THREE DIMENTIONAL FLOOD MODELING WITH HIGH RESOLUTION LIDAR

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Abstract

Several Flood Simulation products can be modeled using LIDAR, GIS and Remote Sensing tools. Flood risk, extent and depth maps represented by actual storm surge flood events were generated from high resolution LIDAR surfaces with a GIS. These products provide valuable information for strategic planning to help prevent coastal flood damage.

The main purpose of this project was to generate flood maps and DEMs with better than 30 cm vertical accuracy for the coastal area of southeastern New Brunswick in support of Climate Change Action Fund (CCAF) Project A591. The CCAF project is a venture partnered with Environment Canada, Geological Survey of Canada, Natural Resources Canada, New Brunswick Resources and Energy, Parks Canada, Universite de Moncton, Nova Scotia Community College and the University of New Brunswick. The aim of the CCAF project team is to collaborate together and generate accurate maps and information that will quantify the impacts of climate change, sea-level rise, storm surge events and coastal erosion in support of sustainable management and the development of adaptation strategies.

Airborne LIDAR systems can obtain high-resolution elevation data that can be processed to produce accurate topographic representations. 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 and an inertial measurement unit to determine the location and attitude of the aircraft so that the ground location of the return laser pulse can be determined. This project used LIDAR data to produce accurate representations of the landscape and to provide accurate hydrological bare earth DEMs that are necessary to perform accurate flood risk modelling.

Flood level data were provided by CCAF project partners, and used to flood landward areas. The highest experienced water level in the region occurred during a storm surge on January 21, 2000 that caused extensive coastal damage to the area. The extreme high-water mark for this event was recorded as 3.6 m above Chart Datum and was used as the first modeled water level. The second water level was based on the January 2000 level plus an estimated 100 year predicted 70 cm relative sea-level rise with extreme conditions. The third level was based on the January 2000 level plus an estimated 100 year predicted 50 cm relative sea-level rise with moderate conditions.

The main study area was divided into ten sections located along the Gulf Shore of New Brunswick from Kouchibouguac National Park south along the coast to Jourimain Island and includes the areas of highest scientific interest and significant priority. Six of the ten study areas have been completed to date and the final four are scheduled to be processed during the fall of 2004. The six study areas flown to date and processed as part of this graduate project contained 40 tiles of LIDAR data, covered about 165,500 square kilometres and contained over 45 million points.

Acknowledgements

Thanks to fellow researchers and staff at the Applied Geomatics Research Group for their assistance throughout this project, specifically: Tim Webster, my project supervisor; Adam Bonnycastle, fellow research associate; and Steve Dickie, former AGRG graduate. I would also like to thank my wife and children for allowing me to spend so much time on this and other projects with the Applied Geomatics Research Group during the past year.

Project funding was provided by Environment Canada through the Climate Change Action Fund project (Réal Daigle, Project Manager) and funding for acquisition of the LIDAR data was provided by the Climate Change Action Fund project, Applied Geomatics Research Group, and the Atlantic Canada Innovation Fund federal research grant.

Orthophotos and topographic base data sets were provided by Service New Brunswick and data used to create flood levels were provided from Climate Change Action Fund project partners (H. Ritchie, K. Thompson, G. Parkes and D. Forbes).

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List of Acronyms

The following acronyms are used within this document.

Acronym	Long Form
3D	Three Dimensional
AGRG	Applied Geomatics Research Group
AIF	Atlantic Innovation Fund
AML	Arc Macro Language
ArcGIS	ESRI GIS Software
ARCINFO	GIS Software by ESRI
ASCII	American Standard Code for Information Exchange
ATV	Atlantic Television
CARIS	Computer Aided Resource Information System
CCAF	Climate Change Action Fund
CD	Chart Datum
CGVD28	Canadian Geodetic Vertical Datum of 1928
CM	Centimetre
COGS	Center of Geographic Sciences
CSR	Color Shaded Relief
CSRS	Canadian Spatial Reference System
DBF	Data Base Format
DEM	Digital Elevation Model
DTM	Digital Terrain Model
DTDB	Digital Topographic Data Base
DVD	Digital Video Device
ESRI	Environmental Systems Research Institute
ETB	Enhanced Topographic Base
FTP	File Transfer Protocol
GB	Giga Byte
GDB	GeoGateway Data Base
GIS	Geographic Information System
GPS	Global Positioning System
GRID	GIS Software by ESRI
GSC	Geological Society Canada
GUI	Graphical User Interface
HPN	High Precision Network
HT1-01	Ellipsoid separation model defined by CGVD28
IPCC	Intergovernmental Panel on Climate Change
IMU	Inertial Measurement Unit
kPa	Kilo Pascal
KM	Kilometre
LIDAR	Light Detection and Ranging
M	Meter

mhz	Mega Hertz
N	North
NAD83	North American Datum of 1983
NB	New Brunswick
NTX	A data interchange format used with the CARIS GIS software product.
PAT	Point Attribute Table
PEI	Prince Edward Island
PCT	Pseudo Color Table
RAM	Read Access Memory
RGB	Red Green Blue
RTK	Real Time Kinematic
SKIPRO	Leica Software for GPS processing
SNB	Service New Brunswick
SSE	South South East
TB	Terra Byte
TPS	Leica Total Station
TIN	Triangular Irregular Network
UTC	Universal Time Conversion
UTM	Universal Transverse Mercator
WGS84	World Geodetic System 1984
XY	Horizontal geographic position
YAG	Yttrium Aluminium Garnet
Z	Vertical geographic position

1.0 Introduction

This is a technical report detailing the methodologies and issues involved with an AGRG graduate project that involved mapping areas at risk to coastal flooding from storm surge events. High resolution elevation data acquired from an airborne LIDAR sensor was used to interpolate three dimensional digital elevation models of the coastal topography and to accurately model flooding for the selected case study areas in southeast New Brunswick.

Based upon the LIDAR DEM and the provided predicted sea-level rise information from storm surge and climate change models, several flood risk maps of the coastal zone of New Brunswick were produced. Further analysis of the spatial relationships between existing structures and land cover types and predicted flood risk maps will be done in collaboration with other sub-projects of the CCAF project committee.

The following paragraph is taken from the CCAF project proposal and briefly illustrates the role of the AGRG/COGS in the CCAF project.

> LIDAR is an active airborne sensor system, which provides elevation (Z) data accurate to within 15 cm. Terra Remote Sensing will be contracted to acquire the LIDAR. The Applied Geomatics Research Group has responsibility for the specifications, quality assurance of the LIDAR and the use of GPS for positional accuracy. There is significant post-processing to ensure proper georeferencing and to separate ground and non-ground points. AGRG will partner with Terra Remote Sensing to ensure that the final clean data sets meet the contract specifications. After cleaning of the LIDAR, a digital elevation model can be constructed in an ArcINFO environment. This data set will be available for use by the other sub-projects for digital mapping, terrain visualization and analysis. From the sea-level rise and storm surge predictions, AGRG will simulate flooding of the coastal areas. This will result in a series of predicted flood levels or contours. These vectors can be overlaid on other two dimensional thematic maps e.g. property parcels, utilities, infrastructure and vegetation to calculate the impact and the associated costs of sea-level rise. The AGRG research team will interact with the other sub-projects to use GIS and Remote Sensing tools for visualization, cartographic and spatial analysis.[1]

[1] Taken from the CCAF project proposal. A591.

2.0 Background

2.1 Sea-level Rise

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 (Shaw, 1998).

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).

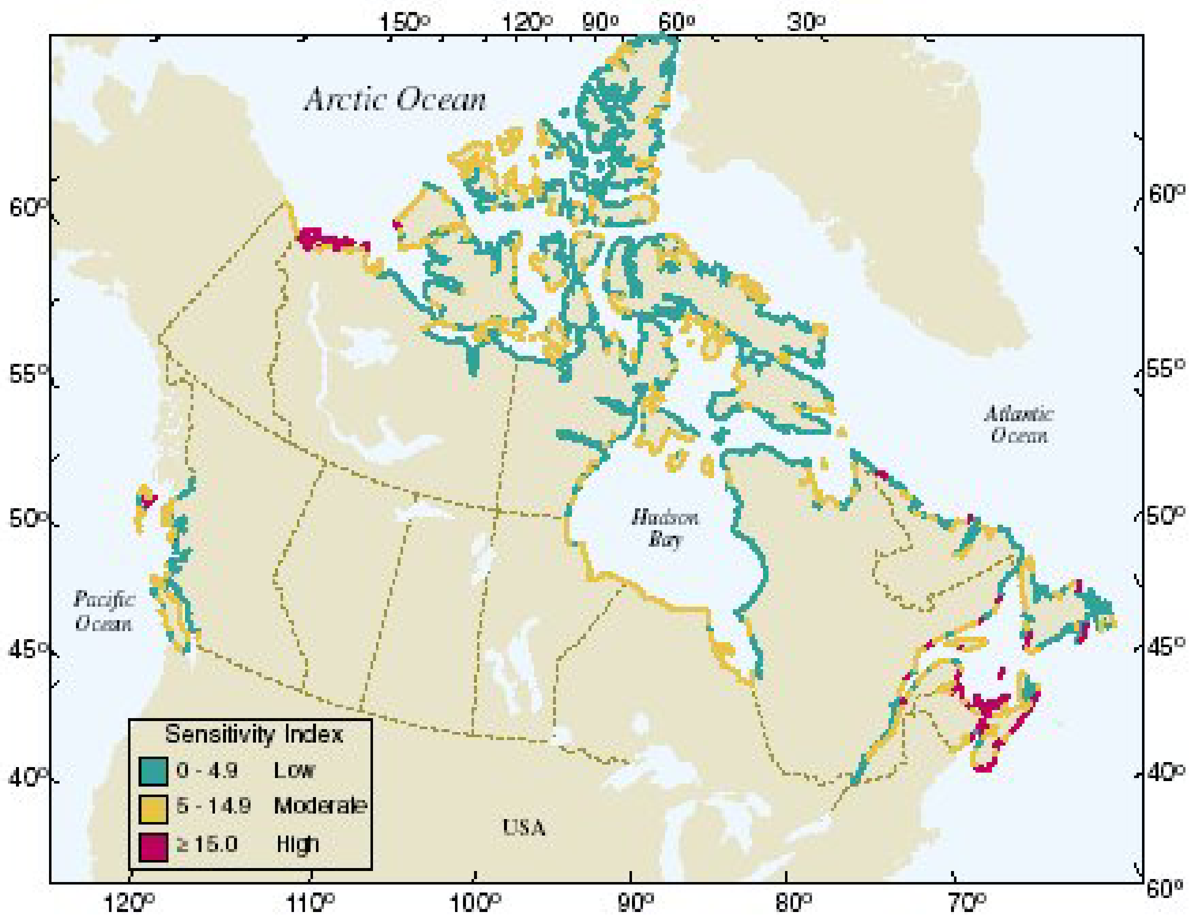

Figure 1 Schematic map representing regions of the Canadian coast that are sensitive to sea-level rise, based on a nation wide overview published by the Geological Survey of Canada in 1998 (Image: Shaw, 1998).

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 0.09-0.88 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 could lead to higher and more frequent flooding of the existing coastal areas and an increase in erosion of coastal features such as dunes (Webster et al., 2003).

Figure 2 The Coastal zones of southeastern New Brunswick incorporate a wide range of different environments including urban settlement along the coast (left) and estuarial tidal flats (right) (Photos: E. MacKinnon, AGRG 2003).

The impacts of rising sea-level and other aspects of climate change in coastal regions can include:

- higher and more frequent flooding of wetlands and adjacent shores
- expanded flooding during severe storms and high tides
- increased near-shore wave energy
- upward and land-ward migration of beach profiles
- saline intrusion into coastal freshwater aquifers
- damage to coastal infrastructure
- impacts on coastal ecosystems

2.2 Storm Surges

The change in sea-level produced by strong winds and low atmospheric pressures that cause coastal waters to flood inland regions are known as a storm surge event. Storm surges are extremely powerful when they coincide during peaks of high tides and can cause extensive coastal flooding. Unlike the tides, storm surges are hard to predict in advance because weather conditions change on a regular basis, and are often only accurately forecast up to a few days in advance.

The predicted tidal height plus the surge is used to determine if a flooding event is likely to occur. Changes in sea-level generated by extreme meteorological events, such as winter storms and hurricanes, cause extensive flooding and massive damage to coastal features, and could become more frequently as the climate changes and sea-level continues to rise. Thus, predicting the timing of storm surges relative to tides are an important goal of meteorologists. Environment Canada has an operation model, developed at Dalhousie University, which they can use to predict storm surge events. Storm surge prediction is critical to help prevent damage to property and loss of life due to such events.

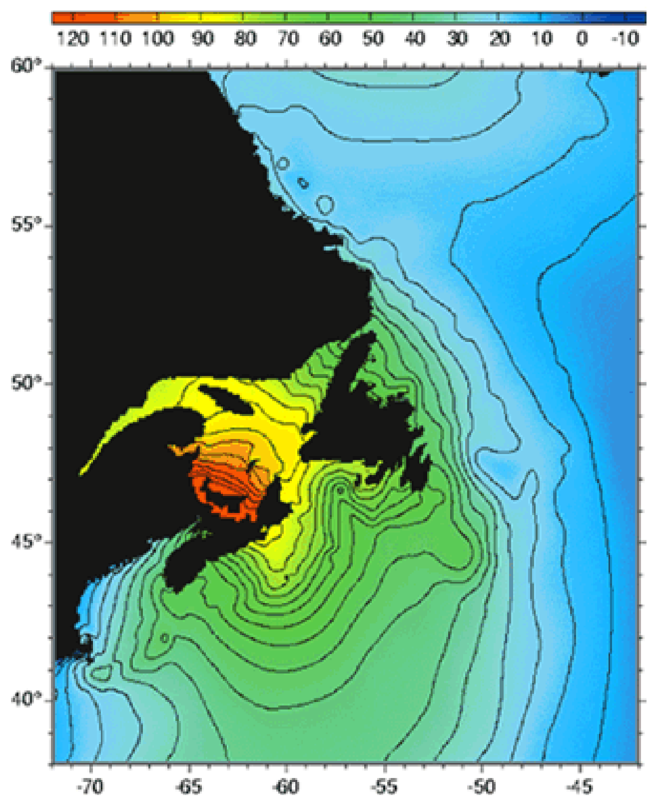

Figure 3 The storm surge of January 2000, (discussed further in this paper) is shown here, modelled with the Dalhousie University Storm Surge Forecast System. Record water levels flooded many parts of the coastal zones of Prince Edward Island, Nova Scotia, and New Brunswick. High water levels in the image are represented by red colors through to blue that represents low water levels (Image: Dalhousie Storm Surge Forecast System).

Many areas in Atlantic Canada on January 21, 2000 experienced severe impacts at numerous coastal locations due to a storm surge event. With a minimum central pressure of 94.5 kPa at 1800 UTC 110 km south southeast of Halifax, the storm passed 55 km east of Charlottetown at 0000 UTC and thence north across the Gulf of St. Lawrence. Coincidence of a 1.2 m storm surge with perigean high tides intensified the impact of the storm at many sites (Environment Canada Website, 2002).

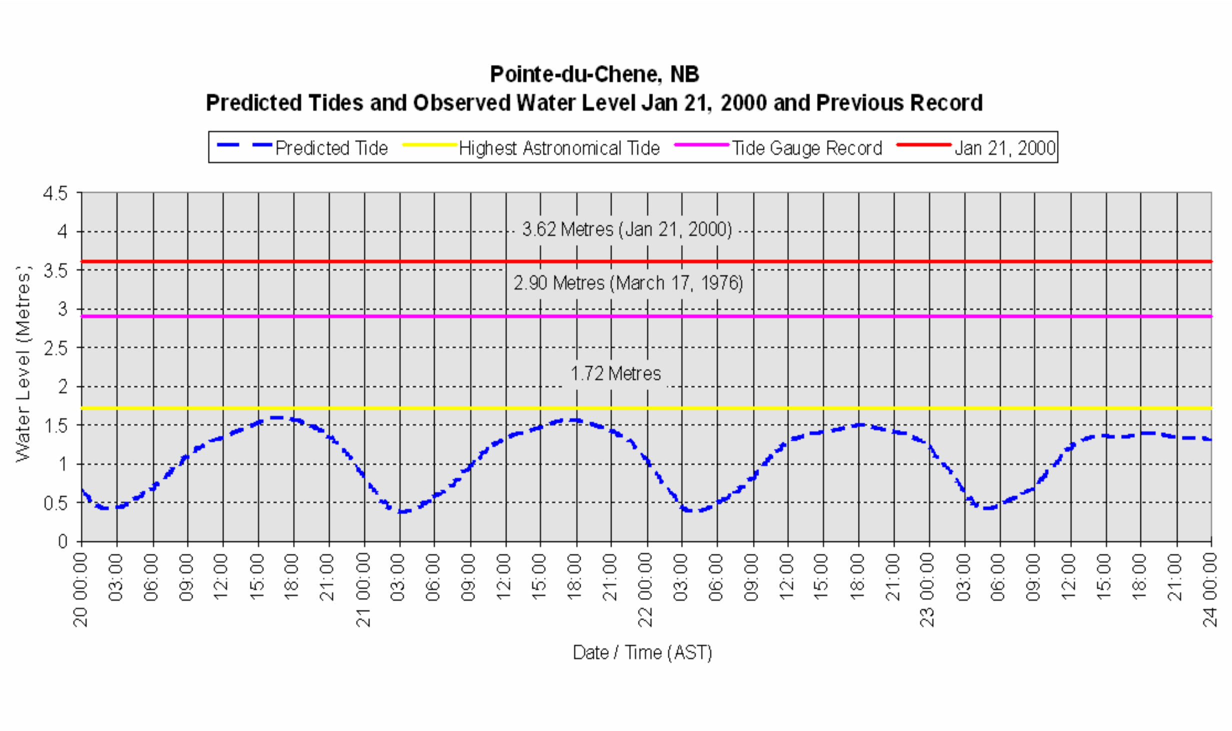

Figure 4 This graph from a tide gauge on the Pointe-de-Chene wharf demonstrates the large difference in predicted tides and the observed water level experienced during the January 21, 2000 storm surge event (Image: D. Forbes, 2002).

A striking feature of this storm was the extent of sea-ice ride-up and pile-up onshore in Prince Edward Island and New Brunswick. While sea-ice limited wave action and protected the north shore of Prince Edward Island, ice ride-up dislodged a lighthouse in Charlottetown and devastated the wharf at Robichaud New Brunswick. Shore-ice pile-up along the Gulf of St. Lawrence coast of New Brunswick, in places over the crest of coastal dunes, caused significant damage and exceeded anything in the recollection of coastal residents (GSC Atlantic Website, 2002).

Figure 5 Sea-ice piled up high during the January 2000 storm surge along the coast of New Brunswick. In some places it even piled up over coastal dunes, caused significant damage to homes (left) and damaged public infrastructure such as buildings and wharfs such as the one on the right (Photos: (left) Weather Channel, 2000, & (right) Mike Campbell, 2000).

Figure 6 Extensive flooding caused havoc in many coastal communities during the January 2000 storm including flooding in the Pointe-de-Chene area, as shown above (Photo: ATV News).

Figure 7 The flood level of the January 2000 storm was preserved after the water had settled back to its normal level with ice remains that were frozen to buildings and various other structures. The two photos above show the frozen water level marks on a cottage in the Pointe-de-Chene area (Photo: Robert Leblanc).

Figure 8 Extensive flooding during the January 2000 storm also flooded across roads making access to the area for rescue vehicles near impossible, such as in the Shediac area (Photo: Bob Belliveau - The Weather Network).

2.3 Study Area

The study area for this project consisted of the coastal Gulf Shore region of southeastern New Brunswick from Kouchibouguac National Park south to Jourimain Island. The area was split into ten smaller polygons, based on sub-project requirements of the CCAF team and comprised the areas of highest scientific interest and significant priority for governments and coastal stakeholders. The polygons (shown in the map of figure 9) have been given the following names: Kouchibouguac National Park, Cap Lumiere, La Dune, Bouctouche, Cormierville, Ile Cocagne, Cap Pele, Shemogue Harbour, Little Shemogue, and Cape Jourimain.

The evolving coastline of Kouchibouguac National Park is an important area of study from the standpoint of understanding potential changes to infrastructure and ecosystems in a nationally designated park. The New Brunswick coast south of Cap Lumiere faces increasing pressures of coastal development and is an important area to study for ecosystem sustainability.

The Bouctouche area has several strong reasons for being included in the CCAF project; it contains the "Irving Eco-Centre La Dune de Bouctouche" that was heavily damaged during the October 29, 2000 storm. It also contains the tourist and historic site "Le Pays de la Sagouine" that was severely flooded during the January 21 and October 29, 2000 storms; and this community has been at the forefront of planning initiatives for regional sustainable development and has seen rapid growth in ecotourism services.

The shores within Cocagne Bay and Shediac Bay are becoming increasingly built-up and are becoming vulnerable to coastal impacts because of a low coastal slope and an erodible substrate. Long-term economic effects need to be considered in planning and regulations. Shediac Bay is a complex coastal and watershed area, highly vulnerable to coastal flooding. Nearby Parlee Beach is a valuable provincial asset and tourist resort.

Shemogue Harbour and Little Shemogue Bay offer areas of little coastal development with undeveloped salt marshes where ecosystem baseline studies can be conducted. Jourimain Island is a national Wildlife Area designed to conserve important wildlife habitat and consists mainly of low lying marsh land. This is also the area where the Confederation Bridge connects New Brunswick to Prince Edward Island.

This work will have direct implications for the socio-economic impacts of climate change in NB coastal areas and communities and lead to the development of potential adaptation strategies. It is particularly timely given the renewed status of the Coastal Areas Protection Policy for New Brunswick. The results will be relevant to the coastal communities, several economic sectors, individual landowners, fisheries interests and harbour authorities, ecologists, and managers and planners at all levels of government and in the private sector.

Six of the ten study areas have been completed to date but four polygons had to be excluded (Kouchibouguac National Park, Shemogue Harbour, Little Shemogue, and Cape Jourimain) from this graduate portion of the project due to technical difficulties that Terra Remote Sensing experienced with their new LIDAR Mark II system. These four polygons were flown during the spring of 2004 and the LIDAR data will be processed by another graduate student at the AGRG during the fall of 2004.

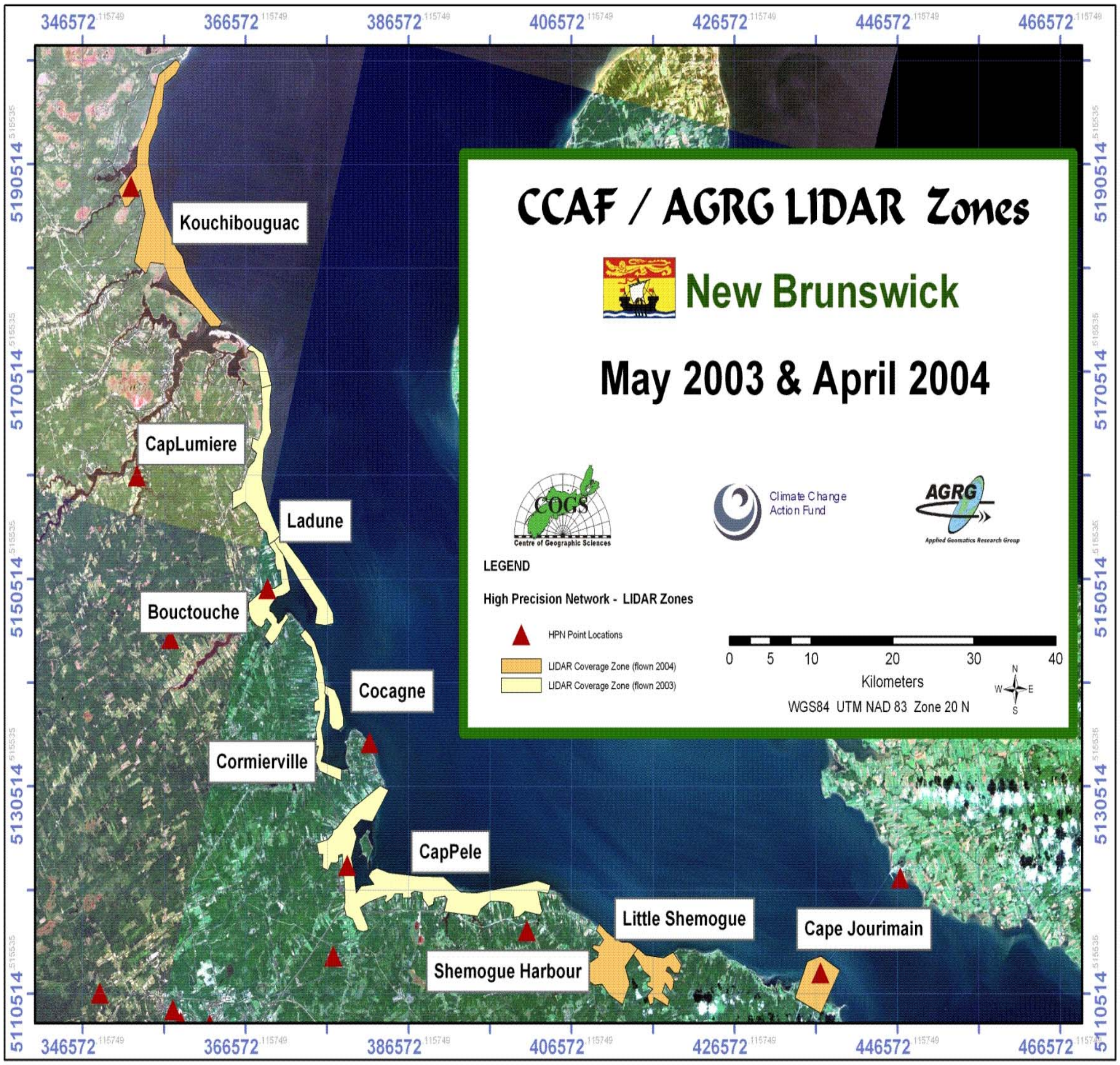

Figure 9 This map contains a LandSat True Color Composite image of southeastern New Brunswick to help spatially define where all the LIDAR study areas are geographically located (Image: E. MacKinnon, AGRG 2004).

2.4 Airborne LIDAR

An airborne LIDAR system was used to obtain high-resolution elevation data that was processed to represent the topography, and was perfect for predicting areas that are at risk to coastal flooding associated with sea-level rise and storm surge events.

The LIDAR system combines a single narrow-beam near-infrared laser with a high tech receiver system. The laser emits a pulse that is transmitted towards the surface, reflected off an object, and returned to the receiver. The laser scan is acquired by rapid repetition of the laser pulse transmitter and cross track zigzag pattern of laser hits on exposed surfaces below the aircraft (Krabill and Martin, 1987). The receiver accurately measures the travel time of the pulse from its origin to its return. The laser pulse is travelling at the speed of light, and since the speed of light is known (and assumed constant), the travel time can be converted to a range measurement.

Combining the laser range, laser scan angle, position from GPS, and orientation of the aircraft (pitch, yaw, and roll) from an IMU, accurate ground coordinates can be calculated for each laser pulse. When combined into one system, they allow the positioning of the footprint of the laser beam as it hits an object, to a high degree of precision. As advancements in commercially available GPS and IMU occur, it is becoming possible to obtain a high degree of accuracy using LIDAR from moving platforms such as an aircraft.

Figure 10 These photos illustrate the hardware used by Terra Remote Sensing in the 2003 LIDAR campaign. The helicopter (left), had the sensor mounted in a pod structure below the aircraft (middle) and the technical equipment such as the IMU (right) was located inside of the aircraft (Photos: T. Webster, AGRG 2003).

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

This separation of data allows for the construction of a digital elevation model (DEM) with all forest, vegetation and other features (non-ground related) removed, providing a true ground representation of the surface. Traditional DEMs are typically derived from photogrammetry, and do not have the vertical accuracy or resolution suitable for most scales of regional flood risk mapping. Good flood simulation must be modeled on a surface that best represents the actual ground elevation.

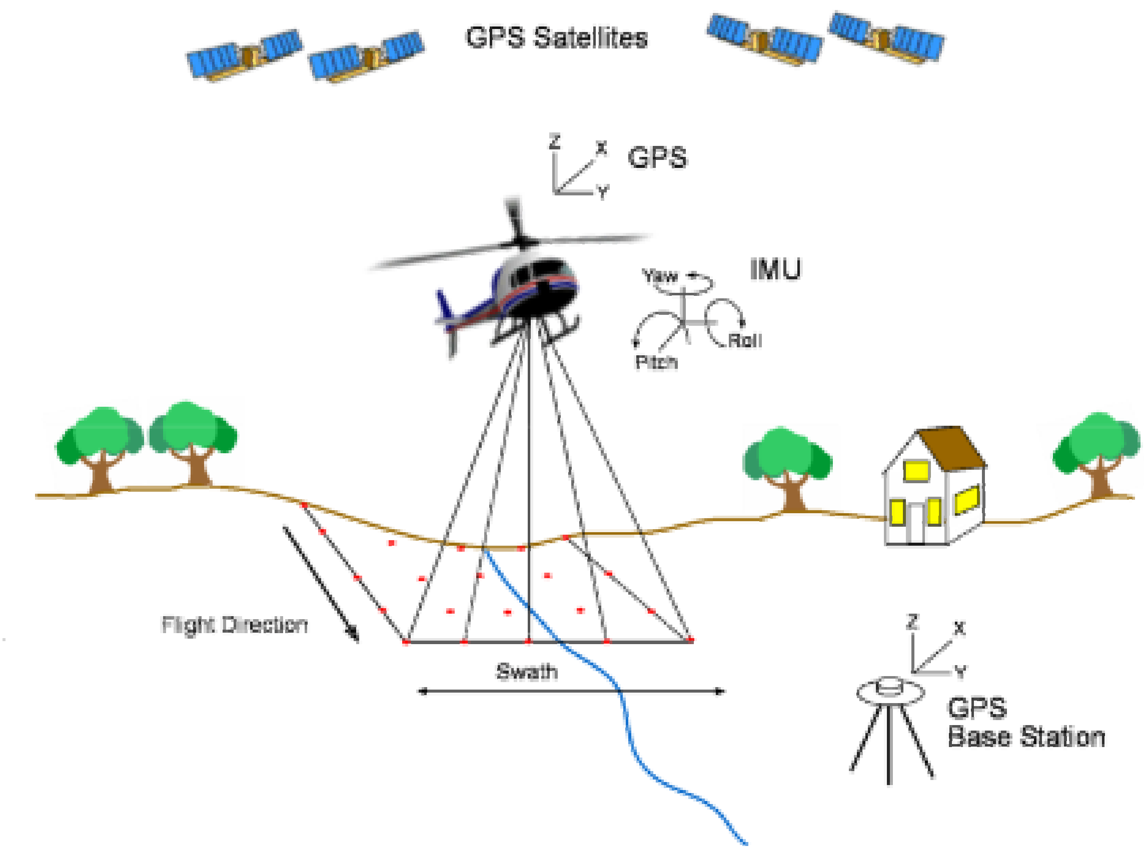

Figure 11 Schematic of airborne LIDAR mapping technology. Global Positioning System and an Inertial Measurement Unit determine the location of the aircraft when the laser pulse is sent and returns (Image: E. MacKinnon, AGRG 2004).

LIDAR data for this project was collected by Terra Remote Sensing during the spring of 2003 and the spring of 2004, as part of the CCAF proposal # A591 requirements. Terra Remote Sensing's sensor is a first return sensor (Mark-I) with a diode pumped YAG scanning laser operating in a wavelength of 1047 nanometres, 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 of non-ground and ground hits. The data was 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).

3.0 Data Resources

3.1 LIDAR

The LIDAR data was provided in an ASCII file format split into two different types; ground only files and non-ground only files. Each file contained 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
Ground spacing in open areas (XY): 0.6 meter
Relative Accuracy: ± 0.15 meters
Absolute Accuracy ± 0.3 meters

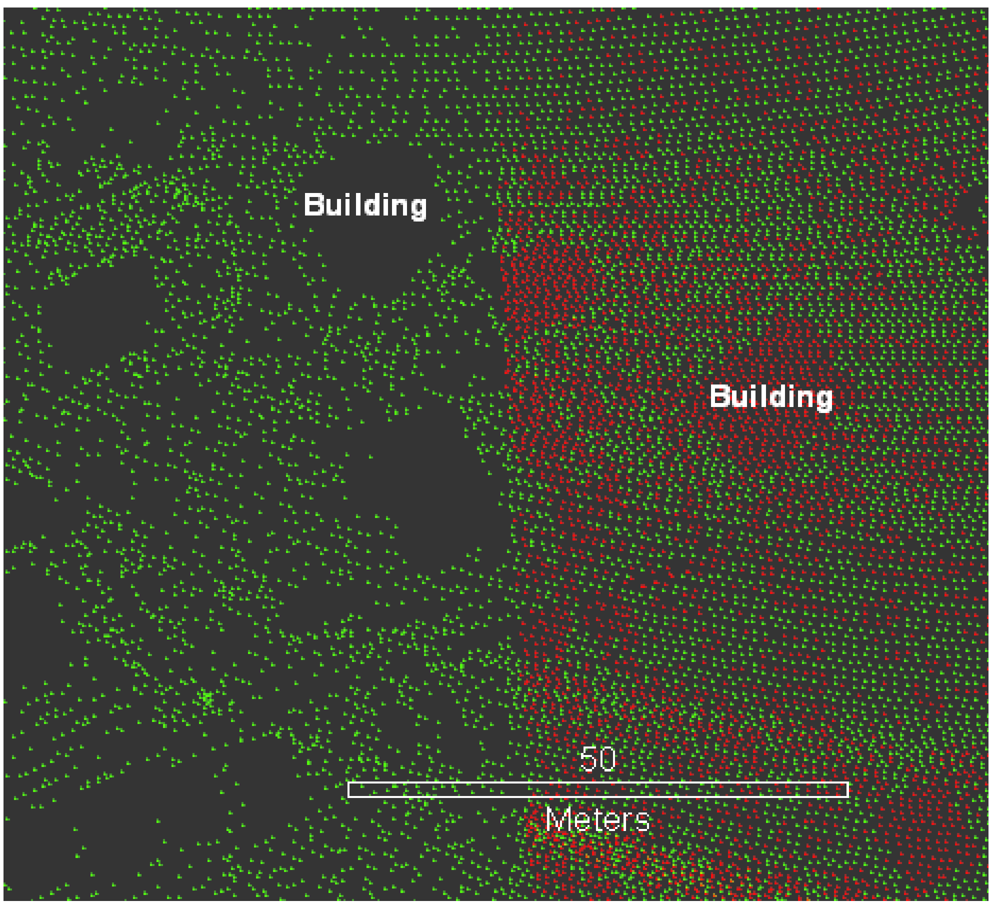

Figure 12 LIDAR point data separated into ground (green) and non-ground (red) point coverages, the non-ground points have been removed from the left hand side of the image to show ground only points (Image: E. MacKinnon, AGRG 2004).

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The ground hits LIDAR data is meant to represent the truest representation of the actual earth's surface, thus certain features are purposefully omitted from the ground model. Features such as bridges, forests, buildings, vegetation and other non-ground structures are separated from the ground only layer and placed into a non-ground LIDAR data set. The separation of points is demonstrated in figure 12, where the ground points have been coloured green and the non ground points have been coloured red. Non-ground points have been removed on the left hand side of the graphic to demonstrate the removal of points. Buildings and trees are clearly visible in this image.

Man-influenced changes to the ground surface are represented if they are judged to be of a permanent nature. As an example, the earthen land forms that make up an approach ramp on a highway are captured while the actual overpass bridgework is not. A bridge that spans a river/stream is not classified as ground but an earthen structure with a culvert that crosses a river is classified as ground.

The non-ground LIDAR data contains all features that are not considered a part of the ground surface. This category contains all manmade features plus vegetation and other non-ground related features.

The default classification also contains outlier points. These points are anomalous LIDAR hits often caused by atmospheric conditions, particularly reflections from aerosols. They often appear as very high altitude or very low sub-ground clouds of points. Terra was supposed to remove these outlier points that were obviously not real features but often did not do an adequate job of it, making some of the all-hits modeled surfaces appear to have many strange pyramid structures or deep sink holes that can be clearly visible in the left hand image of figure 13.

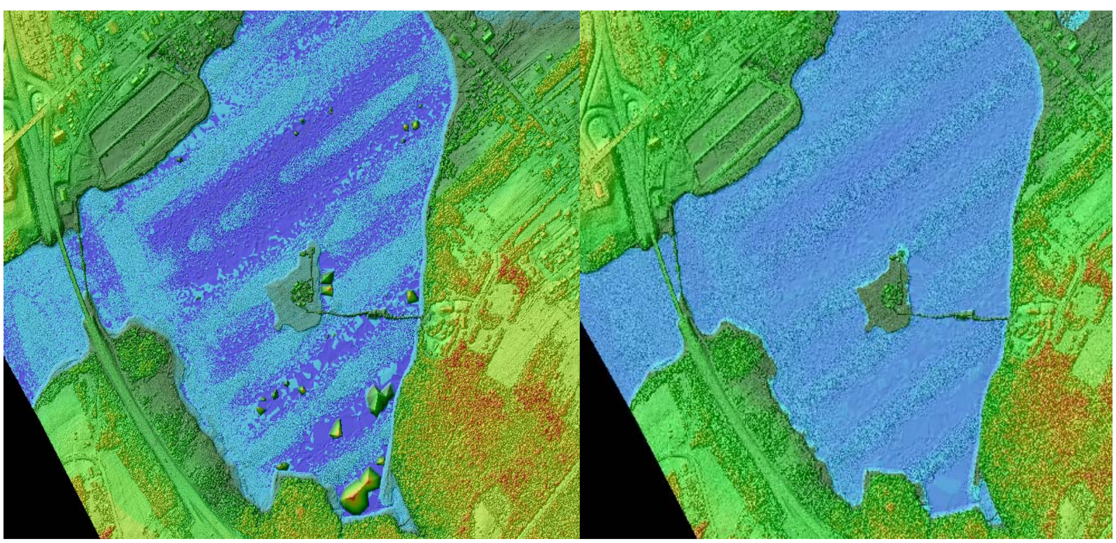

Figure 13 These represent "before and after" images from the exact same location in Bouctouche Harbour. The lower center of the image on the left shows some of the many outlier features that had to be removed from the data. The image on the right has been properly edited and processed to create a representation without all the anomalous data that caused non-realistic features such as these large pyramid structures on top of the water. Images are about 2 km by 1.3 km in size (Image: E. MacKinnon, AGRG 2004).

GPS Day	Date	Area
143	May 23 2003	Cap Pele
145	May 25 2003	Cap Pele
147	May 27 2003	Cap Pele
148	May 28 2003	Cap Pele
148	May 28 2003	Cormierville
148	May 28 2003	Cocagne
149	May 29 2003	Cormierville
149	May 29 2003	Bouctouche
154	June 3 2003	Bouctouche
154	June 3 2003	La Dune
154	June 3 2003	Cap Lumiere

Table 1 The LIDAR data for this project was acquired between May 23, 2003 and June 3, 2003. This table demonstrates what areas where done on what days. This information is important for validation purposes.

Because the LIDAR was used for flood modeling, it was decided that having wharfs and piers should be included with the ground layer since this layer will be used to model the flood data. The vendor had already separated these features out along with other man-made features, thus the point coverages had to be edited and points representing wharfs and break water structures had to be moved into the ground coverages prior to a proper DEM being built and used to map flood risk. This was done with ESRI software because Industry Standard LIDAR editing software tools were unavailable.

The LIDAR point coverages were edited using ArcGIS and then validated with the RTK GPS data and ArcScene. The point data from both the RTK GPS and the LIDAR points were converted to 3D points in ArcGIS so that they could be viewed along with the LIDAR surfaces in ArcScene. The decision of what points were moved from non-ground data sets to ground only data sets was based on the all hits digital surfaces and the orthometric heights of the GPS.

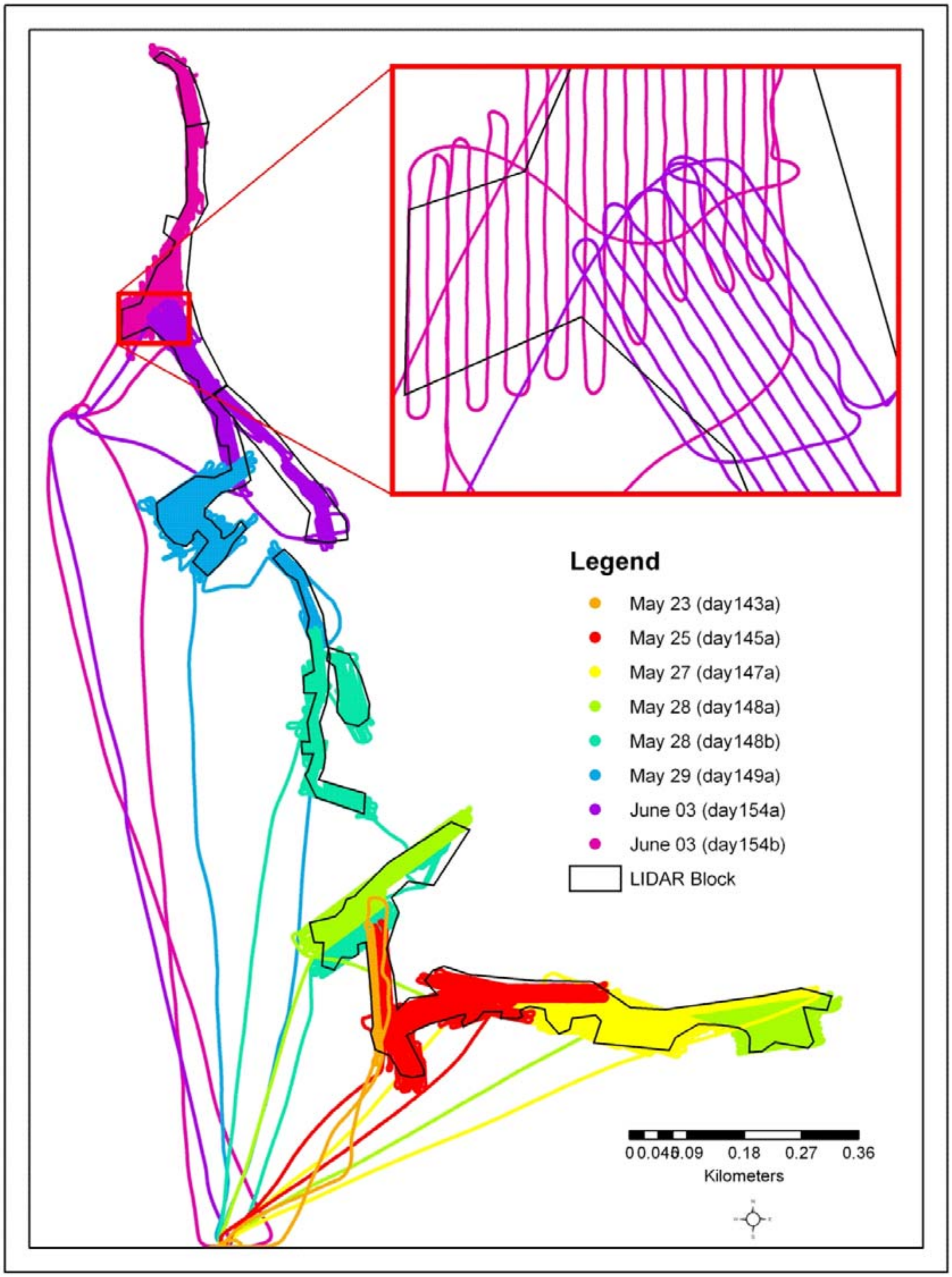

Figure 14 This figure demonstrates visually what areas that Terra Remote Sensing flew and on what days they flew. What may appear to be coloured lines on the graphic are actually coloured points that represent the GPS data collected during each flight. This information was important for validation purposes (Image: E. MacKinnon, AGRG 2004).

3.2 GPS Validation Data

GPS data were collected by AGRG students and staff with a Leica RTK GPS System and sometimes with a Leica Total Station during the fall of 2002, spring of 2003, and the fall of 2003. The data were processed and exported into ESRI shapefile format. The GPS data contained the following fields: easting, northing, orthometric height, geoid separation, GPS time, Standard deviations (X, Y, Z) and field work related attributes such as photo numbers, and ground details.

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

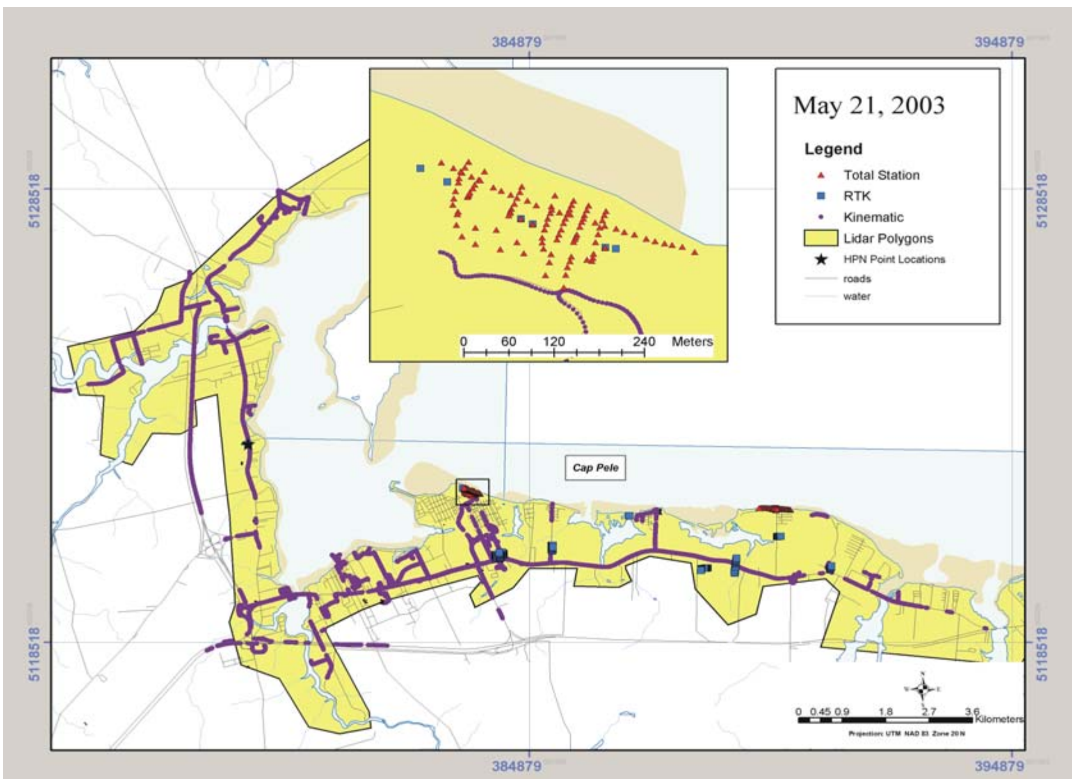

Figure 15 The map displays GPS data collected from the Shediac area during May 2003. The RTK GPS data acquired with a vehicle is represented by the purple circles, the RTK GPS data with a pole by blue squares, and the Total Station data by the red triangles. The GPS data may appear to be coloured lines because of the scale of the image, most points are actually within several meters of each other. The inset represents GPS data from the dunes of the Parlee Beach (Base data: SNB, Image: E. MacKinnon, AGRG 2003).

3.3 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

Figure 16 Digital orthophoto of the Bouctouche area, the orthophotos were created with aerial photographs ranging from 1996 to 1998 (Orthophoto data provided by SNB).

3.4 Topographic Data

Service New Brunswick provided Digital Topographic Data for the study areas from their DTDB98 (Digital Topographic Data Base 1998), created with CARIS (Computer Aided Resource Information System) software. The DTDB98 consisted 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.

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

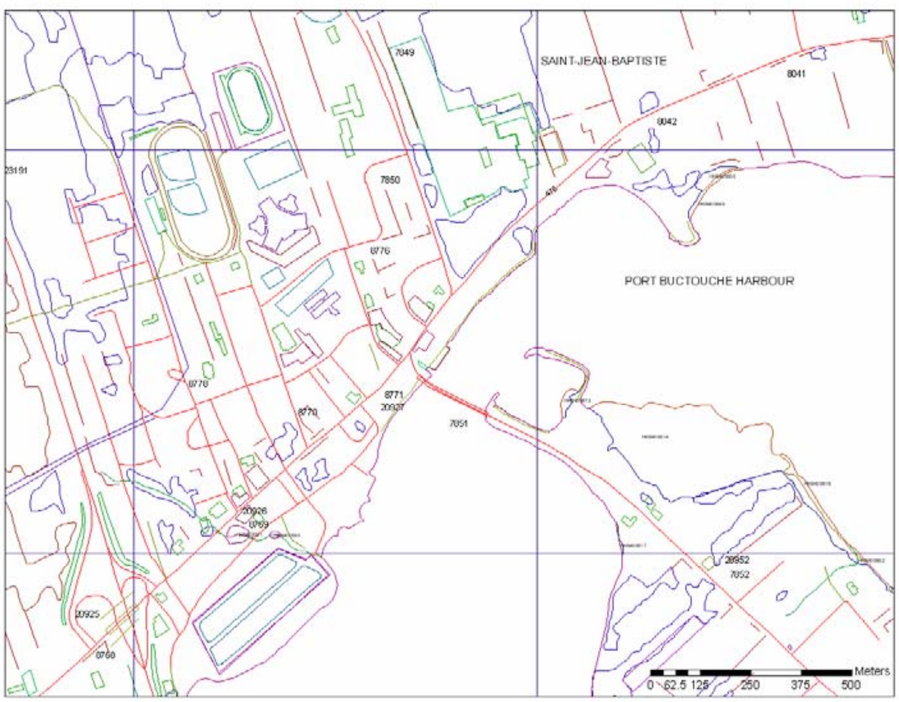

Figure 17 Topographic data for the orthophoto shown above in figure 16 of the Bouctouche area (Base data provided by SNB).

3.5 Other Data Sources

3.51 Digital Photography

Various digital photographs were taken during the field missions to aid in the validation process and include in presentations for the project. Photos were taken with the AGRG canon digital camera. Photos were important for helping with the validation, especially since the processing part of the project was actually done in Nova Scotia without with easy access to the study areas.

3.52 Flood Data

Three different sea-level scenarios based on actual storm surge and flood data were supplied by CCAF Sub projects and described below in the actual document provided.

Flooding Levels for Southeastern New Brunswick

Hal Ritchie, Keith Thompson, George Parkes and Don Forbes met to develop recommended flooding levels for COGS to use with the DEM for Southeastern New Brunswick.

Similar to what was done for Charlottetown, we recommend that there be three main levels considered for illustration purposes at Pointe-du-Chêne:

Extreme observed value
3.6 m above Chart Datum (CD) to start with. This is the current best estimate of the High Water Level value for the 21 January 2000 storm which was clearly the highest flooding event observed there. There is still some uncertainty about this level, and it may be revised by a more accurate survey this coming spring. A flooding demonstration with the DEM for this case would be good for presentation and discussion with the local community to get their feedback on whether it is consistent with their recollections.

Climate change scenarios:
Extreme case: 4.3 m CD. This represents the 21 January 2000 level plus a 100 year predicted 70 cm relative sea-level rise consisting of an IPCC higher estimate of 50 cm global sea-level rise plus 20 cm of crustal subsidence. These values are current best estimates and could be revised during the project as better estimates of regional sea-level rise emerge from the IPCC and more accurate data on crustal subsidence are analysed.
Moderate case: 4.1 m CD. This would correspond to a moderate 100 year rise of 30 cm global sea-level plus 20 cm of crustal subsidence.

For more detailed flooding level examinations, it would be desirable to eventually have a series of flooding maps done at 10 cm increments above highest astronomical tide.[2]

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[2] Information provided by H. Ritchie, K. Thompson, G. Parkes and D. Forbes of the CCAF project.

4.0 Analytical Tools & Equipment

4.1 Software

- ESRI Workstation & ArcGIS 9.0
- Jasc Animation Studio
- Leica SKI-PRO 3.0
- Macromedia Free Hand & Fireworks
- Microsoft Office XP (Excel, Power Point, Word)
- PCI Geomatica 9.1

4.2 Hardware Tools

- Dell Desktop Computer (Dell Intel P4 1.8mhz processor running Windows XP operating system, 1GB RAM)
- Leica RTK GPS System (500 series)
- Leica Total Station (TPS1100 series)
- Sun Micro Systems Unix server (SunFire V480 Unix System with 4 900 mhz Ultra Spark processors running Solaris 9 operating system, 16 GB RAM, 2.6 TB disk space)
- Trimble Geo3 GPS
- Cannon Power shot S40 Digital Camera
- Hewlett Packard Design Jet 1050C Plotter, Tektronix 850 Color Printer

5.0 DATA COLLECTION

5.1 GROUND VALIDATION SURVEY

Differential carrier phase GPS data provides accurate orthometric heights that can be used to validate the accuracy of the airborne LIDAR data. On May 19, 2004, the kinematic GPS survey for the study areas began and continued for four days. It was ideal that the GPS survey coincided with the LIDAR survey to ensure that exact conditions at the time of LIDAR survey were measured. This is most important for features such as heights of vegetation and coastal features such as sand dunes. An important step in ensuring accurate representation of the topography involves comparing the processed data with ground validation points positioned to a higher accuracy than the LIDAR data.

The accepted tolerance level for the accuracy of the LIDAR data provided by Terra Remote Sensing was set at +/-30 cm in vertical values, so it was important that the GPS validation data have a higher accuracy. A Leica RTK GPS system was purchased because it could provide sub decimeter accuracy and save time by avoiding any post processing of the data, and also helped to test if the LIDAR data met the required specifications.

The Leica RTK GPS system was made up of two GPS receivers; one was setup over a well known survey monument from a high precision network (HPN) with published coordinates known as the base station and a mobile receiver that collected unknown points known as the rover. The locations of the HPN monuments are displayed in figure 9. The base station was used to process the GPS data it received from satellites and then sent the corrections to the rover unit via a high frequency radio signal. This trigonometric GPS setup provided precise orthometric measurements up to 2 cm with ideal conditions.

Two different rover setups were used to collect the GPS data; a real time kinematic (RTK) setup on a 2 m pole and a RTK unit setup on top of a moving vehicle. The vehicle setup was used to provide RTK GPS of hard surface features, including roads and parking lots. The offset of the GPS antenna from the ground to the vehicle roof top was recorded and accounted for in the setup. This method of GPS data collection provided a means of gathering precise measurements over a larger coverage area. The RTK on the pole setup was used to provide GPS measurements where a vehicle could not get access to (coastal dunes, wharf edges, etc.).

Figure 18 GPS data were collected with several different setups such as a Leica RTK system on a 2 m pole (right), on top of a vehicle (middle), and with a total station unit (left). The base setup is also visible in the middle photo. (Photos: (left) E. MacKinnon, AGRG 2003, (center) W. Innes, AGRG 2004, (right) T. Webster, AGRG 2003).

A Leica Total Station unit was purchased to collect data in areas were the GPS units could not get adequate satellite coverage such as underneath forest canopy and to supplement data collection with the RTK unit. Base measurements for the Total Station were always provided with the RTK on the pole setup to ensure that the initial coordinates would be as precise as possible when used to validate the LIDAR. Transects along dune structures and coastal regions were done with both the RTK and the Total Station to provide profiles of the surface.

GPS navigation uses the WGS84 ellipsoid, which is a smooth mathematical surface representing the earth, as the reference datum. Elevations found on most topographic maps are measured to a vertical datum based on the geoid (in Canada known as CGVD28). To relate the height measurements to proper sea-level, an adjustment must be made for the local vertical separation between the ellipsoid and the geoid. This adjustment is done with SKIPRO by using the HT1-01 model provided by the geodetic survey of Canada, Natural Resources Canada.

All GPS data were uploaded to Leica SKIPRO software and then exported in ASCII text format so that it could be imported into ArcGIS. The GPS data could then be exported as a shape file and incorporated into a GIS. All field notes were attached as attributes and digital photos were linked to provide a GPS validation product. The dbf portion of the shape files were imported into Microsoft Excel for comparison with the LIDAR data.

6.0 GIS Data Processing

6.1 Creating Point Coverages

The LIDAR, provided by Terra Remote Sensing, (separated into ground files and non-ground files) was extremely large, covering 165, 500 square kilometres and contained over 45 million points, therefore the data was divided into smaller tiles that were based on a grid system created by Terra Remote Sensing. Forty LIDAR tiles in all made up the entire study area and each file was named based on the easting and northing coordinates from the lower left corner of the tile (See Appendix D).

The data files were copied onto the AGRG SUN UNIX server where the majority of the data processing took place, and they were also separated into ArcINFO workspaces containing ground only and non-ground data.

Importing of LIDAR data and processing of point coverages was done using an automated procedure developed with the Arc Macro Language. The AML was modified from existing ones that the AGRG had used with previous LIDAR projects by past graduate students.

The TERRA_IMPORT AML (See Appendix A) would delete all existing temporary files and coverages in the workspace and then create new point coverages for all ASCII files. Individual coverages were generated for each LIDAR tile.

Point coverages were generated from the ASCII LIDAR data files with the *GENERATE* command. However, there were some limitations to this command and another procedure needed to be implemented. The *GENERATE* command can only handle importing the ID, X, and Y columns, but there was more data columns of data to import. Thus the rest of the attribute data were brought into the coverage using a join item**.** An AWK script was used to copy the X and Y data columns from the ASCII file and created a temporary file (comma delimited data that contained only ID, X and Y data) to use with the *GENERATE* command. The ID was important for joining the other columns in the ASCII data with the coverages. The *BUILD* command created topology by generating a point attribute table for the point coverage and was used to join the other columns of the ASCII data.

The Tables environment was utilized to append the remaining columns of data because it allowed for creation, query, and simple analysis and displayed the INFO database for the point coverages. The first step was to define the DAT file and then to populate the items with the space delimited records. The PAT file then needed to be joined with the rest of the columns. A join item was added to both the files and populated with a record number. The INFO file and the point coverages were generated from the same ASCII files thus they should still have the same identifiers and number of records.

The resultant product was spatially referenced point coverages of the ground LIDAR hits. This AML was also used to import the non-ground files. The Point coverages of non-ground and ground LIDAR data were generated for each LIDAR tile, used to validate with the GPS data and then to generate raster surface models such as the DEMs and CSR Models

7.0 RASTER DEM GENERATION

7.1 Building Interpolated Surfaces

Each individual LIDAR tile was rasterized and then mosaicked together to provide a larger continuous surface of each study area. The grids were generated with a 1m grid cell and the TIN method was chosen as the best method for interpolating a surface because it used all of the input points to generate the surface. TIN stands for Triangulated Irregular Network and is a topological data model that uses mass points consisting of X, Y and Z values. The points become nodes and triangles are constructed between all the points. A convex hull (figure 19) is created in areas that contain no data.

The decision to use a grid resolution of 1m instead of 60 cm (the actual spacing of the LIDAR points) was agreed upon by the project team and initiated to save disk space and the amount of time it required for processing the large data sets. Grids generated with resolutions of 60 cm were 25 to 40 percent larger, usually took twice as long to produce and were similar to the output of grids generated with 1 m resolution.

ArcINFO contains several different methods suitable for creating grid cell based surface representations from point data. After several visual examinations of the surface models derived from the LIDAR points, and reading all available ESRI resources about each module, it was determined that the best representation of a true ground DEM surface was from the quintic TIN interpolation method (MacKinnon, 2003).

Generating a grid surface was done using the TILE_GRID AML (see appendix B) that was modified from existing ones that the AGRG had used with previous LIDAR projects by past graduate students. A similar AML (TILE_GRID_ALL) was used to generate an all-hits LIDAR surface (see appendix C).

The *CREATETIN* command generated the TIN surface. Since the LIDAR data contained only one elevation feature type, mass points, it was the main component of the tin. The points had and X, Y, and a Z value and all mass points had equal significance when building a tin.

CREATETIN is an interactive command with its own prompts. The name of the TIN to be created was specified, weed tolerance was ignored because it is used to reduce the number of vertices on any linear features, and our data did not contain any line features. The proximal tolerance was set to the default, which was decided by the precision. No vertical exaggeration was applied to the TIN, so the Z factor was ignored. The *COVER* command was used to indicate which coverages were used to create the TIN surface. The ortho height attribute was used to indicate which field the Z values from the input coverages are located. The end statement was entered after all coverages were specified to begin the TIN construction process.

The TIN was then transformed into a grid using both quintic for ground hits and linear all hits interpolations with a 1 m pixel resolution. A lattice is a surface interpolation of a grid, represented by equally spaced sample points referenced to a common and a constant sampling distance in the X and Y direction. Each mesh point contained the Z value of that location. Surface Z values of locations between lattice mesh points were approximated by interpolation between adjacent mesh points. The quintic method provided a smoother surface than the linear method, and was used to create ground surface DEMs. The linear method was recommended to create the Digital Surface

Models (DSM) because it was known to better interpolate sharp corners (such as buildings).

The command *TINLATTICE* converted the TIN to a lattice by interpolating the mesh points. The point Z values were interpolated from the TIN using either the linear or the quintic method. The output lattice covered a rectangle area, so areas with no data from outside the zone of interpolation (convex hull) were represented by a null value of –9999.

After entering the *TINLATTICE* command, ArcINFO displayed the extent of the grid and required four more entries before the interpolation process began. The first three lines were left as the default values and the distance between the mesh points was set to 1. The interpolation process then began and started to generate the modeled grid.

A lattice containing both the ground and the non-ground hits together was created to provide an all-hits grid. The all-hits grid was an actual surface representation that included all of the possible LIDAR points from the tile. Features such as fields and clear cuts were easily distinguished with the all-hits grid. This layer could be integrated with imagery data to create 3D models of the study area.

The individual grids were then mosaicked together to form a larger continuous surface of each study area with the *MOSAIC* command from the ESRI GRID module (Each individual grid was buffered 150m larger then the actual LIDAR tile extents to ensure that there would be adequate overlap of the individual grids). The Cap Pele Block contained 18 LIDAR tiles mosaicked together, the Cormierville and Cocagne Blocks contained 7 tiles, the Bouctouche Block had 5 tiles, the La Dune had 4 and the Cap Lumiere was made up of 9 LIDAR tiles mosaicked together.

The erroneous convex hull data was then clipped away from the grid using the GRIDCLIP command. The GRIDCLIP command found within the ESRI GRID Module was used to clip away the convex hull because it allowed the grids to be clipped with polygon coverages. Polygons were created from the original study area polygons that were used to clip away the erroneous data.

Grid: <output_grid> = mosaic(<in_grid>,<in_grid>,<in_grid>)

Grid: GRIDCLIP <in_grid> <out_grid> COVER <clip_cover>

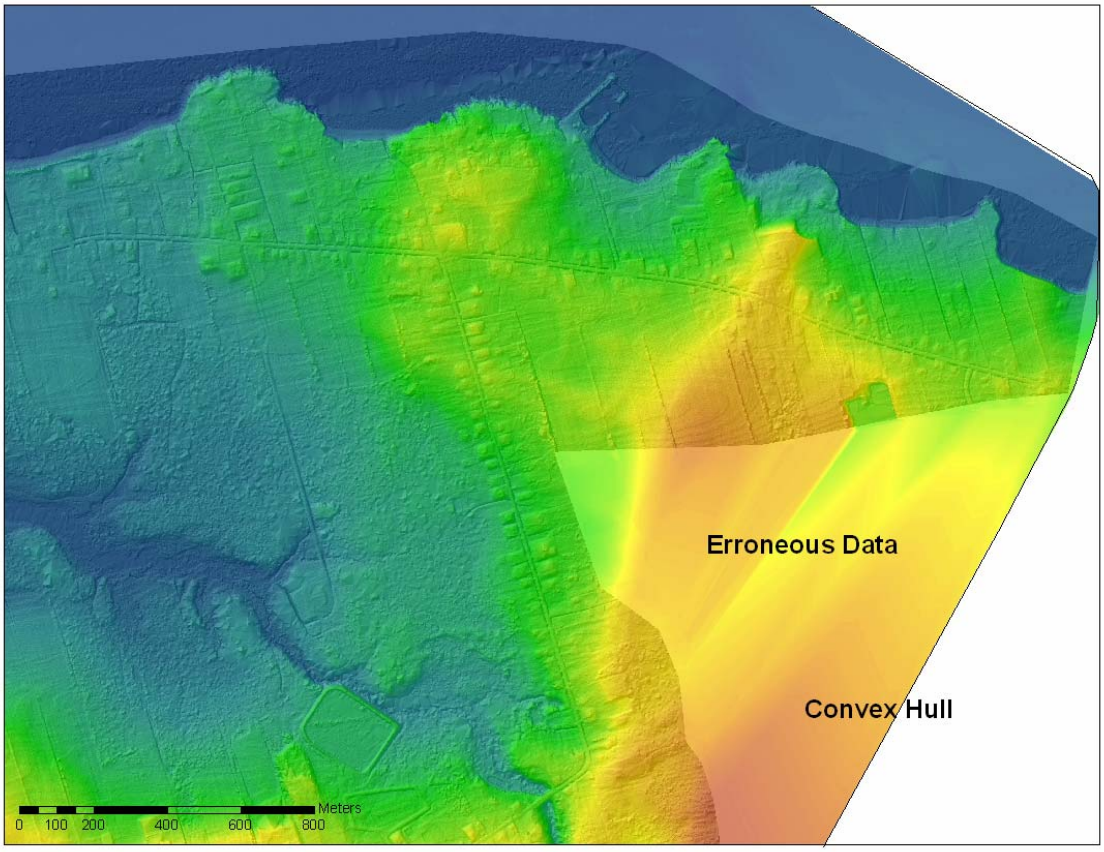

Figure 19 Erroneous data and the Convex Hull was clipped away from the grids to avoid giving users a false impression of data that did not exist (Image: E. MacKinnon, AGRG 2004).

PCI Geomatica image software was used to visualize the DEM to create RGB composite images, color shaded relief images and exporting elevation data for the validation analysis. In order to import the grid lattice into PCI, it had to be converted to ASCII files. The *GRIDASCII* command was used to convert the digital grid surfaces into ASCII file format. It was important that the outputted file had a GRD file extension so that it was compatible with PCI.

Arc: GRIDASCII <in_grid> <output>

8.0 Examining GRID Surfaces

The point coverages were evaluated and were validated individually before being used to generate any surface models. Because all the LIDAR data was acquired at once then later separated into two types, it was necessary to examine the separation provided by the vendor since this is often problematic in LIDAR data.

The *DESCRIBE* command was useful for verifying the details of each lattice grid such as the maximum and minimum elevations that were required when creating the color shaded relief models. This command gave a quick overview with details such as cell size and the coordinate system. ArcMap could then be used to display the resultant TIN or the grid lattice surface for a visual examination of the DEMs. The grids were examined to identify any key problems such as missing data or any artifacts that was present within the data.

9.0 RGB COMPOSITE

PCI Geomatica software was used to create 3D Color Shaded Relief models with the LIDAR DEMs. The grids were imported into PCI and color coded using chromo stereoscopic techniques, illuminated to create a shading effect, and then combined to produce a Color Shaded Relief Model (CSR).

The ASCII file containing the elevation data from the exported grid were imported into new 32 bit PCIDSK files (.pix) with the *FIMPORT* command. This command imported the georeferencing data in addition to the image data. Only file formats supported by the GDB library could be imported with *FIMPORT*, so it was important that the imported file had a GRD file extension.

The nearest neighbour option was chosen as the resampling method and band was chosen for the layout of the image. The band option stored all the data together and produced good results when not all of the bands were being accessed at the same time. The choice of layout was primarily based on performance. Empty channels (8-bit) were added to the file using the *PCIMOD* command. The new channels were needed to hold the results of the following procedures.

The DEMs were scaled from 32-bit real high-resolution images to 8-bit lower-resolution image in order to better represent a correct pseudo color encoding. PCI has a default output value range of 0 to 255, thus the highest elevation was represented by the 255 value and the lowest was represented by the 0 value, with all the other values between that. The values were obtained by using the *DESCRIBE* command in ArcINFO.

The DEM contained a no data value of -9999, set by ArcINFO. When the data was imported to PCI, the software interpreted the range of values from -9999 up to the highest value of the dataset. This resulted in all the data at one end of the possible values. Therefore a histogram of the values would show all of your data near the 255 value, as shown in the example histograms in figure 20.

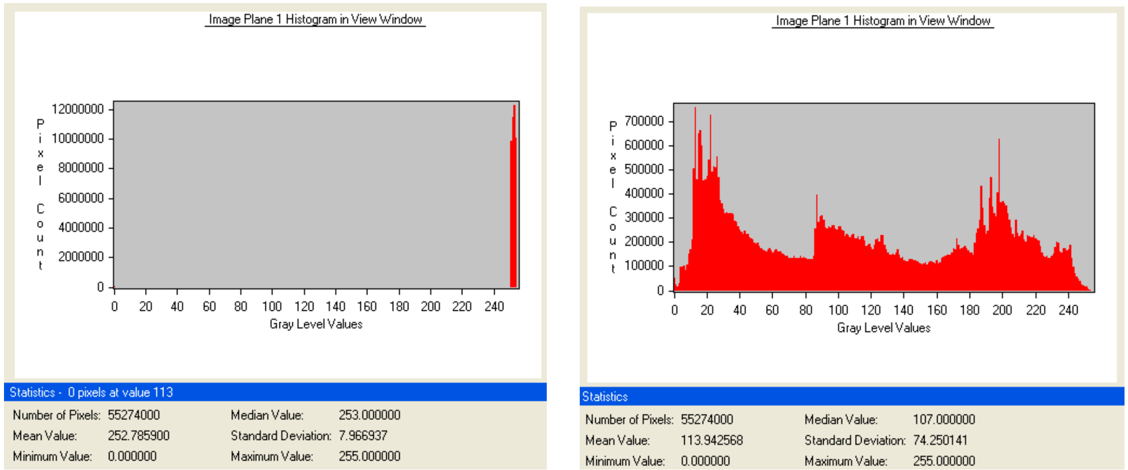

Figure 20 PCI histograms, with the -9999 no data values (left) and the same data after using the (right) SCALE command utilizing all of the data values (Image: E. MacKinnon, AGRG 2003).

The *SCALE* command scaled the data portion of the files to fit into the data range so it could use all the possible data range while avoiding the no data values. Starting the input range from the lowest elevation value (0 m) to the highest elevation value (38 m for ground only hits DEM and 58 m for all hits DSM) means that all of the DEM values less then the lowest value would be omitted, thus the no data value of –9999 will not be taken in effect and only the existing data was scaled into the usable range of 0 to 255. The minimum and maximum values varied for individual tiles but consistent minimum and maximum values were used with all the DEMs so that the pseudo color scheme would remain constant throughout all of the color shaded relief models. The linear option was chosen to allow the data to be scaled equally or linearly among the elevations between the lowest and highest value. After the scaling process was complete, the output histogram of the values occupied the full possible range.

The color option was set to pseudo color in order to examine the scaled image in pseudo color mode. The PCT Range Editor window was opened by selecting PCT Range from the *EDIT* menu. The smooth button was selected and then custom option was chosen to give the image a more suitable pseudo color range. The colors ranged from blue (representing low elevations) to green, to yellow, and to red (representing high elevations). The custom pseudo color table was then saved to a segment of the file by selecting *SAVE PCT* from the *FILE* menu.

The *PCE* command encoded the scaled DEM channel using the PCT segment and created three output channels representing red, green, and blue components. *NORM* option was selected as the encoding method because it completely encoded the input channels into the three output channels and the image was loaded into PCI and was set to RGB, and then they appeared the same as it did with the pseudo color range.

Shaded relief models were produced with the *REL* command using the 32-bit DEM. This method gave the images a texture look by making the slopes facing the user-specified light source (315, 45) appear bright and those facing away appear dark. The shaded grey level at a point was calculated from the cosine of the angle between the normal vector to the surface (slope and aspect) and the direction of illumination. All surfaces that were not illuminated by the light source were set to zero.

The 32-bit DEM was used instead of the scaled DEM as the input source to avoid creating a misrepresented surface with any artificial artifacts. An elevation exaggeration of 5 was applied to enhance the 3D of the surface. The azimuth angle was set to 315 degrees and the elevation angle at 45 degrees. The output pixel size of 1 m was chosen.

The *Model* command which implements a high level modelling language that can be used for raster GIS and imagery applications was used to integrate channels created by PCE with the shaded relief to create a Color Shaded Relief image. This method gave the surface a more pleasing visual appearance and made it easier to depict the elevations of the image.

By using an EASI model, a depiction of how channels of the imagery data and attribute data should be combined will occur. The results were three new channels consisting of fifty percent of the Shaded relief data and fifty percent of the pseudo color data. Color Shaded Relief Images created from this project for each LIDAR study area are included in Appendix F and G.

9.1 Export Elevation Data

The final PCIDSK CSR Image files were then exported as geo-tiffs using the *FEXPORT* command. This command transferred image and auxiliary information from the source file to an output file that was compatible with most GIS and Cartographic software packages.

The exported geo-tiff files were compressed using MrSID (Multi-resolution Seamless Image Database) software by Lizard Tech that utilized a lossy compression technique based on wavelet technology. The MrSID image file format is designed specifically for transporting, managing and storing images. MrSID reduced the size of the high-resolution images (compression ratios of 30:1 to 50:1) while minimizing the quality and integrity of the original. This type of compressed files is suitable for most applications such as ESRI ArcMap.

10.0 LIDAR Validation

The LIDAR points and the interpolated surface models were both validated to ensure that the quality of the data was acceptable and that the vendor maintained the accuracy that they stated in the initial contract. This was done with several methods. A visual process involved checking each DEM for artifacts and other processing errors. PCI, ArcMap and ArcScene were used to help display and visually validate the LIDAR surfaces.

A second validation method involved comparing the GPS to proximal LIDAR points. A two meter search radius was applied to the GPS points and the LIDAR points from within this buffer region was selected and compared with the GPS orthometric heights.

Another validation method involved comparing the GPS points with the surface derived from the LIDAR data. Statistics for the errors encountered were generated with a spread sheet and summarized to see if the vendor's data met the specifications.

10.1 VALIDATION OF RAW LIDAR DATA

One approach of LIDAR validation was to compare the measured GPS points to the LIDAR points within a specified radius of the GPS points. A search radius of 2 m was chosen to compare only the LIDAR points (that had a ground spacing of 0.6 m) that were close to the GPS points. Since the majority of the GPS data was collected using RTK with a vehicle, typically on a paved road, using a radius of 2 m would ensure that the LIDAR points were compared on the same level surface (e.g. shoulder of road vs. center of road). The Orthometric heights of the LIDAR points within the search radius were then statistically compared to those of the GPS orthometric heights.

This section was done utilizing the GUI style menu driven TOOL1.AML (see Appendix H) written by previous AGRG students. The actual GIS computation was done using ArcPlot and involved several AML scripts. This operation was repeated several times for all the different GPS data files (RTK – vehicle, RTK – Pole, and Total Station).

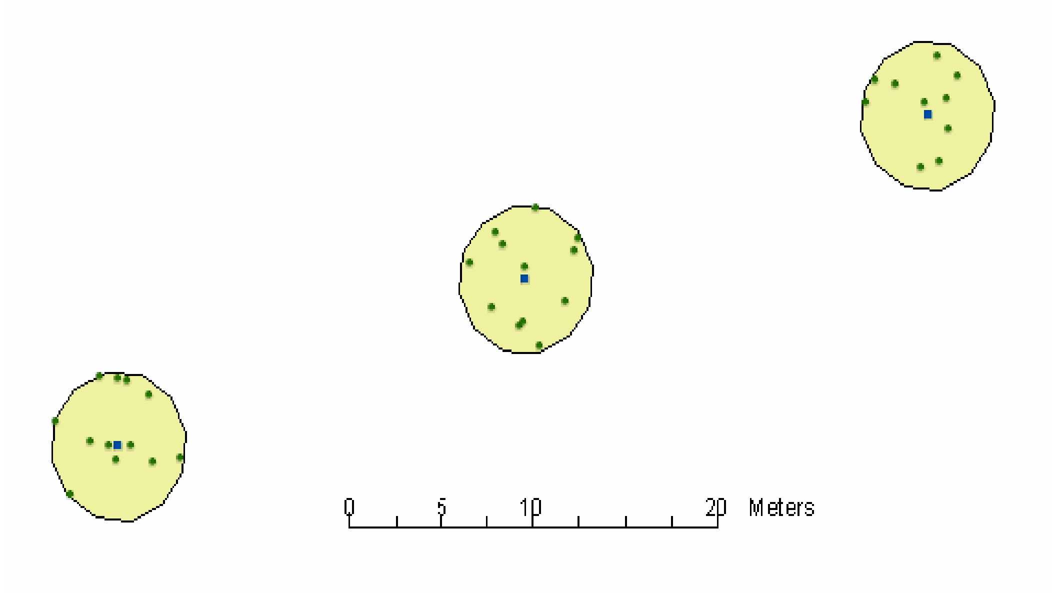

Figure 21 – The blue square points represent GPS points that were buffered with a 2 m radius and the green circle points within the yellow buffered zone are LIDAR points. All other LIDAR points that were not located within the buffered zones were ignored for this validation analysis (Image: E. MacKinnon, AGRG 2003).

Statistics provided from the AML were: frequency of LIDAR points within the buffer, minimum orthometric height difference, maximum orthometric height difference, mean orthometric height difference, and the standard deviation of the ortho height. Histograms were produced from the AML that plotted the difference in orthometric heights with the frequency of points. An ideal histogram would have a bell shape curve and be centered on the X axis. If all graphs were off by a similar amount, it would have indicated that there was a problem with the LIDAR or the validation data. The 2000 AGRG LIDAR study in Charlottetown, PEI had a systematic vertical bias problem. During the validation, it was determined that the DEM was 0.9 m too low, therefore the DEMs were adjusted by adding a value of 0.9 m to raise the entire surface (S. Dickie, 2001; & Webster et al., 2004).

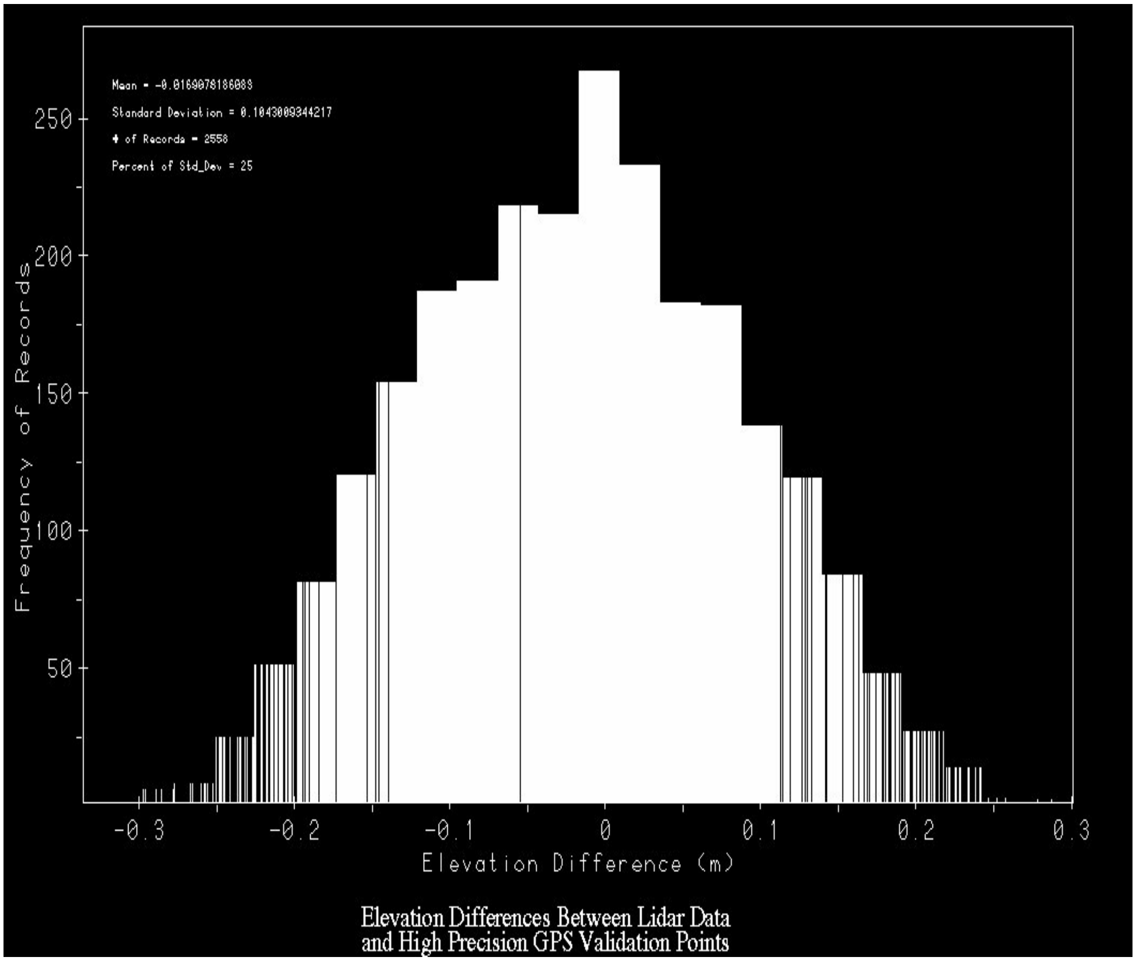

Figure 22 This is one of the many histograms generated from the TOOL1.AML used to validate the LIDAR point coverages. The stats in the top corner are: Number of Records = 2558, Mean = -0.02, Standard Deviation = 0.10, Percent of Std_Dev = 25 (Image: E. MacKinnon, AGRG 2004).

10.2 VALIDATION OF DEMS

This validation approach dealt with comparing the orthometric heights of the GPS points with the DEMs created from the LIDAR interpolations. The GPS data was imported into a Microsoft Excel spreadsheet using the DBF file associated with the shapefile. The *VSAMPLE* command was used to extract the orthometric height values from the LIDAR DEM that corresponded underneath the GPS points and the results were exported to a text file. The LIDAR data was then imported into the same spreadsheet using the text file created with the *VSAMPLE* command.

The orthometric heights for the LIDAR DEM and the GPS measurements were then used to calculate a column containing the difference in elevation for each point. The difference column was then used to create a column containing the absolute difference. Statistics were then calculated using these two columns of data. The mean was calculated from the average of all the difference values. The magnitude of deviation was calculated from the average of all the absolute difference values. The Standard Deviation was calculated from the difference values. The average magnitude was calculated from the difference values. The root mean square was calculated from the square root of the average of all the difference values. A summary of all spreadsheet calculations are listed below.

Elevation Difference = (GPS - DEM)

Absolute Elevation Difference = ABS(GPS - DEM)

Elevation Difference Squared = POWER ((GPS - DEM),2)

Mean = AVERAGE(∑ Elevation Difference)

Average deviation = AVERAGE(∑ Absolute Elevation Difference)

Standard Deviation = STDEV(∑ Elevation Difference)

Magnitude of Magnitude =AVEDEV(∑ Elevation Difference)

Root Mean Square =SQRT(AVERAGE(Elevation Difference Squared))

The statistics were graphed with Excel once all the calculations were computed. A delta Z (Dz) graph representing a comparison between the orthometric heights of the LIDAR plots and the measured orthometric heights from the GPS and a scatter plot graph was plotted to demonstrate the variance of each measured point with the derived LIDAR points.

The scatter plots compared the height difference between the LIDAR DEM and the GPS with the Distance from the GPS point for each file plotted. The expected result for this style of graph is that there should be a larger variance with the results the further you go away from the GPS point. In other words, the tighter the formation of points the more accurate the data was.

10.3 VISUAL VALIDATION

All the tif files, grids, point coverages, shape files and INFO tables were loaded into ArcMap. Each generated surface was examined and evaluated. The LIDAR points were examined and compared to the surfaces that were interpolated from them to ensure that the data had been properly classified by Terra Remote Sensing and that no erroneous points were classified wrong. ArcScene was often used with the validation process because it allowed large artificial artifacts to be easily identified when viewed in a 3D perspective.

The SNB orthophotos were also used to help identify objects during the validation process. The orthophotos supplied by SNB were not as current as the LIDAR and had a 4 m horizontal error so caution was exercised when comparing objects from the LIDAR to the photos. The orthophotos were comprised of aerial photography from 1996 to 1998, while the LIDAR was flown during the spring of 2003, so in many cases some areas have changed quite a bit. It was found that wharf structures were often different and sometimes objects now existed where they had not before. The SNB base vectors (figure 23) were used to validate the vertical alignment.

Figure 23 Topographic data on top of the LIDAR all-hits CSR used to show the horizontal accuracy of the LIDAR data (Topographic data: SNB, Image: E. MacKinnon, AGRG 2004).

11.0 Flood Simulation

Water level data resulting from existing storm surge events and predicted events with respect to height above Chart Datum were provided by CCAF partners[3]. Chart Datum was locally defined as the vertical reference that represented the lowest water level at lowest tide. The three water levels used in the modeling scenarios were: 3.6 meters, 4.1 meters, and 4.3 meters above Chart Datum. The first flood level was observed during the January 21, 2000, storm surge event, in which significant coastal flooding occurred. The 4.1 meter level represents the January 21, 2000 storm event plus a 100 year predicted 50 cm relative sea-level rise. This consists of an IPCC higher estimate of 30 cm global sea-level rise plus 20 cm of local crustal subsidence. This represented a moderate case scenario for 100 years of relative sea-level rise. The 4.3 meter level represented the January 21, 2000 storm event plus a 100 year predicted 70 cm relative sea-level rise consisting of an IPCC higher estimate of 50 cm global sea-level rise plus 20 cm of local crustal subsidence. This represented an extreme case scenario for 100 years of relative local sea-level rise.

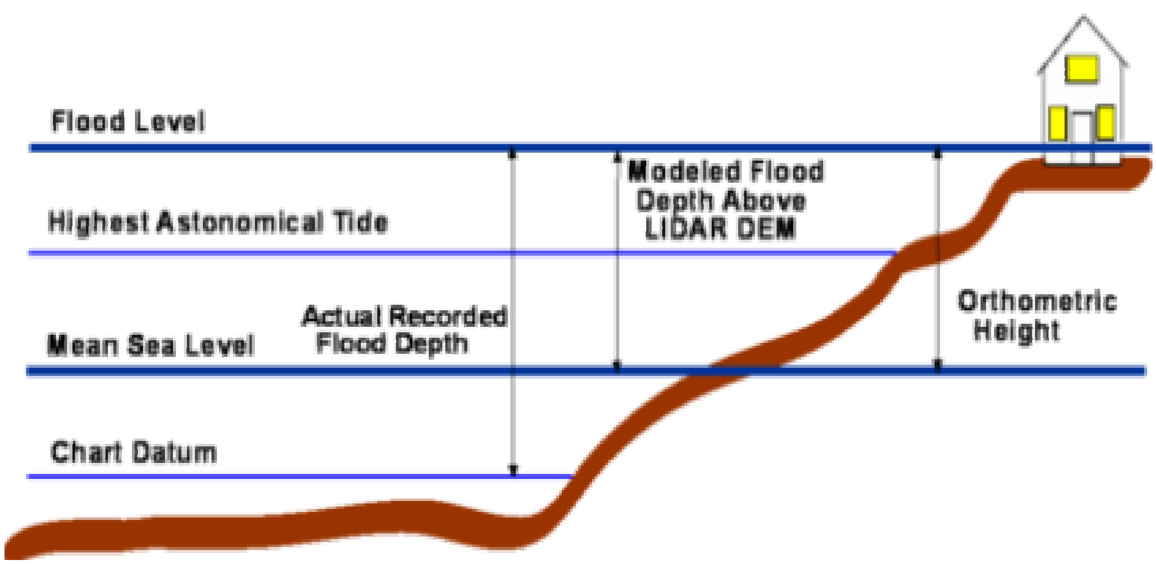

Figure 24 The flood levels provided for this project had to be converted from heights above Chart Datum, to orthometric height so that the flood levels modeled would be consistent with the orthometric heights of the DEMs (Image: E. MacKinnon, AGRG 2004).

[3] H. Ritchie, K. Thompson, G. Parkes and D. Forbes met to develop recommended flooding levels for COGS to use with the DEM for southeastern New Brunswick.

These flood levels were converted to heights above geodetic datum because the LIDAR surface represents orthometric heights above the geodetic datum as demonstrated in figure 24. Chart Datum values measured at meters below geodetic datum (CGVD 28) was provided by the CCAF partners for coastal areas of the Northumberland Strait (King et al., 2002). The values from table 2 were used to convert the flood levels (table 3) modeled with this project to orthometric heights.

LIDAR Polygon	Station Name & #	MWL Above CD	Flood Level Jan. 2000	Flood Level 100 year (extreme)	Flood Level 100 year (moderate)
Bouctouche	Bouctouche – 1817	0.70 m	3.6 m	4.3 m	4.1 m
Cap Lumiere	Richibucto Cape -1820	0.66 m	3.6 m	4.3 m	4.1 m
Cap Lumiere	Saint Edouard De Kent -1805	0.70 m	3.6 m	4.3 m	4.1 m
Cap Pele	Shediac -1805	1.05 m	3.6 m	4.3 m	4.1 m
Cap Pele	Robichaud – 1802	0.70 m	3.6 m	4.3 m	4.1 m
Cocagne	Cocagne – 1812	0.74 m	3.6 m	4.3 m	4.1 m

Table 2 Flood Data used with this project was provided by the CCAF. The mean water level (MWL) measurements above chart datum (CD) were used to convert the mapped flood levels (see table 3).

LIDAR Polygon	MWL Mapped Level Jan. 2000	MWL Mapped Level 100 year (extreme)	MWL Mapped Level 100 year (moderate)
Bouctouche	2.9 m	3.6 m	3.4 m
Cap Lumiere	2.9 m	3.6 m	3.4 m
Cap Pele (Shediac)	2.55 m	3.25 m	3.05 m
Cap Pele (south end)	2.9 m	3.6 m	3.4 m
Cap Pele (north end)	2.86 m	3.56 m	3.36 m
Cocagne	2.86 m	3.56 m	3.36 m
Cormierville	2.86 m	3.56 m	3.36 m
La Dune	2.9 m	3.6 m	3.4 m

Table 3 The actual modeled flood levels with this project were calculated from the provided flood data in table 2 so that the data could be integrated with the LIDAR derived products.

Flood modeling of the three defined flood levels were done on the ground only DEM because it best represented a true earth surface. Using the ground only LIDAR "bald earth" DEM allowed modeling of accurate flood limits that incorporated hydrological features that most DEMs do not include. The ground only LIDAR has all vegetation removed and clearly distinguished features of stream channels and other features in detail that traditional DEMs could not.

It was assumed that a storm surge would affect all parts of the DEM that contained a direct connection to any coastal waters. Flood extents maps, flood depth raster surfaces and flood risk raster surfaces were generated and when combined could be used as a valuable tool for providing information for strategic planning that could help prevent flood damage.

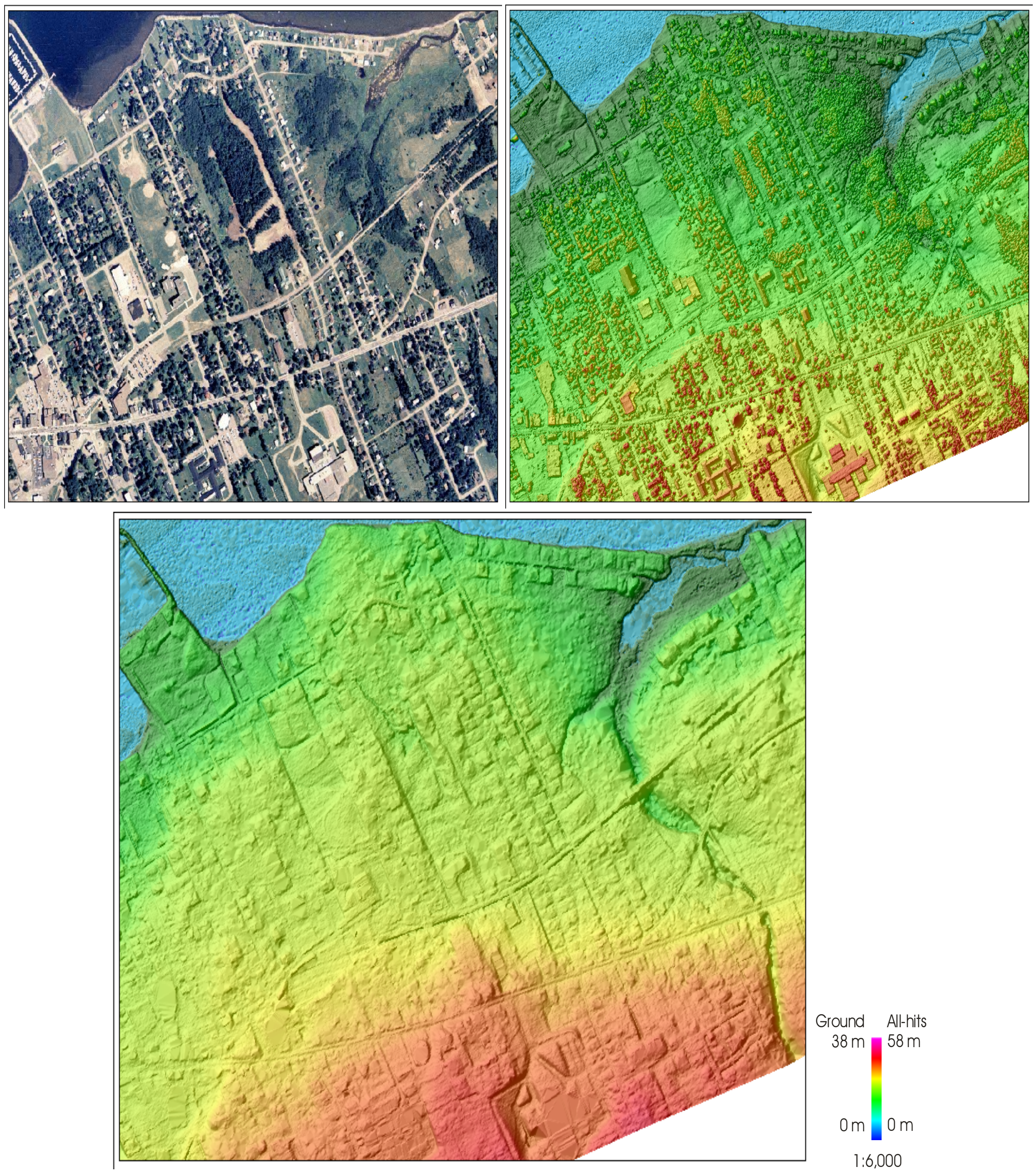

Figure 25 Using a "bald earth" DEM allows to create accurate flood models that incorporate detailed hydrological detailed features that most DEMs do not include. This figure clearly distinguishes features of a stream channel along the right side of the image in the ground only LIDAR CSR (bottom), that is not clearly evident in the all-hits LIDAR CSR (top right) or the orthophoto (top left) for the same area (scale 1:6000) (Image: E. MacKinnon, AGRG 2004)

11.1 Flood Extent

Flood extents are map layers that define how far a given water level will extend inland (see figure 26, and 27). The flood extent layers for this project were derived mathematically from the ground only DEM; by separating the DEM into regions below the flood level and regions above the flood level. This procedure was done using a conditional statement in the ArcINFO GRID environment. The statement below demonstrates the usage of the conditional statement, the new grid and the DEM grids are represented within the <> symbols and the x is the variable indicating the flood level.

Grid: <FLOOD GRID> = con(<DEM GRID> >= x, 1, 0)

The conditional statement mathematically computed new raster grid values defining all regions that would be flooded by the flood level and all regions not effected. The method selects all values that are below the flood level including low lying areas inland that are not connected to the water source and does not address the connectivity issue of flood modeling. Manually editing for connectivity to the flooding source was necessary because this flood modelling method did not incorporate connectivity issues.

The GRIDPOLY command was used to convert the raster flood grids to polygon coverages so that they could be edited for connectivity. Manually examining and editing the flood extent coverage ensured that the result was accurate. The polygon coverage was converted to a shapefile so that it could be integrated with other GIS data and edited within ArcMap. Polygons that were not connected to the ocean and did not have a visible culvert from the NB topographic files were selected and then the grid_code value changed from a value of 0 (flooded) to a value of 1 (not flooded).

Data from the 1:10 k topographic map layers such as location of culverts and the orthophotos were used to help decide if a flooded portion that was unconnected to the source should be included with the flood level.

The edited shape files were converted back into raster grid layers to be used to clip the flood depth layers.

Figure 26 Flood extent for the January 2000 storm surge event in the Pointe-de-Chene area integrated with an orthophoto to make it easier for the user to relate to the actual areas effected by the event (Image: E. MacKinnon, AGRG 2004 and Orthophoto data provided by SNB).

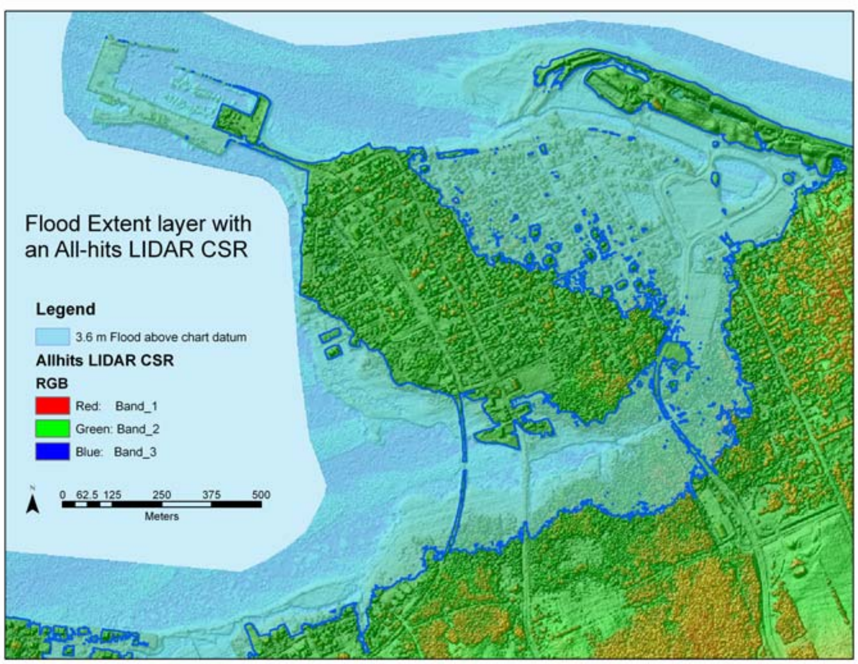

Figure 27 Flood extent for the January 2000 storm surge event in the Pointe-de-Chene area integrated with the LIDAR CSR digital surface model (Image: E. MacKinnon, AGRG 2004).

11.2 Flood Depth

When assessing the damage and severity of a flood, it is important to know the depth of the flood water as well as the extent. Flood depth grids were generated mathematically in the ArcINFO GRID environment from the ground only DEMs. A series of steps were involved and several temporary grids were generated.

Flood depth grids were generated by starting with the flood water level and the LIDAR ground only DEM; adjusting the zero value of the DEM to the flood water level and multiplying it by -1 to reverse the values so that the new grid would have the flood level represented by zero and flood depths would be a positive value. Then another temporary grid was generated to only contain values that were greater then zero so that the grid only contained positive depth values.

```
Grid: <GRIDTEMP1> = (<LIDAR_DEM> – x) * -1
Grid: if (<GRIDTEMP1>  > 0) <GRIDTEMP2> = <GRIDTEMP1>
        else <GRIDTEMP2> = 0
        endif
```

The raster grid flood extent levels were used to clip the flood depth raster to ensure that only flood depth values existed for areas that were within the flood extents; this was done with a conditional statement. A final flood depth GRID represented only depth values that lie within the flood extent after the connectivity was edited.

```
<FLOODDEPTH> = con([<FLOOD_EXTENT>] == 0, [<GRIDTEMP2>], 0)
```

A risk grid was generated by reclassifying the depth grid into sections that would group values together and provide areas with 1m of water, areas with 2m of water and so on. The spatial analyst extension within ArcGIS provides a GIS tool that can classify grids into defined classes. This was very useful for quickly identifying depth of flooding as demonstrated in figure 28.

The flood data created above can now be integrated into a GIS along with topographic data and orthophotos to determine the amount of damage that the water level would cause. The advantage of using a GIS for this task is that a GIS can use several layers. The layers can be made to be transparent to integrate with other data used to analyse amounts of damage.

The flood map in figure 28 shows the depth of the January 2000 flood event for the Point-de-Chene area. The water depths are classified into classes so that general depth of water is easier to depict. The first class is from 0 to 50 cm of water, the second from 50 cm to 1 m of water, and the others increment up at 1 m intervals (see figure 29 for exact values from a reclassified flood depth map). A GIS can integrate other data layers that allow the user to define infrastructure that a flood would effect as seen in the image by adding buildings and road layers that are within the flood extent. The user can quickly examine this flood re-classed depth map and be able to conclude that this flood event effected several homes in the area and that the amount of water flooding the area was deep enough to cause extensive damage in some cases.

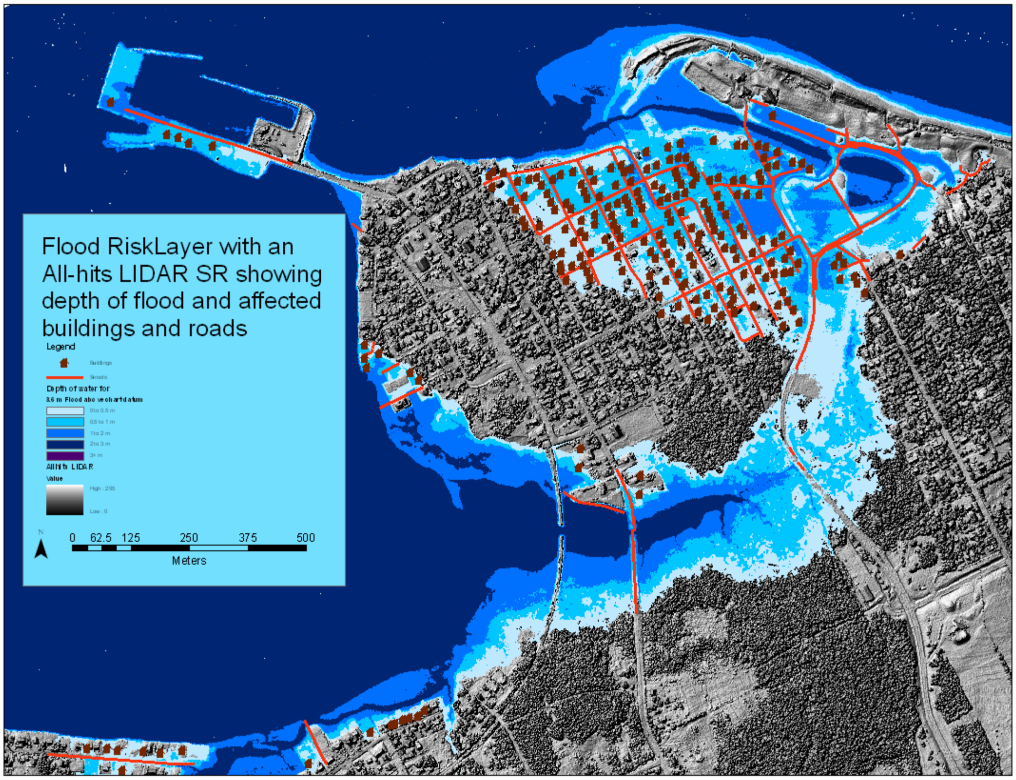

Figure 28 The flood depth grids were classified to make it easier to depict depth of the flood for the January 2000 storm surge event in the Pointe-de-Chene (Image: E. MacKinnon, AGRG 2004).

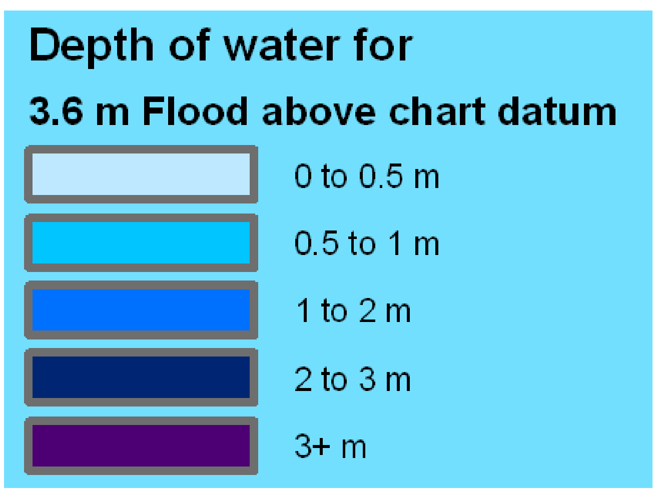

Figure 29 This is an enlargement of the legend for Flood Depth Grid in figure 28 above (Image: E. MacKinnon, AGRG 2004).

11.3 Flood Animation

Animation sequences were created to replicate how the flood would affect areas. Animation is a valuable tool for helping people quickly visualize how serious a flood can be to a region. To be most effective, the animated sequence must be able to show lots of detail, thus it is better to be zoomed in on an area while demonstrating the flood.

The LIDAR study areas for this project covered such a large geography that made it difficult for there to be good detail in the animation sequences when the entire study areas were used, so smaller discrete locations were chosen. Bouctouche and Pointe-de-Chene areas were chosen as the main locations for the flood animation because of project importance and they both experienced heavy storm surge damage in the past.

The animation processing was done with PCI Geomatica and Jasc Animation Studio software packages. PCI EASI scripts (Appendix K & L) were coded to aid in the creation of the images. Perspective views were created with PCI to show a unique 3D visualization of the selected area. Each flood level was then modeled similar to the process that was used to generate the flood extent where either the DEM was flooded or not flooded, resulting in a binary image. The images generated for the animation sequences did not have any analysis for connectivity conducted. These flood images were coloured blue to represent water and mosaicked together with the color shaded relief image. The images were exported as individual image files. This was repeated at 10 cm increments to create 26 different images that could be placed together to represent a gradual increase in water level up to the January 2000 storm surge flood level.

These images were used with Jasc Animation Studio and incorporated into an AVI file that could be played in a Windows Media player program and clearly demonstrate the effects of a storm surge as it increased from mean sea-level up to the flood level. This flood tool is extremely valuable because it helps people see in a 3D environment what the flood maps are actually depicting. Figures 30 and 31 show the before and after scenes of the Point-de-Chene flood sequence that demonstrated a 2.55 m flood above MSL.

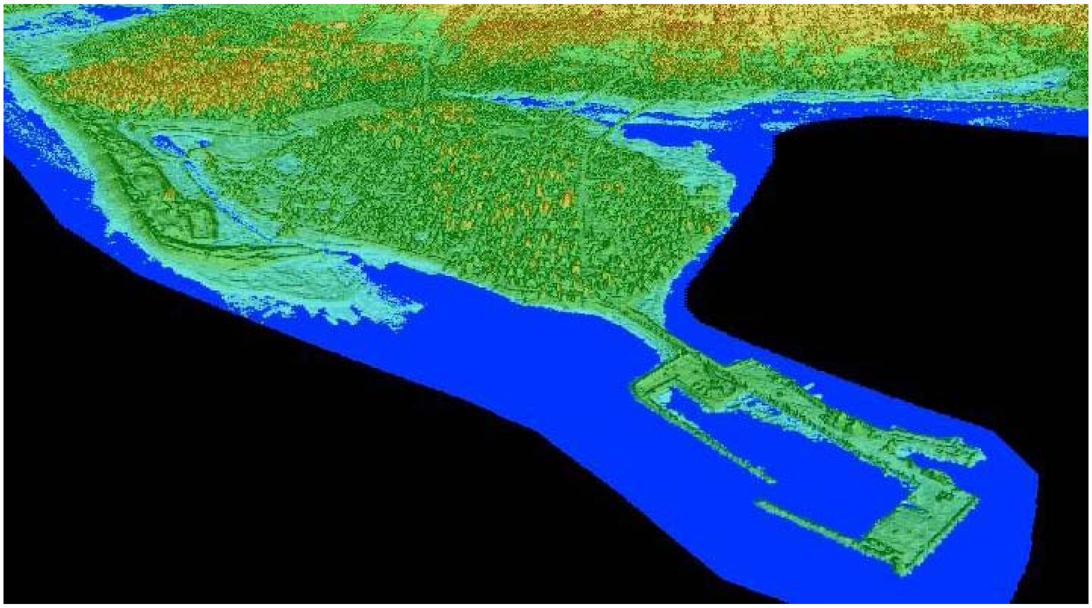

Figure 30 This a perspective view of the Point-de-Chene area (same area as featured in figures 26, 27 & 28) in a southward facing direction (Image: E. MacKinnon, AGRG 2004).

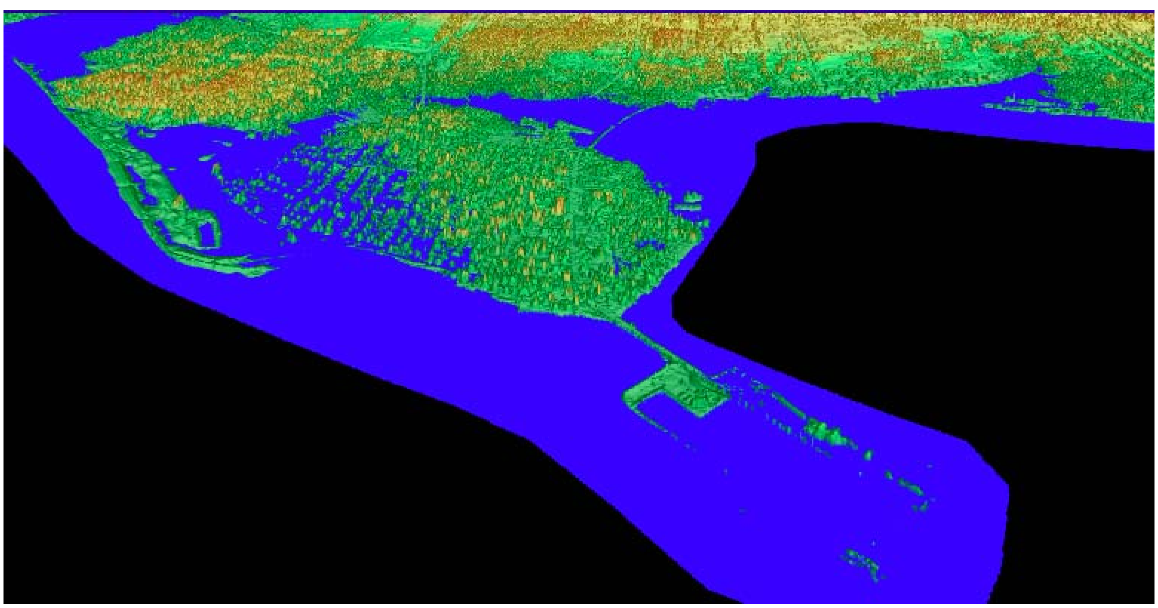

Figure 31 This is the same perspective view as shown in figure 30 but with the January 2000 storm surge flood level of 2.55 m above MSL super-imposed onto it. This image clearly demonstrates the severity of the flooding in this area (Image: E. MacKinnon, AGRG 2004).

12.0 Results & Discussion

The actual GPS and LIDAR acquisition campaign took several weeks to complete and the majority of the work was done by AGRG students and staff that had minimal experience with the RTK GPS system. With that being said, the campaign was pretty successful with only a few minor problems encountered during the data collection process.

Some of the problems experienced during the data collection occurred in the New Brunswick GPS data, but were resolved and the final results of this project were not affected. One of the problems encountered was with the afternoon data collection of May 20, 2003. When the GPS base was setup over top of the Cocagne HPN, the wrong height for the GPS antenna was entered. This resulted in all of the GPS data collected from this base setup to be 1.188 m lower then it actually was. This problem was later corrected at the AGRG lab by re-processing the raw GPS data files with SKIPRO.

Another problem occurred on May 21, 2003 when the GPS base station at the Edgett HPN was setup using the wrong parameters. This HPN was located on top of a cement pillar but the GPS unit parameter was set for the 8502 on a tripod setup instead of 8502 on a pillar. The GPS unit automatically configures the setup based on calibrations of the setup, so in this case it added 36 cm to the measured height of the GPS antenna because of having the wrong selection. Having the wrong setup selected resulted in all of the GPS data collected on this day to be 0.358 m higher then it actually was (the GPS antenna was actually 2 mm above the cement base). This was later corrected at the AGRG by processing the raw GPS data with SKIPRO.

No other known problems have surfaced from the data collection related to this project. The data was integrated into a GIS and linked to the photos to use with the validation of the DEMS. These problems that occurred during the field campaign have actually led to better GPS techniques being practised at the AGRG now.

This project was a large project covering a significant amount of geography (about 165,500 square kilometres), thus the processes involved in creating the value-added products had several stumbling blocks.

The data did not arrive on a timely fashion which caused several problems but mainly delayed the end date of the project. The data was supposed to start arriving near the end of summer but was only available near the end of November 2003, with all of the data finally arriving near the end of January 2004.

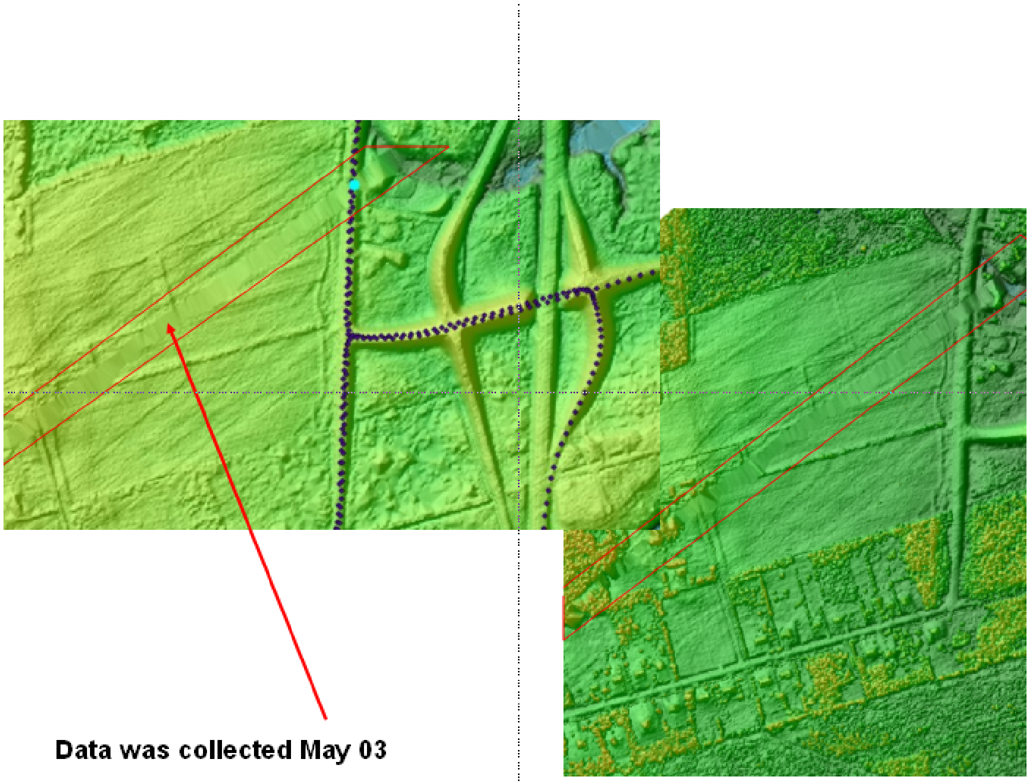

Figure 32 The LIDAR data had to be carefully validated to ensure there were no artifacts or missing swaths as was found here in the Cap Pele Block. The image on the left is a ground only digital elevation model and the image on the right is a digital surface model. Terra RS was notified of the problem and they had the data for this section, it was re-submitted, processed and added to the DEMs (Image: E. MacKinnon, AGRG 2004).

It was discovered after processing the data that parts of the study areas were missing. Two large regions of the Cap Lumiere Block were missing, a swath of data from the Cap Pele Block (figure 32), and a significant part of a wharf in the (figure 33) Cap Pele Block was missing. Missing swaths of LIDAR points resulted in poor surface representations. After conversing with the vendors, it was discovered that a section of the Cap Lumiere Block was not actually flown and had to be re-flown in the spring 2004 mission. The wharf that was missing appeared to have been cut off, so it also had to get re-flown. All other missing sections had been flown and just had to be reprocessed and sent to the AGRG. To date all of these problems have been accounted for or scheduled for later processing. This highlights the detailed inspection and processing required for such a large study area and the large volume of data.

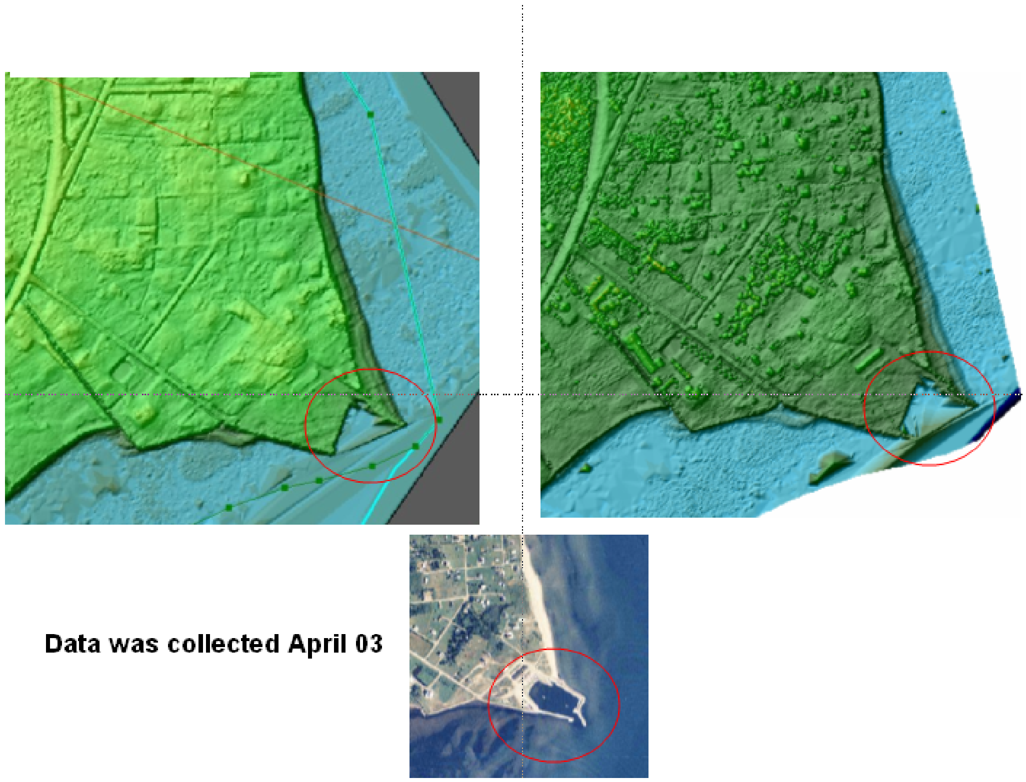

Figure 33 There were times when the LIDAR data would be missing, which caused a misrepresentation of the topography when creating surface models. The image on the left is a ground only digital elevation model, the image on the right is a digital surface model and the image on the bottom is an orthophoto that clearly shows the LIDAR data is miss representing the wharf (Image: E. MacKinnon, AGRG 2004).

Some of the many outliers existing in the data were manually edited out (see figure 13) with ArcINFO and some of it were modeled out with PCI because it was often quicker and easier then sending the data back to get the vendor to reprocess it. The AGRG needs to investigate purchasing proper software for this so that in the future they can process the data themselves and avoid this problem.

Validation of the LIDAR revealed that the LIDAR data was within the accuracy specifications (within 30 cm in both vertical and horizontal values). Two main validation methods were utilized in this project; one method involved a comparison between the GPS data and the LIDAR points and the second compared the GPS data with the interpolated surfaces.

The validation of the LIDAR points resulted in a standard deviation of Dz between 9 and 10 cm (see table 4), and an average mean between 12.5 and 34 cm. The mean Dz value of 34 cm was from the Cormierville Block. The Cormierville Block was carefully examined and the relatively higher error value was a result of the GPS data collection errors and not the actual LIDAR as discussed earlier in this section.

Cap Lumiere

Average Mean	0.16
Average Standard Deviation	0.10
Total number of Points	4913

Bouctouche

Average Mean	0.19
Average Standard Deviation	0.10
Total number of Points	2504

Cormierville

Average Mean	0.33
Average Standard Deviation	0.09
Total number of Points	25404

Cap Pele

Average Mean	0.13
Average Standard Deviation	0.10
Total number of Points	186906

Table 4 Average results from all of the pntstats2.dat files generated from the tool1.aml. Individual tile results are included in Appendix J.

The validation of the LIDAR point data was done with the individual point coverages so when the data was graphed to visualize the errors it resulted in several histograms. One for each tile of LIDAR data was generated from the AML, an example of the histograms is presented in figure 22.

Validation of the LIDAR surfaces resulted in a standard deviation of (GPS Dz measurements minus orthometric heights) the LIDAR between 10 and 13 cm and a mean Dz of 3 to 20 cm for all of the study areas (see table 5). The mean value of 20 cm was from the Cormierville Block. The result of this block having the more significant error value was once again related to the error propagated with the GPS field survey and not the actual LIDAR data. Dz graphs and scatter plot graphs for each LIDAR block are featured in figures 34 thru to figure 41.

	Bouctouche	Cap Pele	Cap Lumiere	Cormierville
Number of GPS Points	3125	20748	810	2426
Number of GPS Points > 0.30 m	137	113	15	605
Number of GPS Points > 35 cm	28	28	2	298
Maximum GPS height	0.497 m	0.53 m	0.441 m	0.476 m
Percent of Points Less then 0.30 m	95.61 %	99.45 %	98.14 %	75.06 %
Mean	0.118 m	0.038 m	0.072 m	0.206 m
Magnitude of deviation	0.128 m	0.092 m	0.111 m	0.213 m
Standard. Deviation	0.101 m	0.107 m	0.118 m	0.124 m
Average Magnitude	0.082 m	0.085 m	0.093 m	0.101 m
Root Mean Square	0.155 m	0.114 m	0.138 m	0.241 m

Table 5 Reults from the validation of the LIDAR surfaces, GPS orthometric heights minus the LIDAR DEM orthometric heights.

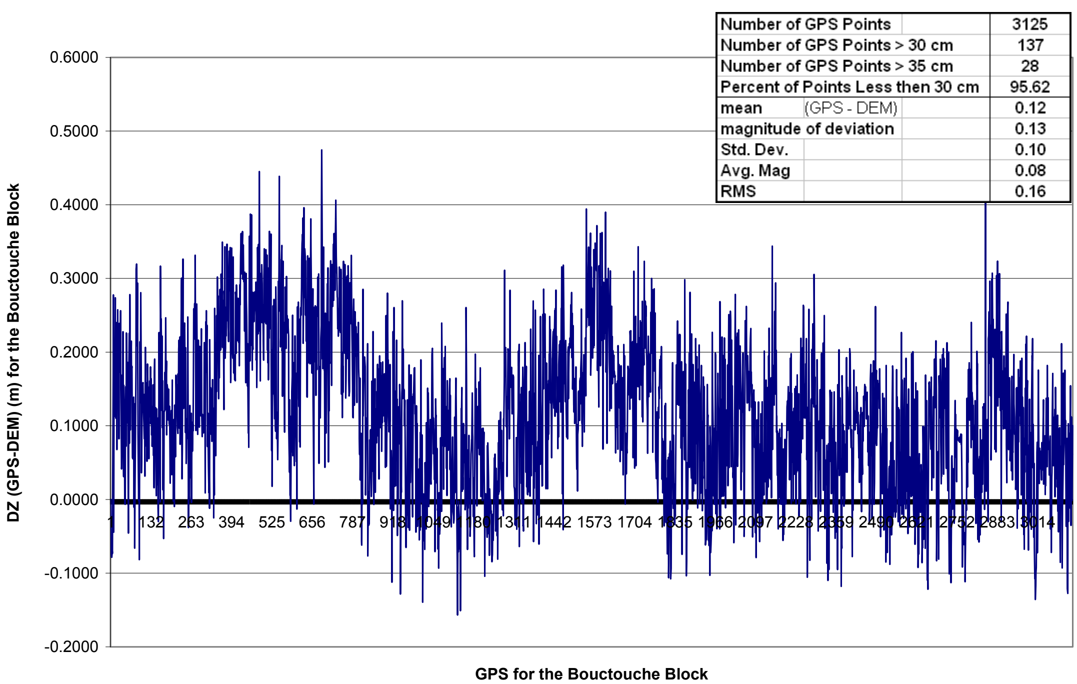

Figure 34 Dz graph for the validation of the Bouctouche LIDAR surfaces.

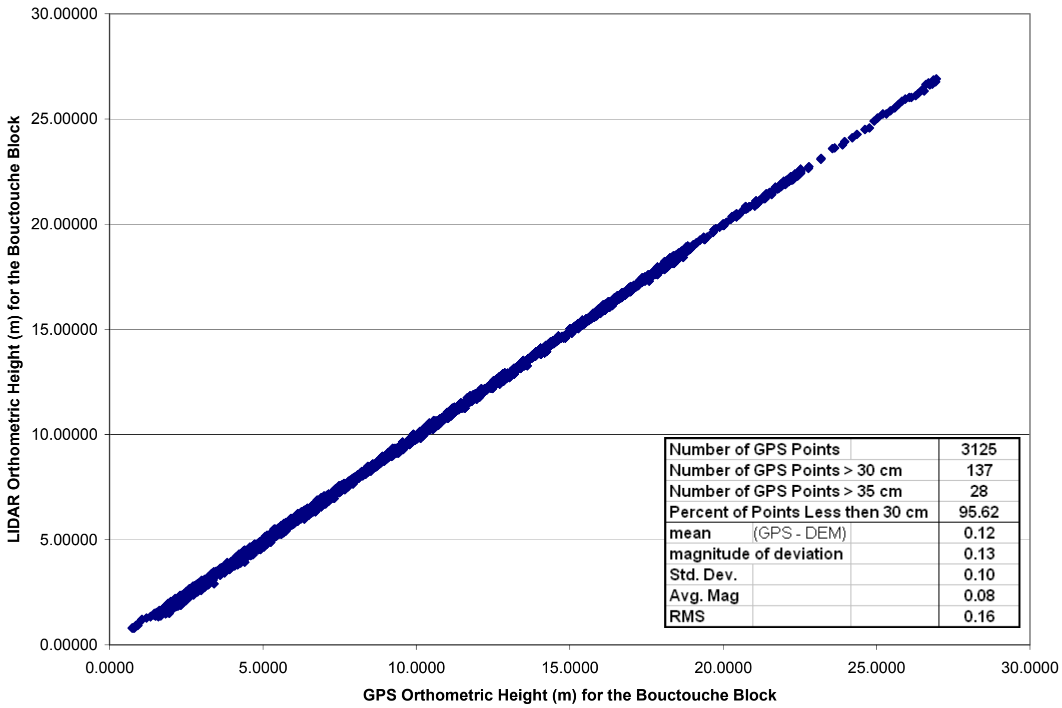

Figure 35 Scatterplot graph for the validation of the Bouctouche LIDAR surface.

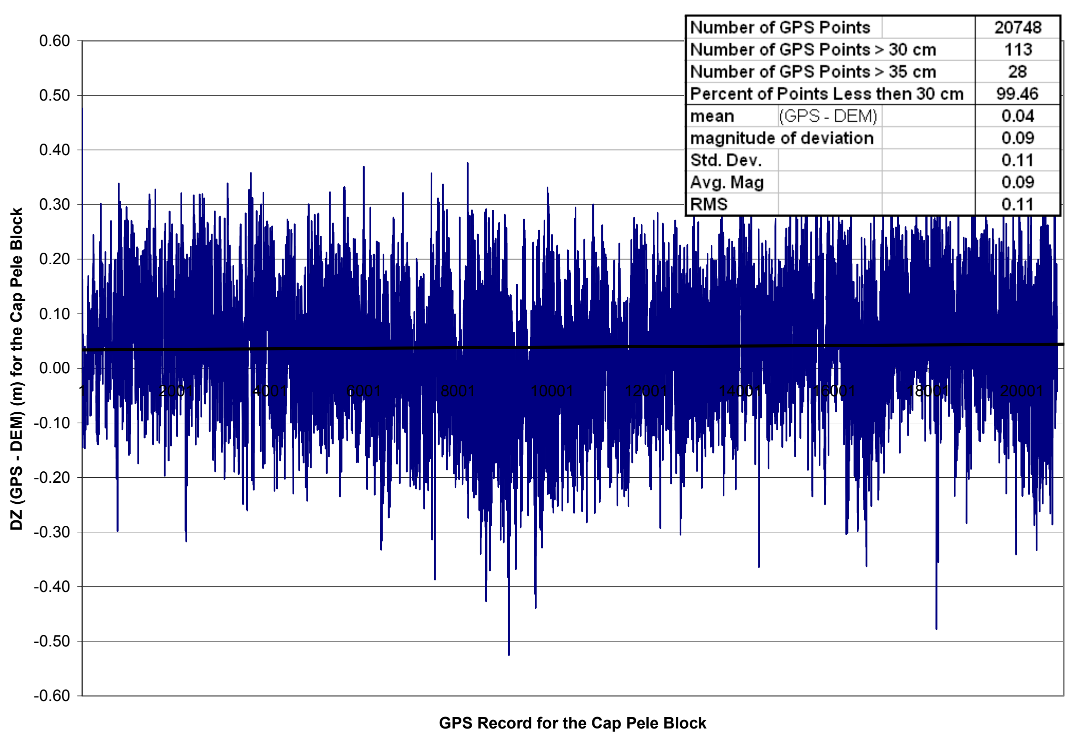

Figure 36 Dz graph for the validation of the Cap Pele LIDAR surfaces.

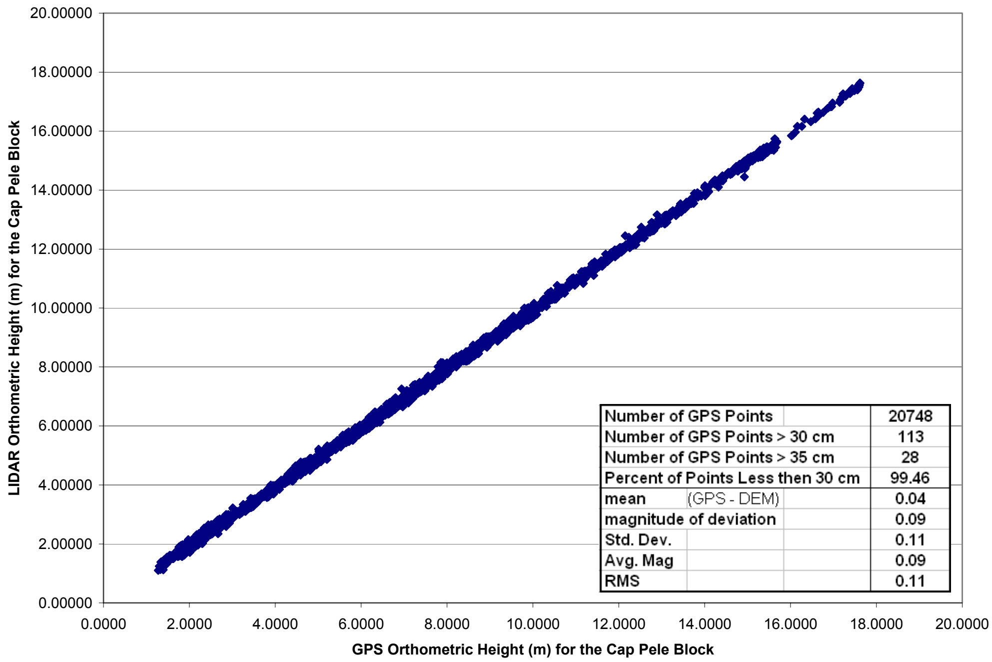

Figure 37 Scatterplot graph for the validation of the Cap Pele LIDAR surface.

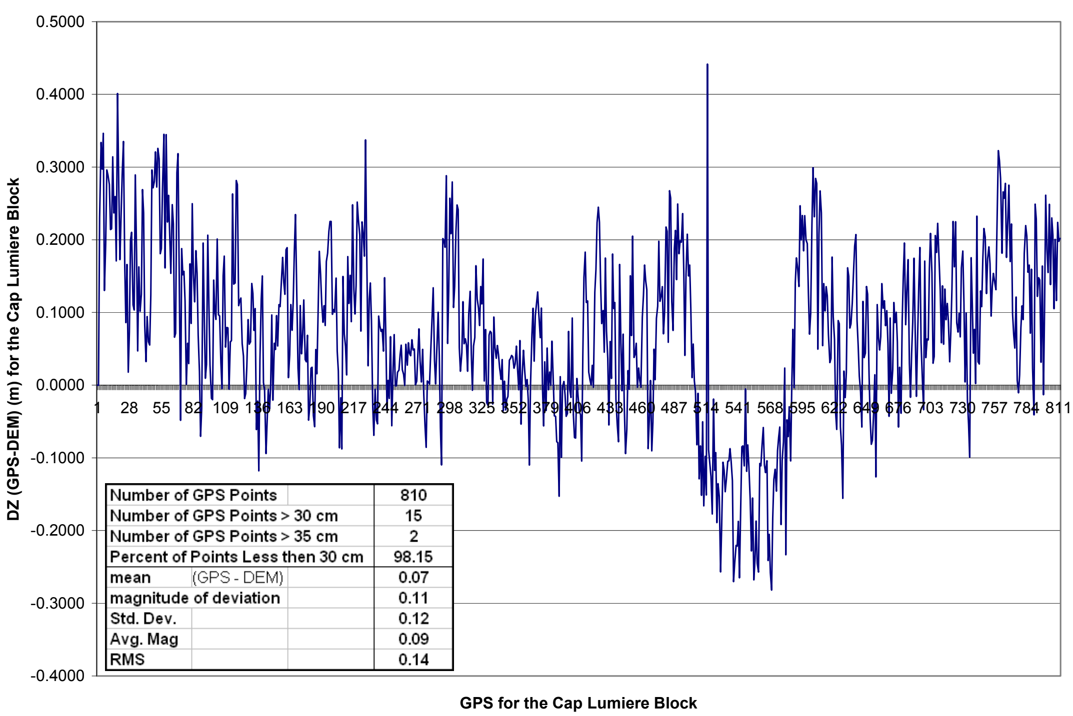

Figure 38 Dz graph for the validation of the Cap Lumiere LIDAR surfaces.

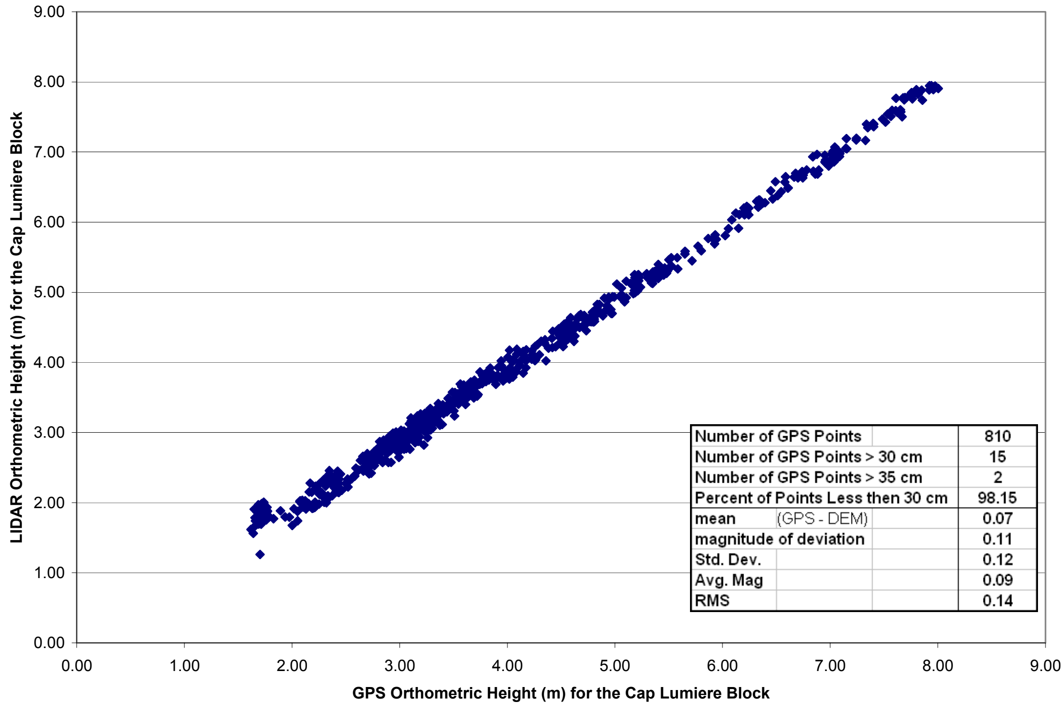

Figure 39 Scatterplot graph for the validation of the Cap Lumiere LIDAR surface.

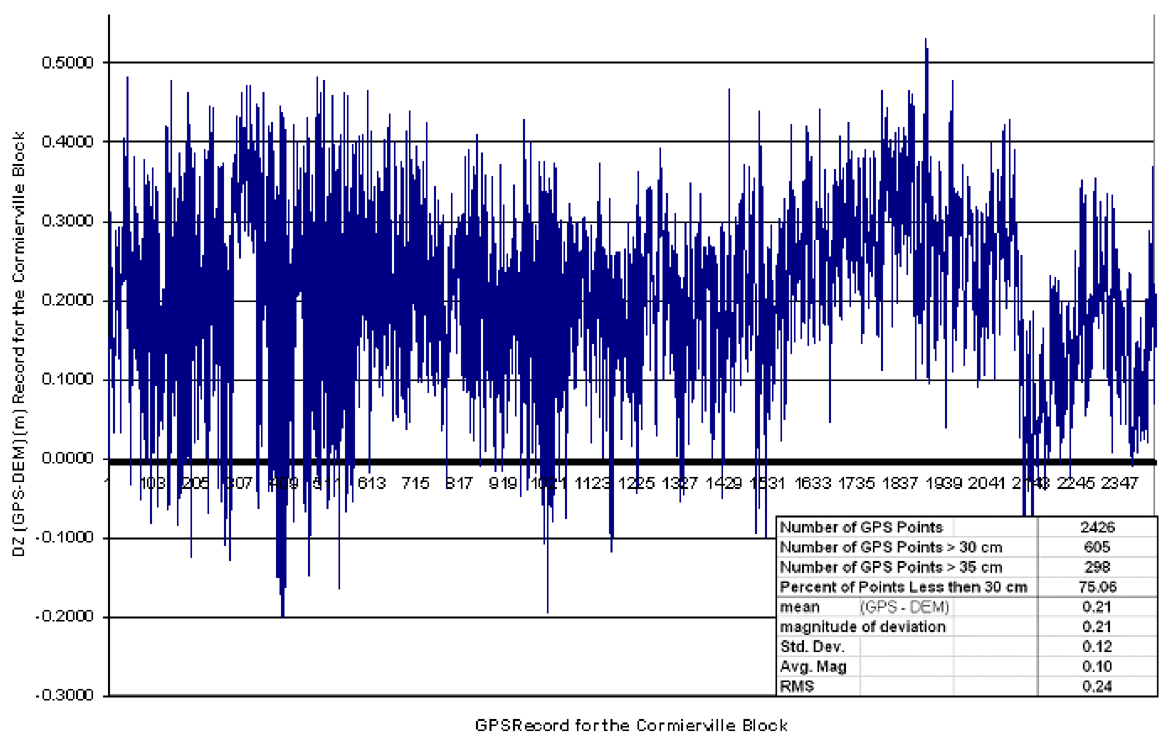

Figure 40 Dz graph for the validation of the Cormierville LIDAR surfaces.

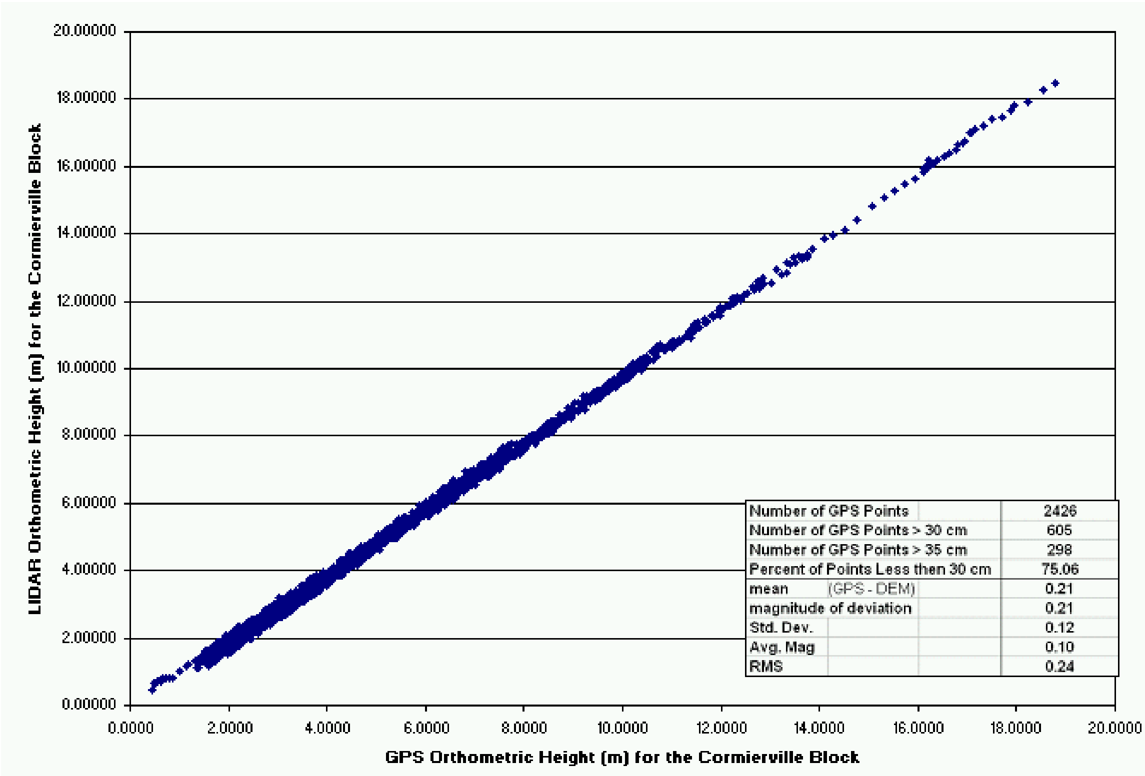

Figure 41 Scatterplot graph for the validation of the Cormierville LIDAR surface.

After examining the interpolated digital surfaces generated from the LIDAR data, it was evident that strange wood grain texture patterns were present in several areas such as the fields shown in figure 42. This texture pattern resulted from ridging artefacts that were produced by the combination of the attitude of the helicopter (pointing forward slightly towards the surface) and the arc-like scan swath created by the oscillating scan mirror used with the laser. Together, these features can create ellipsoidal patterns parallel to the flight path of the aircraft.

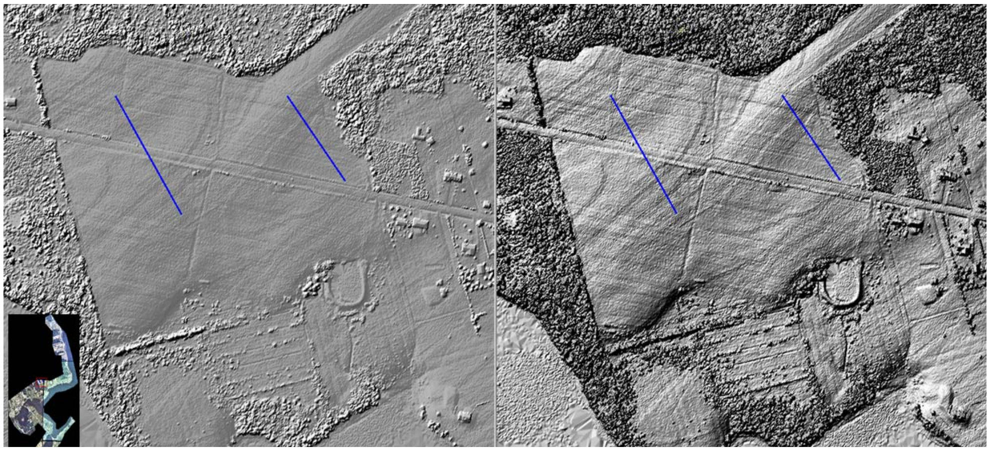

Figure 42 The strange wood grain effect were found throughout the digital surfaces but were always more prominent when the relief was exaggerated such as the shaded relief models. The shaded relief image on the right with the more prominent wood grain effect was created with a vertical exaggeration five times the orthometric height of the DEM where as the one on the left was created with only one time the exaggeration. The size of each image was about 750 m x 625 m (Image: E. MacKinnon, AGRG 2004).

Terra Remote Sensing stated that when the change in ground elevation hovers over flat terrain, the limits of the laser's 10 cm resolution is exploited and it can create small intervals that appear like a wood grain texture. They also guaranteed that this result would not appear with their new Mark II LIDAR sensor because of the better resolution.

The coastal region of New Brunswick is dominantly a low lying area with several fields and along large coastal bodies of water; so this wood grain appearance occurred quite often. It was especially prominent when the vertical heights from the models had been exaggerated to emphasize some of the many features in the data as is often done when color shaded relief models were created (figure 42).

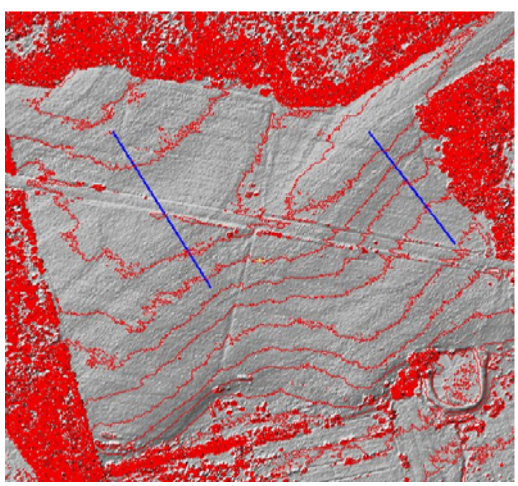

Figure 43 The wood grain effect was not present in contours that were interpolated from the LIDAR digital surfaces. The size of each image was about 750 m x 625 m (Image: E. MacKinnon, AGRG 2004).

Terra Remote Sensing also stated that the texture effect would not affect any products derived from the LIDAR data and that the variance was within their data specifications of points accurate to within 30 cm. Several regions that contained the wood grain texture were tested briefly and always were within the acceptable error levels. Also contour data sets interpolated from the digital surfaces never mimicked the wood grain effect as is visible in figure 43.

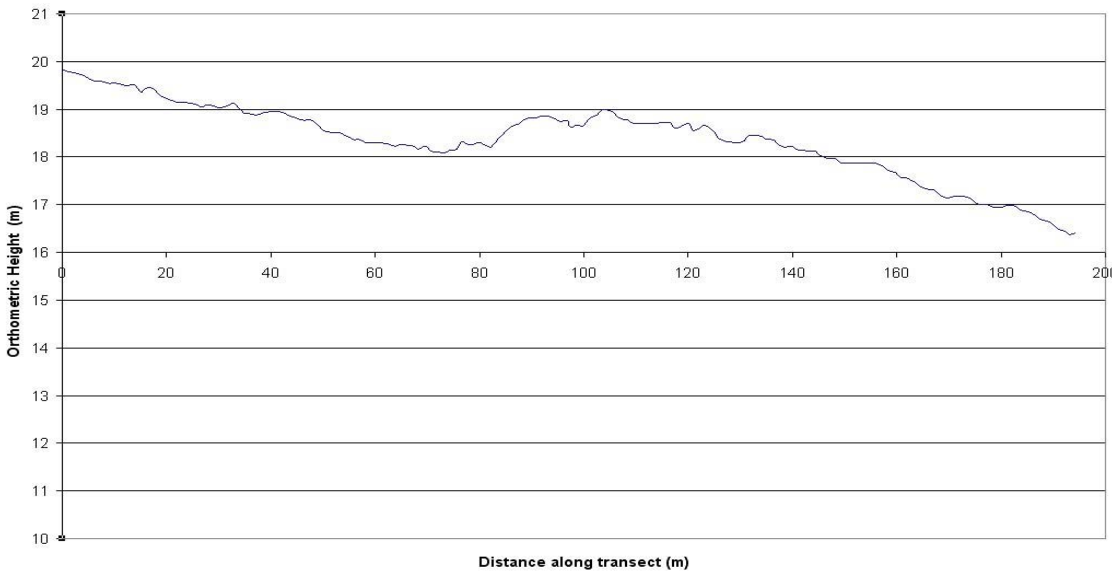

Figure 44 Vertical cross section profiles were used to verify that the wood grain texture was within the acceptable tolerance of the LIDAR data. This profile was derived from the transect along the blue line in figure **** along the left side of the image (Image: E. MacKinnon, AGRG 2004).

Vertical cross sections across the digital surfaces such as the one in figure 44 also confirmed that the LIDAR data was within the acceptable tolerance even when this wood grain texture was present. The ridged artefacts were also not visible enough to be noticed from three dimensional perspectives created from the digital surfaces when incorporated with orthophotos (figure 45). The AGRG has anticipated committing further research into this problem when they obtain their own LIDAR sensor in 2005 and continue to provide state of the art geomatics technology.

Separation of non-ground points from the ground points in the LIDAR data was done by Terra Remote Sensing with TerraSolid software. They defined “Bare-earth” from an algorithm that relies on variables representing building sizes, terrain angles, and iteration lengths and angles.

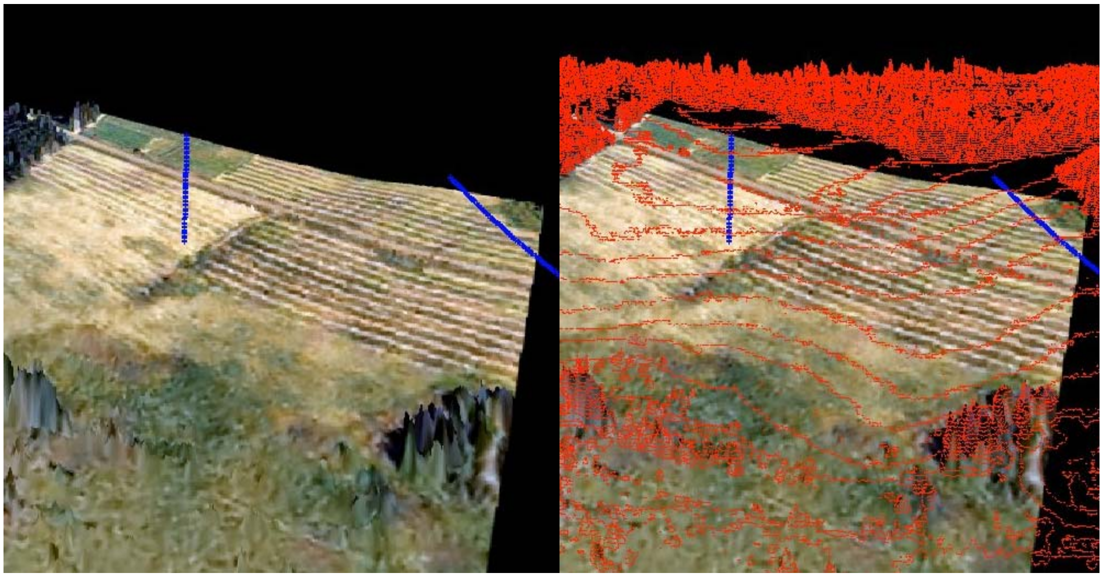

Figure 45 The wood grain textures were not prominent to be visible from three dimensional perspective products created from the LIDAR digital surfaces (Image: E. MacKinnon, AGRG 2004, and Orthophoto data provided by SNB).

The building size attribute identified areas inside the points that made up the structure until a low point among all enclosed points were classified as ground. This process continued until an initial ground hit was defined. Ground data was further separated from initial anchor data based on the terrain angle and iteration parameters until all mathematical possibilities were exhausted.

More precise editing was needed to determine if all reasonable topography had been properly identified. It was likely that possible ground data had been left unclassified due to the LIDAR density and the practical impossibility of addressing each hit. A well-classed file would have a DEM that described sufficiently the finer relief across the study area. Heavy vegetated areas can impair laser penetration, limiting the ability to determine subtle relief characteristics in sub-canopy conditions.

The flooding results for Pointe-de-Chene area were plotted off and brought to show people living in that region during the spring of 2004 to ensure that the extent and flood depth representations actually represented the flood level that the area experienced during the January 2000 storm. The majority of the people that responded agreed that the modeled flood level maps were correct and that indeed the modelled flood was an actual representation of the storm surge event that happened to that area during the January 2000 storm surge event.

The connectivity issue of the flood models need accurate information to determine if an area is flooded or not. The SNB topographic data did not provide sufficient data for all areas and there are perhaps areas in the flood extent areas that could be better refined. Using a GPS to locate all culverts and related information would be a more reliable source of obtaining information to help make the model more accurate.

Figure 46 The following two photos from the Pointe-de-Chene / Parlee Beach area represent before and during the January 2000 storm surge event situations (Images: http://gge.unb.ca/Research/OceanGov/adaptation/).

Base Map data provided by Service New Brunswick was represented in the New Brunswick Double Stereographic projection, while the LIDAR data was WGS84. The base data was also in CARIS format and the AGRG did not have this software so all data had to be converted to ESRI formats in order to incorporate it with the LIDAR data. The different projections caused several delays in the project timeline, since all data had to be projected to the same projection. CCAF partners also requested that all LIDAR products have both projections which also added a significant amount of time to the project. The re-projection of data was very time consuming mainly to the large file size and high detail of the data

13.0 CONCLUSIONS

This research project has described the methodologies involved with producing GIS based flood products with high resolution LIDAR data and the following points can be concluded:

- Detailed ground validation of the resulting DEM is essential to ensure that the LIDAR data meets adequate specifications in vertical and horizontal accuracy and precision to enable reliable mapping. Proper validation and communication with vendors is essential to ensure that the data is of the highest quality.

- The AGRG should acquire the proper software for separating LIDAR point data.

- Airborne topographic mapping of flood limits through the use of LIDAR derived high resolution DEMs can provide an efficient method for defining flood risk hazard zones as a basis for precautionary planning climate change adaptation and emergency response measures.

- The wood grain effect should be further researched by the AGRG when they obtain their own LIDAR sensor in 2005

These methods, although highly accurate in creating flood maps, were based solely on ideal conditions and should not be taken as absolute maps but guides; features such as wind speed and temporary obstacles such as snow banks have not been included into the scenarios and would definitely affect the outcome of flooding. Accurate locations of culverts are needed to ensure that the connectivity issue is accurately represented. The AGRG in conjunction with an AIF project are developing software that will incorporate such variables of a coastal storm surge flood.

In summary, this project has demonstrated the effectiveness and varied utility of LIDAR for the analysis of storm surge flooding in coastal regions. LIDAR is already becoming a main staple in the Geomatics industry and is clearly a valuable tool in flood mapping, and will continue to get better as data acquisition and processing technology advances.

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Appendix A – New Brunswick Double Stereographic Parameters

New Brunswick Double Stereographic Parameters

Parameter	Value
Reference Datum	NAD83-CSRS98
Origin	46°- 30' North , 66°- 30' West
False Easting	2 500 000 m
False Northing	7 500 000 m
Central Meridian	-66.5°
Scale Factor	0.999912°

Table 6 The DEMs and flood data products derived from this project was re-projected into New Brunswick Double stereographic projection using the parameters defined in this table.

Appendix B – AML for Processing Raw LIDAR data

```
/******************************************************************************
/* TERRA_IMPORT.AML
/*
/* Usage:  &RUN terra_import <point_type>
/*
/* This AML is used to process the raw LIDAR data provided by Terra in ASCII format.
/* (Note: It will process all files found in the current workspace. )The files are expected to
/* contain data in space-separated columns and have a file extension of *.<point_type> for
/* all data as follows:
/* GPS week, GPS time, flight line, easting, northing, elevation (ortho), elevation (ellipsoid)
/*
/* The raw LIDAR files will be converted from an ASCII text format to INFO format and then
/* an Arc/INFO point coverage will generated with the proper projection defined.
/*
/* Authors:  Adam Bonnycastle & Ted MacKinnon
/*             Applied Geomatics Research Group, June 2003
/*
/* This AML was based on a previous AGRG AML by:
/*  Steven Dickie, Montfield Christian, & Frances MacKinnon
/*
/******************************************************************************

/* ==================================
/* retrieve type of point file (GND, VEG)
/*===================================

&ARGS point_type
&IF [NULL %point_type%] &THEN &RETURN &WARNING Usage: terra_import <point_type>

/*==============================
/* delete any ARC internal temporary files
/*==============================

&IF [EXISTS xx*.s -FILE] &THEN &SETVAR delstat = [DELETE xx*.* -FILE]

/*=====================
/* create Template INFO file
/*=====================

&IF [EXISTS template.dat -INFO] &THEN; &TYPE Template exists; &ELSE &CALL template

/*==================
/* set variable for list file
/*==================

&SETVAR files = [LISTFILE *.%point_type% -FILE]
&TYPE Processing files: %files%
&SEVERITY &ERROR &IGNORE
&DO input_file &LIST %files%

  /*=====================
  /* set variable for the text file
  /* being used
  /*=====================

  &SETVAR cover_name = %point_type%[SUBSTR %input_file% 1 [CALC [LENGTH %input_file%] - 4]]

  /*===============
  /* display progress
  /*===============

  &TYPE Processing %input_file% to create %cover_name%...

  /*=======================
  /* remove files from previous run
```

```
/*========================

&IF [EXISTS %cover_name% -COVER] &THEN KILL %cover_name% ALL
&CALL cleanup

/*=========================================
/* add record number and comma separation to temporary
/* text file containing only the eastings and northings
/*==========================================

&SYSTEM awk '{print NR "," $4 "," $5}' %input_file% > %cover_name%.xy

/* ===================================
/* ensure that positions are maintained accurately
/*====================================

PRECISION DOUBLE

/*=====================================
/* generate a point coverage using temporary text file
/*=====================================

GENERATE %cover_name%
  INPUT %cover_name%.xy
  POINTS
QUIT

/*=============================
/* build topology for the point coverage
/*=============================

BUILD %cover_name% POINT

/*====================
/* delete any temporary files
/*====================

&CALL cleanup

/*=======================
/* enter the TABLES environment
/*=======================

&DATA ARC TABLES

    /*====================================
    /* append data from text file into temporary INFO
    /* file and calculate relate item
    /*====================================

    COPY template.dat %cover_name%.dat
    SELECT %cover_name%.dat
    ADD FROM %input_file%
    ADDITEM %cover_name%.dat rec 10 10 I
    CALCULATE rec = $RECNO

    /*=============================
    /* calculate relate item for *.PAT file
    /*=============================

    SELECT %cover_name%.pat
    ADDITEM %cover_name%.pat rec 10 10 I
    CALCULATE rec = $RECNO

    /*===============================
    /* exit TABLES environment
    /*===============================
    ~
    QUIT
```

```
    &END

    /*==============================
    /* join *.PAT file to temporary INFO file
    /*===============================

    JOINITEM %cover_name%.pat %cover_name%.dat %cover_name%.pat rec

    /*=====================
    /* define coverage projection
    /*=====================

    &CALL projecting

    /*======================
    /* delete temporary INFO file
    /*======================

    &CALL cleanup

&END

/*======================
/* set severity error to default
/*======================

&SEVERITY &ERROR &FAIL

/*=======================
/* return to ARC environment
/*=======================

&RETURN

/************************************************************************
/* ROUTINE: template
/*
/* This routine establishes the template INFO file containing the appropriate item
/* formatting for the LIDAR data
/*
/* table columns:
/*
/*   GPS week, GPS time (week seconds), flight line, easting, northing,
/*   orthometric height, ellipsoid height
/*
/************************************************************************

&ROUTINE template

    /*===============================
    /* enter the TABLES environment
    /*===============================

    &DATA ARC TABLES
        DEFINE template.dat
        gps_week,5,5,i,0
        gps_time,13,13,n,4
        flt_line,5,5,i,0
        eastings,13,13,n,3
        northings,13,13,n,3
        ortho_ht,10,10,n,3
        ellip_ht,10,10,n,3
        ~
        QUIT
    &END

&RETURN

/************************************************************************
/* ROUTINE: projecting
```

```
/*
/* This routine defines the projection of the generated point coverage containing the
/* LIDAR data as being UTM Zone 20 T WGS84
/**************************************************************************

&ROUTINE projecting

    PROJECTDEFINE COVER %cover_name%
      PROJECTION UTM
      ZONE 20 T
      DATUM WGS84
    PARAMETERS

&RETURN

/**************************************************************************
/* ROUTINE: cleanup
/*
/* This routine removes temporary files
/**************************************************************************

&ROUTINE cleanup

    &IF [EXISTS %cover_name%.dat -INFO] &THEN &SETVAR delstat = [DELETE %cover_name%.dat -INFO]
    &IF [EXISTS %cover_name%.xy -FILE] &THEN &SETVAR delstat = [DELETE %cover_name%.xy -FILE]
    &sys alias rm rm
    &sys rm xx*.*


&RETURN

/*********************************************************************************
/*********************************************************************************
```

Appendix C – AML for Processing LIDAR DEM

```
/******************************************************************************
/* TILE_GRID.AML
/*
/* The tile point coverages located in the 'point' workspace within the current workspace are
/* converted into individual GRIDs that are each buffered 150 m to allow adequate overlap
/* needed to create a larger seamless mosaic of the entire study area.
/*
/* Usage: &RUN tile_grid <cell_size> {LINEAR | QUINTIC}
/*
/* Note: all coverages must exist within the point workspace & adjacent point coverages are also required
/* to create the buffer
/*
/* Authors:  Adam Bonnycastle, Trevor Miline,  & Ted MacKinnon
/*           Applied Geomatics Research Group, June 2003
/*
/******************************************************************************

/* ======================
/* obtain parameters from input
/* ======================

&args cell_size int_style

&if [NULL %cell_size%] &then &return &warning Usage: tile_grid <cell_size> {LINEAR | QUINTIC}
&if [NULL %int_style%] &then &setvar int_style = LINEAR

/* ===============================================
/* create a  list of the available point coverages in the point workspace
/* ===============================================

&setvar result = [LISTFILE [JOINFILE point *] -COVER -POINT covers.lst]

&type Processing files...

/* =============================
/* create TIN & GRID for each LIDAR tile
/* =============================

&setvar fileid = [OPEN covers.lst result -READ]
&setvar base_name = [READ %fileid% result]

&do &while %result% = 0
        &setvar cover_name = [JOINFILE point %base_name%]
        &setvar grid_name = [JOINFILE grid %base_name%%cell_size%m]

        /* =======================
        /* remove files from previous run
        /* =======================

        &if [EXISTS %grid_name% -GRID] &then kill %grid_name% all

        &call cleanup

        /* ======================
        /* run a describe on the coverage
        /* ======================

        &describe %cover_name%

      /*============
      /* compute extents
      /* ============

        &setvar padding = 300
        &setvar x_min = [CALC %DSC$XMIN% - %padding%]
        &setvar y_min = [CALC %DSC$YMIN% - %padding%]
```

```
        &setvar x_max = [CALC %DSC$XMAX% + %padding%]
        &setvar y_max = [CALC %DSC$YMAX% + %padding%]

        /* =================================
        /* create TIN from the LIDAR point coverage
        /* =================================

        createtin temptin # # # %x_min% %y_min% %x_max% %y_max%
                &setvar pfileid = [OPEN covers.lst result -READ]
                &setvar point_cover = [READ %pfileid% result]

                &do &while %result% = 0
                        &setvar point_name = [JOINFILE point %point_cover%]
                        cover %point_name% POINT ORTHO_HT MASS

                        &setvar point_cover = [READ %pfileid% result]
                &end

                &setvar result = [CLOSE %pfileid%]
        end

        /* ====================
        /* interpolate grid from TIN
        /*====================

        tinlattice temptin tempgrid %int_style%
        [UNQUOTE '']
        [UNQUOTE '']
        [UNQUOTE '']
        %cell_size%

        /* ===========================
        /* compute smaller extents to clip grid
        /*===========================

        &setvar padding = 150
        &setvar x_min = [CALC %DSC$XMIN% - %padding%]
        &setvar y_min = [CALC %DSC$YMIN% - %padding%]
        &setvar x_max = [CALC %DSC$XMAX% + %padding%]
        &setvar y_max = [CALC %DSC$YMAX% + %padding%]

        gridclip tempgrid %grid_name% %x_min% %y_min% %x_max% %y_max%

    /* =========================================
    /* remove temporary files & get the name of next coverage
    /* =========================================
        &call cleanup

        &setvar base_name = [READ %fileid% result]

&end

&setvar result = [CLOSE %fileid%]
&setvar delstat = [DELETE covers.lst -FILE]

&return

/*************************************************************************
/* ROUTINE: cleanup
/*
/* This routine removes temporary files
/*************************************************************************

&routine cleanup
        &if [EXISTS temptin -TIN] &then kill temptin all
        &if [EXISTS tempgrid -GRID] &then kill tempgrid all
        &sys alias rm rm
        &sys rm xx*.*

&return
```

Appendix D – AML for Processing LIDAR DSM

```
/************************************************************************************
/* TILE_GRID.AML
/*
/* The tile point coverages in the given ground and nonground 'point' workspaces
/* are converted into all-hits GRIDs and are exported as 16-bit BILs
/* (elevation in cm).
/*
/* Usage: &RUN tile_grid <cell_size> {LINEAR | QUINTIC}
/*
/*
/* Based on AML by Adam Bonnycastle & Ted MacKinnon
/*
/* Updates:
/*          Dec 01 2003          Trevor Milne          Initial version.
/*          Feb 18 2004          Adam Bonnycastle      Add all-hits functionality to tile_grid AML
/*
/************************************************************************************

/* get parameters
&args cell_size int_style

&if [NULL %cell_size%] &then &return &warning Usage: tile_grid_all <cell_size> {LINEAR | QUINTIC}
&if [NULL %int_style%] &then &setvar int_style = LINEAR

/* Get pathnames for ground & nonground point coverages, and for output all-hits GRIDs & BILs

&setvar resp_loop = .FALSE.
&do &until %resp_loop%
	&setvar gndpath = [RESPONSE 'Set the workspace of the ground-only coverages']
	&if [NULL %gndpath%] &then
		&do
			&type User must define a ground-only workspace.
		&end
	&else &if [EXISTS %gndpath% -WORKSPACE] = .FALSE. &then
		&do
			&type Not a valid ground-only workspace.
		&end
	&else &setvar resp_loop = .TRUE.
&end

&setvar resp_loop = .FALSE.
&do &until %resp_loop%
	&setvar nonpath = [RESPONSE 'Set the workspace of the non-ground coverages']
	&if [NULL %nonpath%] &then
		&do
			&type User must define a non-ground workspace.
		&end
	&else &if [EXISTS %nonpath% -WORKSPACE] = .FALSE. &then
		&do
			&type Not a valid non-ground workspace.
		&end
	&else &setvar resp_loop = .TRUE.
&end

&setvar resp_loop = .FALSE.
&do &until %resp_loop%
	&setvar allpath = [RESPONSE 'Set the workspace of the all-hits coverages']
	&if [NULL %allpath%] &then
		&do
			&type User must define an all-hits workspace.
		&end
	&else &if [EXISTS %allpath% -WORKSPACE] = .FALSE. &then
		&do
			createworkspace %allpath%
		&end
	&else &setvar resp_loop = .TRUE.
&end

/* get list of point coverages in ground workspace
```

```
&setvar result = [LISTFILE [JOINFILE %gndpath% *] -COVER -POINT gndcovers.lst]

&type Processing files...

/* create TIN, GRID, and BIL for each tile
&setvar fileid = [OPEN gndcovers.lst result -READ]
&setvar base_name = [READ %fileid% result]

&do &while %result% = 0
        &setvar cover_name = [JOINFILE %gndpath% %base_name%]

        &if [EXISTS [JOINFILE %allpath% grid] -WORKSPACE] = .FALSE. &then createworkspace %allpath%/grid
        &if [EXISTS [JOINFILE %allpath% bil] -WORKSPACE] = .FALSE. &then createworkspace %allpath%/bil

        &setvar grid_name = [JOINFILE %allpath%/grid all[SUBSTR %base_name% 4]%cell_size%m]
        &setvar bil_name = [JOINFILE %allpath%/bil all[SUBSTR %base_name% 4]%cell_size%m]

        /* remove files from previous run
        &if [EXISTS %grid_name% -GRID] &then kill %grid_name% all
        &if [EXISTS %bil_name%.bil -FILE] &then &setvar delstat = [DELETE %bil_name%.bil -FILE]
        &if [EXISTS %bil_name%.hdr -FILE] &then &setvar delstat = [DELETE %bil_name%.hdr -FILE]

        &call cleanup

        /* describe the coverage
        &describe %cover_name%

        /* compute padded extents
        &setvar padding = 300
        &setvar x_min = [CALC %DSC$XMIN% - %padding%]
        &setvar y_min = [CALC %DSC$YMIN% - %padding%]
        &setvar x_max = [CALC %DSC$XMAX% + %padding%]
        &setvar y_max = [CALC %DSC$YMAX% + %padding%]

        /* create TIN
        createtin temptin # # # %x_min% %y_min% %x_max% %y_max%
                &setvar pfileid = [OPEN gndcovers.lst result -READ]
                &setvar ground_cover = [READ %pfileid% result]

                &do &while %result% = 0
                        &setvar point_name = [JOINFILE %gndpath% %ground_cover%]
                        cover %point_name% POINT ORTHO_HT MASS
                        &setvar point_name = [JOINFILE %nonpath% non[SUBSTR %ground_cover% 4]]
                        cover %point_name% POINT ORTHO_HT MASS

                        &setvar ground_cover = [READ %pfileid% result]
                &end

                &setvar result = [CLOSE %pfileid%]
        end

        /* create lattice/grid
        tinlattice temptin tempgrid %int_style%
        [UNQUOTE '']
        [UNQUOTE '']
        [UNQUOTE '']
        %cell_size%

        /* compute smaller padded extents
        &setvar padding = 150
        &setvar x_min = [CALC %DSC$XMIN% - %padding%]
        &setvar y_min = [CALC %DSC$YMIN% - %padding%]
        &setvar x_max = [CALC %DSC$XMAX% + %padding%]
        &setvar y_max = [CALC %DSC$YMAX% + %padding%]

        /* clip grid to smaller extent
        gridclip tempgrid %grid_name% %x_min% %y_min% %x_max% %y_max%

        /* convert data from metre to centimetre
        /* to eliminate need for 32-bit data (ortho_ht < 327m)
```

```
    grid
        tempcmgrid = int(%grid_name% * 100)
    quit

    /* export cm grid as BIL
    gridimage tempcmgrid # %bil_name% BIL

    /* remove temporary files
    &call cleanup

    /* get next tile name
    &setvar base_name = [READ %fileid% result]

&end

&setvar result = [CLOSE %fileid%]
&setvar delstat = [DELETE gndcovers.lst -FILE]

&return

/* removes temporary files
&routine cleanup
    &if [EXISTS temptin -TIN] &then kill temptin all
    &if [EXISTS tempgrid -GRID] &then kill tempgrid all
    &if [EXISTS tempcmgrid -GRID] &then kill tempcmgrid all
    &sys alias rm rm
    &sys rm xx*.*
&return
```

Appendix E – Spatial Index of the individual LIDAR tiles

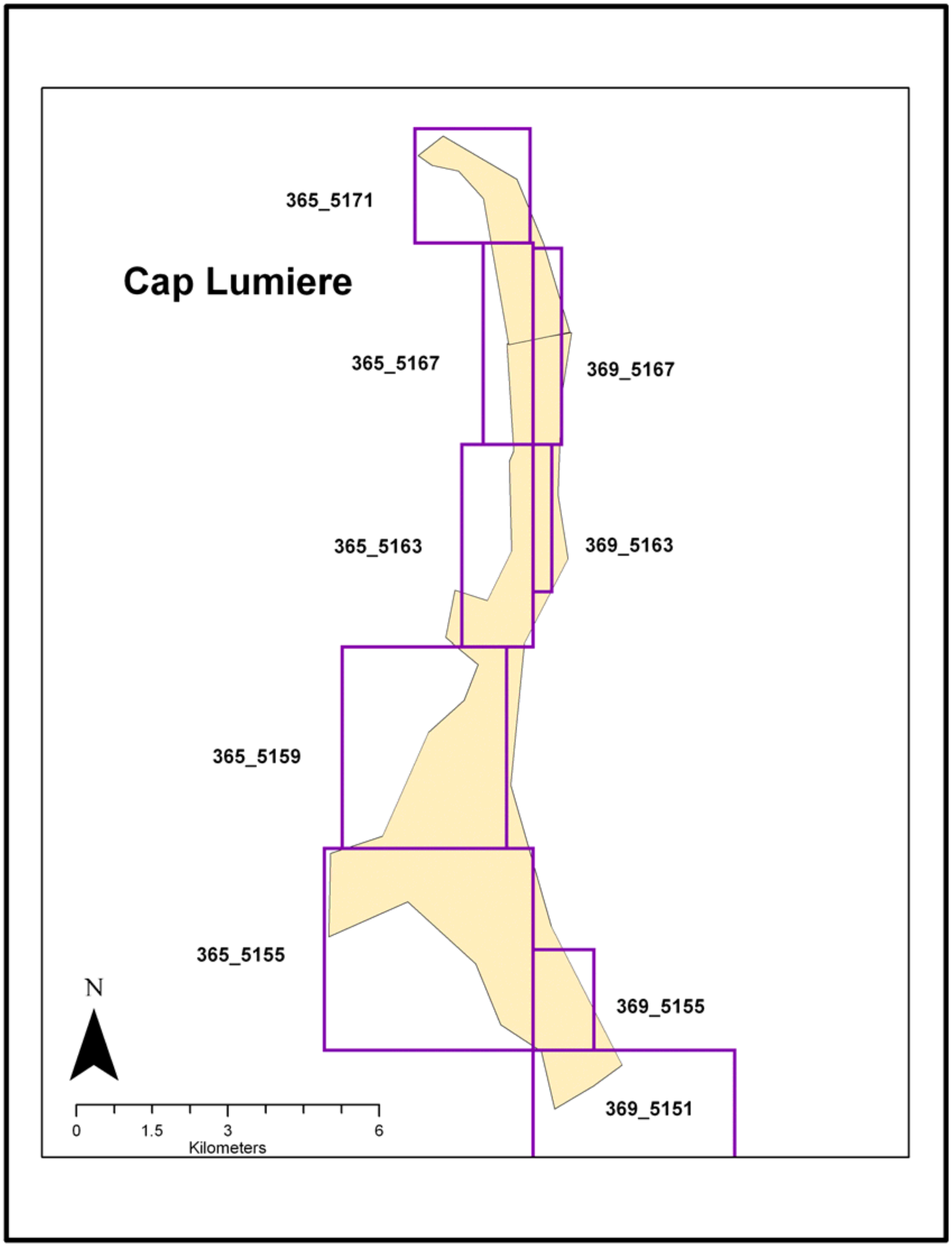


Figure 47 Index key for the Cap Lumiere LIDAR tiles, ground LIDAR points would have a gnd prefix, non-ground would have a non, and all hits would contain an all prefix (Image: E. MacKinnon, AGRG 2004).

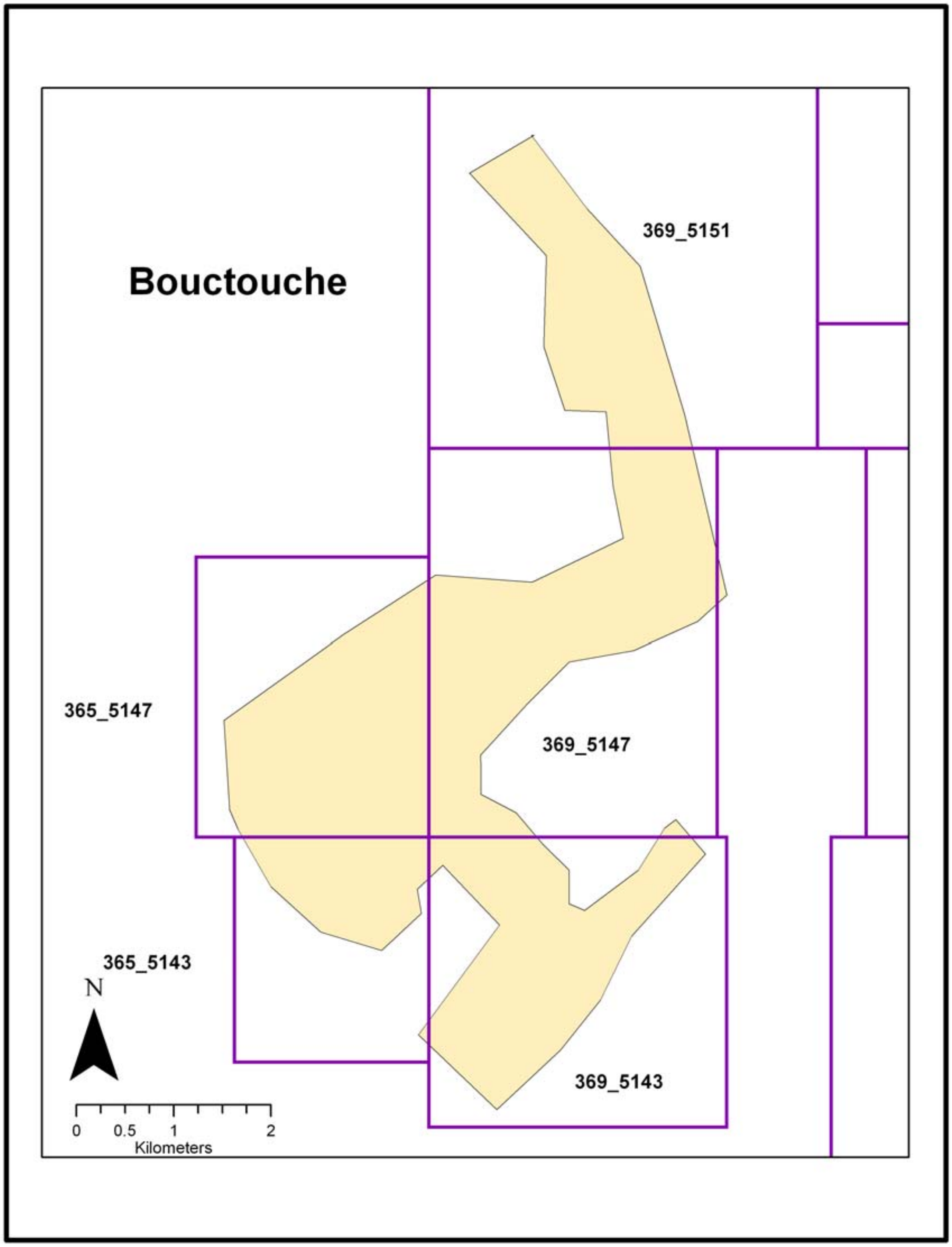


Figure 48 Index key for the Bouctouche LIDAR tiles, ground LIDAR points would have a gnd prefix, non-ground would have a non, and all hits would contain an all prefix (Image: E. MacKinnon, AGRG 2004).

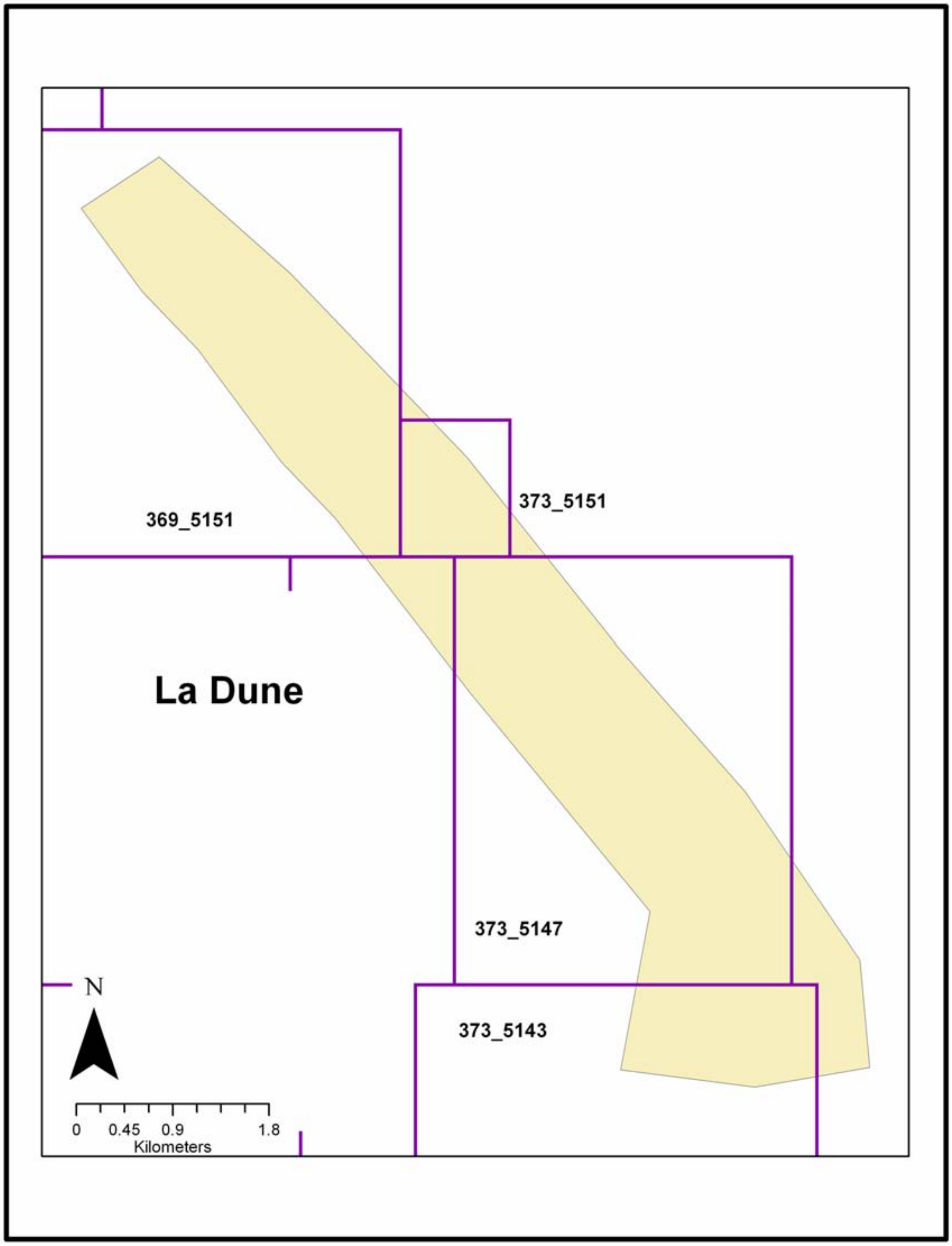


Figure 49 Index key for the La Dune LIDAR tiles, ground LIDAR points would have a gnd prefix, non-ground would have a non, and all hits would contain an all prefix (Image: E. MacKinnon, AGRG 2004).

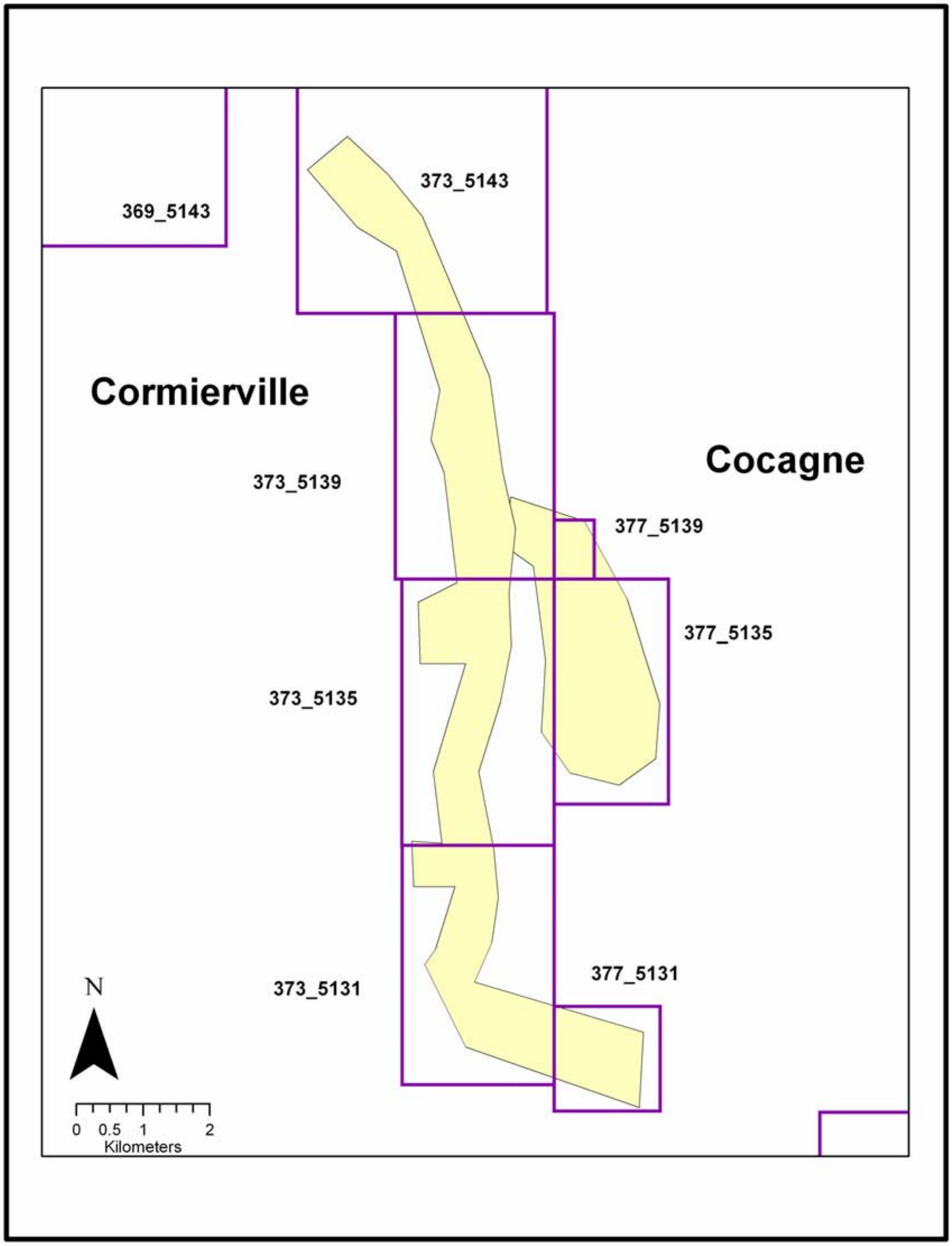


Figure 50 Index key for the Cormierville and Cocagne LIDAR tiles, ground LIDAR points would have a gnd prefix, non-ground would have a non, and all hits would contain an all prefix (Image: E. MacKinnon, AGRG 2004).

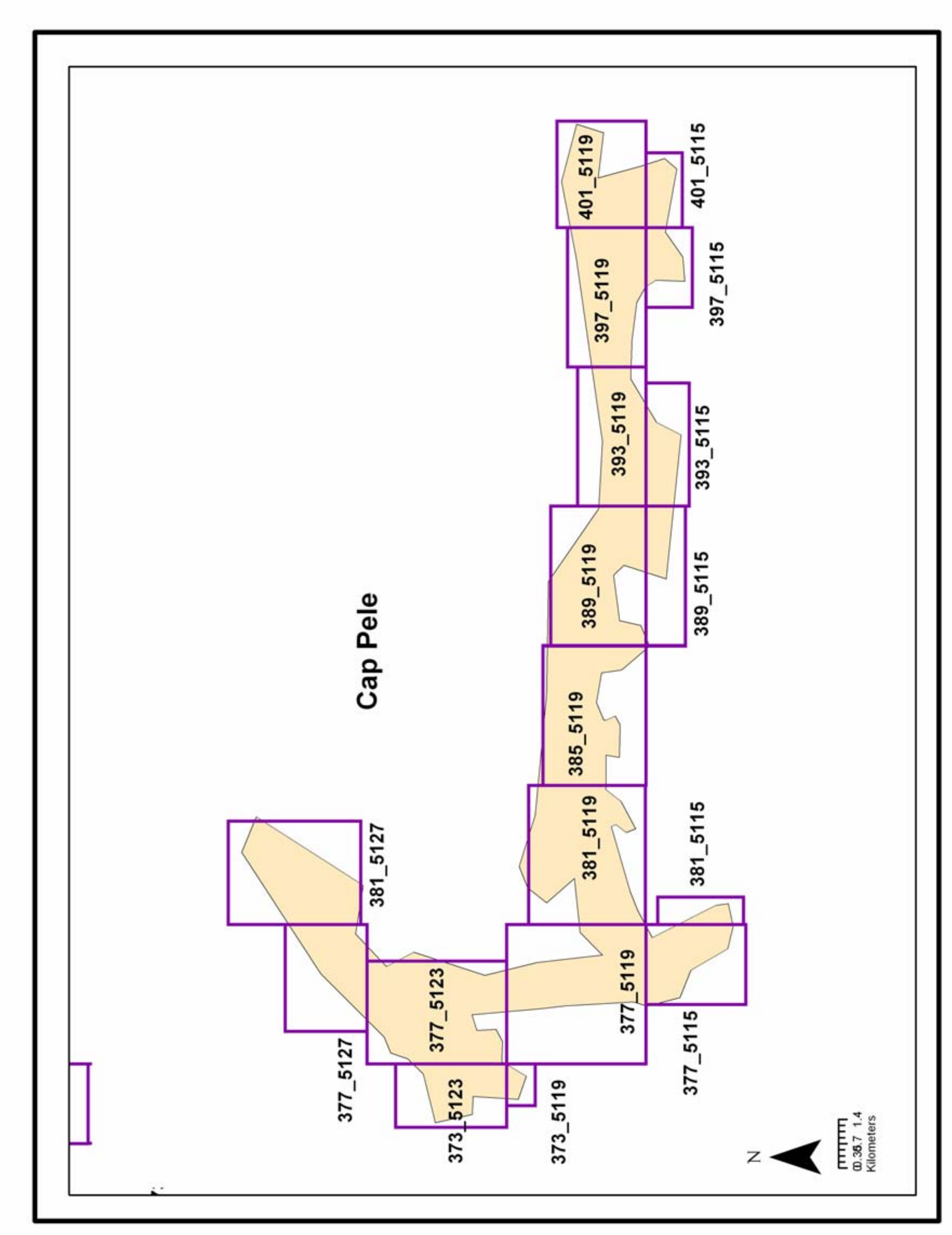


Figure 51 Index key for the Cap Pele LIDAR tiles, ground LIDAR points would have a gnd prefix, non-ground would have a non, and all hits would contain an all prefix (Image: E. MacKinnon, AGRG 2004).

Appendix F – Ground LIDAR CSR Models

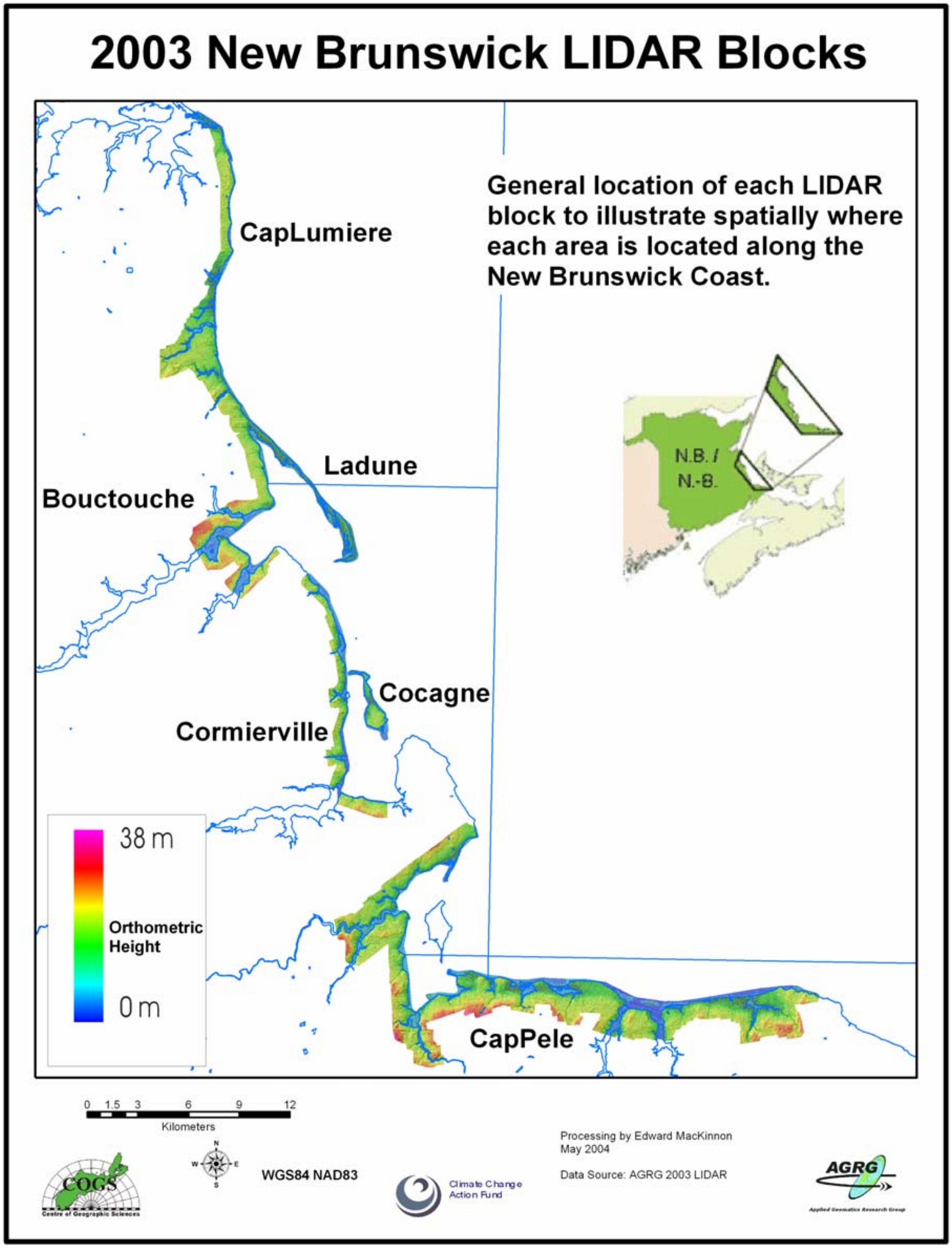


Figure 52 Overview of ground LIDAR CSR Models with the coast map layer displayed to help spatially display the location of each block (Image: E. MacKinnon, AGRG 2004).

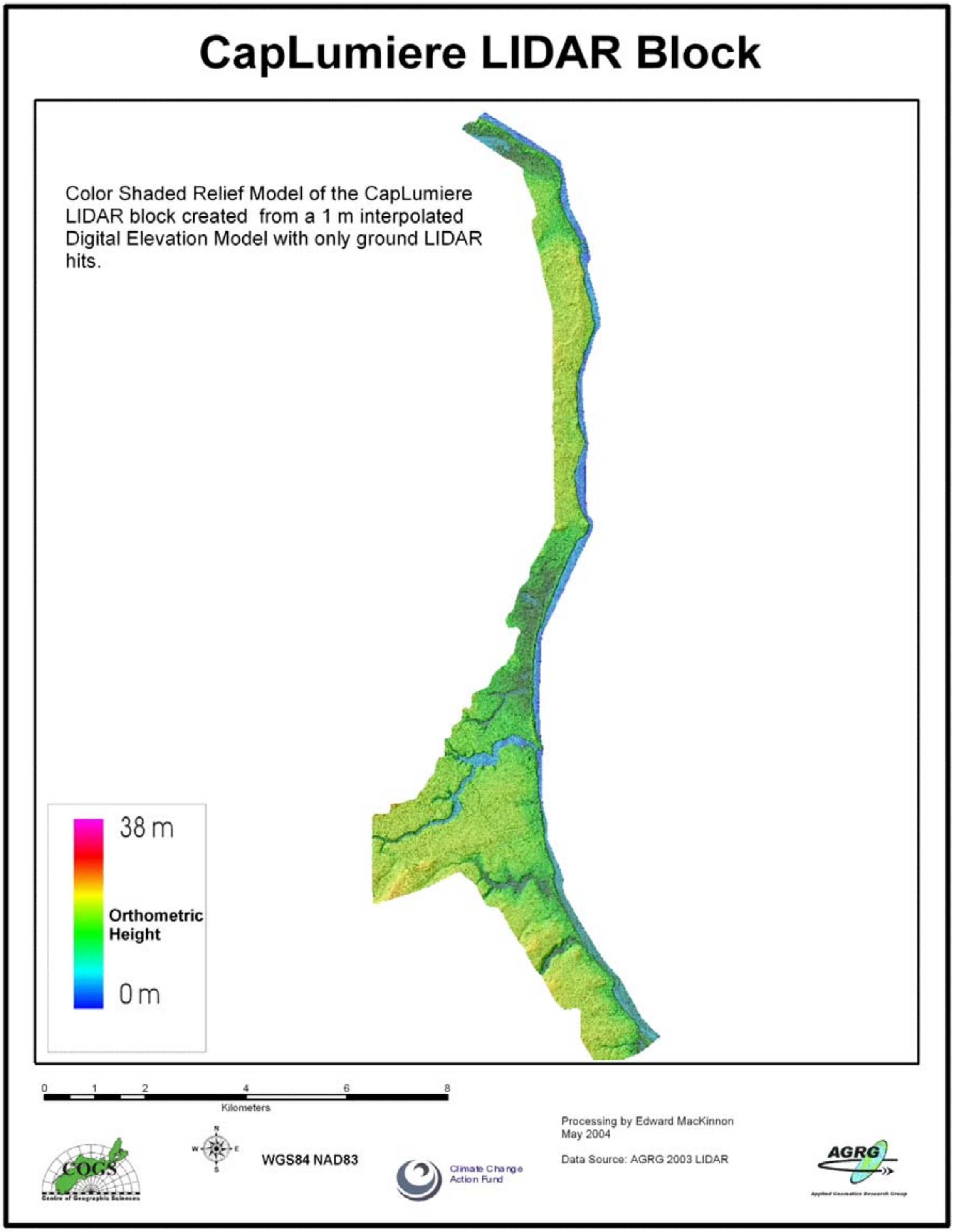


Figure 53 Cap Lumiere Color Shaded Relief Model of the ground only surface (Image: E. MacKinnon, AGRG 2004).

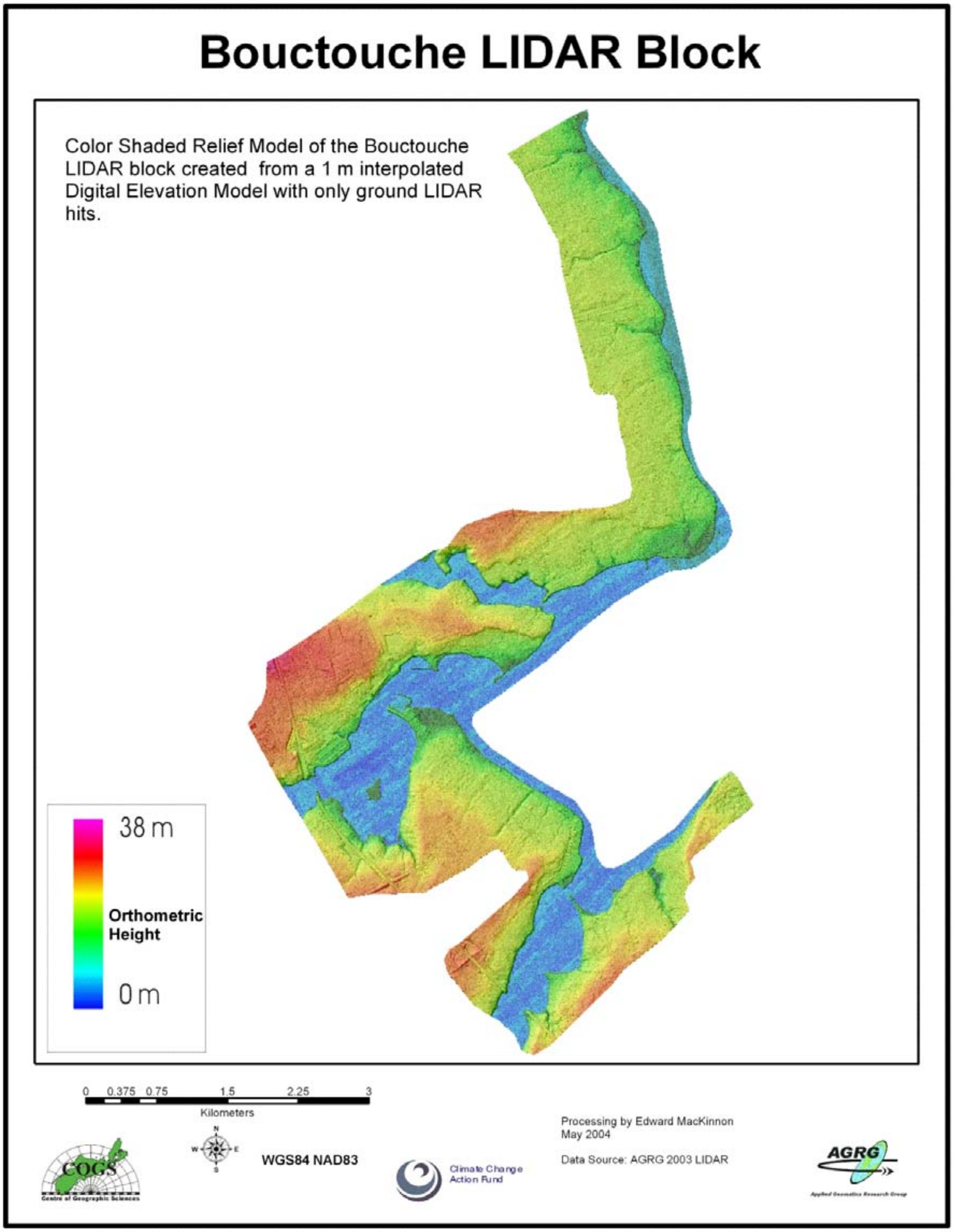


Figure 54 Bouctouche Color Shaded Relief Model of the ground only surface (Image: E. MacKinnon, AGRG 2004).

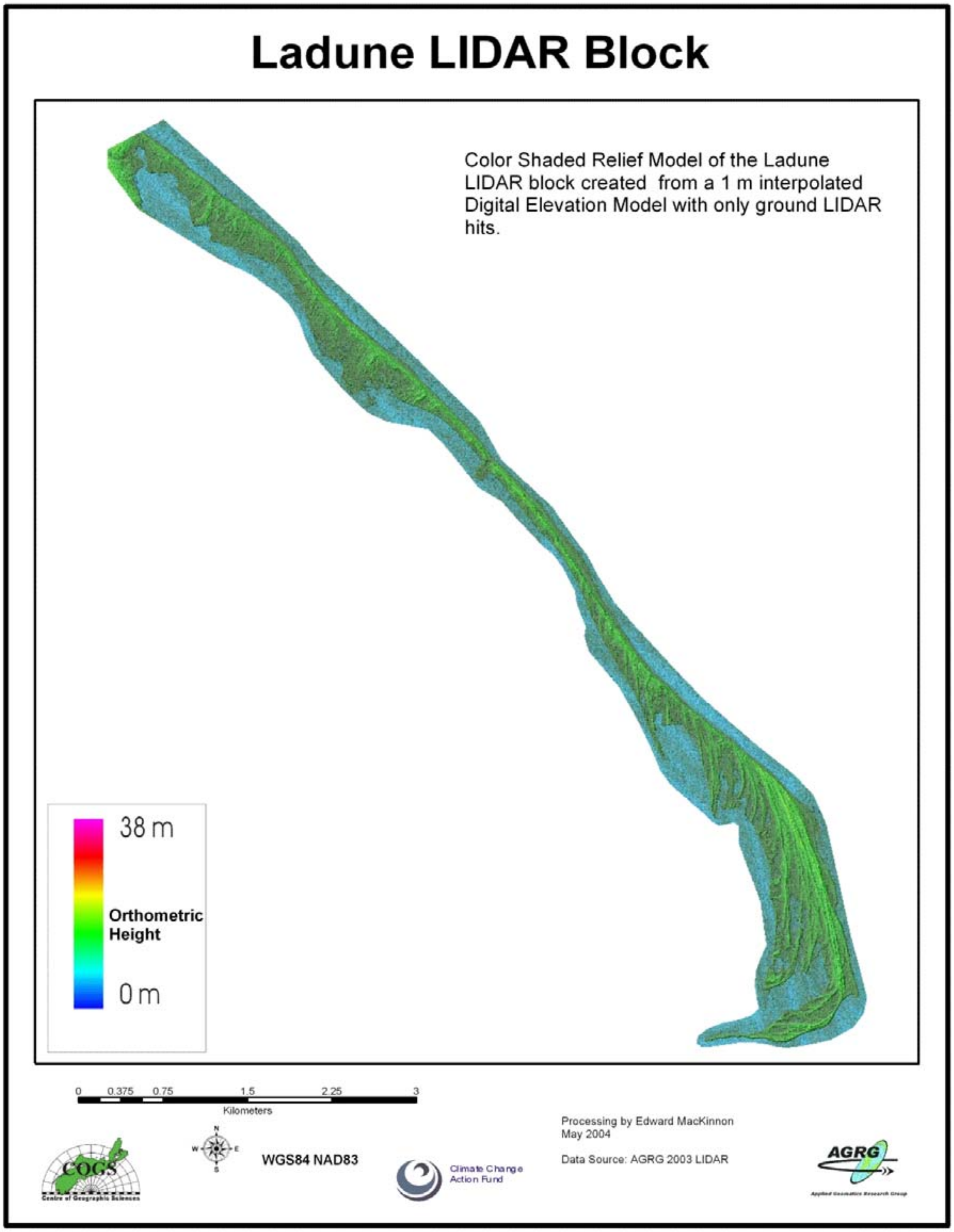


Figure 55 La Dune Color Shaded Relief Model of the ground only surface (Image: E. MacKinnon, AGRG 2004).

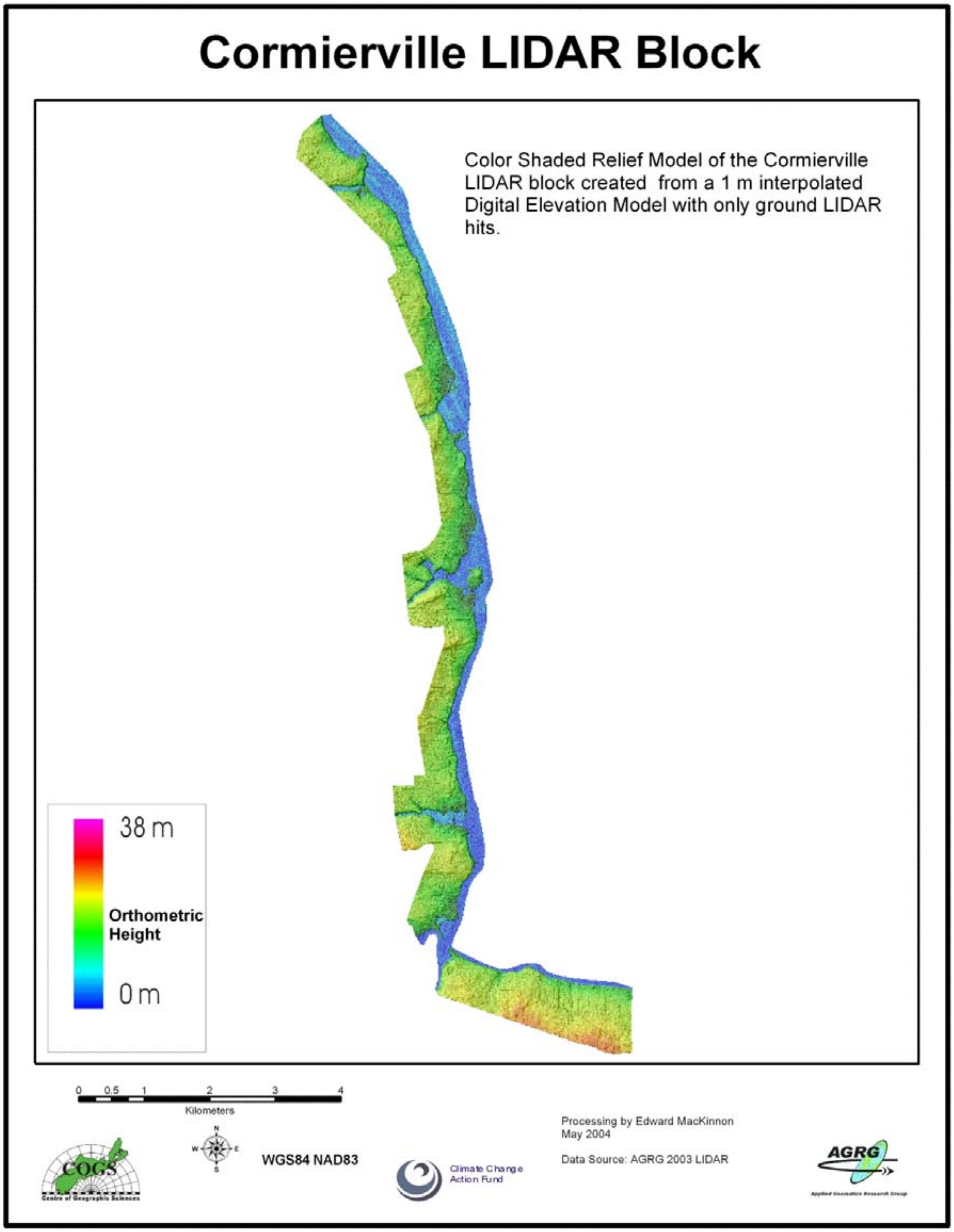


Figure 56 Cormierville Color Shaded Relief Model of the ground only surface (Image: E. MacKinnon, AGRG 2004).

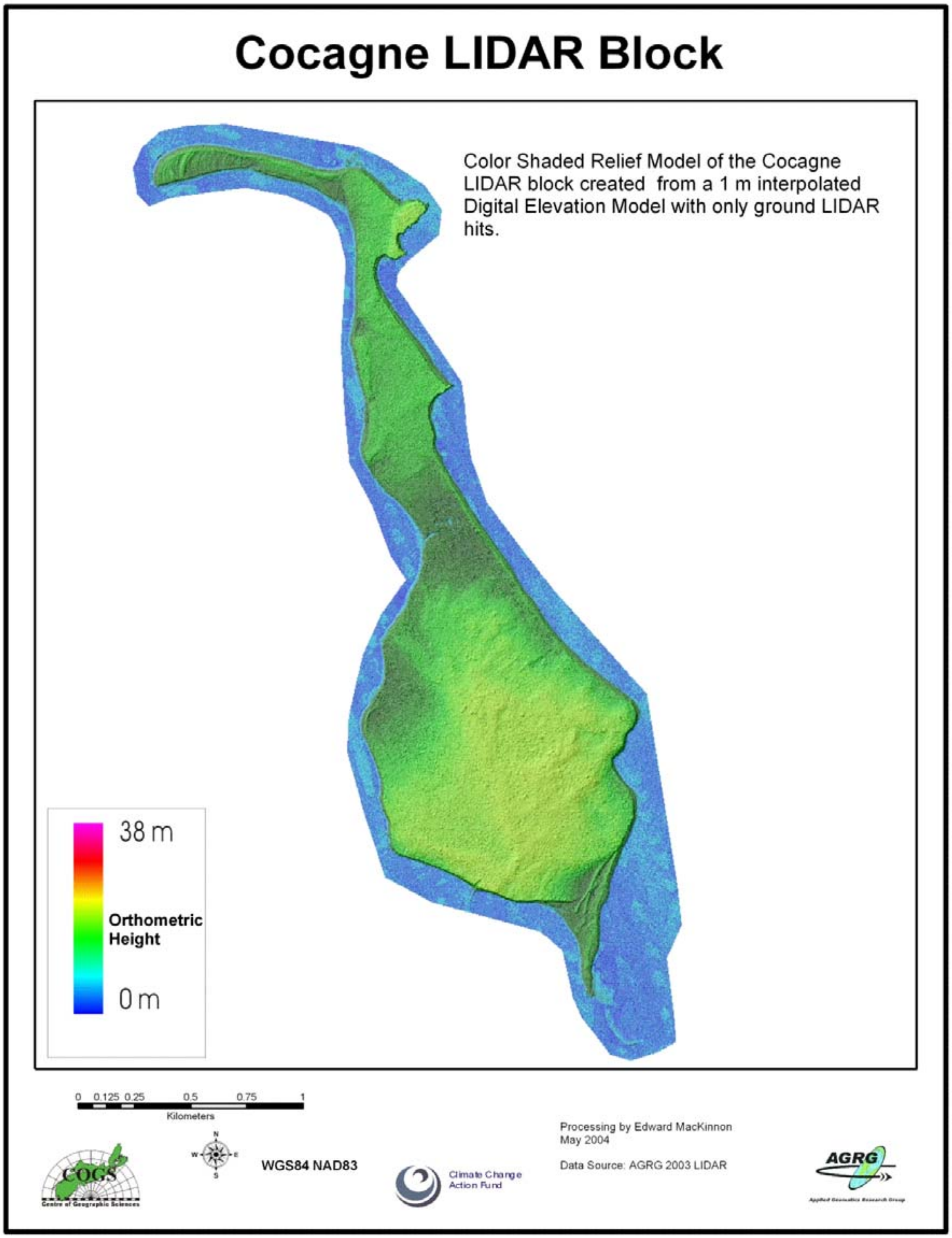


Figure 57 Cocagne Color Shaded Relief Model of the ground only surface (Image: E. MacKinnon, AGRG 2004).

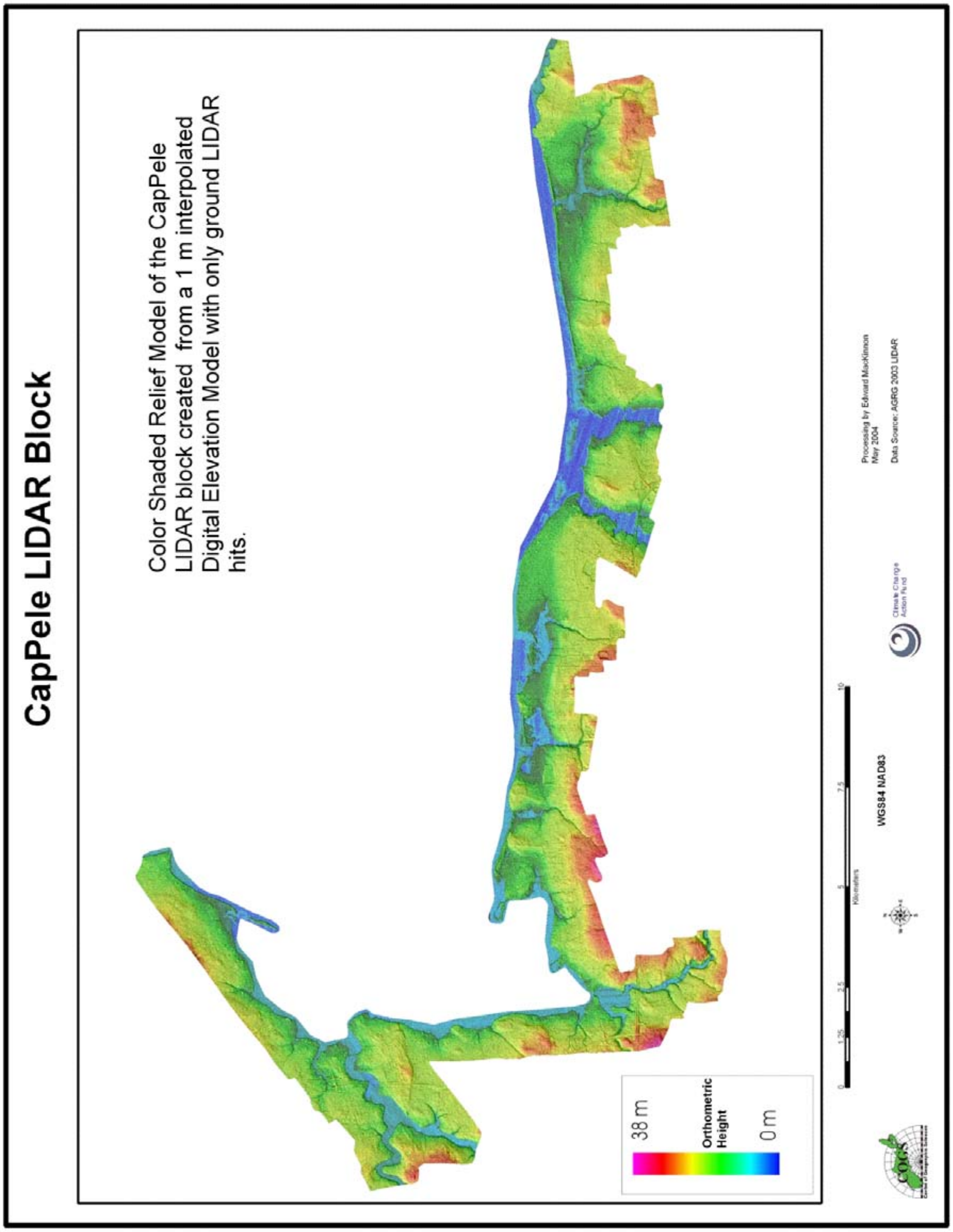


Figure 58 Cap Pele Color Shaded Relief Model of the ground only surface (Image: E. MacKinnon, AGRG 2004).

Appendix G – All-hits CSR Models

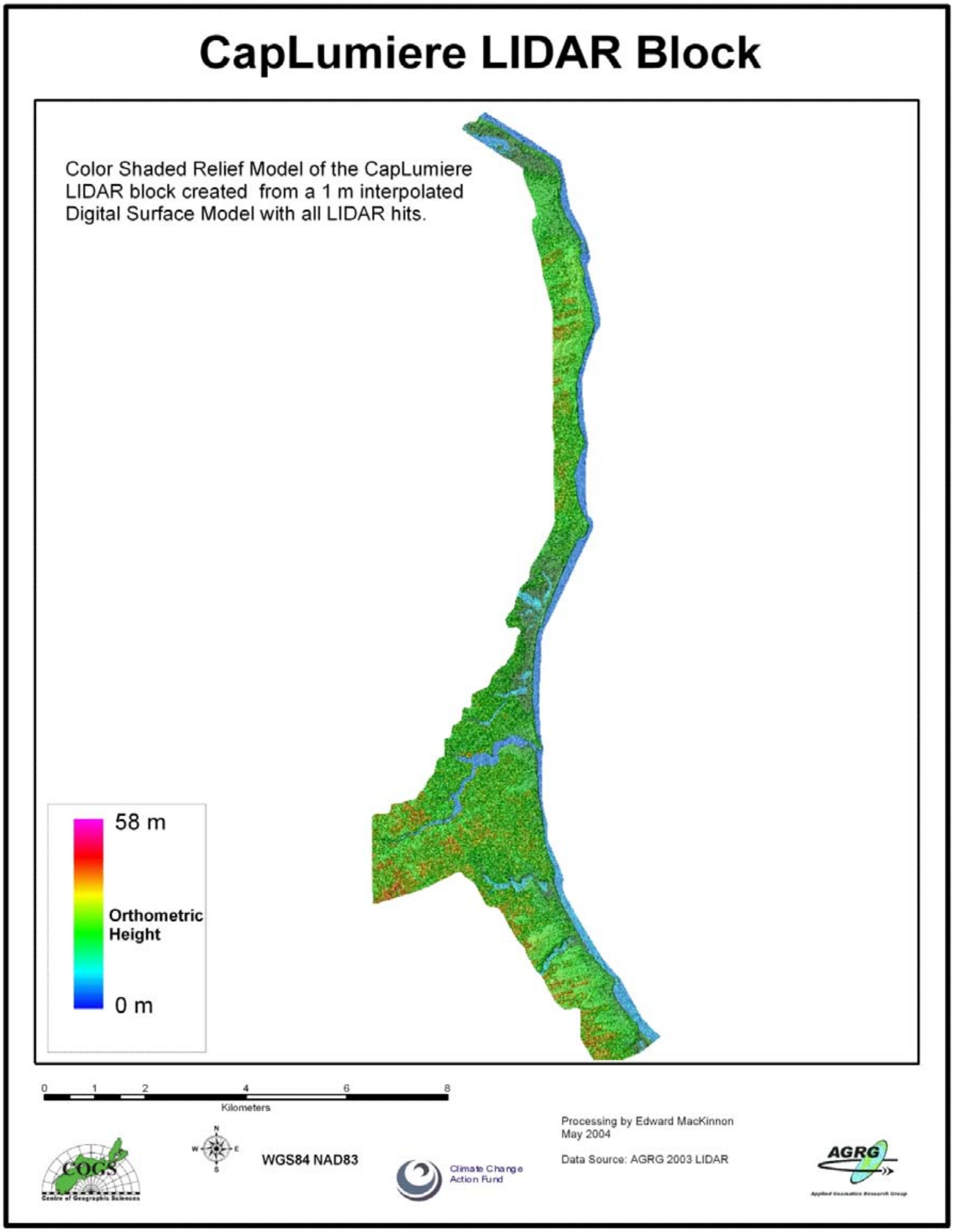


Figure 59 Cormierville Color Shaded Relief Model of the all hits LIDAR surface (Image: E. MacKinnon, AGRG 2004).

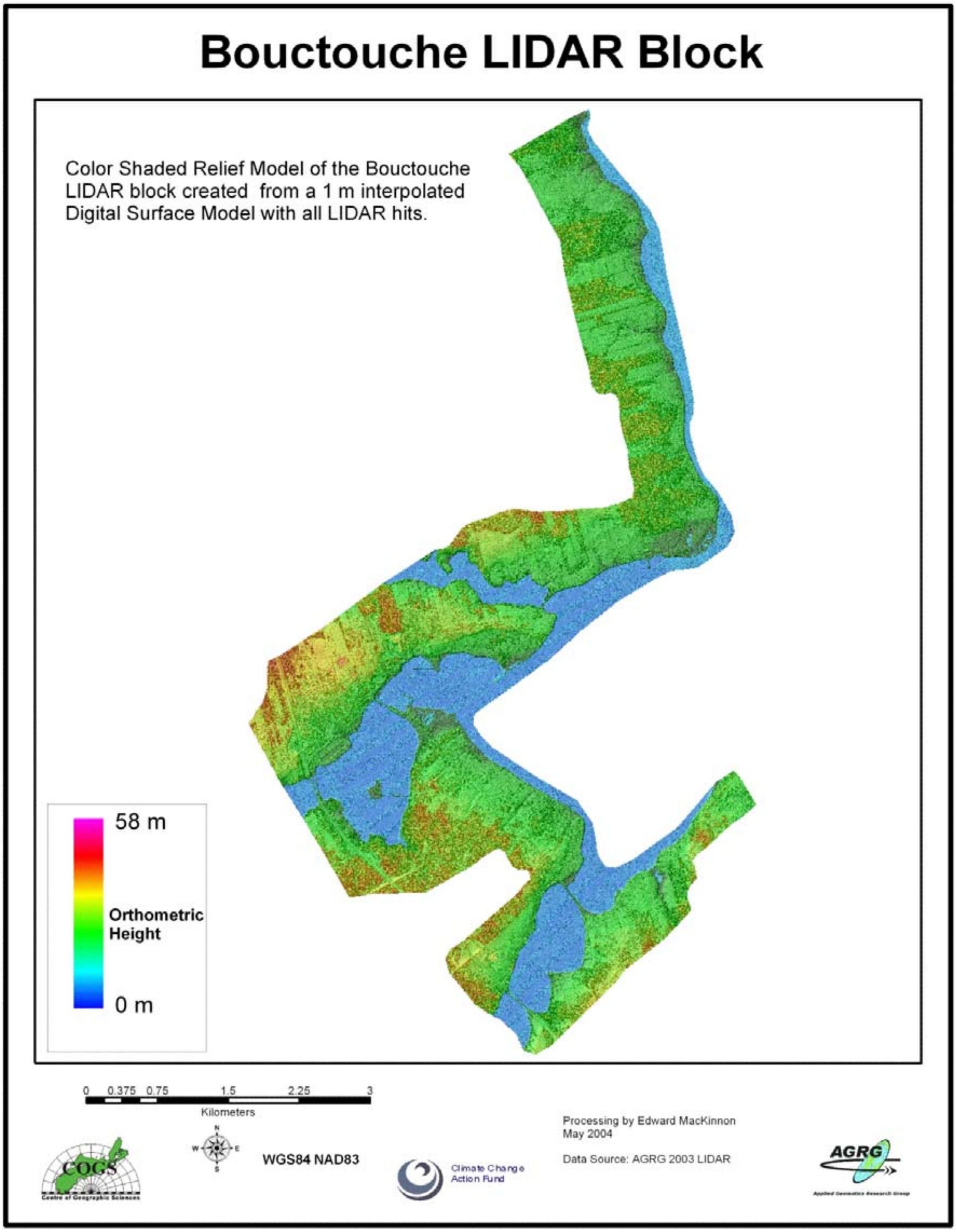


Figure 60 Bouctouche Color Shaded Relief Model of the all hits LIDAR surface (Image: E. MacKinnon, AGRG 2004).

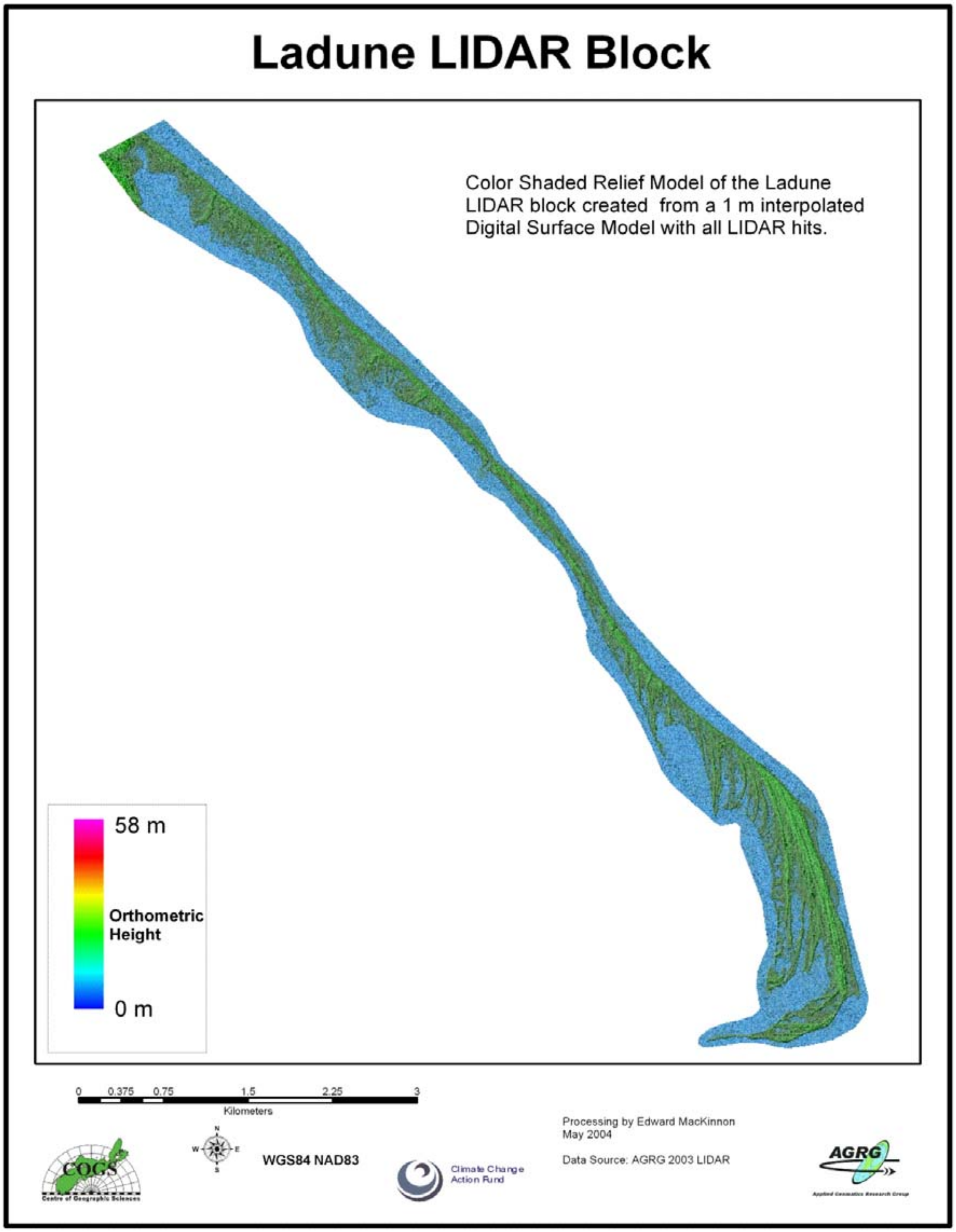


Figure 61 La Dune Color Shaded Relief Model of the all hits LIDAR surface (Image: E. MacKinnon, AGRG 2004).

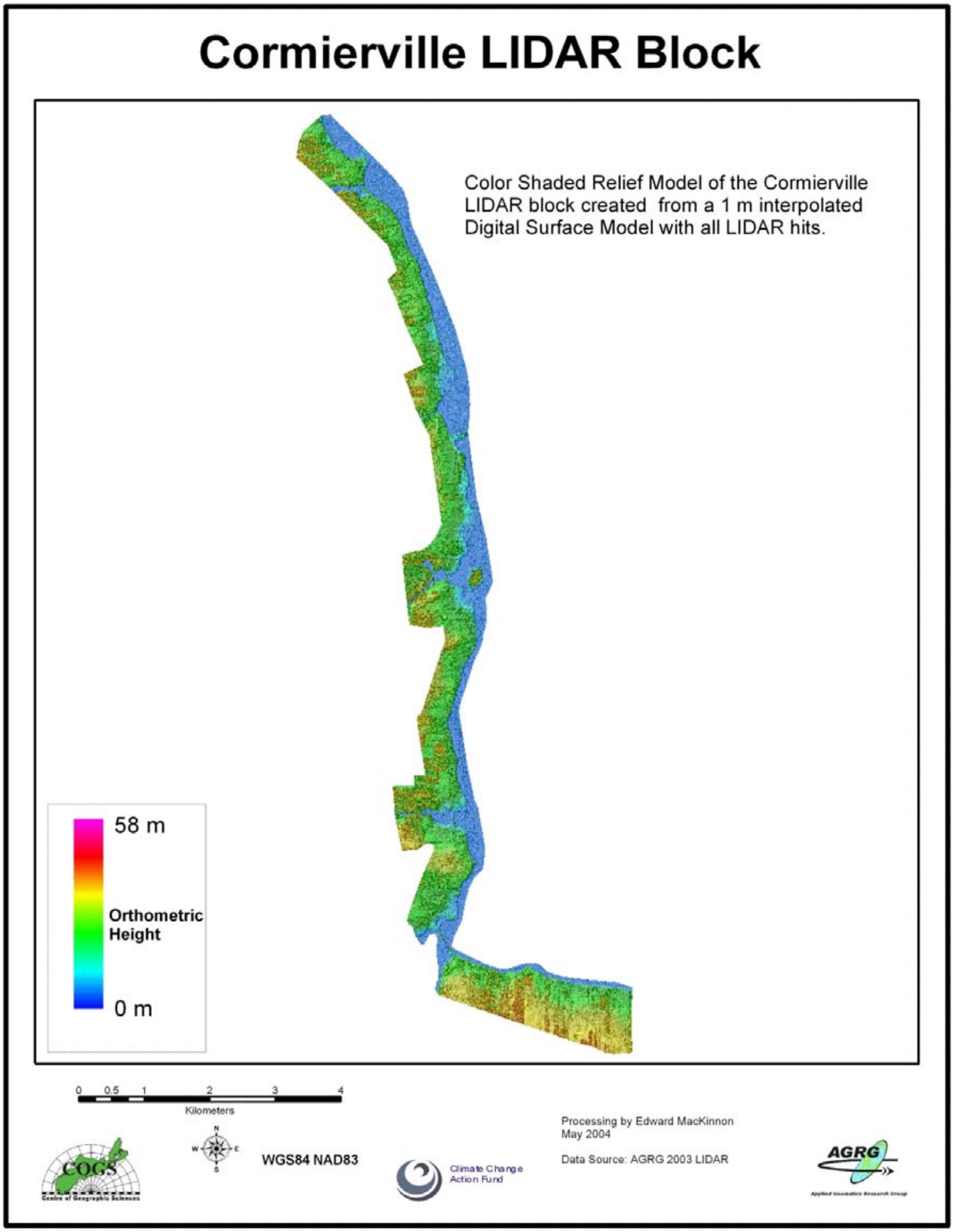


Figure 62 Cormierville Color Shaded Relief Model of the all hits LIDAR surface (Image: E. MacKinnon, AGRG 2004).

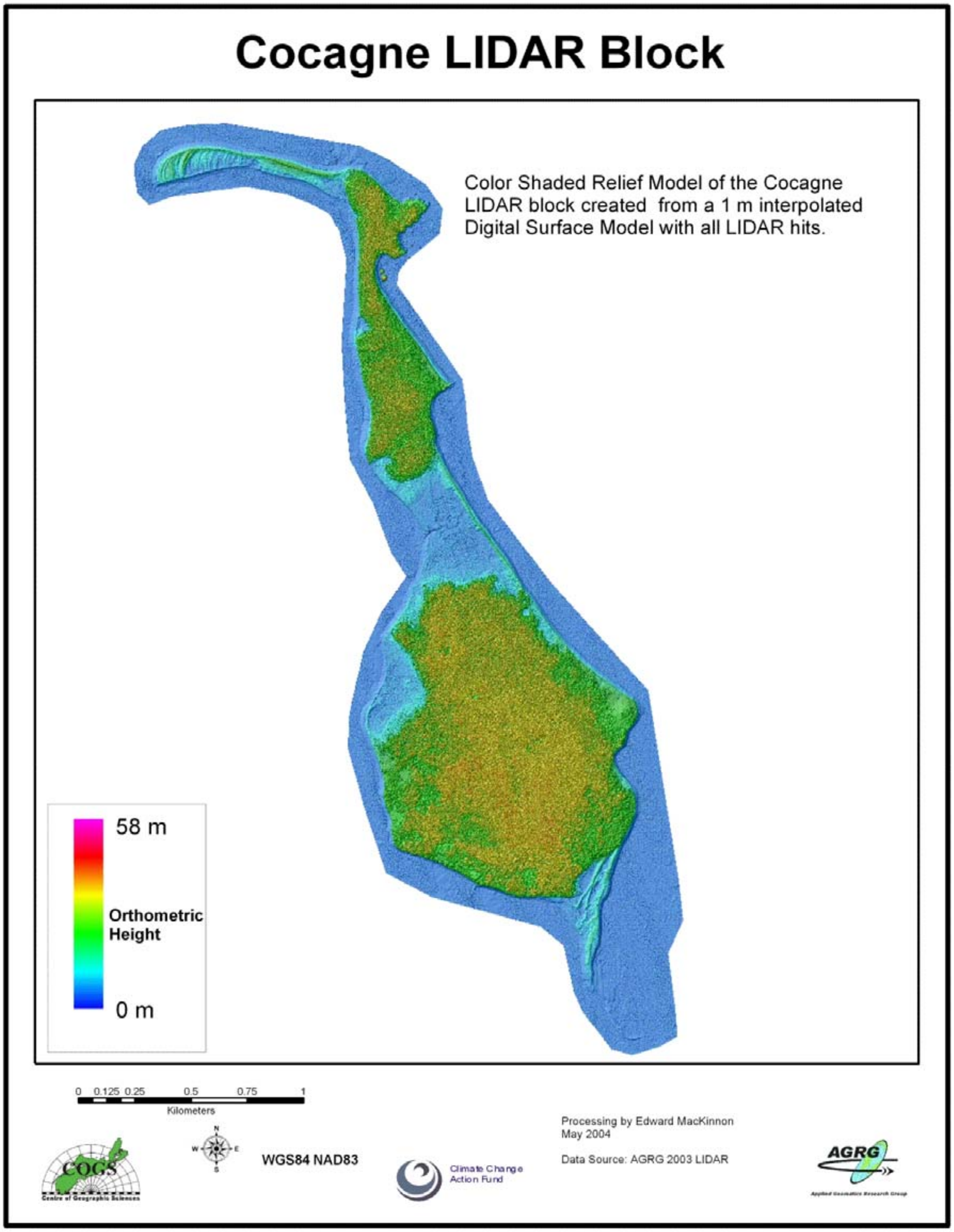


Figure 63 Cocagne Color Shaded Relief Model of the all hits LIDAR surface (Image: E. MacKinnon, AGRG 2004).

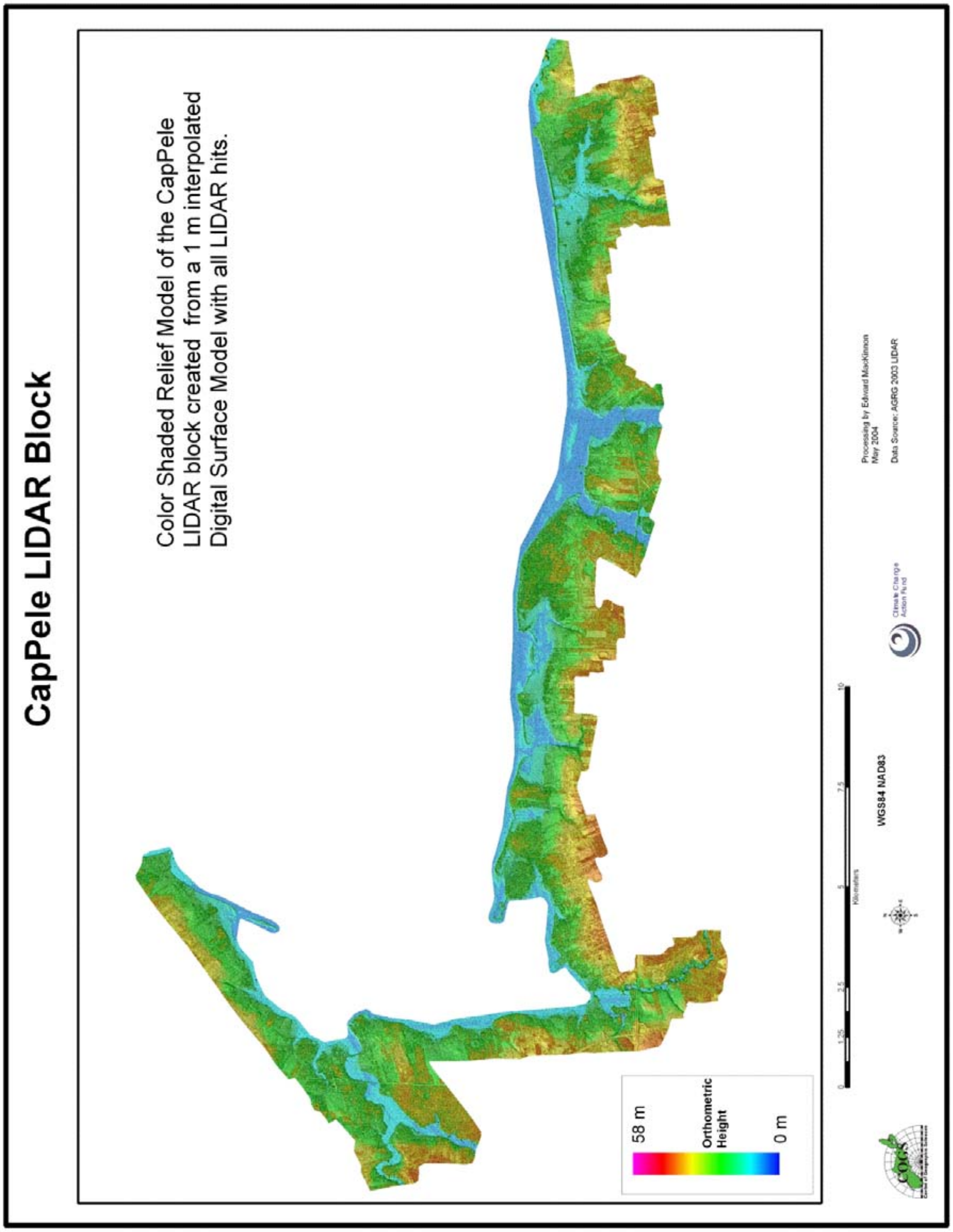


Figure 64 Cap Pele Color Shaded Relief Model of the all hits LIDAR surface (Image: E. MacKinnon, AGRG 2004).

Appendix H – GPS Data Collection Coverage Maps

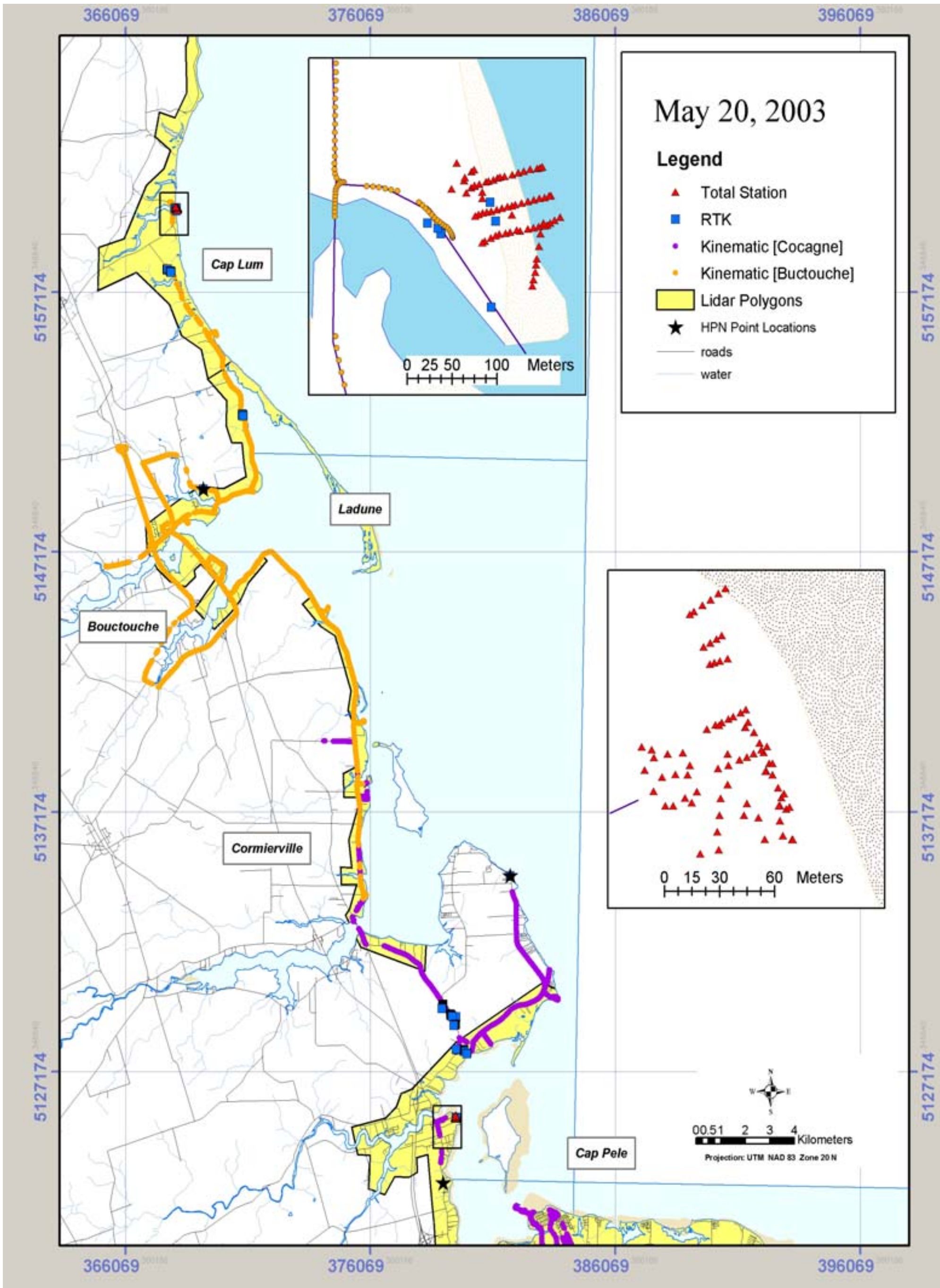


Figure 65 This map of the Bouctouche, Cap Lumiere and Cormierville areas spatially demonstrates how extensive the coverage of GPS field data collection was. The coloured lines are actually coloured points representing individual GPS measurements that are so abundant that at this scale they appear as a solid line. The inset images contain a series of transects across beach dunes that were collected with the Leica Total Station. The top inset is located near Saint Edward de Kent and the bottom one is located at Indian Point (Image: E. MacKinnon, AGRG 2003).

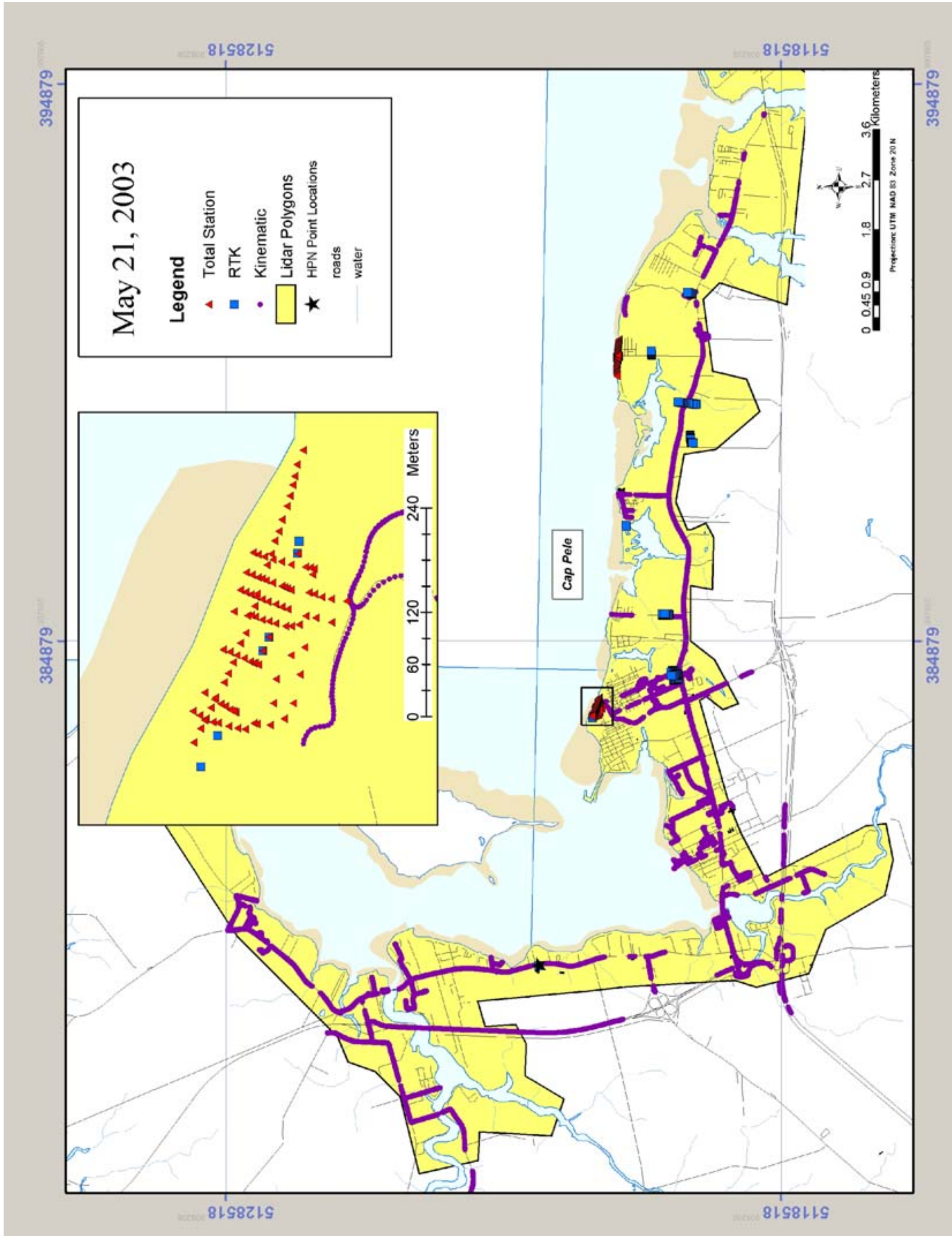


Figure 66 GPS data coverage for the eastern part of the Cap Pele LIDAR Block. The inset image represents data collected with the Leica Total Station at Parlee Beach Provincial Park (Image: E. MacKinnon, AGRG 2003).

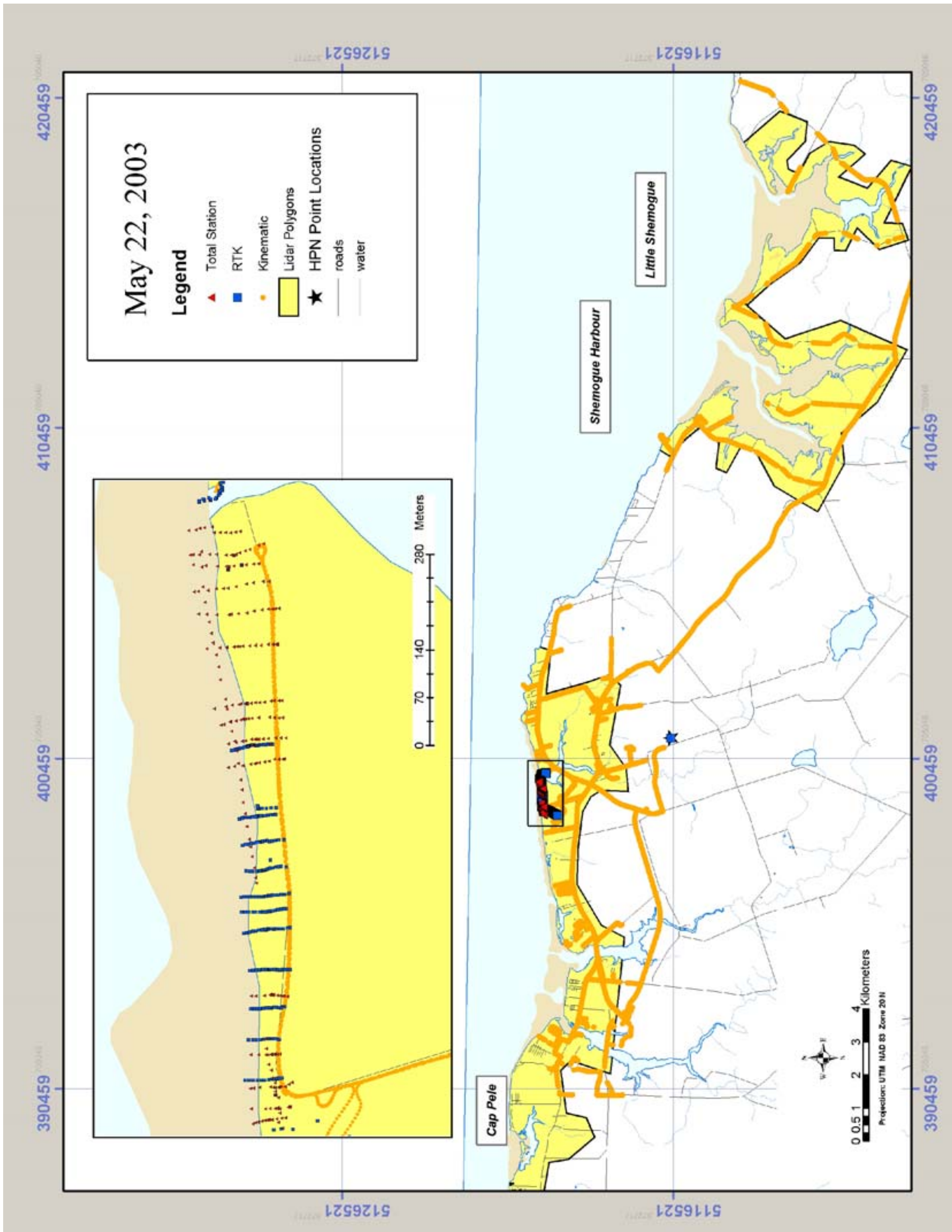


Figure 67 GPS data coverage for the western part of the Cap Pele LIDAR Block and the two Shemogue LIDAR Blocks (Image: E. MacKinnon, AGRG 2003).

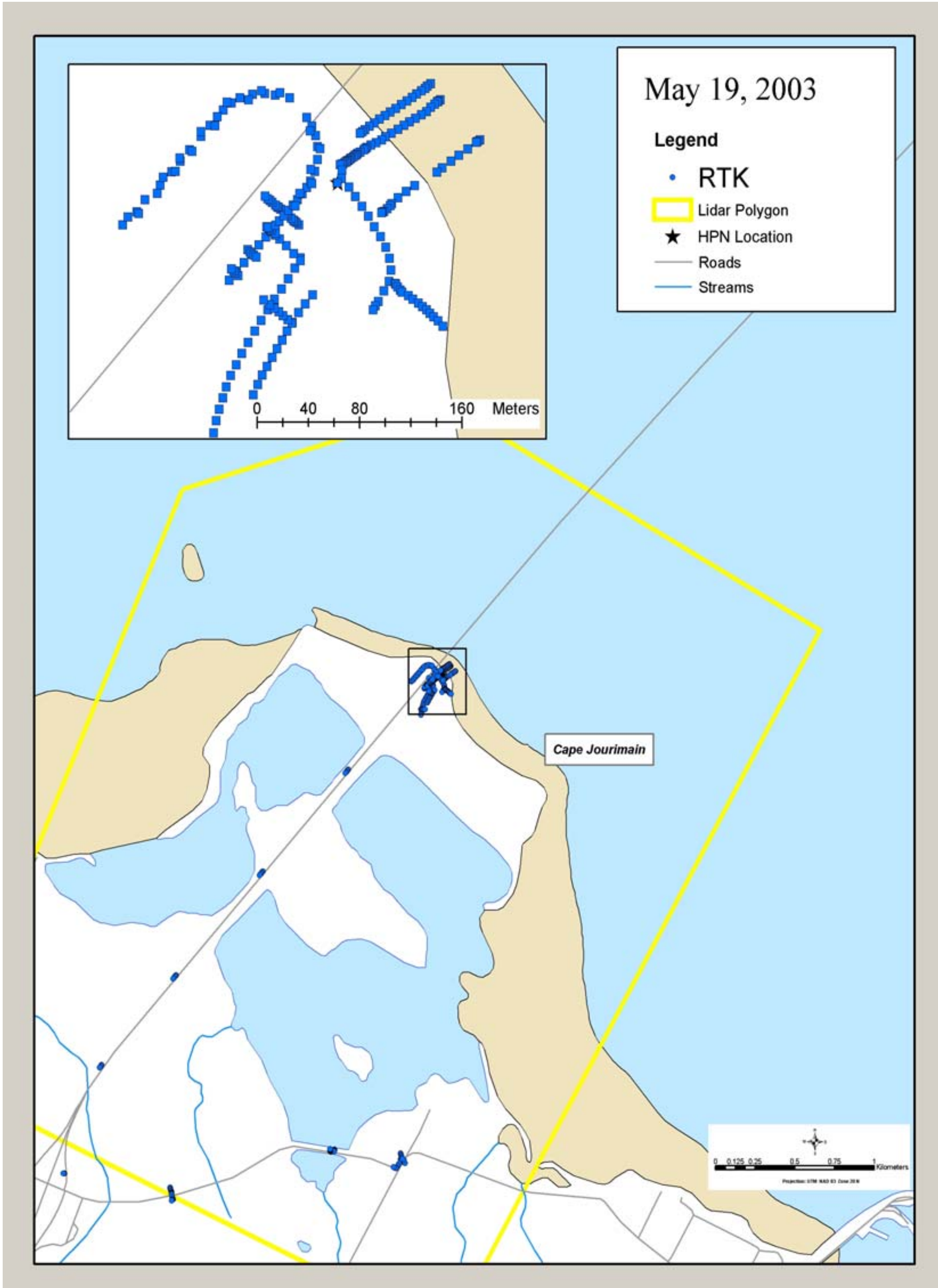


Figure 68 GPS data coverage for the Cape Jourimain LIDAR Block (Image: E. MacKinnon, AGRG 2003).

Appendix I – AML Scripts for Validating LIDAR points

```
/***********************************************************************
/* Program: TOOL1.AML
/* Purpose: run PREP.AML, which compares the quality of LIDAR ground hits to
/* high-precision GPS points.  Then run CALC_FREQ.AML, which creates a histogram
/* of the differences in recorded elevation between the GPS and LIDAR.
/*
/* Globals: .pass_dat - name of final output data file passed  from PREP.AML
/*          .pass_sta - name of final output statistics to passed from PREP.AML
/*
/* Calls: PREP.AML, CALC_FREQ.AML
/*
/* Created by: George Dias October 1, 2001
/***********************************************************************

/* turn messages and echo on for debugging purposes
&messages &on
&echo &on
&terminal 9999


/* set the AML and MENU paths to subdirectories
&amlpath aml
&menupath menu

/* run the AMLs
&r prep.aml
&r calc_freq.aml %.pass_dat% %.pass_sta%

/* delete global variables before exiting
&delvar .*

/* turn echo off, make sure messages are on
&echo &off
&messages &on
```

```
/*****************************************************************************************************
/* Program: PREP.AML
/* Purpose: compare the quality of LIDAR ground hits to high-precision GPS points
/*
/* Routines: MENUS - display menus for user input
/*         NEWDATA - merge multiple LIDAR coverages into one
/*         ANALYSIS - calculate differences between GPS and LIDAR
/*         SUMMARY - return a list of all output to user
/*
/* Globals: .gps_pnts - name of GPS point coverage
/*         .process - name of workspace of LIDAR coverages
/*         .save - name of directory to save output to
/*         .pass_dat - name of final output data file to pass on to graphing AML
/*         .pass_sta - name of final output statistics to pass on to graphing AML
/*
/* Calls: GETCOVER.AML, GETDIRECTORY.AML, GETWORKSPACE.AML, GPSELEV.MENU, HITELEV.MENU,
/*       NEWDIR.MENU, OLDNEWDIR.MENU, OUTPUT.MENU, RADIUS.MENU
/*
/* Created by: George Dias October 1, 2001
/*****************************************************************************************************

/*************************************************************************
/*
/* These are the calls to the routines and a bailout of this app if 'cancel' is ever pressed.
/*
/*************************************************************************

&s p1 = .FALSE.
&s p2 = .FALSE.
&s p3 = .FALSE.

&call menus
&if %p1% = .FALSE. &then
 &return

&call newdata
&if %p2% = .FALSE. &then
 &return

&call analyse
&if %p3% = .FALSE. &then
 &return

&call summary
&if %p4% = .FALSE. &then
 &return

/*set global variables to return to calling aml & return
&s .pass_dat = %.save%/pntdist%radname%.dat
&s .pass_sta = %.save%/pntstats%radname%.dat
&return

/*************************
/* This section runs the menus.
/*************************
&routine menus

/* run this to set the gps coverage and the search radius
/* I don't understand what varname is for...
&r getcover init .gps_pnts * point # 'Select Control Point coverage'
&if [null %.gps_pnts%] &then
 &return

/* extract the name of the coverage (without path) to use for the relate later\
/* either loop to a '/' or a '\' depending on OS
&if [extract 1 [show &os]] = Windows_NT &then
 &do
  &s gpscovname [after %.gps_pnts% \]
  &do &until [index %gpscovname% \] = 0
   &s gpscovname [after %gpscovname% \]
```

```
    &end
  &end
&else
  &do
    &s gpscovname [after %.gps_pnts% /]
    &do &until [index %gpscovname% /] = 0
      &s gpscovname [after %gpscovname% /]
    &end
  &end

/* get the name of the elevation field
&menu gpselev.menu &position &cc &screen &cc &stripe 'Select Elevation Field'
&if [null %gpselev%] &then
  &return

/* get the search radius
&menu radius.menu &position &cc &screen &cc &stripe 'Search Radius'
&if [null %radius%] &then
  &return

/* extract the radius without decimal to use as file suffix
&s radname [unquote [before %radius% .]][unquote [after [trim %radius% -right 0] .]]

/* run this to set the workspace with all the coverages
&r getworkspace init .process * # 'Select workspace where coverages to be processed are'
&if [null %.process%] &then
  &return

/* run this to set the directory where things will get saved and processed
&s choosedir = .FALSE.
&do &while %choosedir% = .FALSE.
  &menu oldnewdir.menu &position &cc &screen &cc &stripe 'Old or new directory?'
  &if [null %oldnew%] &then
    &return

  &if %oldnew% = 'old' &then
    &do
      &r getdirectory init .save * # 'Select directory where new coverages & INFO files will be saved to'
      &if ^ [null %.save%] &then
        &s choosedir = .TRUE.
    &end

  &if %oldnew% = 'new' &then
    &do
      &r getdirectory init .save * # 'Select directory that new directory will be created in'
      &if ^ [null %.save%] &then
        &do
          &menu newdir.menu &position &cc &screen &cc &stripe 'Name of new directory'
          &if ^ [null %newdir%] &then
            &do
              &s choosedir = .TRUE.
              &s .save = %.save%/%newdir%
              createworkspace %.save%
            &end
        &end
    &end
&end

/* next create a list of all point coverages in the workspace
&type [listfile %.process%/ -cover -point %.save%/toclip%radname%.dat]
&s listopen = [open %.save%/toclip%radname%.dat openstatus -read]
&s name = [read %listopen% readstat]

/* get the name of the elevation field
&s hitcov = %.process%/%name%
&menu hitelev.menu &position &cc &screen &cc &stripe 'Select Elevation Field'
&if [null %hitelev%] &then
  &return

/* set part1 as successfully completed and return to calls
```

```
&set p1 = .true.
&return

/**********************************************************************
/* This section creates the new clipcoverage & clips all files to be clipped.
/* The clipped coverages are then merged into one coverage to be used for the analysis.
/**********************************************************************

&routine newdata

'first buffer the validation points
&if ^ [exists %.save%/clipcov%radname% -cover] = .true. &then
  buffer %.gps_pnts% %.save%/clipcov%radname% # # %radius% 0.99814803 point

/* clip all the point coverages and save in directory specified by user
&do &while %readstat% = 0
  &if %.process%/%name% <> %.gps_pnts% &then
    &do
      &if [exists %.save%/%name%%radname% -cover] = .false. &then
        clip %.process%/%name% %.save%/clipcov%radname% %.save%/%name%%radname% point
    &end
  &s name = [read %listopen% readstat]
&end

/* now create a list of new clipped point coverages
/* kill these 2 covers first so they don't get added to the list
&if [exists %.save%/mrg_pnts%radname% -cover] = .true. &then
  kill %.save%/mrg_pnts%radname% all
&if [exists %.save%/results%radname%tmp -cover] = .TRUE. &then
  kill %.save%/results%radname%tmp all
&if [exists %.save%/results%radname% -cover] = .TRUE. &then
  kill %.save%/results%radname% all
&type [listfile %.save%'/'*%radname% -cover -point %.save%/toappend%radname%.dat]

&s listopen = [open %.save%/toappend%radname%.dat openstatus -read]
&s name = [read %listopen% readstat]

/* append all these coverages together
append %.save%/mrg_pnts%radname% point
  &do &while %readstat% = 0
    %.save%/%name%
    &s name = [read %listopen% readstat]
  &end
end

/* set part2 as successfully completed and return to calls
&set p2 = .true.
&return

/**********************************************************************
/* This section creates the table joining each control point to the points to be checked
/* within the user-defined search radius.  Summary statistics and control-point-specific
/* statistics are then calculated.  Finally, a copy of the control point coverage is created
/* with the new case-specific statistics attached.
/**********************************************************************

&routine analyse

/* run pointdistance to "join" the gps points with their associated ground hits
&if [exists %.save%/pntdist%radname%.dat -info] = .TRUE. &then
  killinfo %.save%/pntdist%radname%.dat
pointdistance %.save%/mrg_pnts%radname% %.gps_pnts% %.save%/pntdist%radname%.dat %radius%

/* link the attribute tables to the pntdist table for statistical comparison
relate add gps %.gps_pnts%.pat info %gpscovname%# %gpscovname%# link rw
relate add hits %.save%/mrg_pnts%radname%.pat info mrg_pnts%radname%# mrg_pnts%radname%# link rw
relate save %.save%/relations%radname%.dat

/* add gps_elv and elev_diff field to pntdist.dat
/* gps_elev is the original elevation, elev_diff is the gps_elevation minus the compared elevation
```

```
&s wksp = [show &workspace]
workspace %.save%
tables
  select pntdist%radname%.dat
  additem pntdist%radname%.dat gps_elev 8 8 F 3
  additem pntdist%radname%.dat elev_diff 8 8 F 3
  calc gps_elev = gps//%gpselev%
  calc elev_diff = gps//%gpselev% - hits//%hitelev%
quit
workspace %wksp%

/* calculate summary statistics
&if [exists %.save%/pntstats%radname%.dat -info] = .TRUE. &then
  killinfo %.save%/pntstats%radname%.dat
statistics %.save%/pntdist%radname%.dat %.save%/pntstats%radname%.dat
  min elev_diff
  max elev_diff
  mean elev_diff
  std elev_diff
end

/* calculate statistics for each control point
&if [exists %.save%/pntstats%radname%gr.dat -info] = .TRUE. &then
  killinfo %.save%/pntstats%radname%gr.dat
statistics %.save%/pntdist%radname%.dat %.save%/pntstats%radname%gr.dat %gpscovname%#
  mean gps_elev
  min elev_diff
  max elev_diff
  mean elev_diff
  std elev_diff
end

/* create a copy of the gps coverage in the working directory and attach stats
/* rename mean-elev_diff to gps_elevation and the id# for joinitem to work
copy %.gps_pnts% %.save%/results%radname%tmp
workspace %.save%
tables
  select pntstats%radname%gr.dat
  alter %gpscovname%#, results%radname%tmp#,,,,
  alter mean-gps_elev, gps_elevation,,,,,
quit
workspace %wksp%

joinitem %.save%/results%radname%tmp.pat %.save%/pntstats%radname%gr.dat %.save%/results%radname%tmp.pat
results%radname%tmp#

/* get rid of all the features with no stats (and thus no related points ie, ground hits)
&if [exists %.save%/results%radname% -cover] = .TRUE. &then
  kill %.save%/results%radname% all
reselect %.save%/results%radname%tmp %.save%/results%radname% point
  reselect frequency > 0
  ~
  no
  no
kill %.save%/results%radname%tmp all

/* kill the relations file - it's useless to keep around
&if [exists %.save%/relations%radname%.dat -info] = .TRUE. &then
  killinfo %.save%/relations%radname%.dat

/* set part3 as successfully completed and return to calls
&set p3 = .true.
&return

/*********************************************************************
/* This section displays a summary list of all new files created during this process
/*********************************************************************

&routine summary
```

```
/* these are the variables that will are displayed in the output form
/* either loop to a '/' or a '\' depending on OS
&if [extract 1 [show &os]] = Windows_NT &then
  &do
    &s buff [after %.save%/clipcov%radname% \]
    &do &until [index %buff% \] = 0
      &s buff [after %buff% \]
    &end

    &s merg [after %.save%/mrg_pnts%radname% \]
    &do &until [index %merg% \] = 0
      &s merg [after %merg% \]
    &end

    &s resu [after %.save%/results%radname% \]
    &do &until [index %resu% \] = 0
      &s resu [after %resu% \]
    &end
  &end
&else
  &do
    &s buff [after %.save%/clipcov%radname% /]
    &do &until [index %buff% /] = 0
      &s buff [after %buff% /]
    &end

    &s merg [after %.save%/mrg_pnts%radname% /]
    &do &until [index %merg% /] = 0
      &s merg [after %merg% /]
    &end

    &s resu [after %.save%/results%radname% /]
    &do &until [index %resu% /] = 0
      &s resu [after %resu% /]
    &end
  &end

&s pdis = pntdist%radname%.dat
&s psta = pntstats%radname%.dat
&s pstg = pntstats%radname%gr.dat

&menu output.menu &position &cc &screen &cc &stripe 'Output' &size 750 550

/* delete the lists of files to clip and append
&if [exists toclip%radname%.dat -file] = .TRUE. &then
  &type [delete toclip%radname%.dat -file]
&if [exists toappend%radname%.dat -file] = .TRUE. &then
  &type [delete toappend%radname%.dat -file]

/* set part4 as successfully completed and return to calls
&set p4 = .true.
&return
```

```
/*-----------------------------------------------------------------------------------------------------------
/* Calc_freq.aml
/* Lisa Markham & Dan Deneau, September 2001
/*
/* This AML uses these already calculated stats (mean,std_dev,min,max)
/* in an info table to determine the number of records in each quarter of the first standard
/* deviation; until the min or max of the record set is reached,
/* then calls a graph aml that displays the frequency of points vs elevation difference.
/*
/*Assumes that a point_distance and pntsstats dat files have been created.
/*USAGE: &r calc_freq.aml <pnt_dist_table> <pnt_stats_table>
/*-----------------------------------------------------------------------------------------------------------
/*SETS ARGUEMENTS
&arg pntdist pntsstats


/*Sets the display device
&terminal 9999

/*IF NOT AT THE ARC PROMPT, THEN QUIT
&if [show program] <> ARC &then; quit

/*IF A FREQUENCY ITEM WITHIN THE INFO TABLE EXISTS, THEN DROP THE ITEM
&if [iteminfo %pntdist% -info freq -exists] &then
   dropitem %pntdist% %pntdist% freq

/* ADDS A FREQUENCY ITEM CALLED "FREQ"
additem %pntdist% %pntdist% freq 12 12 N

/*SETS DISPLAY CONFIG
display 0

/*ENTERS ARCPLOT
ap

/*SELECTS ALL VALUES (FROM THE STATS VALUE TABLE) WITH A MEAN ELEVATION DIFFERENCE
/*OF GREATER THAN ZERO
reselect %pntsstats% info mean-elev_diff > -9999

/*DEFINES VARIABLES FOR THE MEAN, STANDARD DEVIATION, MIN, AND MAX VALUES; USING
/*THE STATS INFO TABLE
&s mean = [show select %pntsstats% info 1 item mean-elev_diff]
&s std = [show select %pntsstats% info 1 item std-elev_diff]
&s min = [show select %pntsstats% info 1 item min-elev_diff]
&s max = [show select %pntsstats% info 1 item max-elev_diff]
clearselect

/*DISPLAYS A MENU REQUESTING USER INPUT FOR THE PERCENTAGE OF THE STANDARD
/*DEVIATION TO BE CONTAINED WITHIN EACH BAR IN THE HISTOGRAM
&menu divide.menu &stripe 'Specify Percentage of Standard Deviation'
&s divide = [calc %divide% / 100]

/*DEFINES MATHEMATICAL OPERATORS FOR USE WITH THE "SUBSTRA" COMMAND
/*STARTS A LOOP FOR CALCULATING THE BARS IN THE HISTOGRAM...
&do sgn &list +><=, -<>=

/*SETTING THE "FLAG" VARIABLE...TO CONTINUE LOOPING WHILE IT IS GO; THE
/*FLAG VARIABLE WILL BE SET TO "STOP" WHEN THE MIN AND MAX HAVE BEEN REACHED
   &s flag = GO

/*I IS A COUNTER, INCREMENTS BY .25
   &s i = 0

/*SETTING A VARIABLE "SPLIT0" TO EQUAL THE MEAN (ABOVE)
   &s split0 = %mean%

/*USING A DO LOOP TO CALCULATE THE SECTIONS IN THE HISTOGRAM
/*THE LOOP WILL CONTINUE UNTIL "FLAG" (DEFINED ABOVE) IS EQUAL TO "STOP"
   &do &until %flag% = STOP
```

```
/*SETS THE "i" VARIABLE TO INCREMENT BY .25 EVERY TIME IT LOOPS
/*THE .25 IS THE NUMBER USED TO MULTIPLY BY THE STANDARD DEVIATION IN
/*THE FORMULA BELOW
    &s i = %i% + %divide%
    clearselect

/*THE FORMULA USED TO CALCULATE THE EACH QUARTER OF THE STANDARD DEVIATION
/*TO EMULATE A HISTOGRAM IS: MEAN +/- I * (STD_DEV) ; WHERE I IS A VARIABLE
/*THAT INCREMENTS BY .25 EVERY TIME UNTIL THE MIN AND MAX ARE REACHED
/*THE PLUS SIGN IS USED TO CALCULATE THE BARS TO THE RIGHT OF THE MEAN,
/*WHILE THE MINUS IS USED TO CALCULATE BELOW THE MEAN

/*THE "SPLIT1" VARIABLE REPRESENTS THE RESULT OF THE ABOVE FORMULA...WHICH GIVES
/*THE BREAKLINE OF EACH BAR IN THE HISTOGRAM
    &s split1 = [calc %mean% [substr %sgn% 1 1] [calc %i% * %std%]]

/*RESELECTS RECORDS THAT ARE GREATER THAN THE MEAN (SPLIT0), THEN RESELECTS
/*WITHIN THOSE...THE RECORDS THAT ARE LESS THAN "SPLIT1" (THE OUTCOME OF THE
/*FORMULA)...THIS GIVES THE FIRST BAR TO THE RIGHT OF THE MEAN (LOOP CONTINUES)
    reselect %pntdist% info elev_diff [substr %sgn% 2 1] %split0%
    reselect %pntdist% info elev_diff [substr %sgn% 3 2] %split1%

/*SETS A VARIABLE "RECNUM" TO EQUAL THE NUMBER OF RECORDS SELECTED
    &s recnum = [before [show select %pntdist% info] ,]

/*CALCULATES THE NUMBER OF RECORDS SELECTED INTO THE "FREQ" ITEM IN THE INFO TABLE
    calc %pntdist% info freq = %recnum%

/*IF THE LOOP HAS REACHED THE MIN OR MAX OF THE RECORDS...THEN SET THE FLAG VARIABLE
/*TO "STOP"
    &if %split1% <= %min% | %split1% >= %max% &then
      &s flag = STOP

/*SETS THE SPLIT0 ITEM TO EQUAL SPLIT ONE...THE FIRST (OR NEXT) BREAKLINE IN THE HISTOGRAM
/*SO THAT THE LOOP CAN CONTINUE USING THE SAME VARIABLE NAMES
    &s split0 = %split1%
  &end
&end

/*RESELECTING ALL RECORDS IN THE INFO TABLE TO EXTRACT THE TOTAL # OF RECORDS
/*THIS NUMBER WILL BE USED IN THE GRAPH, FOR DISPLAY
reselect %pntdist% info
&s recnum2 = [after [show select %pntdist% info] ,]

/*CALLS FOR A GRAPH AML TO RUN...TO DISPLAY THE RESULTS OF THE FREQUENCY,
/*IN A BAR GRAPH (HISTOGRAM)
&r graph.aml %pntdist% elev_diff freq %divide% %recnum2% %mean% %std%


&return
```

```
/*-----------------------------------------------------------------------------
/*          Environmental Systems Research Institute, Inc.
/*-----------------------------------------------------------------------------
/*   Program: GETCOVER.AML
/*   Purpose: Browse the file system to select a coverage
/*
/*-----------------------------------------------------------------------------
/*    Usage: GETCOVER INIT <return_var> {wildcard} {coverage_type}
/*                    {'position'} {'stripe'}
/*
/* Arguments: return_var    - name of the variable to receive the value
/*                     returned from the menu
/*          wildcard      - the string (filter) for listing file names
/*                     defaults to '*'
/*          coverage_type - coverage type to list
/*          position      - (quoted string) opening menu position.
/*          stripe        - (quoted string) menu stripe displayed.
/*
/*  Routines:
/*          BAILOUT - error handling.
/*          EXIT - cleanup and exit tool.
/*          HELP - display tool help file.
/*          INIT - initialize tool and invoke menu.
/*          USAGE - return tool usage.
/*
/*   Globals:
/*-----------------------------------------------------------------------------
/*    Calls: get_routines.aml getcover.menu disp_help.aml
/*-----------------------------------------------------------------------------
/*    Notes: This tool is always modal
/*-----------------------------------------------------------------------------
/*   History: Matt McGrath - 02/06/92 - Original coding
/*          Matt McGrath - 11/21/92 - Added ability to save previous path
/*          Matt McGrath - 07/06/93 - replace modal.aml with &modal,
/*                   update EXIT routine
/*          Mark D Zollinger - 10/10/94 - centralize routines in get_routines
/*                              and make VMS compatible
/*==============================================================================

&args routine arglist:rest
&severity &error &routine bailout

/* Check arguments
&if ^ [null %routine%] &then
  &call %routine%
&else
  &call usage
&return

&routine INIT   /*  <varname> {wildcard} {type} {'position'} {'stripe'}
/* Initialize tool interface

&set varname  = [extract 1 [unquote %arglist%]]
&set wildcard = [extract 2 [unquote %arglist%]]
&set type     = [extract 3 [unquote %arglist%]]
&set position = [extract 4 [unquote %arglist%]]
&set stripe   = [extract 5 [unquote %arglist%]]
&set ct1      = ALL ADDRESS ANNOTATIONS ARC LINE LINK NETWORK NODE
&set ct2      = POINT POLYGON TIC REGION ROUTE SECTION
&set covtypes = %ct1% %ct2%
&set type = [before [upcase %type%] .]
&if [null %type%] or %type%_ = #_ &then
   &set type = ALL
&if [keyword %type% %covtypes% ] = 0 &then
&do
   &type Coverage type must be one of the following:
   &type %covtypes%
   &type
   &call usage
&end
```

```
&if [null %varname%] &then
   &call usage
&set .getcover$varname = %varname%
&if [null %wildcard%] or %wildcard%_ = #_ &then
   &set .getcover$wildcard = *
&else
   &set .getcover$wildcard = %wildcard%
&if [null %position%] or %position%_ = #_ &then
  &set position = &cc &screen &cc
&if [null %stripe%] or %stripe%_ = #_ &then
  &set stripe = Select a Coverage - Type: %type%

/* set return variable to null, in case the tool crashes
&set [value .getcover$varname] =

/* Current directory
/* Set path to previous one if this tool has already been used
&if not [variable .arctools$get_savepath] &then
  &set .arctools$get_savepath
&if [null %.arctools$get_savepath%] &then
  &set .getcover$curdir = [show &workspace]
&else &set .getcover$curdir = %.arctools$get_savepath%
&run get_routines curdir .getcover

/* Issue thread delete self if thread depth = 2 and input is tty
&if [show &thread &depth] = 2 and [extract 1 [show &thread &stack]] = tty &then
  &set launch = &thread &delete &self
&else
  &set launch

&if [show &thread &exists tool$getcover] &then
   &thread &delete tool$getcover
&thread &create tool$getcover &modal ~
  &menu getcover ~
  &position [unquote %position%] ~
  &stripe [quote [unquote %stripe%]] ~
  &pinaction '&run getcover exit'
%launch%
&return

&routine UP
/* This routine is never called by the current version of the tool.
/* It is left here for backwards compatibility with the 7.0.2 menu.
&run get_routines up .getcover
&return

&routine CURDIR
/* This routine is never called by the current version of the tool.
/* It is left here for backwards compatibility with the 7.0.2 menu.
&run get_routines curdir .getcover
&return

&routine SUBDIR
/* This routine is never called by the current version of the tool.
/* It is left here for backwards compatibility with the 7.0.2 menu.
&run get_routines subdir .getcover
&return

&routine HELP
/* Display help for this tool
&run disp_help getcover
&return

&routine USAGE
/* Display usage for this tool
&type Usage: GETCOVER INIT <variable_name> {wildcard} {coverage_type}
&type              {'"position"'} {'"stripe"'}
&return &inform

&routine OK
```

```
/* Quit from menu, cleanup
&set [value .getcover$varname] = %.getcover$cover%
/* Save the path for future use of this tool
&set .arctools$get_savepath = %.getcover$curdir%
&call exit
&return

&routine EXIT
/* Clean up and exit menu
&dv .getcover$*
&if [show &thread &exists tool$getcover] &then
  &thread &delete tool$getcover
&return

&routine BAILOUT
&severity &error &ignore
&return &warning An error has occurred in routine: %routine% (GETCOVER.AML).
```

```
/*--------------------------------------------------------------------------
/*          Environmental Systems Research Institute
/*--------------------------------------------------------------------------
/*   Program: GETDIRECTORY.AML
/*   Purpose: Tool for browsing the file system to select a directory.
/*--------------------------------------------------------------------------
/*    Usage: getdirectory INIT <variable_name> {wildcard} {'position'}
/*                   {'stripe'}
/*    Usage: getdirectory <routine_name>
/*
/* Arguments: routine  - name of the routine to be called.
/*
/*          varname  - name of the variable to receive the value returned
/*                 from the menu - used with the INIT routine
/*          wildcard - the string (wildcard) for listing file names -
/*                 defaults to '*'
/*          position - (quoted string) opening menu position.
/*          stripe   - (quoted string)  menu stripe displayed.
/*
/*   Globals:
/*--------------------------------------------------------------------------
/*    Calls: get_routines.aml
/*--------------------------------------------------------------------------
/*    Notes: If the menu is canceled, the variable that was passed in is
/*          set to null.
/*--------------------------------------------------------------------------
/*   History: Matt McGrath - 02/06/92 - Original coding
/*          Matt McGrath - 11/21/92 - Added ability to save previous path
/*          Matt McGrath - 07/06/93 - replace modal.aml with &modal,
/*                 update EXIT routine
/*          Ian DeMerchant - 11/02/94 - added help routine
/*          Mark D Zollinger - VAXinate.  Centralize routines.
/*==========================================================================
&args routine arglist:rest
&severity &error &routine bailout

/* Check arguments
&if [null  %routine%] &then
 &set routine = init

&call %routine%

&return

&routine USAGE

&type Usage: getdirectory INIT <variable_name> {wildcard} {'''position'''}
&type                   {'''stripe'''}
&type Usage: getdirectory <routine_name>
&return &warning

&routine INIT

/* Display the menu
/* Check arguments that must accompany this routine

&if [null %arglist%] &then &call usage
&set varname  = [extract 1 [unquote %arglist%]]   /* required
&if [null %varname%] &then &call usage
&set wildcard = [extract 2 [unquote %arglist%]]  /* optional
&set position = [extract 3 [unquote %arglist%]]  /* optional
&set stripe   = [extract 4 [unquote %arglist%]]  /* optional
&if [null %position%] OR %position%_ = #_ &then
  &set position = '&cc &screen &cc'
&if [null %stripe%] or %stripe%_ = #_ &then
  &set stripe = 'Select...'

/* Set the name of the variable to receive the value set in the menu
&set .getdirectory$varname = %varname%
```

```
/* Initialize other variables
&if [null %wildcard%] or %wildcard%_ = #_ &then
   &set .getdirectory$wildcard = *
&else
   &set .getdirectory$wildcard = %wildcard%

/* Current directory
/* Set path to previous one if this tool has already been used
&if not [variable .arctools$get_savepath] &then
  &set .arctools$get_savepath
&if [null %.arctools$get_savepath%] &then
  &set .getdirectory$curdir = [show &workspace]
&else &set .getdirectory$curdir = %.arctools$get_savepath%

/* Subdirectories in the current directory
&run get_routines curdir .getdirectory

&if [show &thread &exists tool$getdirectory] &then
  &thread &delete tool$getdirectory
&thread &create tool$getdirectory &modal ~
  &menu getdirectory.menu ~
  &position [unquote %position%] ~
  &stripe [quote [unquote %stripe%]] ~
  &pinaction '&run getdirectory cancel'
&return

&routine CURDIR
&run get_routines curdir .getdirectory
&return

&routine SUBDIR

&run get_routines subdir .getdirectory
&return

&routine UP
&run get_routines up .getdirectory
&return

&routine DIRECTORY
/* Apply selected directory value
&set [value .getdirectory$varname] = %.getdirectory$directory%
&return

&routine OK
&set [value .getdirectory$varname] = %.getdirectory$directory%
/* Save the path for future use of this tool
&set .arctools$get_savepath = %.getdirectory$curdir%
&call exit
&return

&routine CANCEL
&set [value .getdirectory$varname]
&call exit
&return

&routine HELP
&run disp_help getdirectory
&return

&routine EXIT
&dv .getdirectory$*
&if [show &thread &exists tool$getdirectory] &then
  &thread &delete tool$getdirectory
&return

&routine BAILOUT
&severity &error &ignore
&severity &warning &ignore
&return &warning An error has occurred in routine: %routine% (GETDIRECTORY.AML)
```

```
/*------------------------------------------------------------------------
/*          Environmental Systems Research Institute
/*------------------------------------------------------------------------
/*   Program: GETWORKSPACE.AML
/*   Purpose: Tool for browsing the file system to select an ARC/INFO
/*          workspace.
/*------------------------------------------------------------------------
/*    Usage: getworkspace INIT <variable_name> {wildcard} {'position'}
/*                    {'stripe'}
/*    Usage: getworkspace <routine_name>
/*
/* Arguments: routine  - name of the routine to be called.
/*          varname  - name of the variable to receive the value returned
/*                from the menu - used with the INIT routine
/*          wildcard - the string (wildcard) for listing file names -
/*               defaults to '*'
/*          position - (quoted string) opening menu position.
/*          stripe   - (quoted string)  menu stripe displayed.
/*   Globals:
/*------------------------------------------------------------------------
/*    Calls: get_routines, disp_help
/*------------------------------------------------------------------------
/*    Notes: If the menu is canceled, the variable that was passed in is
/*          set to null.
/*------------------------------------------------------------------------
/*   History: Matt McGrath - 02/06/92 - Original coding
/*          Matt McGrath - 11/21/92 - Added ability to save previous path
/*          Matt McGrath - 07/06/93 - replace modal.aml with &modal,
/*                   update EXIT routine
/*          Mark D Zollinger - 20/10/94 - Centralize routines.  Fix VMS
/*========================================================================
&args routine arglist:rest

&severity &error &routine bailout

/* Check arguments
&if [null  %routine%] &then
  &call usage

&call %routine%
&return

&routine USAGE
&type Usage: getworkspace INIT <variable_name> {wildcard} {'''position'''}
&type                   {'''stripe'''}
&type Usage: getworkspace <routine_name>
&return &warning

&routine INIT
/* Display the menu
/* set arguments
&set varname  = [extract 1 [unquote %arglist%]] /* required
&set wildcard = [extract 2 [unquote %arglist%]]  /* optional
&set position = [extract 3 [unquote %arglist%]]  /* optional
&set stripe   = [extract 4 [unquote %arglist%]]  /* optional
&if [null %varname%] or %varname%_ = #_ &then
  &call usage
&if [null %position%] OR %position%_ = #_ &then
  &set position = '&cc &screen &cc'
&if [null %stripe%] or %stripe%_ = #_ &then
  &set stripe   = 'Select...'
&set .getworkspace$varname = %varname%

/* Current directory
/* Set path to previous one if this tool has already been used
&if not [variable .arctools$get_savepath] &then
  &set .arctools$get_savepath
&if [null %.arctools$get_savepath%] &then
  &set .getworkspace$curdir = [show &workspace]
&else &set .getworkspace$curdir = %.arctools$get_savepath%
```

```
/* Search string for listing files (list only files containing the string)
&if [null %wildcard%] or %wildcard%_ = #_ &then
  &set .getworkspace$wildcard = *
&else
  &set .getworkspace$wildcard = %wildcard%
&run get_routines curdir .getworkspace

&if [show &thread &exists tool$getworkspace] &then
  &thread &delete tool$getworkspace
&thread &create tool$getworkspace &modal ~
  &menu getworkspace.menu ~
  &position [unquote %position%] ~
  &stripe [quote [unquote %stripe%]] ~
  &pinaction '&run getworkspace cancel'
&return

&routine CURDIR
/* This routine is never called by the current version of the tool.
/* It is left here for backwards compatibility with the 7.0.2 menu.
&run get_routines curdir .getcover
&return

&routine SUBDIR
/* This routine is never called by the current version of the tool.
/* It is left here for backwards compatibility with the 7.0.2 menu.
&run get_routines subdir .getcover
&return

&routine UP
/* This routine is never called by the current version of the tool.
/* It is left here for backwards compatibility with the 7.0.2 menu.
&run get_routines up .getcover
&return

&routine DIRECTORY
/* Apply selected directory value
/*&set [value .getworkspace$varname] = %.getworkspace$directory%
&return

&routine HELP
/* Display help for this tool
&run disp_help getworkspace
&return

&routine OK
/* Quit from menu, cleanup
&set [value .getworkspace$varname] = %.getworkspace$directory%
/* Save the path for future use of this tool
&set .arctools$get_savepath = %.getworkspace$curdir%
&call exit
&return

&routine CANCEL
/* Set values to null to indicate to calling program that nothing was selected
&call exit
&return

&routine EXIT
&dv .getworkspace$*
&if [show &thread &exists tool$getworkspace] &then
  &thread &delete tool$getworkspace
&return

&routine BAILOUT
&severity &error &ignore
&severity &warning &ignore
&return &warning An error has occurred in routine: %routine% (GETWORKSPACE.AML)
```

```
/* $Id: get_routines.aml,v 2.0 1996/01/24 23:44:45 markz Exp $
/*------------------------------------------------------------------------
/*          Environmental Systems Research Institute
/*------------------------------------------------------------------------
/*   Program: GET_ROUTINES.AML
/*   Purpose: File system navigation routines used by the various file
/*          browsers (get*.aml and get*.menu)
/*
/*------------------------------------------------------------------------
/*    Usage: GET_ROUTINES CURDIR <prefix>
/*          GET_ROUTINES SUBDIR <prefix>
/*          GET_ROUTINES UP <prefix>
/*          GET_ROUTINES SETWILD <prefix>
/*
/* Arguments: prefix - Variable prefix in the form .toolname.  This tool
/*                 uses and sets variables using this prefix.
/*                 example: "GET_ROUTINES UP .getcover" reads:
/*                          .getcover$curdir, and .getcover$wildcard
/*                          and it sets:
/*                          .getcover$curdir, .getcover$availdirs, and
/*                          .getcover$olddir
/*
/*   Globals: <prefix>$wildcard  - search string
/*          <prefix>$curdir    - current directory from 'Directory:' field
/*          <prefix>$olddir    - most recent valid directory
/*          <prefix>$availdirs - path & * to show available subdirectories
/*                       (used to populate 'Subdirectories' list)
/*          <prefix>$cancel    - gets set to .TRUE. when CURDIR routine
/*                       returns an error (ie dir does not exist)
/*
/*  Routines: usage - Echo the correct usage of the tool
/*          curdir - Set up the current directory selection
/*          subdir - Change to a selected subdirectory
/*          up - Move up one directory
/*          setwild - User sets a wildcard search string
/*          bailout - Error handling
/*------------------------------------------------------------------------
/*    Calls:
/*------------------------------------------------------------------------
/*    Input: Uses various global variables from the calling program.
/*          Does not check to see if these are correctly set.
/*   Output: Sets various global variable for use by the calling program.
/*------------------------------------------------------------------------
/*   History: Mark D Zollinger - 10/10/94 - Original coding
/*==========================================================================
/*
&args routine prefix

&severity &error &routine bailout

/* Check arguments
&if [null  %prefix%] &then
 &call usage

&call %routine%

&return

/*------------
&routine USAGE
/*------------
/*
&type Usage: get_routines <routine_name> <global_prefix>
&return &inform

/*-------------
&routine CURDIR
/*-------------
/* set up current directory
/*
```

```
/* check for null value
&if [null [value %prefix%$curdir]] &then
&do
  &set %prefix%$curdir = [value %prefix%$olddir]
  &set %prefix%$cancel = .TRUE.
  &return
&end
/* interpret possible environment variables
&set %prefix%$curdir = [pathname [extract 1 [value %prefix%$curdir]]]
/* be sure directory exists
&if ^ [exists [value %prefix%$curdir] -directory] &then
&do
  &set %prefix%$curdir = [value %prefix%$olddir]
  &set %prefix%$msg    = Directory does not exist
  &set %prefix%$cancel = .TRUE.
  &return
&end
/* populate scrolling lists of subdirectories and coverages and reset olddir
&set %prefix%$olddir = [value %prefix%$curdir]
&set %prefix%$curwild ~
    = [joinfile [value %prefix%$curdir] [value %prefix%$wildcard] -file]
&set %prefix%$availdirs = [joinfile [value %prefix%$curdir] * -sub]
&set %prefix%$cancel    = .FALSE.
&return

/*-------------
&routine SUBDIR
/*-------------
/* Change the current directory to the specified subdirectory
/*
&set temp           = [value %prefix%$subdir]
/* workaround SDBsn23981 by removing double slash (only affects unix)
&set %prefix%$curdir = [subst %temp% // /]
&set %prefix%$olddir = [value %prefix%$curdir]
&call curdir
&return

/*---------
&routine UP
/*---------
/* Move up one directory.
&set %prefix%$curdir = [dir [value %prefix%$curdir]]
&set %prefix%$curwild ~
    = [joinfile [value %prefix%$curdir] [value %prefix%$wildcard] -file]
&set %prefix%$availdirs = [joinfile [value %prefix%$curdir] * -sub]
&set %prefix%$olddir = [value %prefix%$curdir]
/*
&return

/*--------------
&routine SETWILD
/*--------------
/* user specifies a wildcard
/*
&set %prefix%$curwild ~
    = [joinfile [value %prefix%$curdir] [value %prefix%$wildcard] -sub]
&return

/*--------------
&routine BAILOUT
/*--------------
/*
&severity &error &ignore
&severity &warning &ignore
&return &warning An error has occurred in routine: %routine% (GET_ROUTINES.AML)
```

```
/*Script: graph.aml September, 2001
/*By:     Dan Deneau Lisa Markham
/*This is the graphing aspect of the
/*Lidar Tool. It plots a graph of the
/*elevation differences versus frequency.
/*The frequency is of ground hits within the
/*search radius.

/*arguments to be passed are the dat file
/*containing the frequency information
/*X is the item containing the elevation difference info
/*Y is the item containing the frequency of records
&arg pntdist,x,y,divide,recnum2,mean,std

display 9999 3

&if [show program] <> ARCPLOT &then; ARCPLOT
clear
clearselect
units page
/*get the lower x limit of the page and add 10%
&s xulim = [calc [extract 1 [show pagesize]] * .90]
/*get the lower Y limit of the page and add 10%
&s yulim = [calc [extract 2 [show pagesize]] * .90]
/*get the upper Y limit of the page and substr. 10%
&s yllim = [calc [extract 1 [show pagesize]] * .10]
/*get the upper X limit of the page and substr 15%
&s xllim = [calc [extract 2 [show pagesize]] * .15]
/*set the graph limits to the calculated page limits
graphlimits %xllim% %yllim% %xulim% %yulim%
graphextent %pntdist% info %x% %y%
linesymbol 1
linecolor 1
lineput 1
units graph
/*pensize 0.5
graphbar %pntdist% info %x% %y%
/*pensize 0.0001
axis horizontal
textoffset 0 -.5
textjustification cc
textsize 0.15
axistext 'Elevation Difference (m)'
axisruler

axis vertical
textoffset -.7 0
textangle 90
axistext 'Frequency of Records'
axisruler

units page
linecolor 1
box %xllim% %yllim% %xulim% [calc %yulim% * 1.05]

/*Displays the mean,standard deviation, # of records, & the divide used
textjustification ul
textprecision 3
textangle 0
textsize .07
move [calc %xllim% * 1.83], [calc %yulim% * .99]
text [quote Mean = %mean%]
move [calc %xllim% * 1.83], [calc %yulim% * .96]
text [quote Standard Deviation = %std%]
move [calc %xllim% * 1.83], [calc %yulim% * .93]
text [quote # of Records = %recnum2%]
move [calc %xllim% * 1.83], [calc %yulim% * .90]
text [quote Percent of Std_Dev = [calc %divide% * 100]]
```

```
/*Title for graph
textjustification cc
textfont 93713 /*times font
textquality proportional
textsize 0.25
move [calc [extract 1 [show pagesize]] * .52] ~
[calc [extract 2 [show pagesize]] * .055]
text 'Elevation Differences Between Lidar Data'
move [calc [extract 1 [show pagesize]] * .52] ~
[calc [extract 2 [show pagesize]] * .03]
text 'and High Precision GPS Validation Points'
```

Appendix J – Result for individual LIDAR tiles from Validating LIDAR the points with GPS

LIDAR Tile	Frequency of Points	Mean	Standard Deviation
Cap Lumiere			
365_5159	1005	0.191868	0.094828
365_5155	1135	0.198919	0.089251
369_5155	2773	0.099029	0.128392
Bouctouche			
369_5151	4582	0.280023	0.104063
369_5147	6534	0.189473	0.106108
365_5147	6864	0.142961	0.087496
365_5143	827	0.126010	0.094096
369_5143	6597	0.217050	0.106160
Cormierville			
373_5143	4767	0.201831	0.104088
373_5139	562	0.349578	0.076199
373_5135	3153	0.357651	0.090621
373_5135	5987	0.321755	0.094193
373_5131	1538	0.381296	0.102131
373_5131	2876	0.410750	0.082580
377_5131	832	0.356196	0.109210
Cap Pele			
381_5127	4456	0.009485	0.089775
377_5127	8110	-0.050302	0.099488
377_5127	2558	-0.016908	0.104301
373_5123	4232	0.299851	0.102681
377_5123	1560	0.079229	0.095082
377_5119	17832	0.144168	0.100976
377_5115	5086	0.089240	0.107029
381_5119	10675	0.207641	0.090259
381_5119	30682	0.172982	0.100728
385_5119	9106	0.157809	0.103057
389_5119	8042	0.147929	0.111133
389_5119	7954	0.159524	0.097814
389_5115	1853	0.155888	0.081907
393_5119	8250	0.191278	0.106231
393_5115	6763	0.178595	0.102554
397_5119	35892	0.123424	0.105039
397_5115	6928	0.090538	0.098120
401_5119	7880	0.155747	0.098295
401_5115	9047	0.084467	0.094394

Table 7 This table contains the results from all of the pntstats2.dat files generated from the tool1.aml for all individual LIDAR tiles that contained GPS data. A summary of this table can be found in table 2.

Appendix K – Script used to create Flood Files

```
!*********************************************************************************
! Flood_BT.mod
!
! The Easi script is designed to create flood images of the LIADR DEM
!
! Note: this script is hard coded to use the Cappele.pix file that is set up with
! the following channels:
! %1 contains a 32 bit DEM
! %2 & %3 are an empty channel
!
! Other scripts similar to this one existed for the other LIDAR blocks but with
! different file names.
!*********************************************************************************

!-------------------------------------------------------
! declare integer variable 'i'
! used for loop counter
!-------------------------------------------------------
local integer i

!-------------------------------------------------------
! declare double precision variable 'j'
! and assign initial value of 0
! used for flood level on DEM
!-------------------------------------------------------
local double j
j = 0

!-------------------------------------------------------
! execute for loop
! will flood incrementally from 0 through 2.6 metres
!-------------------------------------------------------
FOR i = 1 TO 26

 !-----------------------------------------------------
 ! create binary mask for flooded area of adjusted DEM
 ! using model assigns value of 1 to flooded areas
 ! and 0 to dry areas
 !
 !Channel 1 is the 32 bit DEM
 !Channel 2 is an empty channel
 !-----------------------------------------------------
 MODEL ON "/export/home/data/nb_lidar/flood_anim/Bouctouche-3d.pix"
  if (%1 < j) then
   %2 = 1
  else
   %2 = 0
  endif
 ENDMODEL

 !-----------------------------------------------------
 ! set parameters for the FMO task
 ! applies 3x3 pixel mode filter to remove noise
 ! keeps isolated flooded pixels
 !Channel 6 is an empty channel
 !-----------------------------------------------------
```

```
 FILE = "/export/home/data/nb_lidar/flood_anim/Bouctouche-3d.pix"
 DBIC = 2
 DBOC = 3
 FLSZ = 3, 3
 MASK =
 THINLINE = "ON"
 KEEPVALU = 1
 ! execute the FMO task
 RUN FMO

 !-----------------------------------------------------
 ! set parameters for the FEXPORT task
 ! exports binary mask to Arc/INFO GRD file numbered
 !-----------------------------------------------------
 FILI = "/export/home/data/nb_lidar/flood_anim/Bouctouche-3d.pix"
 FILO = "../flood_files/flood"+F$STRING(i)+".pix"
 DBIW =
 DBIC = 3
 DBIB =
 DBVS =
 DBLUT =
 DBPCT =
 FTYPE = "PIX"
 FOPTIONS =
 ! execute the FEXPORT task
 RUN FEXPORT
 !-----------------------------------------------------
 ! increment variable 'j' - flood level by 0.1 metres
 !-----------------------------------------------------
 j = j + 0.1

ENDFOR
```

Appendix L – Script used to create Flood Animation

```
!***********************************************************
! Flood_CP_anim.mod
!
! The Easi script is designed to create flood images to incorporate into an
! animation sequence with Jasc Animation Software.
!
! Note: this script is hard coded to use the Cappele.pix file that is set up with
! the following channels:
! %1 contains a 32 bit DEM
! %2, %3, %4 contains the CSR model
! %5, %6, %7, %8 are empty channels
!
! Other scripts similar to this one existed for the other LIDAR blocks but with
! different file names.
!***********************************************************

!-------------------------------------------------------
! declare integer variable 'i'
! used for loop counter
!-------------------------------------------------------
local integer i

!-----------------------------------------------------
! execute for loop
! for flood levels between 0 and 4 metres above MSL
!-------------------------------------------------------
FOR i = 1 TO 4

  !-----------------------------------------------------
  ! Mosaic channel 1 of flood pix file flood#.pix to
  ! 32-bit DEM pix file
  !-----------------------------------------------------

  FILI = "../flood_files_cp/flood"+F$STRING(i)+".pix"
  DBIC = 1
  DBVS =
  DBLUT =
  FILO = "/export/home/data/nb_lidar/flood_anim/Cappele.pix"
  DBOC = 5
  BLEND =
  BACKVAL =

  RUN MOSAIC

 !-----------------------------------------------------
 ! place flood level polygon on 32-bit CSR of DEM,
 !-----------------------------------------------------

  MODEL ON "/export/home/data/nb_lidar/flood_anim/Cappele.pix"
    if (%5 = 1 ) then
        %6 = 0
        %7 = 50
        %8 = 255
    else
        %6 = %2
        %7 = %3
```

```
    %8 = %4
  endif
 ENDMODEL

 !-------------------------------------------------------
 ! integrate perspective view of CSR with 32-bit DEM to new RGB channels
 !-------------------------------------------------------

 FILI = "/export/home/data/nb_lidar/flood_anim/Cappele.pix"
 DBIC = 6, 7, 8
 DBEC = 8
 ESCALE = 0.1
 FILO = "/export/home/data/nb_lidar/flood_anim/CPper-3d.pix"
 DBOC = 1, 2, 3
 BACKCOL = 0, 0, 0
 EDGECOL = 0, 0, 0
 DBOW =
 VPOINT = 900, 5100, 1500
 VFIELD = 45
 VANGLE = 95, 50
 FRONTPIX = 250
 DBVS =
 BACKELEV = -9999

 RUN PSGIMAG

 !-------------------------------------------------------
 ! export the perspective image of flooded area over CSR DEM
 !-------------------------------------------------------
 FILI = "/export/home/data/nb_lidar/flood_anim/CPperall-3d.pix"
 FILO = "/export/home/data/nb_lidar/flood_anim/cp_pers/flood"+F$STRING(i)+".tif"
 DBIW =
 DBIC = 1, 2, 3
 DBIB =
 DBVS =
 DBLUT =
 DBPCT =
 FTYPE = "TIF"
 FOPTIONS =

 RUN FEXPORT

ENDFOR
```

Appendix M – Flood Maps

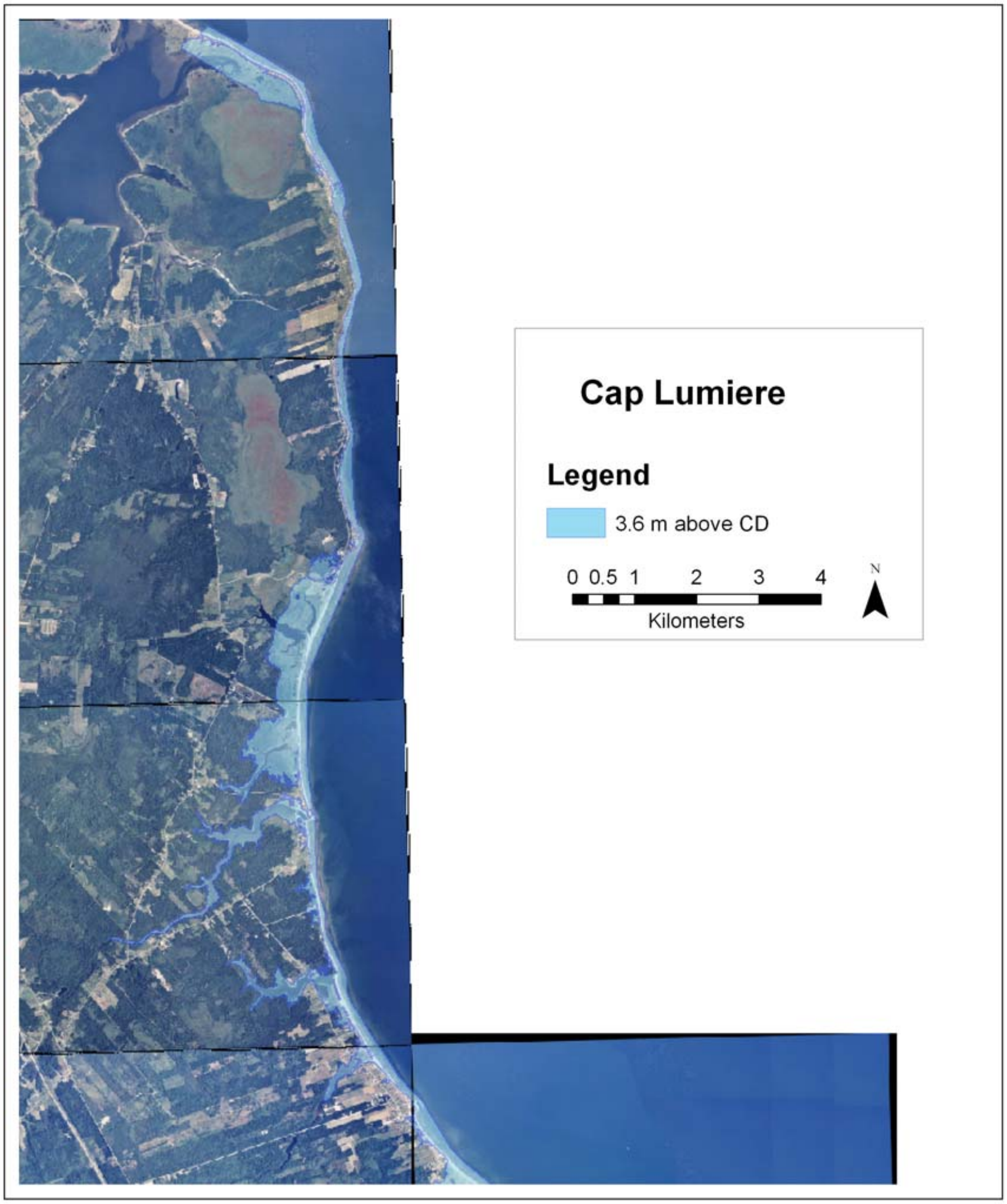


Figure 69 The 3.6 m above CD flood extent layer for the Cap Lumiere LIDAR Block integrated with a SNB orthophoto (Image: E. MacKinnon, AGRG 2004).

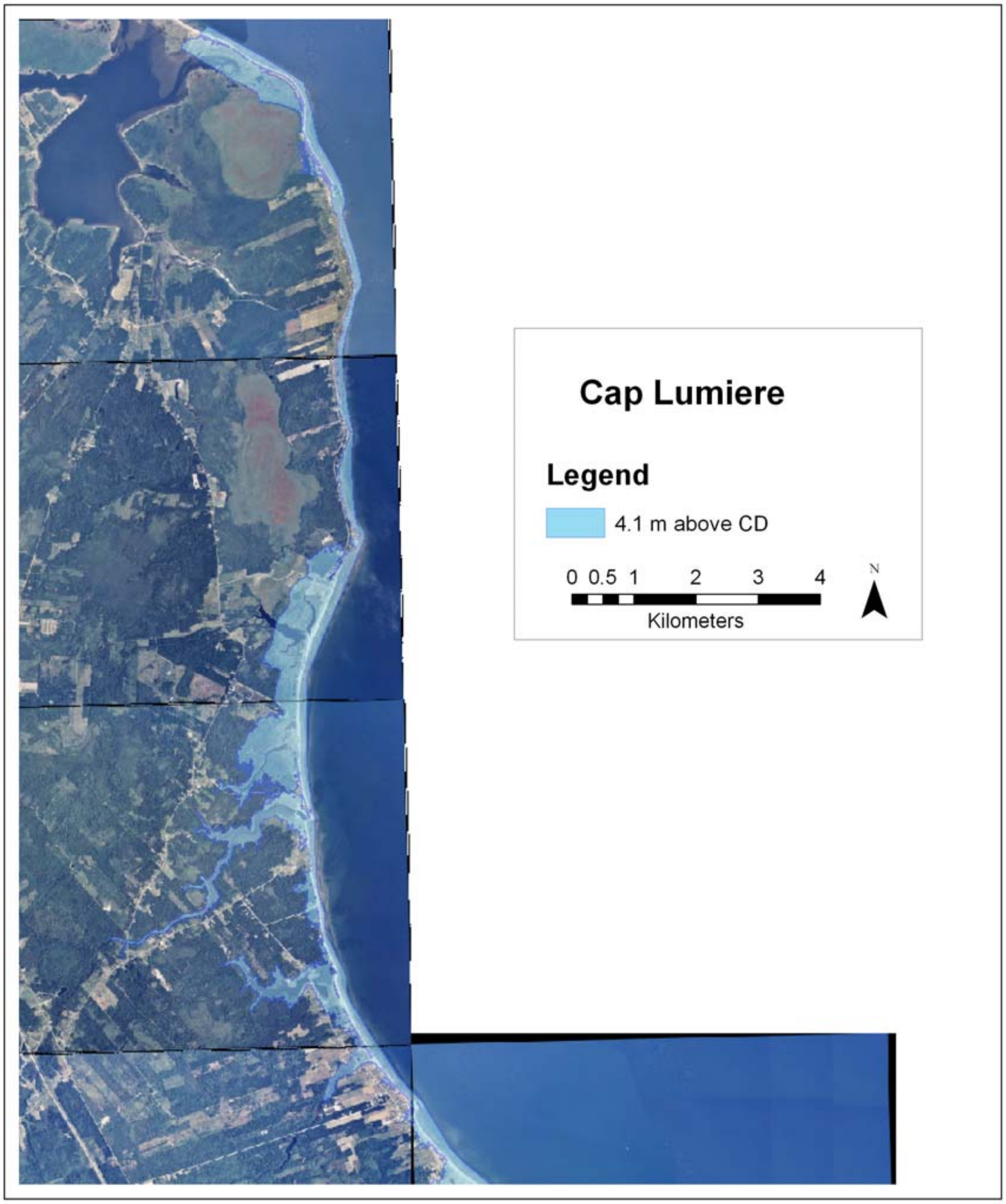


Figure 70 The 4.1 m above CD flood extent layer for the Cap Lumiere LIDAR Block integrated with a SNB orthophoto (Image: E. MacKinnon, AGRG 2004).

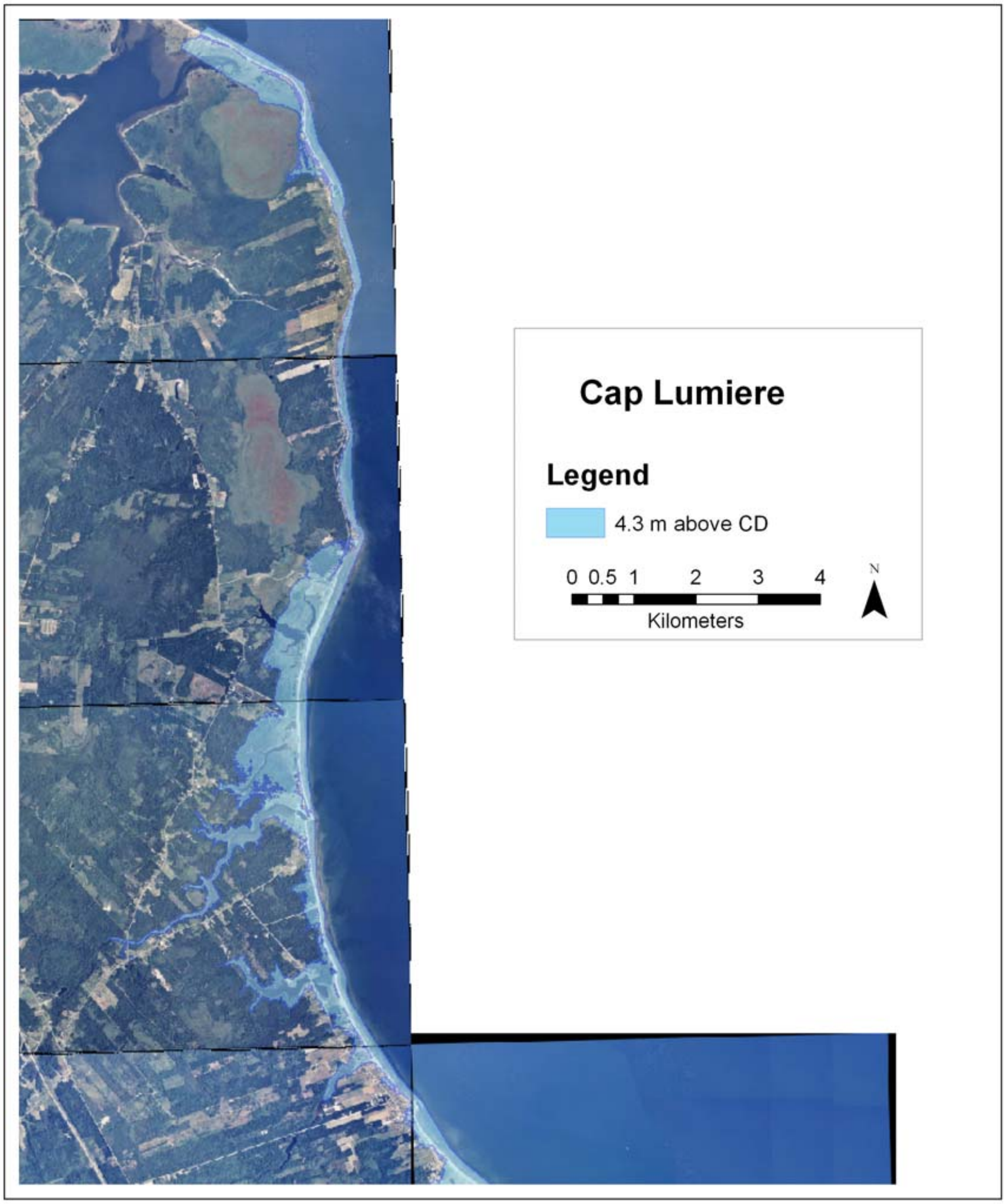


Figure 71 The 4.3 m above CD flood extent layer for the Cap Lumiere LIDAR Block integrated with a SNB orthophoto (Image: E. MacKinnon, AGRG 2004).

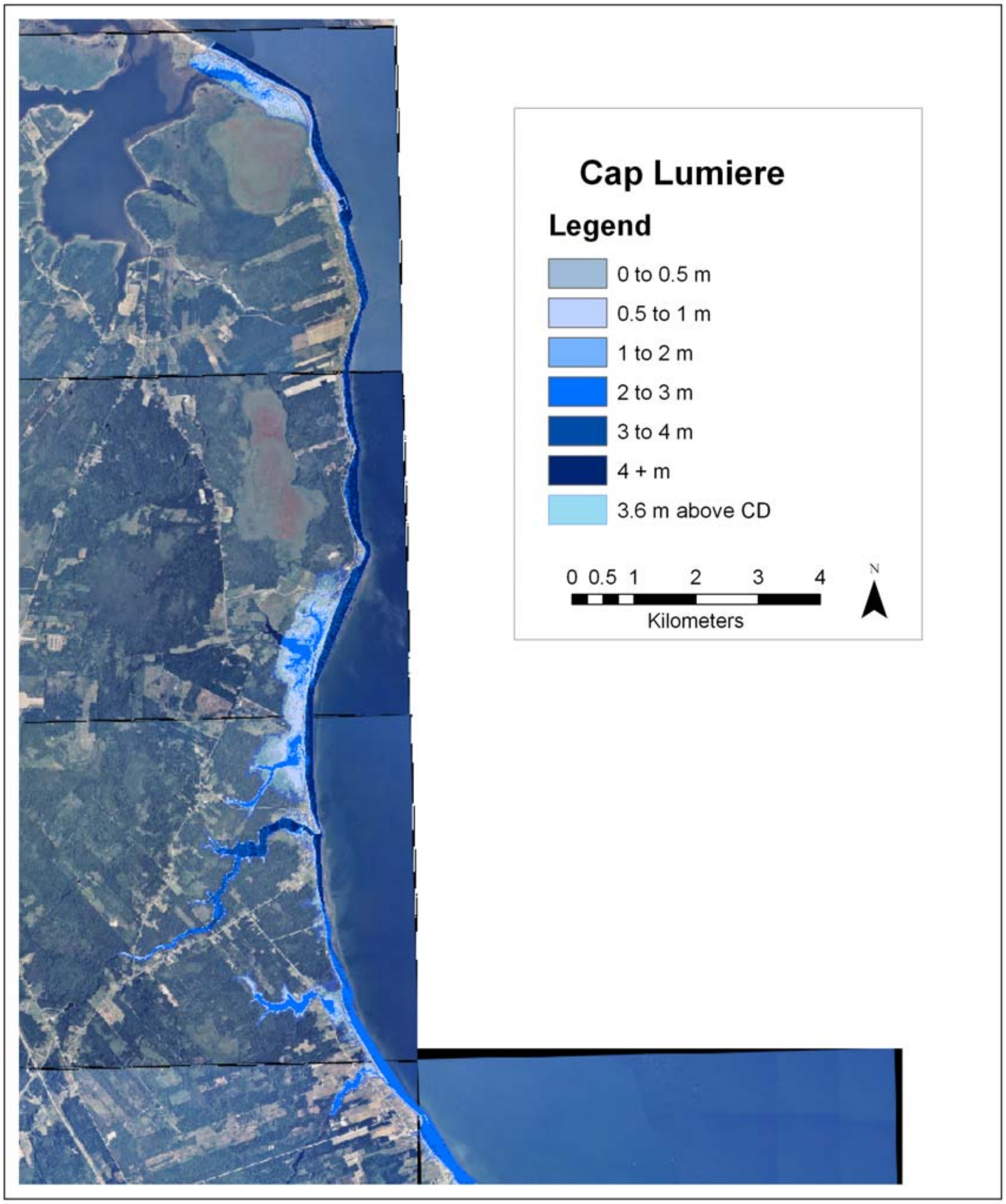


Figure 72 The 3.6 m above CD flood extent layer and the reclassified depth grid for the Cap Lumiere LIDAR Block integrated with a SNB orthophoto (Image: E. MacKinnon, AGRG 2004).

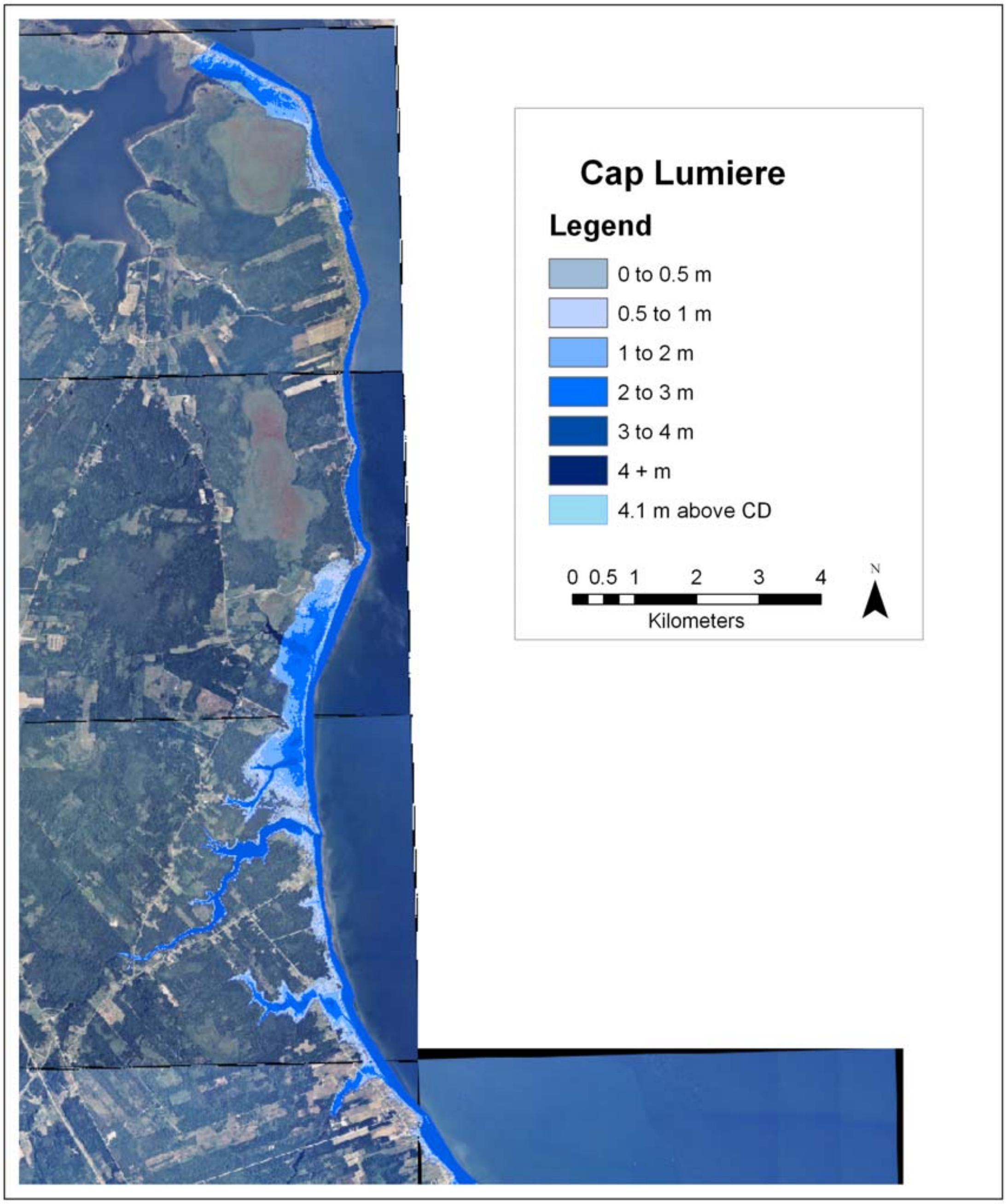


Figure 73 The 4.1 m above CD flood extent layer and the reclassified depth grid for the Cap Lumiere LIDAR Block integrated with a SNB orthophoto (Image: E. MacKinnon, AGRG 2004).

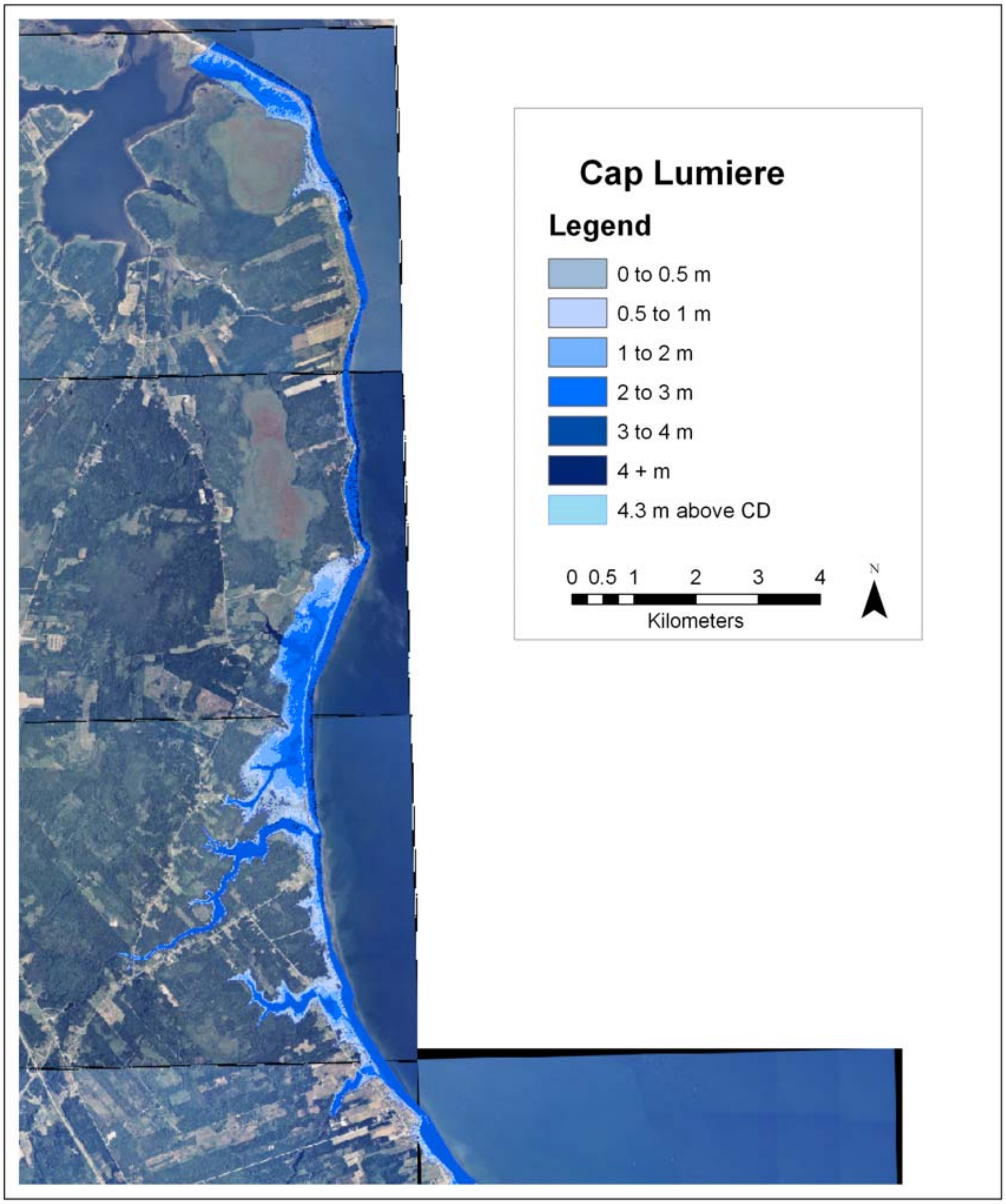


Figure 74 The 4.3 m above CD flood extent layer and the reclassified depth grid for the Cap Lumiere LIDAR Block integrated with a SNB orthophoto (Image: E. MacKinnon, AGRG 2004).

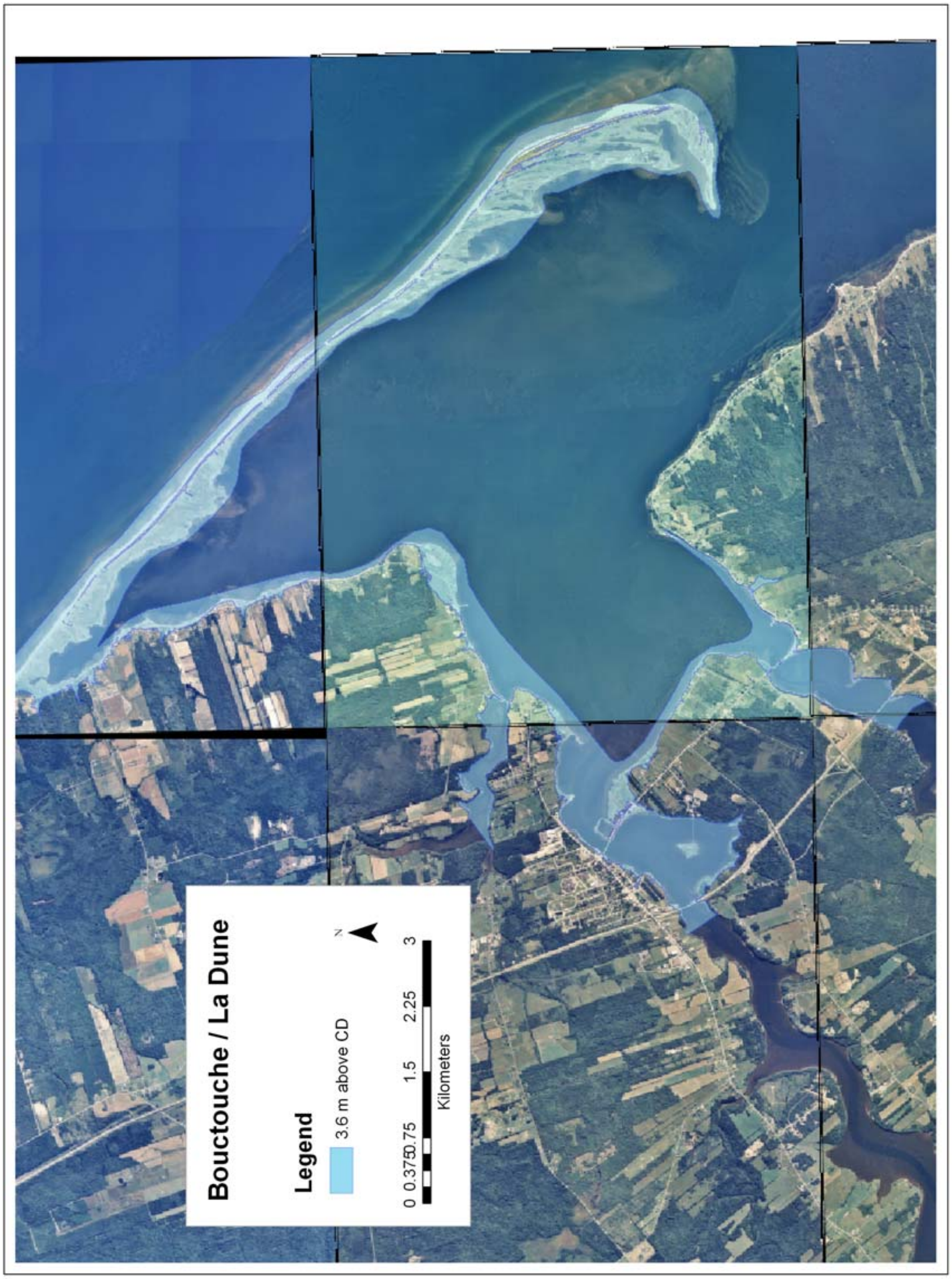


Figure 75 The 3.6 m above CD flood extent layer for the Bouctouche and La Dune LIDAR Blocks integrated with a SNB orthophoto (Image: E. MacKinnon, AGRG 2004).

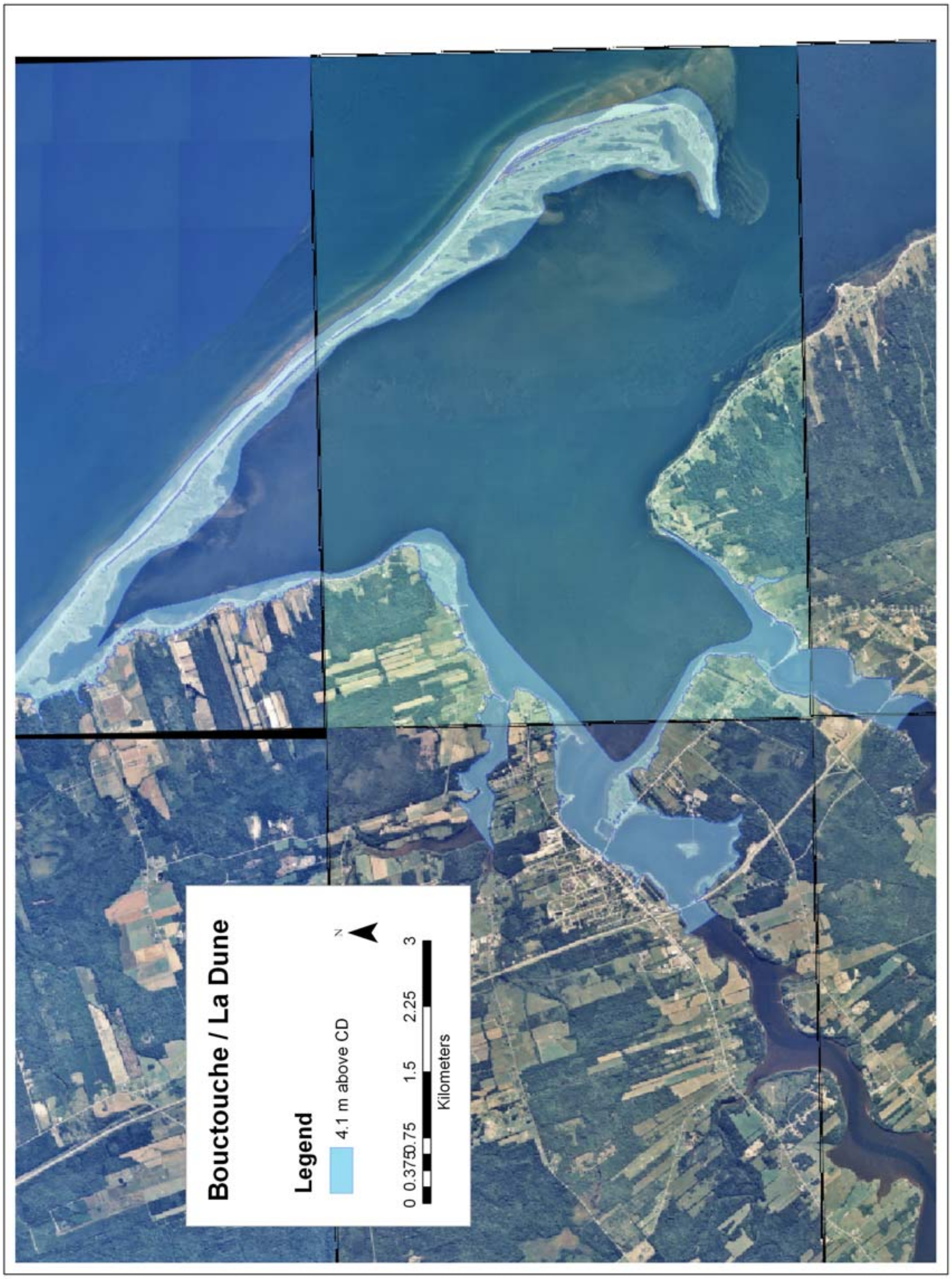


Figure 76 The 4.1 m above CD flood extent layer for the Bouctouche and La Dune LIDAR Blocks integrated with a SNB orthophoto (Image: E. MacKinnon, AGRG 2004).

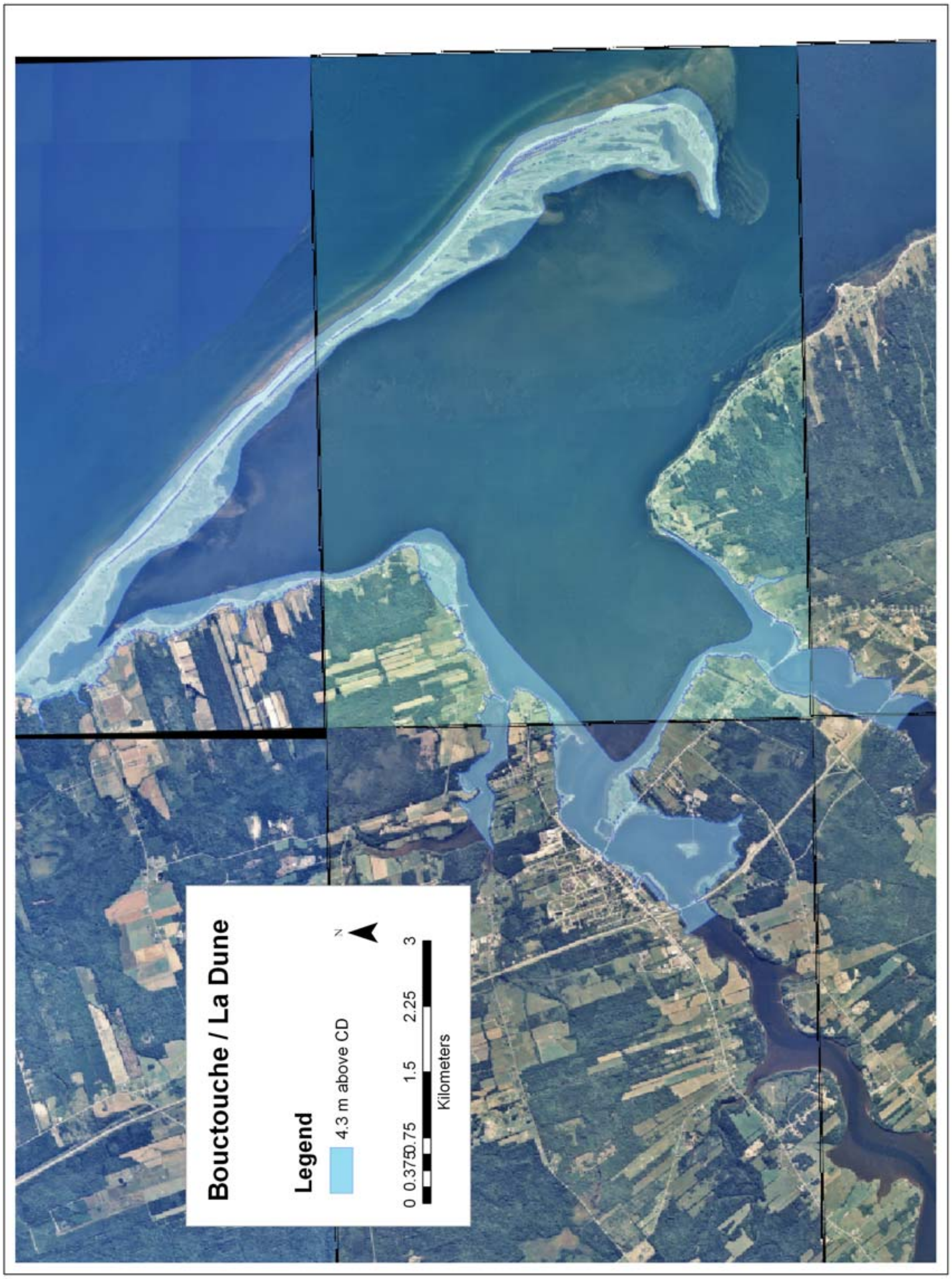


Figure 77 The 4.3 m above CD flood extent layer for the Bouctouche and La Dune LIDAR Blocks integrated with a SNB orthophoto (Image: E. MacKinnon, AGRG 2004).

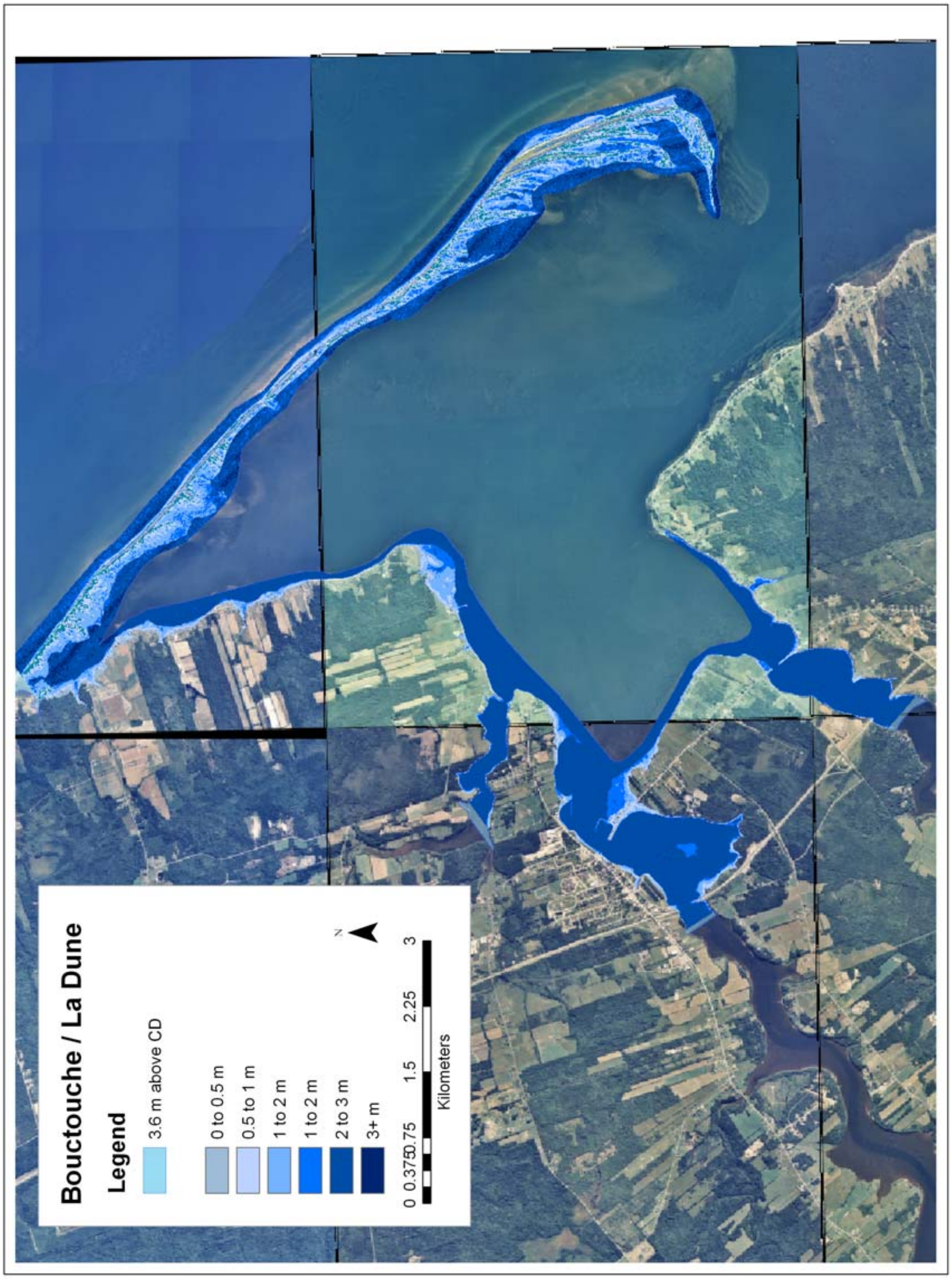


Figure 78 The 3.6 m above CD flood extent layer and the reclassified depth grid for the Bouctouche and La Dune LIDAR Blocks integrated with a SNB orthophoto (Image: E. MacKinnon, AGRG 2004).

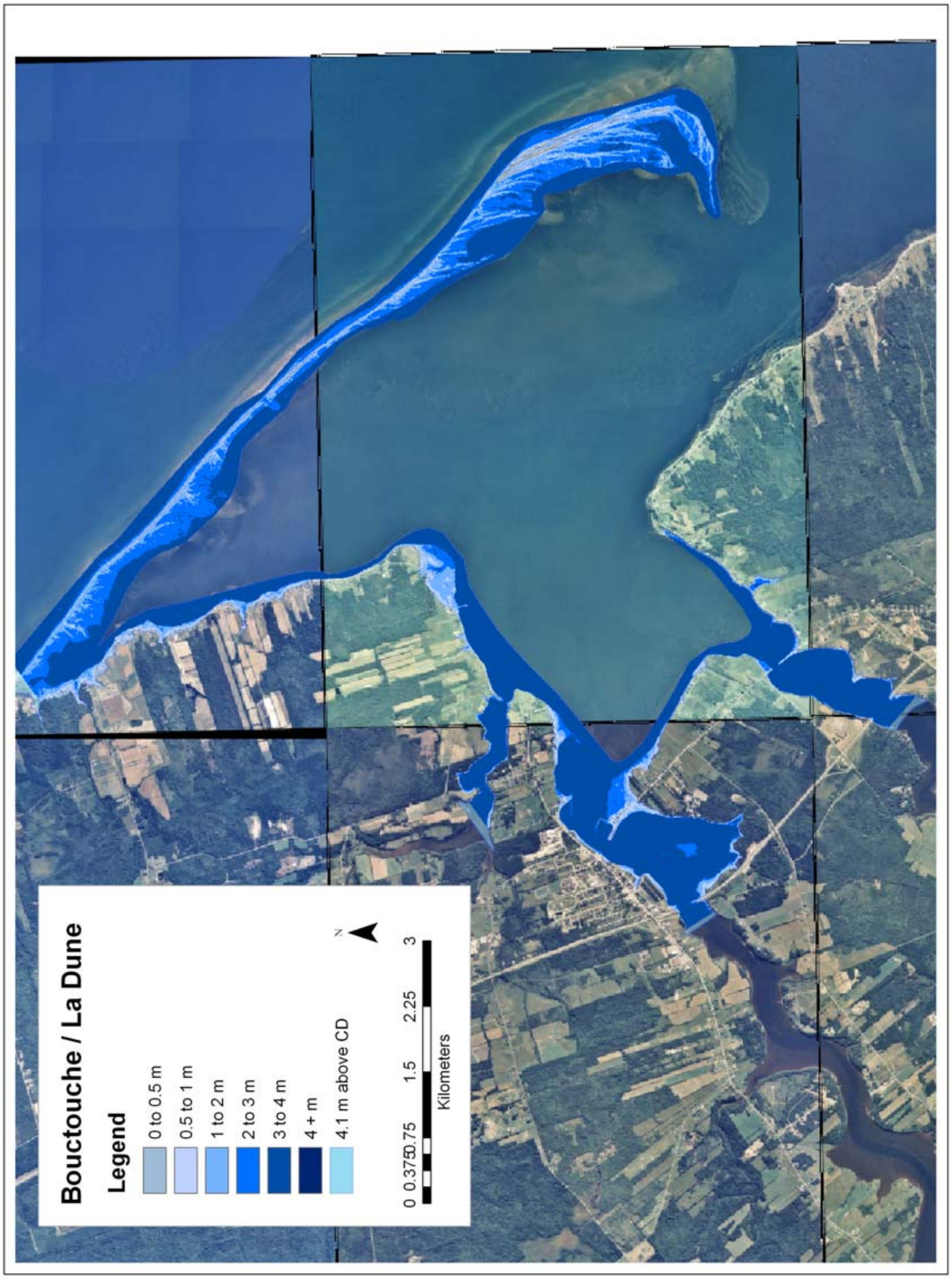


Figure 79 The 4.1 m above CD flood extent layer and the reclassified depth grid for the Bouctouche and La Dune LIDAR Blocks integrated with a SNB orthophoto (Image: E. MacKinnon, AGRG 2004).

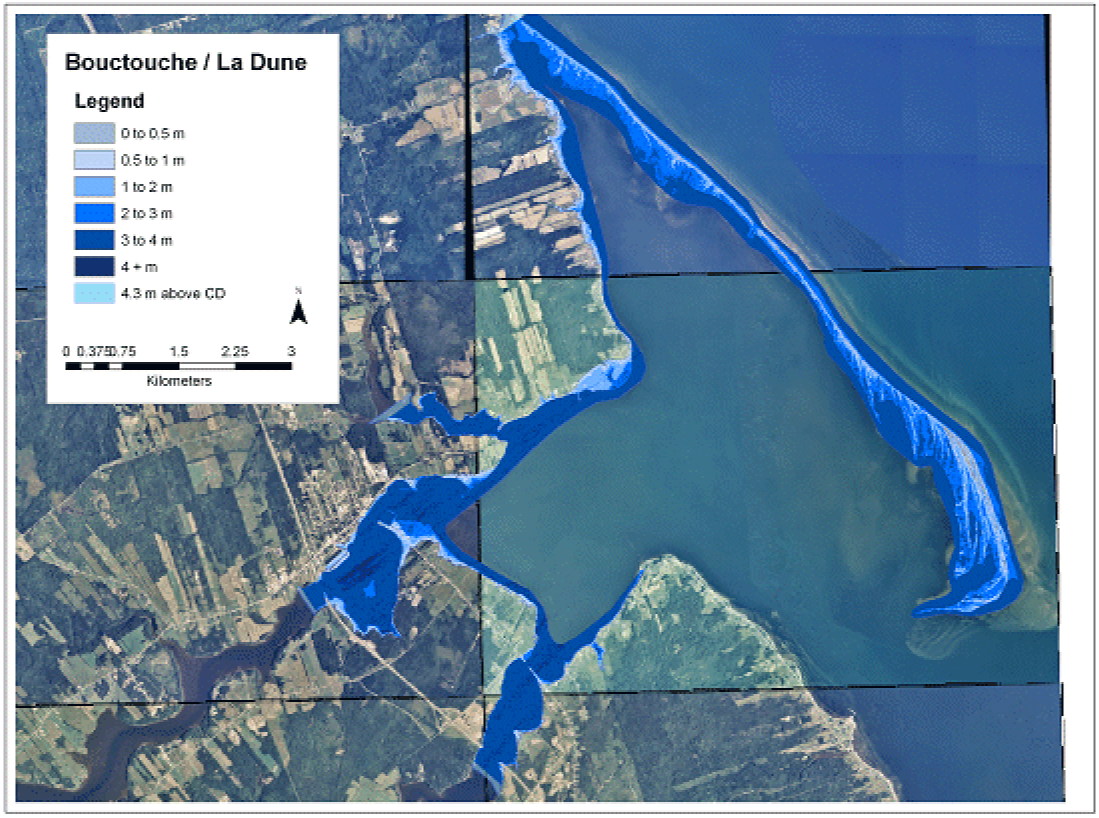


Figure 80 The 4.3 m above CD flood extent layer and the reclassified depth grid for the Bouctouche and La Dune LIDAR Blocks integrated with a SNB orthophoto (Image: E. MacKinnon, AGRG 2004).

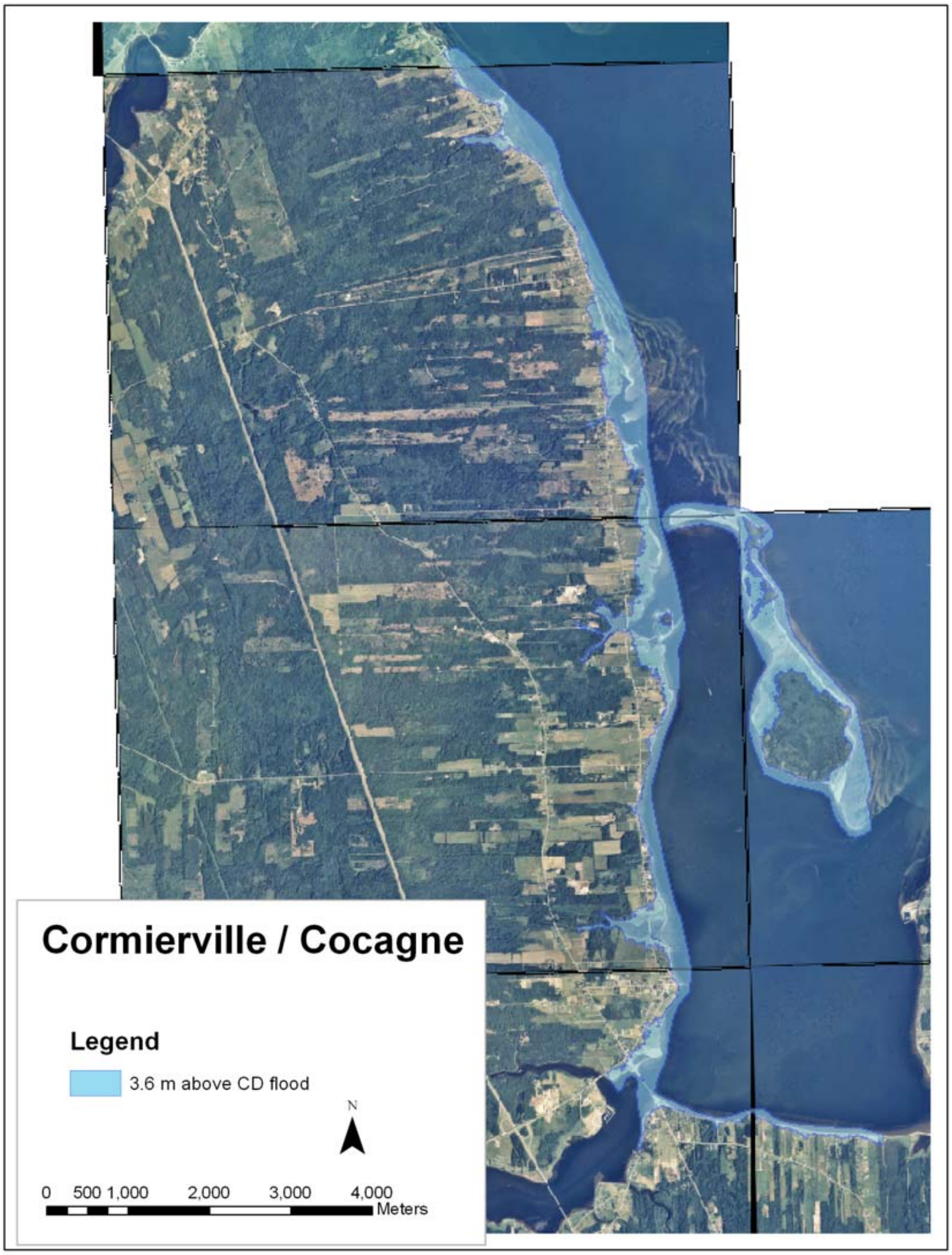


Figure 81 The 3.6 m above CD flood extent layer for the Cormierville and Cocagne LIDAR Blocks integrated with a SNB orthophoto (Image: E. MacKinnon, AGRG 2004).

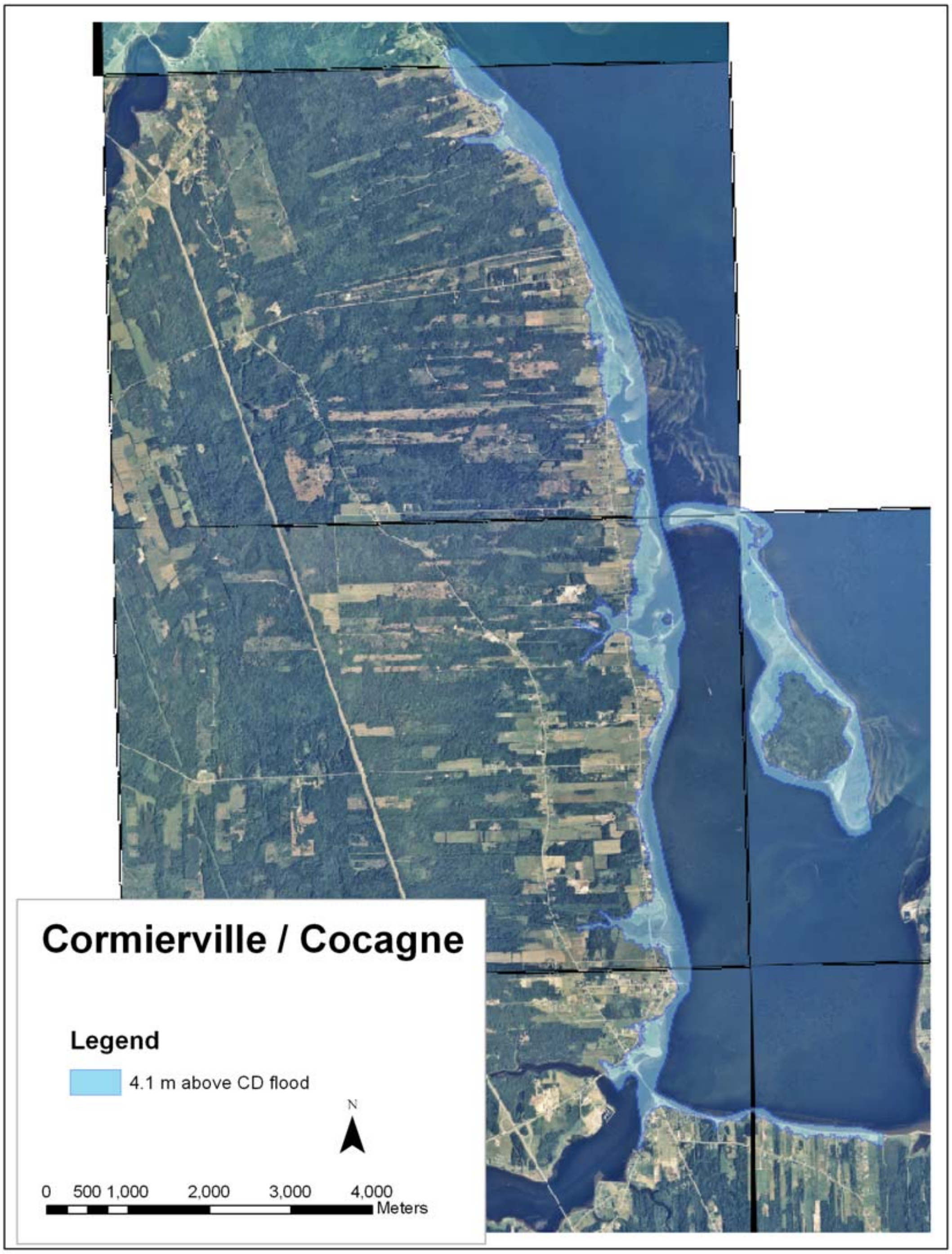


Figure 82 The 4.1 m above CD flood extent layer for the Cormierville and Cocagne LIDAR Blocks integrated with a SNB orthophoto (Image: E. MacKinnon, AGRG 2004).

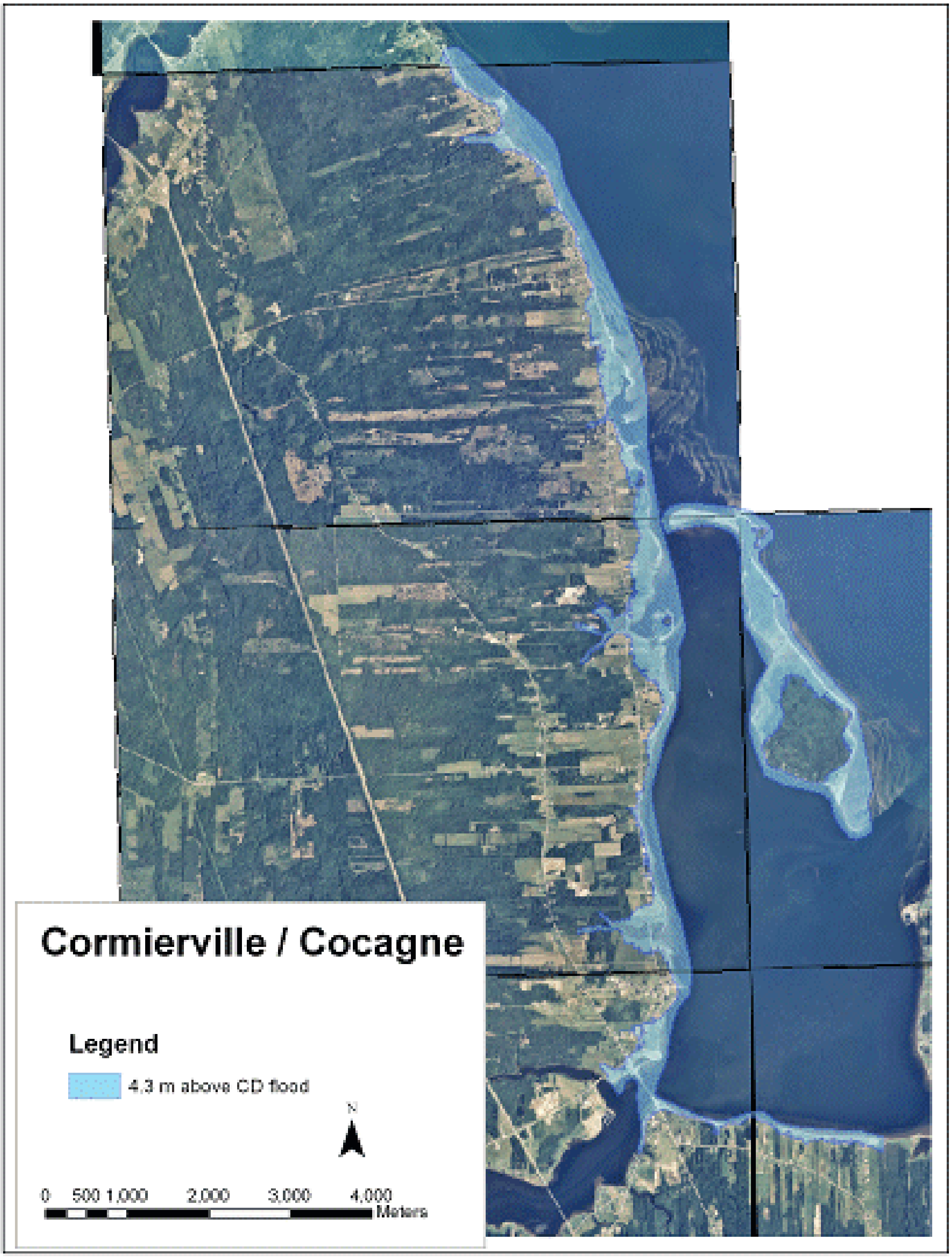


Figure 83 The 4.3 m above CD flood extent layer for the Cormierville and Cocagne LIDAR Blocks integrated with a SNB orthophoto (Image: E. MacKinnon, AGRG 2004).

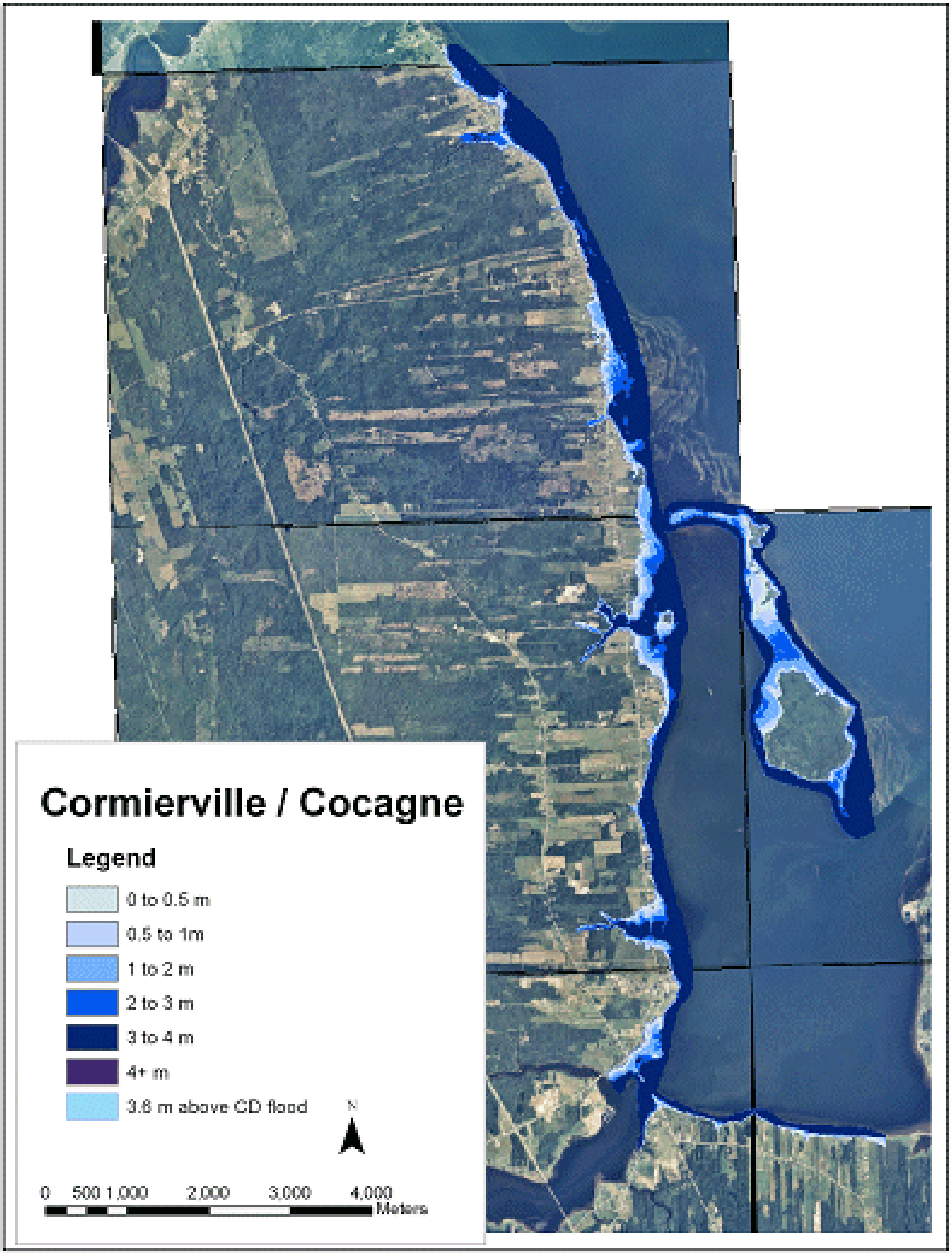


Figure 84 The 3.6 m above CD flood extent layer and the reclassified depth grid for the Cormierville and Cocagne LIDAR Blocks integrated with a SNB orthophoto (Image: E. MacKinnon, AGRG 2004).

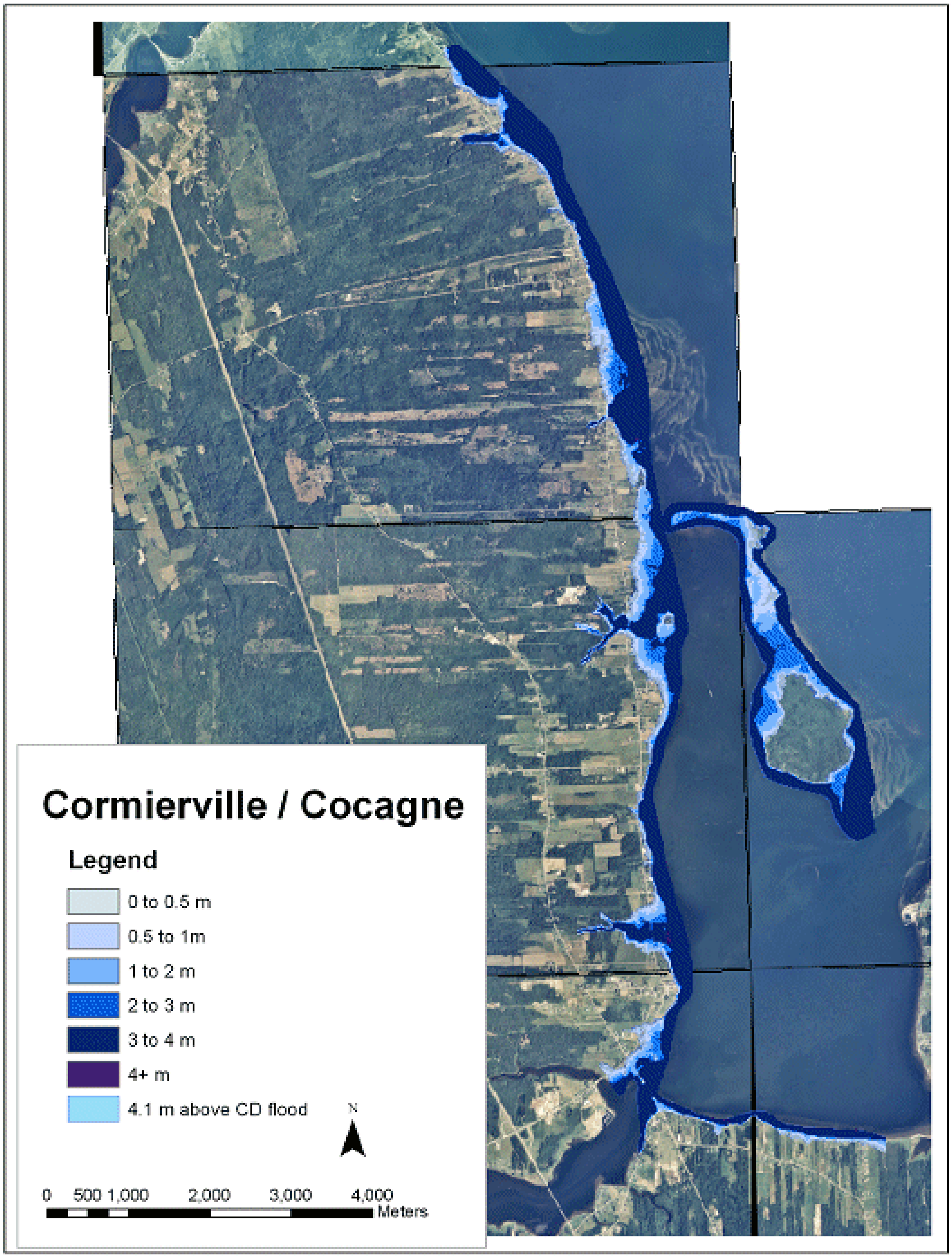


Figure 85 The 4.1 m above CD flood extent layer and the reclassified depth grid for the Cormierville and Cocagne LIDAR Blocks integrated with a SNB orthophoto (Image: E. MacKinnon, AGRG 2004).

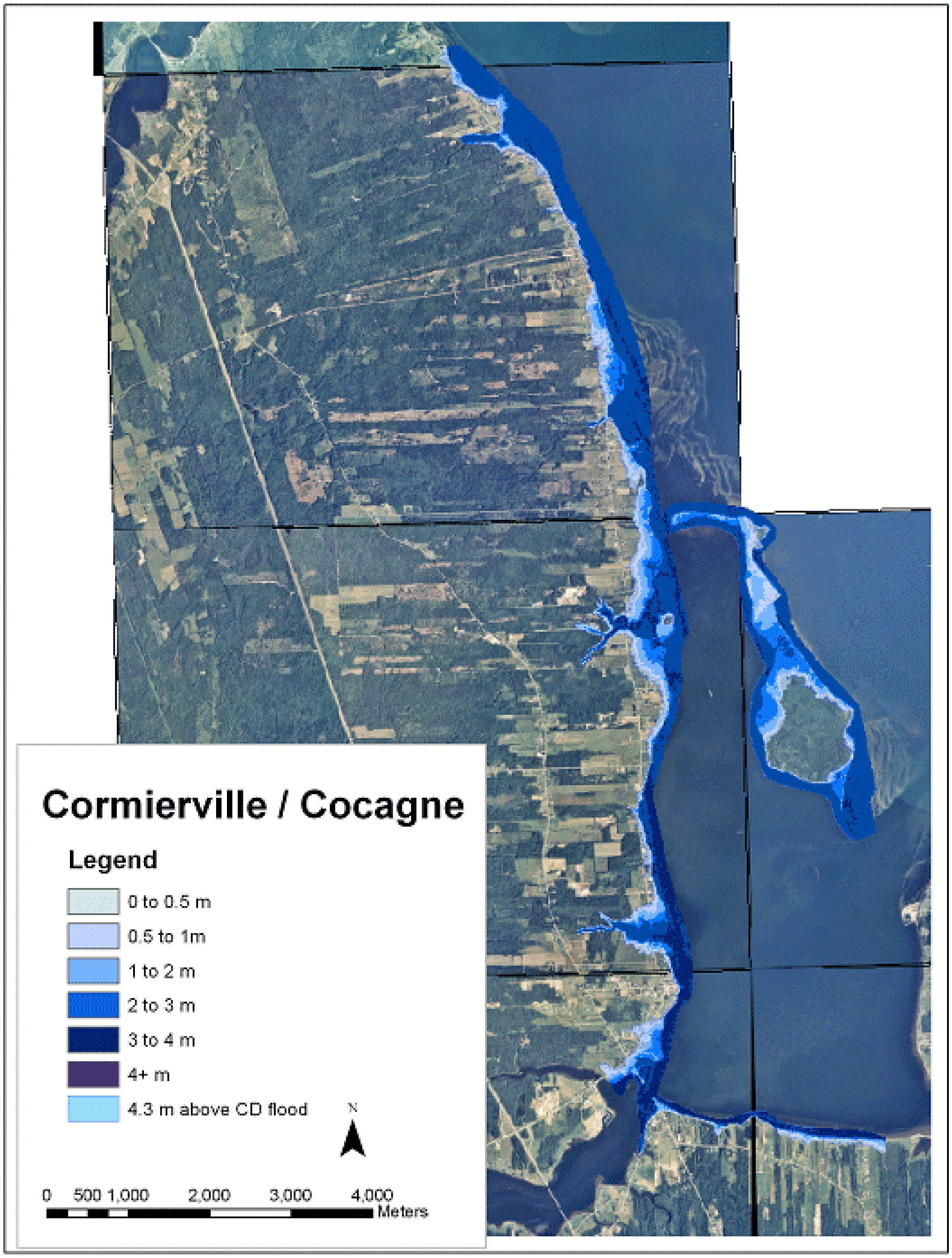


Figure 86 The 4.3 m above CD flood extent layer and the reclassified depth grid for the Cormierville and Cocagne LIDAR Blocks integrated with a SNB orthophoto (Image: E. MacKinnon, AGRG 2004).

Figure 87 The 3.6 m above CD flood extent layer for the Shediac Area integrated with a SNB orthophoto (Image: E. MacKinnon, AGRG 2004).

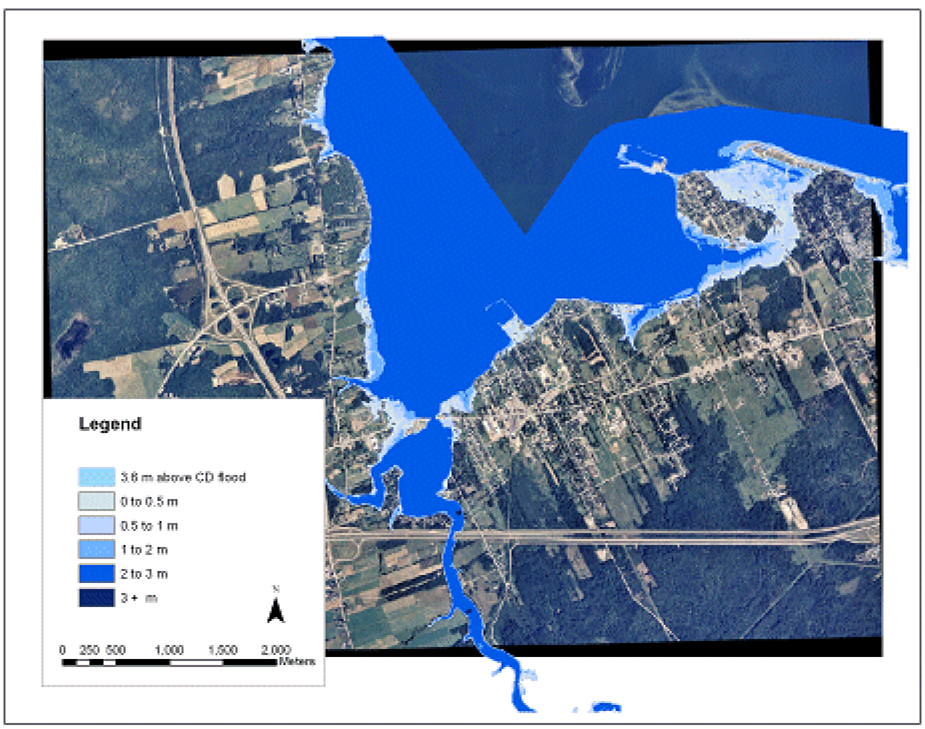


Figure 88 The 3.6 m above CD flood extent layer and the reclassified depth grid for the Shediac Area integrated with a SNB orthophoto (Image: E. MacKinnon, AGRG 2004).

Figure 89 The 3.6 m above CD flood extent layer for the Shediac Area integrated with a SNB orthophoto (Image: E. MacKinnon, AGRG 2004).

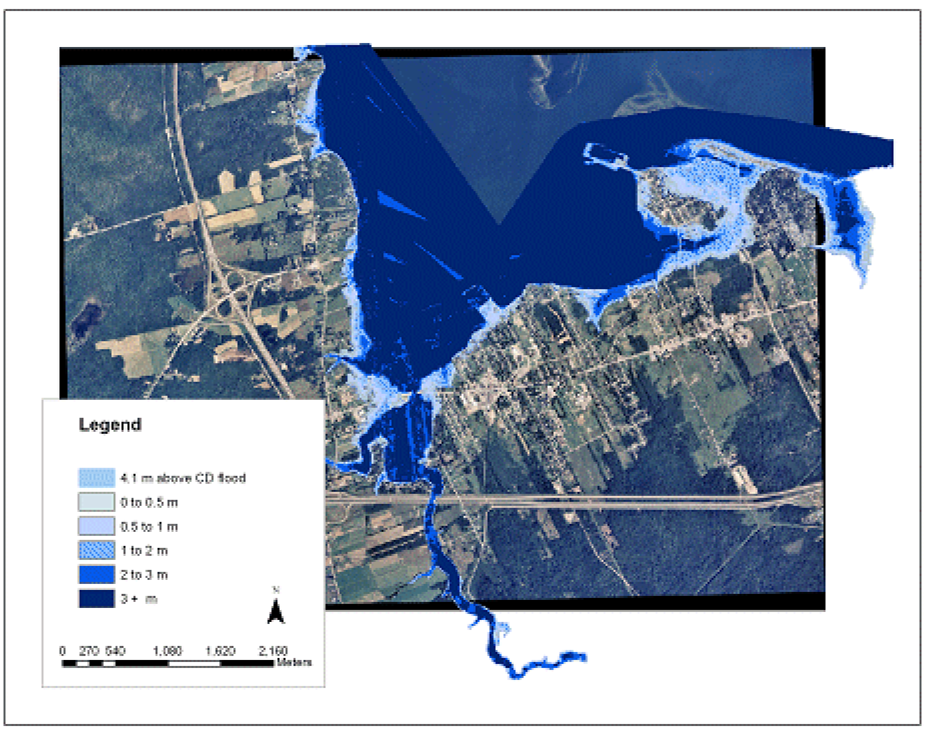


Figure 90 The 4.1 m above CD flood extent layer and the reclassified depth grid for the Shediac Area integrated with a SNB orthophoto (Image: E. MacKinnon, AGRG 2004).

Figure 91 The 4.3 m above CD flood extent layer for the Shediac Area integrated with a SNB orthophoto (Image: E. MacKinnon, AGRG 2004).

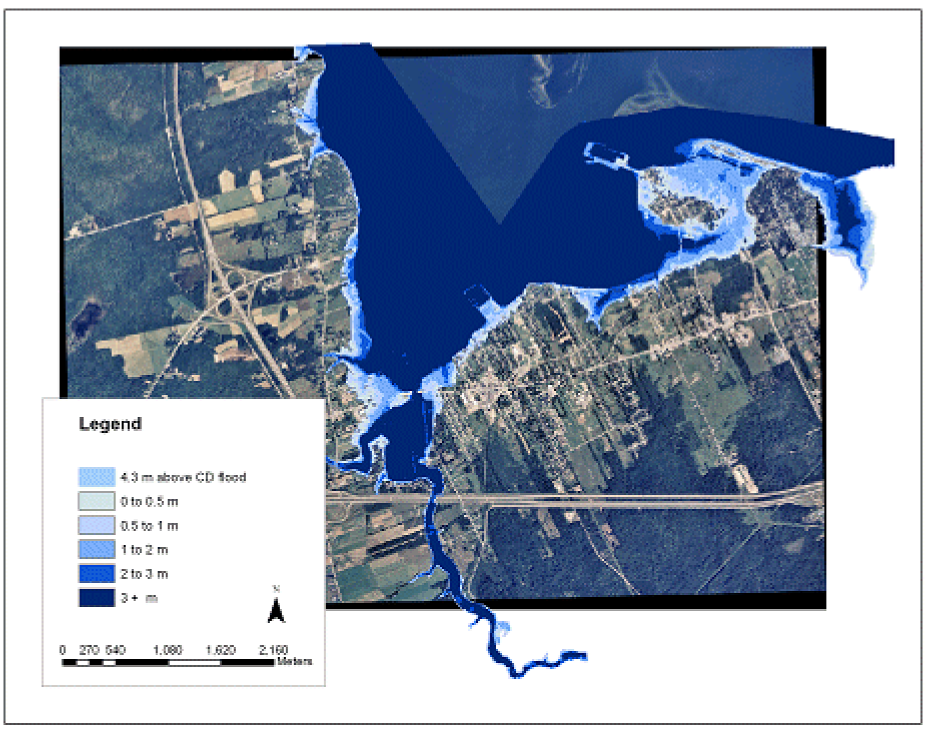


Figure 92 The 4.3 m above CD flood extent layer and the reclassified depth grid for the Shediac Area integrated with a SNB orthophoto (Image: E. MacKinnon, AGRG 2004).

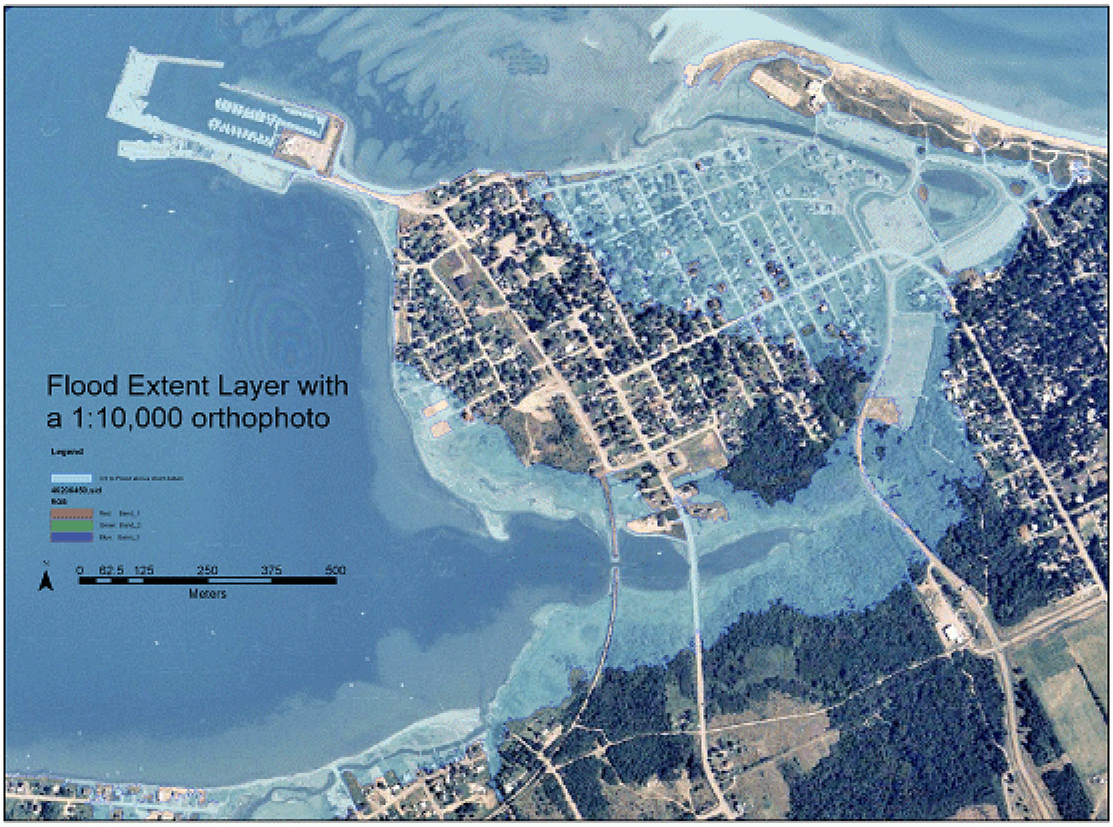


Figure 93 The 3.6 m above CD flood extent layer for the Pointe-de-Chene Area integrated with a SNB orthophoto (Image: E. MacKinnon, AGRG 2004).

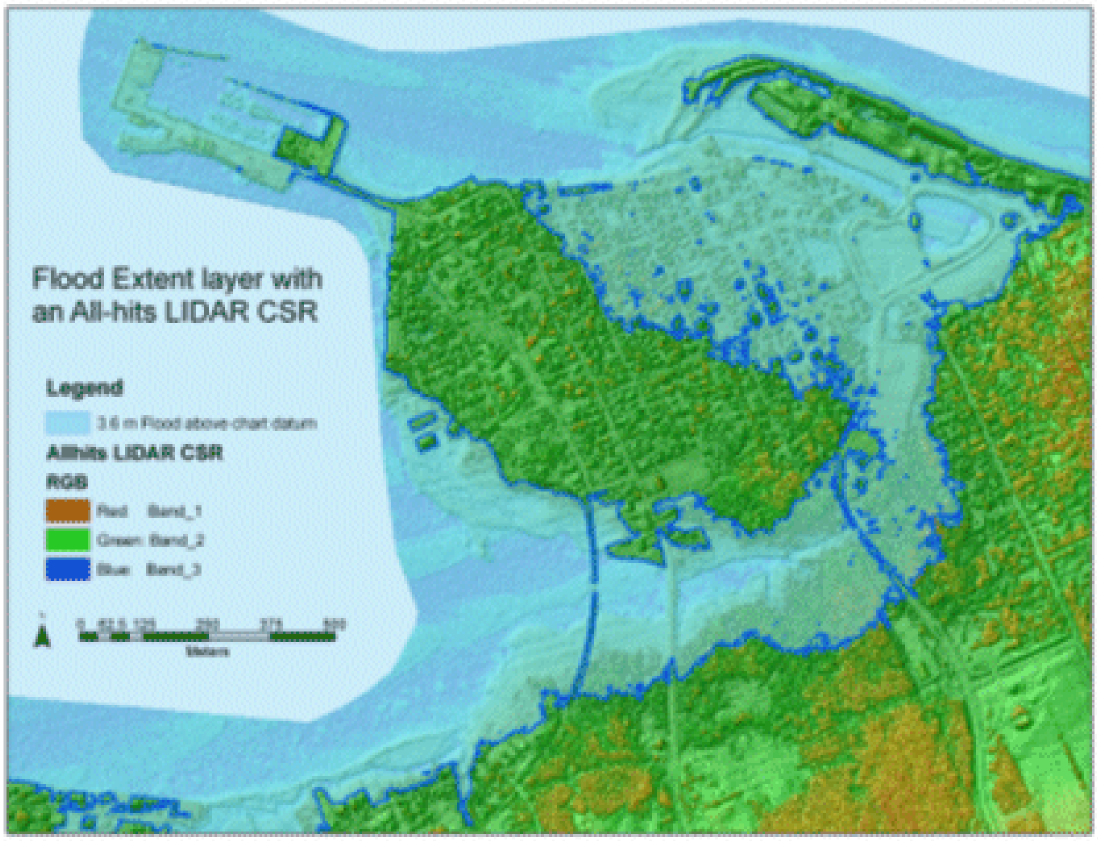


Figure 94 The 3.6 m above CD flood extent layer for the Pointe-de-Chene Area integrated with an allhits LIDAR digital surface Model (Image: E. MacKinnon, AGRG 2004).

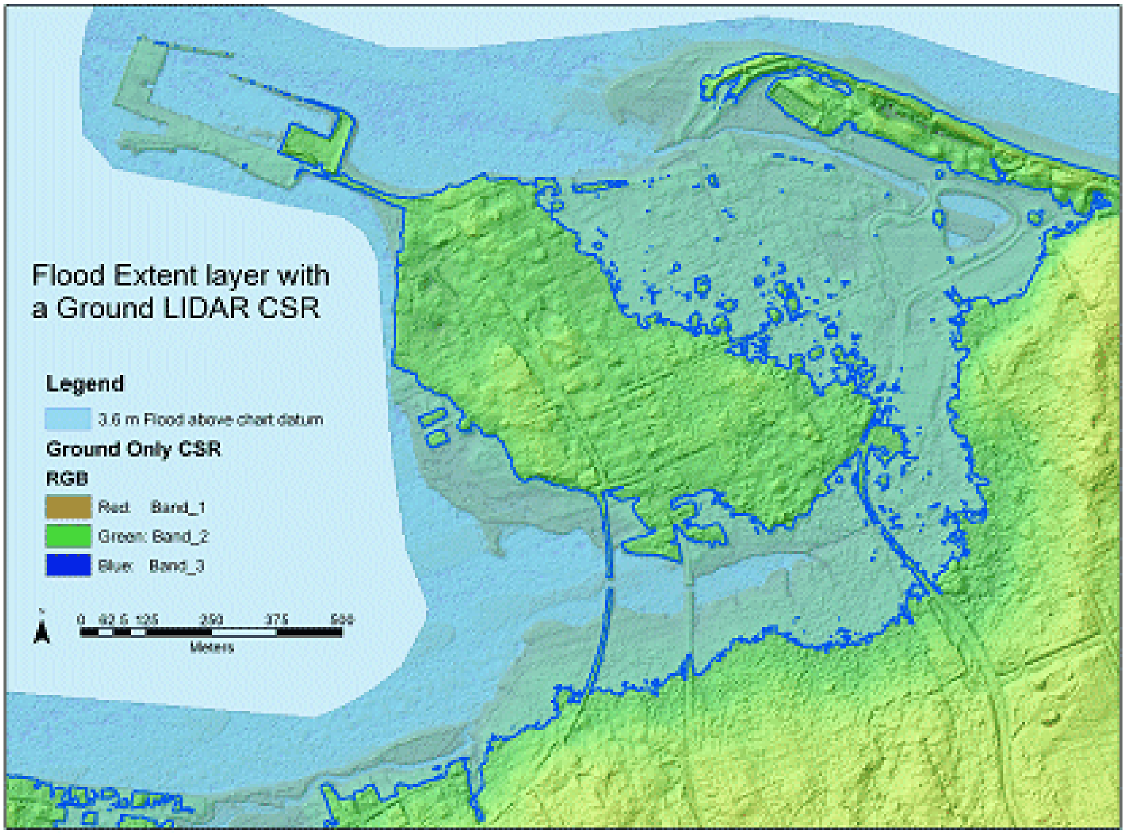


Figure 95 The 3.6 m above CD flood extent layer for the Pointe-de-Chene Area integrated with a Color Shaded Relief created from a ground only DEM (Image: E. MacKinnon, AGRG 2004).

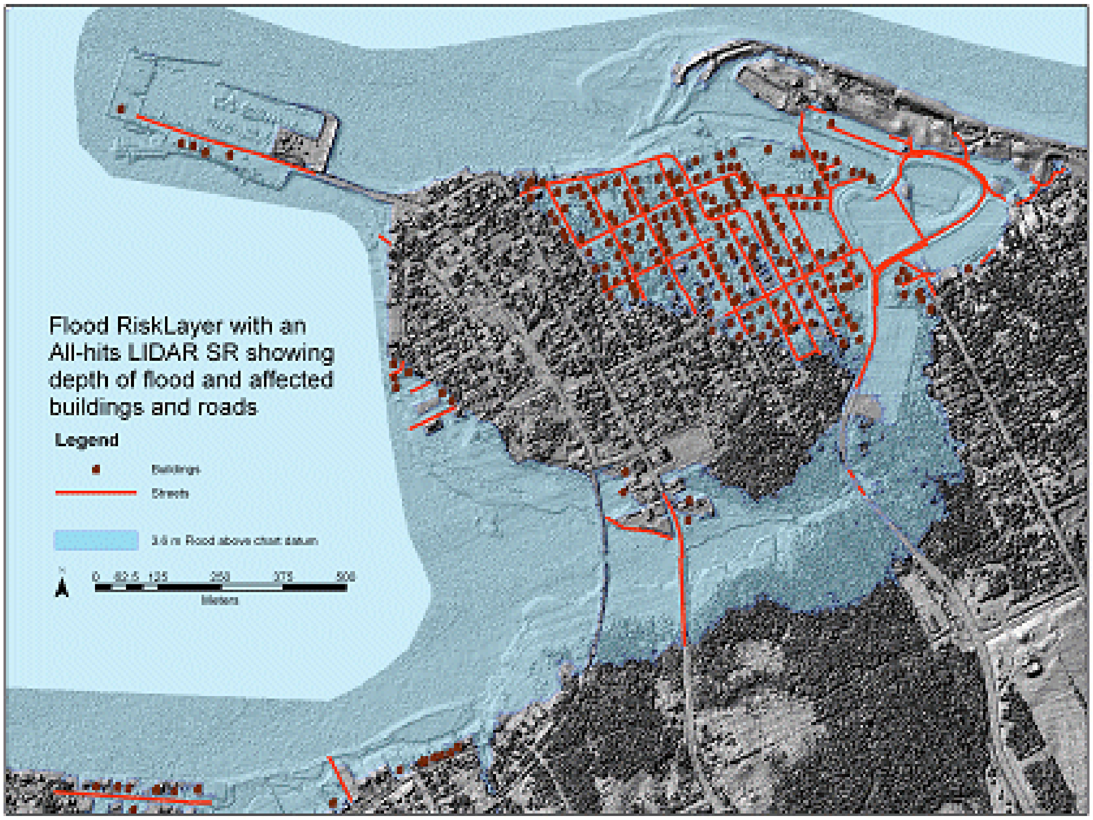


Figure 96 The 3.6 m above CD flood extent layer and the reclassified depth with all buildings that would be affected represented for the Pointe-de-Chene Area integrated with a Shaded Relief Model created from the allhits digital surface model (Image: E. MacKinnon, AGRG 2004).

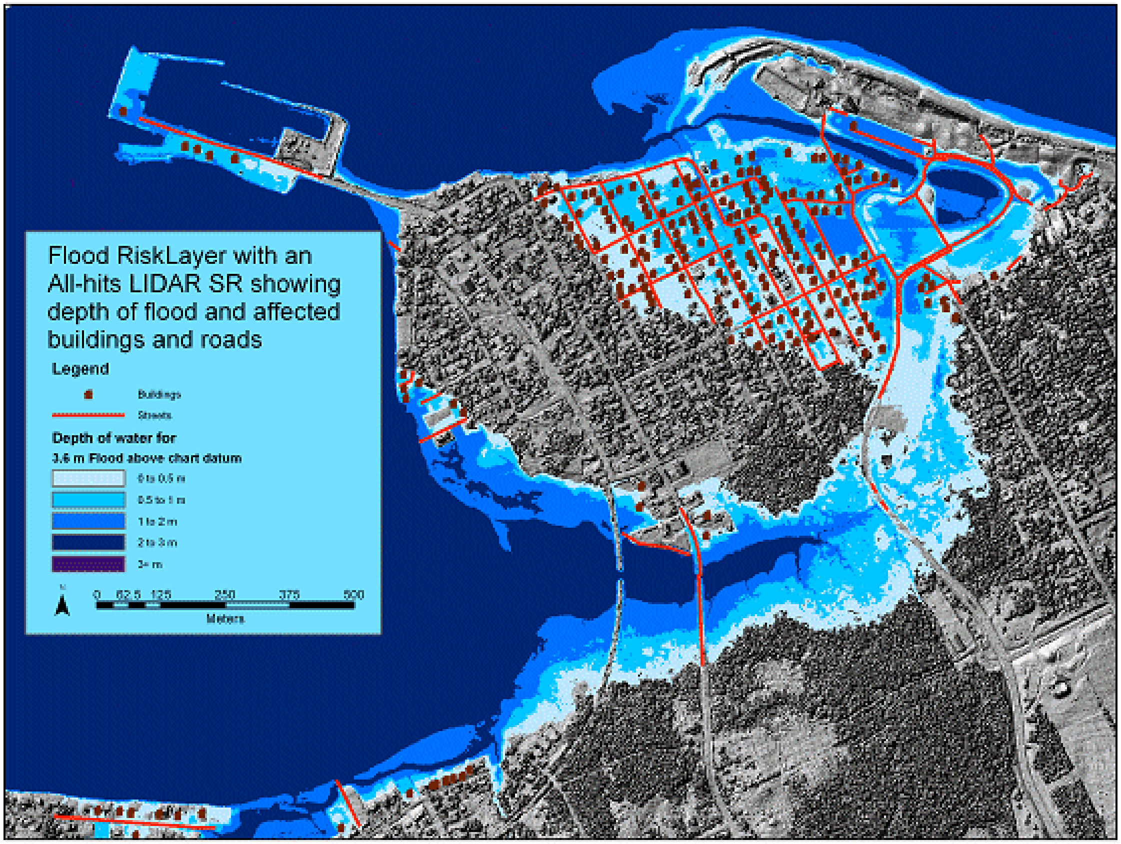


Figure 97 The 3.6 m above CD flood extent layer for the Pointe-de-Chene Area integrated with a Shaded Relief Model created from the allhits digital surface model (Image: E. MacKinnon, AGRG 2004).

Appendix N – 3D Perspective Views

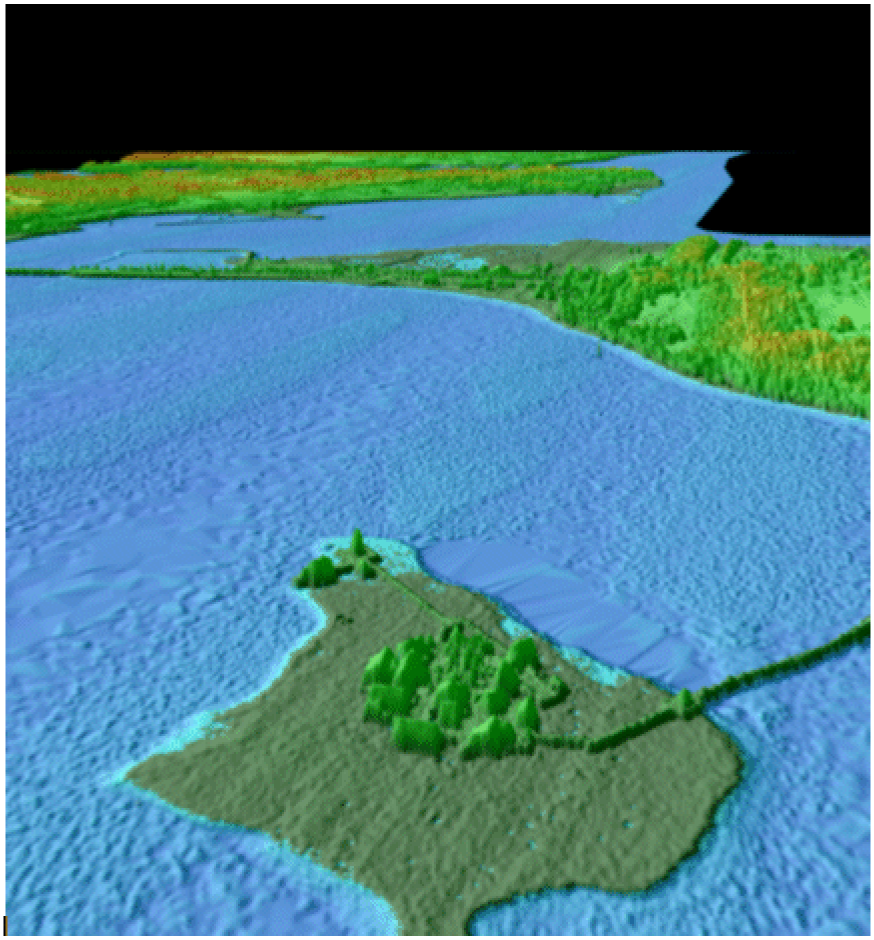


Figure 98 A perspective view (in a north east direction) of the historic site "Le Pays de la Sagouine" located in the Bouctouche LIDAR Block. This area often gets damaged during storm surges and was severely flooded during both the January 21, 2000 and the October 29, 2000 storms (Image: E. MacKinnon, AGRG 2004).

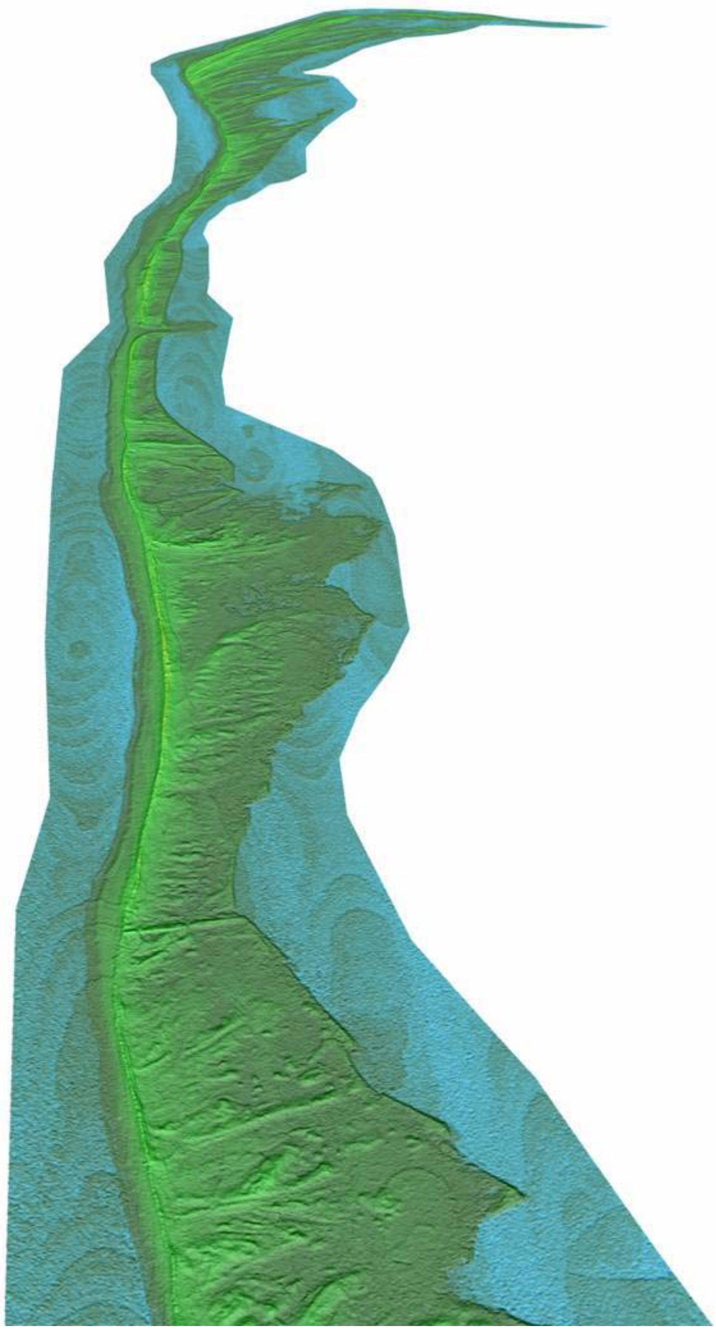


Figure 99 A perspective view (in a south east direction) of the historic “La Dune de Bouctouche”. This area often gets damaged during storm surges and was severely flooded during the October 29, 2000 storm (Image: E. MacKinnon, AGRG 2004).

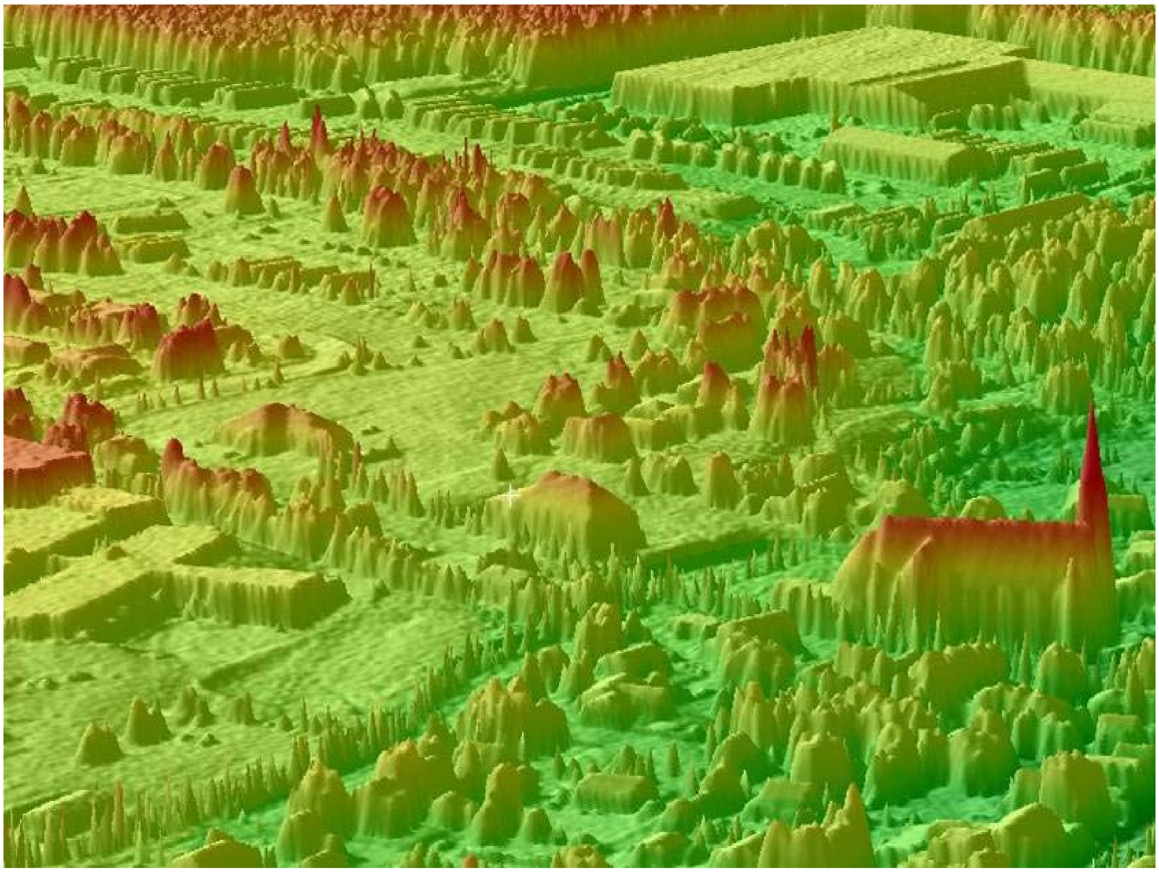


Figure 100 A perspective view (in a north east direction) with ten times exaggeration applied to the Bouctouche Block, A church is clearly visible in the bottom right hand corner of the image (Image: E. MacKinnon, AGRG 2004).

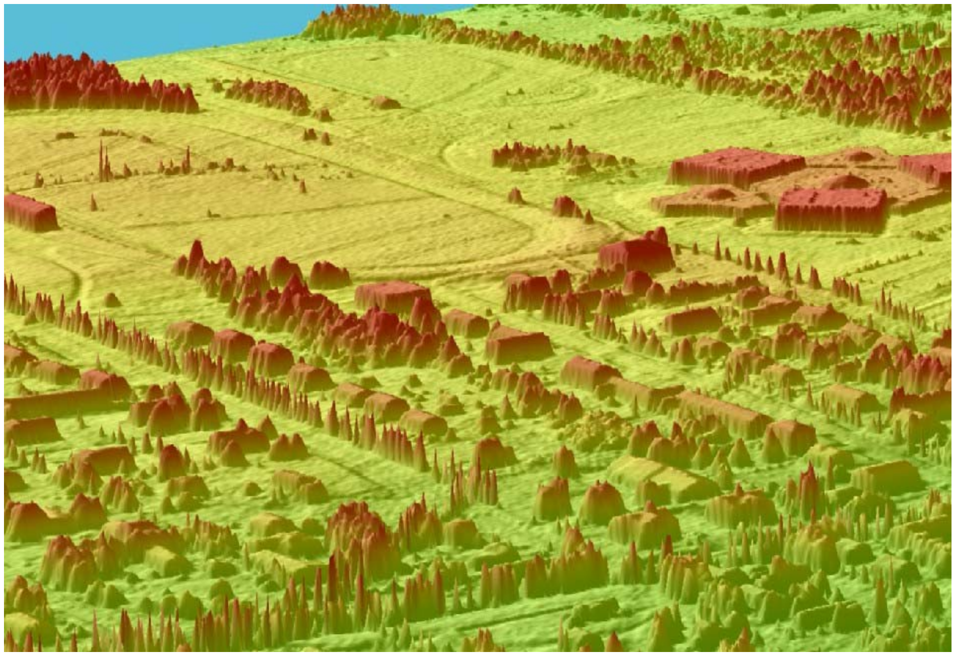


Figure 101 Perspective view (in a north north east direction) with five times exaggeration applied to the Bouctouche Block, highlighting details of buildings, trees and a race track (Image: E. MacKinnon, AGRG 2004).

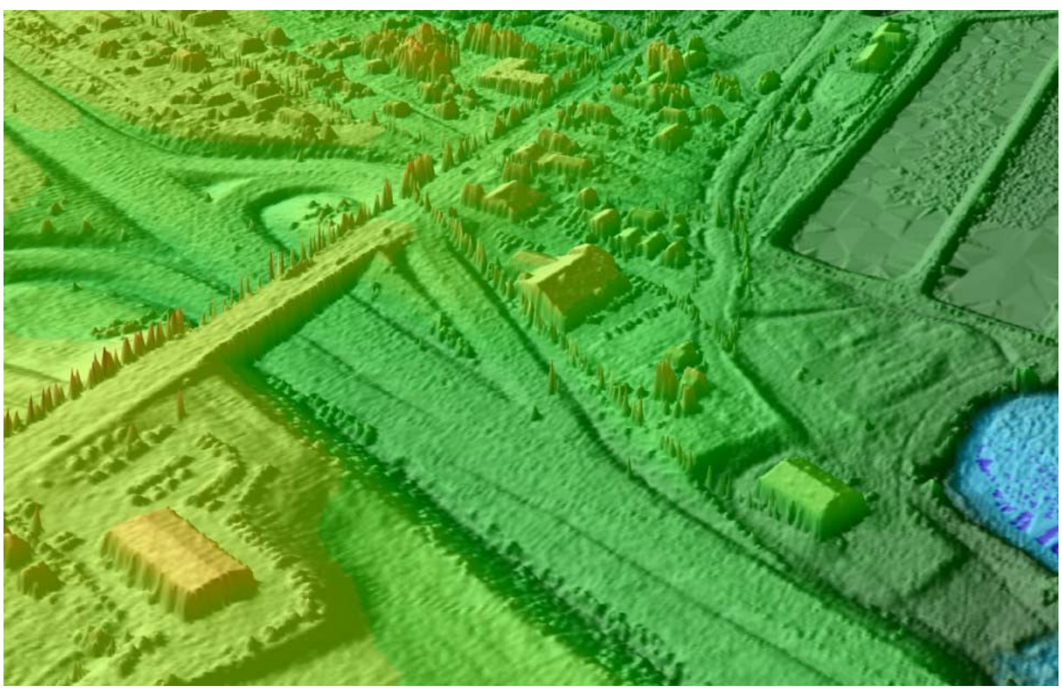


Figure 102 Another perspective view (in a north east direction) with five times exaggeration applied to the Bouctouche Block, highlighting details of buildings, trees and an over pass across the highway (Image: E. MacKinnon, AGRG 2004).

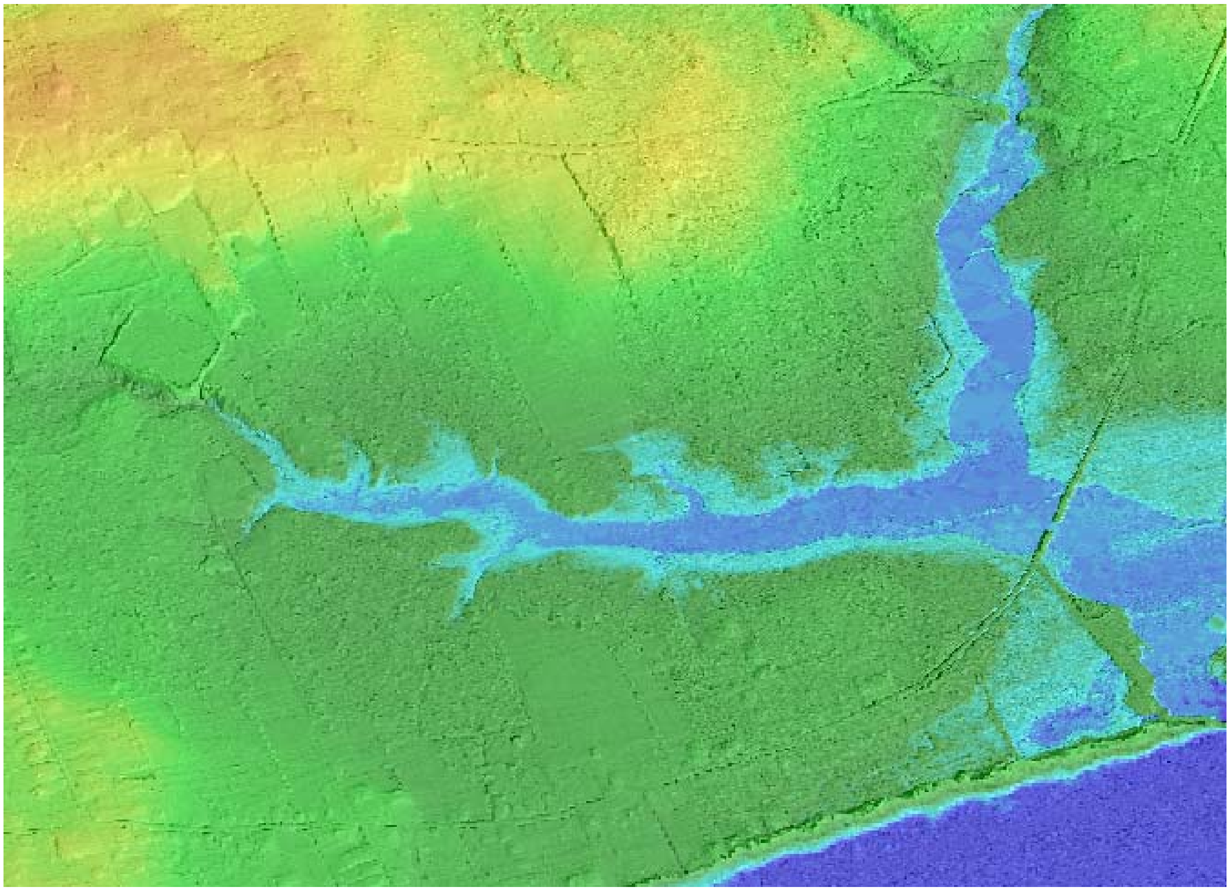


Figure 103 A perspective view (in a south direction) of the Cap Pele area located in the Cap Pele LIDAR Block. This perspective view is of the ground only LIDAR surface with no vertical exaggeration and demonstrates how very little relief that exists in these coastal areas (Image: E. MacKinnon, AGRG 2004).

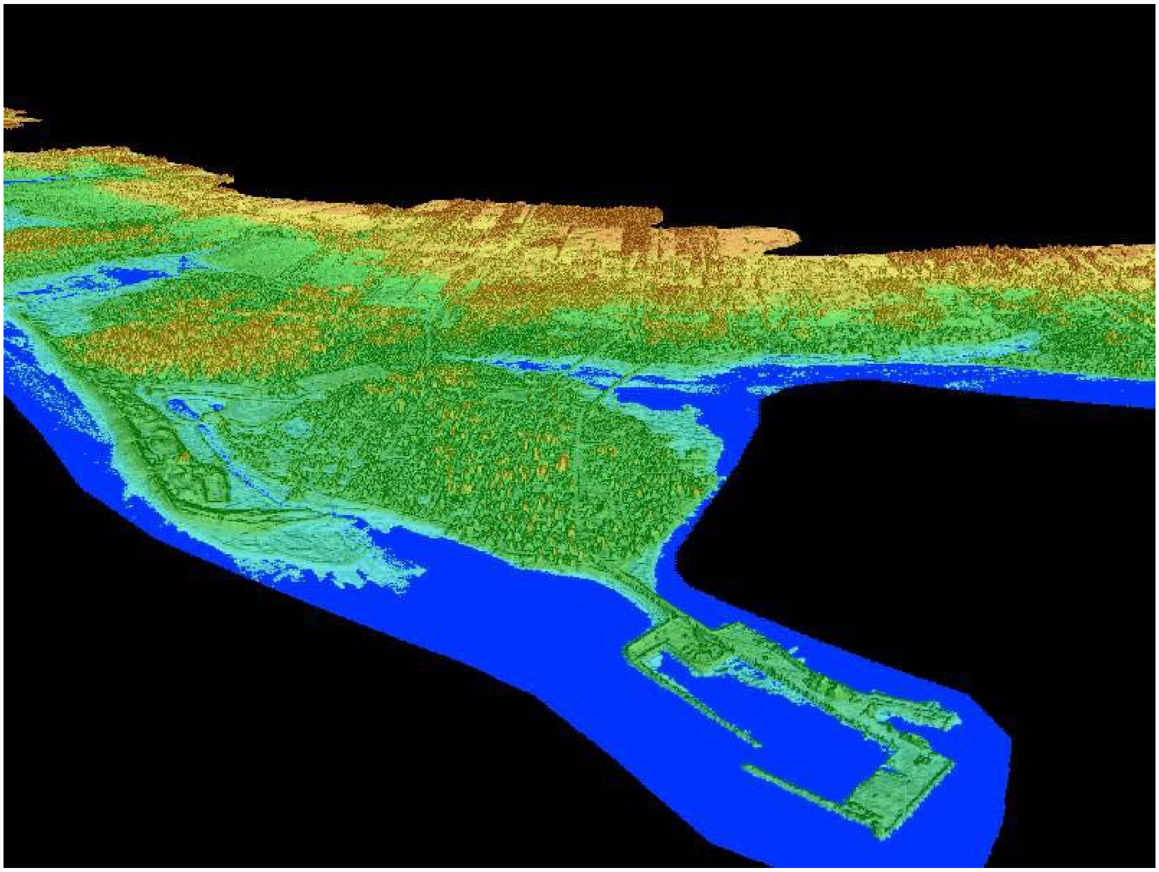


Figure 104 A perspective view (in a south direction) of the Pointe-de-Chene area located in the Cap Pele LIDAR Block. This perspective view was used to create one of the flood animations with this project (Image: E. MacKinnon, AGRG 2004).

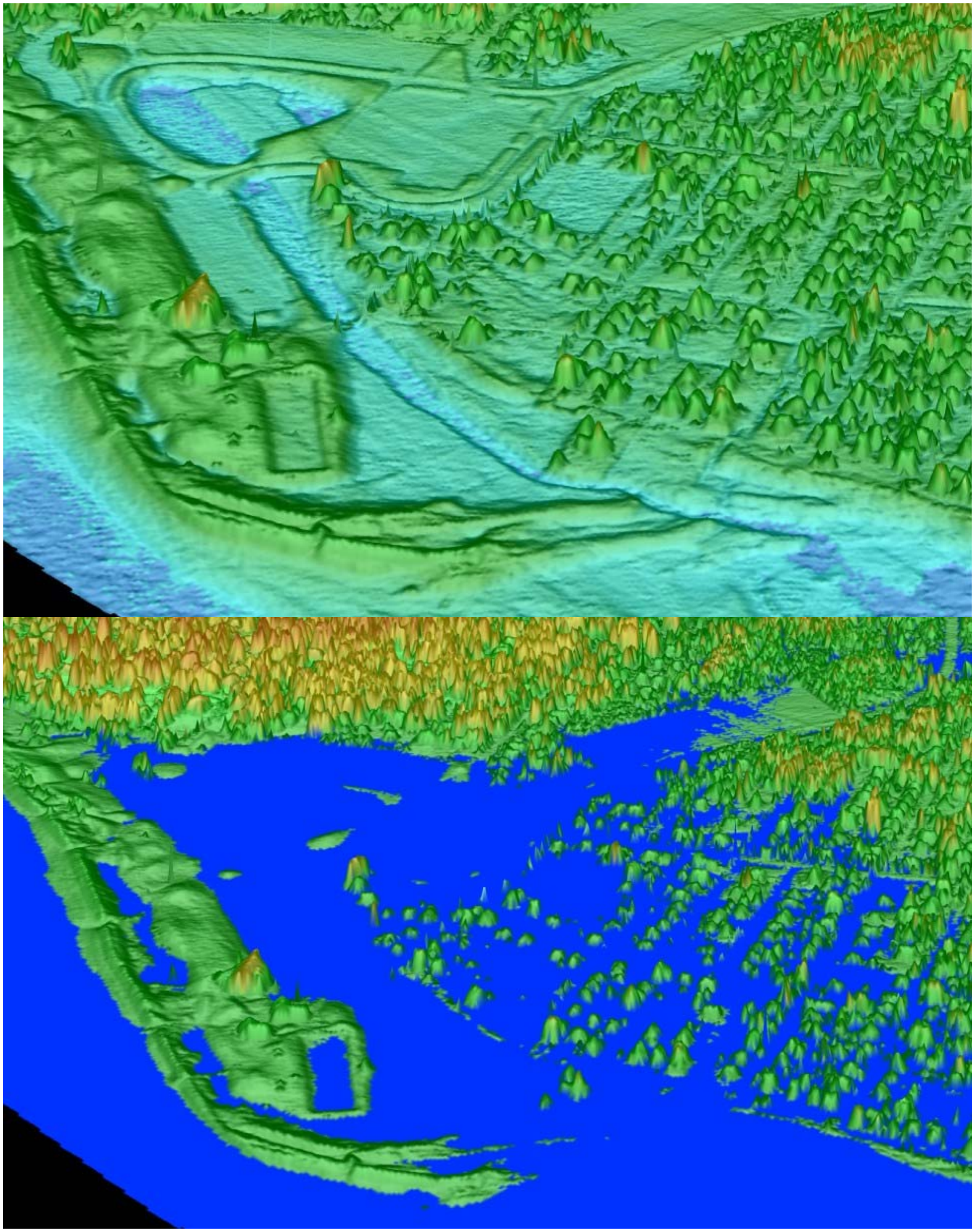


Figure 105 Close up of the perspective views for the Pointe-de-Chene area located in the Cap Pele LIDAR Block. This top image shows a three dimensional model of the Parlee Beach area prior to the January 2000 storm while the bottom image demonstrates the severity that the January 2000 flood had on the area (Image: E. MacKinnon, AGRG 2004).

Appendix O – Posters created for this project

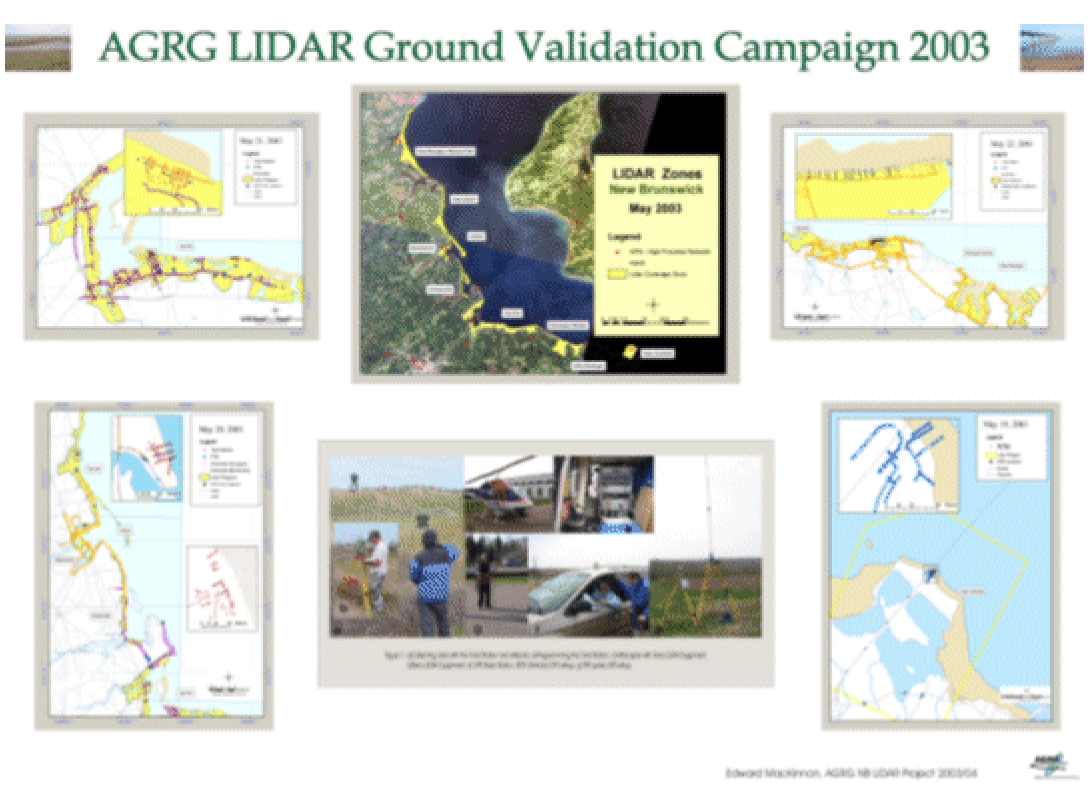


Figure 106 This poster was created August, 2003 to demonstrate the results of the GPS field survey campaign in New Brunswick. A similar poster was also created for the GPS field survey campaign that took place in the Annapolis Valley (Image: E. MacKinnon, AGRG 2003).

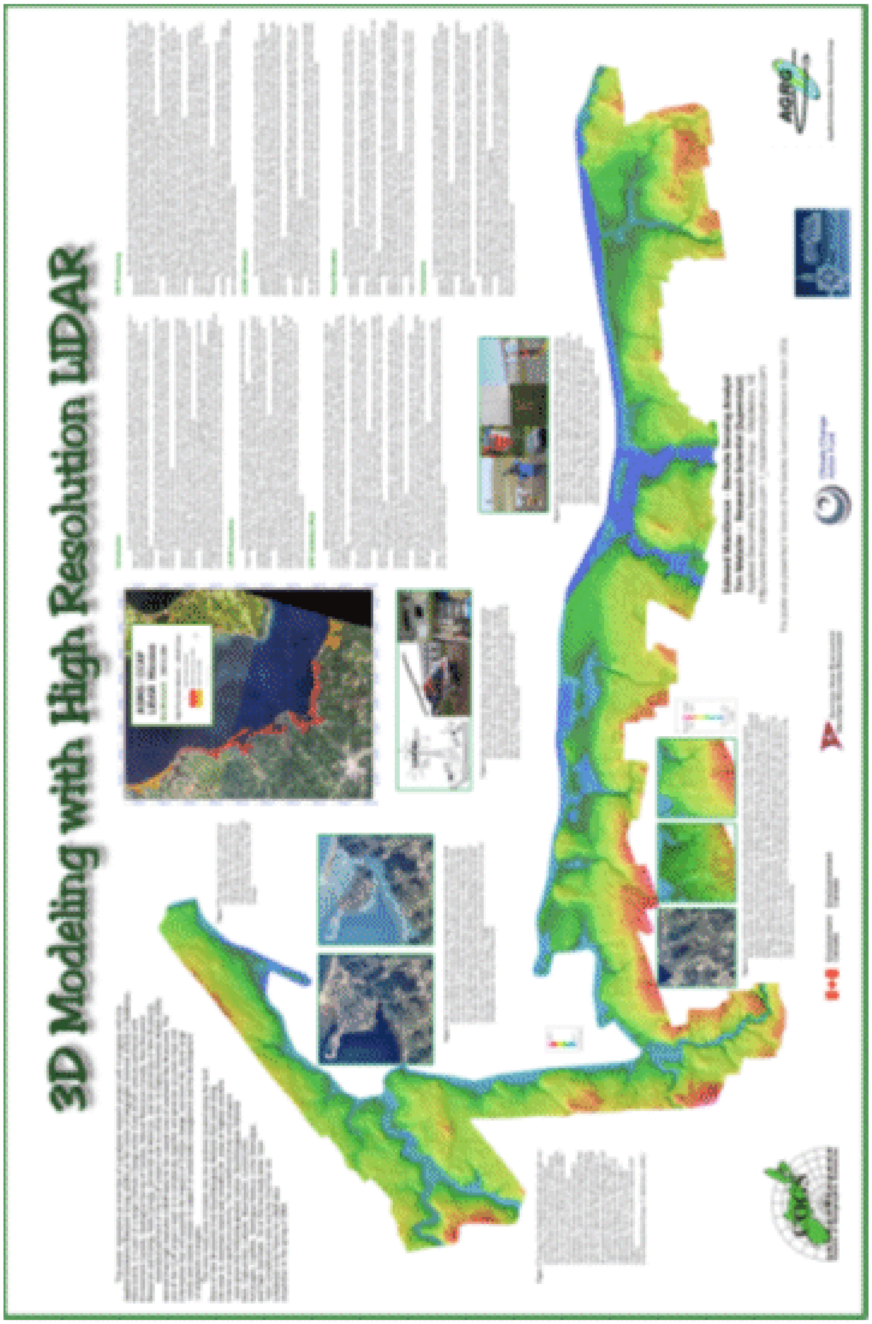


Figure 107 This poster was created March, 2004 and presented at the GeoTech conference that was held in Toronto. It was designed to demonstrate the results of the project to date and to promote the AGRG. (Image: E. MacKinnon, AGRG 2003).

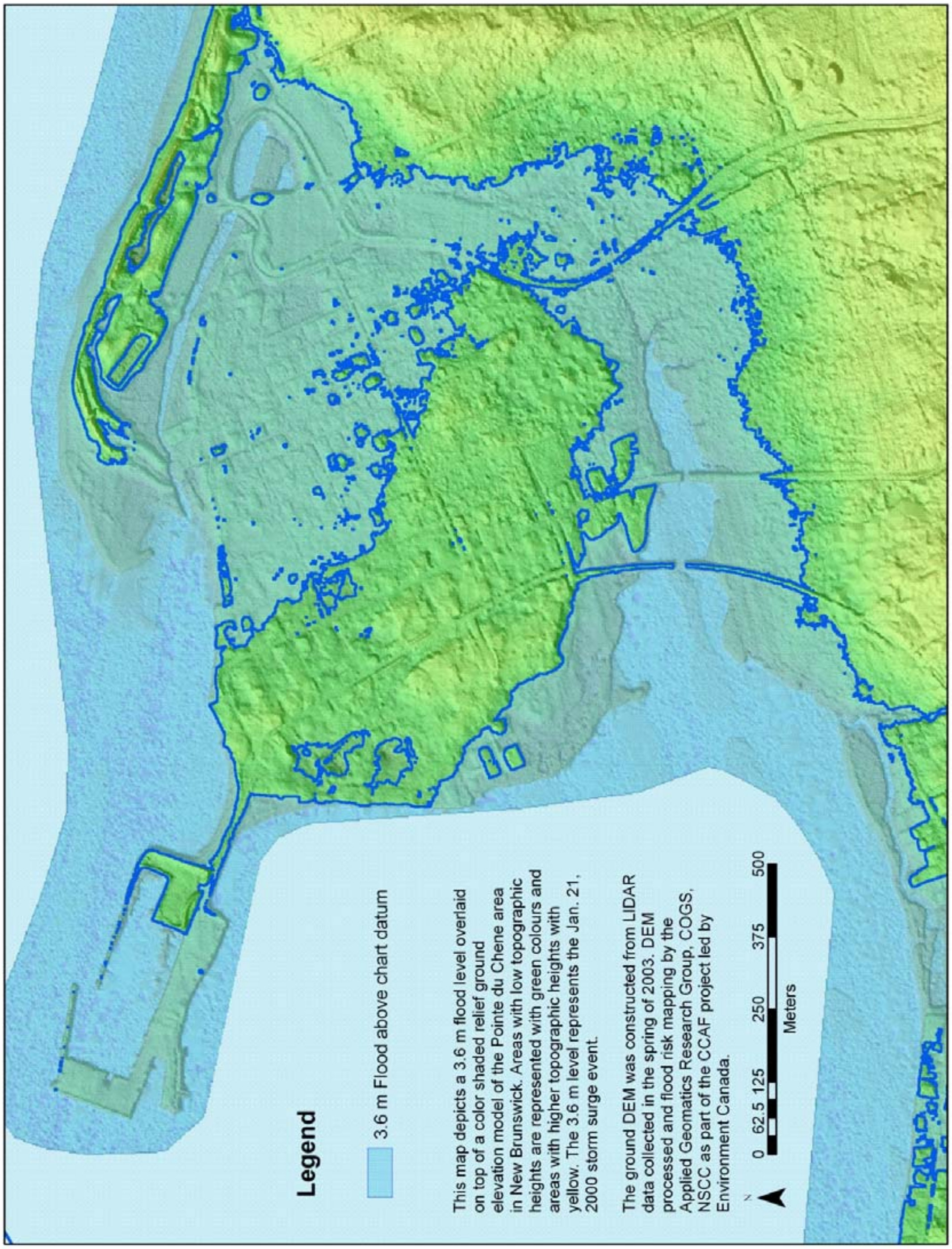


Figure 108 This image was created in March, 2004 for the Environment Canada website (Image: E. MacKinnon, AGRG 2003).

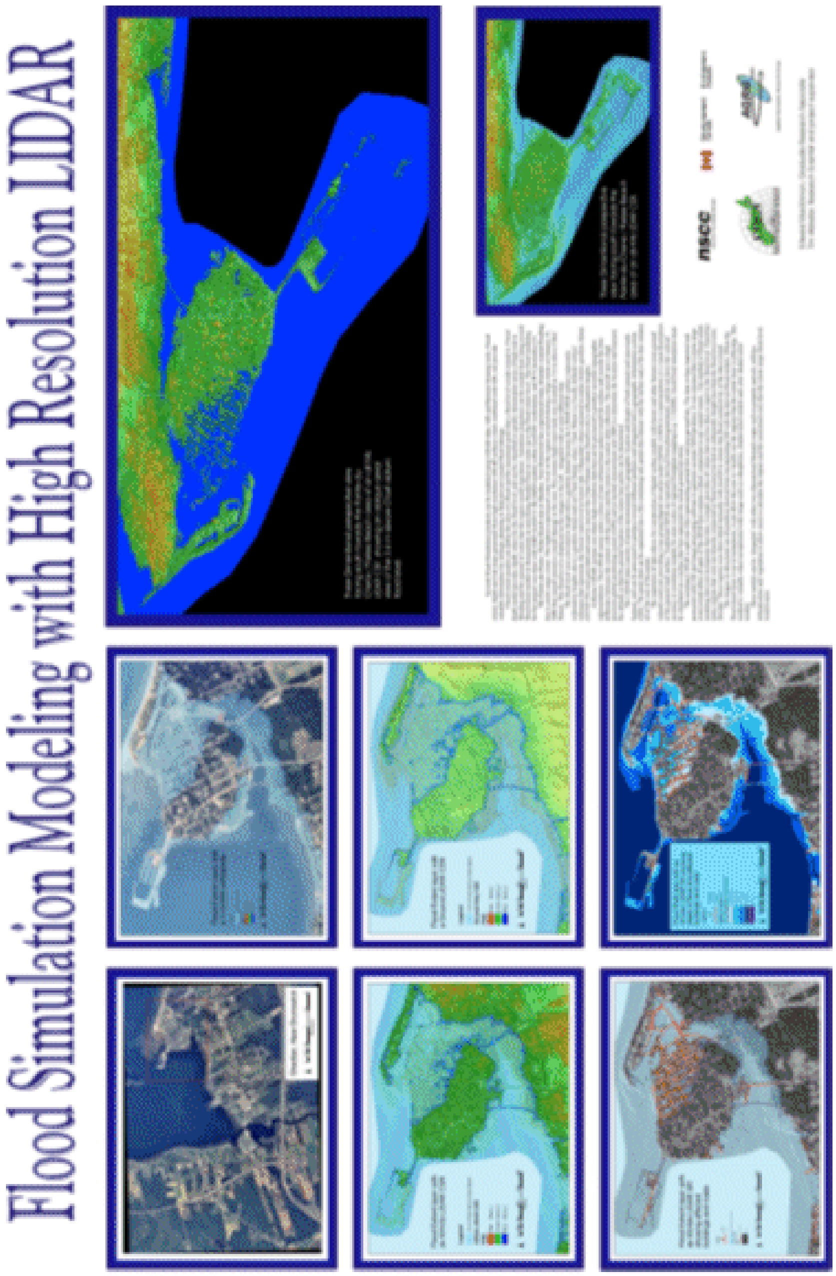


Figure 109 This poster was created May, 2004 and presented at the CCAF meeting at the University of Moncton. It was designed to demonstrate the flooding aspect of the project (Image: E. MacKinnon, AGRG 2003).

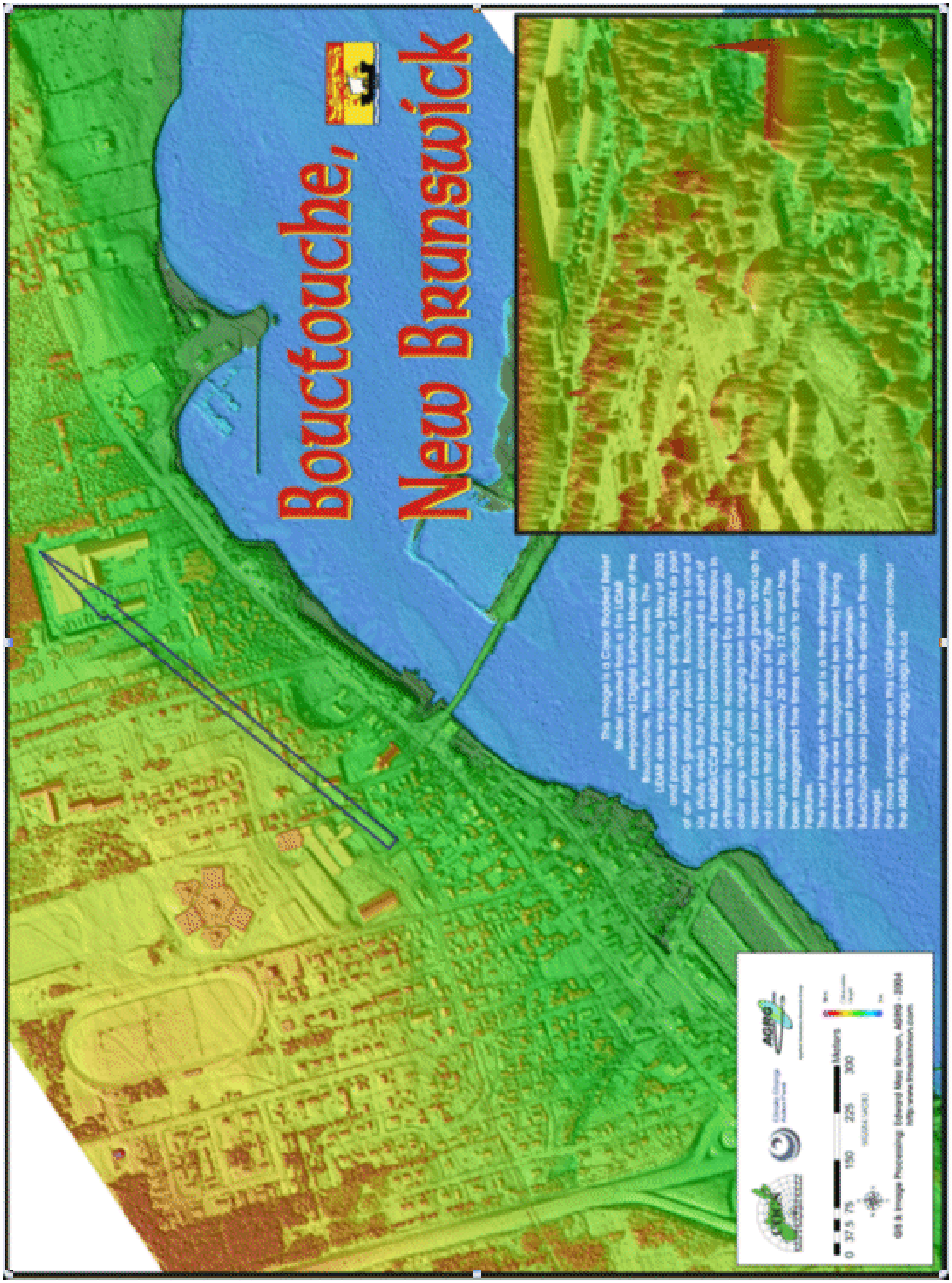
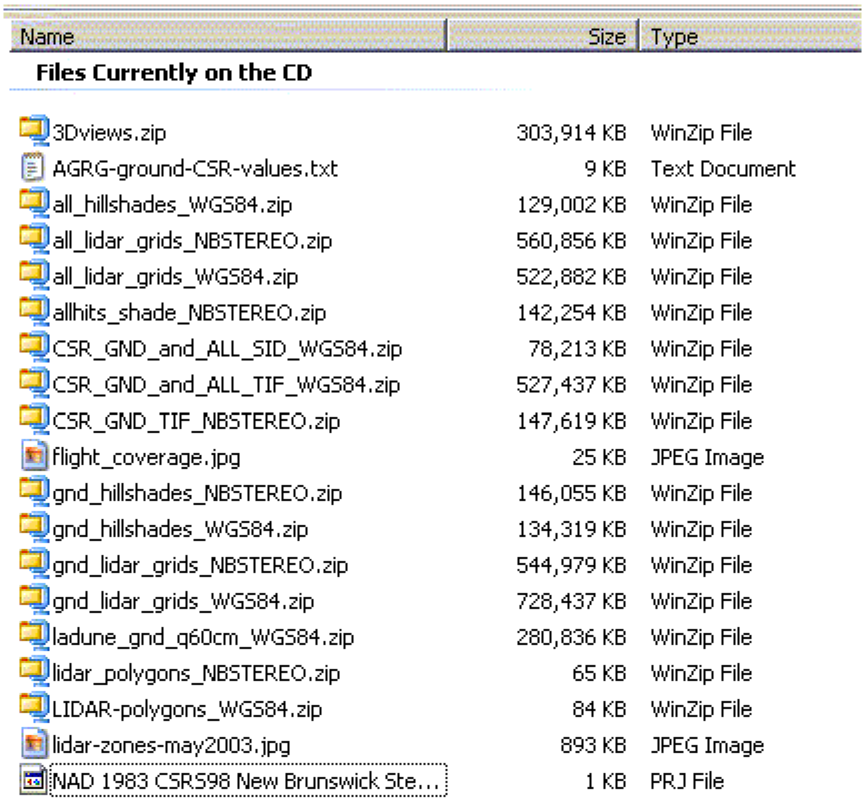


Figure 110 This poster was created May, 2004 to promote CSR and LIDAR at the AGRG. (Image: E. MacKinnon, AGRG 2003).

Figure 111 This is an updated version of the LIDAR zones key map, created May, 2004; the previous version was missing the Cape Jourimain LIDAR block (Image: E. MacKinnon, AGRG 2003).

Appendix P – Contents of NB LIDAR backup Data DVDs



Name	Size	Type
Files Currently on the CD		
3Dviews.zip	303,914 KB	WinZip File
AGRG-ground-CSR-values.txt	9 KB	Text Document
all_hillshades_WGS84.zip	129,002 KB	WinZip File
all_lidar_grids_NBSTEREO.zip	560,856 KB	WinZip File
all_lidar_grids_WGS84.zip	522,882 KB	WinZip File
allhits_shade_NBSTEREO.zip	142,254 KB	WinZip File
CSR_GND_and_ALL_SID_WGS84.zip	78,213 KB	WinZip File
CSR_GND_and_ALL_TIF_WGS84.zip	527,437 KB	WinZip File
CSR_GND_TIF_NBSTEREO.zip	147,619 KB	WinZip File
flight_coverage.jpg	25 KB	JPEG Image
gnd_hillshades_NBSTEREO.zip	146,055 KB	WinZip File
gnd_hillshades_WGS84.zip	134,319 KB	WinZip File
gnd_lidar_grids_NBSTEREO.zip	544,979 KB	WinZip File
gnd_lidar_grids_WGS84.zip	728,437 KB	WinZip File
ladune_gnd_q60cm_WGS84.zip	280,836 KB	WinZip File
lidar_polygons_NBSTEREO.zip	65 KB	WinZip File
LIDAR-polygons_WGS84.zip	84 KB	WinZip File
lidar-zones-may2003.jpg	893 KB	JPEG Image
NAD 1983 CSRS98 New Brunswick Ste...	1 KB	PRJ File

Figure 112 Screen grab image showing the files that are located on the Project backup files DVD1. Below is a more detailed listing showing what files are located within compressed files and folders.

Backup DVD 1 Contents:

3Dviews.zip
- bouctouche3.jpg
- bouctouche4.jpg
- bouctouche.jpg
- Bouctouche-island-3D.tif
- Bouctouche-waterfront-east-3D.tif
- Ladune-southeast-3D.tif
- Shediac-per-3d.tif
- Shediac-per-3d-flood.tif

AGRG-ground-CSR-values.txt

all_hillshades_WGS84.zip
- bouct_sh_all *(ESRI GRID)*
- cappeleallshd *(ESRI GRID)*
- cocagne_allsh *(ESRI GRID)*
- cormier_allsh *(ESRI GRID)*
- ladune_allsh *(ESRI GRID)*
- lumiere_allsh *(ESRI GRID)*

all_lidar_grids_NBSTEREO.zip
- bouctoucheall *(ESRI GRID)*
- caplumiereall *(ESRI GRID)*
- cappeleall *(ESRI GRID)*
- cocagneall *(ESRI GRID)*
- cormierall *(ESRI GRID)*
- laduneall *(ESRI GRID)*

all_lidar_grids_WGS84.zip
- bouctoucheall *(ESRI GRID)*
- caplumiereall *(ESRI GRID)*
- cappele_all *(ESRI GRID)*
- cocagneall *(ESRI GRID)*
- cormierall *(ESRI GRID)*
- laduneall *(ESRI GRID)*

allhits_shade_NBSTEREO.zip
- bouct_sh_all *(ESRI GRID)*
- cappeleallshd *(ESRI GRID)*
- cocagne_allsh *(ESRI GRID)*
- cormier_allsh *(ESRI GRID)*
- ladune_allsh *(ESRI GRID)*
- lumiere_allsh *(ESRI GRID)*

CSR_GND_and_ALL_SID_WGS84.zip
- Allhits-SIDS
  - bouctouche-all-csr-b.sid
  - bouctouche-all-csr-w.sid
  - bouctouche-all-old.sid
  - caplumiere-all-csr-b.sid
  - caplumiere-all-csr-w.sid
  - cappele-all-csr-b.sid
  - cappele-all-csr-w.sid
  - cocagne-all-csr.sid
  - cocagne-all-csr-b2.sid
  - cocagne-all-csr-w.sid
  - cormierville-all-csr-b.sid
  - cormierville-all-csr-w.sid
  - laduneall-csr-b.sid
  - laduneall-csr-w.sid
  - ladune-csr-b.sid
  - ladune-csr-w.sid
- GND-SIDS
  - bouctouche-csr-b.sid
  - bouctouche-csr-w.sid
  - caplumiere-1m-dsm.sid
  - caplumiere-csr-b.sid
  - caplumiere-csr-w.sid
  - cappele-csr-w.sid
  - cocagne-csr-b1.sid
  - cocagne-csr-b.sid
  - cocagne-csr-w.sid
  - cormierville-csr-b.sid
  - cormierville-csr-w.sid
- old-copys.zip (older copies of the above SID files)

CSR_GND_and_ALL_TIF_WGS84.zip
- Allhits_CSR
  - Bouctouche-all-CSR-b.tif
  - Bouctouche-all-CSR-w.tif
  - CapLumiere-all-CSR-b.tif
  - CapLumiere-all-CSR-w.tif
  - Cappele-all-CSR-b.tif
  - Cappele-all-CSR-w.tif
  - Cocagne-all-CSR-b2.tif
  - Cocagne-all-CSR-w.tif
  - Cormierville-all-CSR-b.tif
  - Cormierville-all-CSR-w.tif
  - laduneall-CSR-b.tif
  - laduneall-CSR-w.tif
- Ground_CSR
  - Bouctouche-CSR-b.tif
  - Bouctouche-CSR-w.tif
  - CapLumiere-CSR-b.tif
  - CapLumiere-CSR-w.tif
  - Cappele-CSR-w.tif
  - Cocagne-CSR-b.tif
  - Cocagne-CSR-w.tif
  - Cormierville-CSR-b.tif

Cormierville-CSR-w.tif
Ladune-CSR-b.tif
Ladune-CSR-w.tif

CSR_GND_TIF_NBSTEREO.zip
- Bouctouche-CSR-NB.tif
- CapLumiere-CSR-NB.tif
- CapPele-CSR-NB.tif
- Cocagne-CSR-NB.tif
- Cormierville-CSR-NB.tif
- Ladune-CSR-NB.tif

flight_coverage.jpg

gnd_hillshades_NBSTEREO.zip
- ground_shade
  - bouctouche_sh *(ESRI GRID)*
  - caplumiere_sh *(ESRI GRID)*
  - cappele_sh *(ESRI GRID)*
  - cocagne_sh *(ESRI GRID)*
  - cormier_sh *(ESRI GRID)*
  - ladune_sh *(ESRI GRID)*

gnd_hillshades_WGS84.zip
- gnd_hillshades
  - bouctouche_sh *(ESRI GRID)*
  - caplumiere_sh *(ESRI GRID)*
  - cappele_sh *(ESRI GRID)*
  - cocagne_sh *(ESRI GRID)*
  - cormier_sh *(ESRI GRID)*
  - ladune_sh *(ESRI GRID)*

gnd_lidar_grids_NBSTEREO.zip
- ground_dem
  - Bouctouche *(ESRI GRID)*
  - caplumiere *(ESRI GRID)*
  - cappele *(ESRI GRID)*
  - cocagne *(ESRI GRID)*
  - cormier *(ESRI GRID)*
  - ladune *(ESRI GRID)*

gnd_lidar_grids_WGS84.zip
- gnd_grids
  - bouctouche *(ESRI GRID)*
  - caplumiere *(ESRI GRID)*
  - cappele *(ESRI GRID)*
  - cocagne *(ESRI GRID)*
  - cormierville *(ESRI GRID)*
  - cormwharf1 *(ESRI GRID)*
  - cormwharf2 *(ESRI GRID)*
  - ladune *(ESRI GRID)*
  - lumwharf1 *(ESRI GRID)*
  - lumwharf2 *(ESRI GRID)*
  - shediac *(ESRI GRID)*

ladune_gnd_q60cm_WGS84.zip
- laduneq60cm *(ESRI GRID)*

lidar_polygons_NBSTEREO.zip
- lidar_polygons
  - bouctouche2
  - cap_lumiere2
  - cap_pele2
  - cormierville2
  - ille_cocagne2
  - ladune2
  - Bouctouche.shp
  - Cap_Lumiere.shp
  - Cap_Pele.shp
  - Cape_Jourimain.shp
  - Cormierville.shp
  - Ille_Cocagne.shp
  - Kouchibouguac.shp
  - Ladune.shp

Little_Shemogue.shp
Shemogue_Harbour.shp

LIDAR-polygons_WGS84.zip
- LIDAR-polygons
  - Bouctouche.shp
  - CapLumiere.shp
  - CapPele.shp
  - Cormierville.shp
  - IleCocagne.shp
  - LaDune.shp
  - Clipcovs
    - Bouctclip *(ESRI coverage)*
    - cocagneclip2 *(ESRI coverage)*
    - cormierclip *(ESRI coverage)*
    - laduneclip *(ESRI coverage)*
    - lumiereclip *(ESRI coverage)*
    - peleclip *(ESRI coverage)*
    - clip_polygon_shapefiles
      - Bouctouche2004.shp
      - CapLumiere2004.shp
      - CapPele2004.shp
      - Cocagne2004.shp
      - Cormier2004.shp
      - Ladune2004.shp

lidar-zones-may2003.jpg
NAD 1983 CSRS98 New Brunswick Stereographic.prj

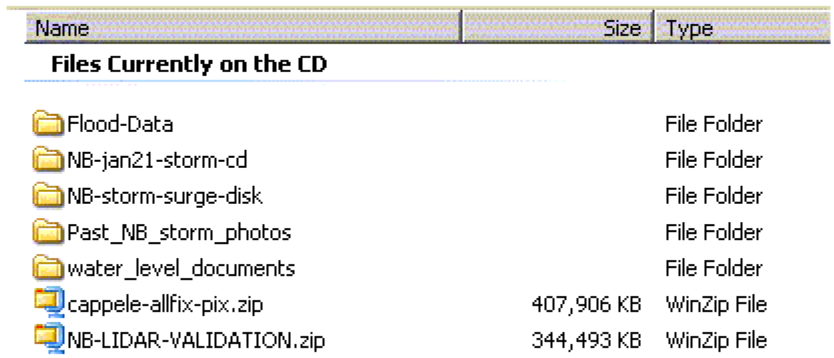


Figure 113 Screen grab image showing the files that are located on the Project backup files DVD2. Below is a more detailed listing showing what files are located within compressed files and folders.

Backup DVD 2 Contents:

- Flood-Data
  - flood_animimation.zip
    - Bouctouche0to5m.avi
    - Bouctouche-tifs.zip
    - Ladune0to2m.avi
    - Ladune-tifs.zip
    - Pntdechene0to5m.avi
    - Pntdechene0to5m.MPG
    - Pointe-de-Chene-tifs.zip
    - Shediac0to5m.avi
    - ShediacBridge-tifs.zip
  - Flood-data.xls
  - Flood-data-temp.xls
  - nb_cent_flood_NBSTEREO.zip
    - c_flood286 *(ESRI GRID)*
    - c_flood336 *(ESRI GRID)*
    - c_flood356 *(ESRI GRID)*
    - nbc_d_286_rc *(ESRI GRID)*
    - nbc_d_336_rc *(ESRI GRID)*
    - nbc_d_356_rc *(ESRI GRID)*
    - nbc_depth286 *(ESRI GRID)*
    - nbc_depth336 *(ESRI GRID)*
    - nbc_depth356 *(ESRI GRID)*
    - nbc1_286_shp.shp
    - nbc1_336_shp.shp
    - nbc1_356_shp.shp
  - NB_Cent_flood_WGS84.zip
    - flood_depth.zip
      - nbc_d_286_rc *(ESRI GRID)*
      - nbc_d_336_rc *(ESRI GRID)*
      - nbc_d_356_rc *(ESRI GRID)*
      - nbc_depth286 *(ESRI GRID)*
      - nbc_depth336 *(ESRI GRID)*
      - nbc_depth356 *(ESRI GRID)*
    - flood_extents.zip
      - c_flood286 *(ESRI GRID)*
      - c_flood336 *(ESRI GRID)*
      - c_flood356 *(ESRI GRID)*
      - nbc1_286_shp.shp
      - nbc1_336_shp.shp

nbc1_356_shp.shp

nb_north_flood_NBSTEREO.zip

bouc_fd_290 *(ESRI GRID)*
bouc_fd_340 *(ESRI GRID)*
bouc_fd_360 *(ESRI GRID)*
bouc_fe_290 *(ESRI GRID)*
bouc_fe_340 *(ESRI GRID)*
bouc_fe_360 *(ESRI GRID)*
bouc_frc_290 *(ESRI GRID)*
bouc_frc_340 *(ESRI GRID)*
bouc_frc_360 *(ESRI GRID)*
flood_290.shp
flood_340.shp
flood_360.shp
lad_fd_290 *(ESRI GRID)*
lad_fd_340 *(ESRI GRID)*
lad_fd_360 *(ESRI GRID)*
lad_fe_290 *(ESRI GRID)*
lad_fe_340 *(ESRI GRID)*
lad_fe_360 *(ESRI GRID)*
lad_frc_290 *(ESRI GRID)*
lad_frc_340 *(ESRI GRID)*
lad_frc_360 *(ESRI GRID)*
lum_fd_290 *(ESRI GRID)*
lum_fd_340 *(ESRI GRID)*
lum_fd_360 *(ESRI GRID)*
lum_fe_290 *(ESRI GRID)*
lum_fe_340 *(ESRI GRID)*
lum_fe_360 *(ESRI GRID)*
lum_frc_290 *(ESRI GRID)*
lum_frc_340 *(ESRI GRID)*
lum_frc_360 *(ESRI GRID)*

NB_North_flood_WGS84.zip

bouct_flood.zip

bctflood2_60 *(ESRI coverage)*
bctflood2_90 *(ESRI coverage)*
bctflood3_10 *(ESRI coverage)*
bctflood3_20 *(ESRI coverage)*
bctflood3_30 *(ESRI coverage)*
bctflood3_40 *(ESRI coverage)*
bctflood3_60 *(ESRI coverage)*
bctflood3_70 *(ESRI coverage)*
bctflood3_90 *(ESRI coverage)*
bt290 *(ESRI GRID)*
bt340 *(ESRI GRID)*
BTFlood2_60.shp
BTFlood2_90.shp
BTFlood3_10.shp
BTFlood3_20.shp
BTFlood3_30.shp
BTFlood3_40.shp
BTFlood3_60.shp
BTFlood3_70.shp
BTFlood3_90.shp
floodbt2_60 *(ESRI GRID)*
floodbt2_90 *(ESRI GRID)*
floodbt3_20 *(ESRI GRID)*
floodbt3_30 *(ESRI GRID)*
floodbt3_40 *(ESRI GRID)*
floodbt3_60 *(ESRI GRID)*
floodbt3_70 *(ESRI GRID)*
floodbt3_90 *(ESRI GRID)*

flood_depth.zip

nb1_d_290_rc *(ESRI GRID)*
nb1_d_340_rc *(ESRI GRID)*
nb1_d_360_rc *(ESRI GRID)*
nbn_depth290 *(ESRI GRID)*
nbn_depth340 *(ESRI GRID)*
nbn_depth360 *(ESRI GRID)*

- - - flood_extents.zip
        - flood_290.shp
        - flood_340.shp
        - flood_360.shp
        - n_flood_290 *(ESRI GRID)*
        - n_flood_340 *(ESRI GRID)*
        - n_flood_360 *(ESRI GRID)*
  - NB_South_flood_WGS84.zip
    - Cappele
      - cappele-flood-data.zip
        - cp_d_290s.shp
        - cp_d_340s.shp
        - cp_d_360s.shp
      - flood_depth.zip
        - cp_d_290 *(ESRI GRID)*
        - cp_d_340 *(ESRI GRID)*
        - cp_d_360 *(ESRI GRID)*
      - flood_extent.zip
        - cp_ext_c_290 *(ESRI coverage)*
        - cp_ext_c_340 *(ESRI coverage)*
        - cp_ext_c_360 *(ESRI coverage)*
        - cp_ext_290 *(ESRI GRID)*
        - cp_ext_340 *(ESRI GRID)*
        - cp_ext_360 *(ESRI GRID)*
    - Shediac
      - flood_depth.zip
        - sheddepth255 *(ESRI GRID)*
        - sheddepth305 *(ESRI GRID)*
        - sheddepth325 *(ESRI GRID)*
        - shediac_255rc *(ESRI GRID)*
        - shediac_305rc *(ESRI GRID)*
        - shediac_325rc *(ESRI GRID)*
      - flood_extent.zip
        - sh_flood2_55.shp
        - sh_flood3_05.shp
        - sh_flood3_25.shp
        - shediac_255 *(ESRI GRID)*
        - shediac_305 *(ESRI GRID)*
        - shediac_325 *(ESRI GRID)*
  - SE-NB_levels.doc
  - shediac_flood_NB_STEREO.zip
    - sh_depth_255 *(ESRI GRID)*
    - sh_depth_305 *(ESRI GRID)*
    - sh_depth_325 *(ESRI GRID)*
    - sh_flood_255e.shp
    - sh_flood_305e.shp
    - sh_flood_325e.shp
    - shediac255e *(ESRI GRID)*
    - shediac255rc2 *(ESRI GRID)*
    - shediac305e *(ESRI GRID)*
    - shediac325e *(ESRI GRID)*
    - shediac_305rc *(ESRI GRID)*
    - shediac_325rc *(ESRI GRID)*
- NB-jan21-storm-cd *(Contents of GSC CDROM)*
- NB-storm-surge-disk *(Contents of GSC CDROM)*
- Past_NB_storm_photos *(JPGs from Town of Shediac)*
- water_level_documents
  - NB_Flood-data.xls
  - SE-NB_levels_rpt2.doc
- cappele-allfix-pix.zip
  - cappele-allfix.pix
- NB-LIDAR-VALIDATION.zip
  - Kinematic_RTK_and_total_station
    - database files
    - Kinematic

shape_files *(GPS data in shape format)*
kinematic-validation-points-2003.mxd

Raw_data

Base-data

Kinematic

May20_kin_am_Buctouche
May20_kin_pm_Cocagne
May20Cocagne_Kin_fixed
May21_kin_Edget
may21Edgett_Kin_fixed
May22_kin_Cap_Pele

Leica_Cards *(raw data from GPS cards)*

Original-photos *(all original jpg files from digital cameras)*

Processed_GPS

RTK

May19_RTK_Cape_Jourimain_T1
May19_RTK_Cape_Jourimain_T2
may19SC07_RTK_fixed
may19SC07_RTK_T2_fixed
May20_RTK_am_Buctouche
May20_RTK_pm_Cocagne
May20Cocagne_RTK_fixed
May21_RTK_Edgett
may21Edgett_RTK_fixed
May22_RTK_Cap_Pele
SC07_RTK_2_Rovers_fixed

total_station

May20_Total_Station
May21_Total_Station
May22_Total_Station

RTK

shape_files *(GPS data in shape format)*

00-RTK-validation-points-2003.mxd *(mxd file is setup to hotlink photos)*

(plus all related photos)

TotalStation

shape_files *(GPS data in shape format)*

00-TS-validation-points-2003.mxd *(mxd file is setup to hotlink photos)*

(plus all related photos)

LIDAR-VALIDATE-HIST (JPGs of histograms created by AML)
cap-lumiere.mxd
CapPele-validation.mxd
gnd365_5191.xls
LIDAR-Points-validation.ppt
lidar-tiles-investigate.mxd
LIDARValidation-woodgrain.ppt
NBLIDAR-DEM-validation-results.xls
NB-lidar-zones-missing.ppt
NB-validate-update.xls
resolution_of_grids.xls

Name	Size	Type
Files Currently on the CD		
3Dviews.zip	1,182,478 KB	WinZip File
bouctouche.zip	1,088,800 KB	WinZip File
caplumiere.zip	357,611 KB	WinZip File
cappele.zip	848,647 KB	WinZip File
cocagne.zip	308,758 KB	WinZip File
cormierville.zip	226,109 KB	WinZip File
ladune.zip	573,164 KB	WinZip File

Figure 114 Screen grab image showing the files that are located on the Project backup files DVD2. Below is a more detailed listing showing what files are located within compressed files and folders.

Backup DVD 3 Contents:

3Dviews.zip
- All-CapLumiere-1m-work.pix
- Bouctouche1m-All.pix
- Bouctouche-60cm-CSRx5.pix
- Bouctouche-60cm-DEM32.pix
- Bouctouche-60cm-SRX5.pix
- Bouctouche-waterfront.pix
- Caplumiere-3d.pix
- Cocagne-3d.pix
- Cocagne-southwest.pix
- Cormierville-3d.pix
- Ladune-southeast.pix

bouctouche.zip
- Bouctouche-ALL-CSR.pix
- Bouctouche-ALL-CSR-b.pix
- Bouctouche-ALL-CSR-w.pix
- Bouctouche-ALL-DEM.pix
- Bouctouche-all-workingfile.pix
- Bouctouche-clip-polygon.pix
- Bouctouche-GND-CSR.pix
- Bouctouche-GND-DEM.pix
- Bouctouche-GND-SR.pix
- Bouctouche-GND-workingfile.pix
- Bouctouche-GND-working-file.pix

caplumiere.zip
- Caplumiere-ALL-CSR-b.pix
- Caplumiere-ALL-CSR-w.pix
- Caplumiere-ALL-DEM.pix
- Caplumiere-ALL-workingfile.pix
- CapLumiere-clip-polygon.pix
- Caplumiere-GND-CSR-b.pix
- Caplumiere-GND-CSR-w.pix
- Caplumiere-GND-DEM.pix
- Caplumiere-GND-SR.pix
- Caplumiere-gnd-work.pix
- CaplumiereGND-workingfile.pix

cappele.zip
- Cappele-ALL-CSR-b.pix
- Cappele-ALL-DEM.pix
- Cappele-ALL-workingfile.pix

CapPele-clip-polygon.pix
CapPele-CSR-w.pix
Cappele-GND-CSR-w.pix
Cappele-GND-DEM.pix
Cappele-GND-SR.pix
Cappele-GND-workingfile.pix

cocagne.zip

Cocagne-ALL-CSR-b.pix
Cocagne-ALL-CSR-w.pix
Cocagne-ALL-DEM.pix
Cocagne-ALL-SR.pix
Cocagne-All-workingfile.pix
Cocagne-clip-polygon.pix
Cocagne-CSR-b.pix
Cocagne-CSR-w.pix
Cocagne-GND-CSR-b.pix
Cocagne-GND-DEM.pix
Cocagne-GND-SR.pix
Cocagne-GND-workingfile.pix

cormierville.zip

CormCocagne-clip.pix
Cormier-Cocg-ALL-workingfile.pix
Cormierville-ALL-CSR-b.pix
Cormierville-ALL-CSR-w.pix
Cormierville-ALL-DEM.pix
Cormierville-clip-polygon.pix
Cormierville-CSR-b.pix
Cormierville-CSR-w.pix
Cormierville-GND-CSR-b.pix
Cormierville-GND-CSR-w.pix
Cormierville-GND-DEM.pix
Cormierville-GND-SR.pix
Cormierville-GND-workingfile.pix

ladune.zip

Cormierville-gnd-work.pix
Ladune-ALL-CSR-b.pix
Ladune-ALL-CSR-w.pix
Ladune-ALL-DEM.pix
Ladune-ALL-SR.pix
Ladune-ALL-workingfile.pix
Ladune-clip-polygon.pix
Ladune-CSR-w.pix
Ladune-GND-CSR-w.pix
Ladune-GND-DEM.pix
Ladune-GND-SR.pix
Ladune-GND-workingfile.pix