Community High-Water Storm Surge Mapping Network

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Climate Change Adaptation Fund

Submitted By

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NOVA SCOTIA
Environment

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Disclaimer

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1. Introduction

This proposal was to establish a set of protocols and procedures for regional Emergency Management Office (EMO) officials to implement after a storm event has affected the coast (coastal flooding mostly but also erosion). In partnership with EMO we organized a workshop to train regional officials to document and mark the high-water location after flood events (e.g. nails in power poles, photos of buildings with s scale from the ground). The EMO official would then contact AGRG (Dr. Tim Webster) to arrange to have these marks surveyed with high precision GPS (Z within 2-5 cm) and document the storm event that affected their community. We have generated a report and maps for EMO & the community documenting the events for future reference and planning. We have built up a database of these events and high-water levels around the province. The number of tide gauges around the province is not sufficient to capture the regional water level of these storm events that are influenced by the local wind and shoreline geometry. We have generated and report of what coastal communities have been impacted and where reliable elevations of high-water levels have been acquired for these events. The benefits are: 1) identifying areas at risk, 2) aid in generating return periods and probabilities of occurrence of flood levels, 3) document and inventory coastal vulnerability, and 4) use these data to construct inundation maps of the storm event and future sea-levels incorporating climate change.

2. Objectives

The short term objectives were: 1) to train regional EMO officials to document and mark the high-water line after flood events in such a way so that the precise elevation can be measured at a later date (e.g. nails in power poles, photos of brick buildings so we could count the bricks from the ground etc.), 2) build up a database of high-water levels of these events for different communities around the province, 3) document and inventory coastal vulnerability from storm events.

Long term objectives are: 1) identify areas that are frequently at risk, 2) aid in generating better return periods and probabilities of occurrence of specific water levels on a community or regional basis, 3) to use these high water levels to simulate flooding and inundation over a high resolution Digital Elevation Model (where it exists, for example RAC study areas and other regions of the coast of the province covered by LIDAR that AGRG has access to) and then project what this storm event could do in the future under various sea-level rise conditions incorporating climate change; and 4) expand to involve other possible government officials in the community (e.g. DNR employees since many are familiar with maps and natural processes and distributed in regional offices).

These objectives will allow us to better understand our current risk from storm surge events and future risk under higher sea-levels from climate change. It is innovative in that it uses high technology survey grade GPS equipment and computer mapping to accurately capture the impact of storm events. It partnered one of the leading Geomatics research groups with EMO to better understand the risks to our coastal communities. It has aided in the knowledge gap regarding coastal water levels and impacts that is a result of the very limited number of tide gauges in the region.

3. Deliverables

A workshop was held with EMO officials to present the idea and protocols for document coastal flooding and erosion events. The workshop was held in Argyle on Oct. 21, 2010 and was organized in collaboration with Steve Mills, and Andrew Lathem, EMO Officials. The storm event of Dec. 6., 2010 was reported and documented by EMO officials as well as ancillary data for Hurricane Juan, Sept. 27-28, 2003 was documented (Appendix A). . Historic high water levels including the Groundhog Day Storm, Feb 3, 1976 that affected Yarmouth and the Jan 2, 2010 storm that affected the northern coast of Nova Scotia and New Brunswick (Port Elgin) were investigated in addition to those reported by EMO (Appendix B).AGRG also Investigated the Dec. 21, 2010 storm that affected the north shore of Nova Scotia along the Northumberland Strait (Appendix B).

4. Storm Documentation

Weather information and tide gauge records were examined for several historic storm events that have been known to cause flooding or erosion around the province. In some cases Newspaper or other media reports are included. Tide gauge and weather records are not available for all storms and locations that were most affected.

The historic storms that were researched included:

Feb 2, 1976 Yarmouth 4.81 m CGVD28 high-water mark via GPS
Feb 2, 1976 Yarmouth 5.67 m CD, 5.67 - 2.31 (CD-CGVD28) = 3.36 m CGVD28 via tide gauge

Jan 3, 2010 Port Elgin high-water mark 3.20 m CGVD28 via GPS

Dec 6, 2010 Lunenburg, Halifax 2.79 m CD, 2.79 – 0.80 = 1.99 m CGVD28 via tide gauge

Dec 21-22, 2010 Shediac 3.18 CD, 3.18 - 0.84 (CD-CGVD28) = 2.34 m CGVD28 via tide gauge
Dec 21-22, 2010 Escuminac 2.66 CD, 2.66 - 0.55 (CD-CGVD28) = 2.11 m CGVD28 via tide gauge
Dec 21-22, **2010** Charlottetwn 3.5 CD, 3.5 - 1.69 (CD-CGVD28) = 1.81 m CGVD28 via tide gauge
Dec 21-22, 2010 Cape John - Skinners Cove pressure sensor = 2.21 m CGVD28 via tide gauge & GPS
Dec 21-22, 2010 Cape John - wrack line GPS = 2.38 m CGVD28 via GPS

4.1 Weather & Water-level Information

Historic weather data was downloaded from the internet for the following sites:

Lunenburg CXLB
http://www.wunderground.com/history/airport/CXLB/2011/3/6/MonthlyHistory.html

Yarmouth, Brier Island Airport CWVU
http://www.wunderground.com/history/airport/CWVU/2010/10/20/MonthlyHistory.html
?req_city=NA&req_state=NA&req_statename=NA

Amherst, Nappan CXNP
http://www.wunderground.com/history/airport/CXNP/2010/10/20/MonthlyHistory.html

Pictou, Caribou Point CWBK
http://www.wunderground.com/history/airport/CWBK/2010/10/20/MonthlyHistory.html?
req_city=NA&req_state=NA&req_statename=NA

Greenwood, Airport CYZX
http://www.wunderground.com/history/airport/CYZX/1974/9/20/MonthlyHistory.html

Observed water levels were downloaded from the federal Department of Fisheries and Oceans website at the following address (http://www.meds-sdmm.dfo-mpo.gc.ca/isdm-gdsi/twl-mne/inventory-inventaire/list-liste-eng.asp?user=isdm-gdsi&region=ATL&tst=1).

The predicted tide levels were down loaded from the following site (http://tbone.biol.sc.edu/tide/).

4.1.1 Feb. 2-3, 1976 Groundhog Day Storm.

The Vanguard Newspaper published several photos of the damage that resulted from the storm around Yarmouth and also produced a booklet documenting the storm damage for southwest Nova Scotia (Fig. 1).

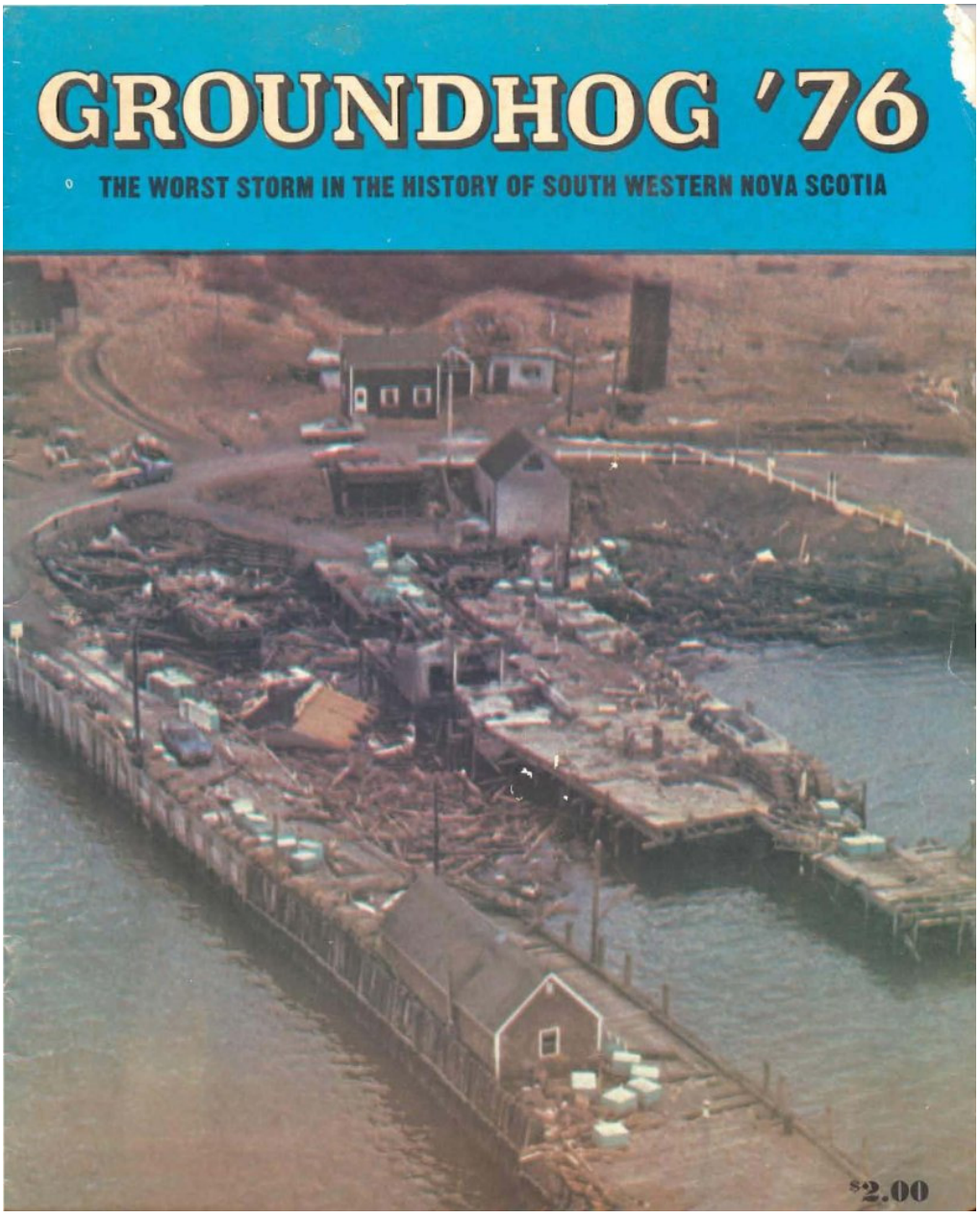

Figure 1 Front cover of a booklet produced by the Vanguard newspaper documenting the Feb. 2-3, 1976 ground Hog Day storm for southwest Nova Scotia.

Monthly (daily) (Fig. 2) and weekly (hourly) (Fig. 3) weather data was down loaded for Greenwood for Feb. 1976 to document the weather conditions during the Groundhog Day storm.

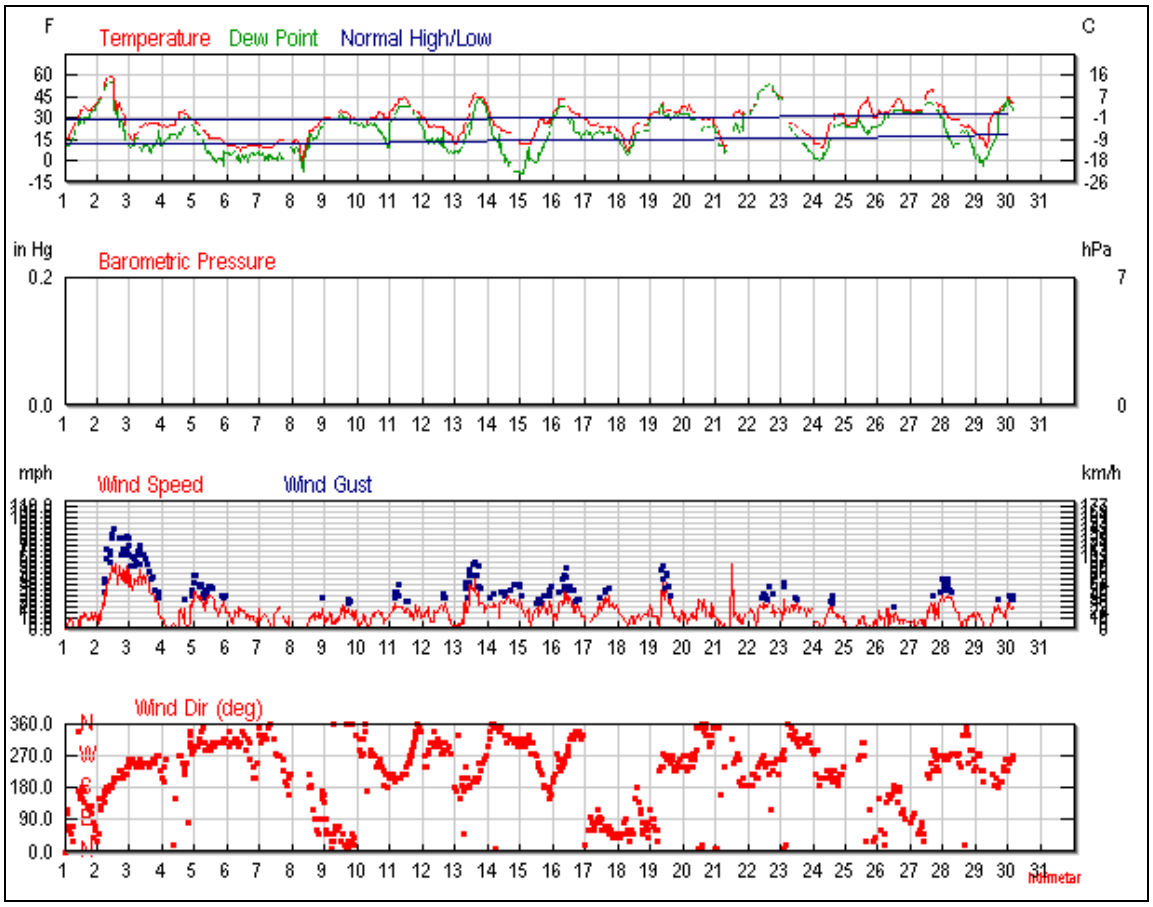

Figure 2 Greenwood airport daily weather readings for the month of Feb., 1976. Groundhog Day storm occurred Feb. 3, 1976. Note the increased wind gusts from the southwest and west on Feb 2.

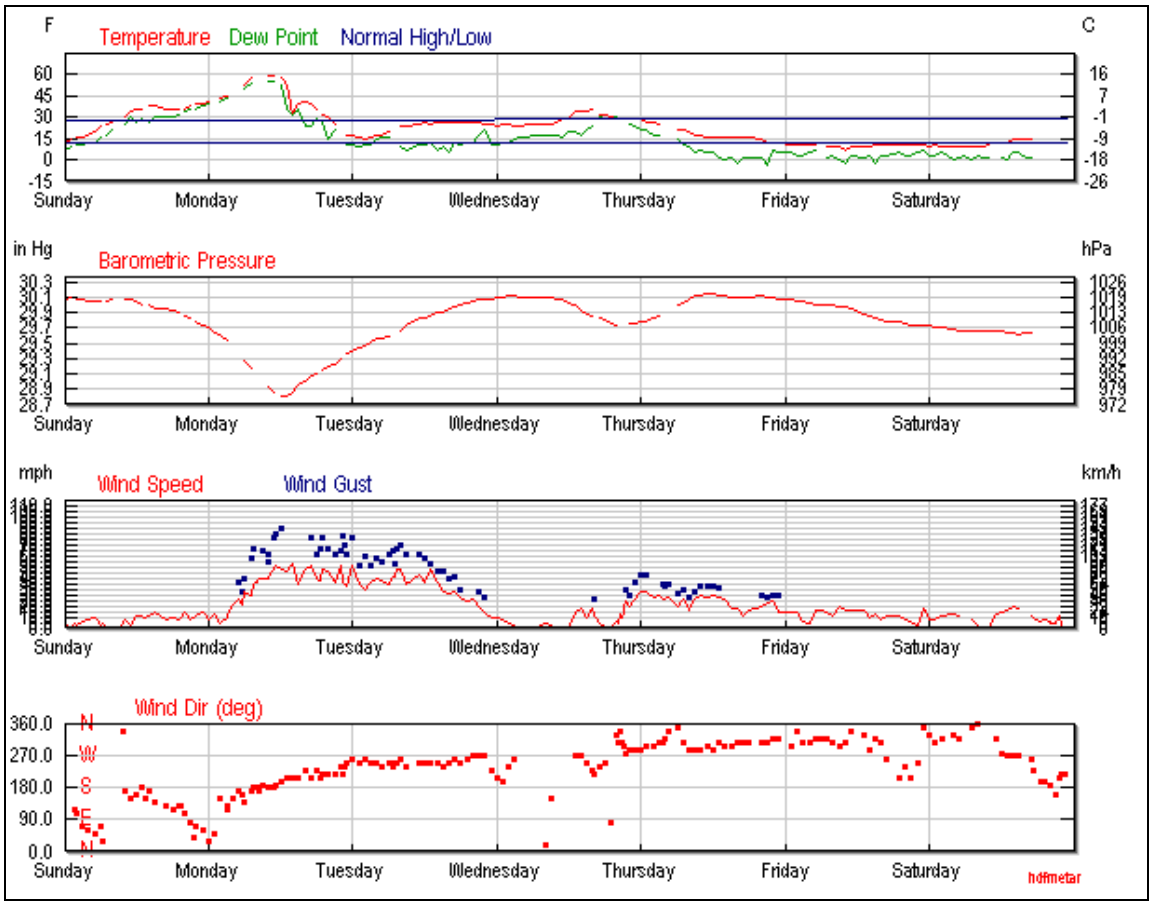

Figure 3 Detailed hourly weather for Greenwood, Feb 1-7, 1976. Note the drop in barometric pressure and increased wind speed on Mon.-Tues. Feb 2-3, 1976.

The Yarmouth tide gauge was operating during the storm event and has been extracted along with the predicted water level in order to calculate the residual differences between predicted and observed, the storm surge (Fig 4). The tide gauge data have been converted from chart datum to orthometric height above CGVD28 (Fig. 5).

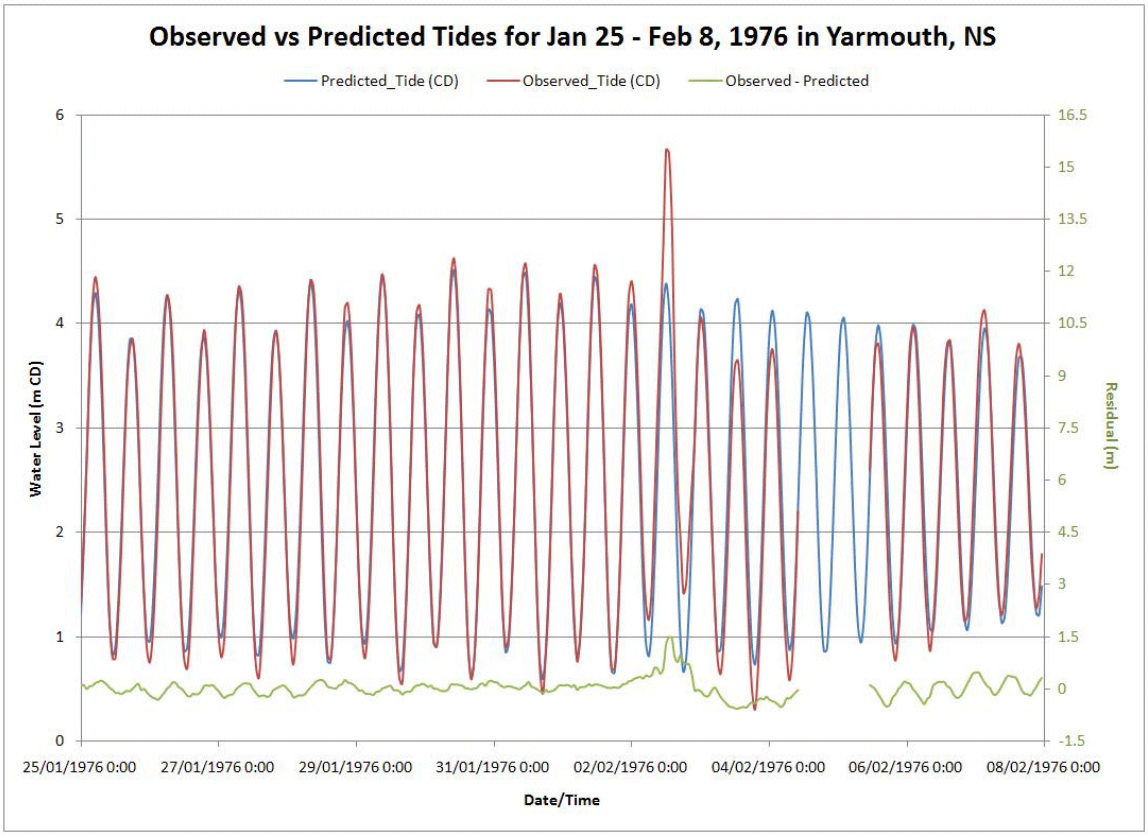

Figure 4 Tide gauge water-level record from Yarmouth for the Feb. 3 Groundhog Day storm. A 1.5 m storm surge was observed. The maximum water level recorded was 3.36 m CGVD28.

The RTK GPS elevation of the high-water marks; one based on eye witness reports of the water coming to the door step of a house (4.81 m CGVD28), and the other mark was estimated based on historical photographs of water covering a cars tires near the present Printer Works building (3.56 m CGVD28) (Appendix B).

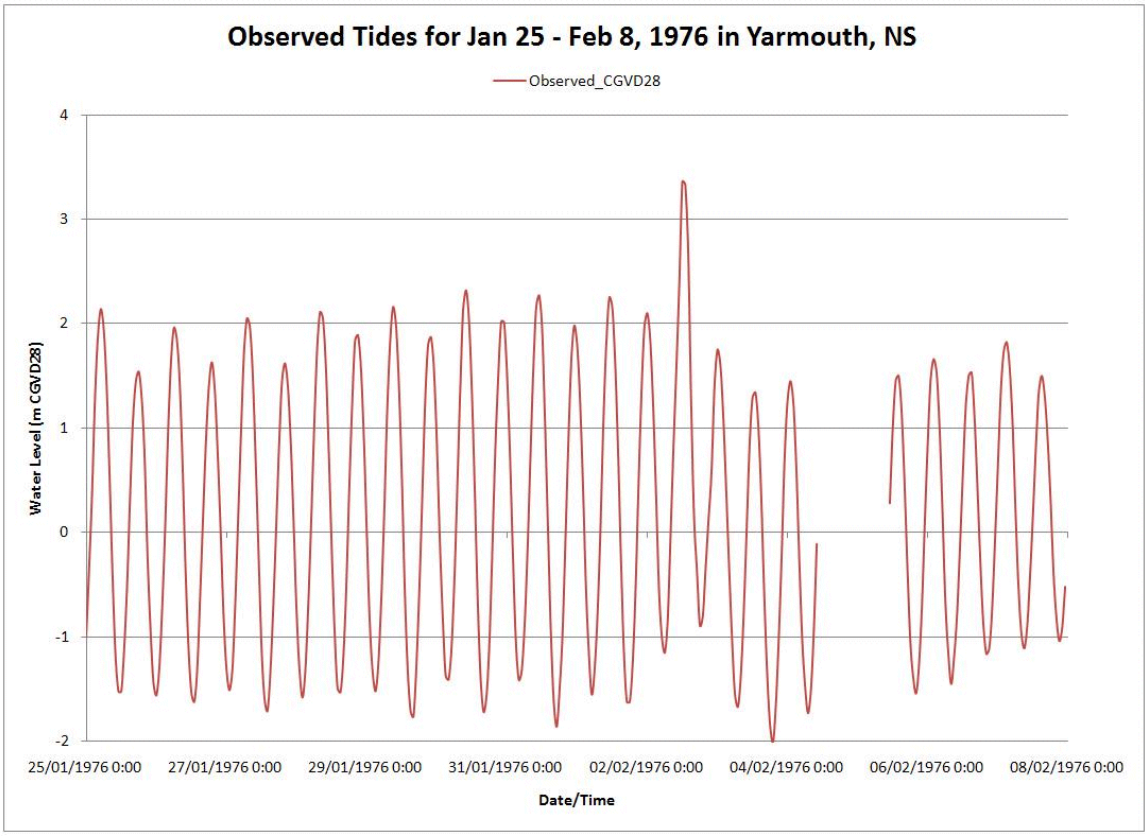

Figure 5 Yarmouth tide gauge water-levels projected to CGVD28 datum.

4.1.2 Jan 3, 2010 Port Elgin, NB Storm event

On Jan. 2-3, 2010 a low pressure storm system affected the coast of the Northumberland Strait. Port Elgin, NB was severely affected and sustained coastal flooding as a result of the storm surge (Fig. 6).

Figure 6 Port Elgin storm damage. Top photos courtesy of Kristy Boudreau. The next row of photos courtesy of Sackville Tribune, Globe and Mail, and the CBC.

Figure 7 Foot bridge in Port Elgin covered in water during the storm surge event Jan 2, 2010 (top) and after the storm (bottom).

The nearest weather station to Port Elgin, NB is Nappan, NS near the Bay of Fundy on the southern side of the isthmus. Daily weather records were downloaded for the month of Jan. 2010 to examine this storm event (Fig. 8).

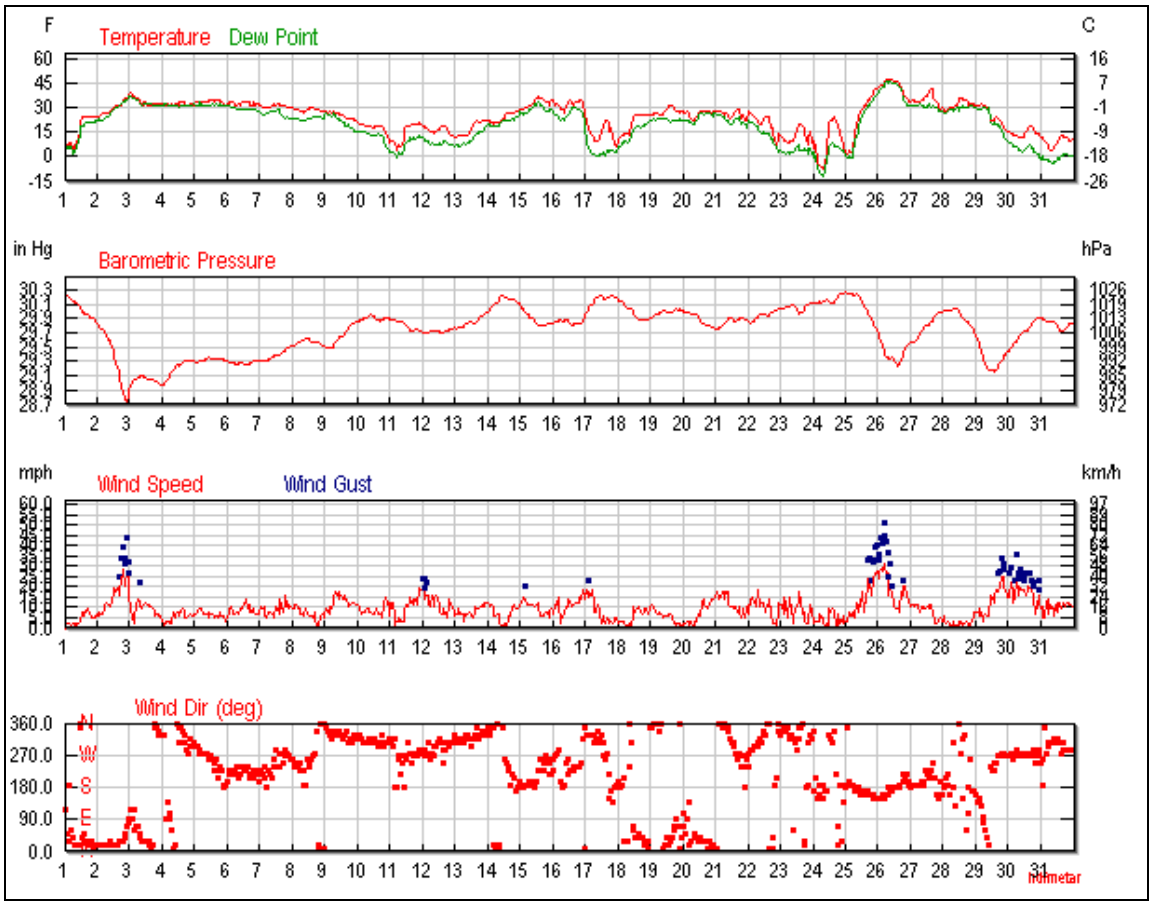

Figure 8 Nappan weather station, daily readings for the month of Jan. 2010. Note the drop in barometric pressure and increased wind speed coming from the east on Jan 3, 2010 associated with this storm event at Port Elgin.

The Charlottetown tide gauge was operating at the time of the storm and has been extracted to observe the water level and residual. Charlottetown is located on the opposite side of the Northumberland Strait and did not sustain the same high water levels as the south coast of the strait (Fig. 9). The Shediac tide gauge was the nearest gauge in operation on the south coast of the Northumberland Strait at the time of the storm (Fig. 10). The hourly records indicate the maximum water level of 2.14 m CGVD28.

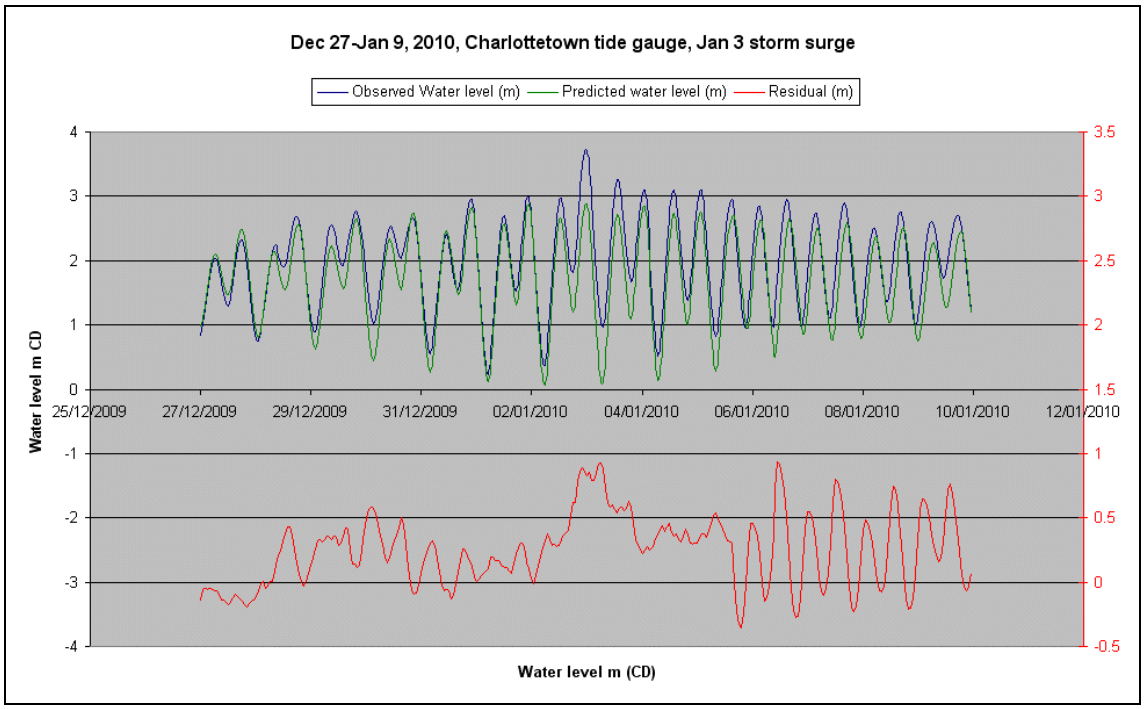

Figure 9 Jan 2-3, 2010 storm surge event as observed at Charlottetown.

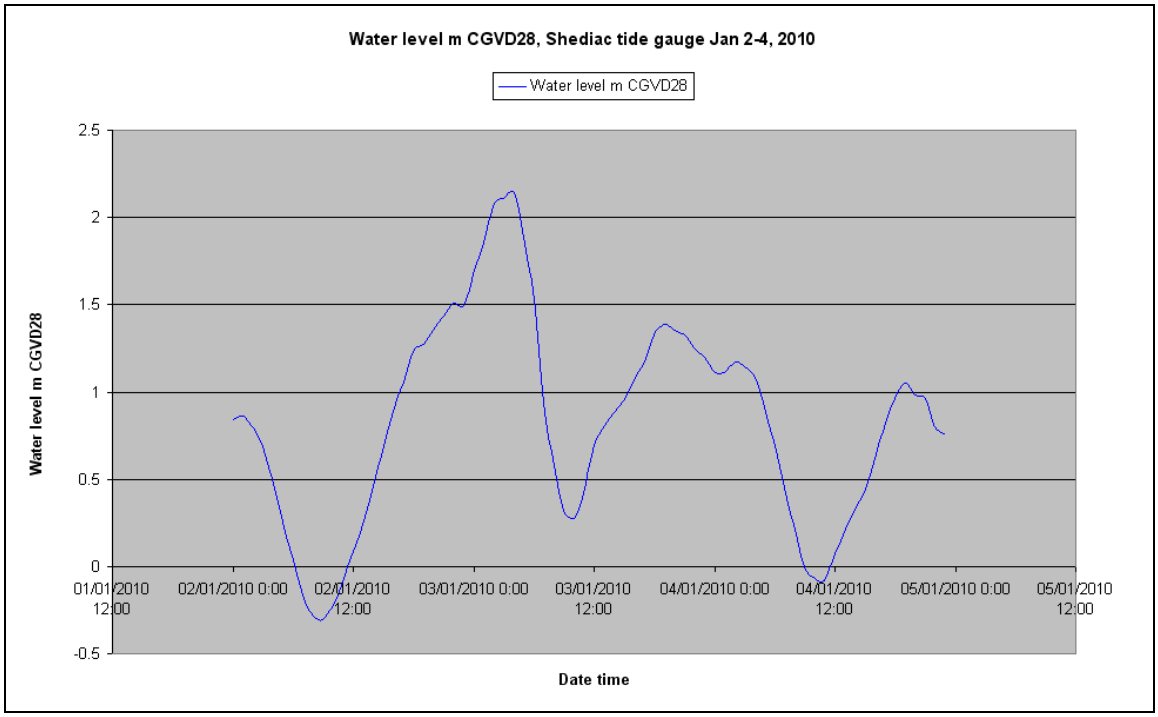

Figure 10 Shediac tide gauge, hourly readings, 2.14 m CGVD28 during the storm surge, Jan. 2-3, 2010.

The high-water mark measured by RTK-GPS indicated a level of 3.20 m CGVD28 (Appendix B) in contrast to the level at Shediac (2.14 m CGVD28) and Charlottetown (3.19 m CGVD28).

4.1.3 Dec. 6, 2010 Storm Surge event along the south shore of NS

EMO officials responded to this storm event and documented the high-water marks. Researchers at the AGRG have not had a chance to survey these elevations with RTK GPS due to snow cover on the control monuments required for precise elevation control. However the weather data for Lunenburg has been down loaded and daily values plotted for the month of Dec.,2010 (Fig. 11).

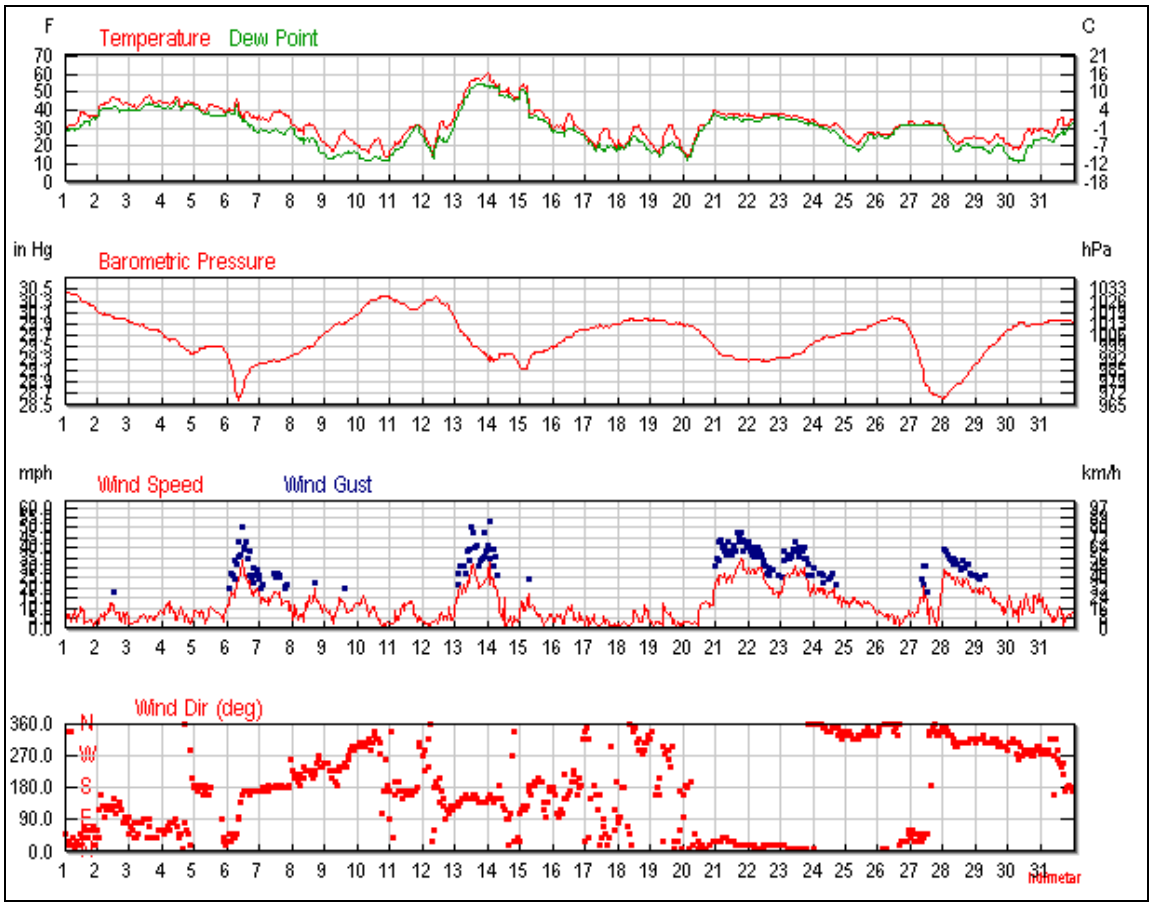

Figure 11 Daily weather records for the month of Dec. 2010 for Lunenburg. Note the drop in barometric pressure and increase in wind speed from the north then changing to the south during the Dec. 6 storm event.

The Halifax tide gauge was operating during the storm event and has been downloaded along with predicted tidal elevations to calculate the residual or storm surge level (Fig. 12). The maximum water level from the hourly tide gauge record at Halifax indicates high-water elevation of 1.99 m (Fig. 12).

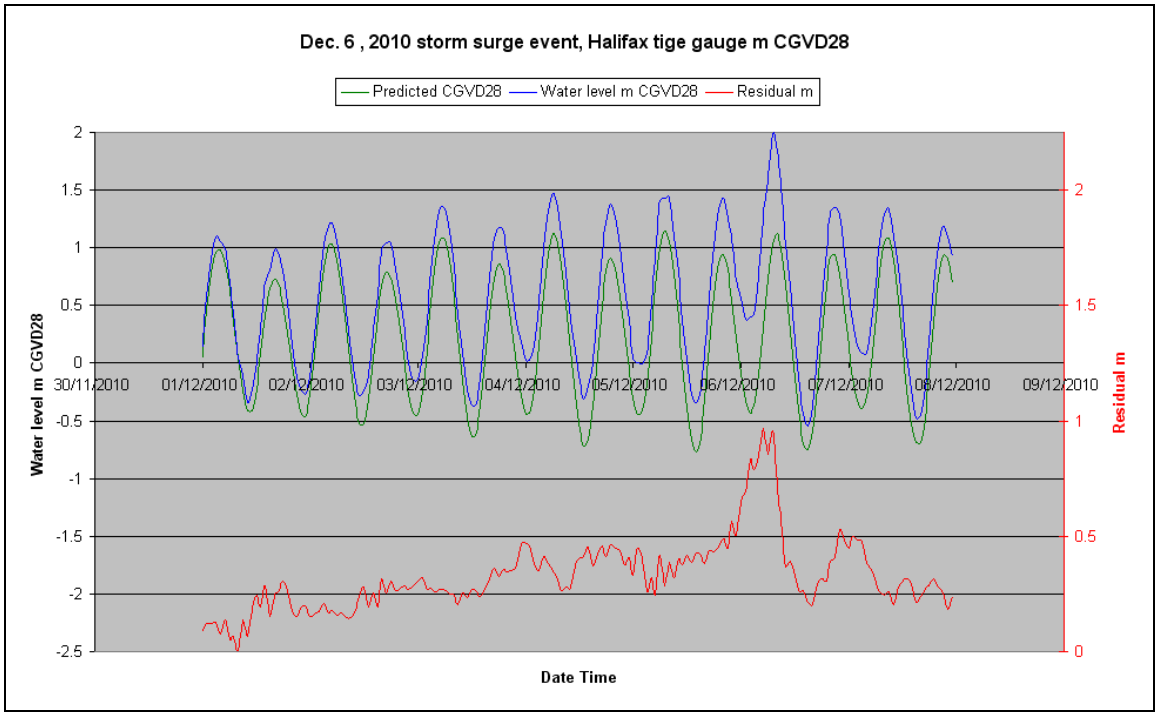

Figure 12 Halifax tide gauge record, hourly readings. The maximum water level is 1.99 m CGVD28 with a storm surge of 0.96 m.

4.1.4 Dec. 21, 2010 Storm Surge, northern coast of the Northumberland Strait

A tide gauge was placed at Skinners Cove, approximately 10 km east of cape John, a site that has been monitored for erosion and coastal flooding from storm surge events by the AGRG since 2005 and earlier using past historical records. Many locations along the Northumberland Strait suffered extensive damage from the storm surge associated with the Dec 21, 2010 storm. Daily weather records were downloaded from the Caribou Island weather station, near Pictou, and plotted for the month of Dec., 2010 which had several storms in addition to the Dec 21 event (Fig. 13).

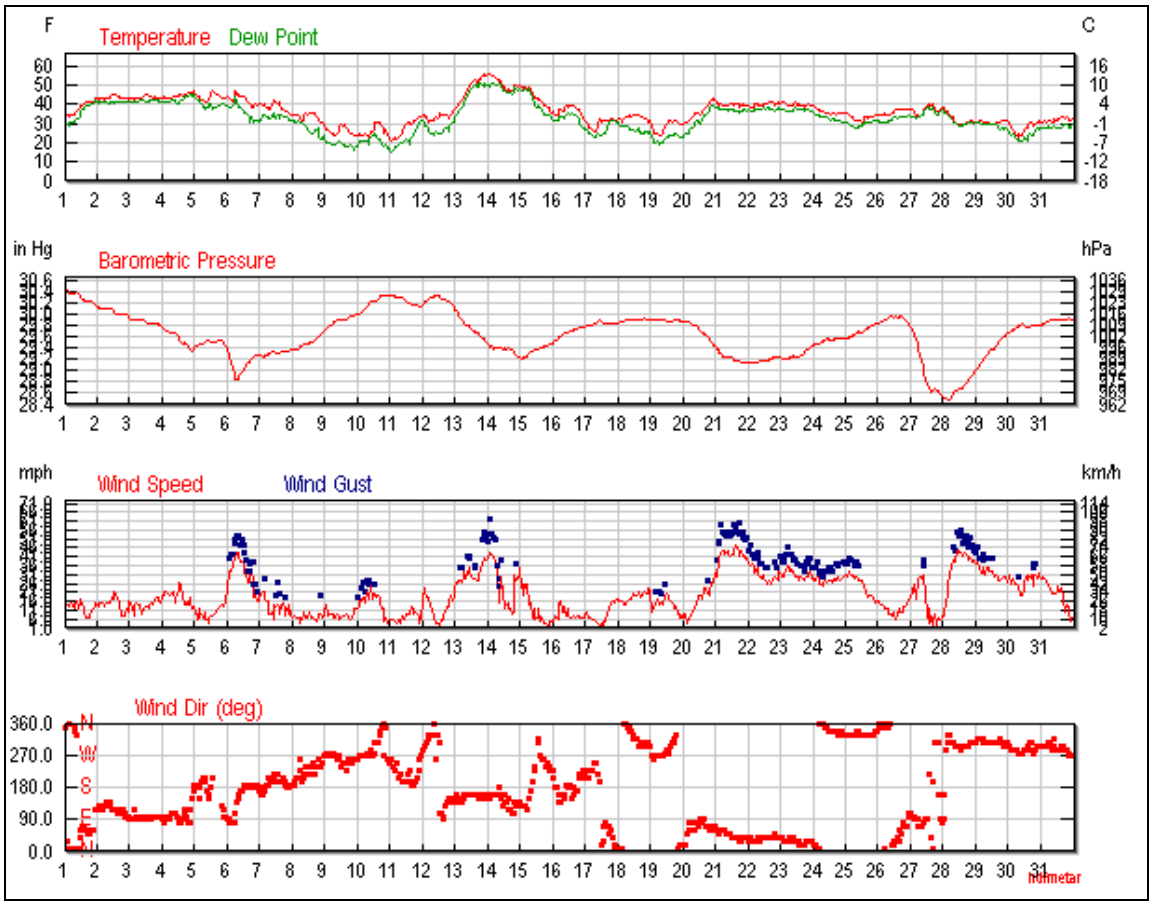

Figure 13 Daily weather records for Caribou Island. Note the low pressure and increased wind speeds for storm events Dec. 6, 14-15, 21-22, and 28th.

The tide gauge at Skinners Cove captured the high-water events for Dec. of which Dec. 21, 2010 was the highest with a recorded water level of 2.21 m CGVD28 (Fig. 14).

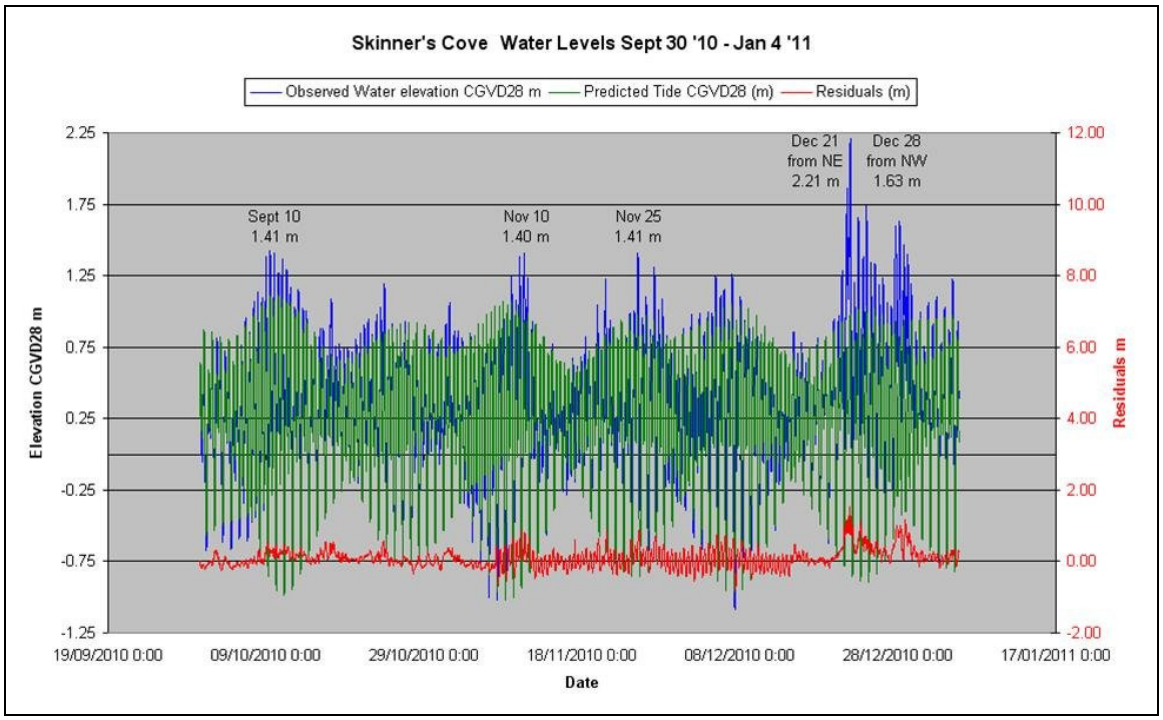

Figure 14 Skinners Cove tide gauge deployed and operated by AGRG. Several high water events were observed from Sept through to Dec 28 at this location. The Dec. 21, 2010 maximum high-water event registered 2.21 m CGVD28 on the gauge which took a reading every 15 minutes.

In addition to the AGRG tide gauge at Skinners Cove, the Shediac tide gauge was downloaded, however the storm was so severe that the communications to the gauge were cut off and the data is not available at the height of the storm (Fig. 15).

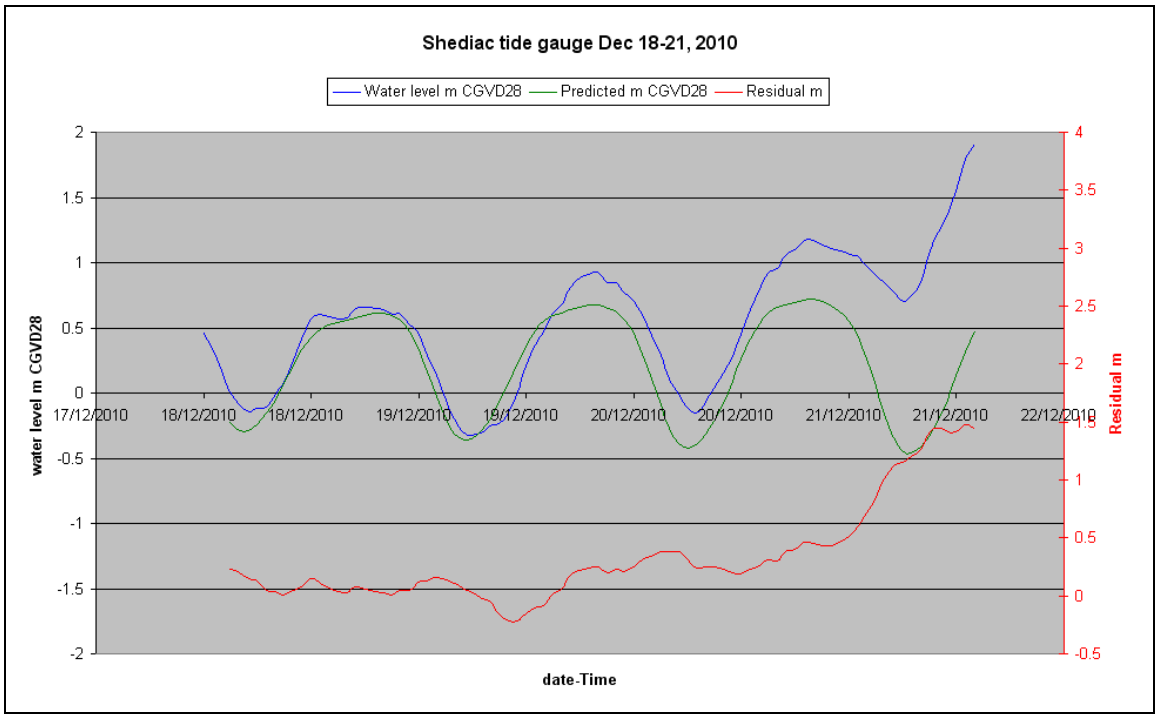

Figure 15 Shediac tide gauge record up to Dec. 21, 2010. A 1.5 m storm surge was observed until the gauge lost communication.

The Canadian Hydrographic Service was contacted to determine the maximum water level for this event at Shediac, which is 3.18 m CD (2.34 m) which is higher than the previous record from the Jan. 21, 2000 storm (P. MacAuley, pers. communication, Feb, 2011).

In addition to these records, J. Hannon, EMO official from Cumberland County and Mike MacDonald of DNR at Oxford have been contacted and will share information from the extent of damage from this storm. Researchers at AGRG are planning a fieldtrip with Mike MacDonald of NS DNR on March 28, 2011 to inspect and possibly survey the evidence from this high-water event.

5. Conclusions

This project has heightened the awareness of EMO officials to the protocols involved with documenting a storm surge event that can later be used to survey the high-water marks for historical record and to better understand the risk a given community has against these storms. Several storms have been researched and weather records retrieved that identify the atmospheric forcing and tidal conditions that were associated with the storm events. In addition to storms this past winter, historical storm events were also researched and incorporated into this report. To my knowledge, no provincial government department documents these storm events, or the associated damage and economic impact of them. Considering climate change is projected to increase sea-level, making the problem more pronounced, this type of project will provide value in documenting the location and types of storms that occur in Nova Scotia and the Maritimes.

Appendix A. Data Sheets & Photos from EMO

Storm Surge High Water Event

Data Collectors Name / Title / Phone Number: **Steve Mills / EMPO / 521-1726**

Community: **Bayport, Lunenburg County**

Date: **2010-12-06**

Tide (low, high, incoming): **High at 0749 hrs**

Phase of moon: **New**

Ice: **Absent**

Time of maximum high water: **45 minutes**

Duration of the storm: **12 hours**

Direction of wind: **South Westerly**

Wave heights: **U/K**

Nails in wood & photo marking high water: **In power pole by wharf**

Photos of the high water events: **Aftermath**

GPS Coordinates of location (UTM, Easting Northing): **20 T 0395060 4909306**

Photo Name	Location	Time	Survey mark on photo
Bayport Wharf	Bayport, NS	0907 hrs	Nail in power pole

Contact: Dr. Tim Webster, Research Scientist, Applied Geomatics Research Group, NSCC Middleton. Phone: 902 825 5475, Fax 902 825 5479, email: tim.webster@nscc.ca.
We would prefer & appreciate digital versions of the info if possible.

Figure 16 Bay Port wharf after Dec 6, 2010 storm surge. Nail in power pole marking the high-water elevation.

Storm Surge High Water Event

Data Collectors Name / Title / Phone Number: **Steve Mills / EMPO / 521-1726**

Community: **Broad Cove, Lunenburg County**

Date: **2010-12-06**

Tide (low, high, incoming): **High at 0805 hrs**

Phase of moon: **New**

Ice: **Absent**

Time of maximum high water: **45 minutes**

Duration of the storm: **12 hours**

Direction of wind: **South Westerly**

Wave heights: **U/K**

Nails in wood & photo marking high water: **In power pole by highway**

Photos of the high water events: **Aftermath**

GPS Coordinates of location (UTM, Easting Northing): **20 T 0391730 4891498**

Photo Name	Location	Time of Photo	Survey mark on photo
Broad Cove	Hwy 331, Broad Cove, NS	1417 hrs	Nail in power pole

Contact: Dr. Tim Webster, Research Scientist, Applied Geomatics Research Group, NSCC Middleton. Phone: 902 825 5475, Fax 902 825 5479, email: tim.webster@nscc.ca.
We would prefer & appreciate digital versions of the info if possible.

Figure 17 Broad Cove after Dec 6, 2010 storm surge. Nail in power pole marking the high-water elevation. Note the gravel from the beach deposited on the road.

Storm Surge High Water Event

Data Collectors Name / Title / Phone Number: **Steve Mills / EMPO / 521-1726**

Community: **Dublin Shore, Lunenburg County**

Date: **2010-12-06**

Tide (low, high, incoming): **High at 0805 hrs**

Phase of moon: **New**

Ice: **Absent**

Time of maximum high water: **45 minutes**

Duration of the storm: **12 hours**

Direction of wind: **South Westerly**

Wave heights: **U/K**

Nails in wood & photo marking high water: **In power pole by highway**

Photos of the high water events: **Aftermath**

GPS Coordinates of location (UTM, Easting Northing): **20 T 0390846 4902502**

Photo Name	Location	Time of Photo	Survey mark on photo
Dublin Shore	4092 Hwy 331, Dublin Shore, Lu Co, NS	1354 hrs	Nail in power pole

Contact: Dr. Tim Webster, Research Scientist, Applied Geomatics Research Group, NSCC Middleton. Phone: 902 825 5475, Fax 902 825 5479, email: tim.webster@nscc.ca.
We would prefer & appreciate digital versions of the info if possible.

Figure 18 Dublin shore after Dec 6, 2010 storm surge. Nail in power pole marking the high-water elevation.

Storm Surge High Water Event

Data Collectors Name / Title / Phone Number: **Steve Mills / EMPO / 521-1726**

Community: **Kingsburg, Lunenburg County**

Date: **2010-12-06**

Tide (low, high, incoming): **High at 0749 hrs**

Phase of moon: **New**

Ice: **Absent**

Time of maximum high water: **45 minutes**

Duration of the storm: **12 hours**

Direction of wind: **South Westerly**

Wave heights: **U/K**

Nails in wood & photo marking high water: **In power pole by roadway**

Photos of the high water events: **Aftermath**

GPS Coordinates of location (UTM, Easting Northing): **20 T 0397994 4904144**

Photo Name	Location	Time	Survey mark on photo
Kingsburg Rd	Rose Bay, NS	1139 hrs	Nail in power pole

Contact: Dr. Tim Webster, Research Scientist, Applied Geomatics Research Group, NSCC Middleton. Phone: 902 825 5475, Fax 902 825 5479, email: tim.webster@nscc.ca.
We would prefer & appreciate digital versions of the info if possible.

Figure 19 Kingsburg Road Cove after Dec 6, 2010 storm surge. Nail in power pole marking the high-water elevation. Note the gravel and debris from the beach deposited on the road.

Storm Surge High Water Event

Data Collectors Name / Title / Phone Number: **Steve Mills / EMPO / 521-1726**

Community: **Upper LaHave, Lunenburg County**

Date: **2010-12-06**

Tide (low, high, incoming): **High at 0832 hrs**

Phase of moon: **New**

Ice: **Absent**

Time of maximum high water: **45 minutes**

Duration of the storm: **12 hours**

Direction of wind: **South Westerly**

Wave heights: **U/K**

Nails in wood & photo marking high water: **In boat house on rear clapboard**

Photos of the high water events: **Aftermath**

GPS Coordinates of location (UTM, Easting Northing): **20 T 0384210 4913481**

Photo Name	Location	Time of Photo	Survey mark on photo
My Boat House	36 Pickings Lane, Upper LaHave, NS	1218 hrs	Nail in rear clapboard

Contact: Dr. Tim Webster, Research Scientist, Applied Geomatics Research Group, NSCC Middleton. Phone: 902 825 5475, Fax 902 825 5479, email: tim.webster@nscc.ca.
We would prefer & appreciate digital versions of the info if possible.

Figure 20 Upper LaHave "Mills Boat House" after Dec 6, 2010 storm surge. The debris line is marking the high-water elevation.

Storm Surge High Water Event

Data Collectors Name / Title / Phone Number: **Steve Mills / EMPO / 521-1726**

Community: **Western Head, Queens County**

Date: **2010-12-06**

Tide (low, high, incoming): **High at 0805 hrs**

Phase of moon: **New**

Ice: **Absent**

Time of maximum high water: **45 minutes**

Duration of the storm: **12 hours**

Direction of wind: **South Westerly**

Wave heights: **U/K**

Nails in wood & photo marking high water: **In power pole by highway**

Photos of the high water events: **Aftermath**

GPS Coordinates of location (UTM, Easting Northing): **20 T 0366491 4873253**

Photo Name	Location	Time of Photo	Survey mark on photo
Western Head	1150 Shore Rd, Western Head, NS	1529 hrs	Nail in power pole

Contact: Dr. Tim Webster, Research Scientist, Applied Geomatics Research Group, NSCC Middleton. Phone: 902 825 5475, Fax 902 825 5479, email: tim.webster@nscc.ca.
We would prefer & appreciate digital versions of the info if possible.

Figure 21 Western Head after Dec 6, 2010 storm surge. Nail in power pole marking the high-water elevation. Note the gravel from the beach deposited on the road.

Storm Surge High Water Event

Data Collectors Name / Title / Phone Number: **Steve Mills / EMPO / 521-1726**

Community: **Bayport, Lunenburg County**

Date: **2003-09-28/29**

Tide (low, high, incoming): **High at 2348 hrs**

Phase of moon: **New**

Ice: **Absent**

Time of maximum high water: **U/K**

Duration of the storm: **U/K**

Direction of wind: **U/K**

Wave heights: **U/K**

Nails in wood & photo marking high water: **Witness pointing to water level**

Photos of the high water events: **N/A**

GPS Coordinates of location (UTM, Easting Northing): **20 T 0395032 4909289**

Photo Name	Location	Time	Survey mark on photo
Bayport Fish Shack	Bayport, NS	0905 hrs	Witness point to water level
Bayport Fish Shack	Bayport, NS	0911hrs	Overview of fish shack

Contact: Dr. Tim Webster, Research Scientist, Applied Geomatics Research Group, NSCC Middleton. Phone: 902 825 5475, Fax 902 825 5479, email: tim.webster@nscc.ca.
We would prefer & appreciate digital versions of the info if possible.

Figure 22 Bay Port fish shack after Hurricane Juan Sept. 28-29, 2003.

Figure 23 Witness pointing to high-watermark from Hurricane Juan, Sept 28-29, 2003.

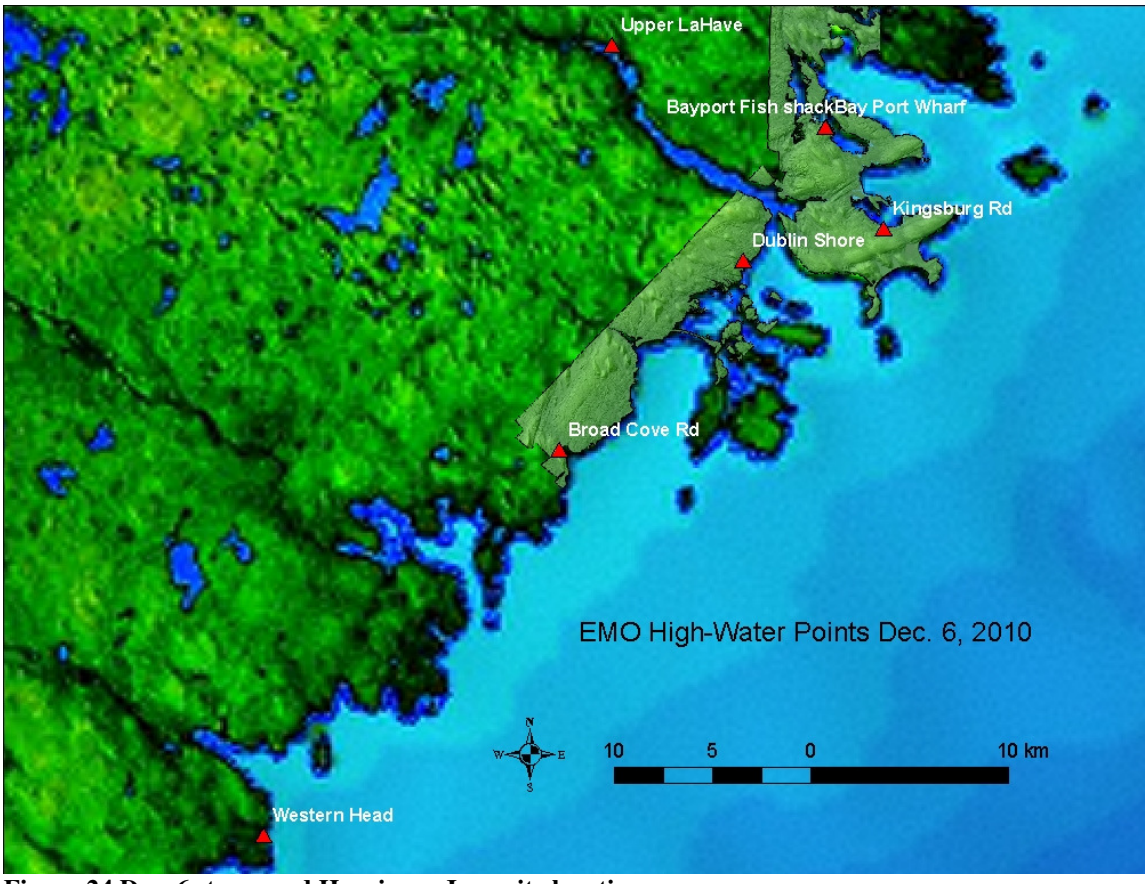

Figure 24 Dec. 6 storm and Hurricane Juan site location map.

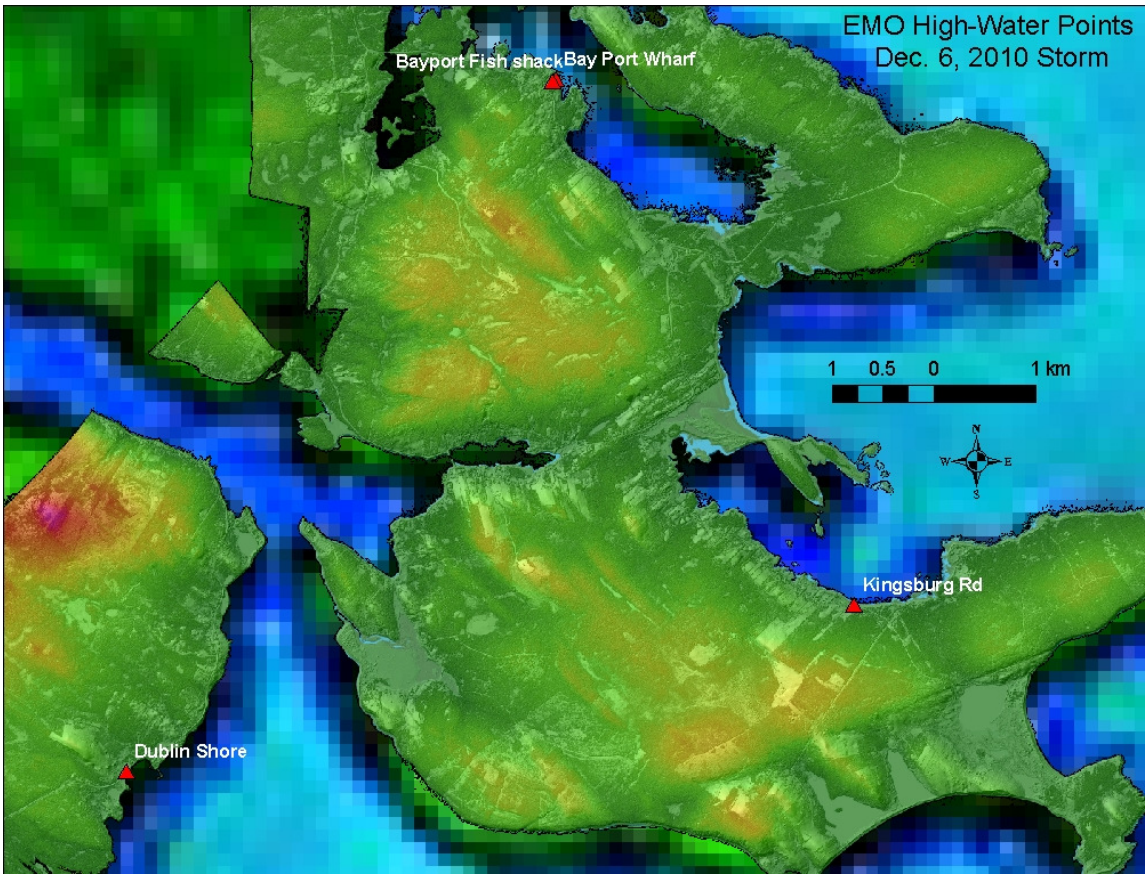

Figure 25 Close up of Dec. 6, 2010 storm EMO site locations with lidar digital surface model in the background.

Appendix B. High-water information from historical storms collected by Tim Webster, AGRG

Tel. 902 825 5475.

Storm Surge High Water Event

Data Collectors Name / Title / Phone Number: **Tim Webster / 902 825 5475**

Community: **Port Elgin, NB**

Date: **2010-01-03**

Tide (low, high, incoming): **High at 0000 hrs**

Phase of moon: **New**

Ice: **Present (based on photos)**

Time of maximum high water: **10:pm to 1:00 am Jan. 3**

Duration of the storm: **U/K**

Direction of wind: **easterly**

Wave heights: **U/K**

Nails in wood & photo marking high water: **Witness pointing to hinge line on shed**

Photos of the high water events: **From eye witnesses**

GPS Coordinates of location (UTM, Easting Northing): **20 T 415897 5100087**

Photo Name	Location	Time	Survey mark on photo

Contact: Dr. Tim Webster, Research Scientist, Applied Geomatics Research Group, NSCC Middleton. Phone: 902 825 5475, Fax 902 825 5479, email: tim.webster@nscc.ca.

We would prefer & appreciate digital versions of the info if possible.

Figure 26 Port Elgin high-water level from eye witness. RTK GPS orthometric height measured 3.20 m.

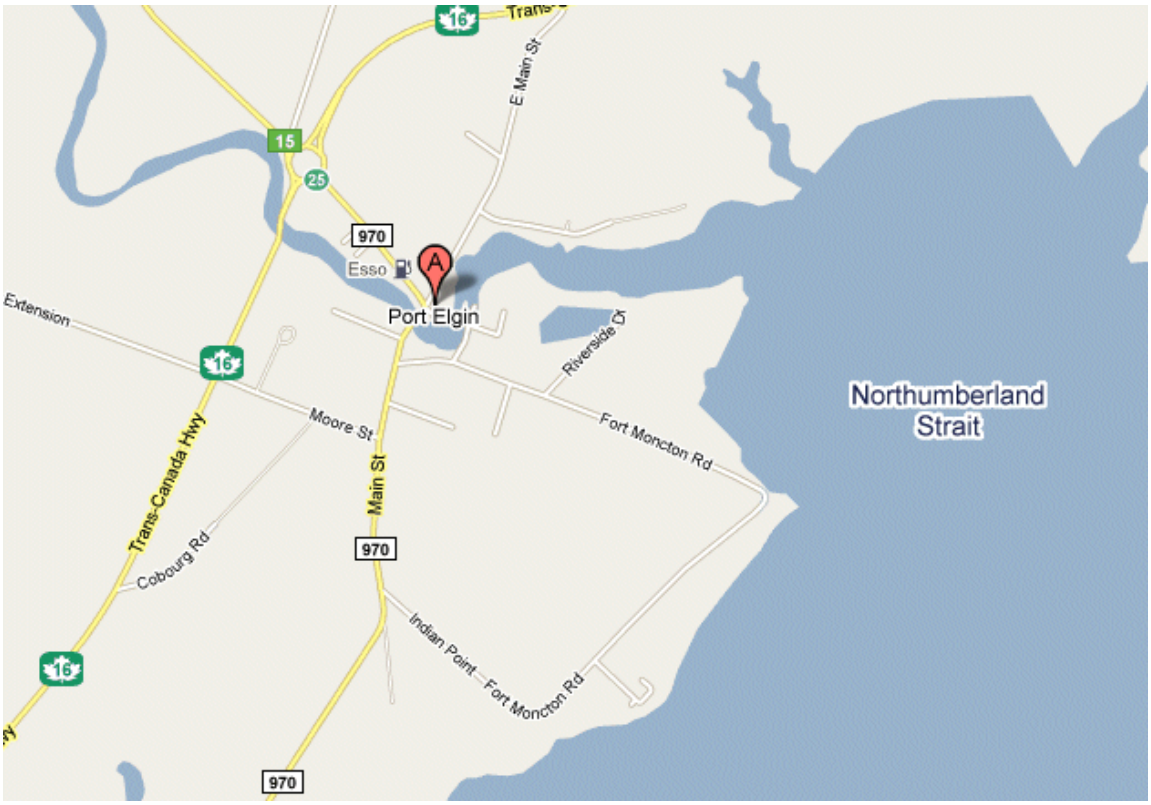

Figure 27 Port Elgin location map. High-water mark elevations were acquired with RTK GPS along the waterfront (at Port Elgin map label location). Photos of storm damage shown earlier were from the south along Fort Moncton and Indian Point Road. Source, Google Maps.

Storm Surge High Water Event

Data Collectors Name / Title / Phone Number: **Tim Webster / 902 825 5475**

Community: **Yarmouth, NS**

Date: **1976-02-03**

Tide (low, high, incoming): **High at 0000 hrs**

Phase of moon: **New**

Ice: **Absent (based on photos)**

Time of maximum high water: **Feb 3**

Duration of the storm: **U/K**

Direction of wind: **South and westerly**

Wave heights: **U/K**

Nails in wood & photo marking high water: **Witness pointing to back door step**

Photos of the high water events: **From eye witnesses**

GPS Coordinates of location (UTM, Easting Northing): **20 T 247830 4861017**

Photo Name	Location	Time	Survey mark on photo

Contact: Dr. Tim Webster, Research Scientist, Applied Geomatics Research Group, NSCC Middleton. Phone: 902 825 5475, Fax 902 825 5479, email: tim.webster@nscc.ca.
We would prefer & appreciate digital versions of the info if possible.

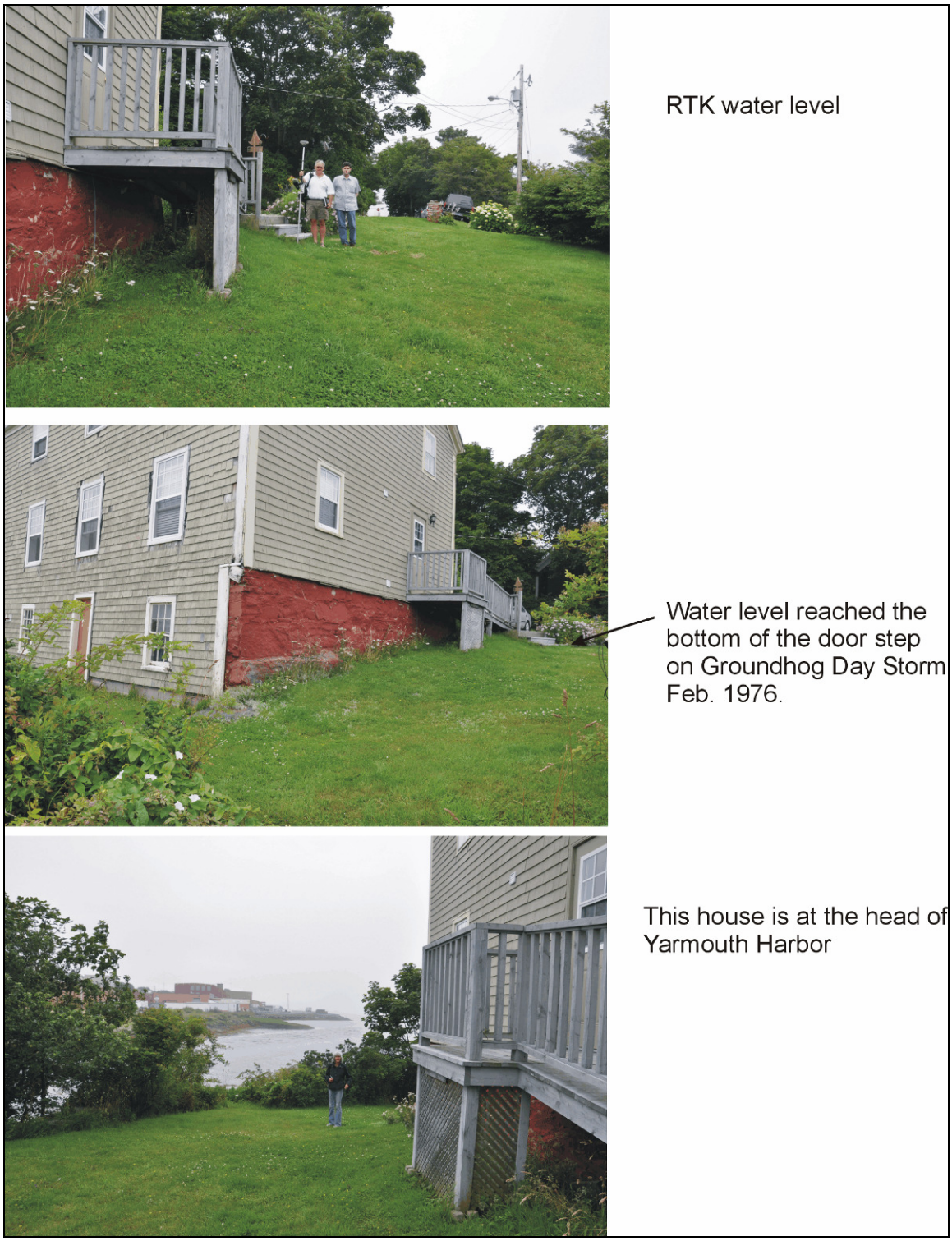

Figure 28 High-water mark being surveyed in Yarmouth from Feb. 3, 1976 Groundhog Day Storm. 4.81 m CGVD28 elevation from GPS of high-water mark.

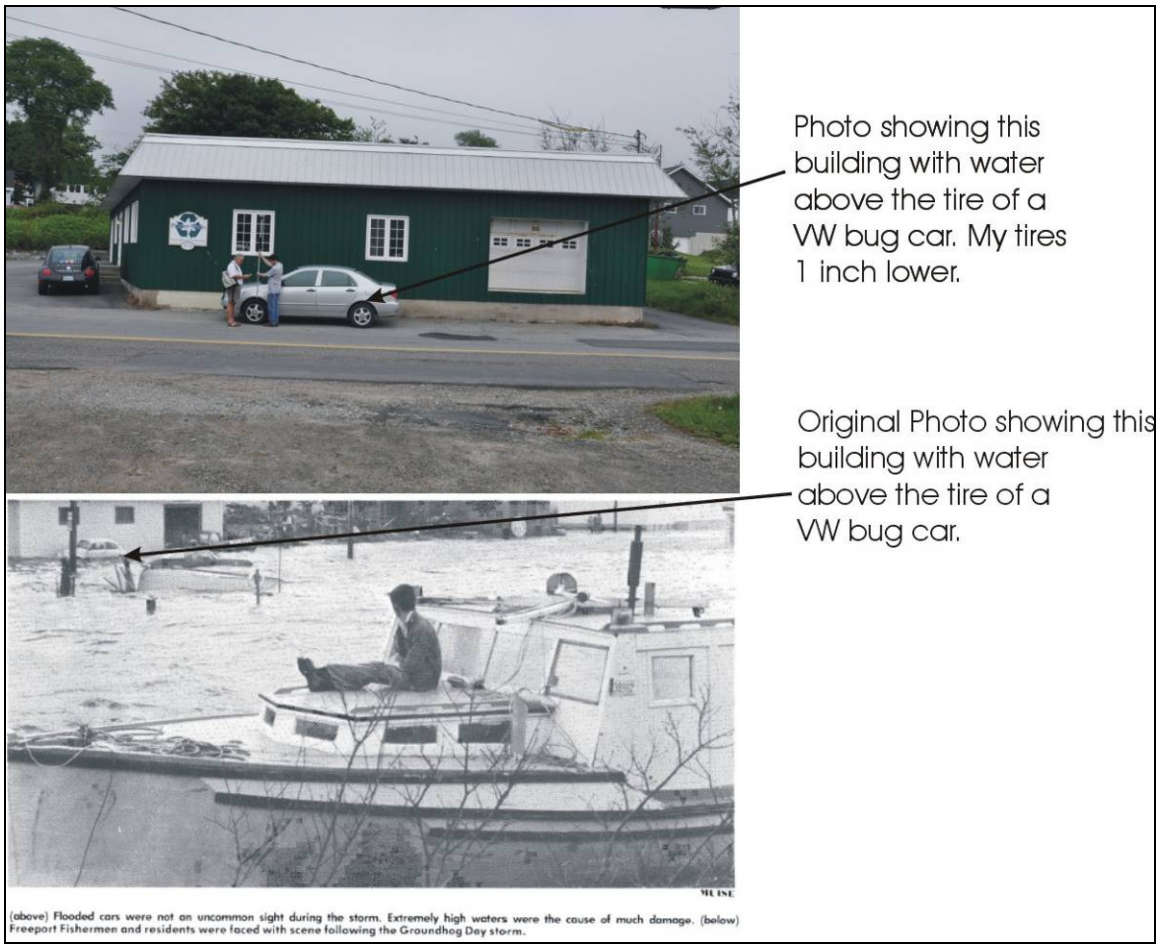

Figure 29 High-water mark being estimated and surveyed based on historic photo Feb 1976 (courtesy of the Vanguard Newspaper). RTK GPS of the top of the tire 3.56 m CGVD28.

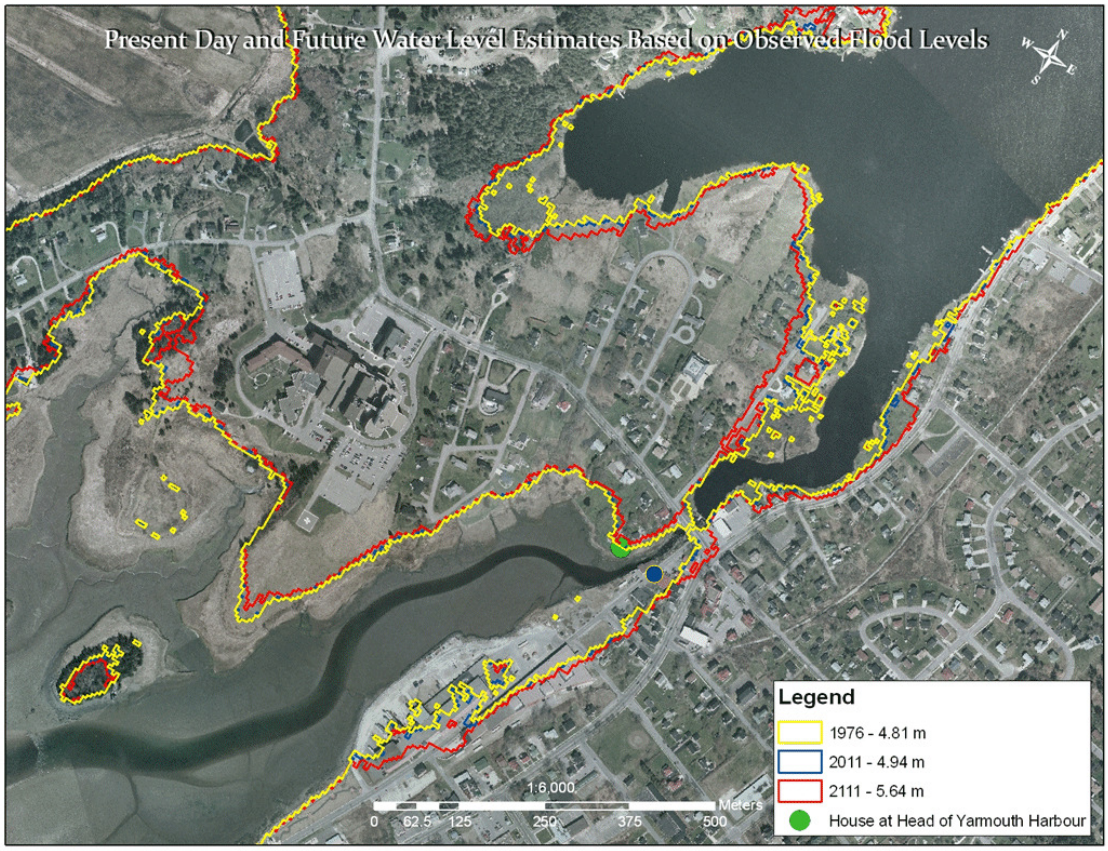

Figure 30 Yarmouth location map. Green dot is the back door step high-water mark and the blue dot is the top of car tire high-water mark RTK-GPS survey locations. The yellow line is the flood limit of 4.81 m high-water (door step elevation), the other lines represent sea-level rise in the future.

Storm Surge High Water Event

Data Collectors Name / Title / Phone Number: **Tim Webster / 902 825 5475**

Community: **Cape John, NS**

Date: **2010-12-21**

Tide (low, high, incoming): **High at 0000 hrs**

Phase of moon: **Full**

Ice: **Absent (based on photos)**

Time of maximum high water: **Dec 21**

Duration of the storm: **U/K**

Direction of wind: **Northeasterly**

Wave heights: **U/K**

Nails in wood & photo marking high water: **Photos of debris (wrack) line**

Photos of the high water events: **From eye witnesses**

GPS Coordinates of location (UTM, Easting Northing): **20 T 492614 5071426**

Photo Name	Location	Time	Survey mark on photo

Contact: Dr. Tim Webster, Research Scientist, Applied Geomatics Research Group, NSCC Middleton. Phone: 902 825 5475, Fax 902 825 5479, email: tim.webster@nscc.ca.
We would prefer & appreciate digital versions of the info if possible.

Figure 31 Debris high-water line from Dec 21-22, 2010 storm at Cape John (top photo). RTK GPS of high-water line indicates a water level of 2.38 m CGVD28.

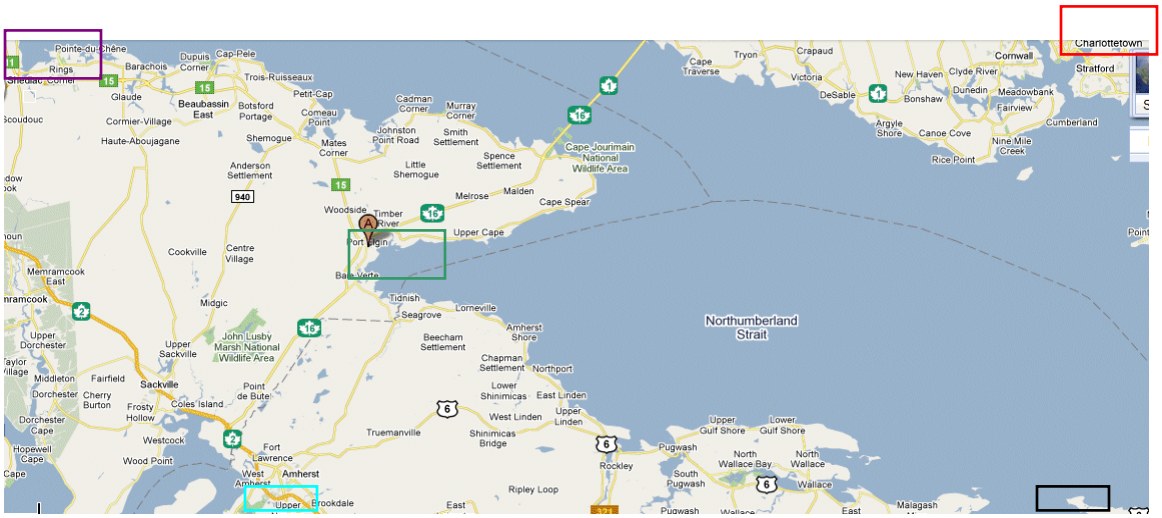

Figure 32 Location map of sites (coloured rectangles) along the Northumberland Strait. Sites of interest include Cape John (black), Charlottetown (red), Port Elgin (green), and Shediac (purple). Nappan (blue) along the upper Bay of Fundy is also on the map.

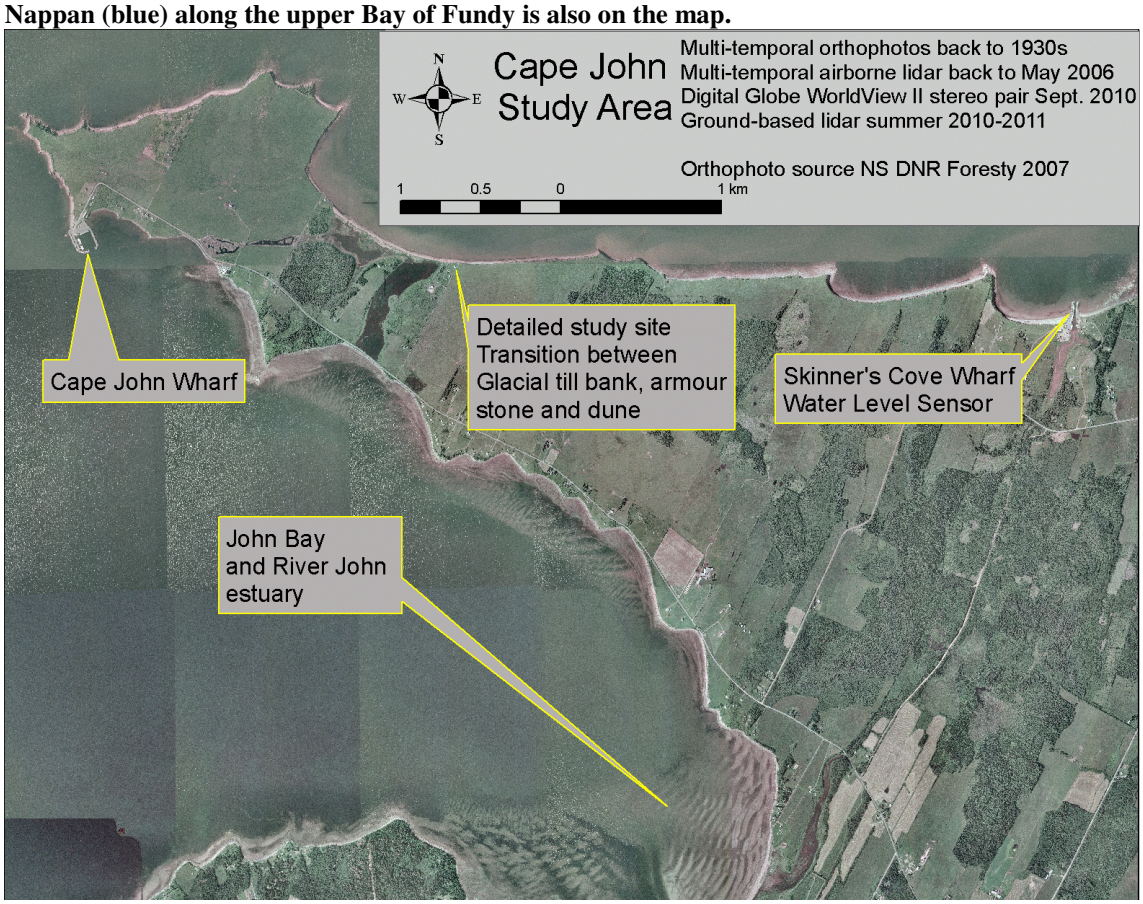

Figure 33 Detailed location of Cape John site (detailed study site label box location) and Skinners Cove (tide gauge location).

Storm Surge High Water Event

Data Collectors Name / Title / Phone Number:

Community:

Date:

Tide (low, high, incoming):

Phase of moon:

Ice:

Time of maximum high water:

Duration of the storm:

Direction of wind:

Wave heights:

Nails in wood & photo marking high water:

Photos of the high water events:

GPS Coordinates of location (UTM, Easting Northing):

Photo Name	Location	Time	Survey mark on photo

Contact: Dr. Tim Webster, Research Scientist, Applied Geomatics Research Group, NSCC Middleton. Phone: 902 825 5475, Fax 902 825 5479, email: tim.webster@nscc.ca.
We would prefer & appreciate digital versions of the info if possible.