CONSULTANCY REPORT FOR RIEDEL AND BYRNE

LEVUKA HARBOUR

(Current Measurements and Water Quality Analysis)

INR ENVIRONMENTAL STUDIES REPORT NO. C42

ISTITUTE OF NATURAL RESOURCES
UNIVERSITY OF THE SOUTH PACIFIC

REPORT

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Consultants . Institute of Natural Resources

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1.0 Introduction

The following report outlines work done in Levuka harbour, Fiji for Riedel and Byrne by the Institute of Natural Resources (INR) during the month of August and September 1989.

Riedel and Byrne, (Consulting Engineers, Melbourne, Australia) were contracted by the Australian International Development Assistance Bureau to design a major extension to the existing PAFCO cannery at Levuka. As part of the extensions there was a requirement to provide clean salt water for thawing fish and to provide an outfall for mainly liquid wastes to sea. For the design to take place information was needed about the existing water quality and offshore current movements.

The intake water is required to meet requirements set by the Canadian "Good Manufacturing Practices" handbook for canned tuna processing. These requirements give a limit on the water used for thawing to contain less than 2 coliform bacteria per 100 mililitres; as determined by DFO Standard Procedures for Bacteriological Analysis for water.

The outlet water would be mainly the return water from the thawing process but may also contain some effluent from the cannery processing and fish meal production. The requirements for the outfall are

i) it must be far enough offshore not to attract sharks to the town beach

ii) it must not cause nutrients to accumulate along the shore

iii) it must not contaminate the intake waters.

To determine the intake water quality INR was contacted to obtain coliform counts on water samples at selected sites in the harbour area. To determine the positions of the intake and outfalls INR was contracted to determine the current flows in the harbour area. The location for the current flow studies is given in Map 1 and the water sampling sites in Map 2. Map 3 is a hydrographic map of the area. The tidal flows were initially to be taken by drouque measurements but they were supplemented by current meter measurements on the final trip.

Levuka (the old capital of Fiji) is the main town on Ovalau, an island off the south east coast of Viti Levu and about 45 km from the present capital Suva. Transport to Levuka is by air (Nausori-Bureta) or by sea (Suva-Levuka or Natovi-Levuka). Because of the sometimes erratic air schedules and connection time delays it was considered essential to do the bacteriological analysis on site.

2.0 Measurement Methods

2.1 Coliform Counts

Three separate trips were made to Levuka in August and in September 1989. Total and faecal coliform counts were taken at 5 selected sites on 7 separate days. The sample dates were : trip 1; 1st August, 2nd August and 3rd August; trip 2; 17th August and 18th August and trip 3, 13th September and 14th September. The seawater samples were taken at average flood and average ebb tides and at the surface and at 1m above the seabed at each location. Maps 4 and 5 gives the actual location of the water sampling sites.

A specially constructed sample bottle was fabricated and tested in Suva harbour to ensure the bacteriological integrity of the samples at depths. Appendix A details the "Zobell" microbiological sampling bottle. The water samples were analysed using the "membrane filtration" technique.

2.2 Current Measurements

During the initial trip to Levuka (starting on 1st August) current measurements were taken with drougues obtained from the Institute of Marine Resources (IMR). Trials held in Laucala Bay, Suva indicated that measurements using bearings taken by a hand held compass were not sufficiently accurate. Thus on the first trip the current speed was measured by letting the drougues drift a set distance on a pre-measured line from an anchored boat. The bearing was taken from the anchored boat to the final drougue position to obtain the current direction. On the second trip (starting on 17th August) the firm of Harrison and Grierson were subcontracted to provide a "total station" measurement facility. By having the "total station" on shore and the reflector on the boat a considerable improvement in accuracy was realized. On the third trip (starting 12th September) an improved drougue design was used in conjunction with a continuous recording current meter.

The IMR drougues had a polystyrene float that protruded somewhat out of the water giving rise to the possibility of wind drag, the improved drougue was trimmed so that virtually no surface wind resistance would result. The improved drougue also had a vane of increased cross sectional area (0.7 m^2 as against 0.4 m^2). Photos 1 and 2 show the improved drougue. The vane was usually set between 3m and 10m below the surface. The current meter used was an Aandera RCM4 manufactured in Norway. The unit was capable of recording current speed, current direction, salinity (conductivity), temperature, and pressure at preset intervals on magnetic recording tape. The pressure

PHOTO 1

FLOAT

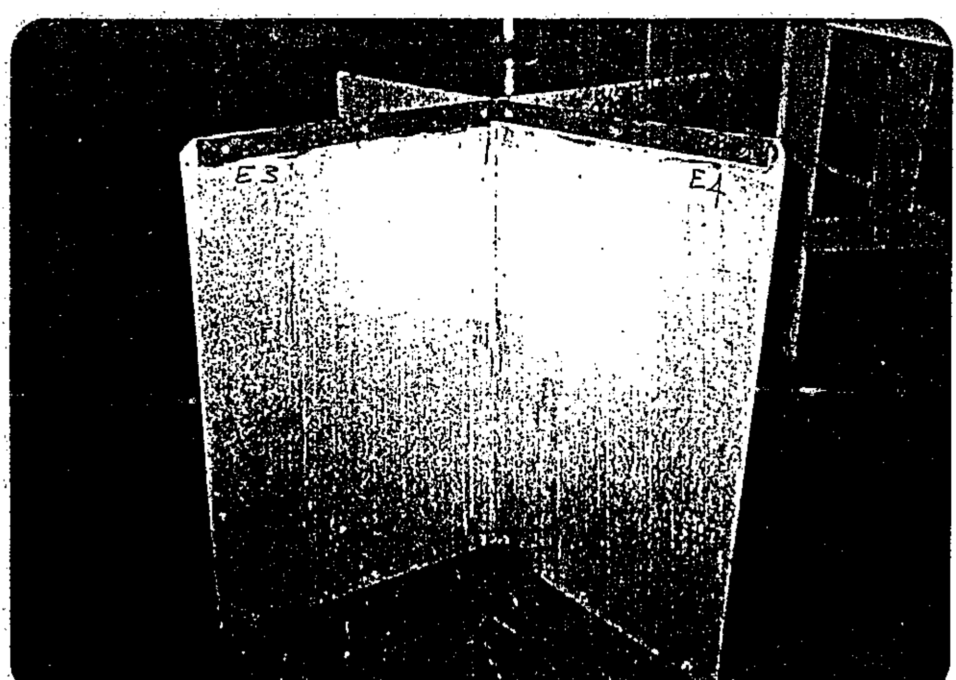
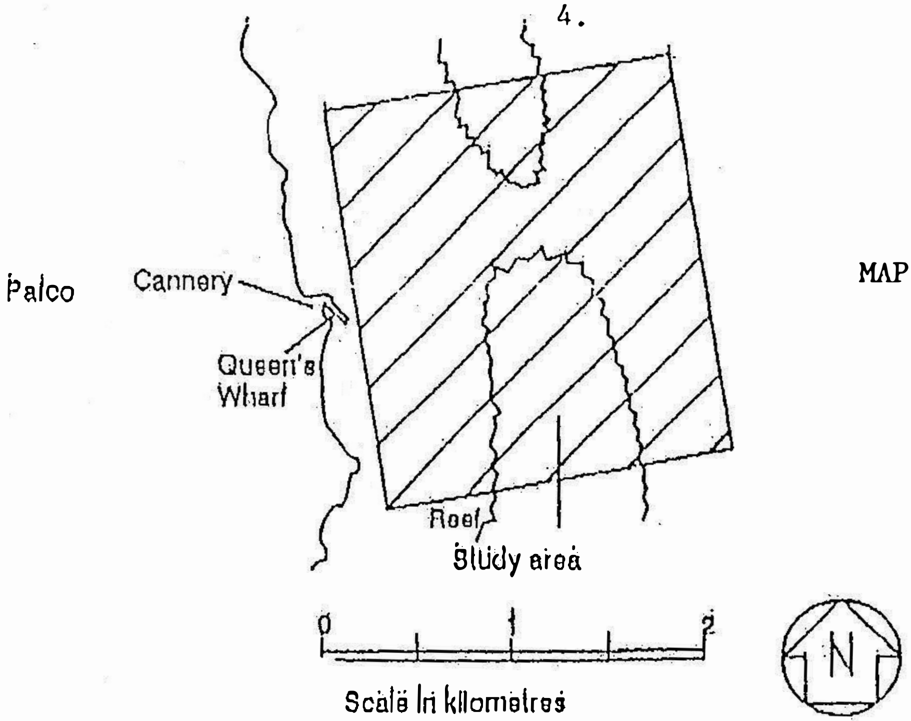


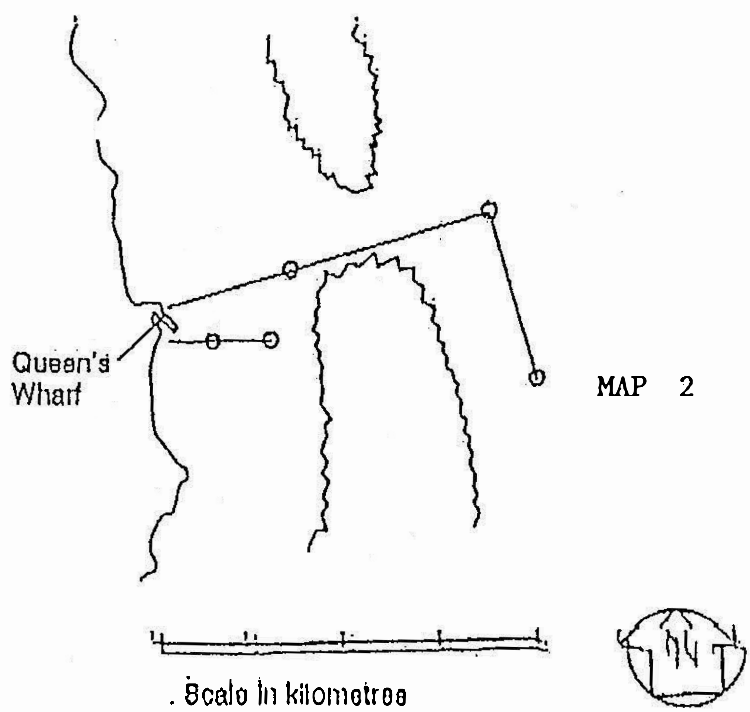
PHOTO 2

VANE



MAP 1

LOCATION FOR TIDAL FLOW STUDY



MAP 2

LOCATION OF SAMPLING SITES

MAP 3

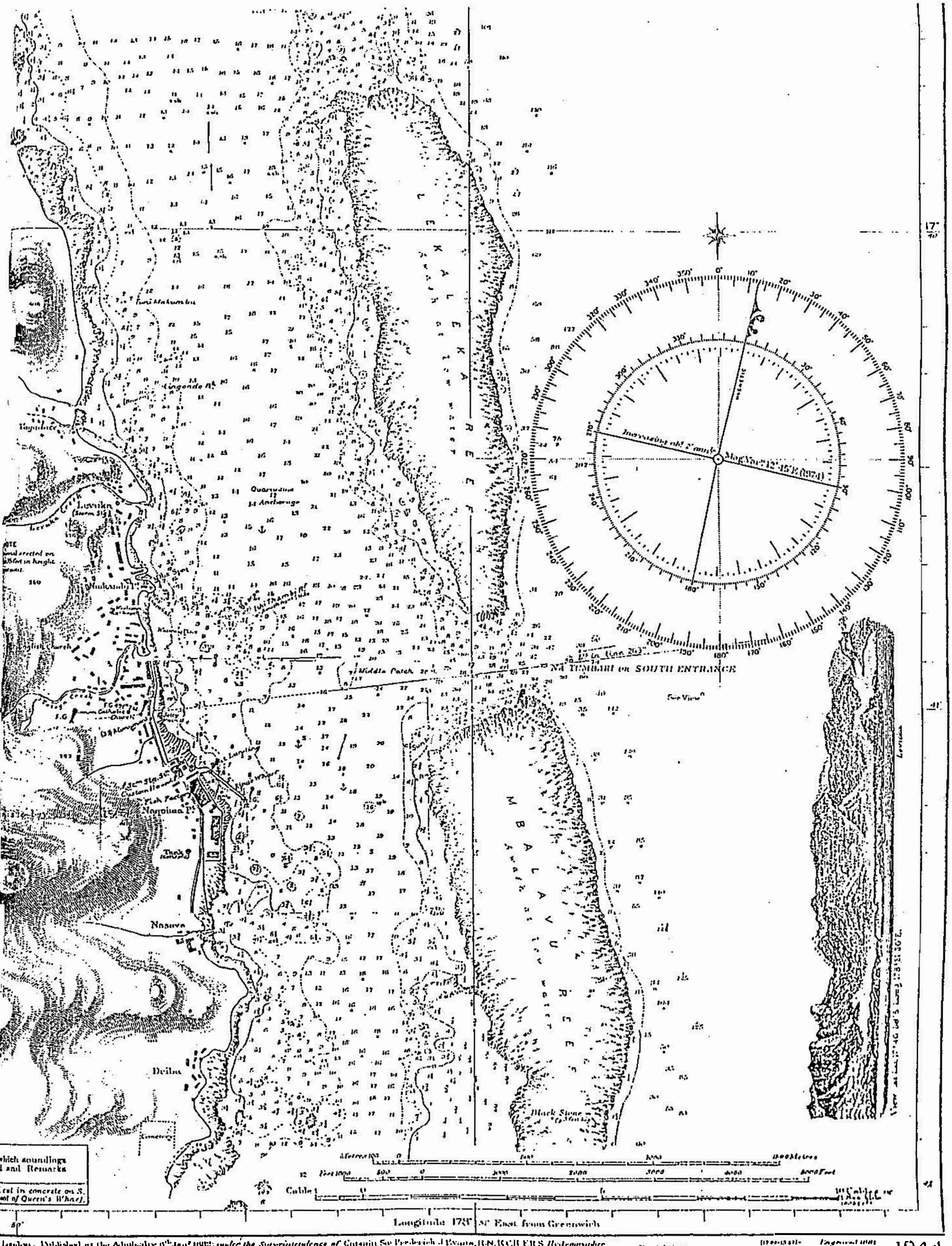
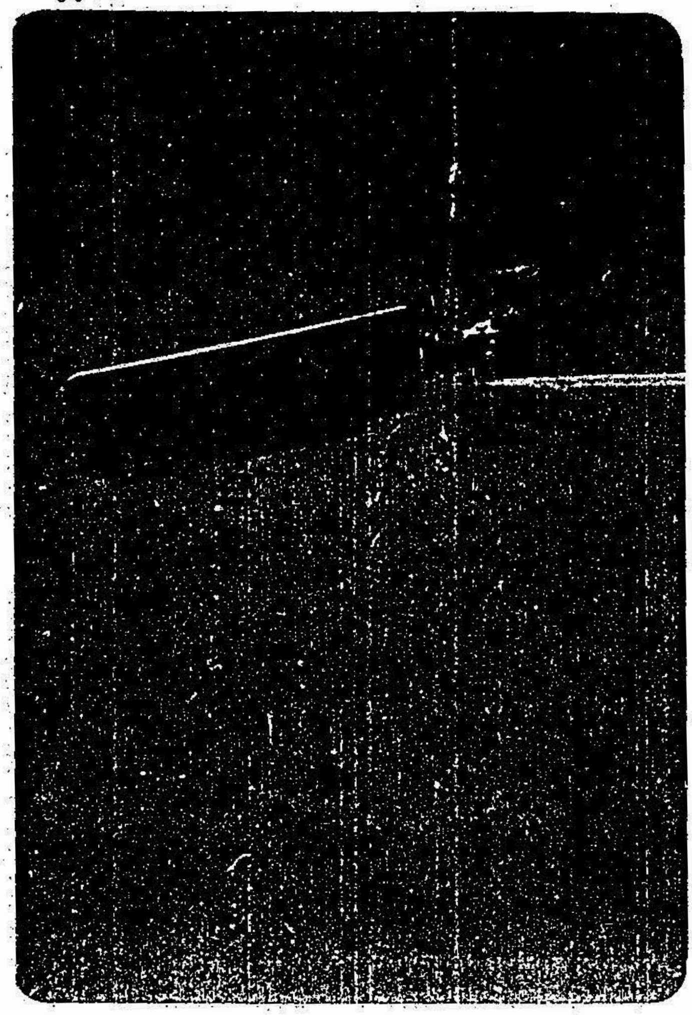
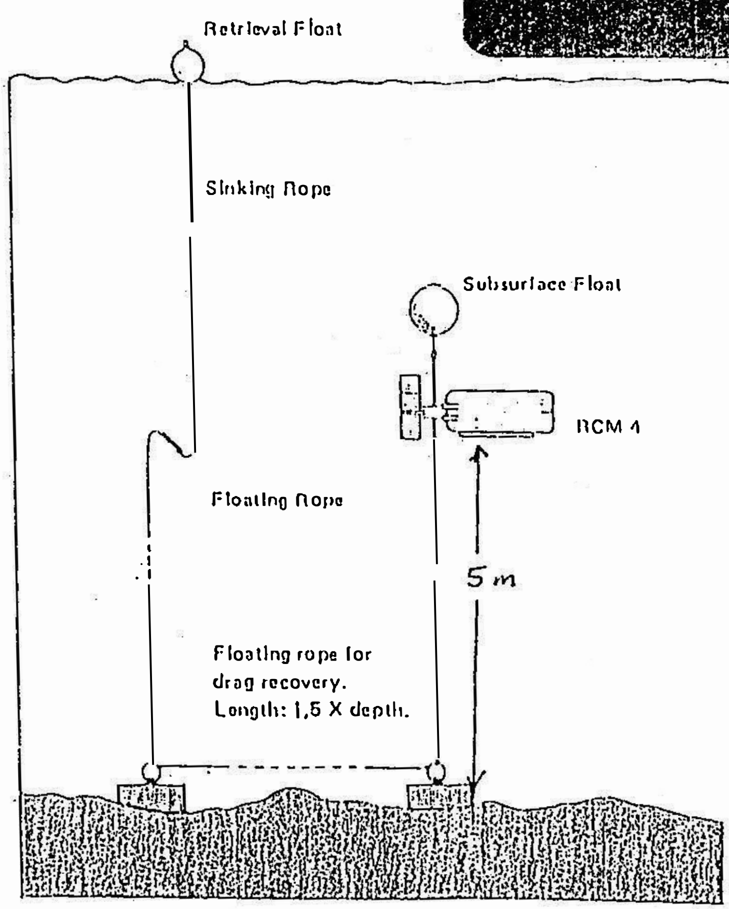

Levuka
Quarantine Anchorage
Middle Patch
NA TEMBARI or SOUTH ENTRANCE
Nasova
Draiba
Black Stone
Cable
Longitude 178° 50' East from Greenwich
© Crown Copyright 1970
1244

PHOTO 3

AANDERA CURRENT METER IN PLACE





U - Mooring

FIG. 1.01 Moorings of Current Meters

FIGURE 1

measurement capability enabled a check to be made on tide height. All sensors except salinity (conductivity) were calibrated in the INR laboratory before the unit was dispatched to the field. The meter was anchored as per Fig. 1. The distance from the meter to the sea floor was set at 5m. The distance between the two anchors was set at 1.5x the total water depth. Appendix A details the current meter specifications. Measurements were taken at 5 minute intervals. The data was transferred from the magnetic tape via a RS 232 line to a "BBC" microcomputer. This data was then transferred to an IBM compatible computer and analysed on a Lotus 123 spreadsheet.

3.0 Results

3.1 Coliform Counts

The results for trips 1 and 2 are detailed in table 1 and the results for trip 3 in table 2. As can be seen no site gave samples that had <2 counts/100 ml on all sampling days.

3.2 Current Measurements

Table 3 and Map 4 gives the results for trip 1. The results for trip 2 and trip 3 are given in Appendix B. The results for the 3 trips include 5 days of measurements. During trips 1 and 2 the wind speed was quite high, around 10 m/s from the south. The results from trip 3, in virtually calm conditions and with the improved drougue design are thought to be the most reliable. Appendix C gives the tide tables for the months of August and September 1989.

3.3 Current Meter Results

The Aandera current meter was installed at two locations (site C3 and site B3) for periods of 24 hours each. The recording time interval was set to 5 minutes. Maps 5 and 6 show the two locations. Site C3 was located in the reef gap in water of depth 15 m. Figures 2 to 5 give the results for site C3. The water at site C3 was very clear with the meter being visible 10 m from the surface. The measurements were entirely as expected with an inward flow [260° N(mag)] peaking at 30 cm/sec just after low tide (flood tide) and an outward flow (100° to magnetic North) peaking at 24 cm/sec just after high tide (ebb tide). The magnitudes of the flows agree well with the drougue results.

Site B was close to shore opposite Nasova. The clarity of the water at site B was very poor with a visibility of only a few metres. The poor visibility necessitated having a diver go down to check the mooring of the current meter at this site. Figures 6 to 9 give the results for site C3.

The measurements showed little to no water movement at this site. Peaks of around 3 cm/sec could be observed for short intervals during the tidal change but for most of the time the flow was less than the detectable limit of 2 cm/sec.

4.0 Conclusions

The measurements indicate that the present levels of coliform bacteria in Levuka Harbour would not enable sea water from inside the reef area to be used directly as thawing water.

Close to the shore there appears to be little horizontal current flow. In the mid areas between the reef and the shore a current flow parallel to the coast towards a Northerly direction predominates. This flow averaged around 10-14 cm/sec and as it was roughly in the same direction as the main prevailing winds may be largely wind driven. Close to the beach reef edge one would expect the main flow to be draining water off the reef driven by wave movement on the front edge. Horizontal current flows betwe 0 and 30 cm/sec were observed in the passage in the reef. The current flows in the passage reversed as per the tidal movement in an entirely predictable manner. A composite picture showing representative paths for both flood and ebb tides are given in Maps 5 and 6.

TABLE 1

LEVUKA HARBOUR

WATER QUALITY RESULTS

		Trip 1						Trip 2			
	DATE	01 AUG		02 AUG		03 AUG		17 AUG		18 AUG	
	SITE	TC	FC	TC	FC	TC	FC	TC	FC	TC	FC
A1	Top	1	Nil	174	Nil	Nil	Nil	Nil	Nil	26	9
A1	Bottom	Nil	Nil	>200	Nil	Nil	Nil	3	3	2	Nil
B1	Top	Nil	Nil	140	Nil	Nil	Nil	3	Nil	Nil	Nil
B1	Bottom	Nil	Nil	Nil	Nil	Nil	Nil	36	Nil	9	Nil
C1	Top	10	4	50	1	Nil	Nil	7	3	44	4
C1	Bottom	17	Nil	120	Nil	8	2	9	5	33	7
D1	Top	Nil	Nil	>200	7	Nil	Nil	18	1	20	12
D1	Bottom	Nil	Nil	>200	Nil	Nil	Nil	9	Nil	21	Nil
E1	Top	Nil	Nil	>200	1	Nil	Nil	*ND	*ND	9	5
E1	Bottom	Nil	Nil	6	Nil	Nil	Nil	16	1	8	2
	Tide When Water Collected	Average Flood Tide		Average Flood Tide		Low Tide		Average Flood Tide		Average Ebb Tide	

NOTES :

1. a) FC = Faecal Coliform
   b) TC = Total Coliform

2. Results reported as counts/100 ml

3. *ND = Not determined (water sample not collected)

4. It must be noted that on the days on which most positive counts were recorded, i.e. 2, 17 and 18 August there was a lot of movement of ships in and out of the Harbour

TABLE 2

TRIP 3 - WATER QUALITY RESULTS

DATE		13 Sept		14 SEPT	
	SITE	TC	FC	TC	FC
A3	Top	370	0	420	1
A3	Bottom	54	0	430	0
B3	Top	>20,000	80	2,600	42
B3	Bottom	75	0	>200	0
	Tide	Flood Tide		Flood Tide	

NOTES :

1. a) FC = Faecal Coliform

   b) TC = Total Coliform

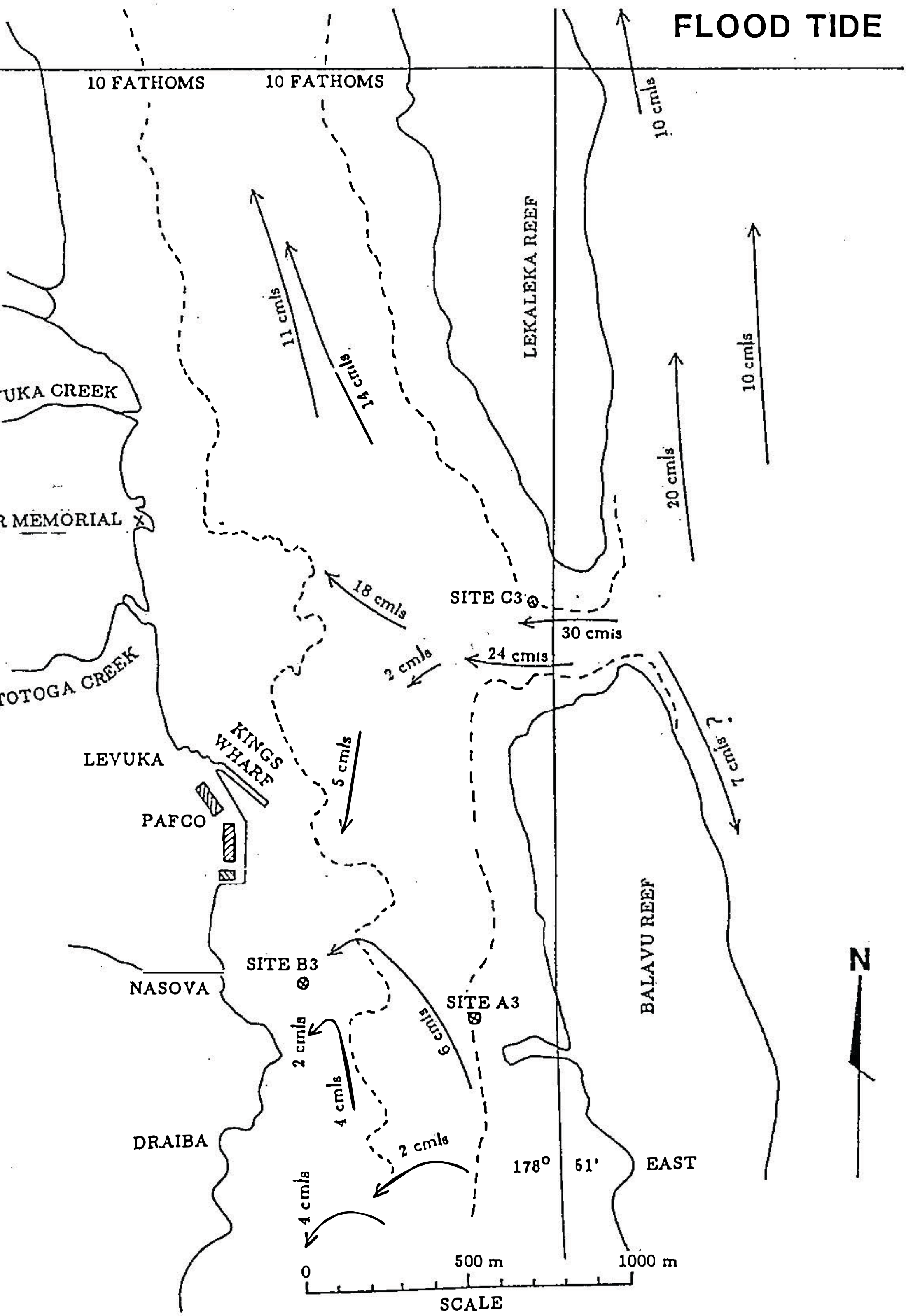
2. Results reported as counts/100 ml

TABLE 4

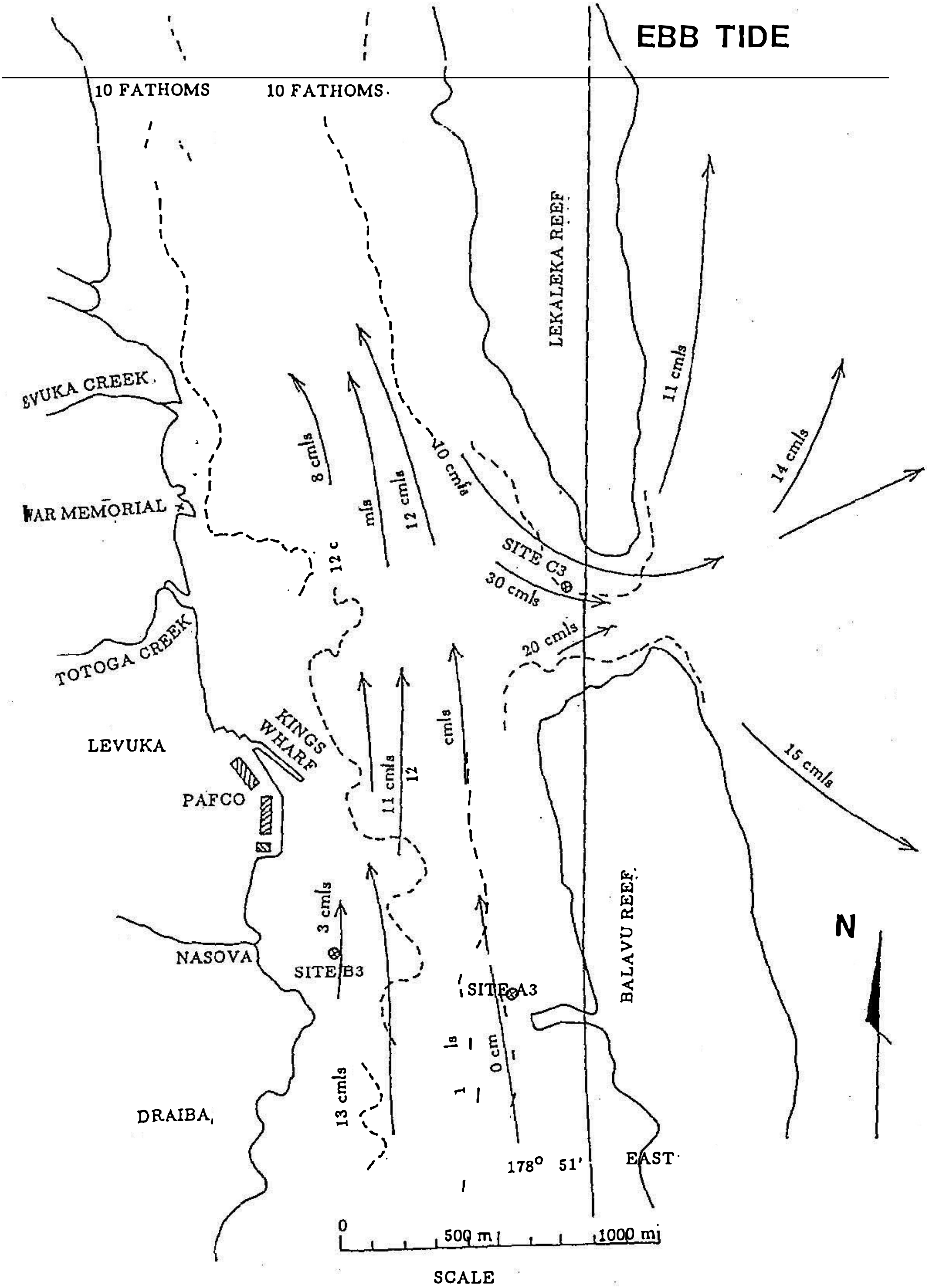
DROUGE SURVEY RESULTS

LEVUKA HARBOUR - 1-3 AUGUST 1989

Date	Path No.	Vane Depth (m)	Time Released	Time Collected	Distance (m)	Average Velocity (m/hr)	cm/s	Direction to North	Tide
1 Aug	1	3	1032	1100	200	429	12	278°	Ebb
	1	10	1115	1133	200	667	18	281°	Ebb
	ave.						15		
	2	10.	1203	1244	100	146	4	300°	Low
	2	3	1252	1346	100	111	3	337°	Low
	ave.						3.5		
	3	3	1610	1640	200	400	11	338°	Flood
	3	10	1648	1746	200	207	6	1°	Flood
	ave.						8.5		
2 Aug	4	10	0945	0958	200	923	26	108°	Ebb
"	4	3	1005	1020	200	800	22	101°	Ebb
	ave.						24		
	5	10	1138	1242	200	188	5	312°	Ebb
	5	3	1250	1315	100	240	7	281°	Low
	ave.						6		
"	6	3	1600	1643	100	140	4	270°	Flood
	6	10	1648	1750	100	97	3	260°	Flood
	ave.						3.5		
3 Aug	7	10	0844	0901	100	353	10	331°	Ebb
	7	3	0907	0925	100	333	9	323°	Ebb
	ave.						9.5		
	8	3	0948	1019	100	194	5	213°	Ebb
	8	10	1023	1051	100	214	6	241°	Ebb
	ave.						5.5		


FLOOD TIDE
10 FATHOMS
10 FATHOMS
10 cm/s
11 cm/s
14 cm/s
LEKALEKA REEF
10 cm/s
UKA CREEK
20 cm/s
R MEMORIAL
18 cm/s
SITE C3
30 cm/s
2 cm/s
24 cm/s
TOTOGA CREEK
KINGS WHARF
LEVUKA
5 cm/s
7 cm/s ?
PAFCO
BALAVU REEF
SITE B3
NASOVA
SITE A3
N
2 cm/s
6 cm/s
4 cm/s
DRAIBA
2 cm/s
178° 51' EAST
4 cm/s
0
500 m
1000 m
SCALE

MAP 5


EBB TIDE
10 FATHOMS
10 FATHOMS
LEKALEKA REEF
VUKA CREEK
WAR MEMORIAL
TOTOGA CREEK
LEVUKA
KINGS WHARF
PAFCO
NASOVA
DRAIBA
SITE B3
SITE A3
SITE C3
BALAVU REEF
8 cm/s
12 cm/s
10 cm/s
11 cm/s
14 cm/s
30 cm/s
20 cm/s
15 cm/s
11 cm/s
12
3 cm/s
13 cm/s
178° 51' EAST
N
0
500 m
1000 m
SCALE

MAP 6

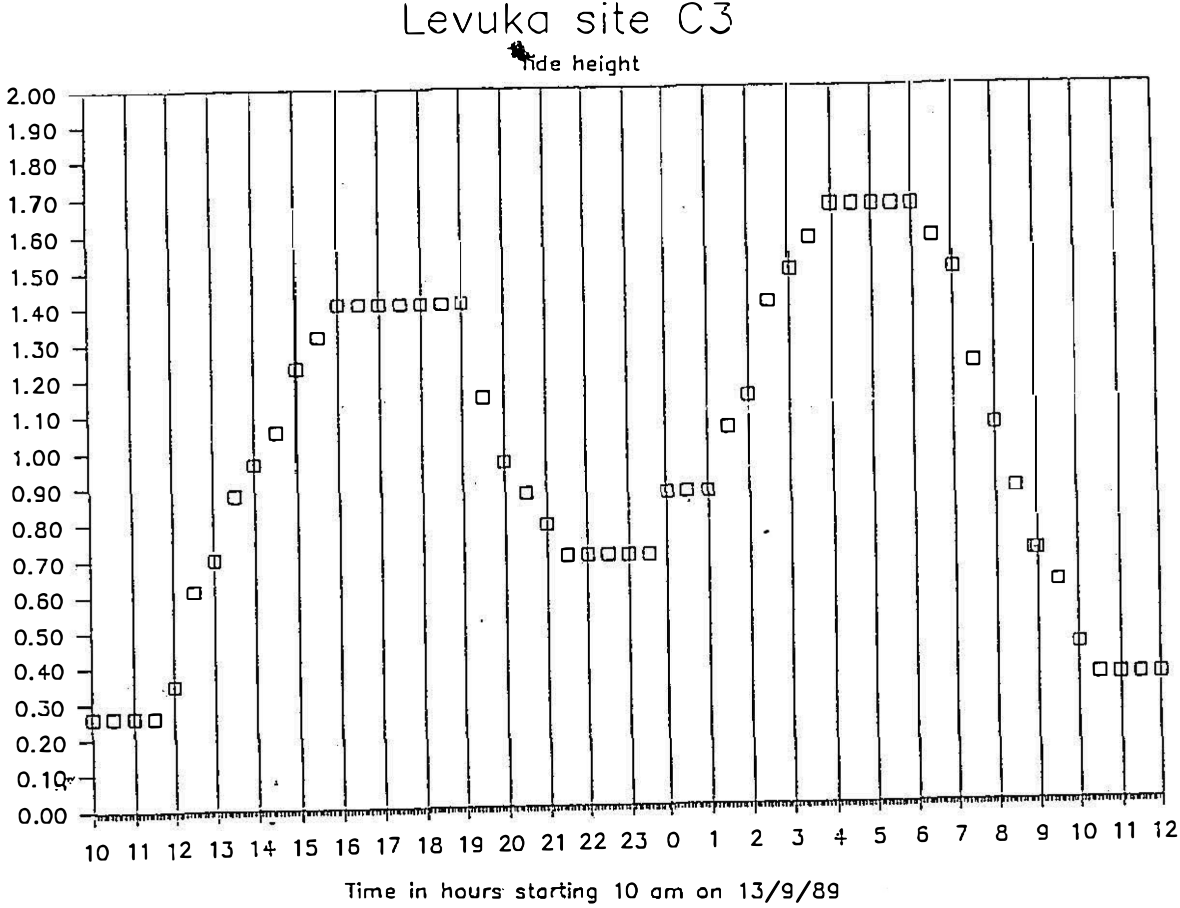


FIGURE 2

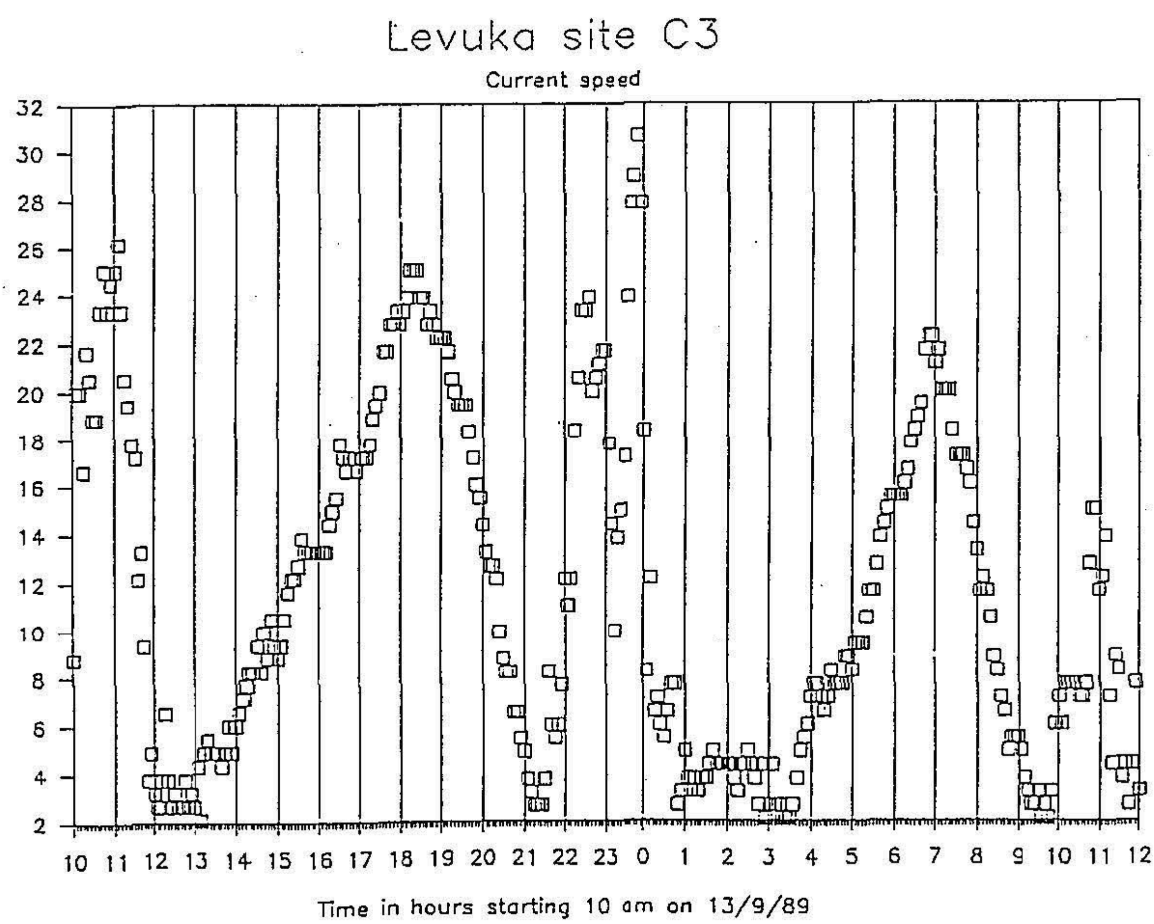


FIGURE 3

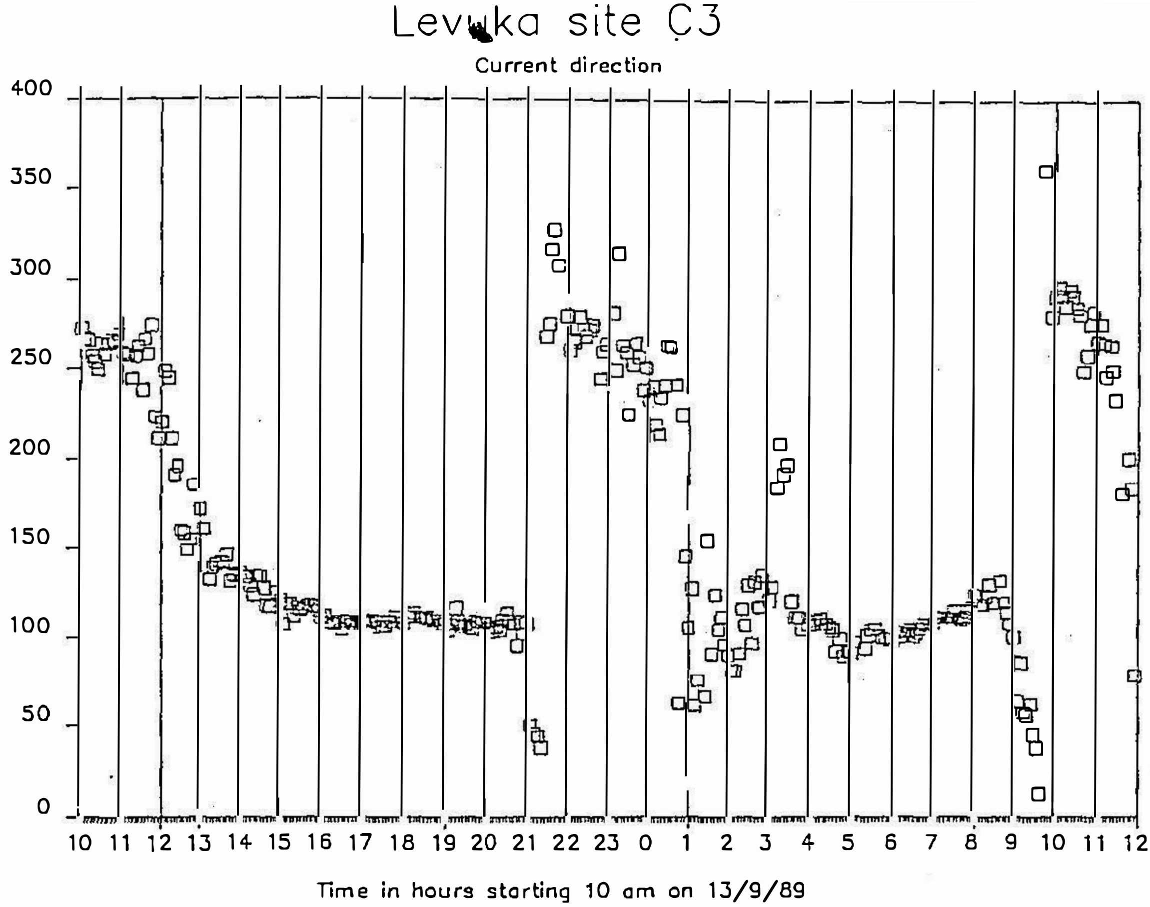


FIGURE 4

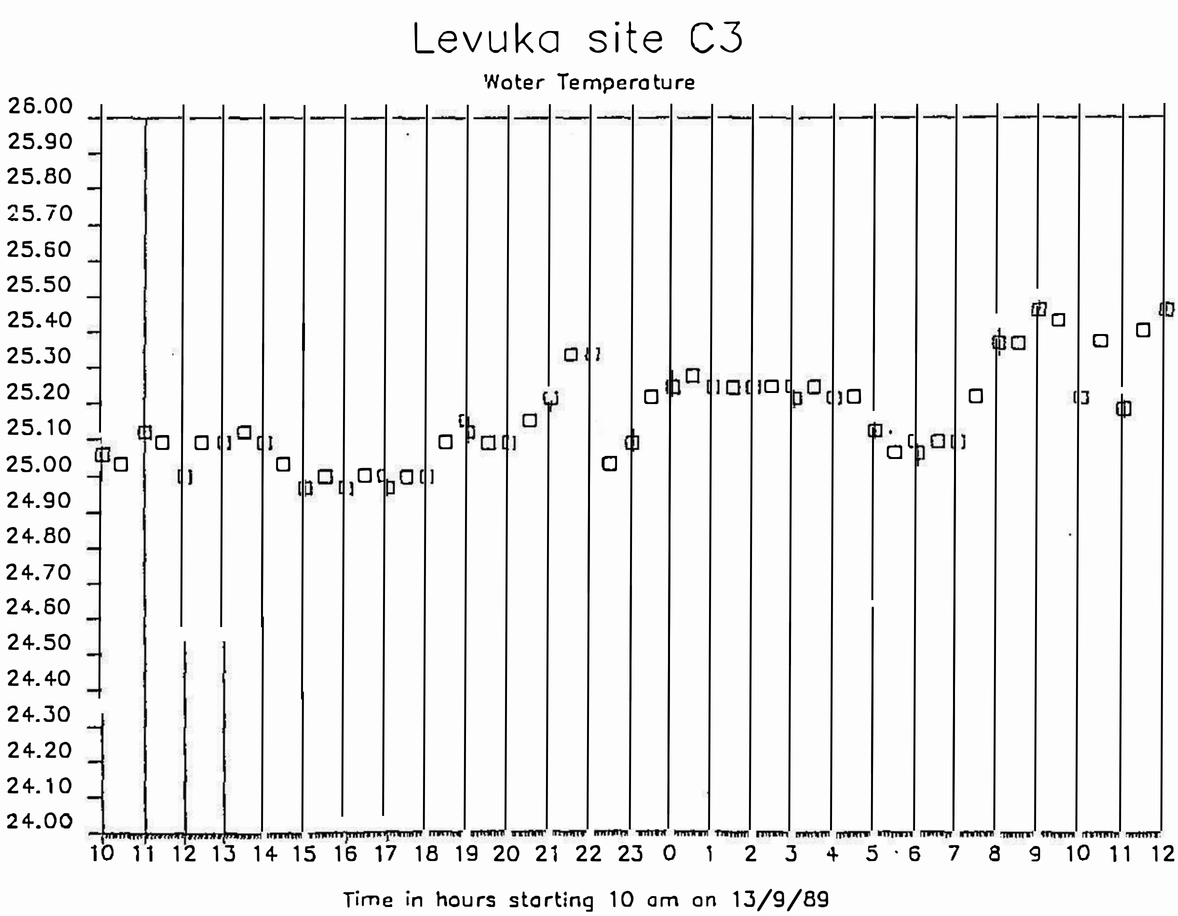


FIGURE 5

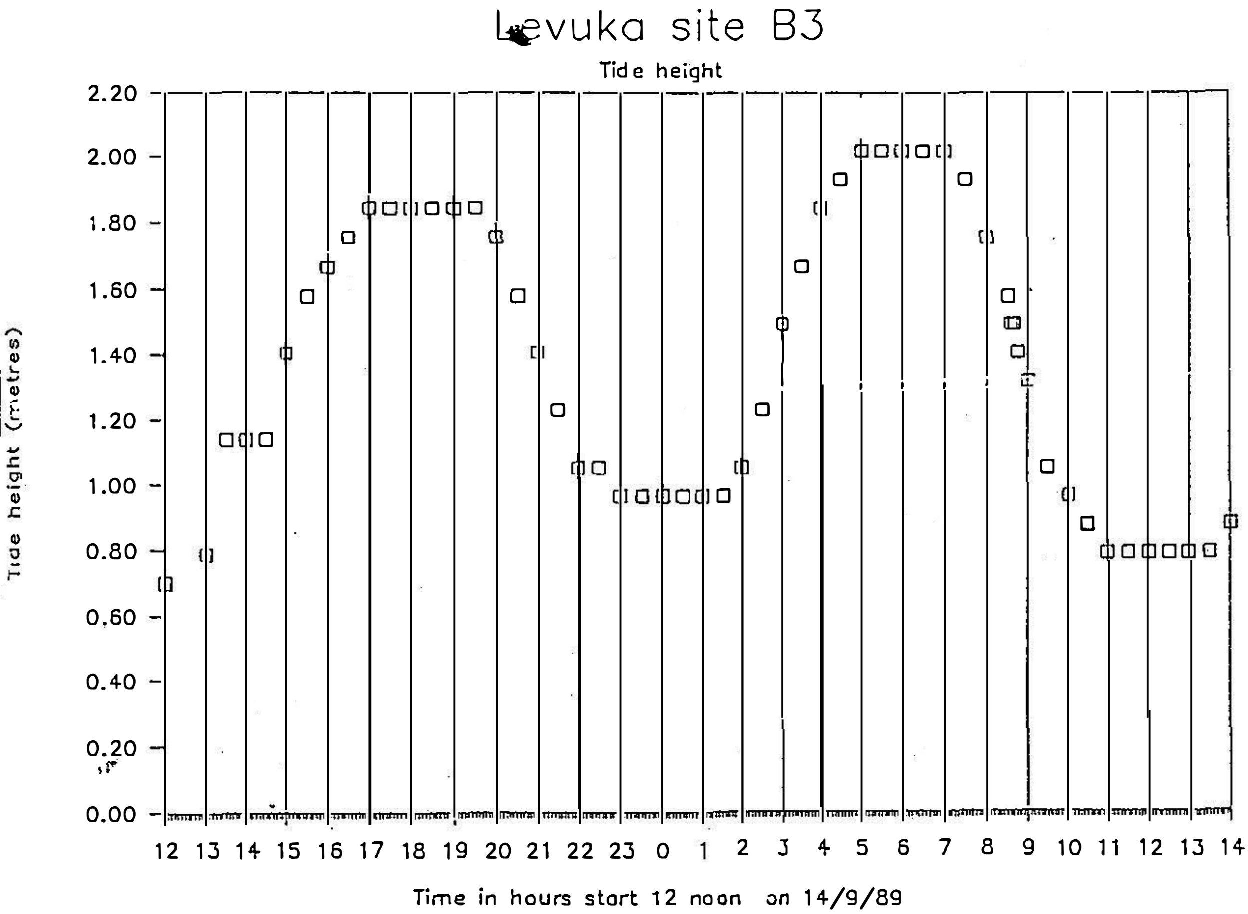


FIGURE 6

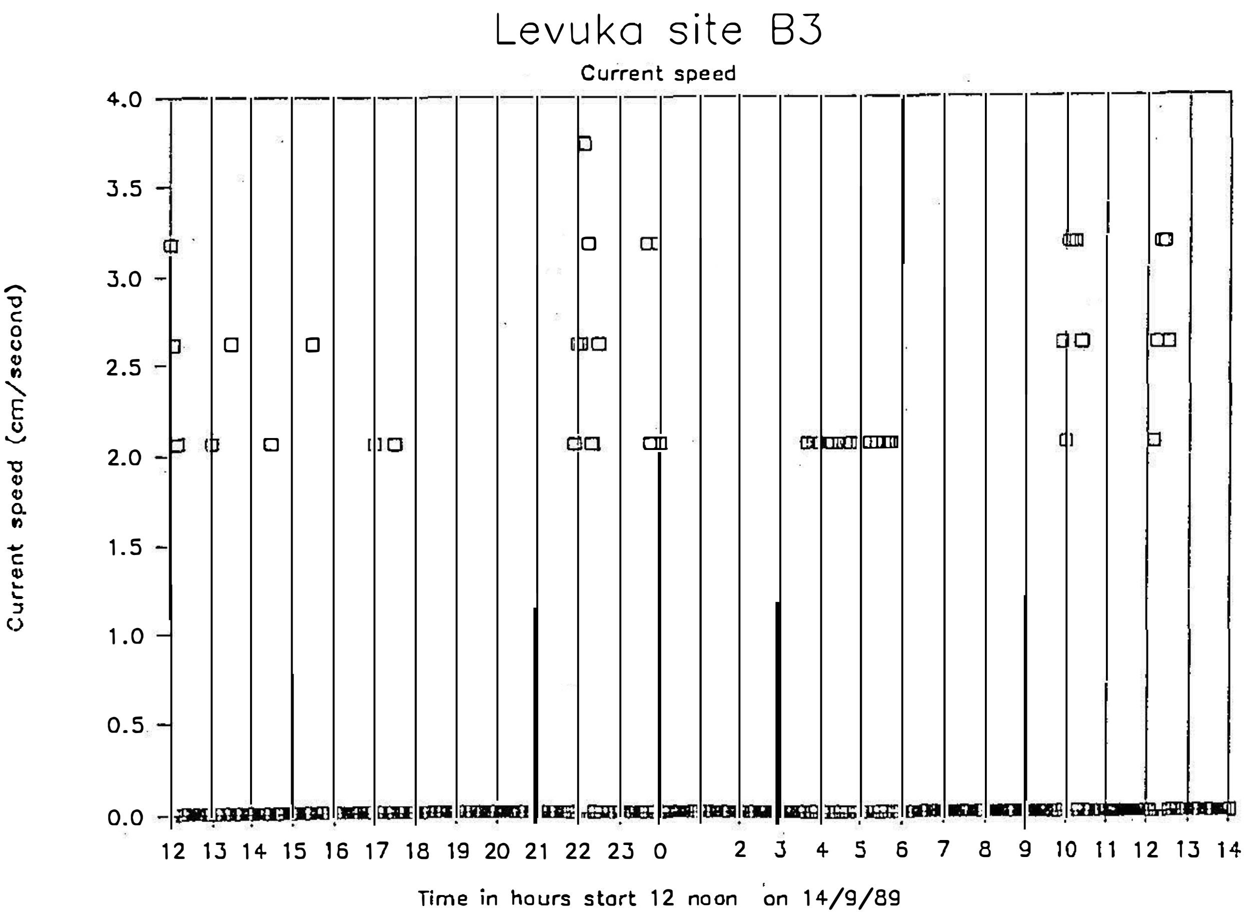


FIGURE 7

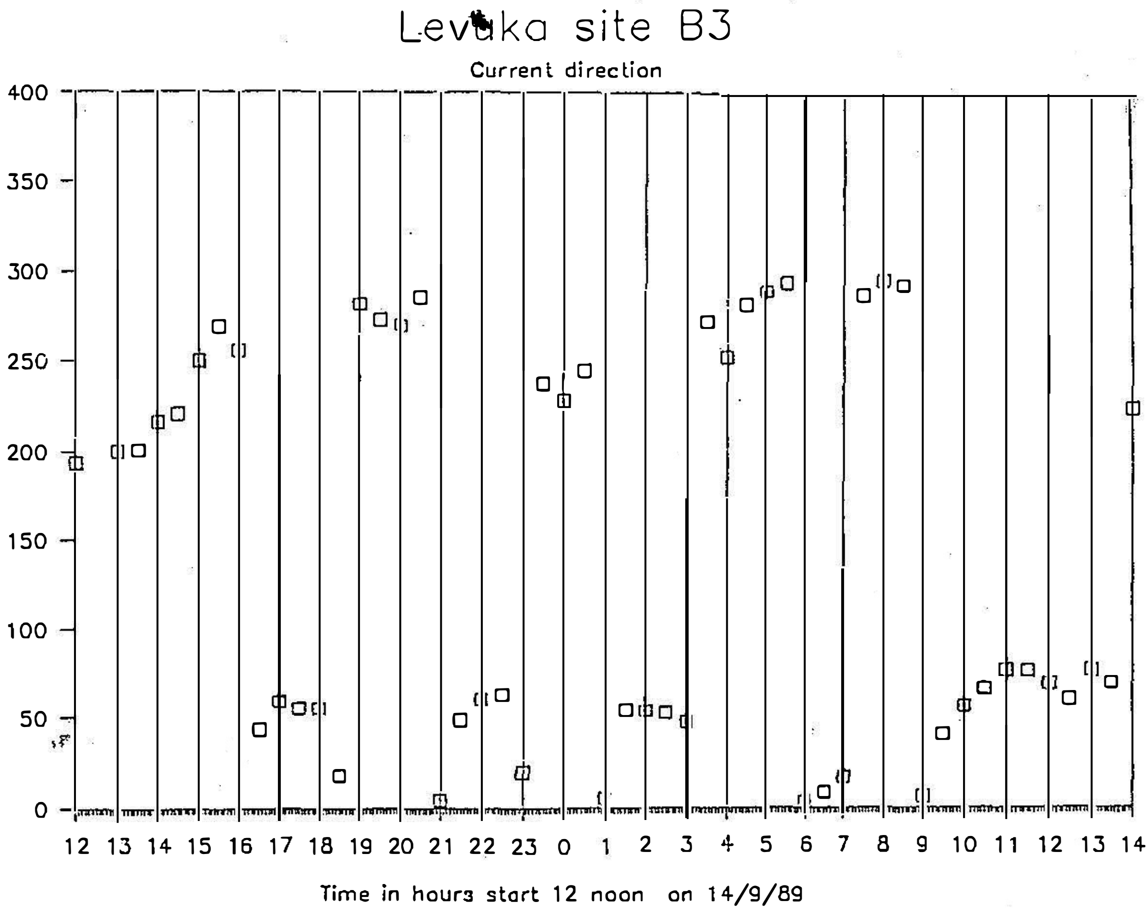


FIGURE 8

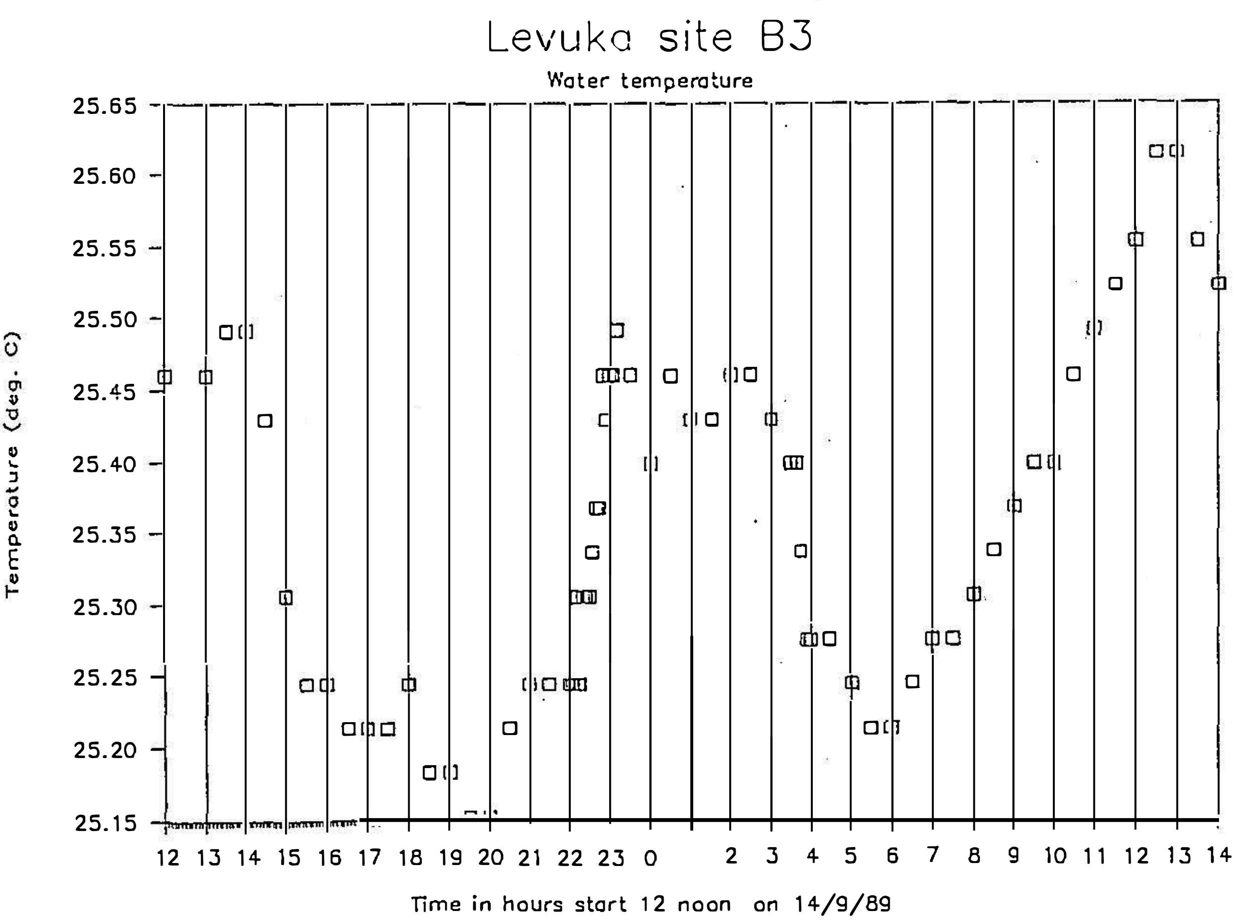


FIGURE 9

ZoBell J-Z Sampler : This sampler described by Zobell in 1941 (4) was designed for deep sea sampling but is also used in fresh waters. Figure 10 shows its general appearance. it has a metal frame (A), a heavy metal messenger (B), a sealed glass tube (C) attached to a rubber tube (D), and a sterile 350 ml glass bottle (E). The messenger (B) is released at the surface when the sampler reaches the desired depth, and breaks the glass tubing (C) at a file mark. The bent rubber tubing (D) then straightens out and the water is drawn in several inches from the sampler. A partial vacuum created by autoclaving of the sealed unit draws the water into the bottle.

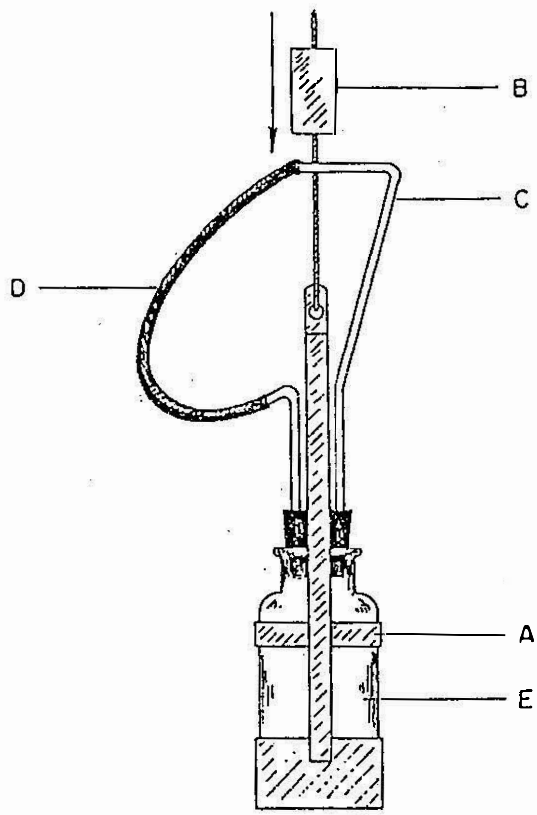


FIGURE 8 :: Zobell J-Z Sampler. (A) metal frame, (B) messenger, (C) glass tube, (D) rubber tube and (E) sterile sample bottle.

The Current Meter

The specifications of the recording current meter are as follows :

MEASURING SYSTEM:

Self balancing bridge with sequential measuring of six channels and recording on magnetic tape. A ten bit binary word is used for each channel.
Measuring Speed: 4 seconds each channel.
The channels are:

1. REFERENCE:

This is a fixed reading that acts as a control on the performance of the *RCM*, and also as an identification of individual instruments.

2. TEMPERATURE:

Sensor Type: Thermistor (Fenwal GB32JM19)
Ranges:
Low: −2.46°C to 21.40°C (standard).
High: 10.08°C to 36.00°C.
Wide: −0.34°C to 32.17°C.
Arctic: −2.64 °C to 5.62 °C
Accuracy: ±0.05°C.
Resolution: 0.1% of range selected.
63% Response Time: 12 seconds.

3. CONDUCTIVITY: (optional)

Sensor Type: Inductive cell.
Range: 0 to 77 mmho/cm., (standard).
25 to 72 mmho/cm.
25 to 38 mmho/cm.
Resolution: 0.1% of range.
Calibration accuracy: ±0.025 mmho/cm.

4. PRESSURE: (optional)

Sensor Type: Bourdon tube driving a potentiometer.
Range: 0-100 PSI, 0-200 PSI, 0-500 PSI, 0-1000 PSI 0-3000 PSI and 0-9000 PSI. (The last range only for RCM5.)
Accuracy: ±1% of range
Resolution: 0.1% of range.

5. CURRENT DIRECTION:

Sensor Type: Magnetic compass with needle clamped on to potentiometer ring.
Resolution: 0.35°.
Accuracy:
±7.5° for current speed within 2.5 to 5 cm/sec., or 100 to 200 cm/sec.
±5° for current speed within 5 to 100 cm/sec.
Maximum Compass Tilt: 12° from horizontal.

6. CURRENT SPEED:

Principle: Rotor with magnetic coupling through instrument case. The number of rotations during the period between two samplings is counted by an electronic counter.
Range: 2.5 to 250 cm/sec.
Accuracy: ± 1 cm/sec., or ± 2% of the actual speed, whichever is greater.
Starting Velocity: 2.0 cm/sec.

CLOCK:

Type: Quartz Clock 2574.
Accuracy: Better than ±2 sec/day within 0°C to 20°C.
Sampling Intervals: 0.5, 1, 2, 5, 10, 15, 20, 30, 60 and 180 minutes, selected by interval selecting switch.
External Triggering: For calibration purposes, a six volts positive pulse to terminal on top end plate will activate the instrument.

RECORDING SYSTEM:

Type: Reel to reel 1/4 inch magnetic tape.
Coding: 10 bit binary words (short and long pulses) in serial form.
Storage Capacity: 10,000 samplings using 600 feet of magnetic tape on three inch reels.

TELEMETRY:

Acoustically:
By switching on and off carrier from acoustic transducer.
Frequency: 16384 Hz ±5 Hz.
Detection Range: Typically 800 meters with *Hydrophone Receiver 2247*.

By Cable:
5 volts negative, short and long pulses from terminal on top end plate may be used for real time readings and for calibration purposes by use of *Printer 2860* or similar readout equipment.

POWER:

Battery: 9 Volts, non-magnetic. NOVEL 5147.
Size: 63 x 50 x 80 mm.
Capacity: sufficient for 10,000 samplings.

MOORING:

Spindle designed for 15 mm. maximum diameter wire rope. Gimbal mounting permits 27° deviation between spindle and instrument.
Breaking load of spindle is 4700 kg.

The drag force on the RCM and the Viny Float is:

	RCM	Viny Float Set 22098
1 knot	0.50 kg	1.50 kg
2 "	1.80 "	2.00
3 "	4.10 "	4.50
4	7.20 "	7.60
5	8.10 "	12.40

EXTERNAL MATERIALS:

Pressure Case: Cu Ni Si alloy (OSNISIL) and stainless acid proof steel, epoxy coated.
Vane: 8 mm PVC.
Other plastic parts: Polyamid and Polystyrene.
Other metal parts: Stainless acid proof steel and nickel plated bronze, epoxy coated.

		RCM4S	RCM5S
DEPTH CAPABILITY:		2000m	6000m
NET WEIGHT:			
Recording Unit,	in air	13.7kg	15.8kg
	in water	9.2kg	11.0kg
Vane Assembly,	in air	12.9kg	13.4kg
	in water	8.1kg	8.5kg
DIMENSIONS:			
Recording Unit:	height	510mm	535mm
	diameter	128mm	
Overall length		1370mm	
Overall height		750mm	
Vane size		370 x 1000mm	
GROSS WEIGHT:			
Recording Unit		19.1kg	21.0kg
Vane Assembly		20.6kg	21.1kg

PACKING:

Recording Unit:
Plywood instrument case, 190 x 230 x 610mm

Vane Assembly:
Plywood case 155 x 400 x 1020 mm

SPARES:

A set of recommended spares is delivered with each instrument. (rotor, bearings, O-rings etc.)

WARRANTY:

One year against faulty materials and workmanship.

APPENDIX B

DROUGUE PATHS

APPENDIX C

Tide Tables for Suva Harbour 1989

AUGUST

		Time	m
1	Tu	0553	1.63
		1227	0.13
		1835	1.45
2	W	0029	0.38
		0639	1.63
		1310	0.14
		1919	1.47
3	Th	0114	0.37
		0723	1.60
		1351	0.16
		1958	1.48
4	F	0158	0.38
		0805	1.56
		1429	0.21
		2037	1.47
5	Sa	0242	0.40
		0846	1.50
		1507	0.27
		2115	1.45
6	Su	0325	0.43
		0925	1.42
		1545	0.35
		2155	1.43
7	M	0410	0.48
		1007	1.34
		1623	0.42
		2235	1.40
8	Tu	0457	0.49
		1055	1.26
		1702	0.49
		2322	1.38
9	W	0544	0.51
		1151	1.20
		1747	0.55
10	Th	0015	1.36
		0638	0.51
		1256	1.16
		1838	0.59
11	F	0112	1.36
		0737	0.50
		1401	1.15
		1935	0.60
12	Sa	0206	1.38
		0839	0.46
		1500	1.18
		2036	0.59
13	Su	0258	1.42
		0936	0.40
		1552	1.23
		2132	0.55
14	M	0349	1.48
		1028	0.32
		1638	1.30
		2228	0.49
15	Tu	0437	1.55
		1113	0.24
		1722	1.38
		2313	0.42
16	W	0522	1.62
		1157	0.16
		1804	1.48
17	Th	0001	0.34
		0608	1.68
		1238	0.10
		1846	1.57
18	F	0049	0.28
		0655	1.71
		1320	0.07
		1930	1.64
19	Sa	0137	0.23
		0742	1.71
		1404	0.07
		2015	1.69
20	Su	0227	0.20
		0832	1.67
		1449	0.10
		2101	1.70
21	M	0319	0.20
		0924	1.60
		1536	0.18
		2153	1.68
22	Tu	0416	0.22
		1023	1.51
		1627	0.27
		2251	1.63
23	W	0513	0.26
		1129	1.42
		1723	0.37
		2353	1.58
24	Th	0617	0.30
		1241	1.36
		1825	0.46
25	F	0059	1.55
		0726	0.32
		1351	1.33
		1934	0.51
26	Sa	0204	1.54
		0836	0.32
		1457	1.34
		2043	0.51
27	Su	0304	1.55
		0941	0.29
		1553	1.37
		2146	0.49
28	M	0357	1.57
		1035	0.25
		1644	1.41
		2240	0.45
29	Tu	0448	1.59
		1122	0.23
		1729	1.46
		2327	0.42
30	W	0534	1.60
		1204	0.21
		1810	1.49
31	Th	0011	0.39
		0618	1.59
		1243	0.22
		1848	1.51

SEPTEMBER

		Time	m
1	F	0053	0.38
		0657	1.56
		1320	0.25
		1924	1.52
2	Sa	0133	0.38
		0737	1.52
		1354	0.30
		1958	1.52
3	Su	0212	0.39
		0813	1.46
		1427	0.36
		2032	1.50
4	M	0250	0.41
		0850	1.39
		1500	0.42
		2107	1.47
5	Tu	0329	0.43
		0931	1.33
		1536	0.49
		2145	1.43
6	W	0412	0.46
		1016	1.26
		1616	0.55
		2231	1.39
7	Th	0459	0.49
		1111	1.20
		1701	0.60
		2325	1.36
8	F	0553	0.51
		1217	1.17
		1756	0.65
9	Sa	0027	1.35
		0655	0.51
		1324	1.17
		1859	0.66
10	Su	0127	1.38
		0759	0.48
		1426	1.21
		2005	0.64
11	M	0225	1.43
		0901	0.42
		1518	1.28
		2104	0.58
12	Tu	0317	1.50
		0952	0.35
		1604	1.38
		2157	0.49
13	W	0404	1.58
		1038	0.26
		1648	1.49
		2248	0.40
14	Th	0452	1.65
		1122	0.18
		1730	1.60
		2336	0.30
15	F	0540	1.71
		1204	0.12
		1812	1.70
16	Sa	0025	0.21
		0629	1.73
		1248	0.10
		1857	1.77
17	Su	0116	0.15
		0720	1.72
		1333	0.11
		1944	1.80
18	M	0206	0.12
		0812	1.67
		1420	0.17
		2033	1.78
19	Tu	0300	0.13
		0910	1.59
		1510	0.26
		2128	1.72
20	W	0355	0.18
		1010	1.50
		1604	0.37
		2228	1.64
21	Th	0454	0.24
		1118	1.42
		1704	0.47
		2333	1.57
22	F	0558	0.31
		1229	1.37
		1812	0.54
23	~~Sa~~	0041	1.52
		0709	0.35
		~~1338~~	~~1.36~~
		1926	0.57
24	Su	0147	1.51
		0818	0.37
		1440	1.38
		2034	0.56
25	M	0246	1.51
		0919	0.36
		1534	1.42
		2134	0.53
26	Tu	0341	1.53
		1010	0.34
		1621	1.46
		2224	0.49
27	W	0428	1.54
		1055	0.33
		1702	1.50
		2309	0.45
28	Th	0513	1.54
		1134	0.33
		1740	1.54
		2351	0.41
29	F	0554	1.52
		1210	0.34
		1815	1.56
30	Sa	0031	0.39
		0634	1.49
		1243	0.37
		1846	1.56