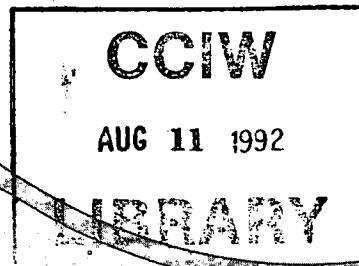
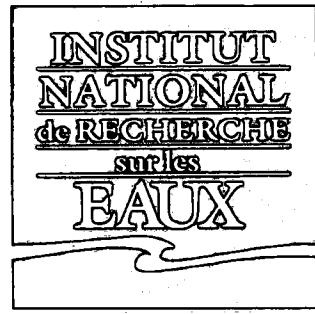
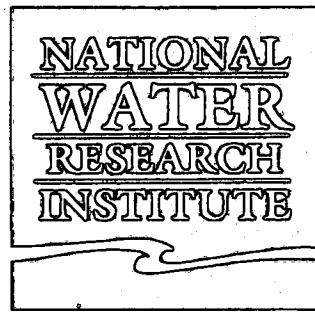


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**GIS ESTIMATES OF CONTAMINATED
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AND LAC SAINT-PIERRE,
ST. LAWRENCE RIVER**

N.A. Rukavina and R.J. Delorme

NWRI Contribution No. 92-64

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**GIS ESTIMATES OF CONTAMINATED SEDIMENT VOLUME IN
LAC SAINT-LOUIS AND LAC SAINT-PIERRE,
ST. LAWRENCE RIVER**

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NWRI Contribution No. 92-64

MANAGEMENT PERSPECTIVE

Sediment data collected by NWRI in Lac Saint-Louis and Lac Saint-Pierre have been analysed with a SPANS geographic information system to determine the volumes and distributions of modern sediments and to estimate the volumes of contaminated sediments. The estimates are preliminary because they are based on physical data only and require a number of assumptions about areal and vertical continuity of the data. They do, however, represent the first values for contaminated-sediment volume developed from a large and consistent data set. Results will be useful as a model for the incorporation of existing chemical data to permit calculation of contaminant levels and also as a structure for planning of further contaminant surveys.

SOMMAIRE À L'INTENTION DE LA DIRECTION

Les données sur les sédiments prélevés par l'INRE dans le lac Saint-Louis et le lac Saint-Pierre ont été analysées à l'aide d'un système d'information géographique SPANS pour déterminer les volumes et les répartitions granulométriques des sédiments actuels et pour estimer les volumes des sédiments contaminés. Les estimations sont préliminaires car elles sont fondées uniquement sur des données physiques et elles nécessitent diverses hypothèses sur la continuité linéaire et verticale des données. Elles représentent toutefois les premières valeurs des volumes de sédiments contaminés, établies à partir d'un grand ensemble homogène de données. Les résultats serviront de modèle à l'intégration de données chimiques existantes pour permettre le calcul des concentrations de contaminants et également de structure à la planification d'autres relevés de contaminants.

ABSTRACT

Sediment data collected in Lac Saint-Louis and Lac Saint-Pierre by NWRI have been analysed with a SPANS geographic information system to determine the volumes and distributions of modern sediments and to estimate the volumes of contaminated sediments (the silt-clay fraction). Sediment thickness and size patterns are highly variable in both lakes and depositional basins are difficult to define, particularly in Lac Saint-Pierre. The thickest sediments in Lac Saint-Louis are also the finest. There are three areas of accumulation: just downstream of the St. Lawrence and Ottawa River entrances and behind the islands of the south shore. Total sediment volume is 10,455,417 m³ of which 7,131,658 m³ (68.2%) are silt and clay. Average modern-sediment thickness is 7.4 cm. Sediment thickness and grain size are not related in Lac Saint-Pierre. Grain size is finest in a band extending from the northwest shore to the axis in the east-central part of the basin; the coarsest sediments are adjacent to the entrance and outlet of the St. Lawrence River. Sediment thickness tends to decrease from west to east but with considerable small-scale variability. Average thickness is 5.5 cm. Total sediment volume is 17,475,274 m³ of which 7,102,750 m³ (40.6%) are silt and clay.

RÉSUMÉ

Les données sur les sédiments prélevés dans le lac Saint-Louis et le lac Saint-Pierre par l'INRE ont été analysées à l'aide d'un système d'information géographique SPANS pour déterminer les volumes et les granulométries des sédiments actuels et pour estimer les volumes des sédiments contaminés (fraction limon-argile). L'épaisseur des sédiments et leur granulométrie sont très variables dans les deux lacs et les bassins sédimentaires sont difficiles à délimiter, en particulier dans le lac Saint-Pierre. Les sédiments les plus épais dans le lac Saint-Louis sont également les plus fins. Il y a trois zones d'accumulation : juste en aval des entrées du Saint-Laurent et de la rivière des Outaouais et en arrière des îles de la rive sud. Le volume total des sédiments s'élève à 10,455,417 m³ dont 7,131,658 (68,2 %) sont du limon et de l'argile. L'épaisseur moyenne des sédiments actuels est de 7,4 cm. L'épaisseur et la granulométrie des sédiments ne sont pas liées dans le lac Saint-Pierre. La granulométrie est la plus fine dans une bande allant de la rive nord-ouest à l'axe de la partie centre-est du bassin; les sédiments les plus grossiers sont adjacents à l'entrée et à l'exutoire du fleuve Saint-Laurent. L'épaisseur des sédiments tend à diminuer d'ouest en est, mais avec une variabilité considérable sur une petite échelle. L'épaisseur moyenne est de 5,5 cm. Le volume total des sédiments est de 17,475,274 m³ dont 7,102,750 (40,6 %) sont du limon et de l'argile.

1 INTRODUCTION

Data on the thickness and grain size of modern sediments in the St. Lawrence lakes Saint-Louis and Saint-Pierre are available from NWRI surveys conducted during the period 1985 to 1990 (Rukavina 1985, 1986b, 1990). They have been used in this report to compute preliminary estimates of the volume and distribution of contaminated sediments. Data analysis was done within a SPANS geographic information system (GIS). The spatial distributions of thickness and grain size were computed and then combined to determine the volume and distribution of the silt-clay fraction with which contaminants should be associated. Results should be useful as interim values for the sediment budgets of the basins, as a basis for planning of future surveys, and as a GIS model for incorporation of contaminants data.

2 BACKGROUND

NWRI surveyed the sediments of Lac Saint-Louis in 1985 and 1990 using a combination of grab sampling, coring and echo sounding. Figures 1 and 2 show the data grids for thickness and grain size. Details of the surveys are described in Rukavina (1985, 1990) and Fortin (1990) and results are summarized in Rukavina (1986a, 1986b) and Rukavina et al (1990). A similar survey in 1986 (Figure 3) mapped the bottom sediments of the north half of Lac Saint-Pierre. Rukavina (1986c) describes the survey and Rukavina (1987) and Hardy et al (1991) report the results. In both lakes, the bottom sediments were found in general to consist of a thin, discontinuous cover of modern sands and muds over bedrock or older cohesive clay of glacial origin.

In the 1985 Lac Saint-Louis survey, grab samples were collected at 151 sites with a Shipek sampler which recovers a maximum thickness of 10 cm of the

surficial sediment. Nineteen sites were cored with a Technical Operations corer to a maximum penetration of 28 cm. In the 1990 survey, Shipek samples were collected at 24 sites and Benthos and diver cores at 41 sites. Maximum core length was 76 cm. Only two of the cores were preserved for laboratory analysis; the rest were extruded and described immediately upon recovery and then discarded. Procedures and specifications for the Shipek sampler and the Benthos and Technical Operations corers are described in Mawhinney and Bisutti (1987).

In Lac Saint-Pierre, 104 sites were sampled with the Shipek grab sampler and 6 sites were cored with a Benthos corer. The longest core recovered was 67 cm long.

Grain size for samples and cores was measured with the standard procedures of the NWRI Sedimentology Laboratory (Duncan and LaHaie 1979) and size statistics were computed with the SIZDIST program (Sandilands and Duncan 1980). The relevant data for this report are the percentages of silt and clay. Grain size was analysed for all the surface-sediment samples and all the 1985 and 1986 cores but only limited data were collected from the 1990 cores.

3 VOLUME COMPUTATIONS

3.1 Assumptions

The surveys provide point data on grain size and sediment thickness which form the basis for the volume computations. The underlying assumptions required to produce estimates of contaminated-sediment volume are as follows:

1. All surficial sediments of silt or clay size are contaminated. No adjustment has been made for spatial or vertical variations in contaminant level.

2. The volume of surficial sediments of silt and clay size can be used as an estimate of contaminated-sediment volume. This is based on the general observation in Great Lakes' (Kemp and Thomas 1976) sediments that contaminants are preferentially bound to the silt and clay size fractions and form an insignificant portion of the coarser size grades. It should be noted, however, that data from Rukavina et al (1990) show a saddle-shaped rather than linear distribution of metal concentration within the silt-clay size range because of the presence of coarser anthropogenic particles. This distribution should be taken into account in any effort to convert the estimates of contaminated-sediment volume herein to contaminant content.

3. Sample thickness or core length provides a minimum value for the thickness of modern silt-clay sediments at those sites where underlying sediment was not penetrated. In those cases where a sample or core shows the contact between modern silt-clays and older glacial sediments or bedrock, the depth to the interface was used as a measure of modern-sediment thickness. Where the contact was not sampled, sample or core thickness was used as a minimal estimate of sediment thickness. The two types of data are distinguished in Appendices 1 and 2 by the symbols "+" for a minimum and "-" for a real value.

Because of sediment compaction in cores, the apparent thickness is less than the true thickness by an amount determined by the cohesiveness of the sediment. No attempt has been made to adjust for this difference because no data on the degree of compaction are available. It should be noted, however, that even minor shortening could have a significant effect on the volume estimates because of the low average thickness values for the two lakes (5.5 and 7 cm).

4. Grain-size data for surface sediments apply at depth as well. The grain size of Shipek grab samples was measured on subsamples of the top 3 cm of the sample. Only qualitative data on size were available below the 3-cm level. If the underlying material was described as silt-clay, the size data for the surface material were assumed to apply to it as well. The same assumption applies to the Lac Saint-Louis cores from 1990 in which only incomplete size data were obtained. Size data for earlier cores in both lakes were available for the entire length of the core and the weighted average for each core was used for the silt-clay content.

5. Point data on sediment thickness and grain size are representative of the local area. Area and volume calculations were based on voronoi polygons created from the point datasets. Voronoi or Thiessen polygons produce an area of influence around a point such that any location within the area is closer to the point than to any other point. The point values are assumed to apply across the area of the associated polygon. Polygons were created at the lowest SPANS resolution (quadtree 14) which permitted separation of closely-spaced samples. The smallest grid elements on the resulting maps were 3.2 m for Lac Saint-Louis and 3.1 m for Lac Saint-Pierre.

The alternative procedures for extrapolating point data - contouring and potential mapping - were tried and rejected because they produced variable results depending upon the choices made for type of interpolation, filtering, and range of influence.

6. Changes in the bottom sediments of Lac Saint-Louis between 1985 and 1990 are small enough to permit combination of data from the two surveys. The resampling in the 1990 survey of stations originally sampled in 1985 seems to bear this out. Most stations showed changes in grain size less than the analytic error of 2 to 4 percent (Rukavina and Duncan 1970). There were no comparable data on thickness changes during the same period. The sedimentation rates from Rukavina

et al (1990) show an increment between 1985 and 1990 of about 2-4 cm in the northern half of the lake and 20-40 cm in the south half. Thickness data from the northern half should be comparable for the two surveys, but the assumption may not apply for the southern half because of its unstable sedimentation and periodic flushing.

3.2 Procedure

The geographic information system, SPANS 5.2, was used to compute volume data from the point data on thickness and grain size. The steps followed are described below and shown as flowcharts in Appendix 3.

1. ASCII files of sample location, grain-size and thickness were edited to remove overlapping samples and samples upstream of Lac Saint-Pierre and then imported into SPANS. The edited files consisted of 99 sites with thickness and grain-size data in Lac Saint-Pierre and 170 sites with thickness and grain-size data and 45 sites with thickness data only in Lac Saint-Louis. Appendices 1 and 2 list the data used for both lakes.

2. Digital shoreline data for both lakes were imported into SPANS and edited to produce basemaps of the sample areas only. The basemaps used for digitizing the shoreline were the National Topographic Series 1:50,000 series maps 31H/5 (Saint-Louis) and 31I/2, 31I/3 and 31I/7 (Saint-Pierre).

3. Maps of Voronoi polygons were constructed for the grain-size and thickness data of Lac Saint-Pierre and for the grain-size data of Lac Saint-Louis.

4. A separate map of Voronoi polygons was constructed for the thickness data in Lac Saint-Louis because of stations with thickness data but no size data.

5. For Lac Saint-Pierre, equations were setup in SPANS to compute the total modern-sediment volume (sum of products of polygon area and associated thickness) and silt-clay volume (sum of products of polygon areas, associated thickness and associated silt-clay percent). For Lac Saint-Louis, an equation was setup to compute the total modern-sediment volume as above. The grain-size and thickness polygons were then combined in SPANS to produce a unique-conditions map in which each new polygon had the attributes of silt-clay percent, thickness and area. An equation was setup to compute silt-clay volume as the product of unique-conditions polygon areas and the associated values of thickness and silt-clay percent.

6. Results were output as SPANS maps showing the thickness distributions of modern and contaminated (silt-clay) sediments and as reports of cumulative volume and contaminated volume. SPANS was also used to compute the areas of the sample grids and weighted averages for modern-sediment thickness and silt-clay percent (Appendix 4). The average thickness is the total modern-sediment volume divided by the sample area. The average silt-clay percent is the silt-clay volume divided by the modern-sediment volume.

4 RESULTS AND DISCUSSION

The modern-sediment volume is the total volume of sediments overlying glacial clay or bedrock regardless of grain size. Because of compaction of the cores and because many of the grab samples did not extend to the underlying glacial sediment or bedrock, the volumes reported underestimate the true sediment volume and must be considered minimal values. The same qualification applies to the total volumes of silt-clay which are based on the total volumes.

Figures 4 to 7 are SPANS maps showing the complex distribution patterns of modern-sediment thickness and texture in both lakes. In both cases, rapid shifts

in grain size and thickness occur between adjacent stations, presumably in response to the changing topography of the underlying glacial and bedrock substrate, and basins of accumulation are not well-defined.

In Lac Saint-Louis, the finest sediments are also the thickest. The areas of accumulation are the northwest and southwest basins and the area shoreward of the south-shore island chain. Total sediment volume is 10,455,417 m³ of which 7,131,658 m³ (68.2%) are silt and clay. Average modern-sediment thickness is 7.4 cm.

Lac Saint-Pierre shows no similar correlation between sediment size and thickness. Grain size is finest in a band extending from the northwest shore to the axis in the east-central part of the basin and coarsest sediments are adjacent to the entrance and outlet of the St. Lawrence. Sediment thickness tends to decrease from west to east but with considerable small-scale variability. Total sediment volume is 9,751,700 m³ of which 3,829,677 m³ (40.6%) are silt and clay. Average modern-sediment thickness is 5.5 cm. These values apply only to the north half of the basin; no surveys were possible in the southern half because it is a Department of National Defence firing range. The surveyed area represents 57.8% of the total area of the open lake. If the same sediment cover is assumed to apply to the southern half of the lake, the adjusted volumes for modern-sediment and silt-clay become 17,475,274 m³ and 7,102,750 m³ respectively.

Appendix 4 summarizes the results for volumes, areas, and averages of thickness and silt-clay percent.

5**RECOMMENDATIONS FOR FURTHER ANALYSIS**

The estimates of contaminated-sediment volume contained herein are based on the assumption that all sediments of silt-clay size are contaminated. No degree of contamination could be specified because the analysis was based solely on physical data. The samples and cores used by NWRI for physical analysis were also subsampled by the Centre Saint-Laurent (CSL) for chemical and biologic analysis (Champoux et al 1990; Hardy et al 1991). Contaminant data for these samples are available at CSL and could be used to convert the silt-clay volumes and distributions presented in this report to contaminant levels and distributions. This could be done in SPANS by overlaying the contaminant data on the silt-clay maps from the SPANS files developed in this study.

Sediment cover in the unsurveyed south half of Lac Saint-Pierre was assumed to be the same as that in the north half. In fact, the southern sediments should be thicker and finer because most of the tributary streams are on the south shore. Better estimates may be possible by using the ratio of tributary sediment loads from the north and south shores to adjust the volume estimates for the south half of the lake.

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Figure 1: Lac Saint-Louis sample sites, thickness data.

Figure 2: Lac Saint-Louis sample sites, grain-size data.

Figure 3: Lac Saint-Pierre sample sites.

Figure 4: Modern-sediment thickness, Lac Saint-Louis.

Figure 5: Modern-sediment thickness, Lac Saint-Pierre.

Figure 6: Silt-clay distribution, Lac Saint-Louis.

Figure 7: Silt-clay distribution, Lac Saint-Pierre.

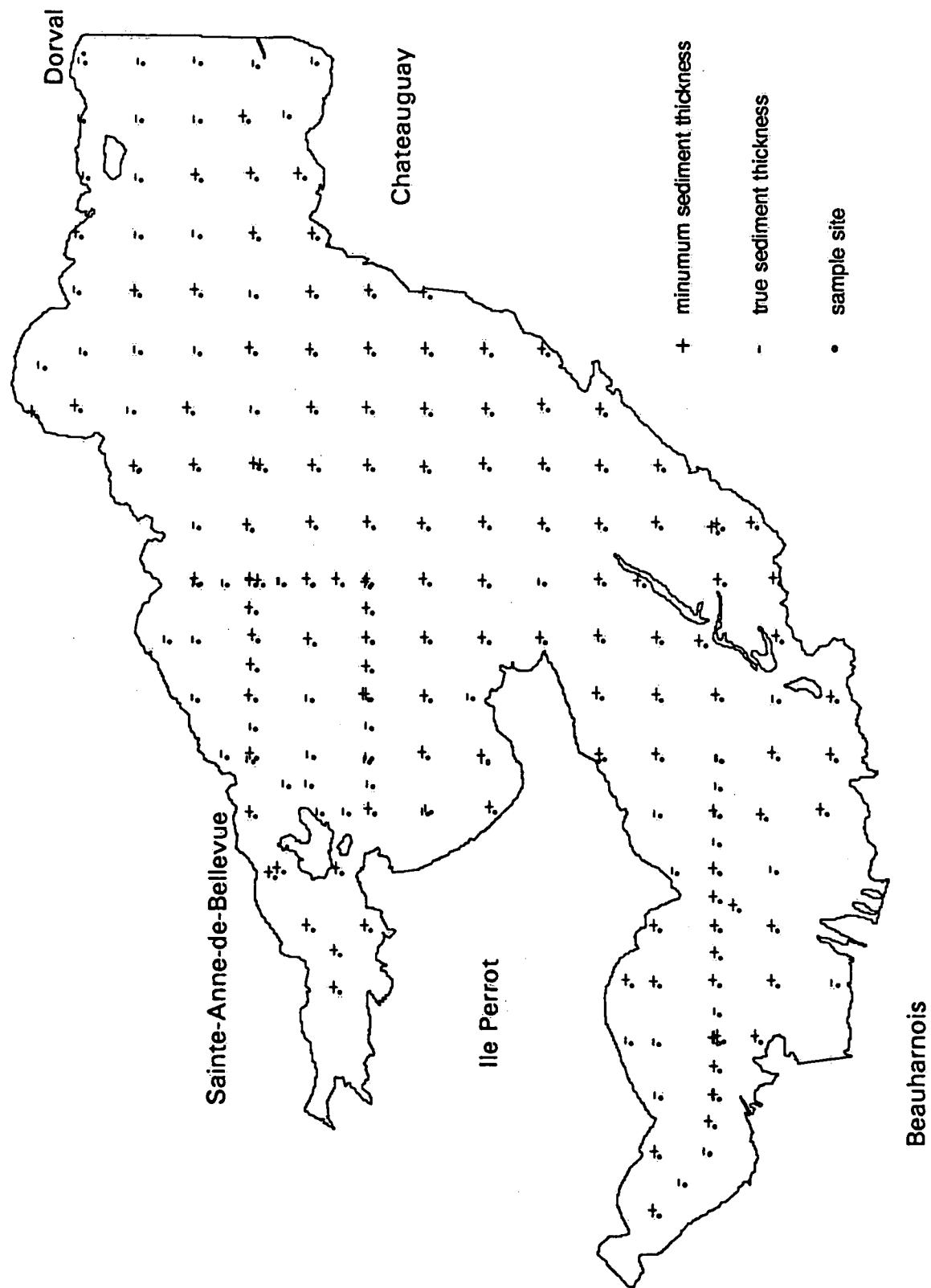


Figure 1. Lac Saint-Louis sample sites, thickness data.

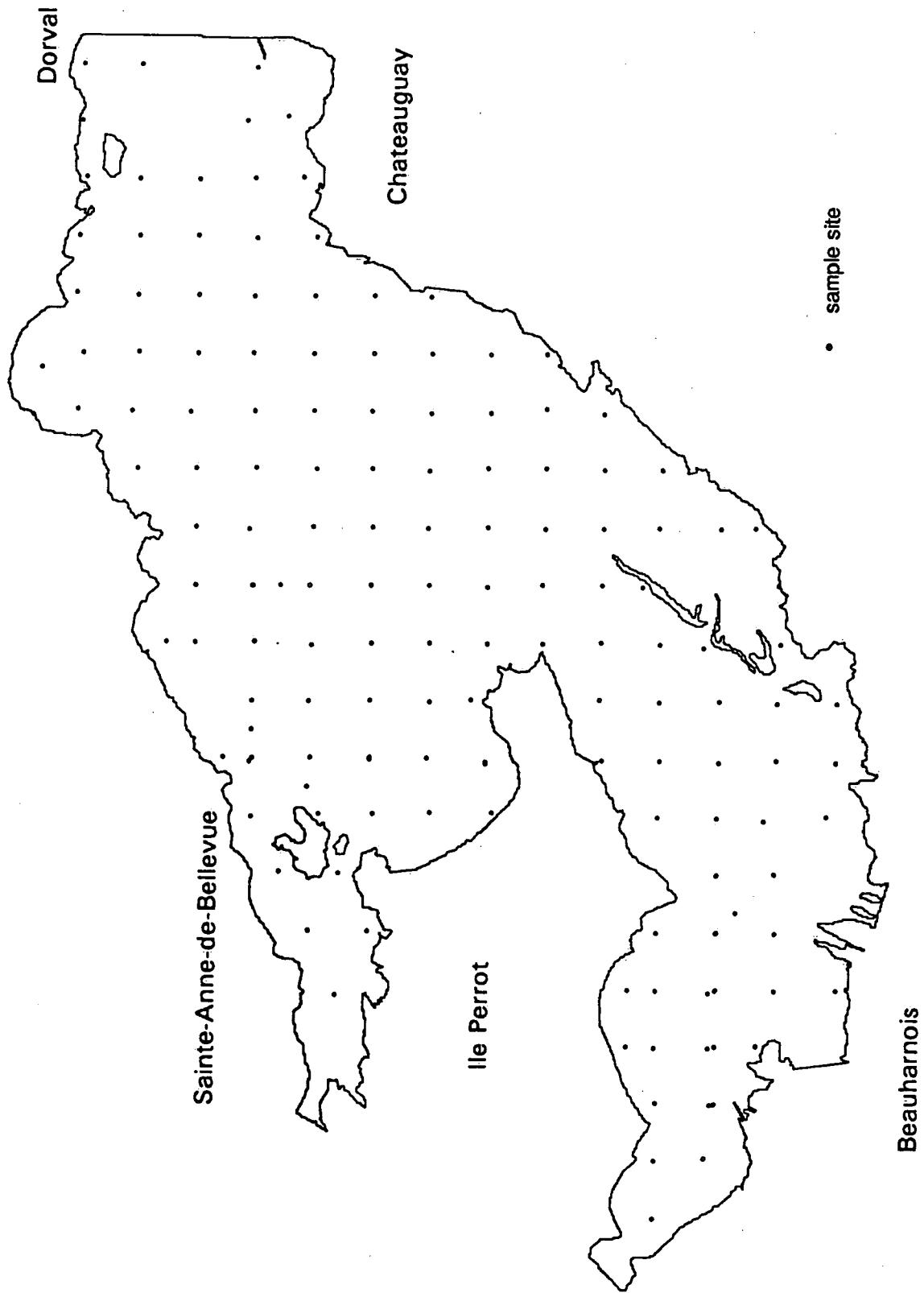


Figure 2. Lac Saint-Louis sample sites, grain-size data.

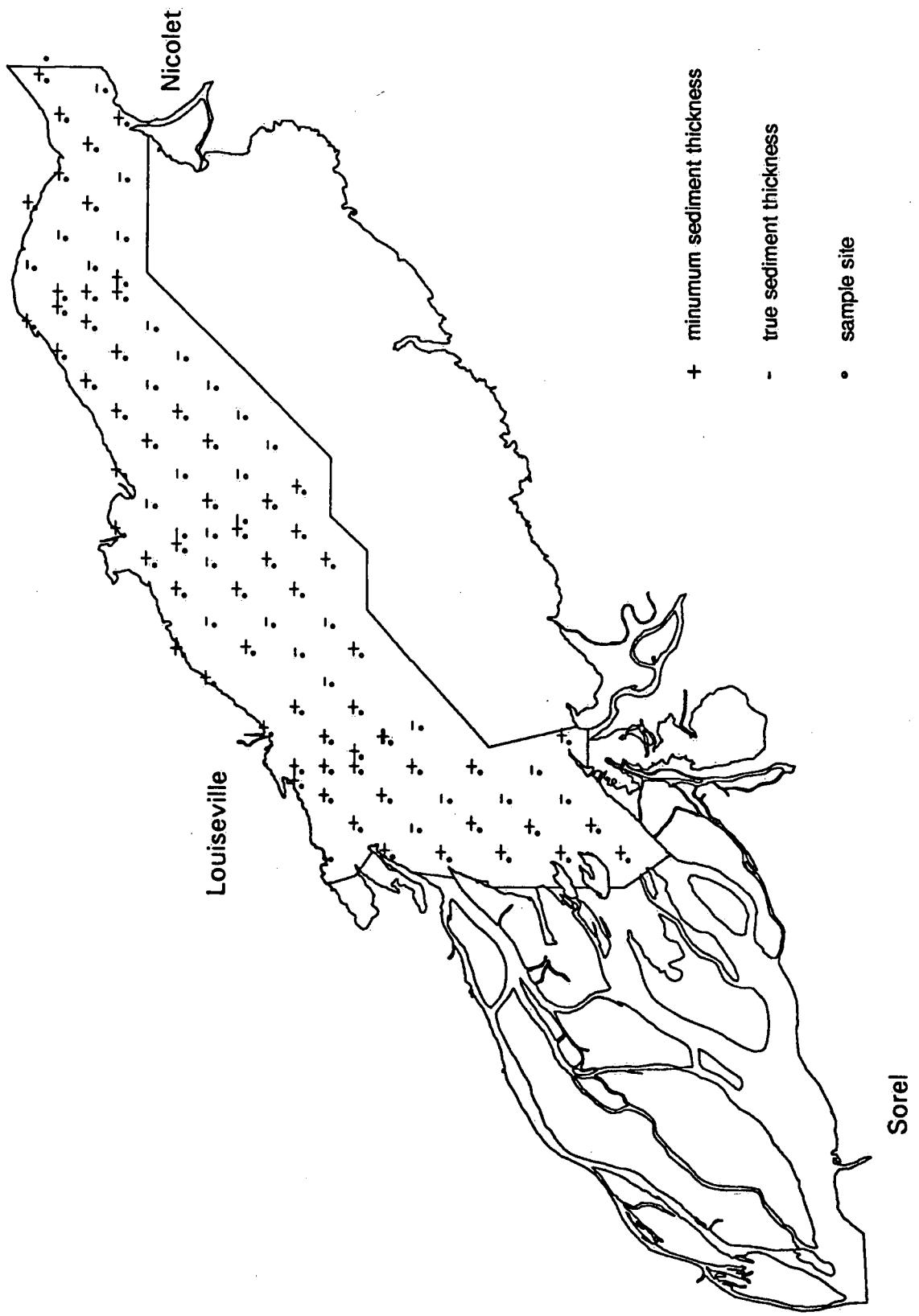


Figure 3. Lac Saint-Pierre sample sites.

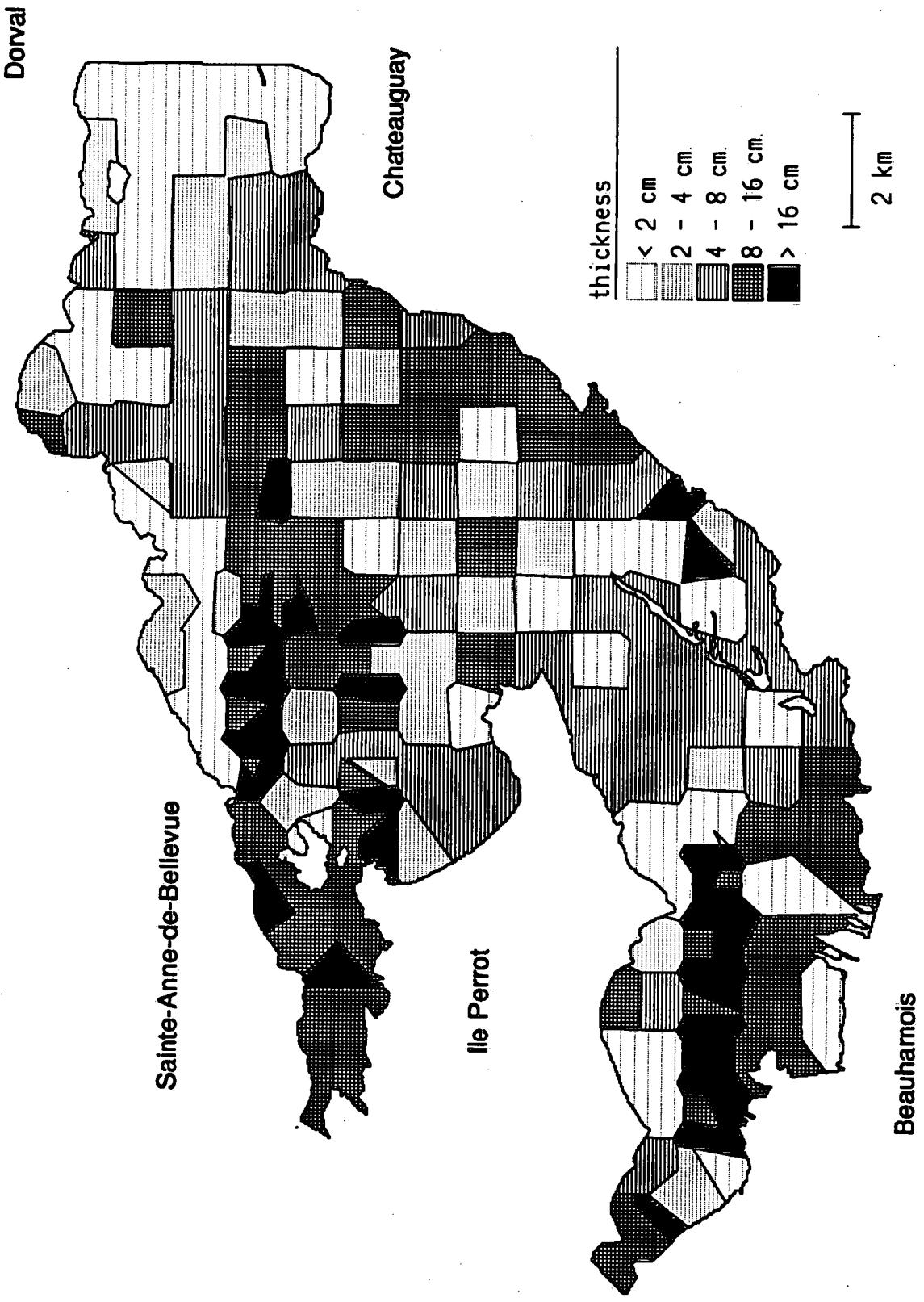


Figure 4. Modern-sediment thickness, Lac Saint-Louis.

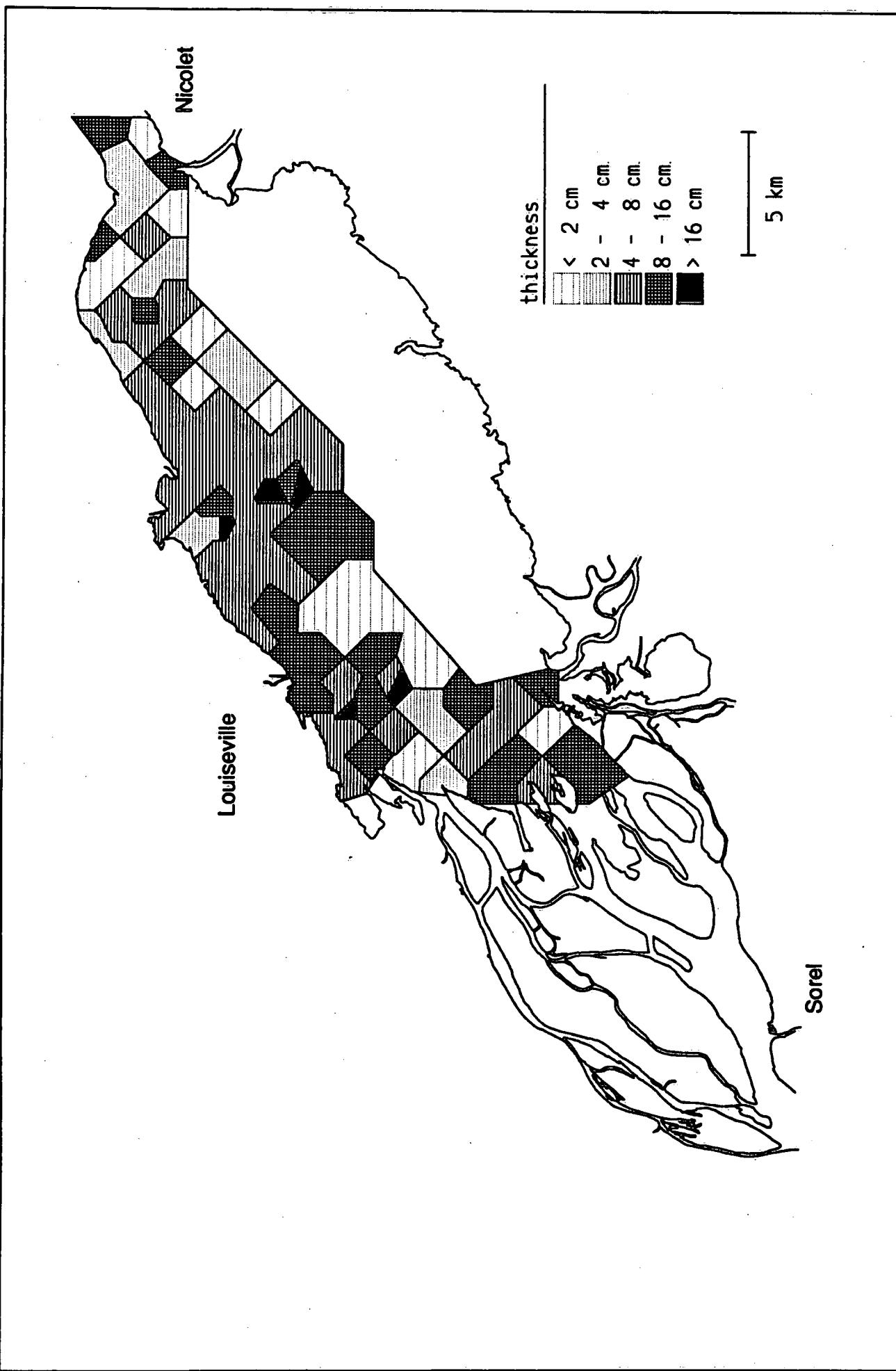


Figure 5. Modern-sediment thickness, Lac Saint-Pierre.

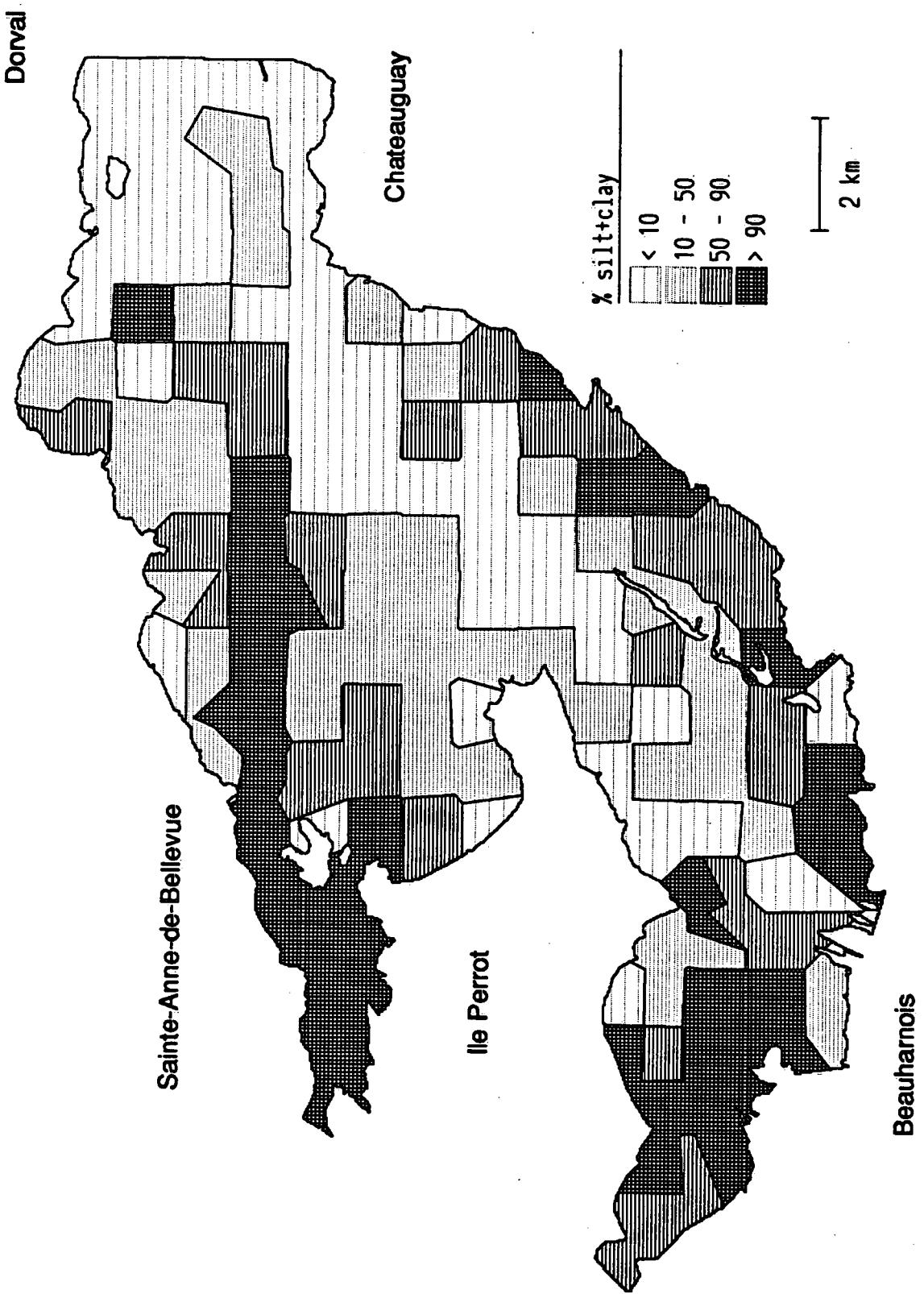


Figure 6. Silt-clay distribution, Lac Saint-Louis.

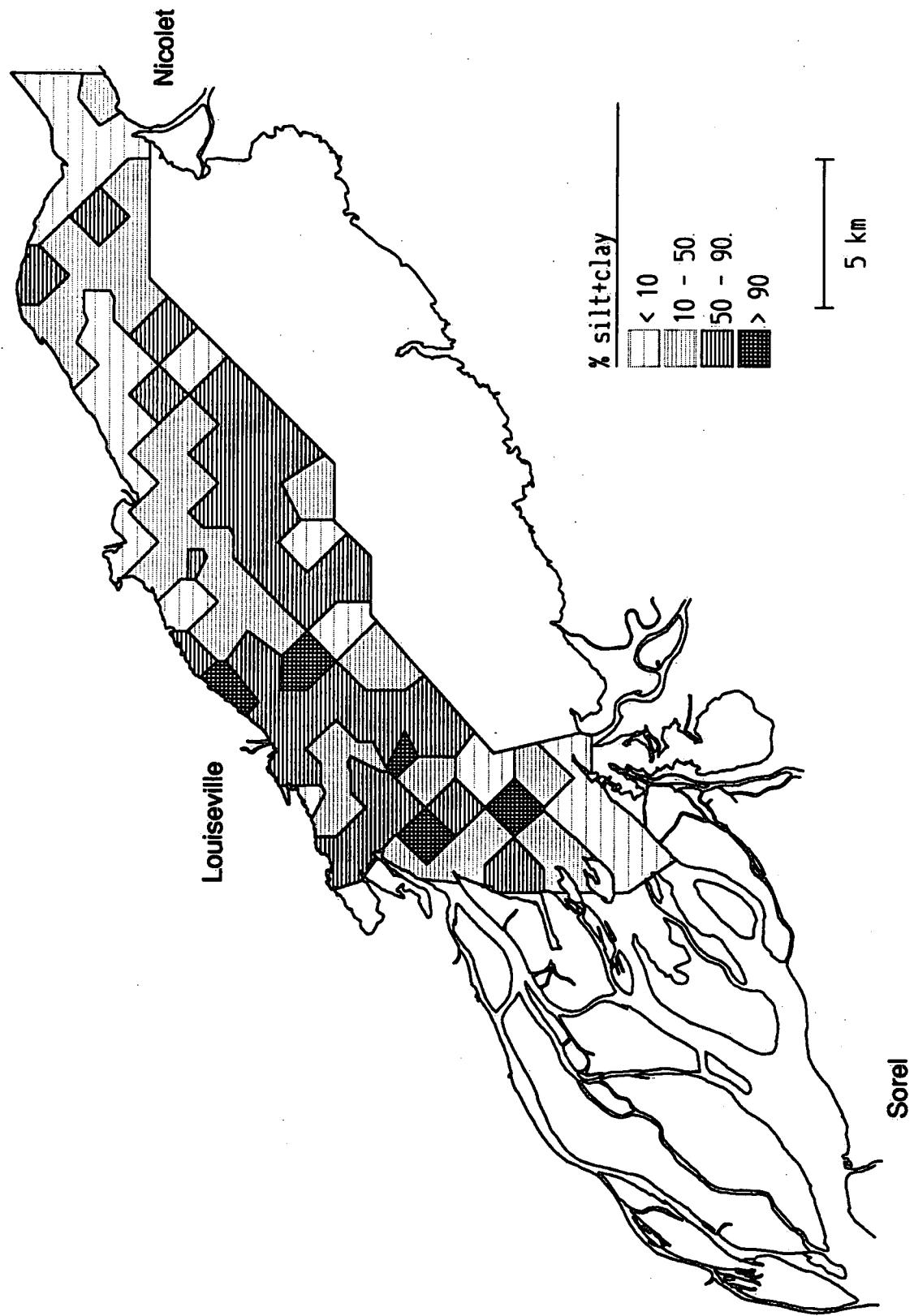


Figure 7. Silt-clay distribution, Lac Saint-Pierre.

APPENDIX 1
Sample data, Lac Saint-Louis

Lac Saint-Louis Thickness Data

Polygon Number	Sample (C=core)	Date	UTM		Thickness cm	true-min +
			Easting	Northing		
1	1	1985	579982	5022010	10.0	+
2	C1	1990	579985	5022005	42.0	-
3	15	1985	584019	5018958	1.0	-
4	14	1985	584002	5019999	11.0	+
5	20	1985	584999	5020004	8.0	+
6	25	1985	586024	5020022	0.0	-
7	C3S	1990	581048	5021145	1.0	-
8	3	1985	581043	5021153	2.0	-
9	C13C	1990	580513	5021572	3.0	-
10	C14	1990	581521	5021060	55.0	+
11	C5	1990	582007	5020987	30.0	+
12	C15	1990	582504	5020987	76.0	+
13	9	1985	583022	5020289	8.0	+
14	C16B	1985	583037	5020917	22.0	+
15	C8	1990	583009	5020987	40.0	+
16	C16	1990	583495	5020992	36.0	-
17	5	1985	582003	5020998	12.0	+
18	8	1985	583005	5020996	9.0	+
19	C16A	1985	582997	5021023	28.0	+
20	2	1985	580993	5022005	5.0	+
21	4	1985	582018	5021984	1.0	-
22	C14	1985	582026	5021984	0.0	-
23	7	1985	582982	5022024	1.0	-
24	6	1985	582996	5022506	0.0	-
25	C17-1	1990	584505	5020991	37.0	+
26	C19S	1990	585002	5020987	16.0	-
27	19	1985	585001	5020993	10.0	+
28	13	1985	583999	5021001	9.0	+
29	C13S	1990	584006	5020996	25.0	+
30	C17A	1985	585348	5020663	28.0	+
31	C18-3	1990	585505	5020998	38.0	+
32	C24-1	1990	585996	5020996	44.0	+
33	24	1985	585998	5020997	11.0	+
34	C24-2	1990	586001	5021005	37.0	+
35	23	1985	585989	5021718	0.0	-
36	19C-1C	1990	586496	5021001	24.0	-
37	12	1985	583996	5022009	5.0	+
38	11	1985	584003	5022491	8.0	+
39	18	1985	585000	5022010	3.0	+
40	10	1985	583880	5027529	8.0	+
41	17	1985	584998	5027000	12.0	+
42	C1	1985	584539	5027528	20.0	+
43	16	1985	584995	5027999	12.0	+
44	22	1985	585994	5027500	12.0	+
45	21	1985	586010	5028503	11.0	+
46	C2	1985	585909	5028645	20.0	+

Lac Saint-Louis Thickness Data

Polygon Number	Sample (C=core)	Date	UTM		Thickness cm	Thickness true-min +
			Easting	Northing		
47	34	1985	587045	5019152	9.0	+
48	45	1985	587980	5019002	9.0	+
49	44	1985	588003	5020001	7.0	+
50	56	1985	589005	5018996	5.0	+
51	55	1985	589004	5019998	0.0	-
52	68	1985	590027	5019951	4.0	+
53	81	1985	591027	5019995	4.0	+
54	33	1985	586949	5020209	9.0	+
55	C32	1990	587011	5020992	0.0	-
56	C20	1990	587479	5020992	1.0	-
57	C43	1990	587958	5020967	2.0	-
58	43	1985	587956	5020973	2.0	-
59	32	1985	587002	5021002	3.0	+
60	C32-2	1990	587000	5021006	0.0	-
61	C32-1	1990	587003	5021003	0.0	-
62	54	1985	589030	5020979	4.0	+
63	67	1985	589948	5021255	4.0	+
64	31	1985	587007	5022010	0.0	-
65	42	1985	587985	5021985	4.0	+
66	41	1985	587985	5022981	5.0	+
67	53	1985	589008	5022001	5.0	+
68	66	1985	590009	5022001	6.0	+
69	52	1985	589046	5023029	7.0	+
70	65	1985	590034	5023010	1.0	+
71	80	1985	591020	5020941	1.0	+
72	92	1985	592013	5020395	4.0	+
73	C22B	1985	591987	5020989	10.0	+
74	91	1985	591999	5020977	3.0	+
75	C22A	1985	591930	5021070	16.0	+
76	78	1985	590986	5022315	6.0	+
77	77	1985	591018	5023002	7.0	+
78	90	1985	592006	5022028	1.0	+
79	C21A	1985	592999	5021987	20.0	+
80	102	1985	593007	5021996	5.0	+
81	89	1985	591990	5022984	1.	+
82	101	1985	592999	5022986	5.0	+
83	113	1985	593970	5023003	10.0	+
84	30	1985	587071	5024882	4.0	+
85	40	1985	587951	5025004	4.0	+
86	C5	1985	587917	5025008	6.5	-
87	64	1985	590009	5024014	4.0	+
88	63	1985	590007	5025000	8.0	+
89	29	1985	587076	5025965	5.0	-
90	C4	1985	587034	5026024	3.0	-
91	39	1985	588008	5026026	7.0	+
92	51	1985	589035	5025271	1.0	-

Lac Saint-Louis Thickness Data

Polygon Number	Sample (C=core)	Date	UTM		Thickness cm	true-min +
			Easting	Northing		
93	50	1985	589000	5025992	2.0	+
94	62	1985	590012	5025999	2.0	+
95	76	1985	591020	5024030	1.0	-
96	75	1985	590982	5025002	3.0	+
97	88	1985	591979	5023992	2.0	+
98	100	1985	593021	5023987	7.0	+
99	87	1985	592010	5025005	8.0	+
100	99	1985	593020	5025014	3.0	+
101	74	1985	591007	5026013	5.0	+
102	86	1985	591984	5026038	2.0	+
103	98	1985	592970	5026029	7.0	+
104	C28	1990	587040	5026937	49.0	+
105	28	1985	587041	5026939	11.0	+
106	C7	1990	587516	5026972	40.0	-
107	C8	1990	587039	5027387	10.0	-
108	C38	1990	587998	5026993	2.0	-
109	38	1985	587988	5027000	7.0	-
110	C6	1985	587933	5027036	14.0	-
111	27	1985	587036	5027849	0.0	-
112	C27X	1990	587514	5028034	3.0	-
113	37	1985	588015	5027995	7.0	-
114	C6	1990	588508	5027000	7.0	-
115	49	1985	589017	5027006	11.0	+
116	C49	1990	589019	5027007	11.0	-
117	C7	1985	589020	5027052	11.0	+
118	C5-1	1990	589509	5026999	18.0	+
119	61	1985	590006	5026994	3.0	+
120	C61	1990	590006	5026997	11.0	-
121	48	1985	588999	5028033	2.0	-
122	60	1985	589968	5028000	8.0	+
123	C9	1990	587505	5028422	3.0	-
124	26	1985	586977	5028991	11.0	+
125	C3	1985	587925	5029036	21.0	-
126	C36	1990	587992	5028975	32.0	-
127	36	1985	587993	5028981	9.0	+
128	35	1985	588001	5029487	1.0	-
129	C10-1	1990	588496	5028997	43.0	-
130	C10	1990	588496	5028999	49.0	-
131	C47	1990	589001	5029003	42.0	-
132	47	1985	589003	5029005	11.0	+
133	C11	1990	589514	5028985	45.0	+
134	C59	1990	590020	5028968	48.0	+
135	59	1985	590023	5028973	11.0	+
136	C4	1990	590513	5026999	18.0	+
137	73	1985	591007	5027009	6.0	+
138	C73-2	1990	591009	5027011	11.0	-

Lac Saint-Louis Thickness Data

Polygon Number	Sample (C=core)	Date	UTM		Thickness cm	Thickness true- min +
			Easting	Northing		
139	C11	1985	590962	5027043	11.0	+
140	C3C	1990	591000	5027524	11.0	+
141	C10	1985	590999	5028027	15.0	+
142	72	1985	590999	5028035	9.0	+
143	C72	1990	590996	5028040	24.0	+
144	85	1985	592004	5026993	1.0	+
145	97	1985	593009	5027012	2.0	+
146	84	1985	592003	5027990	10.0	+
147	96	1985	593003	5027946	2.0	+
148	C12-2	1990	590512	5029003	50.0	+
149	C2-2	1990	590997	5028525	16.0	-
150	C2-2	1990	590997	5028529	12.0	-
151	C2-1	1990	591001	5028526	15.0	-
152	C9	1985	590988	5028880	21.0	+
153	C71-1	1990	590992	5029019	51.0	+
154	71	1985	590996	5029019	8.0	+
155	C1-2	1990	590990	5029499	2.0	-
156	C8	1985	591012	5029960	1.0	+
157	83	1985	591960	5029076	10.0	+
158	C13	1985	592994	5028854	22.0	+
159	95	1985	593023	5028971	10.0	+
160	112	1985	594054	5023999	9.0	+
161	111	1985	593984	5024984	1.0	+
162	122	1985	594998	5025000	11.0	+
163	123	1985	595006	5024008	11.0	+
164	110	1985	593971	5026013	9.0	+
165	121	1985	595008	5026012	9.0	+
166	130	1985	595990	5026041	7.0	+
167	109	1985	594008	5027026	9.0	+
168	120	1985	594999	5027013	2.0	+
169	108	1985	594001	5027994	7.0	+
170	119	1985	594996	5028018	1.0	+
171	129	1985	596008	5027006	9.0	+
172	128	1985	595996	5028010	2.0	+
173	107	1985	593999	5029012	10.0	-
174	118	1985	595005	5029044	9.0	+
175	127	1985	595992	5029034	2.0	-
176	136	1985	597006	5027988	4.0	+
177	141	1985	598044	5028221	4.0	+
178	135	1985	596988	5029001	5.0	+
179	140	1985	598028	5029042	4.0	+
180	146	1985	599101	5028498	1.0	-
181	145	1985	599020	5029197	3.0	+
182	46	1985	588990	5030000	0.0	-
183	58	1985	590004	5029992	1.0	-
184	57	1985	590003	5030474	2.0	-

Lac Saint-Louis Thickness Data

Polygon Number	Sample (C=core)	Date	UTM		Thickness cm	true-min +
			Easting	Northing		
185	70	1985	590986	5029993	0.0	-
186	70	1990	590989	5029997	2.0	-
187	82	1985	591996	5030000	0.0	-
188	94	1985	593006	5030005	5.0	+
189	93	1985	592992	5030995	2.0	-
190	C12	1985	592967	5031017	1.0	+
191	106	1985	593976	5030113	4.0	+
192	117	1985	594998	5030002	4.0	-
193	105	1985	593988	5031103	4.0	-
194	126	1985	596010	5029990	7.0	+
195	116	1985	595010	5031001	0.0	-
196	125	1985	595994	5031018	9.0	+
197	104	1985	594008	5032021	4.0	+
198	115	1985	594987	5031934	1.0	-
199	103	1985	593894	5032748	9.0	+
200	114	1985	594721	5032622	2.0	-
201	124	1985	596036	5032051	0.0	-
202	134	1985	597019	5030011	2.0	-
203	139	1985	598000	5030004	2.0	+
204	133	1985	597011	5031001	0.0	-
205	138	1985	598002	5031007	1.0	-
206	144	1985	599027	5030014	0.0	-
207	143	1985	599026	5031012	0.0	-
208	132	1985	597004	5032013	5.0	+
209	137	1985	598032	5031908	2.0	-
210	142	1985	599004	5031989	2.0	-
211	151	1985	600017	5028021	0.0	-
212	150	1985	599959	5029029	0.0	-
213	149	1985	600014	5030019	0.0	-
214	148	1985	600001	5030988	1.0	-
215	147	1985	600001	5031972	0.0	-

Lac Saint-Louis Silt-Clay Data

Polygon Number	Sample (C=core)	Date	UTM		Silt-clay %
			Easting	Northing	
1	1	1985	579982	5022010	76.3
2	1	1990	579983	5022006	62.8
3	15	1985	584019	5018958	43.2
4	14	1985	584002	5019999	91.0
5	20	1985	584999	5020004	76.4
6	25	1985	586024	5020022	0.2
7	3S	1990	581047	5021145	99.5
8	3	1985	581043	5021153	84.2
9	5	1990	582004	5020988	98.1
10	9	1985	583022	5020289	95.6
11	8	1990	583006	5020988	99.7
12	5	1985	582003	5020998	93.0
13	5X	1990	581988	5021068	98.9
14	8	1985	583005	5020996	98.3
15	8X	1990	582979	5021103	99.5
16	2	1985	580993	5022005	91.1
17	4	1985	582018	5021984	90.5
18	7	1985	582982	5022024	50.7
19	6	1985	582996	5022506	93.8
20	13S	1990	584011	5020991	99.4
21	19	1985	585001	5020993	37.3
22	19S	1990	585011	5020988	98.0
23	13SX	1990	583959	5021115	99.2
24	13	1985	583999	5021001	97.2
25	C17A	1985	585348	5020663	74.6
26	24-3	1990	585994	5021006	92.6
27	24	1985	585998	5020997	79.2
28	12	1985	583996	5022009	11.9
29	11	1985	584003	5022491	4.4
30	18	1985	585000	5022010	17.3
31	10	1985	583880	5027529	95.1
32	17	1985	584998	5027000	95.4
33	16	1985	584995	5027999	93.9
34	22	1985	585994	5027500	95.1
35	21	1985	586010	5028503	96.0
36	34	1985	587045	5019152	90.5
37	45	1985	587980	5019002	93.0
38	44	1985	588003	5020001	87.9
39	56	1985	589005	5018996	6.9
40	55	1985	589004	5019998	89.7
41	68	1985	590027	5019951	98.4
42	81	1985	591027	5019995	87.2
43	33	1985	586949	5020209	30.0
44	av43	**	587956	5020973	27.5
45	32	1985	587002	5021002	9.0
46	54	1985	589030	5020979	38.5
47	67	1985	589948	5021255	33.0

Lac Saint-Louis Silt-Clay Data

Polygon Number	Sample (C=core)	Date	UTM Easting	UTM Northing	Silt-clay %
48	31	1985	587007	5022010	9.4
49	42	1985	587985	5021985	20.2
50	41	1985	587985	5022981	3.6
51	53	1985	589008	5022001	5.1
52	66	1985	590009	5022001	55.1
53	52	1985	589046	5023029	42.8
54	65	1985	590034	5023010	0.1
55	92	1985	592013	5020395	69.2
56	91	1985	591999	5020977	65.9
57	78	1985	590986	5022315	32.0
58	77	1985	591018	5023002	0.1
59	90	1985	592006	5022028	61.3
60	C21A	1985	592999	5021987	97.0
61	102	1985	593007	5021996	100.0
62	89	1985	591990	5022984	26.3
63	101	1985	592999	5022986	100.0
64	113	1985	593970	5023003	89.5
65	30	1985	587071	5024882	100.0
66	40	1985	587951	5025004	16.7
67	C5	1985	587917	5025008	26.8
68	64	1985	590009	5024014	24.0
69	63	1985	590007	5025000	43.7
70	29	1985	587076	5025965	69.3
71	39	1985	588008	5026026	42.9
72	51	1985	589035	5025271	0.2
73	50	1985	589000	5025992	23.0
74	62	1985	590012	5025999	16.3
75	76	1985	591020	5024030	0.1
76	75	1985	590982	5025002	5.2
77	88	1985	591979	5023992	2.8
78	100	1985	593021	5023987	29.4
79	87	1985	592010	5025005	0.1
80	99	1985	593020	5025014	1.1
81	74	1985	591007	5026013	19.8
82	86	1985	591984	5026038	22.8
83	98	1985	592970	5026029	0.0
84	28-3	1990	587042	5026938	92.1
85	28	1985	587041	5026939	91.0
86	38	1985	587988	5027000	69.4
87	38-1	1990	587999	5027007	86.4
88	38-2	1990	588022	5026995	60.3
89	27	1985	587036	5027849	6.1
90	27	1990	587507	5028040	51.4
91	37	1985	588015	5027995	50.5
92	49	1985	589017	5027006	81.4
93	49-4	1990	589019	5027009	88.6
94	61-2	1990	590003	5026986	33.3

Lac Saint-Louis Silt-Clay Data

Polygon Number	Sample (C=core)	Date	UTM		Silt-clay %
			Easting	Northing	
95	61	1985	590006	5026994	28.6
96	48	1985	588999	5028033	20.0
97	60	1985	589968	5028000	42.9
98	26	1985	586977	5028991	98.4
99	C3	1985	587925	5029036	94.4
100	36	1985	587993	5028981	93.7
101	36-2	1990	587992	5028986	99.4
102	35	1985	588001	5029487	18.0
103	C10-1	1990	588496	5028997	96.2
104	47	1990	589002	5028996	97.1
105	47	1985	589003	5029005	91.5
106	59	1990	590020	5028961	94.7
107	59	1985	590023	5028973	90.1
108	73-1	1990	591004	5027008	30.2
109	73	1985	591007	5027009	29.0
110	72	1985	590999	5028035	84.7
111	72-4	1990	590995	5028040	94.4
112	85	1985	592004	5026993	12.4
113	97	1985	593009	5027012	0.8
114	84	1985	592003	5027990	63.7
115	96	1985	593003	5027946	0.6
116	C2-2	1990	590997	5028529	91.0
117	71-2	1990	590992	5029000	99.2
118	71	1985	590996	5029019	99.1
119	83	1985	591960	5029076	90.1
120	95	1985	593023	5028971	90.3
121	112	1985	594054	5023999	89.1
122	111	1985	593984	5024984	1.1
123	122	1985	594998	5025000	73.5
124	123	1985	595006	5024008	100.0
125	110	1985	593971	5026013	61.1
126	121	1985	595008	5026012	45.4
127	130	1985	595990	5026041	0.1
128	109	1985	594008	5027026	0.0
129	120	1985	594999	5027013	1.1
130	108	1985	594001	5027994	0.2
131	119	1985	594996	5028018	0.0
132	129	1985	596008	5027006	28.7
133	128	1985	595996	5028010	8.2
134	107	1985	593999	5029012	65.4
135	118	1985	595005	5029044	60.3
136	127	1985	595992	5029034	0.1
137	136	1985	597006	5027988	1.5
138	141	1985	598044	5028221	0.1
139	135	1985	596988	5029001	13.2
140	140	1985	598028	5029042	25.8
141	146	1985	599101	5028498	0.1

Lac Saint-Louis Silt-Clay Data

Polygon Number	Sample (C=core)	Date	UTM		Silt-clay %
			Easting	Northing	
142	145	1985	599020	5029197	32.3
143	58	1985	590004	5029992	17.1
144	57	1985	590003	5030474	6.5
145	70	1985	590986	5029993	82.9
146	70	1990	590989	5029997	42.9
147	82	1985	591996	5030000	88.1
148	94	1985	593006	5030005	42.5
150	106	1985	593976	5030113	20.1
151	117	1985	594998	5030002	63.8
152	105	1985	593988	5031103	22.6
153	126	1985	596010	5029990	42.5
154	116	1985	595010	5031001	0.0
155	125	1985	595994	5031018	90.6
156	104	1985	594008	5032021	54.8
157	115	1985	594987	5031934	10.8
158	103	1985	593894	5032748	75.9
159	114	1985	594721	5032622	15.6
160	124	1985	596036	5032051	0.1
161	134	1985	597019	5030011	0.1
162	139	1985	598000	5030004	0.2
163	133	1985	597011	5031001	0.8
164	138	1985	598002	5031007	0.3
165	132	1985	597004	5032013	0.2
166	137	1985	598032	5031908	0.1
167	142	1985	599004	5031989	0.9
168	150	1985	599959	5029029	0.0
169	148	1985	600001	5030988	0.6
170	147	1985	600001	5031972	0.1

** average of 1985 sample 43 and 1990 sample 43-2

APPENDIX 2

Sample data, Lac Saint-Pierre

Lac Saint-Pierre Thickness and Silt-Clay Data

Polygon Number	Sample	UTM		Thickness	Silt-Clay %	Mod-sed volume	Silt-clay volume
		Easting	Northing	cm true-min+		m ³	m ³
1	SP6A	656004	5108003	8 +	0.2	228800	457.6
2	SP11	656996	5109007	9 +	0.3	237600	712.8
3	SP5	656005	5109994	4 +	46.8	82400	38563.2
4	SP10	656894	5111044	8 +	28.7	160800	46149.6
5	SP16	658003	5110004	0 -	0.0	0	0.0
6	SP21	659002	5111006	7 -	23.2	184800	42873.6
7	SP25	660031	5110010	8 +	0.1	140800	140.8
8	SP4	655996	5112008	9 +	60.3	244800	147614.4
9	SP3	656007	5113997	3 +	13.0	61800	8034.0
10	SP9	657006	5112993	4 +	25.9	79600	20616.4
11	SP15	657996	5112006	6 -	98.0	121800	119364.0
12	SP20	659000	5113001	8 +	0.2	257600	515.2
13	SP14	658005	5113995	3 -	59.3	60300	35757.9
14	SP8	656996	5115004	1 -	90.0	19100	17190.0
15	SP2	656096	5115903	1 +	37.9	12800	4851.2
16	SP7	657004	5116996	8 +	82.9	158400	131313.6
17	SP19	659003	5115005	3 +	35.9	66600	23909.4
18	SP88	660498	5114997	1 -	53.0	43600	23108.0
19	SP13	657997	5116007	5 +	57.7	99500	57411.5
20	SP18	659001	5117000	10 +	58.4	122000	71248.0
21	SC24	660000	5115997	67 +	93.2	542700	505796.4
22	SP24	660004	5116002	6 +	55.1	50400	27770.4
23	SP87	659500	5117000	10 +	59.3	28000	16604.0
24	SC87	659507	5116998	10 -	29.7	69000	20493.0
25	SP1	655999	5117990	5 -	68.1	91000	61971.0
26	SP12	658000	5118000	6 +	34.1	111600	38055.6
27	SC86	658998	5117996	22 +	14.3	105600	15100.8
28	SP86	659001	5118000	6 +	44.7	29400	13141.8
29	SP23	660010	5118008	7 +	49.3	111300	54870.9
30	SP85	658500	5118994	4 +	0.6	30000	180.0
31	SP17	659000	5118999	8 +	57.3	112800	64634.4
32	SP22	660261	5120055	10 +	88.1	208000	183248.0
33	SP27	661010	5117011	8 +	64.5	210400	135708.0
34	SP34	663010	5117013	1 +	13.8	38600	5326.8
35	SP30	661998	5118001	1 -	50.1	19800	9919.8
36	SP26	661019	5119007	10 +	82.5	247000	203775.0
37	SP33	663001	5119004	1 -	91.8	23400	21481.2
38	SP37B	663993	5117985	1 -	0.2	26800	53.6
39	SP44	665994	5117994	8 +	54.6	260000	141960.0
40	SP40	665017	5119018	9 +	60.4	180900	109263.6
41	SP36	664000	5119994	4 -	23.2	73200	16982.4
42	SP48	666995	5118983	8 +	0.0	184800	0.0
43	SP43	665999	5119999	9 +	63.1	179100	113012.1
44	SP92	668499	5118998	4 +	15.4	111200	17124.8
45	SC51	667997	5119991	19 -	84.2	155800	131183.6
46	SP51	667999	5119998	10 +	70.7	84000	59388.0

Lac Saint-Pierre Thickness and Silt-Clay Data

Polygon Number	Sample	UTM		Thickness	Silt-Clay %	Mod-sed volume m ³	Silt-clay volume m ³
		Easting	Northing	cm true-min+			
47	SP57	669999	5119999	5 -	82.8	151500	125442.0
48	SP28	662000	5122000	4 +	90.6	66000	59796.0
49	SP32	663059	5120683	9 +	50.6	246600	124779.6
50	SP31	663000	5122999	4 +	50.3	45200	22735.6
51	SP39	665000	5120999	6 +	15.2	120600	18331.2
52	SP35	664000	5121999	4 -	31.3	85600	26792.8
53	SP47	667000	5120999	7 +	57.1	85400	48763.4
54	SP42	666007	5122007	6 -	17.7	94200	16673.4
55	SP90	667000	5121999	6 -	33.6	58200	19555.2
56	SP38	665000	5123000	7 +	0.2	157500	315.0
57	SC89	666500	5122995	31 +	76.5	145700	111460.5
58	SP89	666499	5122999	3 -	24.2	15000	3630.0
59	SP46	667000	5122999	10 -	34.4	122000	41968.0
60	SP41	666003	5123995	3 +	13.0	54600	7098.0
61	SP45	667000	5124999	6 +	0.7	127200	890.4
62	SC91	667499	5120999	16 -	66.4	155200	103052.8
63	SP50	668000	5122000	7 +	56.5	110600	62489.0
64	SP54	668999	5120999	5 -	52.6	97000	51022.0
65	SP56	669999	5122000	6 +	63.2	120000	75840.0
66	SP53	668999	5123000	5 -	41.1	100000	41100.0
67	SP60	671006	5121003	1 -	85.9	25800	22162.2
68	SP63	671999	5121999	2 -	76.9	51600	39680.4
69	SP59	670999	5122999	5 +	12.8	100000	12800.0
70	SP66	672999	5123000	2 -	0.0	52000	0.0
71	SP49	668000	5123999	5 -	18.0	100000	18000.0
72	SP55	669999	5124000	6 +	20.7	120000	24840.0
73	SP52	669000	5125000	5 +	5.7	69000	3933.0
74	SP58	671000	5124999	6 +	0.2	139800	279.6
75	SP62	671999	5124000	1 -	84.5	20000	16900.0
76	SP65	673000	5124999	8 +	0.4	160800	643.2
77	SP61	671999	5126009	6 +	0.4	113400	453.6
78	SP64	673000	5127000	3 +	18.7	39000	7293.0
79	SP69	674000	5124000	1 -	77.0	26000	20020.0
80	SP71	675000	5124999	7 +	33.8	89600	30284.8
81	SP95	675500	5125000	6 +	35.3	82200	29016.6
82	SP68	674000	5125999	5 +	0.9	79000	711.0
83	SP94	675005	5125999	10 +	0.3	97000	291.0
84	SP73	676008	5125998	3 -	13.7	47400	6493.8
85	SP75	677000	5124998	3 -	49.3	64500	31798.5
86	SP79	679003	5124986	0 -	15.5	0	0.0
87	SP77	678000	5126000	4 +	72.1	80400	57968.4
88	SP82	680900	5125019	8 +	0.3	120800	362.4
89	SP80	680000	5126000	2 +	0.2	39000	78.0
90	SP84	682009	5125731	1 -	44.7	16900	7554.3
91	SP93	674500	5127000	4 +	33.8	38800	13114.4
92	SP67	674005	5127999	3 +	31.0	31800	9858.0

Lac Saint-Pierre Thickness and Silt-Clay Data

Polygon Number	Sample	UTM		Thickness	Silt-	Mod-sed	Silt-clay
		Easting	Northing	cm true- min+	Clay %	volume m ³	volume m ³
93	SP70	675000	5126999	5 +	13.6	61000	8296.0
94	SP72	676000	5127999	1 -	69.9	21800	15238.2
95	SP74	676998	5127000	1 -	28.1	20000	5620.0
96	SP76	677999	5128000	8 +	0.2	84800	169.6
97	SP78	678994	5127002	3 +	9.4	51300	4822.2
98	SP81	680999	5127001	2 +	0.1	43200	43.2
99	SP83	682329	5127657	9 +	0.0	192600	0.0

APPENDIX 3

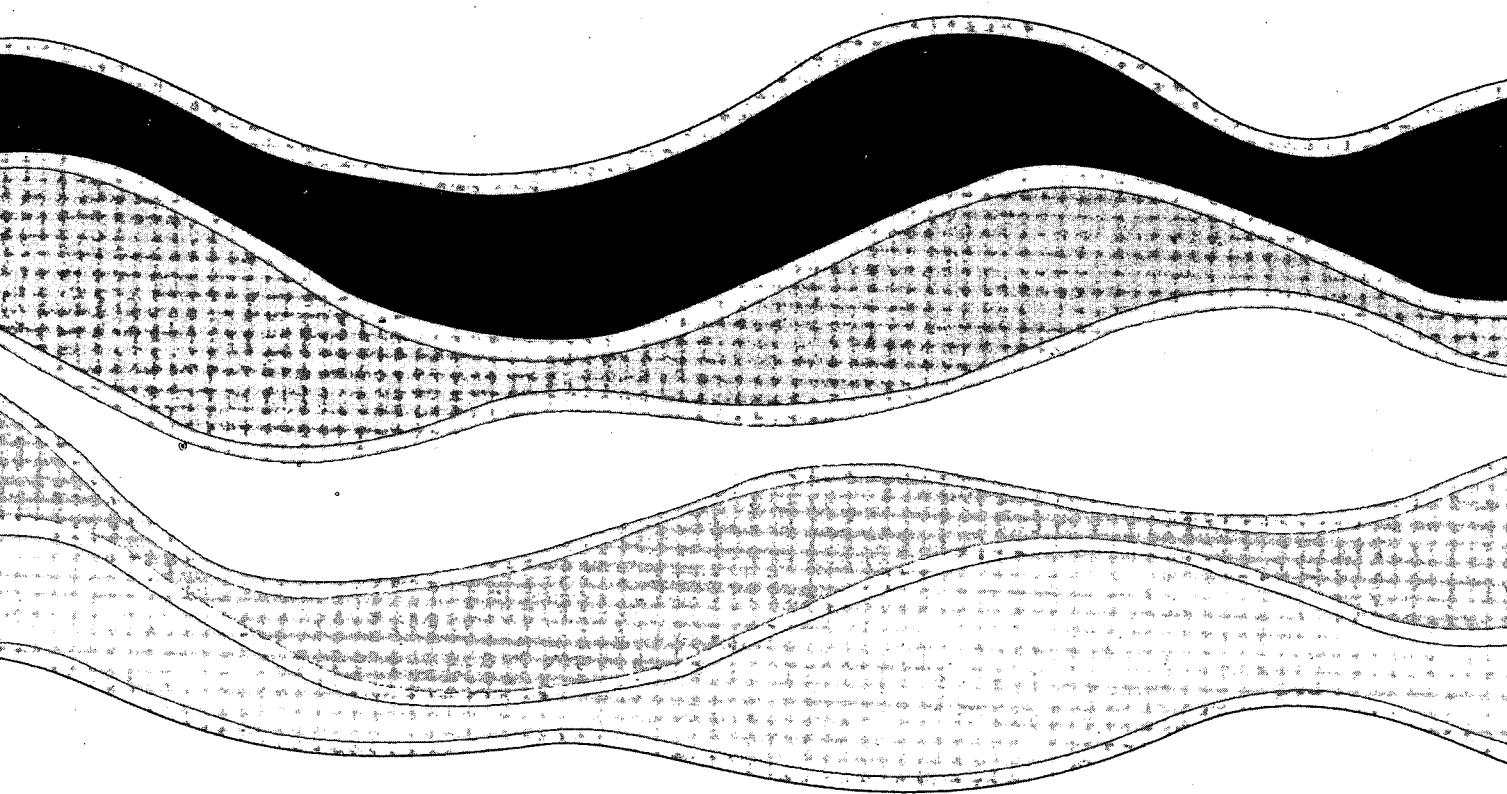
Summary of Results

Lake	Saint-Louis	Saint-Pierre
Sampled area, km ²	142.0 (100%)	183.9 (57.8%)
Open-lake area, km ²	142.0	318.1
Modern-sediment volume, m ³	10,455,417	10,105,500 (north) 17,475,274 (total)
Average modern-sediment thickness, cm	7.4	5.5
Contaminated-sediment (silt-clay) volume, m ³	7,131,658	4,107,337 (north) 7,102,750 (total)
Average silt-clay %	68.2	40.6

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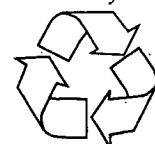
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