Project Title: Study of the relationship between hydrological stranding and water level in Georgian Bay wetlands

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Research contracted by the International Joint Commission's International Upper Great Lakes Study Board for the Ecosystem Technical Work Group (ETWG)

BACKGROUND:

The International Upper Great Lakes Study Board (Study Board) is in the fourth year of a five-year study for the International Joint Commission (IJC). With respect to the Lake Superior Task Team, the objectives of the study are to:

1. Review the operation of structures controlling Lake Superior outflow and the potential effects on water levels and flows and the potential impacts on users;
2. Assess whether changes to the IJC's Lake Superior Orders of Approval or regulation plan are warranted to meet contemporary and emerging needs, interests and preferences for managing the system in a sustainable manner; and
3. Evaluate any options to improve the operating rules and criteria governing the upper Great Lakes system.

The Study Board will make decisions that could affect the Upper Great Lakes for decades, based on its estimate of the impacts from various lake-level regulation alternatives. Those estimates will be based on assumptions about the impact areas each Technical Working Group represents; the environment, commercial navigation, hydropower, shoreline development, recreational boating, and domestic, municipal and industrial water use.

OUTLINE:

The Ecosystem Technical Work Group (ETWG) is tasked with informing the Study Board's discussions and estimates on the ecological impacts from alternative water-level regulation scenarios. The ETWG will do this by estimating the impacts that changes to water levels/flows may have on environmental performance indicators within specific sites in the Upper Great Lakes (which is consistent with the Study Board's approved method of study). The ETWG has chosen several regional sites where ecological impacts will be assessed. Regional site selection was based on: ecological representation and/or significance; data availability and certainty; sensitivity to water-level regulations; and geographic coverage.

One of the regional sites is Georgian Bay (Lake Huron), chosen for its importance as a wetlands ecosystem, high level of susceptibility to changes in water levels/flows, significance as one of the Basin's most ecologically diverse areas, and availability of existing information and datasets.

OBJECTIVE:

We were contracted by ETWG to conduct a study of the relationship between hydrological stranding (i.e. hydrologically disconnected from Georgian Bay) and water level in Georgian Bay. We proposed to randomly select a minimum of 100 wetland/wetland complexes from the McMaster Coastal Wetland Inventory (MCWI) to determine the elevation of their entrances (i.e. sill depths) and to create an associated "Performance Indicator" for use in the ecological response model under development by ETWG. Given the large geographic extent of the Georgian Bay coastline, and the long travel time required to reach northern Georgian Bay, we had to restrict this study to eastern Georgian Bay between Matchedash and Henvey Inlet/Key River (see Figure 1).

RATIONALE:

Coastal wetlands of Georgian Bay are known to support critical spawning and nursery habitat for the fish community of Lake Huron. Midwood and Chow-Fraser (unpub. data) has shown that majority of the fish stay within their home wetland and do not migrate to adjacent wetlands even when they are close by (< 100-500 m away). Therefore, wetlands that are hydrologically disconnected from Georgian Bay are "lost" fish habitat, and this should have serious implications for recruitment of the Lake Huron fishery. The Performance Indicator developed here is therefore the number of wetlands and the total area of wetlands that would be stranded as a function of water levels of Lake Huron.

METHODS:

Selection of sites
The McMaster Coastal Wetland Inventory (MCWI) was completed in April 2010 and identifies all the coastal wetlands along Eastern Georgian Bay (MCWI; Chow-Fraser unpub data). We performed a stratified sampling procedure to ensure that we obtained at least 100 wetlands in proportion to their availability in quaternary watersheds. We used ArcMap 9.2 to import a shapefile of quaternary watershed boundaries (obtained from the Land Information Ontario, Ontario Ministry of Natural Resources; see Figure 2) into the MCWI, and assigned all wetlands into quaternary watersheds. This stratified random sampling procedure ensured that results of this study would be directly applicable to the more than 5300 ha of wetlands in the MCWI found along eastern and northern Georgian Bay. In this study, only wetland > 2 hectares have been included, to be consistent with the size criterion used by the Ontario Ministry of Natural Resources.

Sill Depth Data Collection
All data were collected between May and September in 2010. We used three different methods to collect raw depth and elevation data: 1) a differential GPS (dGPS; Magellan ProMark 3®) base and roving unit; 2) a graduated pole to collect depth information manually together with a Garmin Etrex GPS (herein referred to as the Mobile GPS); and

3) a boat-mounted GPS and sonar depth sounder. We had to use all three methods because the water was too shallow on approach to the wetland entrances (<2 m) for us to use the boat safely, and too deep for us to use the dGPS while wading. To avoid water damage to the roving unit, we only used the dGPS and Mobile GPS equipment to a depth of ~1.2 m. For water depths between 1m and about 3 m, we used the graduated pole in a canoe. The accuracies associated with each source varied, with the dGPS being the most accurate (sub-meter horizontal accuracy and centimeter vertical accuracy). The Mobile GPS had 1-m accuracy horizontally and a 0.5 cm-accuracy for depth. The depth sounder was the least accurate, with approximately 3-m horizontal accuracy with good depth accuracy to 1 cm.

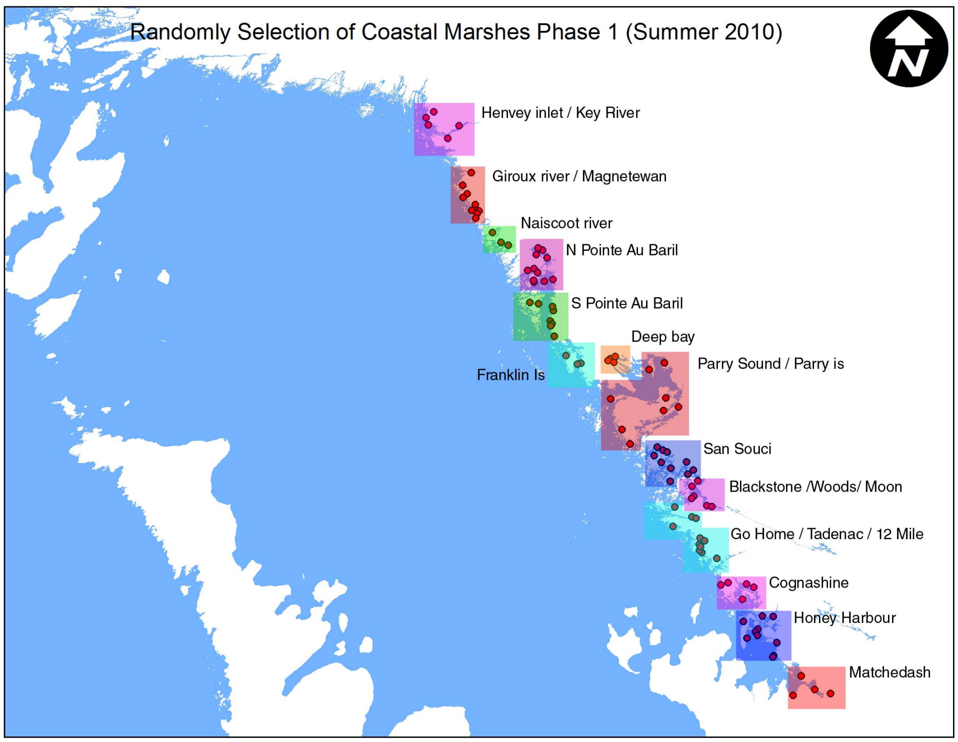


Figure 1. Location of study sites in Georgian Bay included in this study.

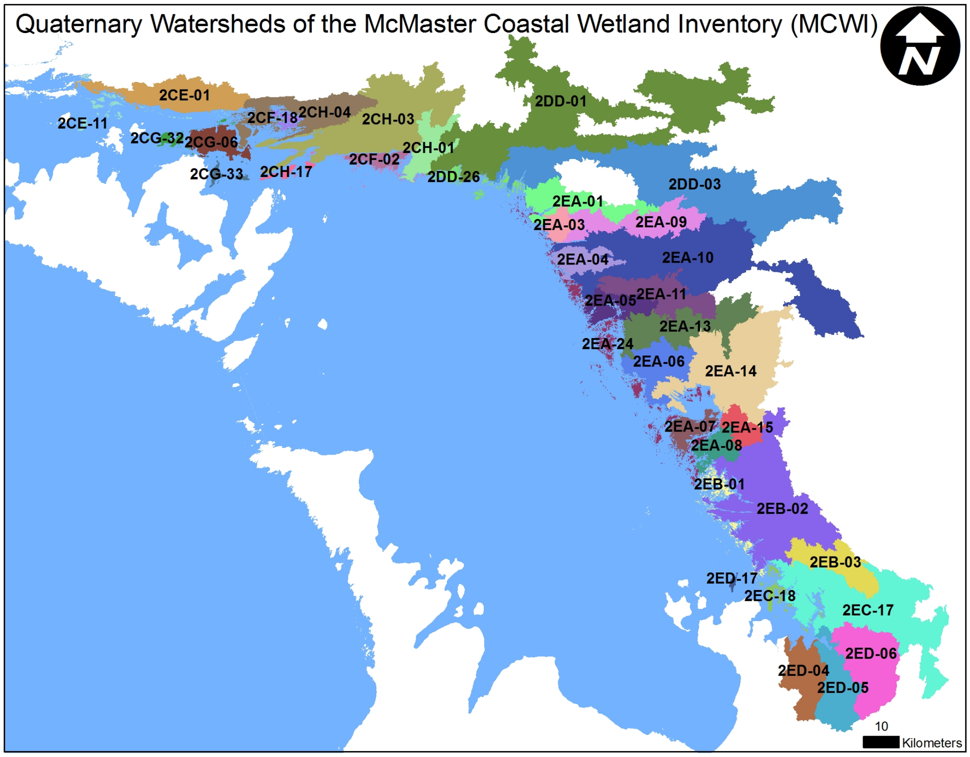


Figure 2. Boundaries and identifier of the quaternary watersheds delineated by Ontario Ministry of Natural Resources

Deriving Elevation

To convert the depth data collected in the field to elevation, we used hourly water-level data measured at Parry Sound (Canadian Hydrographic Service [CHS] of the Department of Fisheries and Oceans [http://waterlevels.gc.ca/C&A/wldata/parythis.htm]; m, IGLD 1985 datum) that approximated the times when we made the field measurements. We also derived elevation data from the depth measurements recorded with the depth sounder and Mobile GPS unit using this information. The dGPS data were adjusted to actual elevation by scaling the values back to the water level recorded at Parry Sound for the specific day and time.

Identifying Sill Depths

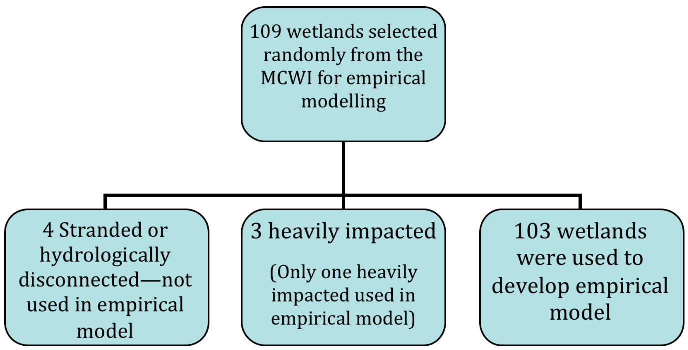
All of the digital information were merged in ArcMap 9.2 and shapefiles were created for each wetland and overlain onto IKONOS imagery made available from Georgian Bay Forever for this project. Most of the images were acquired in 2002, but some had been acquired in 2005 and 2008. Elevation data were visually inspected to determine the sill depth at the entrance to the wetland.

Potential Errors

Depending on the complexity of the wetland geomorphology, we may not have located the highest elevation associated with a sill, and in those instances, the sill elevation would have been underestimated. There was insufficient time in this study for us to conduct exhaustive field work to obtain anything other than coarse coverage. In a few instances, water levels had dropped sufficiently that portions of wetlands had become hydrologically disconnected. In those cases, we subdivided the wetlands and carried out measurements accordingly.

RESULTS:

In total 109 wetlands were selected and sampled (see flowchart below). Of these, 4 were already stranded (i.e. hydrologically disconnected), 3 were heavily impacted by human activities, and of these only 1 were sufficiently intact to be included in subsequent analyses. Therefore, data for 103 wetlands were used to produce the empirical relationship between sill depth or maximum depth of wetland entrance and water level.



The cumulative relative frequency of wetlands that would be stranded were calculated and expressed as percentages and plotted against the water level that corresponds to the elevation of the sill depth of maximum depth of wetland entrance (see Figure 3).

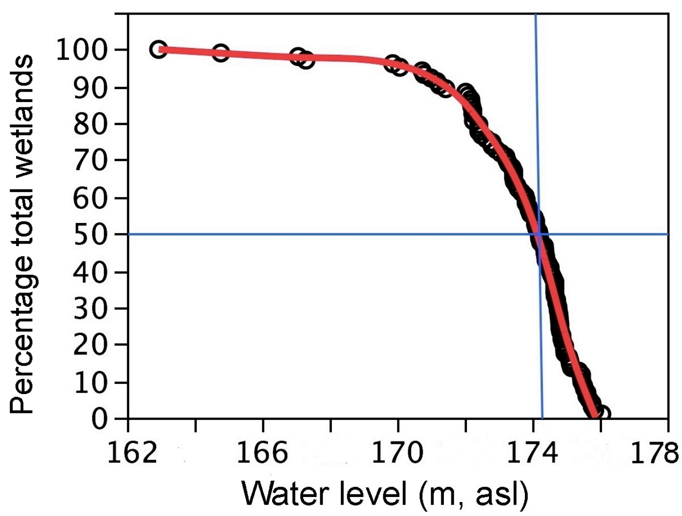


Figure 3. Percentage of wetlands that would be stranded as a function of water level. The red line is a spline fit (lambda=1). The water level that corresponds to a stranding of 50% of wetlands in this study is approximately 174.15 m above sea level, and is highlighted in blue.

Similarly, the total cumulative area expressed as percentages were also calculated and plotted against water levels (see Figure 4).

Figure 4. Percentage of total area that would be stranded as a function of water level. The red line is a spline fit (lambda=1). The water level that corresponds to a stranding of 50% of total wetland area in this study is approximately 174.00 m above sea level, and is highlighted in blue.

DISCUSSION:

The graphs show that 50% of wetlands would become stranded (hydrologically disconnected with Georgian Bay) if water levels were to drop to 174.1 m and that 50% of total wetland area would no longer be accessible to fish if water levels dropped to 174.0 m (Figures 3 and 4, respectively). Another way to interpret this relationship is that wetlands and wetland area are extremely sensitive to water-level fluctuations between 173 and 176 m. Hence, a drop or increase of 30-40 cm has significant impact within this range. We therefore used data corresponding to elevations of 173 and 176 and generated predictive equations as follows:

Cumulative total wetlands = 5016.1308 - 28.52897 * Lake elevation
(r^2=0.97; $P<0.0001$; n=73) Eq 1

Cumulative total area (ha) = 55.448428 - 0.3158886 * Lake elevation
(r^2=0.93; $P<0.0001$; n=73) Eq. 2

CONCLUSION:

This study has confirmed that further water-level decline in Georgian Bay (beyond 176 m) will have a direct and measurable impact on the total number and total area of wetlands that could be stranded. The empirical relationship that we have established here shows wetlands are most sensitive to changes in water levels between 173 and 176 m. Unfortunately, we do not have sufficient data currently to speculate on how wetland area and number would change in response to higher water level.

Table 1: Data for wetlands surveyed in this study.

Region	Wetland Name	Latitude	Longitude	Area_ha	Entrance_Sill elevation (m, asl)
Blackstone/Woods/Moon	Moon River 2	45.109	-79.953	27.067	172.205
Blackstone/Woods/Moon	Grapps Marsh (B)	45.173	-80.018	7.721	174.968
Blackstone/Woods/Moon	Moon Bay 2	45.126	-80.010	2.067	174.726
Blackstone/Woods/Moon	Woods Bay	45.150	-80.008	4.349	173.542
Blackstone/Woods/Moon	Moon River 1	45.111	-79.967	12.425	170.997
Blackstone/Woods/Moon	Blackstone Bay 2	45.160	-79.992	5.338	174.059
Blackstone/Woods/Moon	Captain Allan Channel	45.129	-80.003	2.006	173.453
Cognashene	Clifton Bay	44.957	-79.861	2.359	176.058
Cognashene	Cognashene Lake	44.960	-79.912	3.598	175.114
Cognashene	Outer Cognashene Lake	44.956	-79.931	2.475	175.380
Cognashene	Bone Island North Channel	44.950	-79.841	6.006	174.876
Cognashene	Big Ship Island	44.926	-79.873	2.621	174.819
Deep Bay	Deep Bay 2	45.401	-80.230	3.961	N/A
Deep Bay	Deep Bay 3 (A)	45.405	-80.217	4.557	174.469
Deep Bay	Deep Bay 1	45.397	-80.236	6.968	171.177
Deep Bay	Collins Bay at Deep Bay	45.393	-80.221	1.816	167.301
Deep Bay	Deep Bay 3 (B)	45.404	-80.213	1.141	172.498
Franklin Island	Franklin Island at Burritt Point	45.390	-80.322	16.006	174.370
Franklin Island	Ireland Point	45.392	-80.311	0.609	167.073
Giroux/Magnetawan River	Norgate 1	45.725	-80.624	18.471	174.879
Giroux/Magnetawan River	Mud Channel (A)	45.677	-80.601	1.517	173.907
Giroux/Magnetawan River	Outer Prisque South	45.686	-80.597	5.829	174.811
Giroux/Magnetawan River	Foster Is North	45.693	-80.612	2.377	174.362
Giroux/Magnetawan River	Mud Channel (B)	45.678	-80.604	0.966	174.914
Giroux/Magnetawan River	Giroux River Outlet	45.704	-80.602	17.874	162.939
Giroux/Magnetawan River	Outer Prisque Bay North	45.691	-80.595	2.213	175.128
Giroux/Magnetawan River	Whitefish Channel at Olga Island	45.742	-80.637	2.143	174.572
Giroux/Magnetawan River	Magnetawan River South side	45.766	-80.612	2.463	172.926
Go Home/Tadenac	Gunn Island (A)	45.023	-79.991	0.754	.N/A
Go Home/Tadenac	Black Rock (D)	45.045	-79.969	2.746	175.849
Go Home/Tadenac	Big Bass Bay South	45.031	-79.987	24.929	172.420
Go Home/Tadenac	Big Bass Bay North (A)	45.036	-79.990	9.488	172.420
Go Home/Tadenac	Bernadette Is	45.019	-79.983	6.272	174.528
Go Home/Tadenac	Black Rock (B)	45.045	-79.971	3.693	172.807
Go Home/Tadenac	Gunn Island (B)	45.024	-79.989	1.588	174.771
Go Home/Tadenac	Moose Bay (A)	45.070	-80.051	8.410	173.788
Go Home/Tadenac	Coffin Rock	45.047	-79.988	7.348	171.246
Go Home/Tadenac	Big Bass Bay North (B)	45.037	-79.992	1.471	172.420

Henvey Inlet	Henvey Inlet 2	45.858	-80.646	2.730	172.195
Henvey Inlet	Henvey Inlet 1	45.834	-80.679	16.640	173.070
Henvey Inlet	Key River (A)	45.886	-80.721	2.898	174.668
Honey Harbour	Roberts is 3 (C)	44.852	-79.835	10.755	175.548
Honey Harbour	Roberts Is 3 (A)	44.855	-79.833	13.407	173.694
Honey Harbour	Vennings Bay	44.841	-79.780	11.122	174.620
Honey Harbour	Moore Point South (B)	44.812	-79.792	0.706	175.625
Honey Harbour	Roberts Is 1 (B)	44.868	-79.832	1.555	172.245
Honey Harbour	Roberts Is 2	44.863	-79.838	9.632	174.410
Honey Harbour	Beausoleil Is at Turtle Bay	44.884	-79.870	7.916	174.403
Honey Harbour	Roberts Is 3 (D)	44.856	-79.843	23.304	173.449
Honey Harbour	Roberts Is 3 (B)	44.859	-79.829	1.697	174.378
Honey Harbour	Moore Point South (A)	44.813	-79.792	1.368	174.762
Honey Harbour	Moore Point North	44.815	-79.790	2.478	174.530
Honey Harbour	North Bay 4 West (B)	44.892	-79.821	0.440	174.667
Honey Harbour	North Bay	44.893	-79.789	2.683	172.034
Honey Harbour	Roberts Island 1 (A)	44.869	-79.830	0.881	172.245
Honey Harbour	Beausoleil Is 2	44.850	-79.862	2.517	164.775
Matchedash	Matchedash Bay	44.748	-79.678	1027.349	172.249
Matchedash	Juanita Is South	44.775	-79.715	3.051	174.957
Matchedash	Sturegon South	44.737	-79.738	122.817	173.824
Naiscoot	Charles Inlet at Naiscoot Middle Channel (B)	45.644	-80.542	64.947	174.796
Naiscoot River	Charles Inlet at Naiscoot Middle Channel (A)	45.650	-80.555	61.085	174.724
North Point Au Baril	Sturgeon Bay at Bonnie Island 2	45.617	-80.426	2.103	N/A
North Point Au Baril	Jergens Island (B)	45.552	-80.438	0.670	175.776
North Point Au Baril	Jergens Island (A)	45.552	-80.440	2.361	170.790
North Point Au Baril	Sturgeon Bay at Bigwood Island (A)	45.599	-80.403	5.546	170.081
North Point Au Baril	Tonches Island	45.570	-80.430	4.864	174.206
North Point Au Baril	Rathlyn Island	45.553	-80.411	6.101	173.401
North Point Au Baril	Sturgeon Bay 2	45.605	-80.433	3.216	170.736
North Point Au Baril	Sturgeon Bay 1	45.615	-80.416	6.746	173.216
North Point Au Baril	Pointe au Baril Channel 2	45.578	-80.440	3.396	171.444
North Point Au Baril	Mackenzie Island	45.555	-80.441	1.379	173.594
Parry Sound/ Parry Islands	Hay Bay	45.323	-80.077	3.033	172.643
Parry Sound/ Parry Islands	Surprise Channel	45.262	-80.200	10.569	172.102
Parry Sound/ Parry Islands	Rose Island	45.322	-80.230	11.426	174.667
Parry Sound/ Parry Islands	Barrys Channel at Elizabeth Island (A)	45.391	-80.080	3.021	174.223
Parry Sound/ Parry Islands	Barrys Channel at Elizebeth Island (B)	45.393	-80.079	0.660	174.959
Parry Sound/ Parry Islands	Huckleberry Island	45.379	-80.123	2.157	174.843
Parry Sound/Parry Islands	Barrys Channel at Elizabeth Island (C)	45.392	-80.078	1.882	174.249
San Souci	Spider Bay at Anthony Is	45.227	-80.103	4.904	175.623
San Souci	Gooseneck Bay	45.210	-80.112	2.933	175.520
San Souci	Vanderdasson Is	45.185	-80.065	7.608	173.821

San Souci	Howl Island (A)	45.197	-80.092	0.988	175.160
San Souci	Nightingale Bay	45.159	-80.068	3.134	173.304
San Souci	Port Rawson Bay	45.197	-80.022	5.930	173.881
San Souci	Howl Island (B)	45.195	-80.092	1.056	172.176
San Souci	Spider Lake Portage	45.217	-80.075	3.112	173.452
South Pointe Au Baril	Shawanaga Inlet 5	45.496	-80.387	1.841	175.694
South Pointe Au Baril	Shawanaga Inlet 4	45.476	-80.395	5.934	169.869
South Pointe Au Baril	Shawanaga Inlet 6	45.504	-80.389	5.926	174.100
South Pointe Au Baril	Hole in the Wall	45.524	-80.437	6.210	174.817
Blackstone/Woods/Moon	Blackstone Bay 1	45.181	-80.003	31.475	172.809
Blackstone/Woods/Moon	Grapps Marsh (A)	45.172	-80.016	3.685	174.101
Franklin Island	Franklin Island at Cunningham Bay	45.407	-80.353	2.539	175.771
Go Home/Tadenac	Black Rock (C)	45.039	-79.977	14.578	N/A
Go Home/Tadenac	Twelve Mile Bay	45.089	-80.009	4.224	173.949
Go Home/Tadenac	Black Rock (A)	45.043	-79.974	6.142	174.131
Go Home/Tadenac	Hermans Bay	45.087	-79.997	3.471	174.190
Go Home/Tadenac	Pittsburg Channel at Moreau Bay	45.008	-79.942	4.131	173.467
Henvey Inlet	Key River (B)	45.886	-80.717	4.523	174.668
North Point Au Baril	Pointe au Baril Channel 1	45.575	-80.457	3.860	172.263
Parry Sound/ Parry Islands	Boyne River	45.304	-80.043	4.966	175.469
Parry Sound/ Parry Islands	Peak Island	45.233	-80.177	1.595	175.082
Parry Sound/ Parry Islands	Minominee Channel	45.298	-80.084	4.925	173.252
San Souci	Falkner Island	45.220	-80.087	12.734	.N/A
South Pointe Au Baril	Shawanaga Inlet 3	45.470	-80.391	4.426	N/A
South Pointe Au Baril	Ni Bay (Mud Channel)	45.512	-80.452	9.180	174.790
Honey Harbour	North Bay 4 West (A)	44.894	-79.819	6.398	175.464
North Point Au Baril	Sturgeon Bay at Bigwood Island (B)	45.600	-80.403	1.322	175.460
South Pointe Au Baril	Shawanaga Island	45.509	-80.428	11.614	174.684