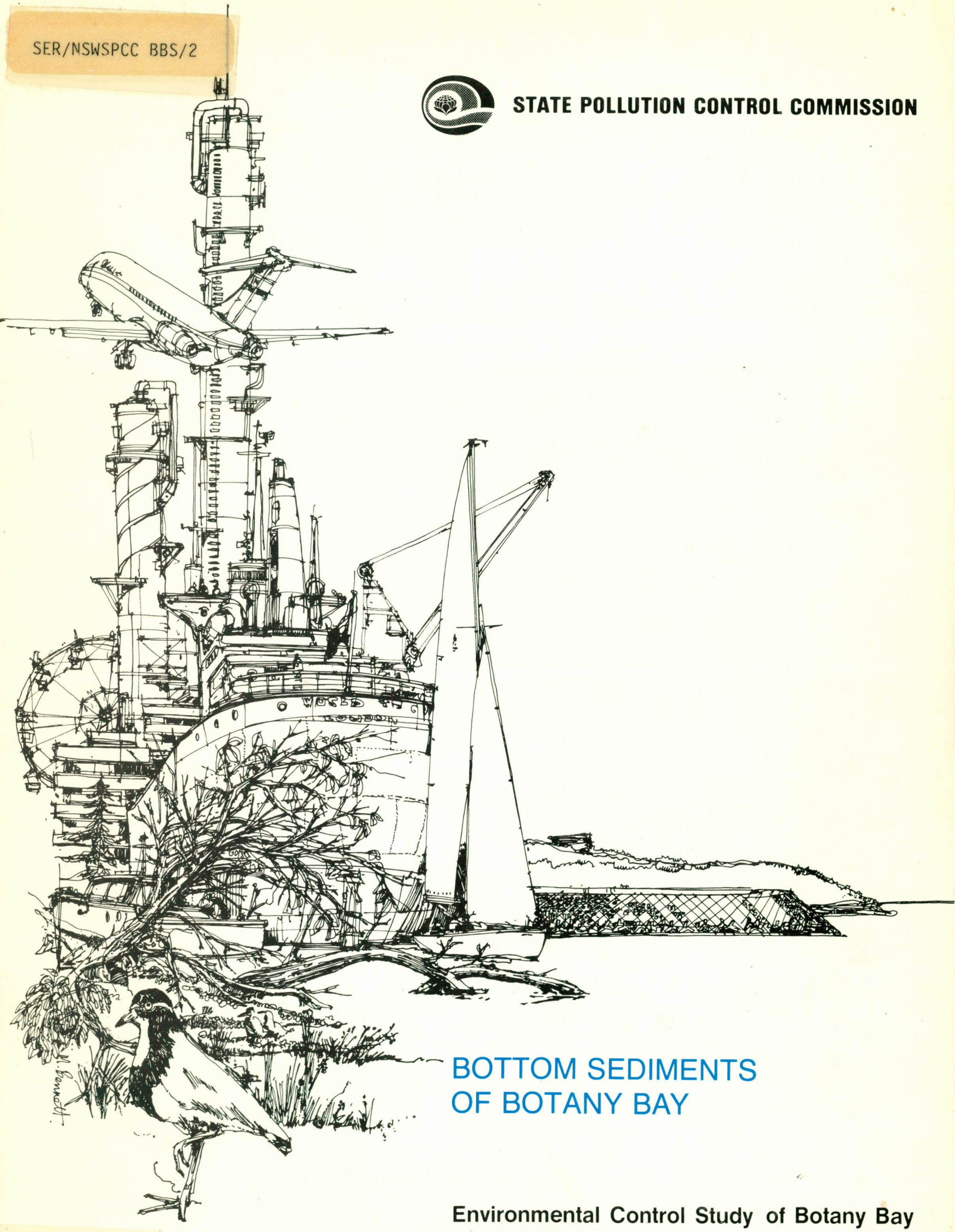
STATE POLLUTION CONTROL COMMISSION



BOTTOM SEDIMENTS OF BOTANY BAY

Environmental Control Study of Botany Bay

Issued under the authority of
THE HON. PAUL LANDA, LL.B., M.L.C.,
Minister for Planning and Environment

STATE POLLUTION CONTROL COMMISSION

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PREFACE

Arrangements were made in 1975 for the State Pollution Control Commission to carry out an environmental control study of Botany Bay and its tributaries. The study, which began in January 1976, developed from initiatives of the Maritime Services Board of New South Wales and the Board has contributed substantially to it.

The study primarily is of water and water-associated environments, so it covers land-based activities within the catchment only to the extent that these have an impact specifically on the water environment.

The State Pollution Control Commission is responsible for management of the study and for making recommendations developed from it, with advice from its Technical Advisory Committee. Throughout the study period, however, the Commission has been assisted by willing cooperation and communication with many other departments and authorities.

Particular elements of the study are being carried out by State Government instrumentalities, universities and consultants. Major elements are supported by technical consultative committees.

Investigations have aimed first to identify and describe the water-associated resources and the activities responsible for environmental change. The effects of activities on important resources can then be assessed and appropriate control measures indicated.

These investigations have led to a series of technical papers on specific aspects, of which this paper is one. Other papers in the series are listed below.

One of the principal objectives of the study is to recommend to the Government a comprehensive water-resource management plan for the Bay and its tributaries. These technical papers will contribute to that objective.

This report has been prepared within the Commission's study team.

BOTANY BAY STUDY SERIES

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BBS 1 *The Study and the Region
Tidal Hydraulics of Botany Bay
Wave Action in Botany Bay
Hydrology and Flooding in Georges River
Salinity and Water Movement in Georges River

BBS 2 *Bottom Sediments of Botany Bay
Erosion Potential in upper-Georges River

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Wetlands of the Tidal Waters
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Benthic Communities in Botany Bay
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Recreational Resources of the Tidal Waters
Recreational Use in Botany Bay
Recreational Angling
Commercial Fishing and Oyster Farming
Port Development and Operations

(* Issued)

ABSTRACT

Bottom sediments in Botany Bay are predominantly marine sands. However, substantial changes in sediment type have occurred in the northern region of the bay since 1970 as a result of port and airport development. Large areas (600 ha) which were formerly sand are now silts and silty sands. The increase in fine sediments is particularly marked in the dredged holes protected by the port and airport revetments.

These changes are not the result of exposure by dredging of silt and clay lenses within the underlying sediments, but probably have been brought about by :

- Deposition of fine material discharged during dredging and reclamation

- Increased deposition of suspended matter from other sources resulting from changes in tidal circulation following port and airport development.

The silt content of sediments in the Port Botany harbour area is expected to increase further. Water turbidity, in turn, will in general be higher as a result of resuspension of fine material by shipping movements.

CONTENTS

FIGURES

1 INTRODUCTION

Large areas of the bed of the northern part of Botany Bay have been disturbed by the extension of the Kingsford-Smith Airport and construction of port facilities. In all, 550 ha have been dredged and 140 ha reclaimed, together representing about 15 per cent of the bay area (Figure 1).

These large-scale developments have caused substantial changes in the hydraulic character of the bay (SPCC, in press). The most obvious effect of the changed patterns of water movement has been on foreshore erosion (Maritime Services Board of New South Wales 1976). Changes can also be expected in patterns of sediment transport and deposition, possibly bringing about long-term changes in the character of bed sediments.

Goodwin (1970) reported that the main part of the Botany Bay bed was sand. At this time, only about 200 ha had been dredged and the first extension of the airport built. Sediment samples from the dredged holes were generally more silty than surrounding areas. Goodwin attributed this to exposure by dredging of silt and clay lenses within the sediment profile.

Dredging and reclamation for the Port Botany development has occurred since 1970. This report :

- Defines the present physical character of surface sediments in Botany Bay
- Documents recent changes in sediment composition
- Predicts the effects of present port development on sediments.

Results of an associated survey of bottom sediments in Georges and Woronora Rivers are presented in Appendix B. The effects of dredging on benthic communities in Botany Bay will be reported separately.

2 METHODS

A total of 355 sediment samples were collected from Botany Bay and analysed for particle size. Sample sites are presented in Appendix A, Figure 1.

Transects were run by boat between charted features (navigation beacons etc) or along theodolite bearings. Sample sites were fixed along these transects by cross bearing to prominent land marks, or calculated from lapsed time at constant boat engine speed. Where the station was near the edge of a dredged hole, depth was measured as a check on position.

Samples were collected using a Kahlisco spring-activated grab which yielded approximately 150 g of surface sediments. Each sample was washed into a plastic bag, labelled and taken to the laboratory. Samples were than transferred to beakers and suspended solids allowed to settle overnight. The supernatant water was decanted and, after a second period of settling, the remaining water removed by siphon.

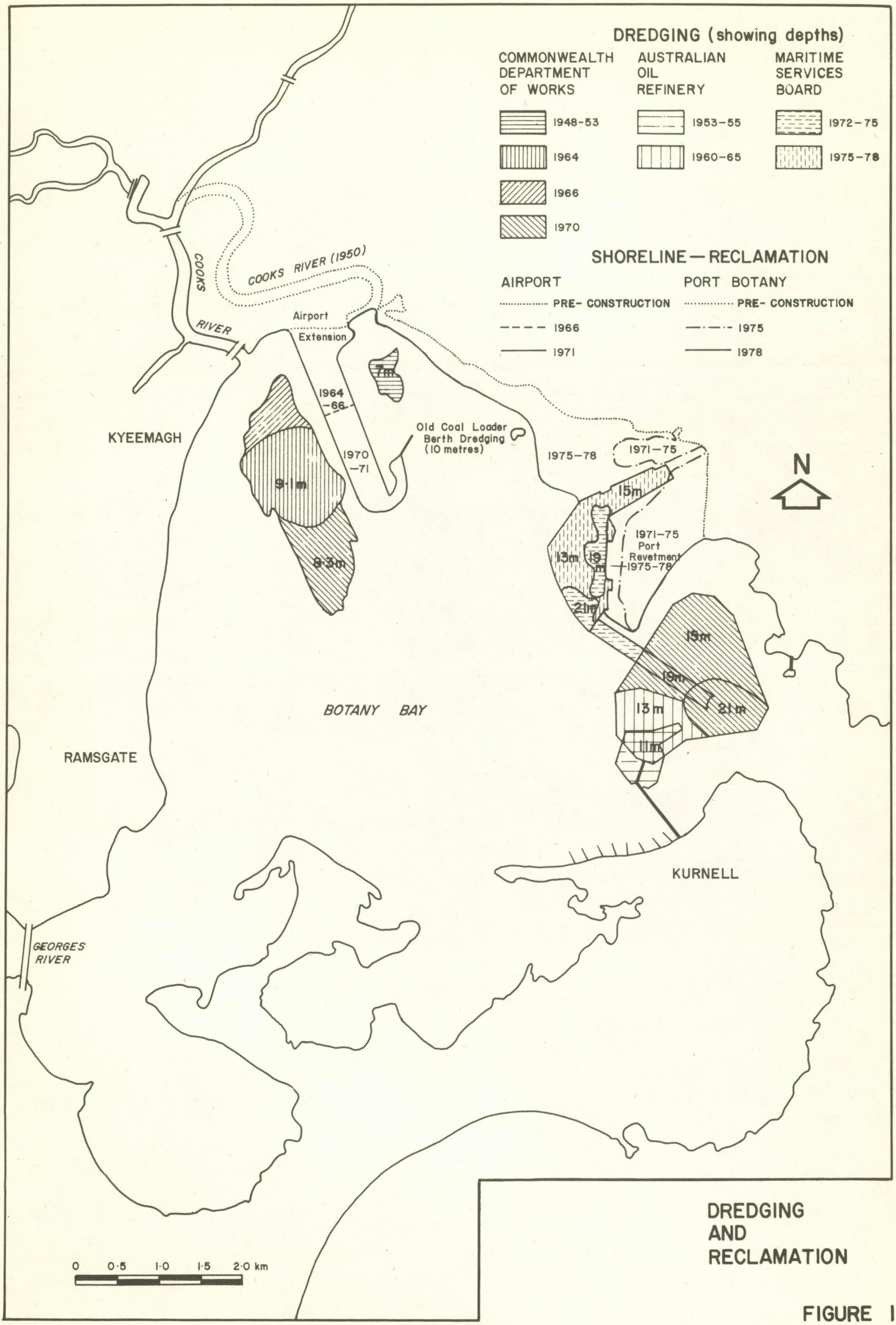
Each sediment sample was mixed thoroughly and an aliquot of approximately 40 mL placed in a volumetric test tube. Sufficient water was then added so that the sample could be stirred to remove occluded air, and the level of the settled sediment adjusted to exactly 40 mL.

Each sample was washed through banked 2 mm and 63 micron aperture sieves until the wash water was clear. The retained material on each sieve was returned to the volumetric test tube and the volume of each fraction, after settling, calculated as a percentage of the original sample (Roy, personal communication).

The results are expressed as percentages by volume, of the following :

- Silt-clay - material passing through the 63 micron sieve
- Sand - material passing through the 2 mm sieve but retained by the 63 micron
- Gravel - material retained by the 2 mm sieve.

In addition to the above sediment samples, three 1 m cores were taken from the dredged hole west of the airport extension (the Kyeemagh hole), to determine the depth of fine material present in the hole. These samples were collected by divers using a



DREDGING AND RECLAMATION

FIGURE 1

tapered box-corer with sliding side (Crawford et al 1976). Each sediment core was partitioned at ten centimetre intervals and the sub-samples analysed for particle size as described above.

3 RESULTS

3.1 Sediments of Botany Bay

The present distribution of sediments in Botany Bay is mapped in Figure 2. The particle size data upon which this map is based are tabulated in Appendix A, Table 1.

Sediments in the central and southern areas of Botany Bay are predominantly clean sands. The only significant deposits of fine material within these areas occur as a "finger" of mud extending eastwards from Ramsgate, and in the southern bays. Isolated pockets of fine material occur in the AOR tanker berth at Kurnell, in the central section of the dredged entrance channel, and near the Single Buoy Mooring. Shell debris is common in samples at the entrance of the Bay.

Quibray and Weeney Bays have large pockets of mud (silt plus clay) within otherwise sandy sediments. In contrast, the sediments of Woolooware Bay are uniformly very silty (50 - 70 per cent silt-clay). The Georges River channel between Captain Cooks Bridge and Dolls Point is also silty with substantial amounts of shell debris in some areas.

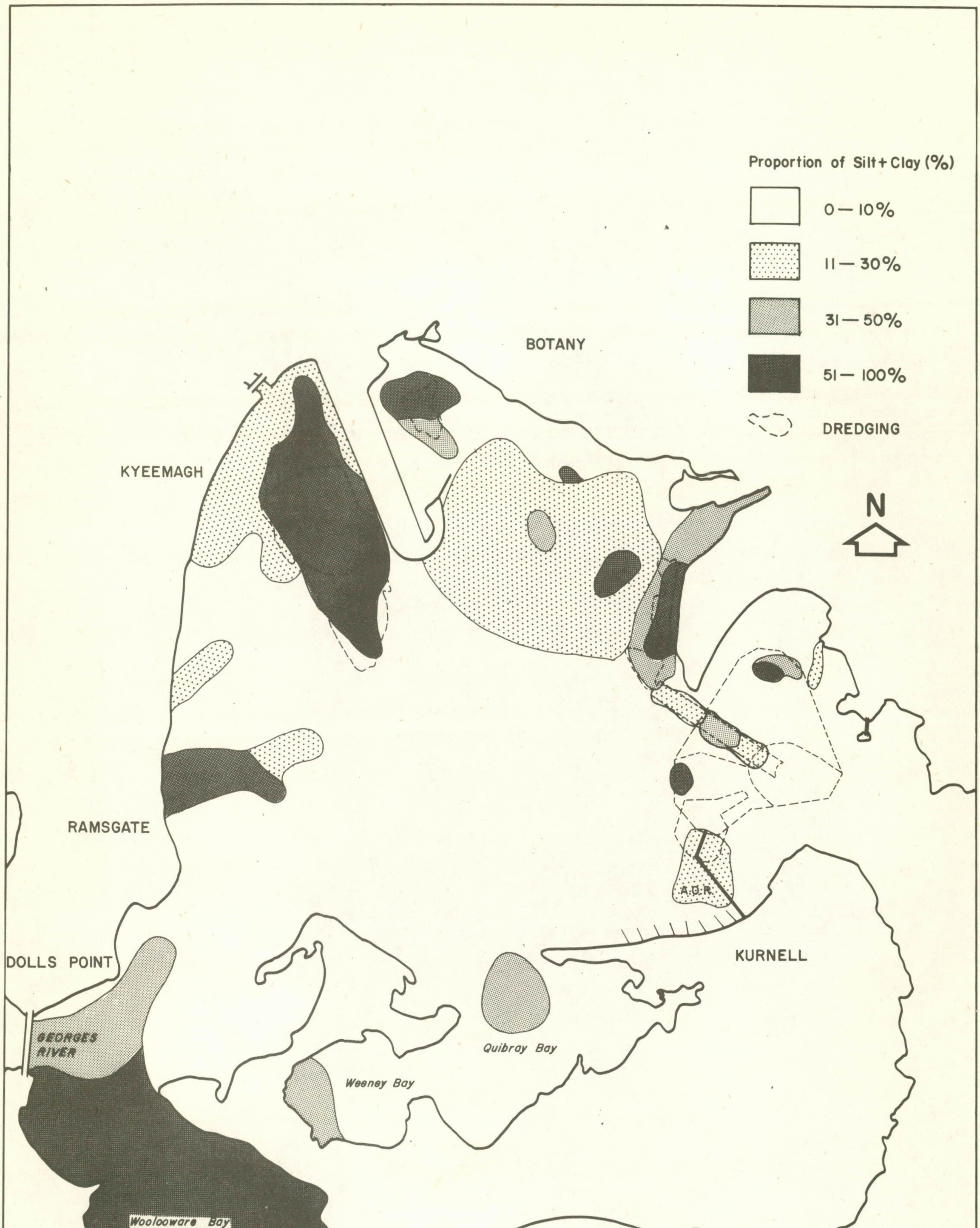
The northern part of Botany Bay presents a complex sediment pattern, with large areas of silty and very silty sediments.

The Kyeemagh hole (about 200 ha) is virtually defined by the occurrence of very silty sediments (Figure 2). Sediment cores indicate that fine material extends to a depth of approximately 60 cm in the central and northern sections of this hole, and approximately 30 cm in the southern section (Figure 3). Assuming an average depth of 50 cm, the volume of the fine material in the hole is about 1×10^6 m^3. The area to the north and west of the Kyeemagh hole (near the mouth of Cooks River) is predominantly silty sands. Sediments to the south of the hole are clean sands.

The extensive area between the port revetment and airport extension is broadly characterized by silty sand. Within this region are two major areas of high silt-clay content: the dredged hole immediately west of the port revetment, and the dredged hole at the old mouth of Cooks River. Smaller pockets of fine material occur in the old coal loading berth off Banksmeadow, and in the central region of the port. A band of clean sands runs along the northern shoreline.

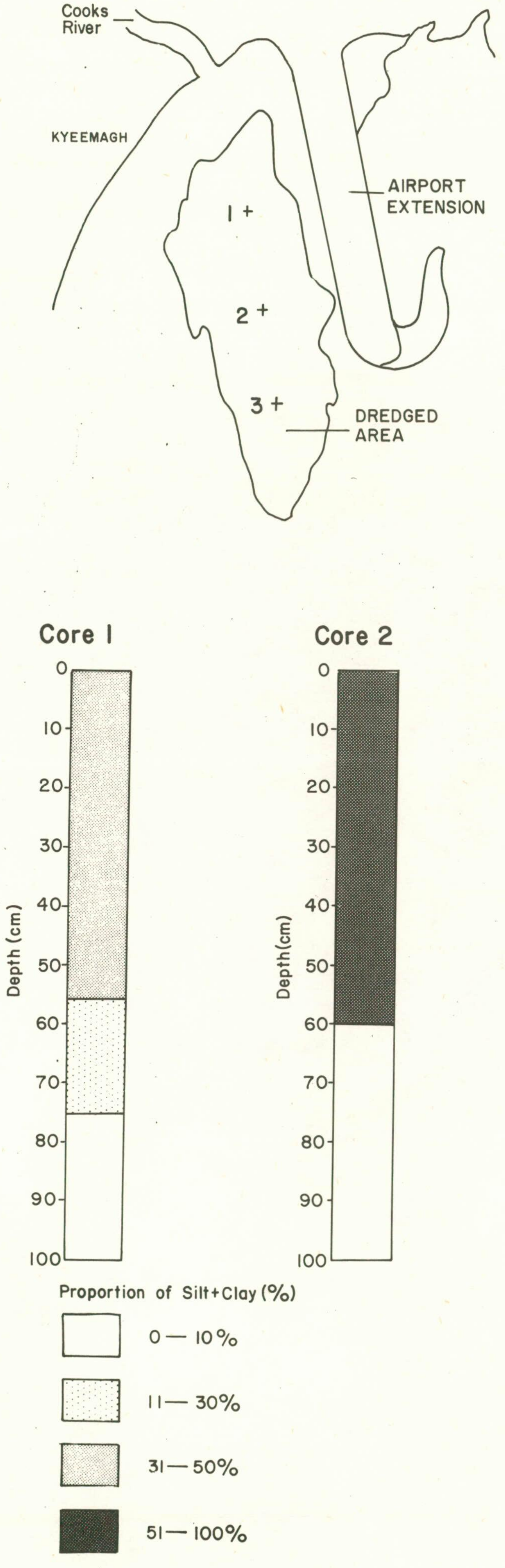
3.2 Areas of Change

The results of Goodwin's (1970) sediment survey of Botany Bay are presented in Figure 4. Comparison of this map with Figure 2 indicates that there has been a substantial increase in fine material in the northern region of Botany Bay since 1970.



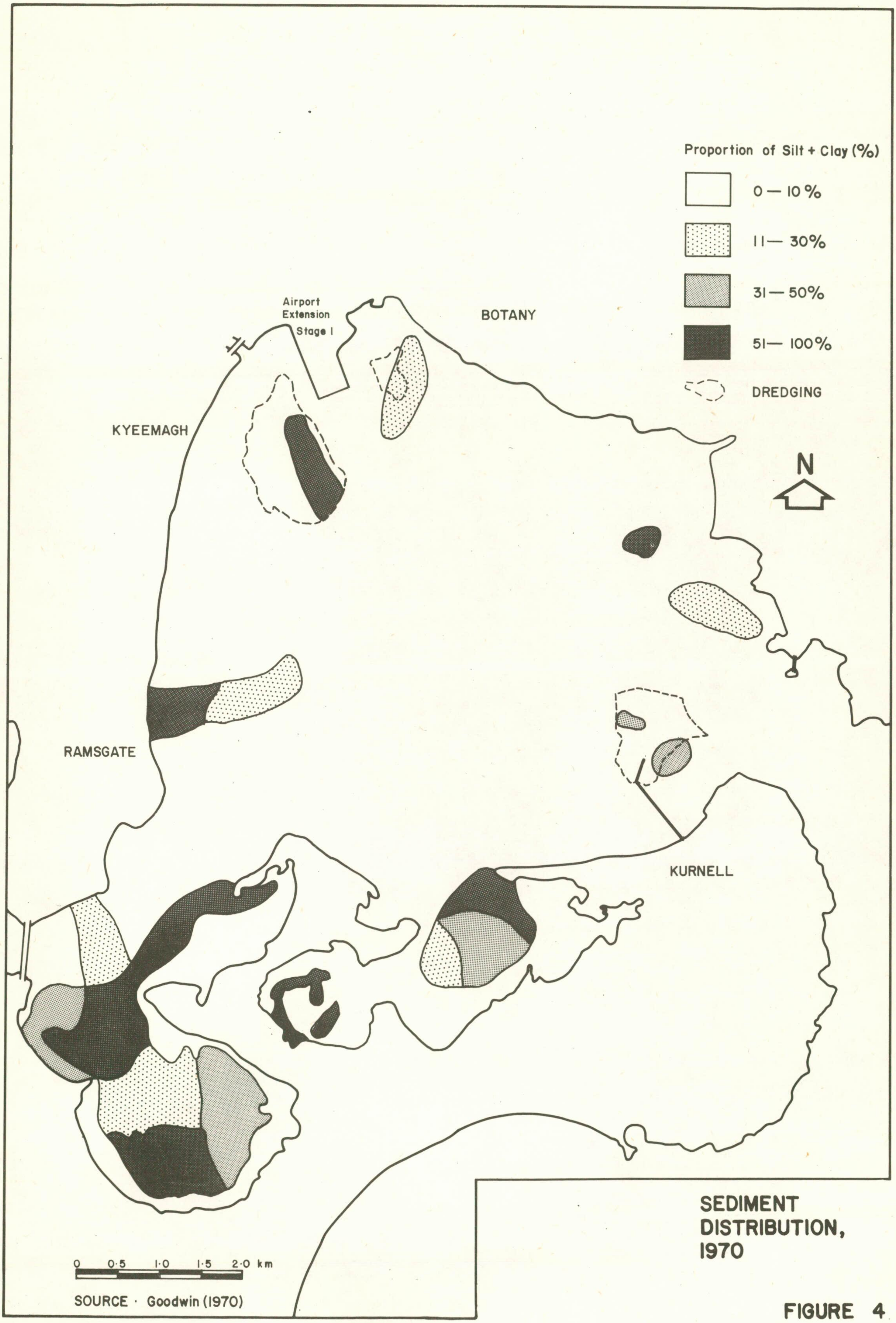
SEDIMENT DISTRIBUTION, 1976

FIGURE 2



SEDIMENT PROFILES, Kyeemagh Hole

FIGURE 3



SEDIMENT DISTRIBUTION, 1970

FIGURE 4

The area between the port and airport extensions, which in 1970 was clean sand, is now predominantly silty sands, with very silty sediments in the dredged holes. This change in sediment type affects an area of approximately 500 ha.

To the west of the airport extension, the zone of silty sediments has also increased, from about 100 ha in 1970 to 200 ha. This increase has apparently occurred in association with the extension of dredging in this area.

3.3 Sediments Exposed by Dredging

The Maritime Services Board of New South Wales and Commonwealth Department of Works drilled sediment bores in the northern part of Botany Bay as a prelude to the dredging associated with the port and airport development (Maritime Services Board of New South Wales 1968, 1969, 1975; Commonwealth of Australia Department of Works 1968). Qualitative descriptions of the sediment profiles were recorded in the borelogs, together with some quantitative analyses of particle size. Where possible, these data have been correlated with post-dredging depths in order to determine the character of sediments exposed by dredging (Appendix A, Figure 2 and Tables 2 to 4).

Determination of exposed sediments was only possible in some sections of the dredged holes. Records of depth were not kept during dredging so correlation was restricted to those areas for which post-dredging hydrographic data were available (Maritime Services Board of New South Wales 1971, 1973a, 1973b, 1974). Similarly, poor correlation between the qualitative descriptions and quantitative analyses of sediment samples recorded in the borelogs meant that only those borelogs with quantitative data for the stratum intersected by dredging could be used.

In most cases, the bore profiles indicated a thick layer of sand overlying discontinuous beds of peat and clay. The sediments exposed by dredging were mainly clean sands except for the area immediately west of the port revetment, where a layer of 40 per cent silt-clay content was exposed. In all cases however, the surface sediments in dredged holes recorded in the present survey contain greater amounts of fine material than expected from the borelog data.

This difference is particularly marked in the southern section of the Kyeemagh hole, where present sediments contain approximately 60 per cent silt-clay content compared with 0-16 per cent recorded in the borelogs.

4 DISCUSSION

4.1 Causes of Recent Change

Sediments in the central and southern areas of Botany Bay have remained essentially unchanged since Goodwin's (1970) survey, and are still characterized by clean sand, although some parts of southern embayments are siltier. The distribution of fine material in this region appears to be stable and Roy (personal communication 1977) suggests that these areas reflect infilling of relict channels of Georges River.

The present survey has identified a major increase in fine material in the northern region of the Bay since 1970. There are four possible sources of this material :

- Direct exposure by dredging of fine material within the sediment profile
- Migration of fine material exposed on the side walls of the dredged holes
- Deposition of suspended matter released during dredging and reclamation works within the bay
- Deposition of suspended matter entering the bay from Georges and Cooks Rivers, and from urban runoff.

Borelogs indicate that dredging would have exposed isolated pockets of fine material, but these are insufficient to account for the distribution and quantity of fine material recorded in the present survey.

Examination of bed profiles of dredged areas by echo-sounding indicates that side slopes vary between 1 in 4 and 1 in 10 and that there is no evidence of major slumping. It is unlikely, therefore, that migration of fine material exposed on the slopes has contributed to the bottom sediments.

It is concluded that the increase in fine sediments in the northern part of Botany Bay has been primarily due to deposition of suspended matter.

It is difficult to estimate the relative contribution of fine material from dredging transport waters and from deposition of fine fluvial sediment brought into the area since dredging. From the borelogs, it is known that a substantial amount of fine material was dredged with the sands. Both the airport and port revetments were constructed by pumping the dredged material over a core of quarried rock and, as settling ponds were not used, much of the fine material in the dredging transport waters was inevitably returned to the Bay. (Suspended solids loads of 30 000 mg/L have been recorded near the discharge area from suction dredging for port reclamation; State Pollution Control Commission, unpublished data.)

May (1973) reported that fine material discharged from a hydraulic dredge rapidly forms a distinct bottom-flowing layer of mud, which moves primarily according to gravity rather than currents. It therefore seems likely that much of the fine material released during dredging and reclamation in Botany Bay flowed back into the dredge cuts.

Within the bay, the low-energy environments created by dredging would also have promoted the deposition of suspended matter in the holes. This effect is of continuing significance, particularly in the Kyeemagh hole which is almost certainly functioning as a sediment trap for suspended matter carried by Cooks River. This suggestion is consistent with the observed bulk of fine material in this hole (approximately $1 \times 10^6 m^3$) and the concentration of very high silt-clay contents in its north-eastern section.

Changes in the overall hydraulic character of Botany Bay associated with the port and airport development have also made the northern region of Botany Bay more conducive to the settlement of suspended matter. Configuration dredging at the bay entrance and construction of the port and airport revetments have reduced wave energy in the northern region of the bay, and altered pattern of tidal currents. Results from Maritime Services Board mathematical modelling indicate that the embayments now formed by the port and airport revetments are essentially by-passed by present tidal currents. Simulation of tidal flows using a physical model of the bay (SPCC, in press) supports the mathematical model and also indicates that cells of water movement are set up within these embayments (Figure 5). It is in such embayments, which have little contact with the main estuarine circulation, that maximum siltation occurs (Rochford 1951). Suspended matter entering Botany Bay is consequently more likely to settle in these low energy environments instead of being flushed to sea.

4.2 Predicted Changes

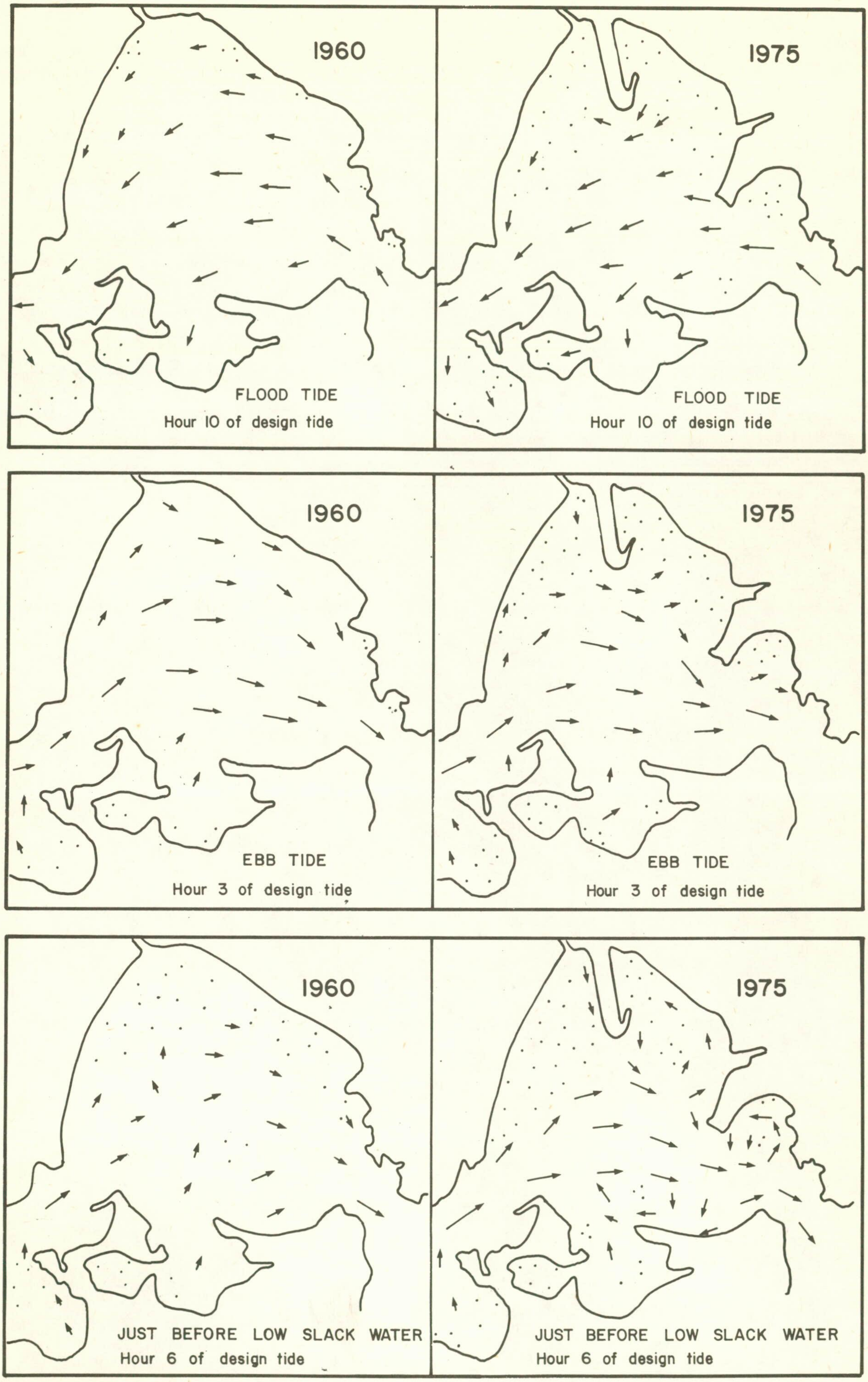
Dredging and reclamation for the construction of container berths and other port facilities associated with Port Botany are presently underway.

Although borelog profiles for the port area indicate that sediments at the depths to be dredged will be predominantly sands (Appendix B, Table 3), it is expected that sediments in this area will become progressively more silty due to deposition. Water movement in this region has already been reduced as a result of port development, and on completion of Port Botany, the quiet, deepwater berthing and turning basins will be even more conducive to the deposition of suspended matter.

Future shipping movements in Port Botany will become an important factor influencing water turbidity. At present, ships in Botany Bay move over predominantly sandy areas and any sediments which are disturbed rapidly settle. Water turbidity is not significantly affected by these shipping movements (State Pollution Control Commission, unpublished data). However, higher frequencies of shipping movements over silty sediments can be expected to increase resuspension of fine materials, causing a substantial increase in the turbidity of these waters.

ACKNOWLEDGEMENTS

We gratefully acknowledge the assistance of the Maritime Services Board of New South Wales through the use of unpublished data and by analyses of sediment cores. Our thanks also to the Department of Mines for advice on methods of analysis and on the geomorphology of Botany Bay and to Commonwealth Department of Construction for use of unpublished data.



Stationary Water

Direction and Magnitude of Surface Currents

SOURCE · SPCC (in press)

TIDAL CURRENTS
(Pre- and Post- Port Development)

FIGURE 5

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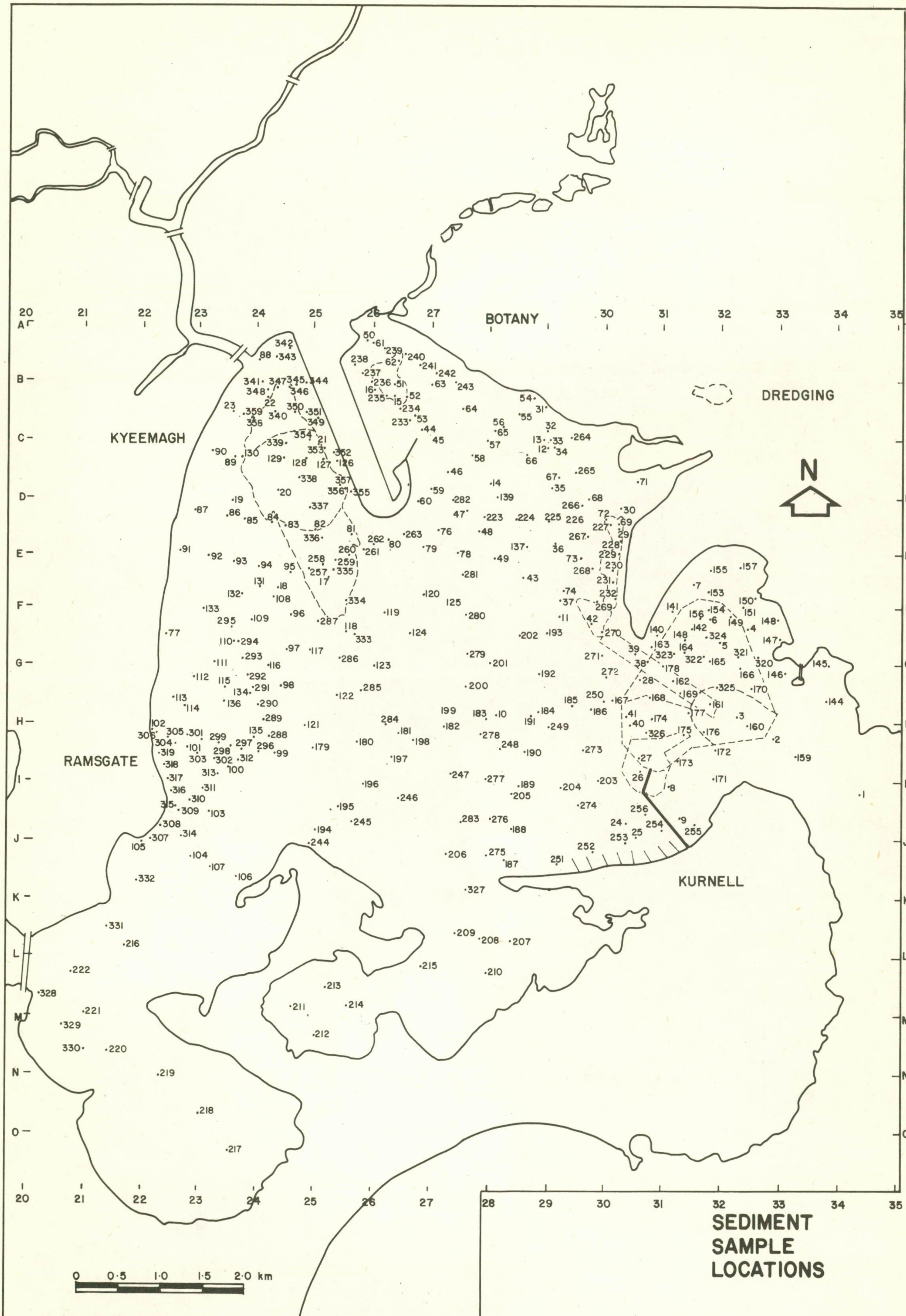
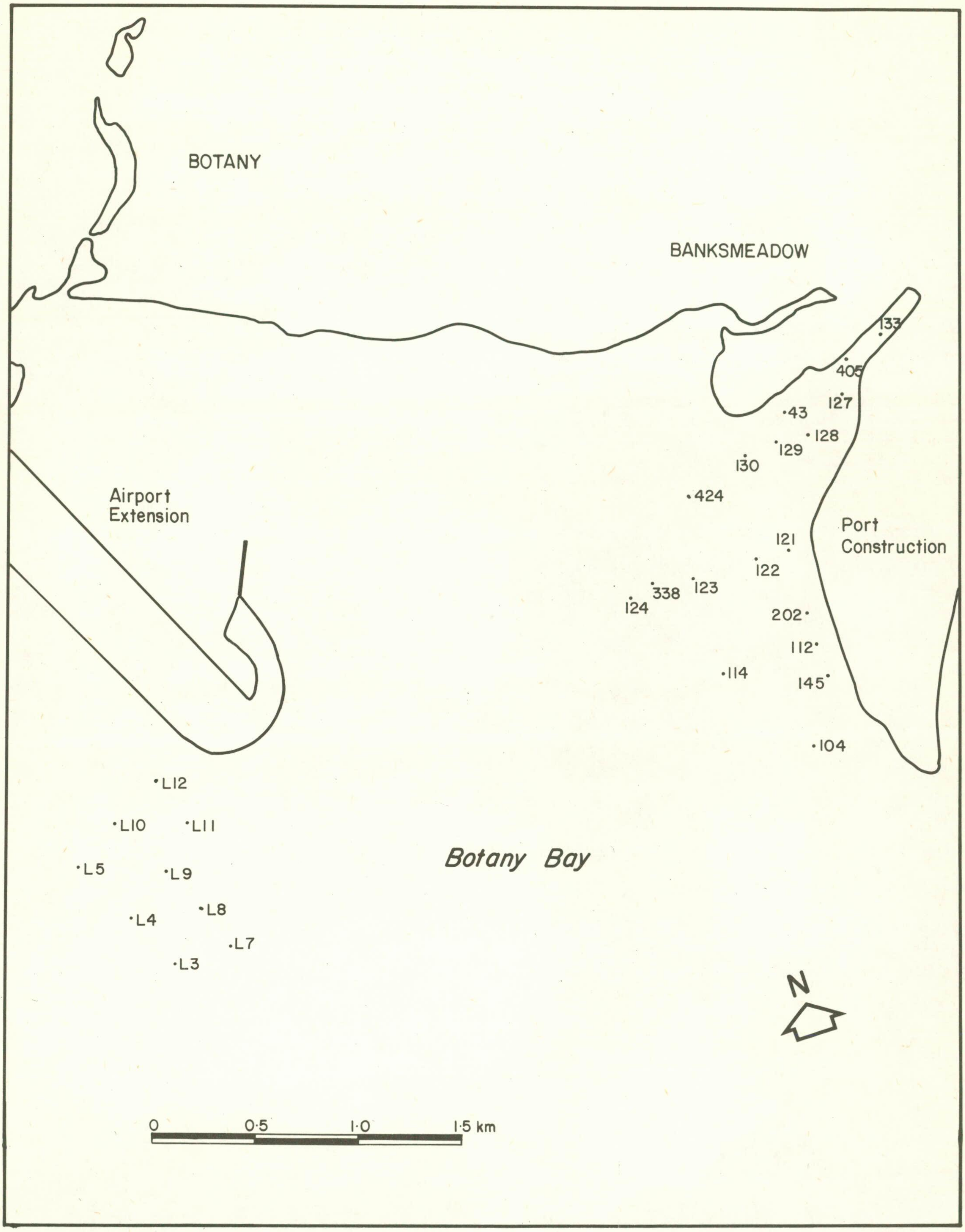
APPENDIX A <u>BOTANY BAY</u>



SEDIMENT
SAMPLE
LOCATIONS

APPENDIX A FIGURE I



SEDIMENT
BORE
LOCATIONS

APPENDIX A FIGURE 2

APPENDIX A

Table 1. Particle Size Analyses - Botany Bay

Sample No.	Approx. Location in Grid	Gravel (%) (O/S)*	Sand (%)	Silt-Clay (%)
1	I 34	-	100	-
2	H 33	-	100	-
3	H 33	-	100	-
4	F 33	-	80	20
5	G 32	-	100	-
6	F 32	-	46	54
7	F 32	-	100	-
8	I 31	-	55	45
9	J 31	-	100	-
10	H 28	-	100	-
11	F 29	-	92	8
12	C 29	-	83	17
13	C 29	-	50	50
14	D 28	-	63	37
15	B 26	-	68	32
16	B 26	-	62	38
17	E 25	-	33	67
18	F 24	-	100	-
19	D 24	-	100	-
20	D 24	-	40	60
21	C 25	-	65	35
22	B 24	-	35	65
23	C 24	-	70	30
24	J 30	-	88	12
25	J 31	-	95	5
26	I 31	-	80	20
27	I 31	-	90	10
28	G 31	-	65	35
29	E 30	-	45	55
30	D 30	-	65	35
31	B 29	5 (O)	92	3
32	C 29	-	92	8
33	C 29	-	35	65
34	C 29	-	88	12
35	D 29	1	75	24
36	E 29	-	60	40
37	F 29	-	86	14
38	G 31	1	75	24

* O - gravel fraction composed of organic matter.
S - gravel fraction composed of shells.

Sample No.	Approx. Location in Grid	Gravel (%) (O/S)*	Sand (%)	Silt-Clay (%)
39	G 31	-	82	18
40	H 31	1	58	41
41	H 31	1	47	52
42	F 30	-	66	34
43	E 29	-	71	29
44	C 27	-	92	8
45	C 27	-	80	20
46	D 27	-	72	28
47	D 28	-	78	22
48	E 28	-	83	17
49	E 28	1	34	65
50	A 26	2(O)	75	23
51	B 26	-	45	55
52	B 27	1	60	39
53	C 27	-	90	10
54	B 29	5(O)	90	5
55	C 28	-	93	7
56	C 28	-	92	8
57	C 28	-	70	30
58	C 28	-	82	18
59	D 27	-	85	15
60	D 27	-	78	22
61	A 26	43(S)	52	5
62	B 26	-	24	76
63	B 27	-	93	7
64	B 28	-	84	16
65	C 28	-	91	9
66	C 29	-	85	15
67	D 29	-	75	25
68	D 30	-	84	16
69	D 30	-	29	71
70	C 31	-	100	-
71	D 30	1	68	31
72	D 30	8(S)	79	13
73	E 30	-	82	8
74	F 29	-	81	19
75	Deleted	-	-	-
76	E 27	-	80	20
77	G 22	-	81	19
78	E 28	-	79	21
79	E 27	-	85	15
80	E 26	-	90	10
81	E 26	-	37	63
82	E 25	-	33	67
83	E 25	-	35	65

Sample No.	Approx. Location in Grid	Gravel (%) (O/S)*	Sand (%)	Silt-Clay (%)
84	D 24	-	82	18
85	D 24	-	87	13
86	D 23	2(S)	91	7
87	D 23	-	87	13
88	B 24	-	85	15
89	C 23	-	93	7
90	C 23	-	81	19
91	E 23	-	100	-
92	E 23	-	99	1
93	E 24	-	92	8
94	E 24	-	97	3
95	E 25	-	99	1
96	F 25	-	98	2
97	G 25	5(S)	95	-
98	G 25	-	63	37
99	H 24	-	97	3
100	I 23	2(S)	98	-
101	H 23	1	98	1
102	H 22	-	45	55
103	J 23	15(S)	85	-
104	J 23	12(S)	88	-
105	J 22	5(S)	75	20
106	K 24	1	99	-
107	J 23	2(S)	98	-
108	F 24	1	96	3
109	F 24	-	95	5
110	G 23	-	98	2
111	G 23	-	98	2
112	G 23	-	100	-
113	H 23	-	53	47
114	H 23	-	47	53
115	G 23	-	96	4
116	G 24	-	100	-
117	G 25	-	100	-
118	F 26	-	84	16
119	F 26	-	99	1
120	F 27	-	95	5
121	H 25	-	100	-
122	H 26	-	97	3
123	G 26	-	97	3
124	F 27	-	97	3
125	F 27	-	97	3
126	C 25	-	30	70
127	C 25	-	27	73

Sample No.	Approx. Location in Grid	Gravel (%) (O/S)*	Sand (%)	Silt-Clay (%)
128	C 25	-	28	72
129	C 24	-	42	58
130	C 24	-	53	47
131	F 24	-	100	-
132	F 24	-	100	-
133	F 23	-	81	19
134	G 24	-	68	32
135	H 24	-	42	58
136	H 23	-	29	71
137	E 29	-	79	21
138	D 29	-	49	51
139	D 28	-	56	44
140	F 31	-	100	-
141	G 31	-	100	-
142	F 32	-	90	10
143	Deleted	-	-	-
144	H 34	-	94	6
145	G 34	-	93	7
146	G 33	-	90	10
147	F 33	44(S)	38	18
148	F 33	1	97	2
149	F 32	1	63	36
150	F 33	37(S)	48	15
151	F 33	2(S)	91	7
152	Deleted	-	-	-
153	F 32	2(S)	98	-
154	F 32	-	66	34
155	E 32	4(S)	96	-
156	F 32	-	45	55
157	E 32	20(S)	80	-
158	G 32	-	97	3
159	H 33	-	97	3
160	H 33	-	100	-
161	H 32	-	96	4
162	G 31	-	93	7
163	F 31	-	97	3
164	G 32	-	92	8
165	G 32	2(S)	95	3
166	G 33	-	100	-
167	H 30	-	95	5
168	H 31	-	100	-
169	H 32	-	85	15
170	G 33	8(S)	72	20
171	I 32	-	91	9

Sample No.	Approx. Location in Grid	Gravel (%) (O/S)*	Sand (%)	Silt-Clay (%)
172	I 32	7(O)	91	2
173	I 31	1	91	8
174	H 31	-	100	-
175	H 32	-	100	-
176	H 32	-	96	4
177	H 32	2(O)	98	-
178	G 31	-	62	38
179	H 25	-	100	-
180	H 26	3(S)	97	-
181	H 27	-	97	3
182	H 27	-	100	-
183	H 28	-	100	-
184	H 29	-	93	7
185	H 30	-	100	-
186	H 30	-	100	-
187	J 29	-	100	-
188	J 29	-	100	-
189	I 29	-	100	-
190	I 29	-	100	-
191	H 29	-	100	-
192	G 29	-	100	-
193	G 29	-	98	2
194	J 25	6(S,O)	90	4
195	J 26	10(S,O)	87	3
196	I 26	2(S)	98	-
197	I 27	-	100	-
198	H 27	-	100	-
199	H 27	-	100	-
200	G 28	-	98	2
201	G 28	-	100	-
202	G 29	-	97	3
203	I 30	2(S)	98	-
204	I 29	2(S)	98	-
205	I 29	-	100	-
206	J 27	5(O)	92	3
207	L 29	10(S,O)	84	6
208	L 28	-	63	37
209	L 27	-	46	54
210	L 28	12(O)	68	20
211	M 25	4(O)	62	34
212	M 25	15(O)	76	9
213	M 25	12(O)	83	5
214	M 26	4(S,O)	78	18
215	L 27	7(S,O)	83	10

Sample No.	Approx. Location in Grid	Gravel (%) (O/S)	Sand (%)	Silt-Clay (%)
216	L 23	27(S)	45	28
217	O 23	3(S)	45	52
218	O 23	7(S)	28	65
219	N 22	4(S)	27	69
220	N 22	-	53	47
221	M 21	2(S,O)	38	60
222	L 21	1	98	1
223	D 28	1	84	15
224	D 29	1	75	24
225	D 29	-	70	30
226	D 29	-	46	54
227	E 30	2(O)	55	43
228	E 30	1	49	50
229	E 30	-	28	72
230	E 30	-	44	56
231	F 30	1	43	56
232	F 30	1	77	22
233	C 27	-	56	44
234	B 27	2(O)	34	64
235	B 26	8(O)	34	58
236	B 26	-	42	58
237	B 26	4(O)	67	29
238	B 26	-	24	76
239	A 26	-	48	52
240	A 27	2(O)	32	66
241	B 27	2(O)	41	57
242	B 27	10(O)	82	8
243	B 28	18(O)	79	3
244	J 25	1	98	1
245	H 29	-	100	-
246	I 27	-	100	-
247	I 27	2(S)	94	4
248	I 28	7(S)	93	-
249	H 29	1	97	2
250	H 30	-	95	5
251	J 29	-	100	-
252	J 30	-	98	2
253	J 30	18(O)	72	10
254	J 31	12(O)	77	11
255	J 32	10(O)	85	5
256	J 31	-	93	7
257	E 25	1	29	70
258	E 25	-	38	62
259	E 25	-	66	34

Sample No.	Approx. Location in Grid	Gravel (%) (O/S)	Sand (%)	Silt-Clay (%)
260	E 26	2(S)	98	-
261	E 26	2(S)	95	3
262	E 26	-	92	8
263	E 26	-	84	16
264	C 30	1	78	21
265	D 30	-	87	13
266	D 30	2(S,O)	74	24
267	E 30	1	71	28
268	E 30	1	68	31
269	F 30	2(S)	47	51
270	F 30	-	50	50
271	G 30	-	95	5
272	G 30	-	97	3
273	I 30	2(S)	98	-
274	I 30	1	99	-
275	J 28	2(S)	97	1
276	J 28	2(S)	96	2
277	I 28	-	96	4
278	H 28	-	94	6
279	G 28	-	87	13
280	F 28	-	98	2
281	E 28	-	75	25
282	D 27	-	78	22
283	J 28	2(S)	98	-
284	H 26	-	94	6
285	G 26	1	93	6
286	G 26	1	95	4
287	F 25	-	96	4
288	H 24	2(S)	92	6
289	H 24	-	91	9
290	H 24	1	76	23
291	G 24	-	84	16
292	G 24	-	96	4
293	G 24	-	96	4
294	G 24	-	100	-
295	F 24	-	100	-
296	I 24	1	98	1
297	H 24	2(S)	93	5
298	H 24	1	96	3
299	H 23	7(S)	92	1
300	H 23	2(O)	70	28
301	H 23	-	40	60
302	I 23	1	31	68
303	I 23	2(S)	98	-

Sample No.	Approx. Location in Grid	Gravel (%) (O/S)	Sand (%)	Silt-Clay (%)
304	H 23	-	33	67
305	H 22	-	43	57
306	H 22	-	100	-
307	J 22	8(S)	90	2
308	J 23	3(S)	97	-
309	I 23	5(S)	95	-
310	I 23	3(S)	92	5
311	I 23	4(S,O)	95	1
312	I 24	2(S)	98	-
313	I 23	3(S)	96	1
314	J 23	7(S)	91	2
315	I 23	2(S)	96	2
316	I 23	3(S)	95	2
317	I 22	1(S)	94	5
318	I 22	6(S)	94	-
319	I 22	2(S)	98	-
320	G 33	9(S)	88	3
321	G 33	5(S)	90	5
322	G 32	-	99	1
323	G 32	-	95	5
324	F 32	-	98	2
325	G 32	-	98	2
326	H 31	2(S,O)	98	-
327	K 28	4(O)	61	35
328	M 20	7(S,O)	34	59
329	M 20	-	28	72
330	N 21	-	20	80
331	L 22	8(S,O)	49	43
332	K 22	29(S,O)	30	41
333	F 26	-	77	23
334	F 26	-	50	50
335	E 25	-	47	53
336	E 25	-	36	64
337	D 25	1	32	67
338	D 25	-	22	78
339	C 25	-	22	78
340	C 24	-	26	74
341	B 24	1	86	13
342	A 25	2(O)	74	24
343	B 24	1	28	71
344	B 25	3(O)	73	24
345	B 25	1	47	52
346	B 24	2(O)	30	68
347	B 24	1	24	75

Sample No.	Approx. Location in Grid	Gravel (%) (O/S)	Sand (%)	Silt-Clay (%)
348	B 24	1	74	25
349	C 25	2(O)	72	26
350	C 25	1	24	75
351	C 25	-	33	67
352	C 25	1	46	53
353	C 25	1	45	54
354	C 25	2(O)	31	67
355	D 26	8(O)	47	45
356	D 26	1	28	71
357	D 25	1	28	71
358	C 24	-	29	71
359	C 24	-	80	20

APPENDIX A

Table 2. Sediments Exposed by Dredging, Kyeemagh Hole (Commonwealth Department of Works 1968)

Core No.	Depth (m, ISLW)		Sediments at Dredged Depth*	Material Removed During Dredging
	Dredged	Pre-Dredged		
L 3	7.8	3.8	Grey f & m sand with few clay nodules. (0%)	3.8 - 4.1 m : coarse grey sand 4.1 - 7.8 m : grey f & m sand
L 4	8.1	3.9	Grey f & m sand (2%)	3.9 - 4.3 m : coarse grey sand 4.3 - 8.1 m : grey f & m sand
L 5	8.3	3.9	Grey f & m sand (3%)	3.9 - 4.5 m : grey-brown coarse sand 4.5 - 8.3 m : grey f & m sand
L 7	8.4	4.1	Grey silty f & m sand (1%)	4.1 - 4.7 m : grey-brown coarse sand 4.7 - 6.1 m : grey m sand 6.1 - 8.4 m : grey silty f & m sand
L 8	7.5	4.2	Grey m sand (0%)	4.2 - 4.8 m : grey coarse sand 4.8 - 7.5 m : grey m sand
L 9	8.5	4.5	Grey silty f & m sand (16%)	4.5 - 4.9 m : grey-brown coarse sand 4.9 - 7.4 m : grey m sand 7.4 - 7.7 m : grey sl. silty f & m sand 7.7 - 8.5 m : grey silty f & m sand

* Figures in brackets represent % silt-clay content

c = coarse
m = medium
f = fine

Core No.	Depth (m, ISLW)		Sediments at Dredged Depth	Material Removed During Dredging
	Dredged	Pre-dredged		
L 10	7.6	5.8	Grey/brown silty medium sand (7%)	5.8 - 6.5 m : grey m and coarse sand 6.5 - 7.6 m : grey brown silty m sand
L 11	7.9	4.5	Grey slightly silty medium sand (1%)	4.5 - 5.0 m : grey brown coarse sand 5.0 - 6.4 m : grey m sand 6.4 - 7.9 m : grey slightly silty m sand
L 12	8.8	4.5	Grey sand overlying peat layer (sand 1%, peat 68%) Peat layer charted.	4.5 - 4.8 m : grey brown coarse sand 4.8 - 8.8 m : grey m sand (8.8 - 9.0 m : dark brown laminated peat)

APPENDIX A

Table 3. Sediments Exposed by Dredging, Present Port Area (Maritime Services Board of N.S.W. 1968, 1969)

Core No. App. A Fig. 2	Depth (m, ISLW)		Sediments at Dredged Depth*	Material Removed During Dredging
	Dredged	Pre-dredged		
104	21.7	8.5	Compact, grey slightly clayey f & m sand	8.5 - 17.7 m : f & m sand 17.7 - 22.0 m : grey slightly clayey f & m sand
112	20	8.8	mineralised sandstone over-lying black sandy charcoal peat = 60% sands 33% silt 7% clay	8.8 - 10.7 m : fawn f & m sand 10.7 - 20.0 m : brown or grey, slightly silty f & m sand (20.0 - 20.7 m : bl. sandy charcoal peat)
121	19.4	8.2	gr. sl. silty f & m sand with lenses of decayed wood and mineralised sandstone, over-lying bl. charcoal peat and silty clay	8.2 - 10.4 m : very silty to silty f & m sand 10.4 - 19.5 m : grey, slightly silty f & m sand (19.5 - 21.3 m : bl. charcoal peat and silty clay).

* Figures in brackets represent % silt-clay content.

c = coarse
m = medium
f = fine

Core No. App. A Fig. 2	Depth (m, ISLW)		Sediments at Dredged Depth*	Material Removed During Dredging
	Dredged	Pre-dredged		
122	16.6	8.6	Fawn sl. silty f & m sand	8.6 - 12.2 m : grey slightly silty f & m sand 12.2 - 16.6 m : fawn slightly silty f & m sand.
145	19.1	9.0	black, sandy charcoal peat = 60% sand 23% silt 17% clay	9.0 - 13.3 m : grey and fawn f & m sand 13.3 - 19.1 m : grey slightly clayey f & m sand (19.1 - 20.1 m : bl. sandy charcoal peat)
202	21	9.2	grey f & m sand overlying dark grey clayey peat and silty clay.	9.2 - 13.7 m : grey & fawn f & m sand with some peat fragments below 35' 13.7 - 21.0 m : light grey f & m sand with lens of mineralised sand-stone below 20.4 m. (21.0 - 22.6 m : dark grey clayey peat and silty clay).

APPENDIX A

Table 4. Sediments to be Exposed by Dredging on Completion of Port Botany (Maritime Services Board of N.S.W. 1968, 1975)

Core No. App. A Fig. 2	Depth (m, ISLW)		Sediments at Dredged Depth	Materials to be Removed During Dredging
	Dredged	Pre-dredged		
123	13	8.1	Brown sl. silty f & m sand	8.1 - 17.2 m : brown, slightly silty f & m sand.
114	13	8.1	Brown silty f & m sand	8.1 - 9.5 m : brown f & m sand 9.5 - 12.2 m : brown silty f & m sand 12.2 - 12.5 m : black, sandy charcoal peat 12.2 - 20.3 m : brown silty f & m sand
129	15.2	4.1	Fawn sl. silty f & m sand	4.1 - 5.2 m : grey silty f & m sand 5.2 - 13.7 m : brown silty f & m sand with occasional lenses of organic silty clay. 13.7 - 21.3 m : fawn slightly silty f & m sand
424	13	5.1	Fine brown sand	5.1 - 6.1 m : grey silty sand 6.1 - 8.2 m : peat & peaty sand 8.2 - 13.0 m : fine brown sand

c = coarse
m = medium
f = fine

Core No. App. A Fig. 2	Depth (m, ISLW)		Sediments at Dredged Depth	Materials to be Removed During Dredging
	Dredged	Pre-dredged		
338	13	7.5	Dark brown organic f & m sand	7.5 - 13.0 m : dark brown organic f & m sand
405	15.2	2.5	Grey f. sand	2.5 - 3.6 m : silty sands 3.6 - 13.5 m : grey f. sand with some clay in lower stratum 13.5 - 15.1 m : grey f & m sand with some bands of peaty sand.
413	15.2	3.55	Grey-brown f & m sand	3.55 - 4.55 m : grey f & m sand 4.55 - 5.75 m : dark brown predom. f. sand 5.75 - 15.2 m : f & m sand grey-brown
128	15.2	3.7	Yellow f & m sand	3.7 - 5.5 m : gr. sl. silty f & m sand 5.5 - 9.1 m : br. silty f & m sand 9.1 - 15.2 m : yellow f & m sand
127	15.2	3.4	Fawn f & m sand	3.4 - 5.2 m : grey f & m sand 5.2 - 11 m : brown silty f & m sand 11.0 - 15.2 m : fawn f & m sand
130	15.2	4.3	Br. sl. silty f & m sand	4.3 - 5.5 m : grey sl. silty f & m sand 5.5 - 13.7 m : brown silty f & m sand 13.7 - 15.2 m : brown sl. silty f & m sand

Core No. App. A Fig. 2	Depth (m, ISLW)		Sediments at Dredged Depth	Materials to be Removed During Dredging
	Dredged	Pre-dredged		
124	13	7.5	Br. silty f & m sand	7.5 - 9.8 m : fawn f & m sand 9.8 - 13.0 m : br. silty f & m sand
133	15.2	2.3	Bl. sandy charcoal peat	2.3 - 10.4 m : br. f & m sand 10.4 - 14.8 m : br. silty f & m sand 14.8 - 15.2 m : bl. sandy charcoal peat

APPENDIX B

BOTTOM SEDIMENTS OF GEORGES AND WORONORA RIVERS

1 METHODS

Sediment samples were collected from Georges and Woronora Rivers and analysed as previously described. Sample locations and results are presented in Figure 1 and Table 1.

2 RESULTS

Sediments in lower sections of both Georges and Woronora Rivers are silts and silty sands, except where sand banks have formed alongside the main channel. Georges River sediments vary between 60 - 90 percent silt-clay content, the highest values occurring in the side-bays. Woronora River sediments are generally more sandy than those of Georges River, with silt-clay contents averaging approximately 45 per cent.

Munro et al (1967) provided qualitative descriptions of sediments in Georges River. Comparison of their descriptions with the results of the present survey, indicates there has been a change in sediment type between Como Bridge and Alfords Point. Whereas sediments in this reach were formerly described as "uniform medium sands", they are now soft silts with 50 - 70 per cent silt-clay content.

3 DISCUSSION

The catchments of Georges and Woronora Rivers are predominantly Hawkesbury sandstone, although the Georges River catchment has a large area of Wianamatta shale. Bed sediments of the rivers would therefore be expected to be mainly sands, with silts or silty sands in quiet water areas.

During the last 50 years, however, both catchments have been disturbed by urban development. The upstream bed and floodplain of Georges River has also been also been extensively dredged for commercial sand and numerous side-bays have been reclaimed by local councils for refuse disposal and sports amenities.

These developments have altered land drainage patterns and changed the hydraulic character of the estuary (Warner et al 1976). The overall effect has been widespread erosion in the upper reaches of Georges River and extensive deposition in the lower estuary. Warner and Pickup (1977) estimated that since 1959, approximately 1.4×10^6 m^3 sediment have accumulated in the main channel of Georges River downstream of Salt Pan Creek. Channel widths have also generally decreased and numerous inlets have become heavily silted.

The results of the present survey are consistent with the above findings. In particular, the increase in silt-clay content between Como Bridge and Alford's Point supports Warner and Pickup's conclusion that Georges River is adjusting to an increased sediment load.

Extraction of sand from the Georges River floodplain will continue for about ten more years (Lands Department of New South Wales 1975). The adjustment to this and past disturbances can be expected to continue for some years, resulting in further siltation, particularly in the side-bays which are poorly flushed by tides (SPCC, in press).

The Woronora River catchment has not yet been extensively developed. Urbanisation is planned, however, and proposals have been made for sand extraction from the river. Siltation in the downstream reaches is consequently likely to increase.

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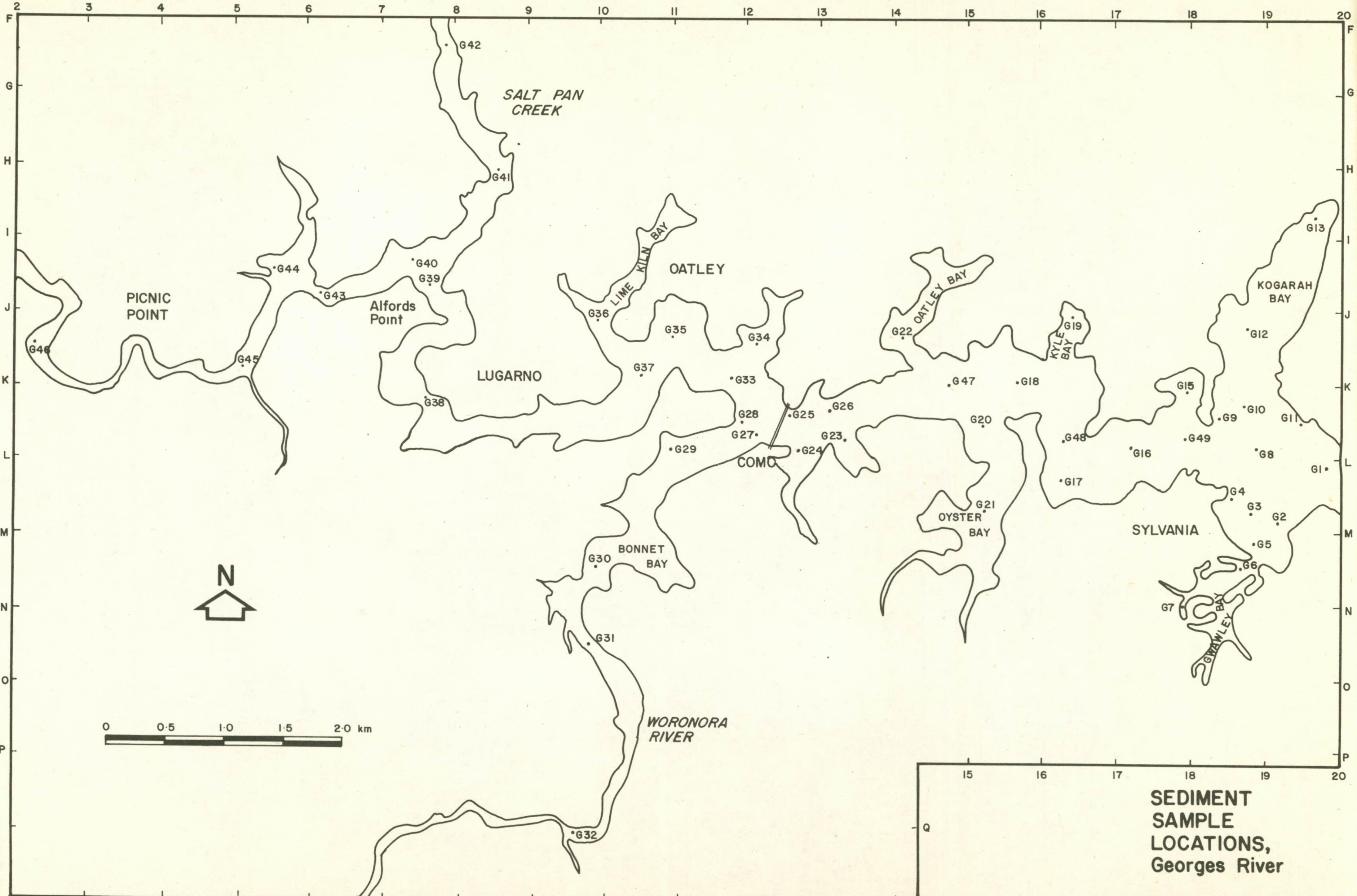
APPENDIX B

Table 1. Particle Size Analyses - Georges River

Sample No.	Approx. Location on Grid	Gravel (%) (O/S)*	Sand (%)	Silt-Clay (%)
G1	L 20	14(O)	38	48
G2	M 19	-	12	88
G3	M 19	-	35	65
G4	L 19	-	20	80
G5	M 19	-	17	83
G6	M 19	-	10	90
G7	N 18	-	12	88
G8	L 19	-	14	86
G9	K 18	-	18	82
G10	K 19	-	18	82
G11	K 19	-	16	84
G12	J 19	-	10	90
G13	I 20	-	19	81
G14	Deleted	-	-	-
G15	K 18	2(O)	8	90
G16	L 17	-	22	78
G17	L 16	-	15	85
G18	K 16	-	18	82
G19	J 16	-	18	82
G20	K 15	-	30	70
G21	M 15	-	18	82
G22	J 14	-	10	90
G23	L 13	-	20	80
G24	L 13	-	17	83
G25	K 13	35(S)	50	15
G26	K 13	-	26	74
G27	L 12	-	33	67
G28	K 12	-	40	60
G29	L 11	-	36	64
G30	N 10	-	58	42
G31	O 10	10(S)	40	50
G32	Q 10	-	57	43
G33	K 12	-	21	79
G34	J 12	-	9	91

* O - gravel fraction composed of organic matter
S - gravel fraction composed of shells



SEDIMENT SAMPLE LOCATIONS, Georges River

APPENDIX B FIGURE 1

FIGURE B2

Sample No.	Approx. Location on Grid	Gravel (%) (O/S)*	Sand (%)	Silt-Clay (%)
G35	J 11	1	99	0
G36	J 10	-	10	90
G37	K 10	-	40	60
G38	K 8	-	41	59
G39	J 8	5(S)	80	15
G40	I 7	-	30	70
G41	H 8	-	8	92
G42	F 8	2(O)	11	87
G43	J 6	-	10	90
G44	I 5	-	20	80
G45	K 5	-	7	93
G46	J 2	-	12	88