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NWRI Contribution No. 04-208

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Abstract

Field surveys based on the RoxAnn™ seabed-classification system and underwater video have been used to map the bed sediments of several sites in the Bay of Quinte. Surveys in the western part of the Bay were carried out on behalf of the Quinte RAP as part of a study on sediment quality. Work in the Picton area was requested by Burlington DFO to support studies of habitat assessment.

RoxAnn was able to distinguish several acoustic bottom types in both parts of the Bay, and underwater-videos surveys and limited sampling were used to calibrate the acoustic data and determine the physical-sediment types they represented. Most of the floor of bay was found to be fined-grained sediment with a high water content. More variability occurred in the inshore zone where bottom types were a mixture of coarser sediment with a macrophyte cover and bedrock or boulder bottom coated with zebra mussels.

RELEVÉS ACOUSTIQUES ET VIDÉO DES SÉDIMENTS DE LA BAIE DE QUINTE

Résumé

Des relevés faisant appel au système de classification des fonds marins RoxAnn^{TM} et à la vidéo sous-marine ont servi à cartographier les sédiments de fond de plusieurs sites de la baie de Quinte. Dans la portion ouest de la baie, les relevés ont été effectués au nom du Plan d'assainissement de la baie de Quinte dans le cadre d'une étude sur la qualité des sédiments. Dans la région de Picton, c'est le bureau de Burlington du MPO qui a demandé la réalisation des travaux pour soutenir les études sur l'évaluation de l'habitat.

Grâce au système RoxAnn, on a pu distinguer plusieurs types de fonds selon leur signature acoustique dans les deux portions de la baie. Des relevés vidéo sous-marins et un échantillonnage limité ont été utilisés pour étalonner les données acoustiques et déterminer les types physiques de sédiments qu'elles représentaient. On a découvert que la plus grande partie du fond de la baie était formée de sédiments fins à forte teneur en eau. La zone littorale présentait davantage de variabilité : les fonds étaient constitués de sédiments grossiers couverts de macrophytes combinés à des zones d'assise rocheuse et de blocs colonisées par les moules zébrées.

1. Introduction

Environment Canada conducted a sediment-mapping survey of the Bay of Quinte in June and October 2000 on behalf of the Quinte RAP and Department of Fisheries and Oceans. The purpose of the survey was to provide data on the distribution of bottom-sediment types in the western end of the bay as a contribution to the sediment-quality concerns of the local Remedial Action Plan, and to map substrates in its eastern part in support of DFO's habitat-assessment program. This report describes the field equipment and procedures used and displays and discusses the results of the acoustic and video mapping.

2. Background

The general features of the Bay of Quinte and its geological setting are described in a field guide by Sly and Christie, 1980. They note that the bay has a narrow, z-shaped outline determined by jointing in the local bedrock, and that the hydrology is controlled largely by drainage from the Trent, Moira and Napanee Rivers. The original survey of sediment types in the Bay was conducted in 1972 by NWRI (Damiani and Thomas, 1974). Their echo-sounding records show that the bed of the bay is floored by a complex of late glacial and post-glacial sediments overlying limestone bedrock.

The earlier survey was based mainly on grab samples and echo-sounder records. The current survey was intended to update part of the earlier data and to provide better resolution of the bed sediments by using a combination of acoustic classification of bottom sediments with RoxAnn™ and underwater-video records.

3. Field Equipment and Methods

RoxAnn is an acoustic processor which analyzes echo-sounder returns to produce a classification of bottom-sediment types which is then confirmed or adjusted with independent sample, diver or video data (Chivers et al, 1990; Rukavina and Caddell, 1997; Rukavina, 1998 and 2001). Acoustic data are logged and displayed on a notebook computer running the survey program, Microplot©. Microplot logs RoxAnn data and associated GPS positions at one-second intervals or about 2-3 m for the standard survey speed of 2-3 m/s and at depths greater than 2 m. Acoustic bottom types are displayed as they are collected on an electronic chart of the survey area within the Microplot program. Figure 1 is an example of a typical RoxAnn computer display. The coloured lines are the tracklines, and the colours represent the acoustic types assigned by the boxfile which classifies on the basis of the acoustic hardness and roughness of the echo-sounder echoes.

The RoxAnn sounder was a Knudsen 320M™ hydrographic sounder operating at a frequency of 200 kHz. Penetration of surface sediments at this frequency ranges from a few cm to about 50 cm depending on the sediment type and porosity. The echo sounder was adjusted for transducer draft and operated at a constant rpm equivalent to a velocity of sound of 1480 m/s. No barchecks were taken to correct for the effect of temperature on sound velocity.

Navigation for the survey was provided by a Sercel™ differential GPS with corrections from a beacon receiver. It was not possible to check GPS accuracy rigorously because no information on benchmarks was available. However, comparison of landmarks and the electronic charts used with the Microplot software confirmed that the GPS was performing properly. Accuracy of survey fixes based on past performance was assumed to be in the range of 2-4 m.

The groundtruth data for RoxAnn calibration consisted of surface samples (Shipek,

mini-Ponar, minibox corer) and underwater-video and diver records. Sites for the samples and video were selected in areas of consistent, acoustic bottom type and supplemental data from other sampling surveys were also used.

Video surveys in selected areas were also conducted with the camera mounted on a tripod frame with calibrated legs. This system permits the video records to be used to measure the soft-sediment thickness as well as to identify the bottom type.

The CCG launch Puffin, which is currently outfitted for and dedicated to RoxAnn work, was used for all the acoustic and video surveys and most of the sampling.

4. Survey schedule

All surveys were carried out in the summer and fall of 2000 within the area shown in Figure 2. The western part of the bay was surveyed from May 29 – June 2. RoxAnn traverses were run in the area offshore from Belleville, in the inshore portion of Big Bay, and from Belleville to Trenton. Grab samples were collected with a Shipek sampler at the Belleville site in June and at Trenton in November, and further sampling in both areas was done with a mini-Ponar and mini-boxcore in September and October. Underwater-video surveys were run during June at the Belleville site and in Big Bay, and the video tripod was used for sediment-thickness measurements in the Belleville area.

Field work in the eastern part of the bay took place between October 1 and 5. RoxAnn tracks were run in Picton and Hays Bays, at Glenora and Conway, and along the inshore portion of the reach between Picton and Bethany. Shipek and mini-boxcore samples were collected along the reaches between Picton and Bethany and Picton and Conway. Underwater-video surveys were conducted in Picton Bay, at the entrance to Hays Bay and at Glenora and Conway.

Details of the survey schedule are shown in Appendix 1.

4. Data Analysis

The independent data on bottom-sediment type needed for RoxAnn calibration were obtained from the bottom samples (Figures 3 and 4, Appendix 2) and underwater video (Figures 5 and 6, Appendix 3). The samples were analysed for grain size, and the size data were used in combination with the sample descriptions to define a number of sediment types. The underwater-video data were converted to a digital file and edited in QuickTime. The resultant file was then examined and used to define additional bottom types based on relief and macrophyte and zebra-mussel cover as well as grain size. Data on soft-sediment thickness was also extracted from the video records.

The Microplot software which is used to collect and display RoxAnn data uses a series of ranges of acoustic hardness and acoustic roughness called a boxfile to classify the incoming data from the sounder. The boxfile appears within the program as an xy plot with a number of boxes whose position and size are determined by the groundtruth data.

A spreadsheet-macro procedure was used to locate all RoxAnn data within a 5-m radius of the groundtruth sites so that a pair of hardness and roughness values could be associated with the sediment type at each site. An x-y plot of these values was then used to determine the size and location of the boxes and their physical labels.

The underwater-video records (Appendix 3) indicate that little of the bottom is composed of a single sediment type. Most of the substrate consists of a mix of mud, zebra mussels, macrophytes, and cobbles or boulders without well-defined boundaries. Because of this, the data from the bottom samples do not reflect the bottom variability and are of only limited use for RoxAnn calibration. The boxfile was based mainly on the

underwater-video observations which were subdivided into seven bottom types representing: 1) mud, 2) gassy mud, 3) mud with a partial cover of weeds and/or zebra mussels, 4) mud or sandy mud with weeds and/or cobbles, 5) zebra mussels with interstial mud and a partial cover of weeds, 6) thick and sometimes high weeds on a variety of bottom types, and 7) dense, thick zebra mussels on sand over shallow bedrock. The shallow bedrock of type 7 was inferred rather than observed because the combination of very high acoustic-hardness values and low to moderate roughness has been recorded elsewhere only on exposed bedrock or shallow bedrock with a sand cover.

The new, locally-calibrated boxfile was then used to reanalyze the RoxAnn records and to assign colours to correspond with the 7 bottom types determined from the groundtruth data. Figure 7 shows the entire boxfile and Figure 8 an enlargement of the class boundaries of the smaller classes.

5. Results and Discussion

The bed materials at both the western and eastern sites consist of uniform basin muds and an inshore shelf with a variable substrate. Figures 9 and 10 show the calibrated RoxAnn maps of bottom-sediment types for the western and eastern basins respectively and Figures 12 to 15 are enlargements of the Belleville basin and of the survey sites in the eastern basin. The seven bottom classes resolved by RoxAnn generally represent groupings of more than one substrate type in which one size class or coating is dominant. This is particularly true of the shelf sediments which have a mud or sandy-mud matrix and highly variable proportions of macrophytes, zebra mussels and cobbles or boulders. The contact between the muds and the shelf sediments generally occurs at a depth of between 4 and 6 m. The high RoxAnn hardness values interpreted as shallow bedrock have a limited and patchy distribution. They occur at the mouth of the Trent River, offshore from Bakelite in the Belleville basin, at the southeastern end of Big

Bay and at the northern end of the Bethany to Hay Bay reach.

The sites at which zebra mussels and bottom weeds were observed in the samples and underwater video are shown in Figures 13 and 14. These are not necessarily sites in which either type is the dominant one with the result that the distribution does not necessarily agree with the RoxAnn pattern. Because no descriptions were available for about a quarter of the samples, there may be additional sites with mussel or weed content that are not represented here. Based on the sample or video data only, occurrences of both zebra mussels and bottom weeds were more common in western Quinte along the north shore and occurred in isolated patches in eastern Quinte with a concentration at the north shore at Conway.

Because of time constraints, RoxAnn and video coverage through most of the study area was limited to transects across the mud-shelf boundary. A more detailed survey was carried out in the Belleville basin. Sediments in the basin (Figure 12) generally follow the same pattern of mud at depth and coarser, weedy sediments inshore. High concentrations of both weeds and zebra mussels on a base of muds and sandy muds occur offshore from Bakelite, Meyers Pier, and Zwick Island and at the mouth of the Moira River. Sediment thickness along the north shore of the basin was measured by lowering a tripod equipped with a video camera to refusal and measuring the penetration. Thickness ranged from 20 to 90 cm and generally exceeded 50 cm. This penetration was achieved with a tripod weighing less than 30 kg, an indication that the surface muds are very soft and have a small bearing strength. No information is available about the material in which refusal occurred but the earlier surveys indicate that it should be either compact glacial sediments or bedrock.

Size-analysis data for the grab samples for the west and east areas expressed as gravel/sand/silt/clay percentages are shown in Figures 16 and 17 and listed in Appendix 2. Silt-plus-clay content ranged from 0 to 100 % in both areas and averaged 82% in the west and 75% in the east. Grain size generally increased in an inshore direction.

6. Conclusions

RoxAnn and video mapping of the western and eastern parts of the Bay of Quinte has been able to distinguish seven bottom types ranging from mud to near-surface bedrock. The basin sediments are thick, uniform muds, and the shelf sediments have a mud or sand matrix but with a highly variable cover of coarser sizes (generally cobbles or boulders) or zebra mussels and thin to dense macrophytes. The boundary between the basin and shelf types generally occurs in the depth range 4 to 6 m.

The grain size of the sediments is generally mud or muddy sand with an average silt-clay percentage of 82% in the west and 75% in the east, and is generally depth dependent with coarser sediments occurring in shallower depths.

Sediment thickness measured along the north shore of the Belleville basin generally exceeded 50 cm and the sediments there were easily penetrated. No information was obtained about the underlying substrate, but this is know to be either compact glacial sediment or bedrock. If the distinction is important, then further surveys with a free-fall penetrometer could be undertaken to measure both the shear strength of the overlying sediments and that of the substrate base.

The occurrence of zebra mussels and bottom weeds as observed directly in bottom samples and video records was highest along the north shore of the Belleville basin and on north shore at Conway.

RoxAnn was effective in discriminating the simple basin and complex shelf sediments but less successful in resolving the variability in the shelf sediments because similar acoustic responses were obtained from different substrate types or combinations of types. The video surveys were essential for both the RoxAnn calibration and for the detail they provided on the sediment thickness and variability.

8. Acknowledgements

H. Biberhofer of Environment Canada's Ontario Region and K. Minns of DFO Burlington's Great Lakes Laboratory for Fisheries and Aquatic Sciences requested the survey. NWRI's Technical Operations Section provided the launch and coxswain (D. Gilroy). The RoxAnn operator was B. Trapp of NWRI's AEMR Branch. Supplemental samples were provided by D. Milani of NWRI and P. Mudroch of Environment Canada's Environmental Protection Branch. M. Dunnett of NWRI and contractor, C. Prokopec were responsible for the reduction of much of the data. Video clips were edited and assembled by B. Trapp and C. Prokopec. The development of RoxAnn as a sediment mapping tool is being funded by Environment Canada's Great Lakes 2000 Cleanup Fund.

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Figures

Appendices

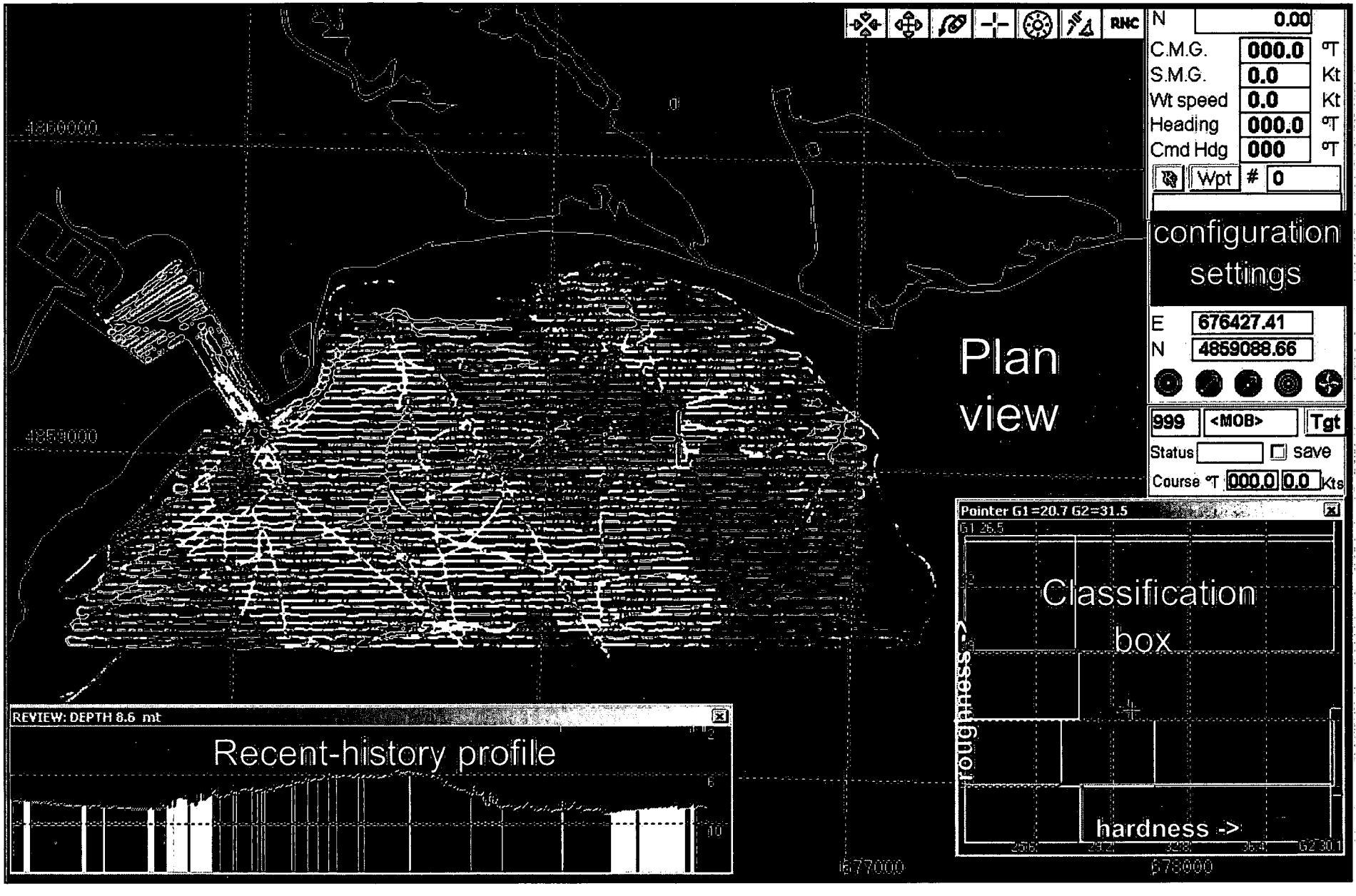

Figure 1. Microplot display of RoxAnn data

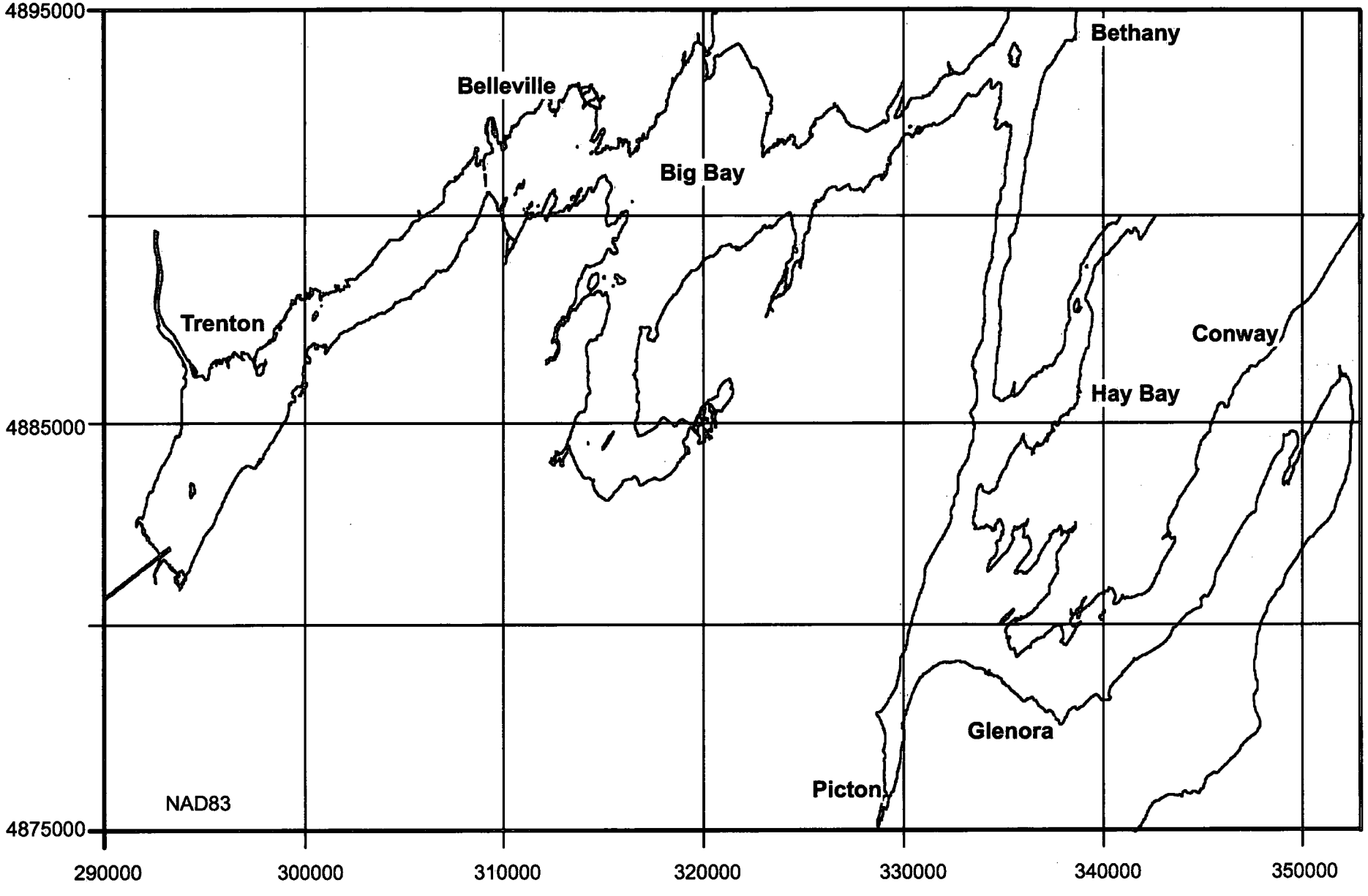

Figure 2. Site Map

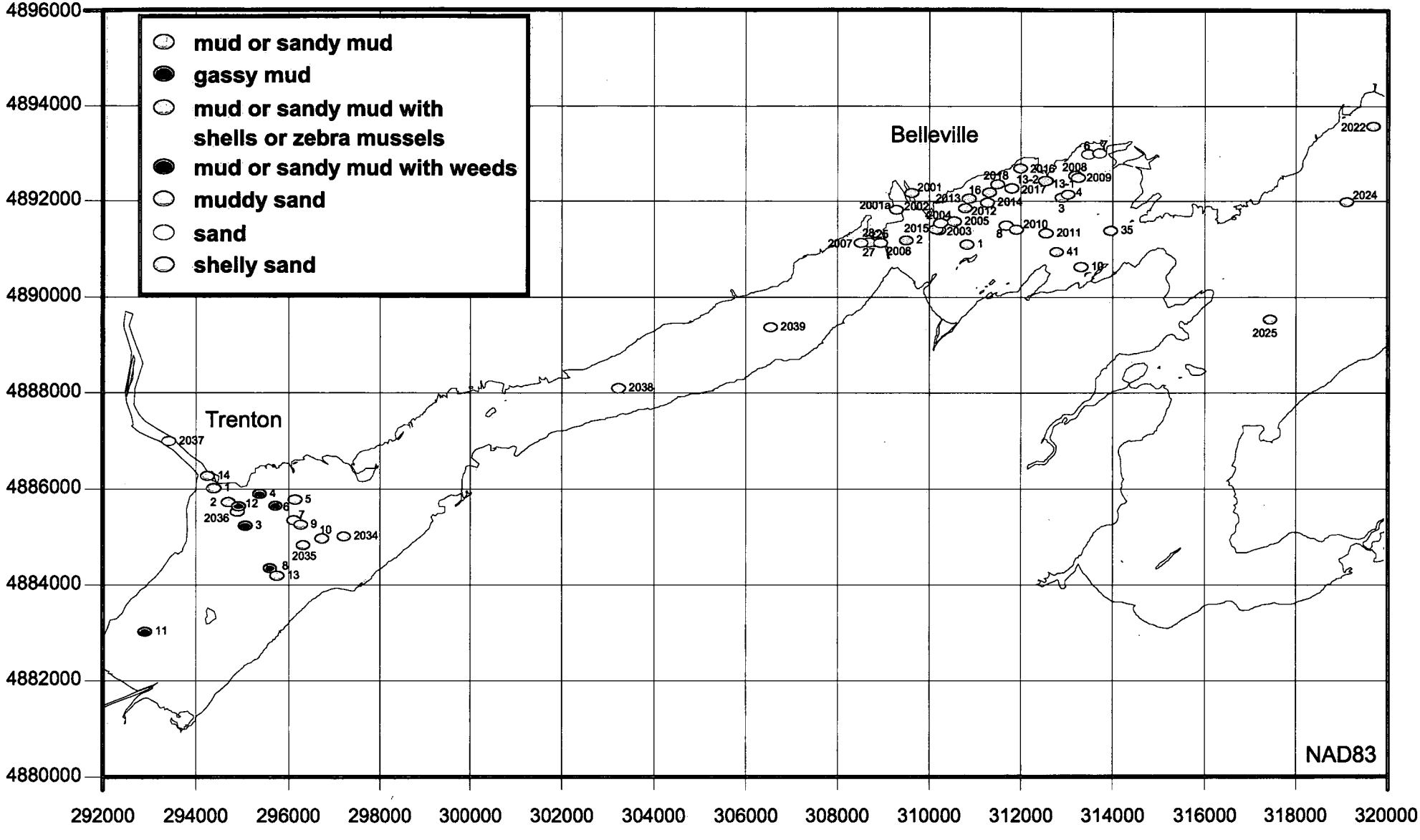

Figure 3. Bottom samples, west Quinte

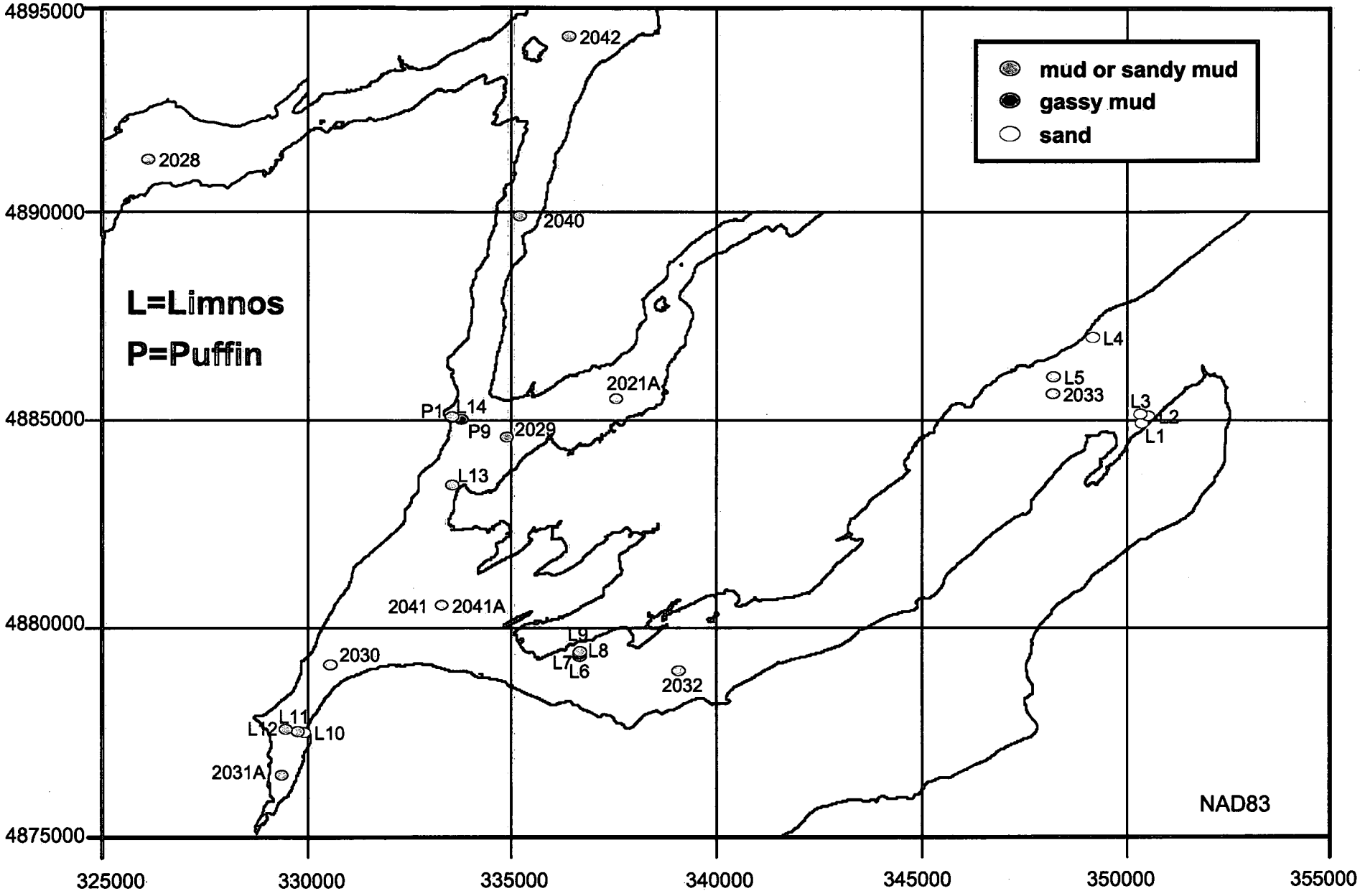

Figure 4. Bottom samples, east Quinte

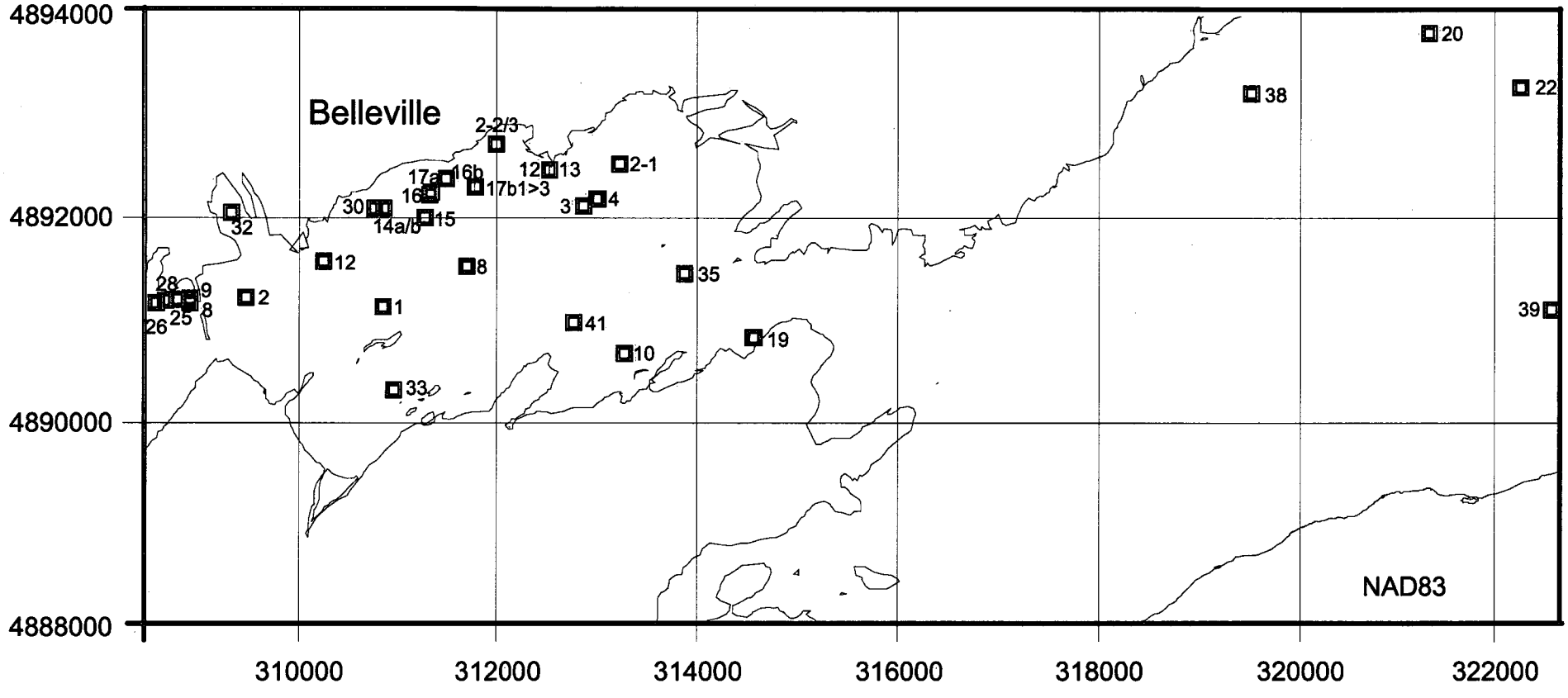

Figure 5. Underwater-video sites, west Quinte

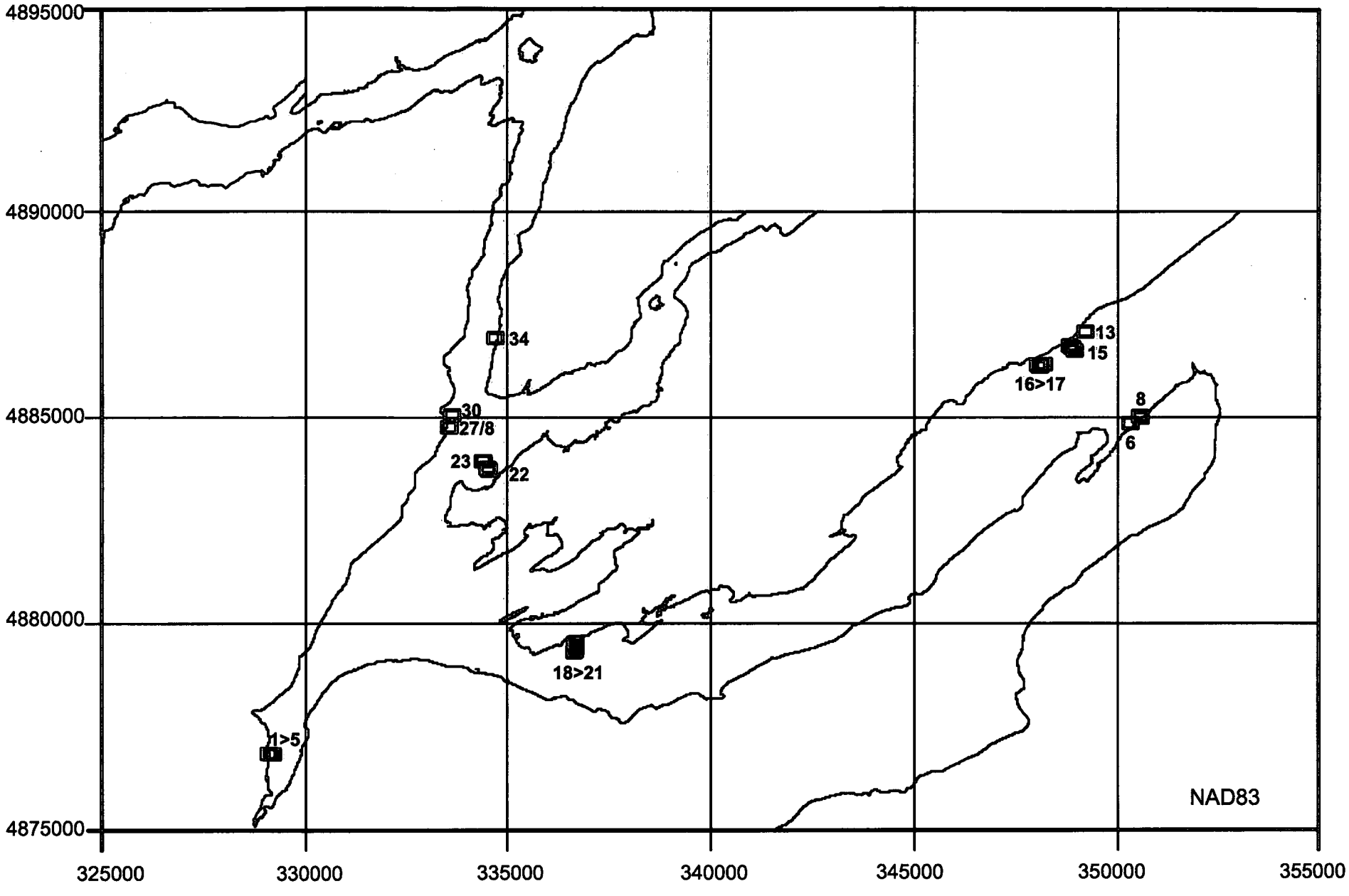

Figure 6. Underwater-video sites, east Quinte

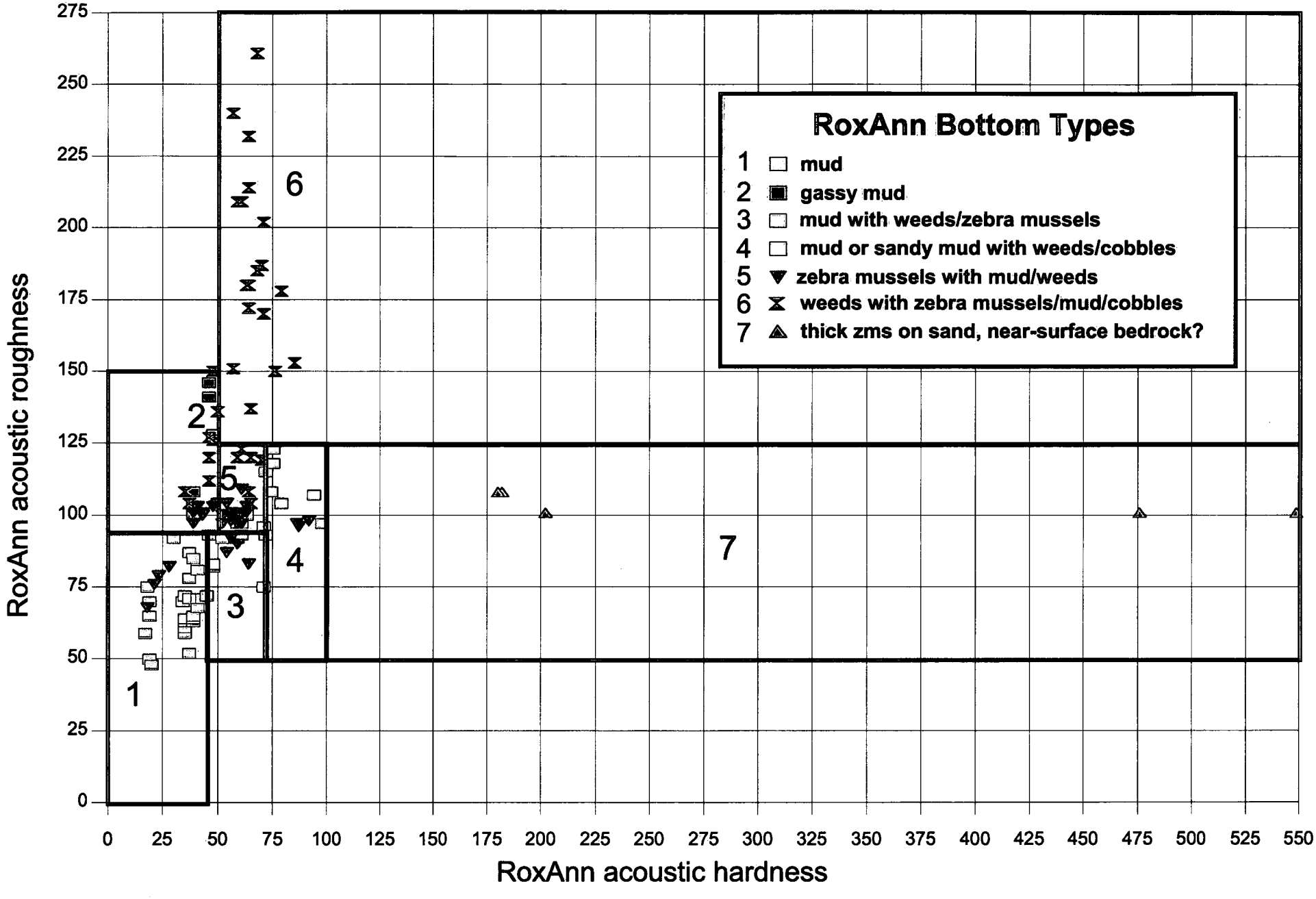

Figure 7. RoxAnn boxfile (calibration) file

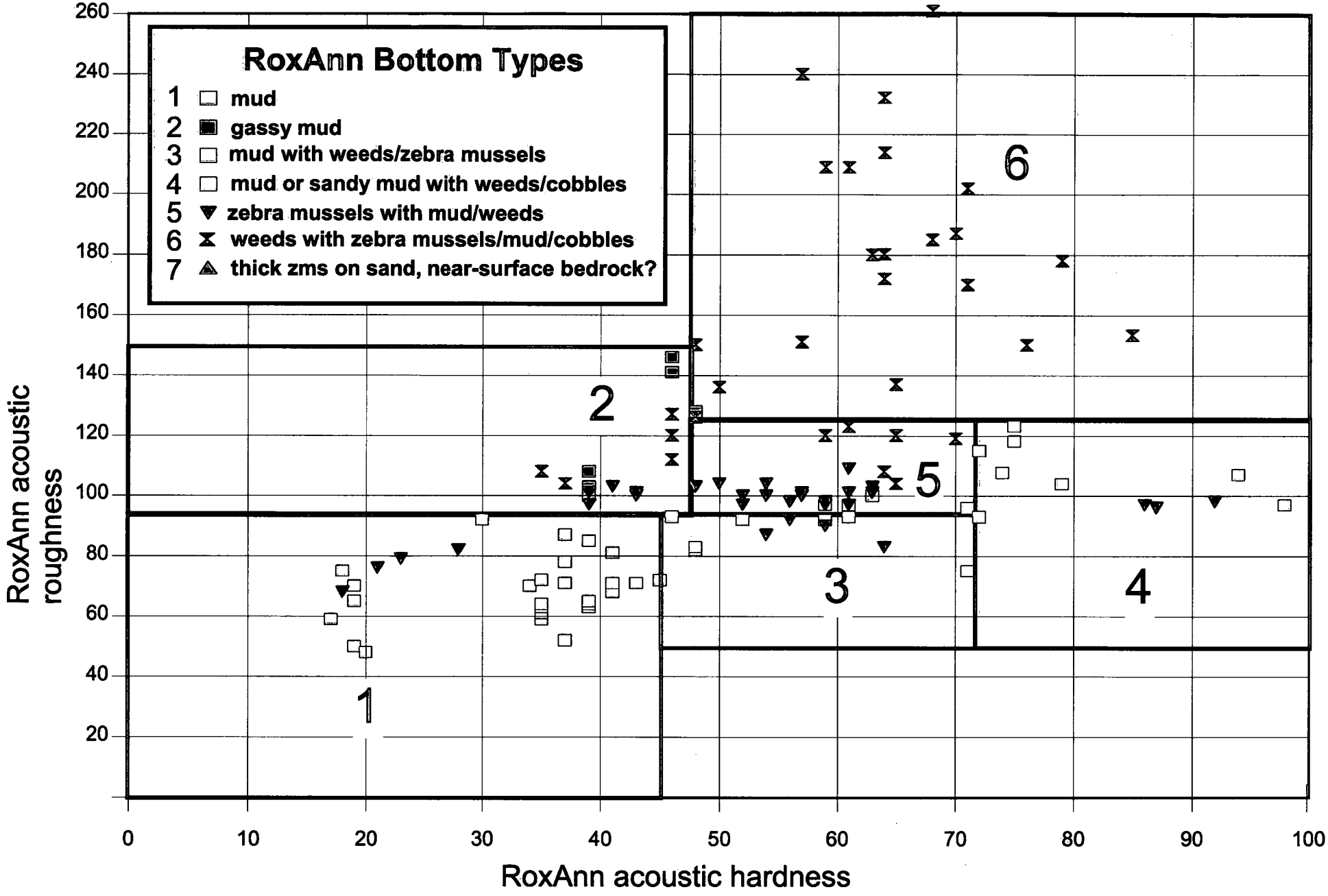

Figure 8. RoxAnn boxfile detail

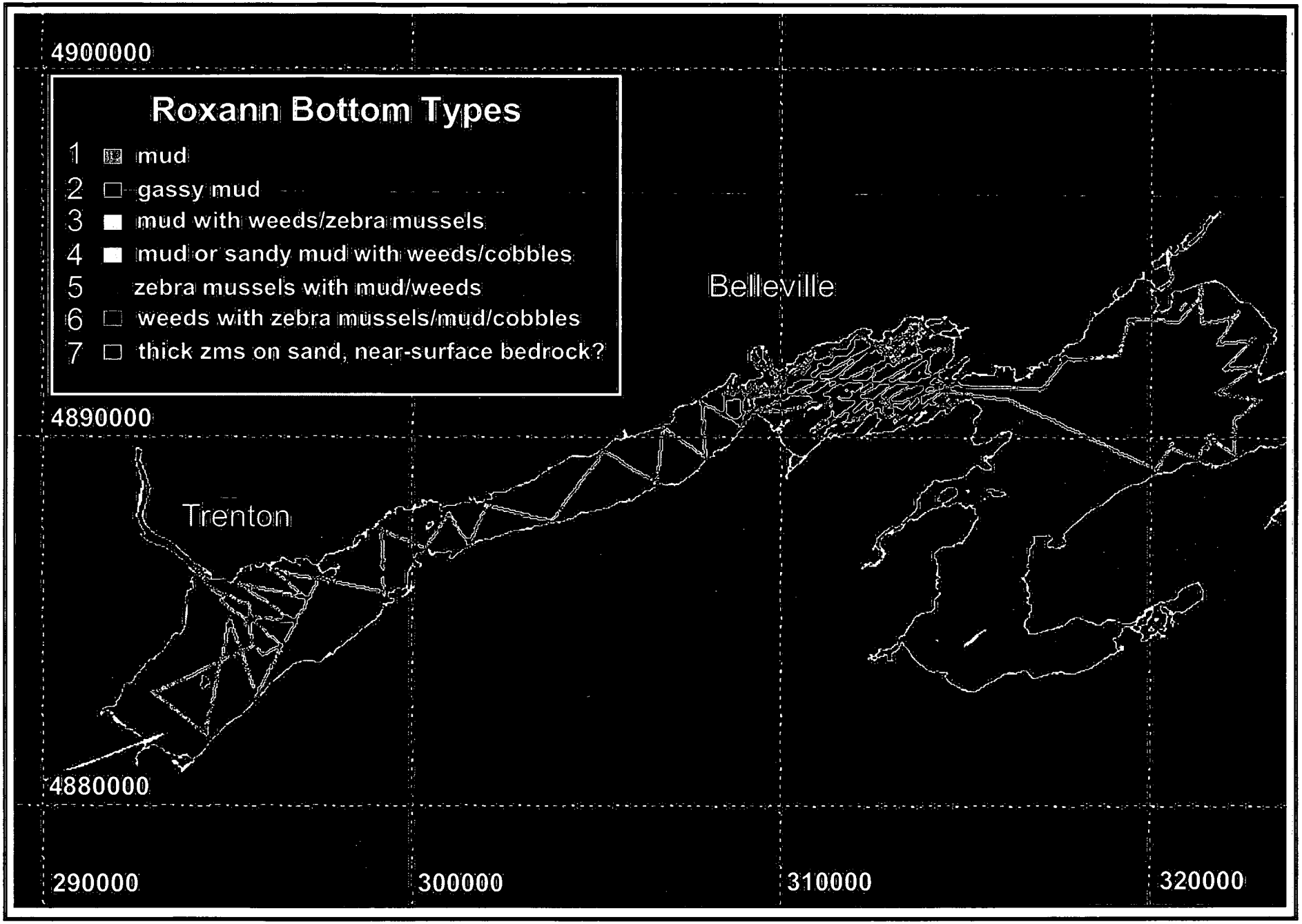

Figure 9. RoxAnn bottom types, west Quinte

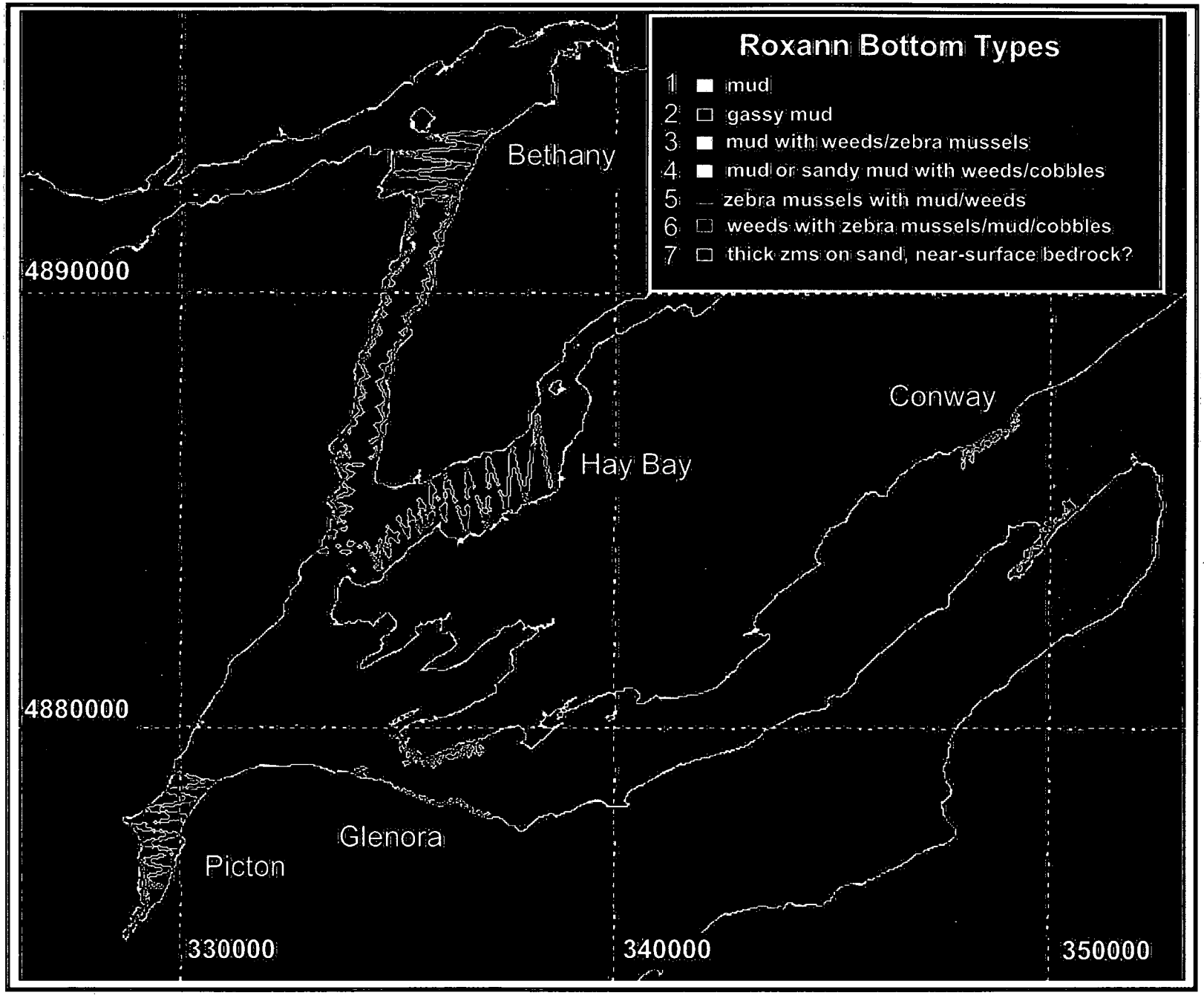

Figure 10. RoxAnn bottom types, east Quinte

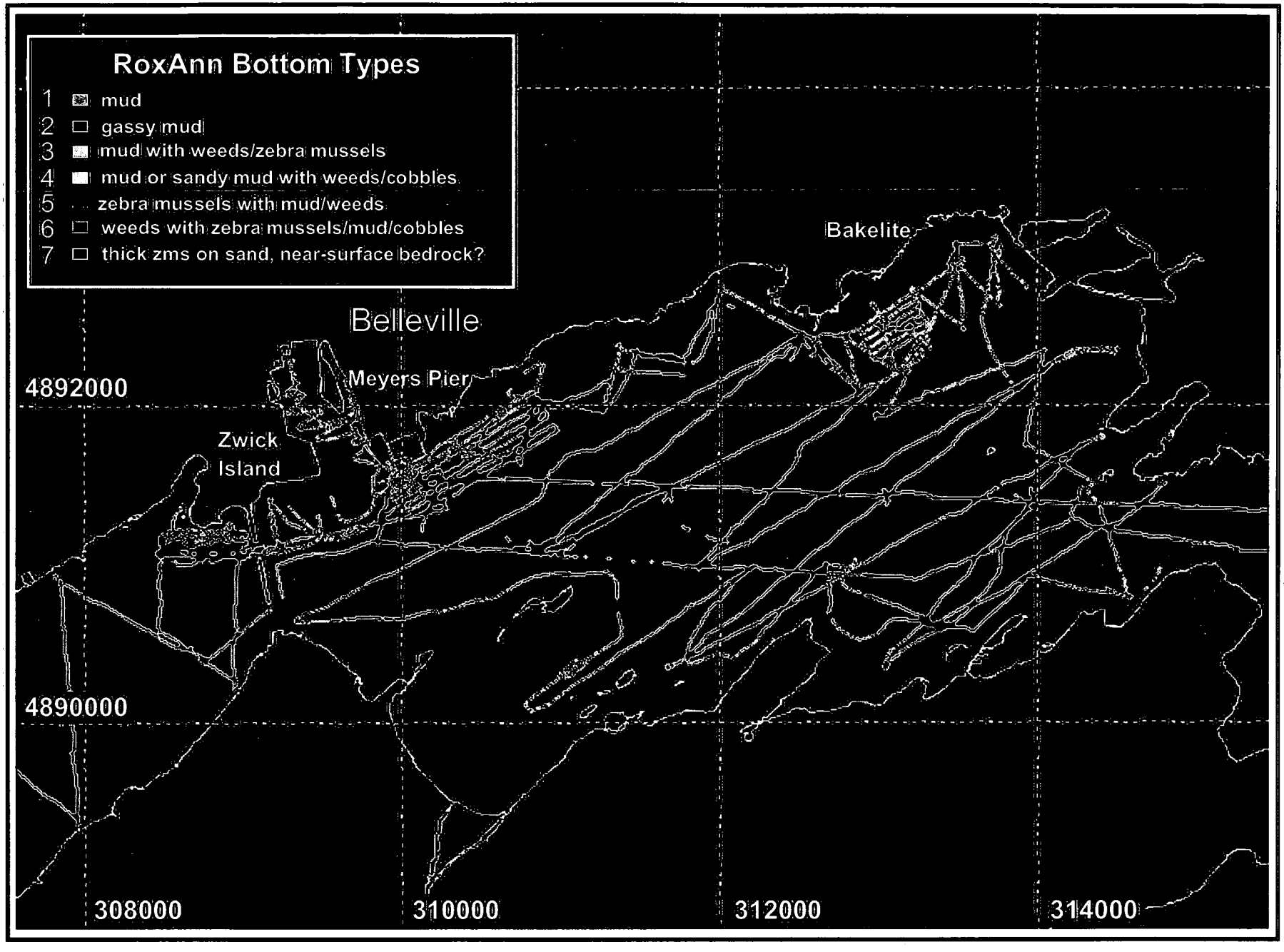

Figure 11. RoxAnn detail, Belleville basin

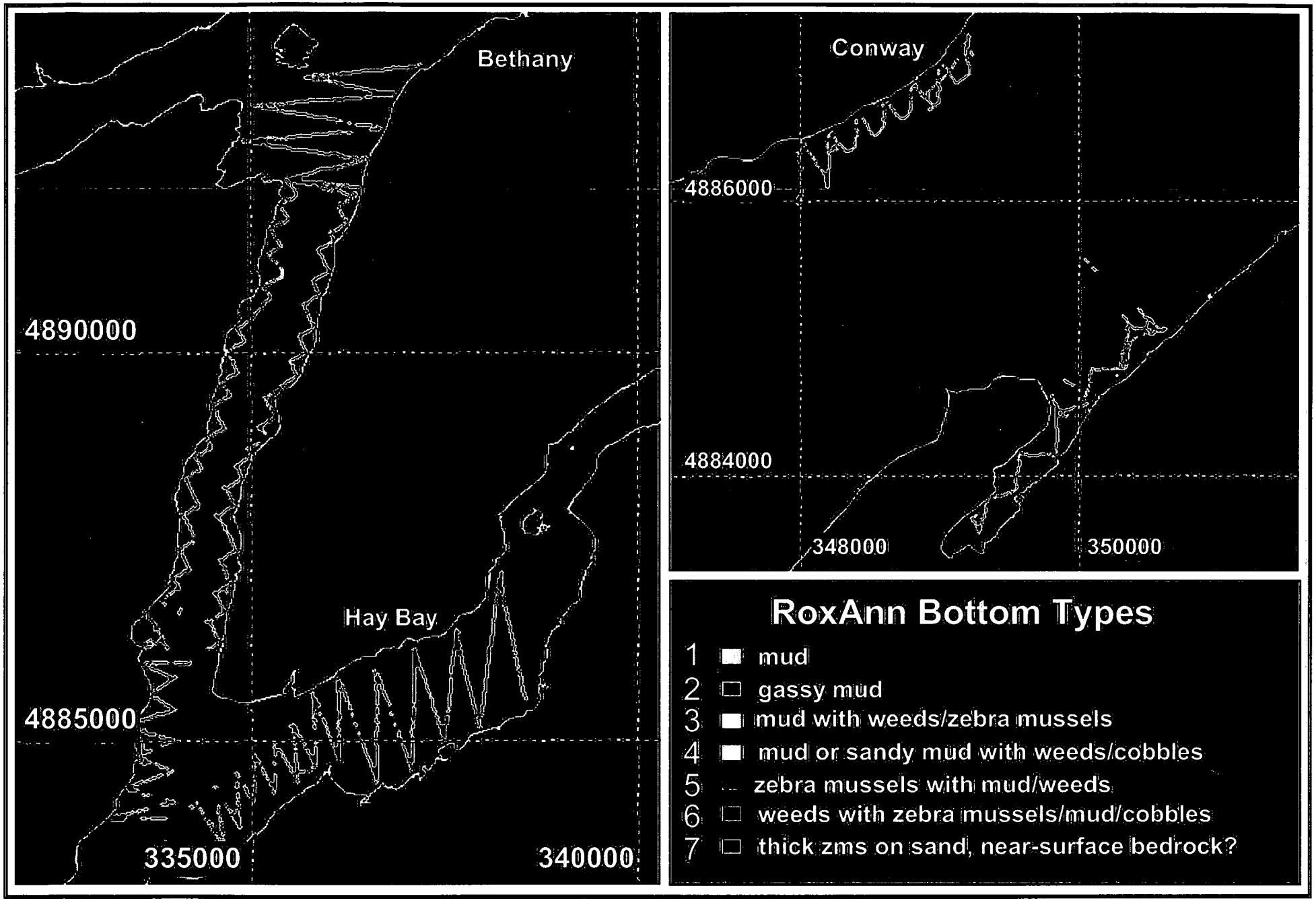

Figure 12. RoxAnn detail from Bethany to Hay Bay and at Conway

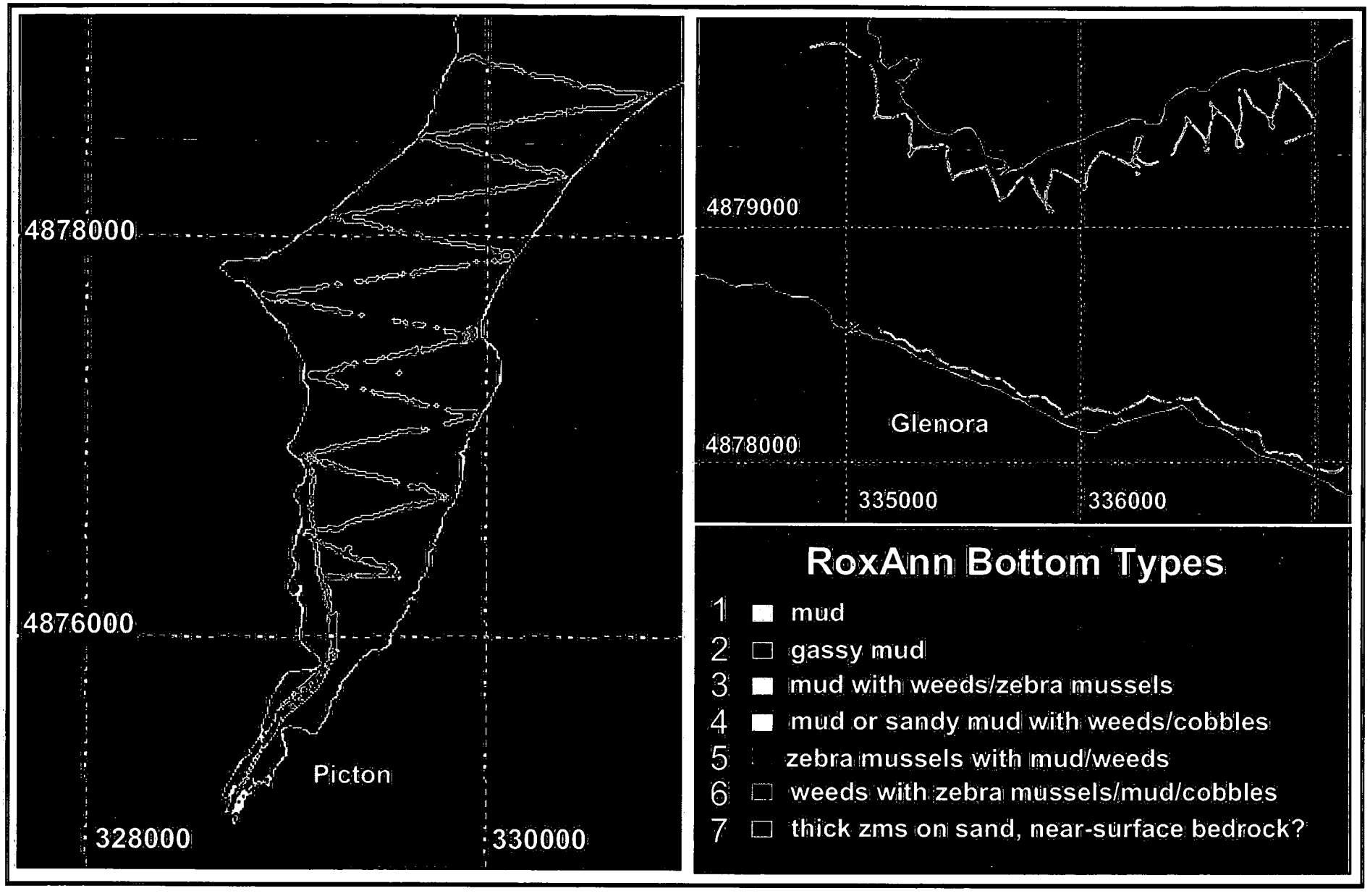

Figure 13. RoxAnn detail at Picton and Glenora

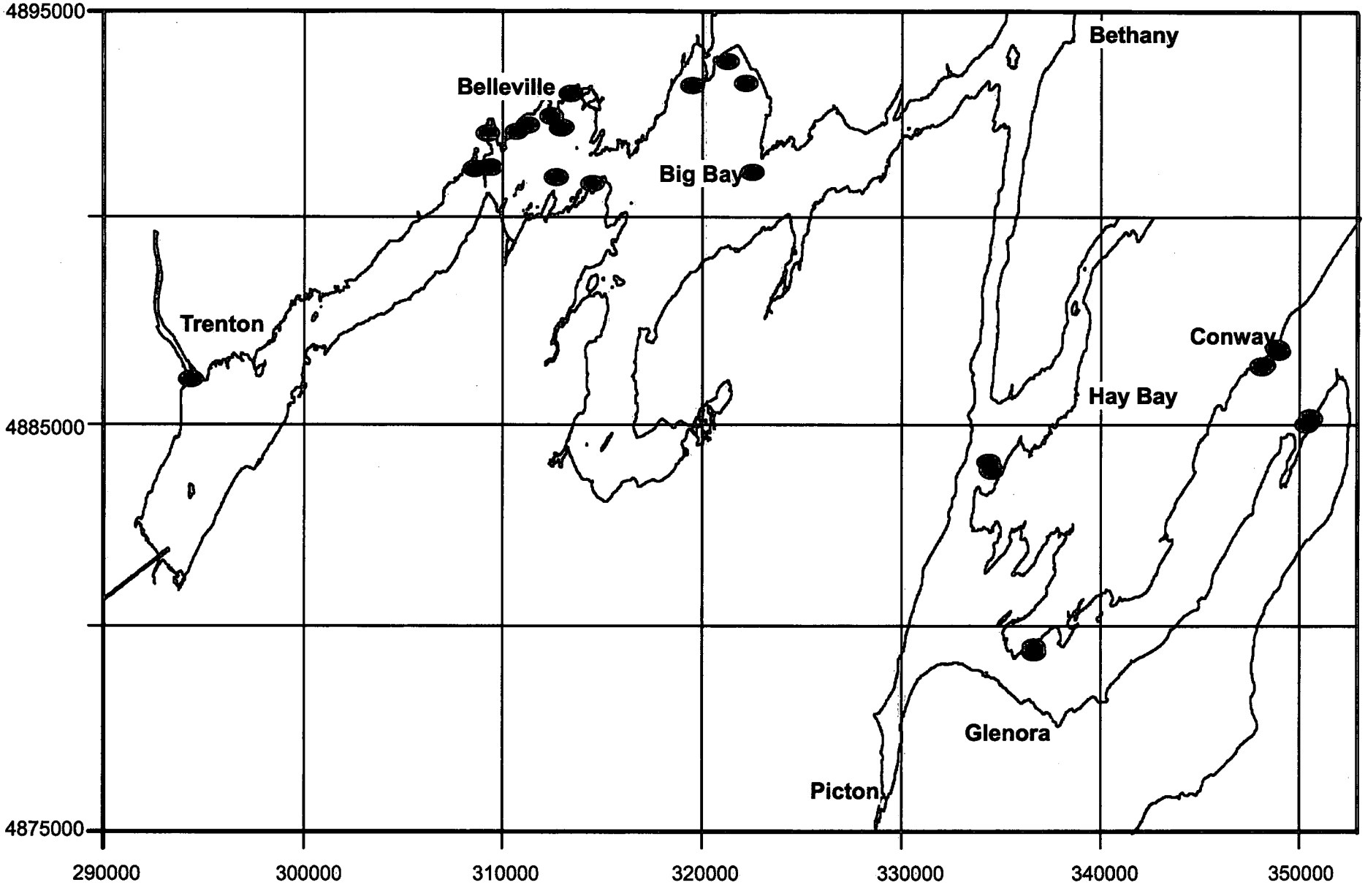

Figure 14. Zebra mussels in samples and video

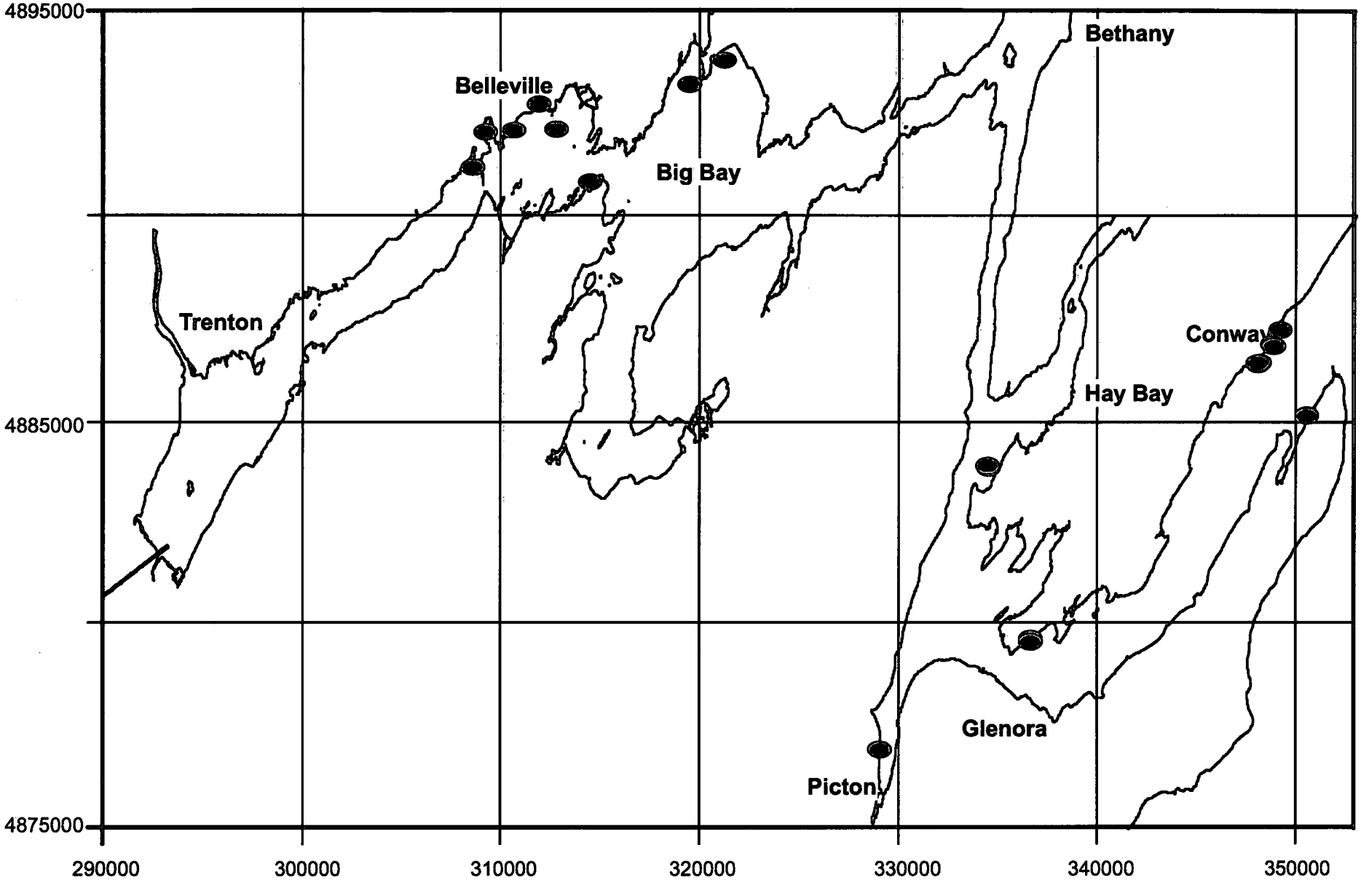

Figure 15. Weeds in samples and video

Appendix 1: Survey schedule

West Quinte survey

May 29

- left CCIW for Belleville at 930, arrived after lunch
- launched at the marina and resolved some problems with the boat engine and GPS control
- afternoon RoxAnn survey of the small basin offshore from Belleville

May 30

- zig-zag inshore RoxAnn lines east of the marina in the morning
- inshore survey of Big Bay in mid afternoon
- late afternoon RoxAnn surveys of the harbour, around Zwick Island and just east of Bakelite

May 31

- RoxAnn survey of the Belleville to Trenton reach in the morning
- met with Hans Biberhofer and Paul Mudroch at the Trenton east-shore marina to discuss detailed RoxAnn work to be done off the Trent River mouth, at Zwick Island, east of Meyer's Pier and east of Bakelite
- completed this work in the afternoon

Jun 1

- underwater-video survey of 32 sites offshore from Belleville and in Big Bay in the morning
- afternoon sampling with the Shipek grab at 14 sites
- late-afternoon tests of the frame-mounted, underwater-video system at Meyers Pier and Zwick Island

Jun 2

- underwater-video survey of sediment thickness at 18 sites in the Bakelite deposit, at the east end of the Meyers deposit, and Zwick Island in the early morning
- packed up and left for CCIW at 1115, arrived at 1430

East Quinte survey

Oct 2

- left CCIW for Picton in midmorning and arrived in mid afternoon
- launched at the boat launch, set up the Puffin, and checked the local GPS control
- RoxAnn survey of Picton Harbour in the late afternoon

Oct 3

- RoxAnn surveys at South and North Conway and Hay Bay in the morning
- afternoon RoxAnn survey of the inshore part of the reach between Hay Bay and Deseronto

Oct 4

- continuous underwater-video traverses on the west side of Picton Harbour and inshore at North and South Conway in the morning
- Hay Bay east and west video profiles in the afternoon

Oct 5

- RoxAnn detailing in the morning just south of Bethany and in Hay Bay
- afternoon RoxAnn traverse of the south shore opposite Glenora
- started Shipek sampling opposite Hay Bay in the late afternoon but had to abandon after two sites because of winch problems
- dockside at 1640

Oct 6

- morning trial in Picton Bay of a new version of the RoxAnn Microplot software
- packed and left at about 1115 and arrived at CCIW at 1500

Appendix 2. Sample data

West Quinte												
Serial No.	Sample Label	Collection Date	Northing NAD83 Zone 18	Easting	Depth m	Sample Type	% Gravel	% Sand	% Silt	% Clay	% Silt-Clay	Description
							Grain Size					
1	1	2000-06-01	4891094	310834	5.8	Shipek	0.0	1.4	65.8	32.8		full bucket of brown-black ooze over very soft mud
2	2	2000-06-01	4891179	309507	5.9	Shipek						half bucket of zebra-mussel clusters in a mud matrix
3	3	2000-06-01	4892076	312888	5.5	Shipek	0.0	1.2	69.1	29.7		full bucket of brown-black mud, surface ooze and soft below
4	4	2000-06-01	4892148	313031	4.8	Shipek						1/2 bucket of zebra mussels in mud matrix
5	6	2000-06-01	4892983	313481	3.1	Shipek	1.3	95.5	0.0	0.0		full bucket with inclined surface, brown-black sandy mud with some rusty sand lenses, sticks and clam shells
6	7	2000-06-01	4893010	313723	2.6	Shipek	0.6	95.6	0.0	0.0		full bucket with inclined surface, mix of dark brown-black muddy sand and fibrous organic ooze, clamshell fragments
7	8	2000-06-01	4891488	311697	5.0	Shipek	0.0	1.8	61.1	37.1		full bucket of brown-black mud, surface ooze and soft below
8	10	2000-06-01	4890632	313310	5.0	Shipek	0.0	1.4	64.3	34.3		full bucket of brown-black mud, surface ooze and soft below, disturbed during recovery
9	13-1	2000-06-01	4892430	312550	5.1	Shipek						1/8 bucket of brown-and-black ooze with some crushed zebra-mussel shells
10	13-2	2000-06-01	4892436	312537	5.0	Shipek						1/3 bucket of zebra mussels with minor ooze
11	16	2000-06-01	4892184	311323	4.5	Shipek	0.0	4.8	64.9	30.3		full bucket of brown-black mud, surface ooze and soft below, gritty feel may be organics
12	25	2000-06-01	4891153	308822	4.5	Shipek	0.0	2.6	64.0	33.4		full bucket of brown black mud, surface ooze and soft at depth, bubbles on recovery
13	29-1	2000-06-01	4891143	308689	3.6	Shipek						clumps of zebra mussels with mud matrix
14	29-2	2000-06-01	4891140	308695	3.6	Shipek						clumps of zebra mussels with mud matrix
15	35	2000-06-01	4891385	313963	6.3	Shipek	0.0	0.8	66.1	33.1		full bucket of brown-black ooze over very soft mud
16	41	2000-06-01	4890944	312776	4.7	Shipek						1/2 bucket with dense, zebra-mussel clusters in a mud matrix
17	2001	2000-09-19	4892175	309620	2.2	mini Ponar	0.0	12.9	65.5	21.6		black mud
18	2002	2000-09-19	4891828	309296	3.8	mini Ponar	0.0	10.0	61.3	28.6		black mud, heavy macrophyte cover
19	2003	2000-09-19	4891396	310229	3.5	mini Ponar	0.0	12.5	57.6	29.8		black mud
20	2005	2000-09-19	4891574	310556	3.7	mini boxcore	0.0	4.9	66.6	28.5		black mud
21	2012	2000-09-19	4891856	310803	3.6	mini boxcore	0.0	11.3	61.8	26.8		black mud
22	2014	2000-09-19	4891968	311284	3.8	mini boxcore	0.0	1.3	66.1	32.6		black mud
23	2015	2000-09-19	4891418	310155	3.2	mini boxcore	0.0	11.3	59.5	29.2		black mud
24	2034	2000-09-19	4885007	297238	3.3	mini Ponar	0.0	0.6	74.5	24.9		black mud
25	2035	2000-09-19	4884825	296343	3.2	mini Ponar	0.0	3.0	69.5	27.5		black mud
26	2036	2000-09-19	4885523	294921	1.3	mini Ponar	0.0	54.1	30.6	15.3		
27	2004	2000-09-20	4891545	310255	3.0	mini Ponar	0.0	13.0	59.1	27.9		black mud, wood chips
28	2006	2000-09-20	4891128	308949	4.4	mini Ponar	0.0	2.6	66.8	30.7		brown mud
29	2007	2000-09-20	4891133	308516	3.4	mini boxcore	0.0	2.3	65.5	32.2		
30	2010	2000-09-20	4891405	311912	4.2	mini boxcore	0.0	0.7	59.8	39.5		brown mud
31	2011	2000-09-20	4891328	312557	4.5	mini Ponar	0.0	2.0	62.7	35.3		brown mud
32	2013	2000-09-20	4892062	310880	3.0	mini boxcore	0.0	21.0	55.2	23.9		black mud
33	2016	2000-09-20	4892685	311999	2.8	mini Ponar	0.0	8.4	61.5	30.0		brown mud
34	2017	2000-09-20	4892270	311804	3.8	mini boxcore	0.0	1.3	66.5	32.2		brown mud
35							0.0	1.0	64.7	34.3		
36							0.0	2.5	62.4	35.1		
37	2018	2000-09-20	4892360	311506	3.3	mini Ponar	0.0	9.3	59.0	31.7		brown mud
38	2037	2000-09-20	4886995	293449	3.1	mini Ponar	0.0	96.5			3.5	sand and cobbles with some soft sediment
39	2038	2000-09-20	4888104	303271	4.6	mini boxcore	0.0	0.7	65.5	33.7		brown mud
40	2039	2000-09-20	4889368	306565	4.7	mini boxcore	0.0	0.4	67.6	32.0		brown mud
41	2001a	2000-09-21	4891829	309296	2.0	mini boxcore						
42	2008	2000-09-21	4892535	313189	3.2	mini Ponar	0.0	71.7	16.1	12.2		brown, sandy mud
43	2009	2000-09-21	4892493	313264	3.3	mini boxcore	0.0	68.7	18.7	12.6		brown, sandy mud
44	2022	2000-09-21	4893570	319712	1.5	Ponar	0.0	76.1	17.6	6.3		sand over clay
45	2024	2000-09-21	4891986	319130	5.2	mini boxcore	0.0	1.4	60.3	38.3		black mud
46	2025	2000-09-21	4889527	317449	5.0	mini boxcore	0.0	0.8	70.6	28.6		black mud
47							0.0	0.8	66.0	33.3		
48							0.0	0.3	62.8	36.9		

East Quinte												
Serial No.	Sample Label	Collection Date	Northing NAD83 Zone 18	Easting	Depth m	Sample Type	% Gravel	% Sand	% Silt	% Clay	% Silt-Clay	Description
							Grain Size					
49	2028	2000-09-21	4891356	326141	6.6	mini boxcore	0.0	1.2	63.9	35.0		black mud
50	2041	2000-09-21	4880581	333314	5.8	mini boxcore	0.0	0.2	66.4	33.4		dark-brown mud with a 0.5-cm coating of light-brown silt
51	2042	2000-09-21	4894334	336417	5.7	mini boxcore	0.0	0.7	62.2	37.1		black mud
52	PUFFIN Sample 1	2000-10-05	4885125	333547	4.3	Shipek	0.0	2.2	55.2	42.6		full bucket of green-black ooze, some brown mottling and slightly firmer at depth, gas bubbles on impact, 2 vial samples
53	PUFFIN Sample 9	2000-10-05	4885078	333785	8.4	Shipek	0.0	0.0	51.8	48.4		full bucket of disturbed, green-black ooze with some brown streaks, firmer below, fewer bubbles than site 1, 2 vial samples
54	Limnos Sample 1	2000-10-24	4884979	350342	3.2	mini boxcore	0.0	95.3			4.7	
55	Limnos Sample 10	2000-10-24	4877507	329920	8.0	mini boxcore	0.3	98.5			1.2	
56	Limnos Sample 11	2000-10-24	4877541	329755	8.2	mini boxcore	0.0	0.7	65.9	33.4		
57	Limnos Sample 12	2000-10-24	4877591	329462	8.0	mini boxcore	0.0	0.9	58.2	40.9		
58	2029	2000-10-24	4884647	334908	8.0	mini boxcore	0.0	1.1	58.0	41.0		0-5 cm of light-brown silt, 5-10 cm of dark-brown mud
59	2030	2000-10-24	4879138	330561	9.5	mini boxcore	0.0	0.3	61.3	38.4		0.5-cm layer of light-brown silt over of dark-brown mud
60	2031A	2000-10-24	4876486	329364	5.5	mini boxcore	0.0	1.1	59.6	39.3		1 cm of brown silt over 9 cm of black silt
61	2032	2000-10-24	4878987	339064	23.7	mini boxcore	0.0	0.5	66.3	33.1		thin layer of soft, silty, light-brown mud over black
62	2040	2000-10-24	4889980	335219	7.0	mini boxcore	0.0	0.6	65.8	33.6		1-10 cm of dark-brown mud with lighter-brown striations
63	Limnos Sample 2	2000-10-25	4885153	350488	11.0	mini boxcore	0.1	90.3			9.6	
64	Limnos Sample 3	2000-10-25	4885196	350300	19.0	mini boxcore	0.1	92.0			7.9	
65	Limnos Sample 4	2000-10-25	4887042	349135	3.5	mini boxcore	0.0	99.8			0.2	
66	Limnos Sample 5	2000-10-25	4886097	348190	23.4	mini boxcore	0.0	52.0	29.0	19.0		
67	Limnos Sample 6	2000-10-25	4879340	336673	12.0	mini boxcore	0.0	0.0	65.6	34.4		
68	Limnos Sample 7	2000-10-25	4879400	336669	12.0	mini boxcore	0.0	0.0	62.5	37.5		
69	Limnos Sample 8	2000-10-25	4879431	336677	11.5	mini boxcore	0.0	38.9	34.0	27.1		
70	Limnos Sample 9	2000-10-25	4879467	336683	5.9	mini boxcore	0.0	0.0	51.6	48.4		
71	Limnos Sample 13	2000-10-25	4883484	333570	10.0	mini boxcore	0.0	1.0	59.0	39.9		
72	Limnos Sample 14	2000-10-25	4885139	333576	6.0	mini boxcore	0.0	1.1	58.0	40.9		
73	2021A	2000-10-25	4885569	337556	6.0	mini boxcore	0.0	1.0	54.7	44.4		thin layer of brown-over-black mud
74	2033	2000-10-25	4885686	348169	35.2	mini boxcore	0.0	0.8	57.2	42.0		soft, brown silt
75	2041A	2000-10-25	4880581	333314	12.0	mini boxcore	0.0	0.3	57.2	42.4		0.5 cm of light-brown silt over dark-brown mud
76	1	2000-11-28	4886010	294420		Shipek	0.0	92.4	4.1	3.5		3/4 bucket of flat, firm, dark-brown sandy silt; a few zebra mussels and crushed white shells
77	2	2000-11-28	4885723	294735		Shipek	0.0	85.3	8.6	6.1		full bucket of soft, greyish-brown muddy silt; some small crushed shells, oil sheen
78	3	2000-11-28	4885231	295096		Shipek	0.0	54.2	26.6	19.2		full bucket of soft, rippled, greyish-brown muddy silt; many weeds
79	4	2000-11-28	4885898	295407		Shipek						3 sampling attempts, no recovery, hard bottom
80	5	2000-11-28	4885781	296172		Shipek	0.0	24.2	53.2	22.6		full bucket of soft, greyish-brown muddy silt; small pieces of branches and shells
81	6	2000-11-28	4885650	295737		Shipek	0.0	29.2	48.2	22.5		full bucket of soft, flat, brownish-grey muddy silt
82	7	2000-11-28	4885348	296142		Shipek	0.0	1.6	66.8	31.6		full bucket of flat, soupy, mainly-brown muddy silt; a few weeds
83	8	2000-11-28	4884348	295627		Shipek	0.0	9.4	64.1	26.5		full bucket of soft, greyish-brown, muddy silt
84	9	2000-11-28	4885256	296304		Shipek	0.0	12.6	63.3	24.1		overfull bucket of soupy, greyish-brown muddy silt; a few weeds and crushed shells
85	10	2000-11-28	4884970	296767		Shipek	0.0	2.2	67.2	30.7		full bucket of flat, soupy muddy silt; a few shell fragments
86	11	2000-11-28	4883028	292930		Shipek	0.0	1.8	68.7	29.5		full bucket of flat, soupy, brownish-grey mud; many weeds, slight oil sheen on surface
87	12	2000-11-28	4885642	294948		Shipek	0.0	25.3	50.9	23.8		full bucket of flat, soupy, dark-grey muddy silt; many weeds
88	13	2000-11-28	4884191	295783		Shipek	0.0	5.8	64.8	29.4		full bucket of flat, soft, greyish-brown muddy silt
89	14	2000-11-28	4886268	294290		Shipek	0.1	99.3			0.5	<1cm of hard-packed, light-brown sand; large number of small, crushed shells; 2 attempts with Shipek, high-energy environment

Appendix 3. Underwater-video data

Site No.	Collection Date	Time	Northing	Easting	Depth	Description
			NAD83 Zone 18		m	
West Quinte						
32	2000-06-01	9:15:15	4892011	309332		mud, weeds, boulders, zebra mussels
26	2000-06-01	9:27:14	4891118	308587	4.7	soft mud with dimples
28	2000-06-01	9:32:32	4891145	308686	3.4	mud, cobbles, zebra mussels, a few weeds
25-1	2000-06-01	9:39:36	4891157	308802	4.5	soft mud
25-2	2000-06-01	9:39:50	4891155	308804	4.6	thick, soft mud
2	2000-06-01	9:52:26	4891172	309487	6.2	mud with zebra-mussel patches and scattered shells
30-1	2000-06-01	10:08:18	4892049	310763	3.2	mud, zebra-mussel patches, thin high weeds
30-2	2000-06-01	10:08:22	4892051	310762	2.5	mud, zebra-mussel patches, thin high weeds
14a	2000-06-01	10:15:16	4892040	310837	4.0	mud
16a	2000-06-01	10:20:32	4892182	311322	4.6	thick soft mud
17a	2000-06-01	10:23:38	4892209	311337	4.3	mud, a few cobbles with zebra-mussel patches
12	2000-06-01	10:29:14	4892425	312532	5.0	patchy sand and zebra mussels, near-surface bedrock?
13-1	2000-06-01	10:30:02	4892424	312536	5.0	thick zebra mussels, sand patches, near-surface bedrock?
13-2	2000-06-01	10:31:26	4892432	312537	4.9	sand, zebra-mussel patches, near-surface bedrock?
3	2000-06-01	10:35:34	4892077	312875	5.6	thick, soft mud, a few weeds
4-1	2000-06-01	10:38:42	4892141	313011	5.1	thick, soft mud, scattered zebra mussels
4-2	2000-06-01	10:39:02	4892141	313013	4.8	zebra mussels, sand or muddy-sand patches, a few boulders
4-3	2000-06-01	10:39:40	4892144	313018	4.9	dense zebra mussels with sand or muddy-sand patches
35	2000-06-01	11:08:30	4891382	313941	6.2	soft, thick mud with small regular holes
38	2000-06-01	11:22:36	4893175	319544	3.5	thick pillow of algae on zebra mussels, some low weeds
20	2000-06-01	11:30:56	4893768	321328	4.5	zebra-mussel and mud patches, a few cobbles and thin weeds
22	2000-06-01	11:38:04	4893238	322259	4.0	dimpled sand with clumps of zebra mussels
39-1	2000-06-01	11:48:04	4891057	322573	5.8	dimpled sand with clumps of zebra mussels, near-surface bedrock?
39-2	2000-06-01	11:48:22	4891058	322575	5.8	dimpled sand with zebra-mussel patches and some boulders, near-surface
19-1	2000-06-01	12:21:04	4890782	314573	3.1	high weeds over mud with zebra-mussel patches
19-2	2000-06-01	12:23:18	4890783	314582	3.6	high weeds over mud with zebra-mussel patches
19-3	2000-06-01	12:23:26	4890783	314583	5.0	high weeds over mud with zebra-mussel patches
10-1	2000-06-01	12:28:20	4890624	313283	4.9	thick soft mud, hummocky surface
10-2	2000-06-01	12:28:32	4890631	313285	5.1	thick soft mud, hummocky surface
41-1	2000-06-01	12:36:32	4890932	312775	4.9	dense zebra mussels with sand or muddy-sand patches
41-2	2000-06-01	12:36:32	4890932	312775	5.0	dense zebra mussels with sand or muddy-sand patches
33	2000-06-01	12:45:16	4890262	310959	3.6	high weeds on mud
41-3	2000-06-01	12:36:40	4890934	312774	5.0	dense zebra mussels with sand or muddy-sand patches
8	2000-06-01	12:52:26	4891481	311699	5.5	soft, thick mud
1	2000-06-01	12:56:30	4891085	310848	5.9	soft, thick mud
2-1	2000-06-02	8:39:56	4892487	313238	4.5	soft, thick mud

Site No.	Collection Date	Time	Northing	Easting	Depth m	Description
			NAD83 Zone 18			
2-2	2000-06-02	8:52:32	4892680	311992	3.8	soft, thick mud, clumps of weeds, suspended sediment
2-3	2000-06-02	8:52:52	4892683	311992	3.7	soft, thick mud, clumps of weeds, suspended sediment
17-b1	2000-06-02	9:01:22	4892260	311778	5.0	soft, thick mud
17-b2	2000-06-02	9:01:48	4892262	311776	4.9	soft, thick mud
17-b3	2000-06-02	9:02:14	4892262	311776	4.3	soft, thick mud
16b	2000-06-02	9:07:44	4892338	311485	4.4	soft, thick mud
15	2000-06-02	9:15:14	4891956	311273	4.8	soft, thick mud
14-b1	2000-06-02	9:21:08	4892041	310857	4.0	soft, thick mud
14-b2	2000-06-02	9:21:32	4892044	310861	4.1	soft, thick mud
12	2000-06-02	9:40:02	4891535	310245	4.1	soft, thick mud
8-1	2000-06-02	9:59:36	4891118	308931	5.7	soft, thick mud
8-2	2000-06-02	9:59:44	4891116	308931	5.8	soft, thick mud
9	2000-06-02	10:03:00	4891159	308928	4.6	soft, thick, gassy mud
East Quinte						
1-1	2000-10-04	9:30:44	4876892	329088	3.6	soft mud, scattered weeds
1-2	2000-10-04	9:31:02	4876890	329089	3.5	soft mud, scattered weeds
2	2000-10-04	9:37:14	4876891	329074	2.0	soft mud, high weeds
3-1	2000-10-04	9:40:00	4876874	329127	3.4	soft mud, high weeds
3-2	2000-10-04	9:40:12	4876873	329128	3.4	soft mud, high weeds
4-1	2000-10-04	9:43:08	4876871	329150	4.4	soft mud with a shell coating
4-2	2000-10-04	9:43:08	4876871	329150	4.5	soft mud with a shell coating
4-3	2000-10-04	9:43:26	4876870	329150	4.5	soft mud with a shell coating
5-1	2000-10-04	9:46:44	4876869	329174	6.0	soft, thick mud
5-2	2000-10-04	9:46:56	4876869	329176	5.8	soft, thick mud
6	2000-10-04	10:30:48	4884915	350326	7.2	dense but loose zebra mussels in mud
8-1	2000-10-04	10:41:42	4885084	350558	6.0	dense zebra mussels, mud base
8-2	2000-10-04	10:42:28	4885074	350565	6.2	dense zebra mussels, mud base, scattered low weeds
8-3	2000-10-04	10:42:32	4885074	350568	6.2	dense zebra mussels, mud base, scattered low weeds
8-4	2000-10-04	10:42:40	4885072	350573	5.5	dense zebra mussels, mud base, scattered low weeds
8-5	2000-10-04	10:42:42	4885070	350576		dense zebra mussels, thick weeds
8-6	2000-10-04	10:42:46	4885070	350578		dense zebra mussels, thick weeds
8-7	2000-10-04	10:42:50	4885068	350581		dense zebra mussels, thick weeds
8-8	2000-10-04	10:42:54	4885067	350584		dense zebra mussels, thick weeds
8-9	2000-10-04	10:42:58	4885066	350586		dense zebra mussels, thick weeds
8-10	2000-10-04	10:44:20	4885048	350580		dense zebra-mussel mounds, thick weeds, irregular bottom

Site No.	Collection Date	Time	Northing	Easting	Depth	Description
			NAD83 Zone 18		m	
13	2000-10-04	11:01:46	4887153	349208	3.3	thick, high weeds over mud?
15-1	2000-10-04	11:11:16	4886812	348834		thick, low weeds over mud
15-2	2000-10-04	11:12:48	4886779	348878	6.4	dense zebra mussels with thin weeds on mud
15-3	2000-10-04	11:12:54	4886776	348880	7.9	dense zebra mussels with thin weeds on mud
15-4	2000-10-04	11:13:00	4886773	348882		dense zebra mussels with thin weeds on mud
15-5	2000-10-04	11:13:06	4886770	348883		dense zebra mussels with thin weeds on mud
15-6	2000-10-04	11:13:14	4886766	348884		dense zebra mussels with thin weeds on mud
15-7	2000-10-04	11:13:48	4886754	348897		dense zebra mussels with thin weeds on mud
15-8	2000-10-04	11:13:54	4886754	348900		dense zebra mussels with thin weeds on mud
15-9	2000-10-04	11:17:04	4886690	348956	17.8	thick, soft mud with scattered zebra mussels
16	2000-10-04	11:26:04	4886358	348198	8.9	dense zebra mussels on mud, scattered low weeds
17-1	2000-10-04	11:32:42	4886303	348098		dense zebra mussels on mud, scattered low weeds
17-2	2000-10-04	11:33:06	4886300	348100		dense zebra mussels on mud, scattered low weeds
17-3	2000-10-04	11:34:56	4886337	348064		zebra mussels, some coating cobbles, thick low weeds
17-4	2000-10-04	11:35:00	4886340	348062		zebra mussels, some coating cobbles, thick low weeds
17-5	2000-10-04	11:35:02	4886341	348062		zebra mussels, some coating cobbles, thick low and scattered high weeds
18-1	2000-10-04	12:24:06	4879583	336667	2.1	thick low weeds, substrate not visible
18-2	2000-10-04	12:24:06	4879590	336681	2.3	thick low weeds, substrate not visible
19	2000-10-04	12:25:08	4879583	336673		thick low and scattered high weeds and algae over soft mud
20-1	2000-10-04	12:27:20	4879522	336682		thick high weeds, substrate not visible
20-2	2000-10-04	12:27:24	4879519	336683		thick high weeds, substrate not visible
20-3	2000-10-04	12:27:50	4879505	336684		thick high weeds, substrate not visible
20-4	2000-10-04	12:28:08	4879495	336685		patchy zebra mussels and mud
20-5	2000-10-04	12:28:36	4879492	336683		patchy zebra mussels and mud
21-1	2000-10-04	12:29:08	4879482	336684		dense zebra mussels on mud
21-2	2000-10-04	12:29:12	4879480	336685		dense zebra mussels on mud
21-3	2000-10-04	12:29:20	4879476	336685		dense zebra mussels on mud
21-4	2000-10-04	12:29:28	4879473	336685		dense zebra mussels on mud
21-5	2000-10-04	12:29:36	4879472	336684		dense zebra mussels on mud
21-6	2000-10-04	12:29:48	4879469	336684		dense zebra mussels on mud, scattered boulders
21-7	2000-10-04	12:30:14	4879466	336682		dense zebra mussels on mud, scattered boulders
21-8	2000-10-04	12:30:22	4879463	336683		dense zebra mussels on mud, scattered boulders
21-9	2000-10-04	12:30:30	4879460	336683		dense zebra mussels on mud, scattered boulders
21-10	2000-10-04	12:30:56	4879450	336683		dense zebra mussels on mud, scattered boulders
21-11	2000-10-04	12:31:10	4879448	336681		dense zebra mussels on mud, scattered boulders
21-12	2000-10-04	12:31:54	4879430	336677		dense zebra mussels on mud

Site No.	Collection Date	Time	Northing	Easting	Depth	Description
			NAD83 Zone 18		m	
21-13	2000-10-04	12:32:02	4879429	336676		dense zebra mussels on mud
21-14	2000-10-04	12:32:28	4879427	336674		patchy zebra mussel and mud
21-15	2000-10-04	12:33:18	4879400	336669		patchy zebra mussel and mud
21-16	2000-10-04	12:34:12	4879380	336665		thick, soft mud with scattered zebra mussels
21-17	2000-10-04	12:34:20	4879379	336664		thick, soft mud with scattered zebra mussels
21-18	2000-10-04	12:35:30	4879350	336660		thick, soft mud with scattered zebra mussels
21-19	2000-10-04	12:35:34	4879348	336660		thick, soft mud with scattered zebra mussels
22-1	2000-10-04	13:03:08	4883767	334556	2.7	mud with scattered weeds
22-2	2000-10-04	13:04:00	4883777	334545		scattered weeds, zebra mussels and white shells on muddy sand
22-3	2000-10-04	13:04:08	4883780	334544		scattered weeds, zebra mussels and white shells on muddy sand
22-4	2000-10-04	13:04:16	4883784	334544	3.8	scattered weeds, zebra mussels and white shells on muddy sand, scattered
22-5	2000-10-04	13:04:48	4883799	334540	4.0	weeds, substrate not visible
22-6	2000-10-04	13:06:00	4883817	334522		mix of zebra mussels and mud, scattered weeds
22-7	2000-10-04	13:06:08	4883818	334521		mix of zebra mussels and mud, a few weeds or algae
22-8	2000-10-04	13:06:28	4883820	334517		mix of zebra mussels and mud, a few weeds or algae
22-9	2000-10-04	13:07:14	4883834	334509		mix of zebra mussels and mud, a few weeds or algae
22-10	2000-10-04	13:07:28	4883837	334508		mix of zebra mussels and mud, a few weeds or algae
23-1	2000-10-04	13:11:58	4883997	334409		mud with patchy zebra mussels
23-2	2000-10-04	13:12:04	4883995	334410		mud with patchy zebra mussels
23-3	2000-10-04	13:12:10	4883995	334409		mud with patchy zebra mussels
27	2000-10-04	13:23:26	4884815	333571	10.2	mud with a cover of suspended sediment
28	2000-10-04	13:33:14	4884825	333593	13.4	soft, thick mud with suspended sediment
30	2000-10-04	13:45:04	4885109	333637	8.5	soft, thick mud with suspended sediment
34	2000-10-04	13:59:26	4886989	334705	6.0	soft, thick mud with suspended sediment

Appendix 4. Thickness data

Sediment thickness, Bay of Quinte, video-tripod data										
Site no.	Northing	Easting	Depth	Thickness		Site no.	Northing	Easting	Depth	Thickness
	UTM NAD83		m	cm			UTM NAD83		m	cm
West Quinte: 2000-06-02						East Quinte: 2000-10-04 cont'd				
1	4892507	313103	4.4	50-55		30	4887037.1	349138.2	2.01	5-10
2	4892494	313242	4	20-30		31	4886770.6	348882.3	7.89	5-10
3	4891168	308532	4.3	60		32	4886699.1	348951.4	17.75	>20
4	4891126	308507	4.7	>70		33	4886335	348185.2	9.9	5-10
5	4891063	308509	5.4	>70		34	4886239	348135.9	12.74	~5
6	4891059	308750	6.3	>70		35	4886299	348090.5	9.6	~5
7	4891062	308932	5.8	>70		36	4886316.6	348069.4	8.36	~5
8	4891117	308937	4.5	>70		37	4879589.5	336681.2	2.31	>20
9	4891161	308928	4	20-40		38	4879502.5	336684.3	5.11	>20
10	4891538	310249	4.6	>50		39	4879492.2	336683.5	5.85	>20
11	4891574	310571	4.5	60-90		40	4879472	336684.7	6.36	~10
12	4891844	310801	4	70-80		41	4879437	336680.5	10.11	>20
13	4892045	310867	4.9	~50		42	4879342.5	336659.4	15.16	>20
14	4891958	311277	4.3	>90		43	4883633.2	334590.4	3.22	10-20
15	4892345	311490	5	40-60		44	4883766.9	334556.1	2.68	10
16	4892261	311779	3.7	>90		45	4883797.1	334541.1	3.98	5-10
17	4892685	311998		~50		46	4883996.7	334409	8.64	10
						47	4883997.6	334395.3	8.78	>20
East Quinte: 2000-10-04						48	4884018.7	334391	8.94	>20
18	4876893	329088	3.6	20		49	4884796.1	333546.2	4.49	2-10
19	4876904	329075	3.66	10-20		50	4885144.9	333532.6	3.85	>20
20	4876874	329127	3.39	>20		51	4885117.2	333618.1	8.22	>20
21	4876869	329174	5.97	>20		52	4885109.1	333636.6	8.47	>20
22	4884915	350326	7.2	10		53	4887009.3	334754.6	2.81	2-8
23	4885072	350560	5.97	5-10		54	4886996.3	334739.2	4.62	10
24	4885077	350559	6.24	5-10		55	4887006.9	334738.6	4.66	10
25	4885137	350502	12.65	10		56	4886988.7	334704.8	5.99	>20
26	4885145	350463	15.11	>15						
27	4885126	350442	15.13	10						
28	4885126	350393	16.23	>20						
29	4887151	349209	3.85	~10						

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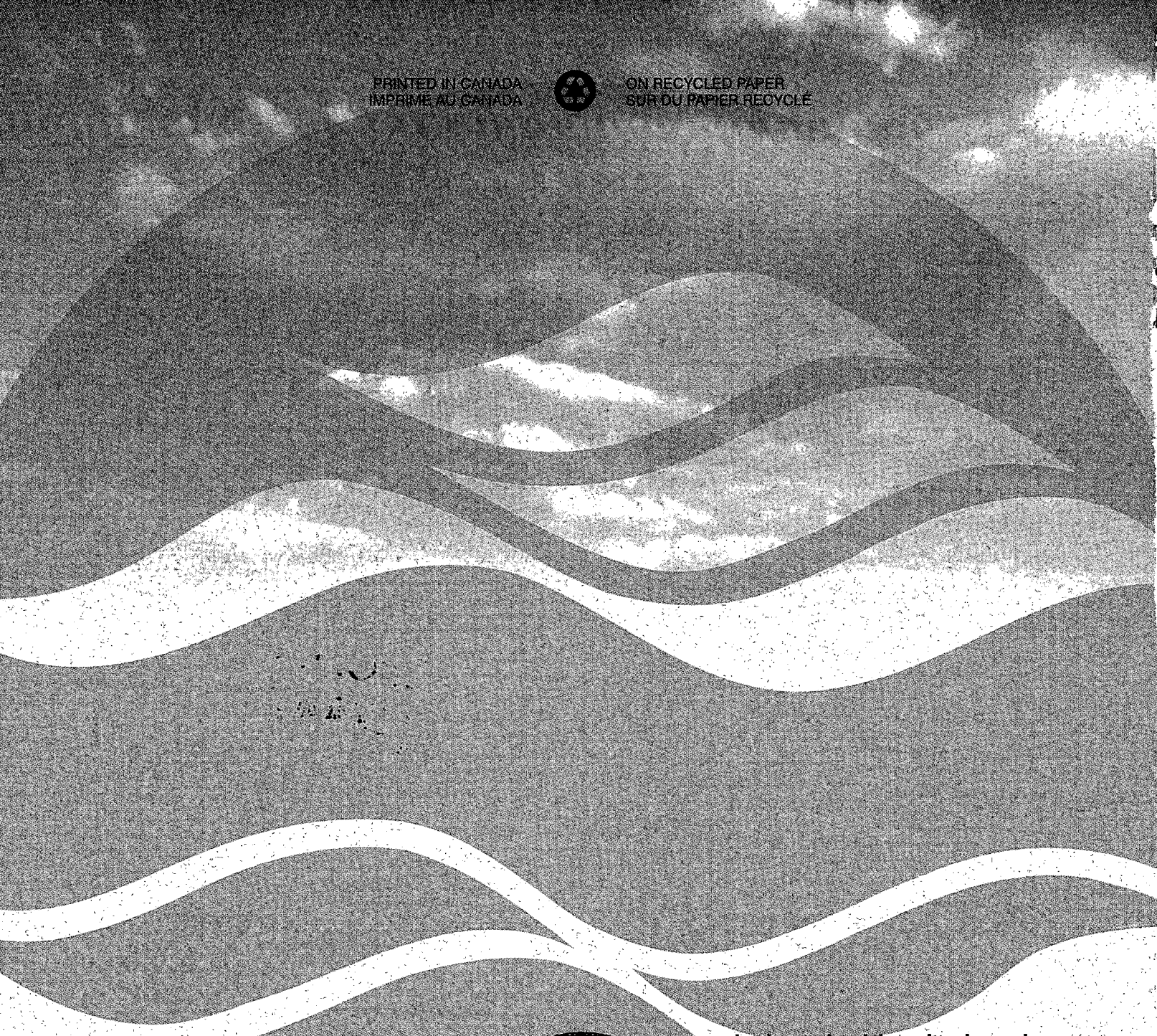

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