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MEASUREMENTS OF CONTAMINATED-SEDIMENT THICKNESS AT THE RANDLE DREDGE SITE, HAMILTON HARBOUR

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Management Perspective

This work was done in support of the GL2000 Program for the assessment and remediation of contaminated sediments in Hamilton Harbour. It is part of the Remedial Action Plan Program (Stream 1.1 RAPS/AOCS). The work began in 1998 and will be continued in 1999.

The thickness and volume of contaminated sediments at the Randle Reef dredge site in Hamilton Harbour are required for estimates of removal and processing costs and for the use of the dredging contractor in planning extraction. Sediment cores show a stiff clay layer underlying the contaminated sediment but the core lengths are poor estimates of sediment thickness. A more consistent set of data on depth to refusal has been obtained with an NWRI penetrometer and used to generate a thickness pattern and an estimate of sediment volume and to assess acoustic data obtained with a sub-bottom profiler survey.

Future work will consist of measurements with a free-fall penetrometer at the site in the spring of 1999 and comparison of its results with those of a conventional geotechnical survey.

Abstract

Data on contaminated-sediment thickness and volume are needed to plan and carry out a remedial dredging program at the Randle Reef site on the south shore of Hamilton Harbour. Previous estimates of sediment thickness based on core data are unreliable because of a number of errors introduced by the coring procedure. A consistent set of measurements of depth to refusal in the soft surficial sediments was obtained with a tripod penetrometer developed at NWRI. Data were collected at 25 sites and used to map the thickness distribution and to estimate the soft-sediment volume. Thickness ranged from 0.68 to 1.86 m and averaged 1.20 m. Sediment volume was approximately 36,000 m^3 most of which was located in the west-central part of the site. Tripod thickness and volume were higher than those obtained from an uncalibrated sub-bottom profiler survey of the same site.

1. Introduction

Reliable data on the thickness of unconsolidated contaminated sediments at the Randle Reef dredge site in Hamilton Harbour are required for estimates of removal and processing costs and for the use of the dredging contractor in planning extraction. Existing data consist of 112 Benthos cores collected in two surveys in May and December 1996. Many of the cores contained a stiff grey clay at the base which was inferred to be the base of modern sediments and the depth of this layer in the core has been used as an estimate of contaminated-sediment thickness.

Because the thickness data from the cores were not consistent from survey to survey, a second set of measurements of thickness to refusal was made with a tripod-penetrometer developed at NWRI. This is a weighted tripod which is lowered into the sediment and settles until there is sufficient resistance to counter its submerged weight. Penetration is measured either visually with an underwater television camera or acoustically with an echo sounder. Because tripod weight, rather than momentum, determines the degree of penetration, the resultant thickness data are more consistent and reliable.

Penetrometer data have been used to map the distribution of sediment thickness across the site and to provide an estimate of the volume of soft sediment. They have also provided the control for an independent survey of sediment thickness with a Klein acoustic sub-bottom profiler.

2. Sediment-coring procedures and results

Information about the coring procedures used was obtained from the Technical Operations staff responsible for the May and December 1996 coring surveys (J. Milne/S. Smith, personal communication). In both cases the positioning was by

differential GPS with beacon corrections from the Youngstown beacon. The May 1996 cores were collected with a Benthos corer weighted with 100 kg, the December cores with the same corer but weighted with 80 kg. The objective of the coring was to collect the maximum length of core possible and the free-fall distance was varied to try to accomplish this. Appendix 1 is a summary of the core data.

Corer penetration is dependent upon the corer weight and the free-fall distance. Because corer weight for the two surveys differed by 20 kg and because no precautions were taken to standardize the free-fall distance, no consistency in the amount of penetration or recovery should be expected and none was observed.

Comparison of the May and December data was limited to the 28 cores whose sites were within 5 m of each other. The expectation was that the December cores would be longer because of the additional 20kg-weight used with the corer. In fact, there was no consistent difference in core length for the two data sets and differences between core pairs ranged from 4 to 89 cm.

Many of the cores intercepted or bottomed on a stiff clay horizon which was assumed to be the base of contaminated sediments. This horizon varied widely in both colour and texture and it was not certain that it represented a single layer. The clay was observed in 35 cores from the May survey and 44 cores from the December survey. Clay level in the May cores ranged from 26 to 188 cm and averaged 79 cm; level in the December cores ranged from 20 cm to 215 cm and averaged 81 cm. In the 13 core pairs in which the clay was observed, the difference in level ranged from 15 to 58 cm.

3.0 Acoustic Tripod Measurements

Measurements of sediment thickness to refusal were carried out at a subset of the core sites (Figure 1) with an acoustic-video tripod developed inhouse at NWRI. The tripod is

a stainless-steel frame 2.5 m high with an underwater video camera and lights on its frame and an echo-sounder transducer installed on its top plate. Weight of the system can be adjusted by adding diver weights to holders on the legs. The total submerged weight of the tripod used for this survey was 47.6 kg.

Measurements of soft-sediment thickness were made by positioning the launch Puffin over each site with differential GPS and then lowering the tripod slowly into the bottom sediment to refusal. Because visibility was extremely poor, the measurements were made acoustically rather than with an underwater video camera. The echo-sounder transducer on the top plate of the tripod measured the distance to the sediment-water interface and the difference between this distance and the tripod height was the depth to refusal. The depths were recorded on a Lowrance X-16 dry-paper recorder at a scale which permitted depth to be read reliably to the nearest ±3 cm. Measurements were taken on July 28, 1998, at the 25 sites listed in Appendix 2.

3. Tripod results

Tripod thickness ranged from 0.68 - 1.88 m and averaged 1.19 m (Appendix 2). The program Surfer was used to map the distribution of thickness and to compute an estimate of sediment volume. Figures 2 and 3 are contour and 3D maps of thickness. Thickness peaks in the southwest part of the area and the thickest sediments occur along a southwest to northeast axis. Computed sediment volume was approximately 36,000 m^3.

The tripod data are consistent but they do not necessarily define the depth of a more resistant substrate, i.e. the "clay" layer observed in the cores. The tripod sinks until it encounters sufficient resistance to support its weight. That can occur because of a well-defined layer of more resistant material or because of the gradual increase in sediment strength with depth because of decreasing water content. Standard

penetration tests and geotechnical data from associated core samples will be needed to determine the significance of the depth of refusal mapped by the tripod.

4. Sub-bottom profiler data

An acoustic survey of soft-sediment thickness at the Randle site was run by McQuest Marine Sciences Limited in December 1998 (McQuest 1999). Data were collected with a Klein 3.5 kHz sub-bottom profiler along 26 survey lines spaced at 25 m and run parallel to the Stelco dock. Soft-sediment thickness over a harder substrate was interpreted from the record characteristics and data were made available by McQuest for comparison with the tripod data.

Figures 4 and 5 are the Surfer contour and 3D maps of profiler thickness for the same area as the tripod data. Profiler values were generally lower than tripod values and the southwest to northeast zone of higher thickness was missing. Values ranged from 0.28 to 1.49 m and averaged 1.09 m. Computed volume was approximately 31,000 m^3, about 13% less than the tripod volume.

By matching site coordinates for the tripod data with those of the profiler survey, it was possible to identify 29 data pairs with a separation of 6 m or less. The profiler data were about equally distributed between values greater than and less than the tripod control. The maximum difference was 86 cm and the average absolute difference was 24 cm.

The acoustic thickness values are uncalibrated and their physical significance is unknown. They represent the apparent depth below the sediment-water interface at which record quality changes assuming that the sound velocity in the sediments is equal to that in the water column. A higher sound velocity in the sediments would result in higher thickness values more comparable with the tripod data. It could not, however,

explain the difference in the thickness patterns of the tripod and profiler data. Again standard penetrometer and geotechnical testing will be needed to confirm that the acoustic reflector represents a real interface and to calibrate it if it does.

5. Conclusions and Recommendations

Sediment cores collected at the proposed dredge site at Randle Reef showed a resistant clay or sand at some sites which was inferred to be the base of soft contaminated sediments. Because of inconsistencies in the coring method, the data on the soft-sediment thickness were too variable to be used to define the sediment base.

A survey based on an acoustic-tripod penetrometer was successful in recording depth to refusal at 25 sites within the proposed Randle dredge site in Hamilton Harbour. Precision of the measurements was ±3 cm. Recorded thickness ranged from 0.68 - 1.62 m and averaged 1.19 m. A map of thickness distribution and estimate of soft-sediment volume within the area surveyed were obtained from the program Surfer. Total sediment volume above the depth of refusal is about 36,000 m^3.

A sub-bottom profiling survey of the dredge site detected a reflector ranging in depth from 0.28 to 1.49 m and with an average depth of 1.09 m. Data were uncalibrated and the significance or physical reality of the reflector is not known. Computed sediment volume from the raw data was about 31,000 m^3, about 13% less than the tripod volume, and thickness pattern differed from the tripod results by as much as 86 cm.

The tripod data represent a consistent depth of refusal but it is not certain that this is a measure of the depth of the resistant sediment recovered in the cores. The physical significance of the acoustic profiler data is not known. In both cases, standard geotechnical testing and penetrometer data are needed to determine whether a well-

defined base of soft sediment exists and how well the tripod or profiler data measure its level.

Standard penetrometer and geotechnical tests should take place at a subset of the tripod sites so that they can be used to assess and calibrate the tripod and acoustic data. Sites 1, 6, 8, 11, 13, 18, 21 and 23 (circled in Figure 1) are recommended for further testing because they provide good areal coverage of the site and of the range of tripod depth.

6. Acknowledgements

NWRI's Technical Operations Section provided the launch and staff support for the tripod measurements, and B. Trapp of NWRI's Aquatic Ecosystem Restoration Branch (AERB) assisted in the surveys. D. Gilroy of Technical Operations helped with the reduction of the data and the graphics. The sub-bottom profiler data were made available by McQuest Marine Services. A. Zeman of AERB reviewed the report and made suggestions for its improvement. The tripod survey and the development of the tripod penetrometer as a sediment mapping tool were funded by Environment Canada's Great Lakes 2000 Cleanup Fund.

7. References cited

McQuest Marine Services 1998. Geophysical survey report, Randle Reef, Hamilton Harbour, December 1998. Contract report for Environment Canada.

Figures

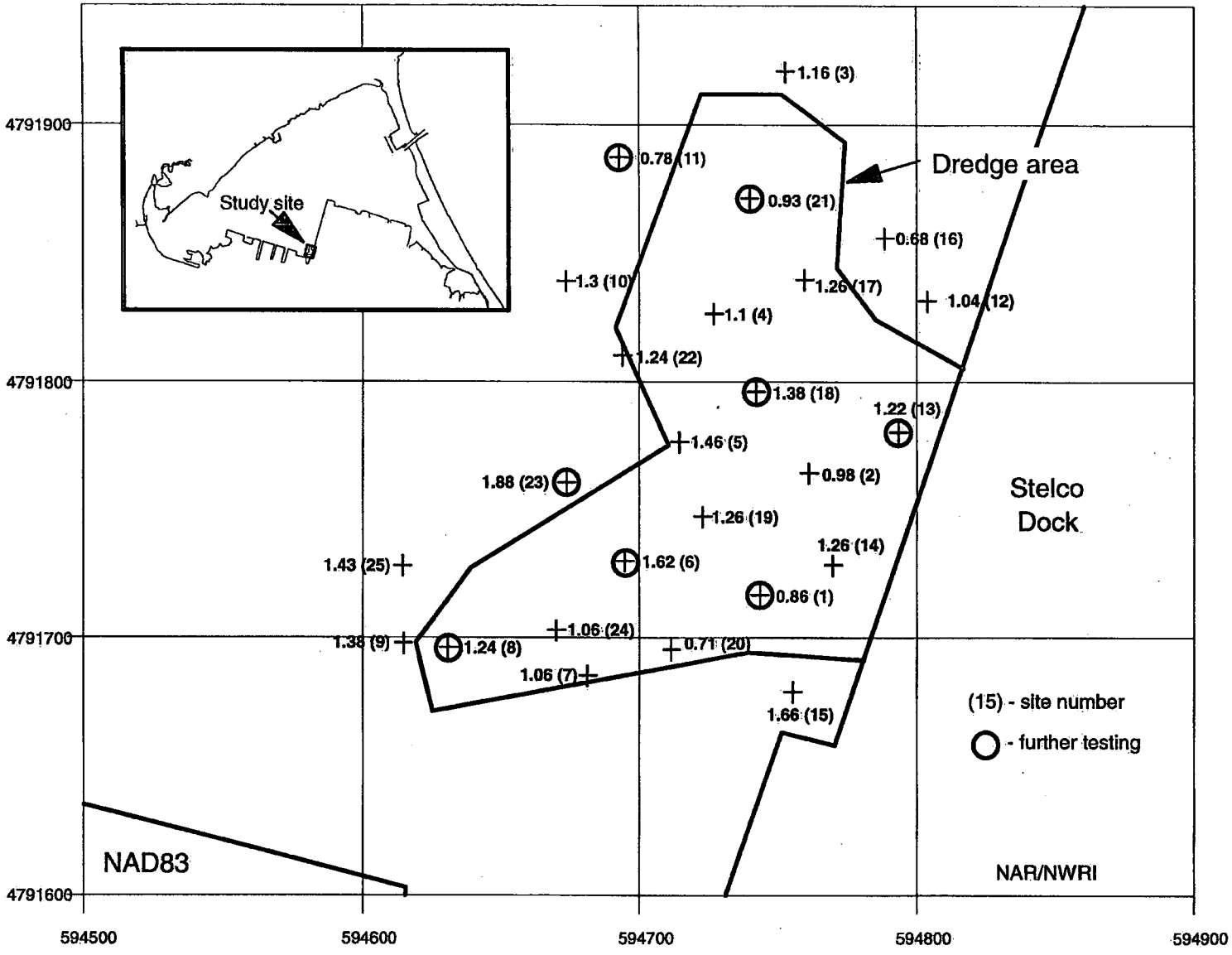

Figure 1. Tripod sites and thickness (m)

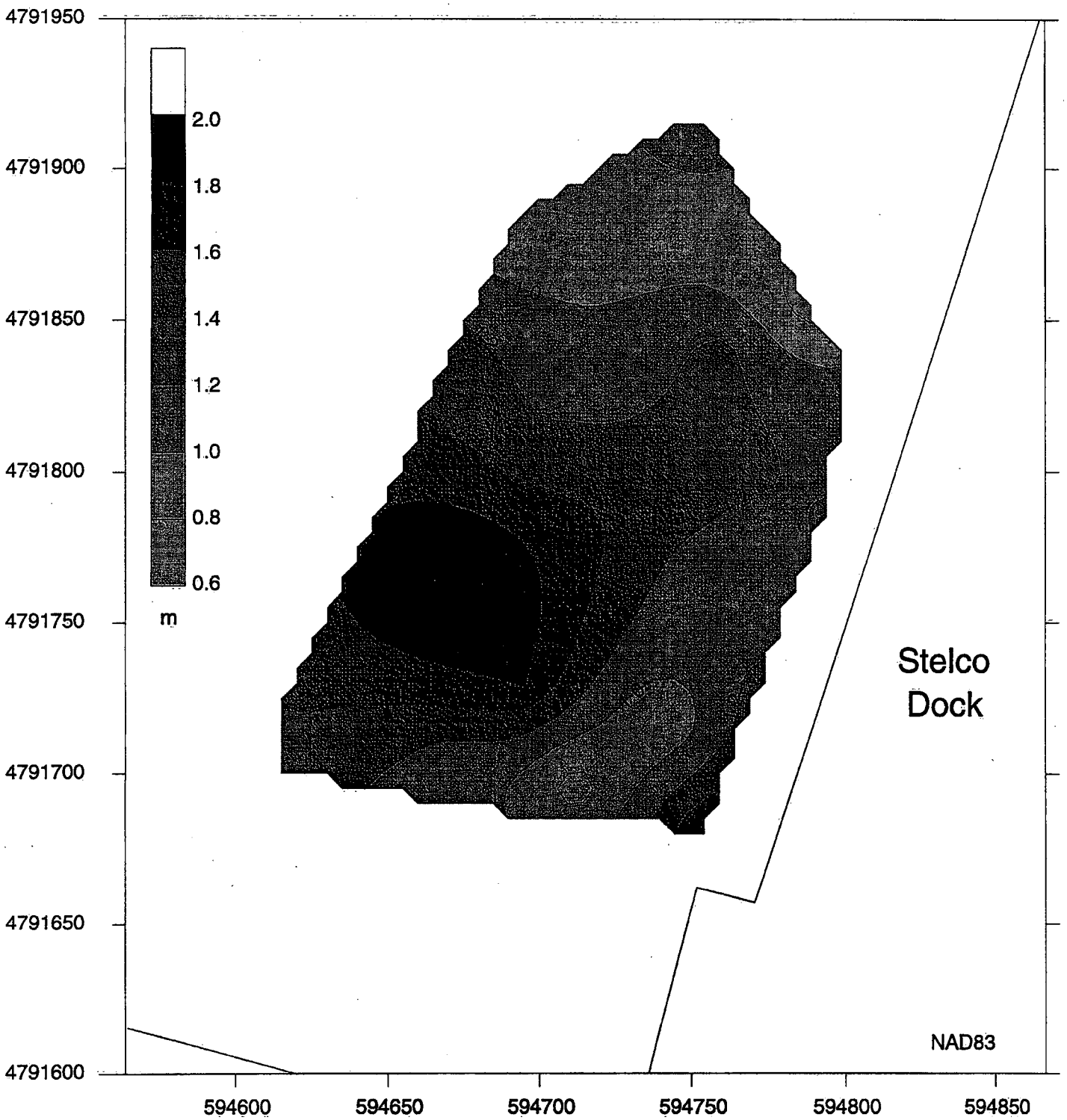

Figure 2. Tripod thickness contours, m

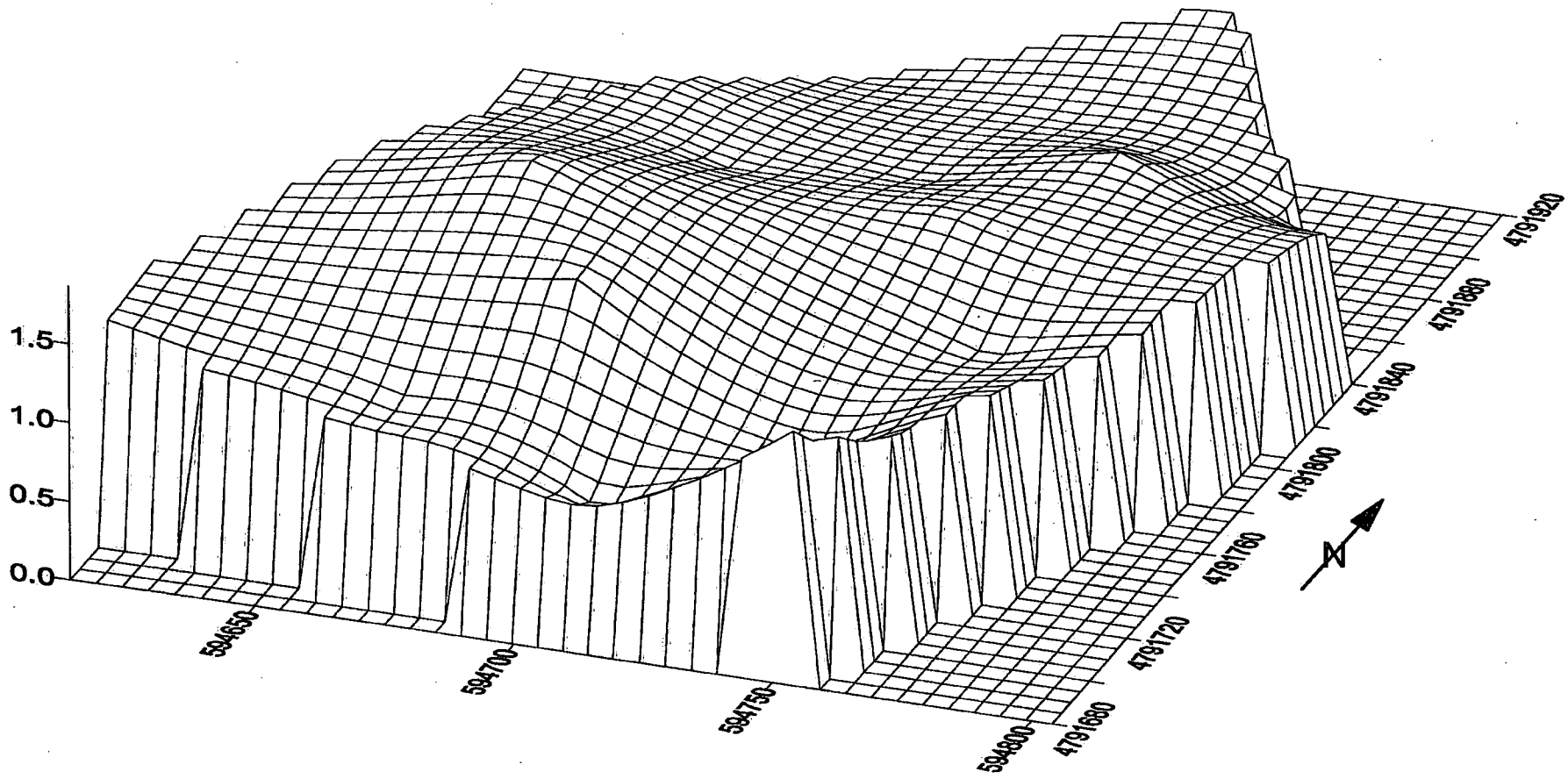

Figure 3. Tripod 3D thickness, m

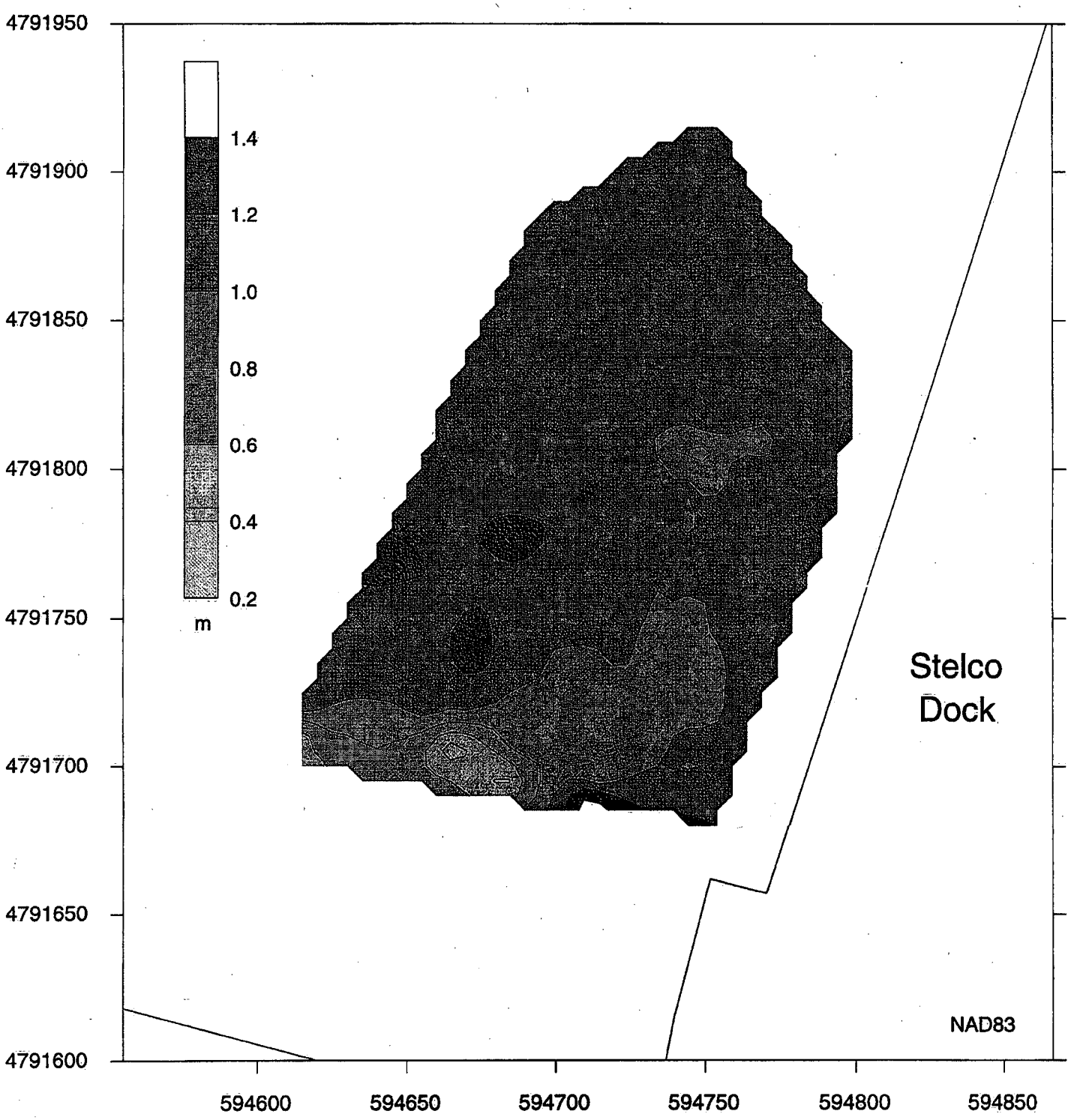

Figure 5. Profiler thickness contours, m

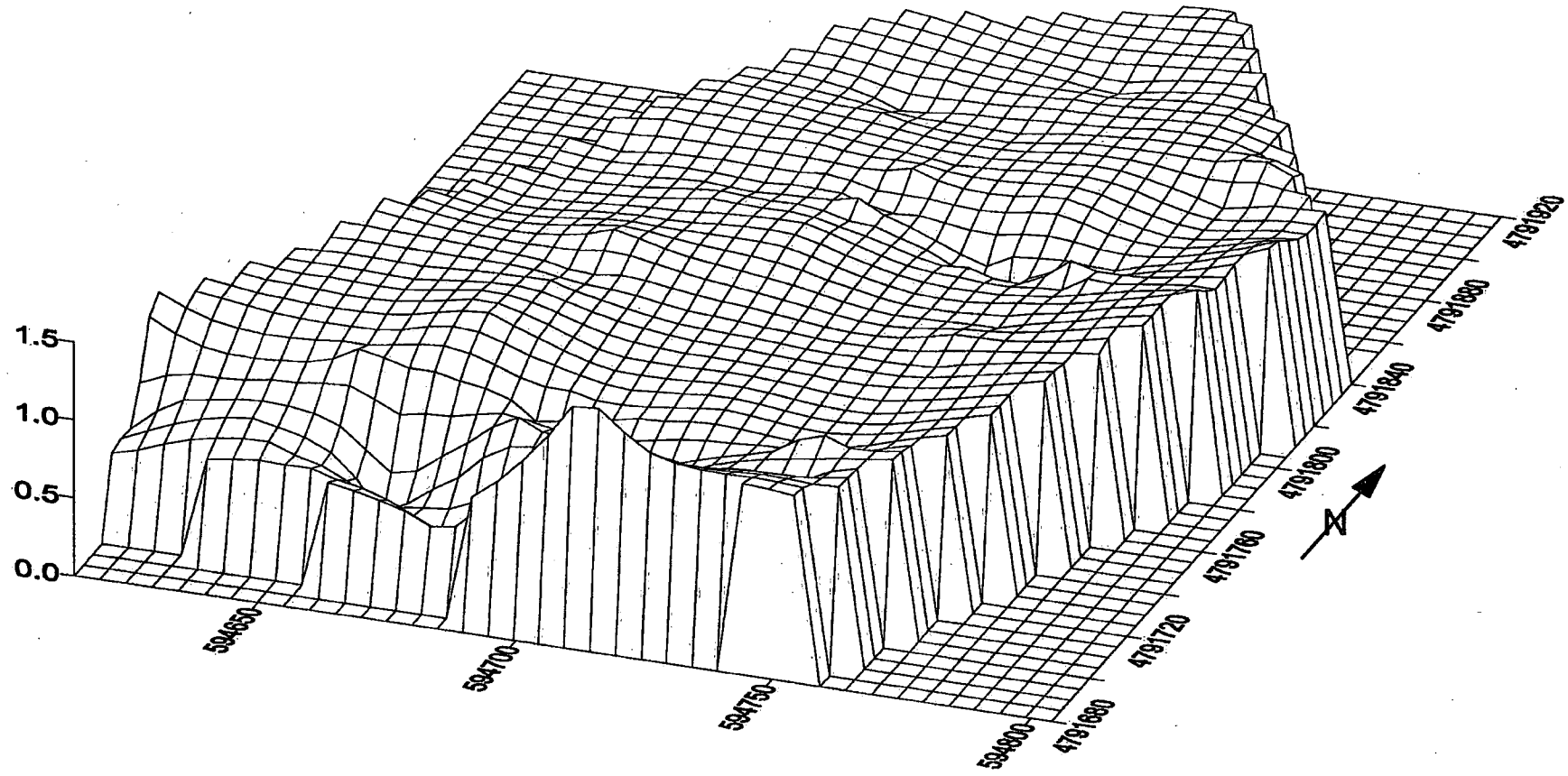

Figure 5. Profiler 3D thickness, m

Appendix 1: Core Data

Site	Easting	Northing	Length, m	Depth to		"Clay" description
May/96	NAD83			"clay"		
1	594654	4791507	0.90	0.65?		reddish brown, clay?
2	594669	4791556	0.66	0.66		
3	594714	4791622	1.73	1.73+		
4	594729	4791670	2.05	1.10?		red brown, clay?
5	594743	4791717	1.00	0.77		grey
6	594757	4791766	1.10	1.10+		
7	594771	4791813	1.13	0.65 or 0.90		reddish or light grey
8	594752	4791922	0.80	0.64		red brown
9	594723	4791827	0.64	0.30 or 0.50		red brown or light brown
10	594708	4791779	1.88	1.88		
13	594632	4791696	0.86	0.63		light grey
16	594674	4791839	0.99	0.87		red brown
17	594689	4791887	0.50	0.50+		
18	594655	4791949	0.69	0.5		grey sandy
19	594626	4791852	0.52	0.34		red brown
20	594612	4791805	0.35	0.26		red brown
21	594598	4791756	1.10	0.98		
22	594583	4791708	0.58	?		
23	594569	4791660	1.37	1.3		
24	594520	4791673	1.35	1.2		grey brown
25	594535	4791721	1.13	0.94		grey
26	594549	4791769	1.37	1.28		grey
27	594564	4791816	0.77	0.6		brown and grey
28	594592	4791912	0.70	0.59		red-brown
29	594559	4791973	0.43	0.31		red grey
30	594529	4791877	0.54	0.47		red brown
31	594515	4791829	0.80	0.7		grey
32	594501	4791781	0.69	0.52		grey
33	594487	4791733	0.84	0.72		grey
34	594473	4791686	1.10	0.98		grey
35	594438	4791746	0.79	0.63		grey
37	594480	4791890	0.84	0.6		red grey
38	594433	4791902	0.78	0.5		brown
39	594376	4791710	1.05	0.89		grey
40	594404	4791807	0.94	0.7		grey
41	594666	4791634	1.70	1.26		grey

Site	Easting	Northing	Length, m	Depth to	"Clay" description
Dec/96	NAD83			"clay"	
1	594648	4791503	1.20	0.60?	grey-green organic
2	594668	4791558	1.20	0.7	sand
3	594699	4791622	1.48	1.20?	hard sand
4	594726	4791669	2.20		
5	594742	4791718	1.00	0.60?	red-brown sand
6	594756	4791765	1.40		
7	594778	4791811	0.90	0.35	sand
9	594723	4791826	0.45	0.45	
10	594709	4791778	1.45		
11	594694	4791731	2.05	1.9	
12	594678	4791685	1.29	1.3	
13	594611	4791697	2.15	2.15	
14	594646	4791743	1.10		
15	594660	4791791	1.00	0.60?	brown grit/sandy clay/green organic
16	594674	4791838	0.75	0.75	
19	594627	4791853	0.40	0.32	sand
21	594598	4791756	1.06	0.4	grey-green grit
22	594581	4791708	1.20	0.95?	sand, clay layer at 1.2 m
23	594588	4791660	1.40	1.00?	coarse grit
25	594532	4791720	0.90		
26	594548	4791770	0.75	0.75	
27	594562	4791815	0.60	0.40?	sandy clay
30	594528	4791876	0.60		
31	594511	4791827	0.87		
32	594596	4791779	0.90		
32A	594496	4791779	0.89		
33	594489	4791733	0.70	0.7	
34	594474	4791686	0.60	0.70?	
35	594435	4791744	0.96		
36	594605	4791650	1.50	1.32	clay plug, 1.32-1.4 m, soft black below
39	594375	4791711	0.90		stiffer, sandy?
40	594402	4791810	0.50		
41	594663	4791638	1.37	1.37	
42	594805	4791836	0.80	0.3	sand
43	594788	4791780	0.80		
44	594772	4791730	1.60	?	base of record sheet missing
45	594757	4791683	1.40	1.20?	sandy
46	594787	4791857	0.74	0.5	
48	594754	4791841	0.70	0.7	hard clay
49	594740	4791795	1.70	1.7	hard sand
50	594723	4791747	1.32	1.32	stiff black

Site	Easting	Northing	Length, m	Depth to		"Clay" description
Dec/96	NAD83			"clay"		
51	594708	4791699	0.72			
52	594694	4791653	1.75	1		hard sand (how penetrated?)
53	594680	4791605	1.40			
54	594662	4791532	0.32			
55	594734	4791871	0.55	0.55		
56	594645	4791590	0.80	?		base of record sheet missing
58	594690	4791809	1.20	0.60?		grey-green clay, shells, sandy clay at 80?
59	594675	4791762	1.20	?		base of record sheet missing
60	594662	4791710	0.65	0.65		
61	594648	4791668	0.80	0.60?		sandy
63	594641	4791821	0.95			
64	594626	4791768	1.10			
65	594612	4791727	1.00	1		
66	594594	4791681	1.40	1.4		grey-green clay
67	594593	4791836	0.59			
68	594575	4791786	0.60			
69	594565	4791738	1.20	1		
70	594547	4791703	0.90			
72	594575	4791869	0.20	0.25?		
73	594548	4791845	0.58	0.4		
74	594531	4791797	0.55	0.55		
75	594515	4791748	0.90	0.8		
76	594500	4791700	0.95	0.95		grey
78	594494	4791857	0.59			
79	594480	4791810	0.60			
80	594465	4791765	0.77			
81	594450	4791715	0.90	0.45		
82	594436	4791669	0.42			
83	594458	4791840	0.67			
85	594417	4791704	1.07	0.5		
86	594428	4791822	0.42			
87	594415	4791775	0.89			
88	594401	4791730	0.40	0.2		
90	594391	4791759	0.50	0.7		

Appendix 2: Tripod Data

Tripod Site	UTM, NAD83		Tripod thickness, m	Closest core
	Easting	Northing		
1	594743.8	4791716.8	0.86	M5
2	594761.5	4791764.3	0.98	M6
3	594753.2	4791921.5	1.16	M8
4	594727.3	4791826.4	1.10	D9
5	594714.5	4791776.6	1.46	D10
6	594695.0	4791730.0	1.62	D11
7	594681.4	4791685.4	1.06	D12
8	594631.5	4791696.0	1.24	M13
9	594614.9	4791697.9	1.38	D13
10	594673.7	4791839.2	1.30	M16
11	594692.8	4791887.5	0.78	M17
12	594804.1	4791831.6	1.04	D42
13	594793.6	4791780.5	1.22	D43
14	594770.2	4791728.5	1.26	D44
15	594755.8	4791679.1	1.66	D45
16	594788.9	4791855.8	0.68	D46
17	594759.9	4791839.8	1.26	D48
18	594742.4	4791796.2	1.38	D49
19	594723.1	4791747.3	1.26	D50
20	594711.7	4791695.4	0.71	D51
21	594740.2	4791871.4	0.93	D55
22	594694.2	4791810.4	1.24	D58
23	594674.0	4791761.0	1.88	D59
24	594670.3	4791702.9	1.06	D60
25	594614.7	4791728.1	1.43	D65

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