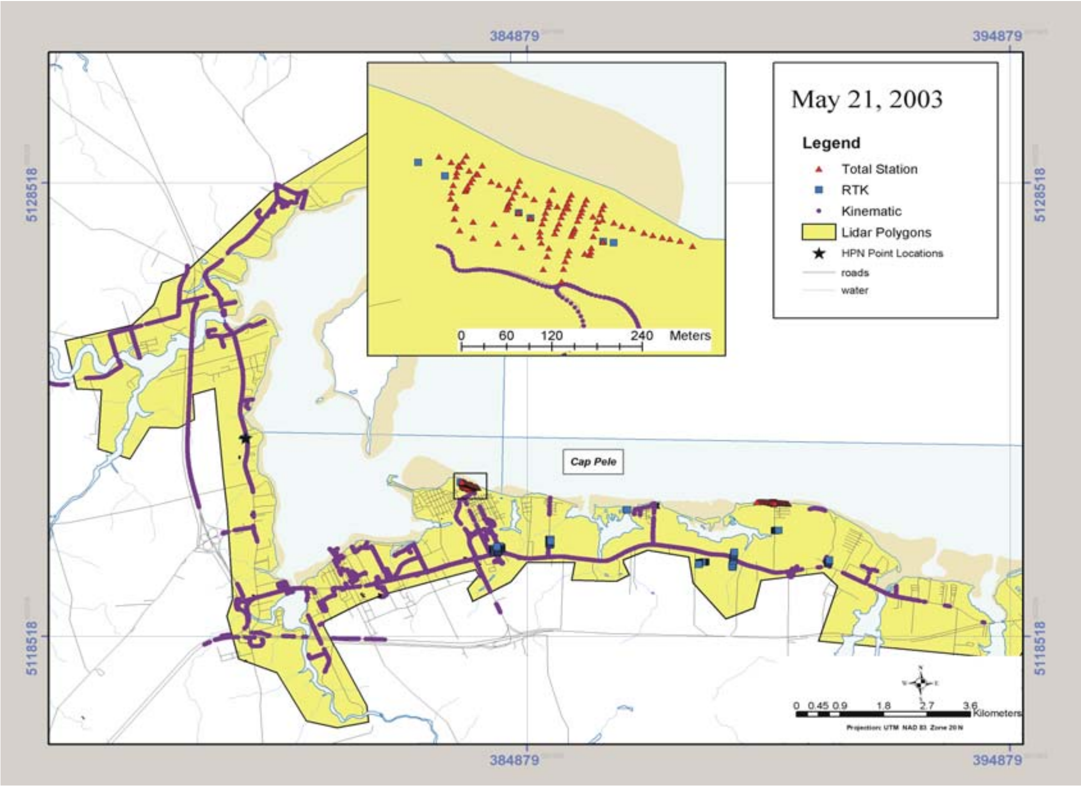

Figure 7 – This map displays the GPS data collected from the Shediac area. The RTK GPS data acquired with a vehicle is represented by the purple, the RTK GPS data with a pole by blue, and the Total Station data by the red.

Orthophoto Data

Service New Brunswick provided digital Orthophotos for the study areas from their SODB (Softcopy Orthomap Data Base). The orthophotos are compressed utilizing a lossy compression technique based on wavelet technology using a compression engine called Multi-resolution Seamless Image Database (MrSID). More information on MrSID is available from LizardTech, Inc. (www.lizardtech.com).

Reference System: NAD83(CSRS)
Projection: NB Double Stereographic
Resolution (XY): 1.0 metre
Nominal Scale: 1:10 000
Accuracy: ± 4 metres for well defined features

Digital Topographic Data

Service New Brunswick provided Digital Topographic Data for the study areas from their DTDB98 (Digital Topographic Data Base 1998), created with CAIRIS (Computer Aided Resource Information System) software. The DTDB98 consists of two distinct data bases; the Enhanced Topographic Base (ETB) and a Digital Terrain Model (DTM) Data Base.

The ETB contains two-dimensional (X, Y) topographic features and associated attributes. The files contain topographic features organized into nine general categories: Buildings, Designated Areas, Delimiters, Land Cover, Land Features, Transportation (Road/Railroad), Structures, Utilities and Hydrography. Transportation and Hydrography are each maintained in their own files, *.198,*.398 respectively. The remaining seven general categories are maintained in one *.g98 file.

The *DTM Data Base* contains elevation data. The files, *.d98, contain elevation mass points, check points, and spot heights.

Reference System: NAD83 (CSRS)
Projection: Stereographic Double
Resolution (XY): 1.0 metre
Resolution (Z): 0.1 metre
Nominal Scale: 1:10 000
Accuracy: ± 2.5 metres for well defined features

Other Data Sources

Digital photography – Various digital photographs were taken during the field missions to aid in the validation

Flood Data – Three different sea level scenarios based on actual storm surge and flood data will be supplied by CCAF Sub projects

Analytical Software Tools

- Leica SKI-PRO 3.0
- ESRI Workstation
- ESRI ArcView 3.3
- ESRI ArcGIS 9.0 Betta II
- PCI Geomatica 9.0
- Helical
- Microsoft Office

Hardware Tools

- Leica RTK GPS System (500 series)
- Leica Total Station (TPS1100 series)
- Sun Micro Systems Unix server
- Dell PC (SPECS)
- Printers / plotters

Methodology

The following represents a basic overview of the methodology that is involved with this project. The final report will contain more elaborate details.

Ground Validation Work

Differential GPS data provides accurate orthometric heights to validate the LIDAR data with. A Leica RTK GPS system provided the centimeter accuracy needed to ensure that the LIDAR data will meet the required specifications. Three different GPS configurations were used to collect this data, RTK on a pole, RTK with a vehicle, and a Total station.

Figure 8 – GPS data were collected with a Leica RTK system on a pole (left), on top of a vehicle (middle), and with a total station unit (right).

The Leica GPS unit was mounted to a vehicle to provide RTK GPS of hard surface features, including roads, and parking lots. This method of GPS data collection provided a method of collecting accurate measurements over a larger coverage area.

RTK on the pole was used to provide the base measurements for the total station, and to take GPS measurements where a vehicle could not get access to (coastal dunes, wharf edges etc.). Transects were done with both the RTK and the Total station, to provide profiles of the surface. The total station will be used to collect validation data underneath forest canopy.

All GPS data was processed with LEICA SkiPro software and then xported as ASCII text format imported into ArcView and exported as a shape file. All field notes were attached as attributes and digital photos were hot linked to provide a GPS validation product.

GIS Processing

The LIDAR data was imported onto a Sun Microsystems Unix platform. The files were then processed into point coverages with ESRI ArcInfo Workstation. DEMs will be generated by creating triangulated irregular networks (TIN) using the point coverages. The point coverages will be assessed to ensure that the ground versus non ground separation has been properly applied by Terra.

PCI Geomatica software will be used to create 3D color shaded relief models with the DEMs and to export the data into geo-tiff format. PCI will also be used to create a seamless DEM surface model for each polygon. Perspective views of the surface will be generated with PCI and ESRI.

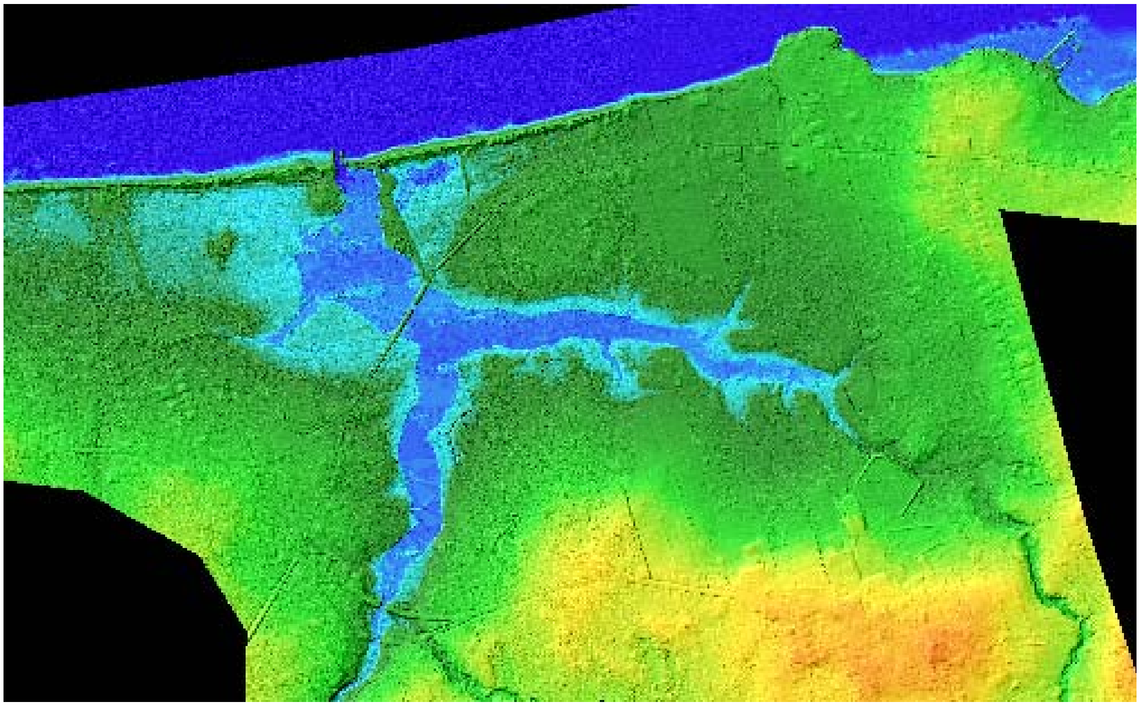

Figure 9 – Color shaded relief image created from the LIDAR DEM of the ground topography in the Cap Pele area (Image is about 4km by 2.5km).

LIDAR Validation

The interpolated surface models will be validated to ensure that the quality of the data is acceptable and that the vendor maintains the accuracy. This will be done with several methods. A visual process will involve checking each DEM for artefacts and other processing errors.

A second method will involve comparing the GPS to proximal LIDAR points. A two-meter search radius will be applied to the GPS points and the LIDAR points from within this buffer region will be selected and compared with the GPS orthometric heights.

A third method will involve comparing the GPS points with the surface derived from the LIDAR data. Statistics for the errors encountered will be generated with a spread sheet, and summarized to see if the vendor's data meets the specifications.

Flood Simulation

3D digital surface models will be created with PCI. The sea level rise data will be acquired and then polygon layers will be generated representing the various sea level scenarios. The derived layers will then be applied to the 3D models to provide Flood Risk maps. Exact procedure will be similar to the procedure outlined by Dickie (2002) and Webster et.al (2003) documented in final report. A tool designed by the AGRG will be used to test the model for connectivity issues that often arise when creating flood risk maps.

Deliverables

1) Flood Risk Maps (CCAF and AGRG)
    - Maps demonstrating areas at risk to flood for different sea level scenarios

2) Three dimensional visualization (CCAF and AGRG)
    - 3D visualizations of the land surface under different sea level scenarios
    - Color Shaded relief Models of the regions

3) DEM using ESRI tools (CCAF and AGRG)

4) GPS validation work (AGRG)
    - All GPS data, field work, photos incorporated into an ArcMap Project

5) CD-ROM copies to CCAF clients (CCAF and AGRG)

6) Final Report, Posters and Presentation (AGRG)

Time Line

Ground Validation	May 2003 & Nov 2003
Post Processing of LIDAR data	February 2004
Build digital elevation models	March 2004
Flood Risk Maps	April 2004
Ground Validation (Spring Flights)	May 2004
CCAF Interim Report	April 2004
Final Report / Presentation	May 2004

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