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CRUISE REPORT

NAHA WASTE WATER OUTFALL, HONIARA, SOLOMON ISLANDS

17 June - 8 July 1981

by

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INTRODUCTION AND BACKGROUND

This study was undertaken as part of the CCOP/SOPAC Work Programme CCSP-1/SI.17 (Study of inshore environments in the coastal zone of the Solomon Islands) and CCSP-1/SI.19 (Foundation studies for engineering projects in nearshore areas of the Solomon Islands).

OBJECTIVE OF THE FIELD PROGRAMME

The Solomon Islands Government (SIG) is considering the construction of a marine outfall to handle the residential sewage from perhaps 250 to 650 units which are planned, under construction, or already in existence in the vicinity of Naha Valley. SIG has requested the UNDP to obtain information on the impacts of the planned discharge. Environmental information relative to the design and construction of the planned outfall is also being sought.

Outfall design studies normally require investigation of winds, waves, tides and currents, water mass characteristics, and the configuration and composition of the sea bed. Since there are already 5 other outfalls discharging into the Honiara nearshore waters within 700m of the planned outfall site, it was also appropriate to make a limited investigation of the environmental impacts generated by the existing discharges. A very brief inspection was made of habitats in the area of existing outfalls and the site of the proposed outfall.

Results of the present study are presented in the tables and text of the report and on the following figures accompanying this report:

Figure 1 Bathymetry and Dive Tracks

2a, b, & c Tidal Curve

3a, b, & c Drogue Tracks

4 Location of Waste Water outfalls

Figure 5 Map of station locations for water samples collected for coliform analysis

PERSONNEL PARTICIPATING

Wendell Gayman, Marine Scientist, UNDP
Garry Gauss, Marine Geologist (Engineering), UNDP

Canoe operators were provided by the Geological Survey Department and shore labour was provided by the Public Works Department, Honiara.

EQUIPMENT AND FACILITIES

The UNDP supplied the following items of equipment:

- Decca Trisponder radio positioning system
- Raytheon DE-719 echo sounder
- NBA DNC-3 current meter
- Nikonos IV underwater camera
- Secchi disk
- Wooden drogues

The above equipment worked satisfactorily most of the time. However, the DNC-3 current meter failed on the last day of use, and several drogues were lost, perhaps due to loss of buoyancy. There was some evidence that the crowding of equipment in the canoe and the intensive spray may have been hard on the electronic gear.

The Solomon Island Government (SIG) supplied the following equipment and services:

- 2 Suzuki jeeps with petrol and oil
- 2 outboard motors with petrol and oil
- 1 canoe
- 1-4 labourers/boatmen for 8 days
- office/storage space with telephone
- telex facilities
- aerial photographs
- surveying assistance
- cloth sample bags
- foul weather gear
- scrap metal
- kerosene lanterns

- ice boxes
- analysis of 32 water samples for total coliform and faecal coliform
- computerized wind data summaries for Henderson Field
- data on characteristics of the Honiara area outfalls
- continuous tidal predictions and records from June 26 through July 7

In addition, recorded wind data for July 1-July 8 has been promised, as soon as it becomes readily available. All of the labour, services, and materials supplied by SIG were satisfactory except that the canoe was a little small for some of the field work carried out.

PRELIMINARY RESULTS

Climate

The weather and climate of the Solomon Islands can be explained largely by the seasonal movement and development of the equatorial trough, the belt of low pressure migrating between hemispheres following the apparent movement of the sun, and the subtropical ridge of the southern hemisphere, the belt of high pressure typically located at about latitude 30^{o}-35^{o}S (Solomon Islands Ministry of Agriculture and Lands, 1980).

West and northwesterly monsoonal winds blow through the Solomon Islands from January to March when the equatorial trough is usually found close to or south of the Solomons. When the equatorial trough moves north of the equator from May to October the Islands lie within the region of the southeast tradewinds. The tradewinds are usually stronger and more persistant than the monsoonal winds. The transition months between the two seasons are marked by a greater frequency of calm periods.

Throughout the Islands, the average frequency of cyclone occurrence is 1-2 per year. Because the cyclones are usually in their early stages of development, they are often relatively small.

Winds

A knowledge of winds in the region is important because the local winds generate most of the waves occurring in the area, and also some of the nearshore currents.

East to southeast winds are usual from May to October or November. West to northwest winds occurring from January to March are usually lighter than the southeast trades and much less persistent. Also, there is a strong diurnal wind pattern caused by the islands themselves. In coastal areas the seabreeze strength typically reaches 20-30km/hour. At night land breezes can occur due to the more rapid cooling of the land. However, these offshore breezes are much weaker than the daytime seabreezes (Solomon Island Ministry of Agriculture and Lands, 1980).

Strong winds averaging at least 39km/hour (24mph) are likely to occur in Honiara less than 6 days per year.

The nearest recording anemometer to the field area is located next to the Marine Department offices on Point Cruz about 3km west of Naha Creek. Although this instrument is designed to record wind speed and wind direction continuously, gaps in the records frequently occur due to instrument failure. Unfortunately the winds records from this instrument were not available for the preparation of this report. When the records become available, they will be summarized in an addendum.

Another recording anemometer is located at Henderson Field, about 7km to the east of Naha Creek, and about 1.6km inland from the shoreline. Probably data from this anemometer is not as representative of the wind conditions at the field site as information from the Point Cruz recorder. However, 4 to 6 years of summarized wind data representing all times of days is available from the Henderson Field Station.

The wind direction at the field site was occasionally determined with a hand compass, and wind speed estimates were made visually; these crude observations were based upon the sea state.

The occurrence of prolonged repeated periods of calm is of particular importance to the study because during such periods the mixing rate of surface waters may be minimal. When the wind is not blowing and the sea is calm, mixing will be limited to whatever rates may be generated by tidal or regional currents.

Summaries of the Henderson Field wind records show that about 98% of the time wind speeds in the area are less than 13km/hr (7 knots) from midnight to 0900. Wind speeds exceed 13km/hr occur about 30%, 47%, and 24% of the time at 1200, 1500, and 1800hrs respectively. At 2100hrs, winds in excess of 13km/hr occur about 5% of the time (Table 1). Wind velocities over the sea surface may be 30-40% greater than overland areas. However, wind velocities of less than 20km/hr (10.8 knots) are not likely to generate waves or currents of much significance. The midday and afternoon winds blow predominantly from the northeast, and occur about 18% of the time.

The Henderson Field summaries of monthly wind data also show that periods of calm occur throughout the year, varying from 54.6 to 63.5 percent of the time. Calm periods occur somewhat more often in April and December, and are least common during August and February (Table 2).

From January through March winds blow most frequently from the northwest. During the second and fourth quarter of the year, winds from the northeast are most common. From July through September the winds come predominantly from the southeast and east.

The frequency of occurrence of winds less than 13km/hr in the afternoon ranges from 34-35% of the time in August and October to 73% of the time in December (Table 3). The dominant direction of the afternoon winds for the various months is the same as for wind at all hours, except for July when the dominant wind directions for all hours, and for the 1500 observations are eastnortheast and southeast, respectively.

During the afternoons on July 1, 2, 3 and 6th the afternoon sea breeze was observed to begin rising between 1130 and 1300. The breeze blew from the northeast at an average estimated speed of 15 to 20 knots and persisted until 1600-1800 or later. These observations should be confirmed whenever the recording anemometer records become available from the Marine Department.

Rainfall

Honiara lies in the rain shadow of the 2400m mountain range which extends the length of Guadalcanal. Nevertheless, Honiara normally receives about 90-100mm or more of rain per month throughout the tradewind season. The wettest months in the Solomon Islands occur during the northwest monsoon season (January through March). Average monthly rainfalls in Honiara during this season range from 277mm in January to 362mm in March. Total average rainfall in Honiara is 2177mm per year. The average number of rainy days per month ranges from 13 (June, August, and September) to 23 (March).

In 1981 a severe drought began in March and persisted through the end of the period of field investigation on July 8. For this reason, the runoff from Vura and Naha Creeks and the Mataniko River during the field investigations period was much less than normal.

Bathymetry

A detailed bathymetric survey was undertaken off Naha Creek in order to obtain accurate water depths over the sea bed area likely to be traversed by any proposed offshore wastewater pipeline. Survey lines were perpendicular to the coastline; survey lines were about 25m apart. The survey covered an area extending about 400 metres offshore and about 250m to the west of, and 100m to the east of, Naha Creek (figure 1).

Out to 40 to 50m from the shoreline (as shown on the 1:2500 topographic map) water depths are in most places too shallow to allow access by the survey canoe and the sea bed is generally rugged and rocky. In many places the rocks may be above water for much of the time. Between 40 and 50 metres from the shoreline there is a sharp drop in sea bed level to between 2 and 3 metres beneath datum and the sea floor becomes sand covered. From this level the sea bed slopes in the offshore direction with a gradually increasing steepness attaining a depth of 30 metres about 400m offshore, at the northern edge of the area surveyed. No distinctive bathymetric features of any significant size occur in the area surveyed and the echo sounder records show a generally smooth sea bed.

Sea Bed Sediments and Benthic Habitats

A diving inspection survey was carried out along a route extending from a position about 300m north of Naha Creek to the mouth of the Creek itself. A second dive was made at a position about 350m north of the mouth of Naha Creek (see figure 1). A third dive was made in 3 to 7m of water, traversing parallel to shore from the Vura outfall west to Naha Creek.

Dive 1: The sea bed proved to be largely sandy along the entire route. At the offshore end of the route, in about 17m of water, a few isolated boulders of algal material up to about 60cm across occurred. These have probably formed by growth *in situ*. Along most of the route from the offshore end up to within about 50m from the rocky shoreline the sea bed sand is partially covered by a thin mat of brown algae. In many places this is disturbed by the burrowing of marine organisms. This suggests that in this area there had evidently been no recent sea bed sediment transport by currents. Inshore of this, however, the sea bed surface sand was strongly rippled and the sediment was being disturbed by wave action.

Sand samples recovered at the offshore end of the route, and from a depth of about 6m near the inshore end, consisted largely of a medium grained grey sand with some granule sized particles. The dominant sand material appears to be volcanic rock particles with a little light coloured biocarbonate material.

A number of benthic fish and invertebrates, and an abundance of organism burrows were observed along this traverse. The sand deposited on the sea bed surface around the organism burrows was somewhat darker grey than the surrounding surface sediment. This suggests the presence of reducing conditions. Reducing conditions are often indicative of polluted environments However, the colour contrast was not great, and various fauna and the organism burrows were fairly common.

For these reasons, these crude qualitative observations suggest that the bottom is not necessarily polluted.

Dive 2: This dive was undertaken near the offshore edge of the survey area north of Naha Creek. Inspection of the sea bed was carried out over a distance of about 50m in water depths ranging from about 27 to 29m. The sea bed surface sediment here consisted of a silty, fine to medium grained, brownish-grey sand. One boulder of algal material about 40cm across was observed lying on the sea bed in the area of this dive. The sand surface was covered by a thin brown algal mat except where this was disturbed by burrowing organisms. On the basis of the number of benthic fish, invertebrates, and organism burrows this area also can be considered to have at least a moderately healthy bottom.

Dive 3: This dive was made to observe the condition of the sea bed in the vicinity of the Vura outfall and the mouth of Naha Creek. Colour photographs were taken of the sea floor.

Sea urchins, star fish, live coral and other invertebrates were observed living within 10-20 metres of the Vura outfall terminus. However, in the same area sand and rocky areas were often covered with a thin brown mat of organic material; there were extensive barren areas of rock, and dead coral; organism burrows were much less common than elsewhere, and small and large pieces of junk were common on the bottom (of course, the larger objects could not have come through the outfall pipe).

The qualitative conclusion was that the sea bed showed definite signs of pollution (i.e. degradation of biological habitats) within 20 to 40 metres of the Vura outfall terminus.

In the vicinity of the Naha Creek mouth the water was much clearer than it was 10m from the Vura outfall, and the sand and rock bottom areas appeared much healthier, although the organic deposits were still present in some areas.

Waves

All of the higher waves observed in the nearshore waters off Honiara occurred in the afternoon hours, and all appeared to be generated by sea breezes in the local area. These waves approached the shoreline from the same direction as the wind, i.e. from the northeast. The maximum wave height was about 1.0 metre, and the higher waves had periods of 3-5 seconds. The afternoon wave action repeatedly observed could possibly have been directly responsible for an estimated 10-20% of the westerly currents.

During the night and early morning hours the maximum wave height decreased to 30cm or less. Usually, only occasional very low swells were observed during these periods. Probably these low swells come from the direction of Sealark Passage, and it is assumed that they were generated by the tradewinds further east.

Wind direction statistics indicate that during January through March the waves arriving at the Kukum shore must in many cases come from the north or northwest. Probably these waves will have less effect than the sea breeze waves on the generation of currents.

Tides

A knowledge of the tides is important for outfall studies because

1) changes of water level must be considered when determining water and sea floor depths;
2) tidal changes may be responsible for the major currents in the nearshore area, and
3) tidal fluctuations create a distinct habitat along the shore for intertidal organisms.

Tidal predictions for Honiara can be made by applying corrections to the Admiralty tidal predictions for Dredger Harbour, Papua New Guinea (Hydrographer of the Navy, 1980). Also, tidal predictions for Honiara, based upon Honolulu, Hawaii, tides have been prepared by Ken Slade, Australian Naval Hydrographer presently assigned to the Solomon Island Marine Dept. in Honiara.

During the first 6 months of 1981 the Honiara tides have been recorded only intermittently. However, on June 26, 1981 Mr Slade commenced a one month continuous tidal recording period. The recorded tides for the period 26 June through 8 July are presented in figure 2, and Table 4.

The Honiara tides are predominantly of the daily type, having one high and one low during a 24-hour period. However, the Dredger Harbour predictions suggest that during a few days each month the tides may shift to a semi-daily type, characterized by two high tides and two low tides each day. During the 11 day period June 27-July 7, the recorded tidal range varied from 0.37m to 0.85m (Table 4). The Interval between the high and the succeeding low tide varied from 10hr. 30min. to 12hr. 30min. The interval between lows and the following highs ranged from 11hr. 45min. to 13hrs. 13min.

During the neap tidal period the tidal ranges based upon the Admiralty predictions were approximately the same as those recorded, while the ranges derived from the Hawaiian predictions were about 10-20% higher than the recorded tides. During the spring tidal period predictions based on the Admiralty tides for Dredger Harbour were 30-40% too high, while predictions based on the Honolulu tides were only 10-16% too high. The high tide predictions obtained from the Admiralty tables generally were within one hour of the recorded high tides, but time differences as large as 135 minutes did occur. The time of the high tide predictions based on the Hawaiian tides was approximately 12 hours out of phase with the times of the recorded Honiara high tides.

Currents

Currents are important to outfall studies because current flows are likely to be primarily responsible for the direction and rate of movement of the discharged effluent, and the turbulence associated with the currents may be important in determining the rate with which the effluent mixes with the surrounding sea water.

Currents may owe their origin to: 1) local winds; 2) tidal changes; 3) wave action; and 4) large scale eddies, which may be associated with major or regional ocean currents.

Currents in the Honiara coastal waters were studied during the first 8 days of July by tracking surface and subsurface drogues, and by measuring velocities with an NBA DNC-3 current meter. The daily current studies carried out generally lasted for several hours in the morning and/or afternoon. However, in order to obtain data from all hours of the day, and from a complete 24 hour tidal cycle, measurements were made during a 9-hour, largely daylight period on July 3, and during a 10-hour period during the night of July4-5.

The drogues used were 8 square foot (0.7sq.m.) current crosses constructed of plywood. Most were designed to float at the surface, but one was built to determine the current at a depth of 9m. One to four drogues were tracked at any given time. Initially, these were placed in the sea off Naha Creek in a line perpendicular to shore. Normally drogue positions were determined at approximately 30 to 60 minute intervals, but on some occasions a period of 2-2.5hrs passed between fixes. Drogue positions were usually determined with a Decca Trisponder but horizontal sextant angles were used for positioning during short periods on July 2 and 3. During a 54 minute period of measurement on July 8, only one drogue was used, and positions were visually estimated relative to nearby shoreline features. Drogues were tracked over distances of 50 to 3500 metres. Whenever the drogues moved east of Renadi industrial area, or to the west of the hospital, they were retrieved and relocated some distance up current from the mouth of the Naha Creek.

It was found that most of the time the drogues moved parallel to the shoreline, in an eastward or westward direction (figures 3a through 3c). Probably the path of the drogues did not depart more than 20-30° from the parallel, for more than 10% of the time. Only rarely did the drogues drift ashore.

The data collected indicate that the drogues generally drifted to the eastward during the night time and morning hours. Usually, the current direction changed sometime between 1100 and 1400, when the drogues began moving to the west. On July 4, the westward drift shifted to the eastward between 2100 and 2200.

Velocities obtained by drogue tracking are most representative of true current velocities when the current is fairly constant in speed and direction. When current directions are changing 180°, the velocities obtained by drogue tracking are likely to be much lower than the actual current velocities occurring at the beginning and end of the tracking period. Velocities determined by drogue tracking ranged from 0.04 to 0.4cm/sec (about 0.08 to 0.8 knots). However, most of the time velocities varied from 0.1 to 0.2cm/sec (0.2-0.4 knots).

The subsurface drogue which measured currents at a depth of 9m usually followed fairly closely the movement of the surface drogues released in the same vicinity.

The data collected was insufficient to indicate any strong correlation between current speed and wind velocity, stage of tide, or hour of the day (i.e. day time or night time conditions).

The rough correlation between westerly flow and the afternoon sea breezes suggests that westerly currents may owe their origin to the local winds, and that during calm periods, the nearshore currents may revert to a predominantly eastward flow which might be related to the regional currents in the area. During the period of the field investigation, the wind blew every afternoon from the east or northeast at speeds of 10-20 knots or more. During the same period the current flowed to the westward at speeds of 0.2-0.4cm/sec or more. However, it was noted that the eastward current sometimes persisted 1-2 hours after the afternoon winds had attained a considerable velocity (estimated in excess of 15-20 knots). Also on July 3 and 4 the westward flow persisted for several hours after the afternoon sea breeze had diminished. Finally, during the mornings of July 7 and 8 the change from easterly to westerly current appeared to precede the rise of the afternoon winds by one and several hours, respectively.

The observed pattern of local currents might alternatively be attributed to the tides. If the currents were predominantly of tidal origin then one would expect that the current direction would change when the tides change, or at least the time of the change in current would take place at some relatively constant interval before or after the change in tide. During the first 7 days in July, the observed eastward currents usually occurred when the tide was falling, and the observed westward currents usually coincided with a rising tide.

On July 1, 2 and 3 drogue observations suggest that the midday current change from east to west took place less than one hour before, or simultaneously with the change of tide (Table 5). On July 6 the current change may have occurred $1\frac{1}{2}$ to $2\frac{1}{4}$ hours before the change of tide, and on July 7 the current change occurred about $2\frac{1}{2}$ hours before the change in tide. (Unfortunately, drogue tracking is not a good method for determining the precise time of current changes, unless the positions are determined at intervals less than 10 minutes. If drogue fixes are determined hourly, then the exact time of current change may be unknown within a period of 90 minutes or more. Also, it should be noted that the times of the current shift may vary with both distance along shore and offshore).

During the night of July 4-5, the westward flowing current changed to an easterly direction about 8 hours after the change in tide and about 2-5 hours after the afternoon wind dropped. A perhaps anomolous westward to eastward current change occurred during a short period of observation at about 0913 on July 8 when there was no wind. This change occurred about 3 hours after the high tide peak.

If the westward flowing nearshore currents off the Honiara shoreline are predominantly due to wind action, then such currents may be expected to occur every day whenever a substantial sea breeze from the northeast occurs. In the absence of an afternoon sea breeze one might expect the eastward flowing currents observed during night and early morning hours to continue all day. If these easterly currents are of regional nature, they may be expected to change substantially with the seasons.

On the other hand, if the westward flowing afternoon currents are predominantly of tidal origin, then one may expect that the time of the current changes will shift gradually, as the time of high and low tide periods change from month to month. Also, one might expect the current velocities to increase during the spring tidal periods (which occur every two weeks) and to decrease during the intermediate neap tidal periods.

Further work will be required in the area in order to determine the origin of the local currents.

Some additional current data was obtained using the NBA DNC-3 current and water quality meter (Table 6). Most of this data was colected from the survey canoe while it was moored to buoy station YB. This station is located in 28m of water about 350m off the Naha Creek shoreline (Figures 1 and 3).

The DNC-3 data is not considered to be very good because of the extreme variation in speed and direction that was noted over periods of tens of seconds and minutes. This variation is believed to be due to:

1) wave action which caused the direction of movement of surface waters to reverse every 3-6 seconds whenever the waves were high (i.e. during the occurrence of the afternoon sea breeze)
2) the swinging of the canoe through a 90° to 180° arc while moored to the buoy. This created a strong relative motion through the water at angles up to 90° from the prevailing current direction.

Surface and near surface currents to a depth of 17m usually moved in directions departing not more than 30^{o} from the trend of the coastline.

Surface and near surface (i.e. to depths of 17m) current speeds ranged from 0.05 to 0.30cm/sec and probably averaged between 0.1-0.2cm/sec. The easterly flowing current directions measured usually varied from 070^{o} to 090^{o} True while the currents to the west generally flowed in a direction from 270^{o} to 310^{o}T. The currents 1-3 metres above the bottom varied from 0 to 0.25cm/sec but were generally slower than the surface currents. Easterly bottom currents occasionally flowed in a more northerly direction (050 to 080^{o}T). Some observations of currents flowing on courses 140^{o} to 190^{o} T are believed to result from the swinging of the canoe.

Water Mass Characteristics

Water mass characteristics were measured on July 1, 2, 3, 4 and 5 using a Secchi disk and the NBA DNC-3 current meter which was fitted with electronic thermistor and conductivity sensor. No calibration was carried out. Most of the measurements were made at the yellow buoy which was located about 350 metres offshore in 28 metres of water, but some were made closer to the shoreline (Table 6 and figure 3).

Sea water temperatures ranged from 27.8^{o}C to 28.9^{o}C. The accuracy of the sensor is claimed to be $\pm$ 0.4^{o}C. Consequently, these differences are not considered to be significant. There did not appear to be any consistent variation in temperature with depth. Possibly, there was a slight tendency for the lower temperatures to occur more often during the late night time hours.

Electrical conductivity ranged from 53.5 to 54.0 m.mho/cm; accuracy of the sensor is $\pm$ 1.2m.mho/cm. These values correspond to salinities of 32.8 $\pm$ 0.7 ppt (parts per thousand). The differences recorded do not appear to be significant. There did not appear to be any correlation between conductivity or salinity and depth.

While diving during daylight hours near the shoreline it was noticed that there was a marked shimmering (or distortion of light waves) near the water surface in depths of 10 to 50cm. Such distortion is typical of a fresh water (or brackish water) - salt water interface. Apparently there was a low density layer of fresh or brackish water at the surface near the shoreline. Probably this layer was produced by sewage discharges and/or flows from Naha and Vura Creeks. Unfortunately, it was not possible to make quantitative measurements of this fresh or brackish water surface layer.

Secchi disk readings ran as high as 15 metres, and probably would have been much greater if the sky had been clear and the sea surface calm. In less than 10m of water the disk could be seen on the bottom almost all the time except when the canoe was actually in the dense gray cloud of effluent that was sometimes visible around the Vura outfall when the sea was calm.

Waste Water Discharges into the Honiara Coastal Waters

The Ministry of Public Works services 10 waste water outfalls which discharge into the sea in the Honiara area (figure 4). These outfalls discharge primarily residential wastes, but the Point Cruz, Renadi and Rove outfalls also carry wastes from laundries, printing plants, warehouses, a commercial garage, a clinic, a prison, and an electrical company.

The average volume of discharge is about 130,000 gallons per day (Table 7). This does not include septic tank wastes discharged into the Vura outfall from pumping trucks (about 800gpd), and septic tank overflows from several additional facilities, such as the hospital. Average daily discharges from individual outfalls range from about 2,600 gpd (Bahia) to about 40,000 gpd (Vura). The average discharge from the proposed Naha outfall might range from 30,000 gpd for 250 residential units to 78,000 gpd for 650 units.

The effluent is pumped through two of the outfalls (Point Cruz and King George VI School). The other outfalls are simple gravity drains. The various outfalls were constructed during the period 1968 through 1972, except for the Renandi outfall, which was built in 1975.

The Point Cruz outfall pipe was built of concrete. The others have been constructed from cast iron pipe. The depths of the outfall termini range from 1 to 4 metres below the high water level. Most of the outfalls that have been constructed across the slightly raised coral reef terminate within one to several metres from the outer edge of this reef. However, the Point Cruz outfall has a total length of 90 metres.

At low tide, only the Point Cruz outfall extends for more than 30m, across the sea floor.

There are 5 outfalls located in the Kukum area within 700 metres of the mouth of Naha Creek. These have a total average daily discharge of about 79,000 gpd, or about 60% of the total Honiara area discharge.

All of the 5 outfalls closest to Naha Creek terminate at the edge of the raised coral reef which outcrops in the intertidal zone. Because of broken pipes, some of the effluent is discharged to the landward of the edge of the reef.

The proposed Naha outfall would discharge 30,000 to 78,000 gpd, depending on the number of residential units hooked up. The minimum proposed discharge would be roughly similar to the present discharges from the Mbua outfall (about 100m west of Naha Creek) or from the Vura outfall (about 220 metres east of Naha Creek). The maximum proposed discharge would be roughly equivalent to the present discharge from all 5 outfalls in the Kukum area.

Turbid waters, and an abundance of pink toilet paper fragments, were commonly observed within 30 metres of the Vura and Mbua outfalls, and were sometimes observed around the other Kukum area outfalls. Human faeces and oily slicks were occasionally seen floating on the surface within 60-100m of all of the Kukum outfalls. Obnoxious odours were sometimes detected along the shore in the vicinity of outfalls, but in some cases such odours may have resulted from the common uses of much of the shoreline area as a toilet.

Toilet paper, faeces, and other residential sewage debris was abundant in the shoreline area around the Vura and Mbua outfalls.

There were fewer signs of a polluted shoreline around the smaller Kukum area outfalls. These smaller outfall areas were frequently used for fishing.

Coliform Bacteria Counts

Factors affecting bacteria concentrations in receiving waters

The use of coliform bacteria counts is a widely accepted method of determining the hazards which various aquatic environments may pose to public health and safety.

Waters which consistently or frequently show total coliform counts in excess of 100mpn (most probable number) per 100 millilitres are usually considered to be unsafe for recreational use (Hazbun et al. 1979).

When assessing the results of coliform surveys, a wide variety of factors should be considered (Table 8).

The rate of die off of coliform bacteria in salt water is usually considered to be a function of salinity, time, and rate of dilution. Higher salinities and longer periods of exposure result in more rapid die off rates.

Thus the expected coliform concentrations in the vicinity of any sewage outfall may be inversely related to the distance from the outfall (a function of current velocity and time) and to rates of mixing. Mixing rates will depend upon turbulent conditions. Strong turbulence is favoured by high winds, rapid current velocities, and intensive wave action. Mixing is retarded by stratification which results from the presence of water masses of different salinity or temperature.

In the Honiara area relatively strong winds (with speeds greater than 10 knots) occur most often in the afternoons. Winds are usually quite calm during night and morning periods. Because of the strong afternoon sea breezes the waves are also highest in the afternoon. The sea is usually quite calm during night and morning hours but a low (15-30cm high) swell may be present, as a result of a) winds occurring some distance to the east, and b) waves approaching the Honiara shoreline through Sealark Passage. Although this swell or surge does not produce much mixing offshore, it may cause an alternate submergence and draining of intertidal areas along the shore which, in turn, might cause significant mixing of the waters located very close to the shoreline.

The introduction of large volumes of fresh water into the nearshore area tends to produce stratification. Because of lower density, fresh or brackish waters tend to remain on or flow to the surface, and resist mixing with denser, more saline waters. Introduced fresh water flows include both natural river and creek waters draining into the sea and sewage water discharges. Honiara area sewage water effluents discharged at a depth of 1 to 3 metres may be expected to rise rapidly to the surface with relatively little dilution. The dilution might be substantial for effluents discharged at greater depths. The resulting brackish water (effluent) may spread out in all directions at the surface whenever weak currents and calm seas prevail. If currents are moderate to strong and parallel to the coastline the effluent will form an elongate pattern along the shore, extending away from the outfall in the down current direction.

Higher rates of freshwater inputs (or effluent discharges) will promote greater or more persistent stabilities of the brackish surface layers. Such conditions will tend to reduce mixing rates and promote the spreading of high coliform concentrations.

Variations in fresh water inputs may result from regular and intermittent fluctuations in both natural and induced discharges into the sea. Sewage effluent discharges fluctuate regularly following 24-hour pattern. Peak discharges occur between 0600 and 0700 in the morning, and from 1700 to 1930 in the late afternoon and early evening. Minimum rates of discharge may occur in the very early hours of the morning before 0600.

Natural creek and river flows fluctuate according to the rainfall occurring during short periods immediately preceding the time of discharge. Natural flows may also depend on the degree to which the soils are saturated by rains which may have taken place during a period of several weeks prior to the occurrence of any given discharge.

The natural waters may be characterized by high coliform counts due to contamination of surface run-off by scattered (randomly distributed) human wastes, or by wastes discharged directly into the water. At least one septic overflow line is known to drain directly into the Mataniko River about 900m above the highway bridge. Seven of 10 water samples collected from the sea about 100m off the Mataniko River mouth during 1978-79 were found to be polluted, and the single sample collected from the River itself (near the mouth, see figure 4) was found to be polluted.

Clearly, increased fresh water discharges into the coastal waters will increase stratification, which tends to retard mixing. For this reason, and because the coliform concentrations in run off might be rather high, one might expect periods of heavy run off would promote the pollution of surface waters. If this effect commonly occurs in the Honiara nearshore waters, then one might expect the coliform bacteria concentrations in the surface waters of the sea to be greater most of the time, than the concentrations determined in late June and early July 1981 during the period of drought.

Existing data

In December 1978 Solomon Islands Ministry of Health officials began an 8-month monitoring programme of the marine waters off several Honiara outfalls (Hazbun, et al. 1979). At two month intervals surface water samples collected from 5 stations located in close proximity to the various outfall termini and from one station off the Mataniko River were analysed for coliform bacteria (figure 4). Two water samples were collected at each station, one at the surface, and a second deeper sample at an arm length below the surface. Each of the outfall stations was located about 100 metres north of the outfall terminus. It is believed that all or most of the samples were collected in the morning when the sea is usually calm and dispersive conditions are minimal.

If one accepts the definition of polluted waters as those containing 100 or more mpn (most probable number) of coliform bacteria per 100 millilitres, then the findings from the Hazbun et al. study may be described as follows. Of the 60 samples collected, 48 (80%) were polluted. Twenty three (61%) of the samples collected were very polluted (i.e. the total coliform count being equal or greater than 1000mpn/100ml). Fifty percent of the unpolluted samples were taken during the first sampling period in December, 1978, and 50% of the unpolluted samples represent the deeper water (arm length) collections. All of the unpolluted samples were from off the Mataniko River, the wharf area station (more than 600 metres from the nearest outfall at Pt. Cruz), or from the Point Cruz outfall station. During the entire 8 month survey period no unpolluted samples were found off the fishing village (Vura outfall), the hospital outfall, or the Rove outfall.

June-July 1981 Coliform Analysis

Between June 30 and July 8 thirtytwo water samples were collected for bacteriological examinations. The Honiara hospital laboratory analyzed each of these samples for total coliform counts, faecal coliform, and *E. coli* (Table 9). One sample was collected from the Mataniko River (near the mouth) and all of the other samples were taken in the nearshore waters off Kukum. All samples were taken from the top 10-25cm.

The total coliform counts of all except 4 samples (12.5%) exceeded 100mpn (most probable number) count per 100ml. This 100mpn/100ml is a widely accepted limit for safe recreational use of aquatic areas (Hazbun et al. 1979). If natural waters with bacteria counts exceeding this number are considered to be polluted, then the only samples analyzed which were not polluted were from: 115m north of (offshore from) the Vura outfall; 115m and 210m east of (up current from) the Vura outfall, and 30m north of (offshore from) the Bahia outfall.

All of the other samples were found to be polluted. Twelve samples (37%), with counts exceeding 1000, can be considered very polluted. In five cases the mpn count exceeded 1800; actual coliform counts for these 5 samples may have been much higher, because the detection limits of the analytical method were exceeded.

Samples 1-5 were collected on June 30 about 30-46m offshore, directly off each of five different outfalls (see Table 9 and Figure 5). At the time of collection there was a stiff breeze blowing, abundant white caps, and the water appeared to be quite clear. Because of the relatively high waves and clear water, the coliform count was expected to be low. However, coliform counts on these five samples ranged from 350 to 550.

Samples 6-10 were collected early in the morning on July 1 in the vicinity of the same five outfalls. There was no wind, and the sea was calm, although there was a low (30cm) swell which caused the alternate submergence and draining of intertidal areas. This swell action may have caused substantial aeration and mixing of the nearshore waters. In each case the samples were collected from shore about 30m west of the outfall termini. Coliform counts were expected to be high. Total coliform counts ranged from 250 to 1800+. The higher values in the vicinity of the Mbua and Vura outfalls appear to reflect the higher rates of discharge.

Samples 11 through 15 were collected on the same day just as the afternoon winds were starting to rise. No white caps had developed yet, but waves and swell to 30cm were common. Again the samples were collected about 30m directly offshore from each of the five outfalls. The currents were changing from east to west during the period of collection. Moderate coliform counts were expected. Actual counts ranged from 20 to 1600. The lowest value was from off the Bahia outfall which has the lowest average rate of effluent discharge.

After the results of the analysis of the first 15 samples were reviewed and discharge predictions for the Naha outfall became available it was decided to concentrate the sampling around the Vura and Mbua outfalls, and to increase the distance between the outfall termini and the sampling stations.

At about 1000hrs on July 6, six samples (#16-22) were collected about 60 metres to the east, west, and north (seaward) of the Vura and Mbua outfalls, and an additional sample was collected about 120m to the east (down current) of the Vura outfall. The sea was calm, and currents were running to the east at 12-17cm/second. Coliform counts ranged from 275 to 1800+.

Samples 24 through 32 were collected on the morning of July 8 when there was no wind, the sea was calm, and the current was changing from west to east. Water samples were taken at six stations located 115m to the east, west, and north (seaward) of the Vura and Mbua outfalls. Coliform counts ranged from 17 to 1800+. Three of the counts were very high. An additional sample taken 210m east of the Vura outfall had a count of 550, and another sample taken 240m offshore from the Vura outfall was found to be unpolluted (mpn count: 25).

One water sample collected at 1010 on July 6 from the Mataniko River close to the mouth was also polluted. It is assumed that this sample represents a low flow (drought) condition.

The coliform analyses suggest that the surface marine waters off the Kukum area are polluted when the sea is calm (probably about 18-20 hours/day on the average) out to a distance of 30 to 100 metres. Even when the sea is rough, the waters may often be polluted for at least 30m offshore. Probably the frequency and degree of pollution are most closely dependent upon the proximity to the outfall and the rate of discharge. Of course, when the currents are strong, the polluted waters will be largely limited to areas down current from the outfalls.

CONCLUSIONS

Methods of Pollution Assessment

The impacts created by discharge of sewage into coastal waters are of three general types:

1) esthetic
2) public safety and public health
3) effect on ecological communities

Esthetic impacts are those readily noticed by people utilizing and viewing the shoreline and nearshore areas. They include: 1) the visible distribution and/or accumulation of human wastes and toilet tissue, and other articles commonly flushed into the sewage system; 2) the discoloration of nearshore waters; 3) the generation of unsightly surface slicks; and 4) the creation of obnoxious odours.

The primary public safety impacts are those associated with the spread of disease, either by direct water contact (i.e. swimming, diving, fishing) or by the ingestion of sea food. The investigation of public health hazards almost always involves the determination of total and or faecal coliform bacteria counts in the waters receiving the sewage effluent. Public health hazards may extend to areas well beyond the range of adverse esthetic effects.

The discharge of sewage effluent into coastal waters may cause changes in the ecological communities. Such communities can be divided into benthic (bottom) organisms and pelagic (above bottom) species, and may also include intertidal groups. Because of the relatively rapid circulation of the waters overyling the sea bed and because the species inhabiting these waters are constantly in motion, the pelagic communities are not likely to be strongly affected by sewage discharges unless effluent concentrations are unusually high, or unusually toxic. However, bottom sediments and bottom communities (including coral) suffer from the cumulative long term effects resulting from any degradation of water quality.

Thus the long term impacts of sewage discharge on bottom organisms (coral, crabs, shrimp, other shellfish, and fish) are likely to be far more widespread than other impacts. Unfortunately, such impacts are often the most difficult to detect. The dead coral found in an area of sewage discharge cannot readily be distinguished from coral killed by natural causes. Also the elimination of certain fish and invertebrates from communities cannot easily be detected.

Esthetic Impacts

The judgement of esthetic impacts is a highly subjective process. It can be asserted that one person's opinion is no better than anothers. Nevertheless, the following brief evaluation is offered by the authors.

From a distance (say 100m, or from the coastal highway) no adverse impacts from the present sewage discharges were discernable. No odours were detected; no unsightly views were observed.

However, in the vicinity of the Vura and Mbua outfalls the shoreline area is degraded by unsightly turbid waters, strand lines marked by toilet paper fragments, and occasional slicks and faeces. Obnoxious odours from one source or another are also present. Clearly, from close proximity the shoreline is esthetically polluted in the vicinity of the discharges.

Public Health Impacts

Coliform analysis of 60 samples taken off the Kukum area at 2 month intervals from December 1978 through August 1979 showed that the surface waters to 100m offshore contained coliform concentrations exceeding 100mpn/ml. Twenty eight of thirty similar samples collected off 5 Kukum area outfalls in late June and early July 1981 also contained coliform concentrations exceeding this standard for recreational contact.

The finding can be interpreted to show that at least during 6 months of the year (December, February, April, June, July and August) the nearshore waters are likely to be polluted much of the time out to a distance of 100m offshore when the waters are calm. Additional evidence suggests that, when the seas are relatively rough, due to afternoon sea breezes, the nearshore waters are polluted for at least 30 meters from shore.

There are no particular reasons for believing that the nearshore waters would be substantially more or less polluted during the 3-month period (September-November) or the one month periods (January, March and May) not sampled. However, it is quite possible that current velocities and rates of mixing may be much different during the occurrence of strong winds and waves from the northwest. It is also possible that during prolonged periods of no wind, which may occur any time of year (but are likely to be most common during December and March) currents may be much weaker and pollution conditions more severe.

Ecological Impacts

Observation of the intertidal zone and the shallow sea floor around the Vura and Mbua outfalls suggests that any obvious degradation of habitats is limited to a zone within about 30 meters of the outfall terminus. There very well may be a variety of subtle adverse ecological changes taking place in a much broader area along the shore, due to the long term cumulative effects of the outfall discharges.

Any beneficial effects on the marine environment due to the introduction of nutrients with the sewage effluent are likely to be limited to areas some distance from the outfalls, where the effluent concentrations are very low. Such beneficial effects, if any, would be very difficult to observe.

Impacts predicted to result from the Naha waste water outfall discharges

The minimum discharge from the planned Naha outfall would be about 30,000 gpd, which is about 25% greater than the present discharge from the Mbua outfall (Table 7). Therefore, one might expect that the impacts from this proposed discharge would be similar to the impacts generated by the Mbua discharge. However, the Naha outfall probably would be built only 100 metres east of the Mbua outfall, and about 220m to the west of the Vura outfall. Therefore, the impacts from the future discharge would be to some extent cumulative. The minimum Naha discharge would increase by about 125% the rate of effluent influx in the Mbua area, and would increase the total effluent influx into the Kukum area by about 38%. The maximum Naha discharge (78,000gpd) would double the effluent influx in the Kukum area and would result in the discharge of about 140,000gpd along a 320m segment of shoreline extending from the Mbua outfall to the Vura outfall.

The proposed Naha discharges would be expected to increase the adverse esthetic, public health, and ecological impacts in the Kukum area unless the outfall was extended well offshore, or the effluent was of higher quality. The importance of the increased adverse impacts may depend considerably on the increase in the rate of effluent discharge into the receiving waters.

Increased esthetic impacts will include more extensive turbid clouds of discoloured water, longer and more conspicuous toilet paper strand lines, and more unsightly surface slicks and floating faeces.

Increased public health impacts will include the formation of a thicker and more widespread brackish water surface layer which may be expected to support high coliform bacteria concentrations. During periods of calm seas, westerly currents may carry these high concentrations as far as the port area on the east side of Point Cruz.

Increased discharges in the Kukum area will increase the underwater area of visible habitat degradation, as well as the more extensive areas where unobserved, subtle adverse changes are likely to be taking place.

RECOMMENDATIONS

Any substantial increase in the discharge of raw sewage effluent off the Kukum area will result in increased pollution of the nearshore waters. The alternatives to such pollution increases in the nearshore environment include: 1) discharging through a longer outfall; 2) treating the sewage before discharge, and 3) discharging the effluent somewhere else, on land or at sea. Probably all of these alternatives are very expensive. For each alternative it may be difficult to predict the benefits from the increased expenditures.

Even if one of these courses of action is implemented, the waters off Kukum will remain in their present degraded condition. The extent of this degradation would be expected to increase with any future increases in effluent discharge through existing or newly constructed outfalls. Consequently, the adviseability of any plan to treat or dispose of the Naha waste water which would involve substantial expenditures would be subject to question if it did not also consider the discharge of the raw sewage which is presently polluting the nearshore waters off Kukum.

Qualitative observations and experience elsewhere suggests that if the planned Kukum discharge could be carried out at a depth of about 15m, about 250m offshore, the expected dispersion probably would be sufficient to prevent any significant increase in the pollution of the nearshore waters.

If a 380m outfall pipe was constructed to a depth of 30m it is probable that the dispersion resulting from the rising effluent would be sufficient to prevent any increased pollution of shoreline areas, even if the entire existing and planned Kukum area discharges (140,000gpd) were routed through the outfall. Such suggestions are, of course, highly speculative. Verification would require further oceanographic studies and an extensive analysis of the data collected.

At present the UNDP personnel involved in the offshore studies do not have the competence to comment on the desirability or economic feasibility of providing extensive sewage treatment, or of discharging the effluent in other areas.

WORK REMAINING

An addendum to this report should be prepared whenever the Marine Department wind records from Port Cruz have been received.

It should be noted that the UNDP project office is committed to carry out more extensive studies of the nearshore environment in the vicinity of all of the Honiara area waste water outfalls. This commitment is described in the Programme Element PE/SI.17 Task 3.

It is suggested that future environmental studies in the area might be concerned with:

- determining more precisely the origin of the currents;
- preparing a budget for the influx of all fresh waters into the coastal area;
- investigating the distribution and movement of the fresh and brackish water surface layers in the area;
- additional current studies to be carried out during prolonged periods of calm, and during the occurrence of northwest winds;

- attempts to correlate coliform concentrations with surface salinities;
- the use of dyes to trace the movements of existing effluents;
- an investigation of the feasibility of unconventional low cost methods for laying pipes across the sea floor;
- the determination of organic carbon concentrations and pH in the surface sediments surrounding the existing outfalls.

REFERENCES

Hazbun, J.A., Loleniae, T., and Luilamo, G. 1979: Monitoring of Honiara Marine Outfalls, Solomon Islands Ministry of Health and Medical Services, Environmental Health Division, 7 page report dated 23 October 1979.

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TABLE 1

SUMMARY OF HOURLY DISTRIBUTION OF LOW VELOCITY HONIARA AREA WIND OBSERVATIONS[1]

Hour	% calm speed less than 1.0km/hr	% freq. of occurrence of wind speeds less than 13km/hr (7.0kts)	Predominant wind Direction[2] (all velocities)	
			Sector	% frequency of occurrence
0000	82.5	97.7	SE	5.1
0300	84.7	98.1	SE	3.8
0600	82.1	97.9	SE	5.4
0900	78.9	97.8	SE	5.9
1200	19.5	70.0	NE	17.8
1500	10.7	53.5	NE	18.5
1800	39.1	75.6	E	11.6
2100	75.2	94.6	SE	5.6
Average	59.1	85.7		

[1] Based upon Henderson Field data collected from 1974-1980 and analyzed by the Australian Bureau of Meterology. The percent frequency of occurrence for each time interval is based upon more than 2100 observations. Henderson Field is about 7km east of the area of investigation and has an elevation of 7.9m.

[2] 22.5^{o} sector from which wind blew most frequently at hour of observation.

TABLE 2

SUMMARY OF LOW VELOCITY MONTHLY WIND OBSERVATIONS FROM HONIARA AREA[1]

Month	% calm speed less than 1.0km/hr	% freq. of occurrence of wind speeds less than 13km/hr (7.0kts)	Predominant wind direction (all velocities	
			Sector[2]	% freq. of occurrence
January	56.0	84.4	WNW	7.9
February	56.0	86.6	NW	5.8
March	60.0	89.1	NW	4.9
April	63.5	89.2	NE	6.2
May	63.0	88.5	NE	6.9
June	61.2	87.7	NE	7.3
July	56.8	83.5	SE	8.9
August	54.6	79.9	E	9.8
September	59.8	82.5	E	7.2
October	55.3	80.0	ENE	8.2
November	60.1	87.8	NE	6.2
December	63.3	91.6	NE	6.1
Average	59.1	85.9		

[1] Based upon Henderson Field data collected from 1974-1980, and analyzed by the Australian Bureau of Meteorology. The percent frequency of occurrence for all hours during each month is based upon 1360 to 1736 wind velocity observations. Henderson Field is located about 7km east of the area of investigation, at an elevation of 7.9m.

[2] $22\frac{1}{2}^{o}$ sector from which wind blew most frequently during month of observation.

TABLE 3

MONTHLY SUMMARY OF AFTERNOON (1500HRS) WIND OBSERVATION FROM THE HONIARA AREA[1]

Month	% calm (speed less than 1.0km/hr	% freq. of occurrence of speeds less than 13km/hr (7.0kts)	Predominant Wind Direction (all velocities) Sector[2]	% frequency of occurrence
January	13.4	56.9	WNW	15.1
February	9.4	57.7	NW	18.8
March	12.4	67.7	NW	16.1
April	7.8	58.3	NE	25.0
May	17.4	57.4	NE	27.7
June	10.0	56.6	NE	31.3
July	9.7	47.2	ENE	23.9
August	7.1	33.6	ENE	22.6
September	11.7	42.0	ENE	22.9
October	4.6	35.5	ENE	29.0
November	12.2	62.8	NE	19.4
December	13.4	73.1	NNE	18.3
Average	10.8	53.9		

[1] Based on Henderson Field data collected from 1974-1980, and analyzed by the Australian Bureau of Meteorology. The percent frequency of occurrence for the 1500 hours observations during each month is based upon 150 to 217 observations collected each month. Henderson Field is located about 7km east of the area of investigation at an elevation of 7.9m.

[2] 22.5^{o} sector from which wind blew most frequently at hour of observation.

TABLE 4

Summary of Honiara Tidal Data for selected period during June and July, 1981[1]

Date	High Tide Ht.(m)[2]	High Tide Time	Low Tide Ht.(m)	Low Tide Time	Range (metres) Recorded (metres)	Predicted Admir.[3]	Predicted Haw.[4]
June 26			1.20	1545			
27	1.58	0345	1.21	1345	0.37	0.37	0.44
28	1.62	0045	1.15	1215	0.47	0.47	0.52
29	1.63	0200	0.95	1230	0.68	0.59	0.66
30	1.59	0145	1.00	1230	0.59	0.74	0.80
July 1	1.69	0200	1.09	1230	0.78	0.85	0.89
2	1.69	0300	0.84	1400	0.85	1.10	0.94
3	1.68	0400	0.88	1400	0.80	1.11	0.93
4	1.66	0415	0.90	1400	0.76	1.07	0.86
5	1.75	0515	0.93	1400	0.82	.98	0.90
6	1.70	0545	0.99	1500	0.71	.87	0.64
7	1.62	0600					

Footnotes:

1. All data and predictions based upon information supplied by Ken Slade, Australian Hydrographer attached to the Solomon Islands Government.
2. Zero of datum is on tide staff at Point Cruz.
3. Predictions based on Admiralty Tide Tables which relate Honiara tides to tides of Dredger Harbour, Papua New Guinea.
4. Predictions based upon Honolulu tides in the Hawaiian Islands.

TABLE 5

Comparison of Times of Tidal and Current Changes

Date	Time of Current Change				Time of Tidal Change[1]	Time Difference[2] (minutes)	Direction of Current Change
	Drogue Data			Current Meter			
	#	Period between fixes	Middle Period				
			Low Tides				
July 1	1	1212-1328	1250		1340	+50	E to W
	5	1216-1332	1254			+46	E to W
	6	1228-1400	1343			+26	E to W
July 2	6	1224-1347	1305		1320	+15	E to W
	1	1134-1244	1209			+71	E to W
July 3	1,3,6	1320-1406	1343		1350	+7	E to W
July 6	1	1158-1324	1241		1450	+129	E to W
	6	1319-1325	1322			+88	E to W
July 7	1	0956-1153	1057		1530	+273	E to W
July 4	1	2052-2215	2136		1400	-456	E to W
	3	2054-2218	2136			-456	E to W
	6	2122-2315	2232			-512	E to W
	7	2121-2313	2217	2218		-497	E to W
			High Tides				
July 5	1,3,6,7				0500	no change for at least 2½ hours after high	
July 8		0840-0913				-193	W to E

Footnotes:

[1] determined from smoothed tidal curve

[2] + indicates current changed before tidal change;
- indicates current changed after tidal change.

DATE	TIME	DEPTH (M)	CURRENT DIRECTION[1] DEG. MAG.	CURRENT SPEED CM/SEC.	TEMP. ^{o}C	CONDUCTIVITY m.mho/cm
			see TSC-1 (figure 3a)			
July 1	1401	0	-	-	28.6	54.2
	1402	5	-	-	28.6	54.0
	1404		-	-	28.6	54.1
			TSC-2 (see figure 3a)			
July 1	1410	0	-	-	28.4	53.7
	1410	2.5	-	-	28.7	53.6
	1411	5.0	-	-	28.7	53.9
			30m north of Vura Outfall			
July 4	1028	0.5	-	-		53.8

Footnote:

[1] Add 9^{o} to obtain true direction.

TABLE 6

Current and Water Characteristics determined with the NBA DNC-3 Current and Water Quality Meter

DATE	TIME	DEPTH (M)	CURRENT DIRECTION[1] DEG. MAG.	CURRENT SPEED CM/SEC.	TEMP. °C	CONDUCTIVITY m.mho/cm
		yellow buoy (figure 1)				
July 2	1443	1	160-290	0.05-0.40	28.7	54.0
	1446	9	260-300	0.01-0.25	28.9	53.8
	1449	16	160-300	0.05-0.19	28.8	53.8
	1452	28.5B	160	0-0.2	28.8	53.8
July 4	2140	2.5	250	0.1	28.6	53.8
	2147	7.5	250	0.05	28.6	53.8
	2155	17.5	270	0.03	28.6	53.8
	2213	0.4	-	-	28.6	53.8
	2240	2.5	080	0.25	28.5	53.8
	2248	6.5	070	0.2	28.7	54.0
	2252	17	070	0.12	28.7	54.0
	2258	27	1.65	0.15	28.8	54.0
	2323	27	130	0.10	28.0	53.5
	2327	27	180	0.10	-	-
	2230	17	060	0.25	28.4	53.6
	2237	6.5	060	0.25	28.5	53.5
July 5	0019	6.5	065	0.25	28.1	53.7
	0024	17	075	0.25	28.3	54.0
	0028	27	055	0.20	28.3	54.0
	0159	27	050	0.25	28.3	53.5
	0211	16.5	070	0.30	28.5	-
	0217	6.5	075	0.30	28.6	-
	0234	0.5	-	-	27.8	-
	0235	6.5	070	0.28	28.3	-
	0242	6.5	-	-	-	-
	0244	12	070	0.25	28.6	-
	0247	16.5	065	0.25	28.6	-
	0253	27.5	055	0.10	28.6	
	0317	27.5	040	0.10	28.3	
	0321	16.5	060	0.15	28.5	
	0324	6.0	075	0.15	28.6	

DATE	TIME	DEPTH (M)	CURRENT DIRECTION[1] DEG. MAG.	CURRENT SPEED CM/SEC.	TEMP. °C	CONDUCTIVITY m.mho/cm
			see TSC-1 (figure 3a)			
July 1	1401	0	-	-	28.6	54.2
	1402	5	-	-	28.6	54.0
	1404		-	-	28.6	54.1
			TSC-2 (see figure 3a)			
July 1	1410	0	-	-	28.4	53.7
	1410	2.5	-	-	28.7	53.6
	1411	5.0	-	-	28.7	53.9
			30m north of Vura Outfall			
July 4	1028	0.5	-	-		53.8

Footnote:

[1] Add 9° to obtain true direction.

APPENDIX I

TABLE 7

Comparison of Honiara Area Waste Water Outfalls

OUTFALL	LOCATION	YEAR COMPLETED	AVERAGE DAILY DISCHARGE GALLONS/DAY	NO. OF UNITS SERVED[1]	INDUST. EFFLUENT	PIPE DESCRIPTION INSIDE DIA. (IN.)	PIPE DESCRIPTION LENGTH (M)	TERMINUS DEPTH BELOW HWL[2] (M)	MATERIAL[3]	FLOW PUMPED	FLOW GRAVITY
King George VI	6000m E of Pt Cruz	1970	14,400	500 students & staff		6	36	3.0	CI	X	
Renadi	4900m E of Pt Cruz	1975	4,200	14 indust. sites	X	6	42	2.7	CI		X
Vura	3000m E of Pt Cruz	1970	40,000	283 R.U.		9	42	3.7	CI		X
Mbua	2680m E of Pt Cruz	1969	22,000	183 R.U.		9	42	1.7	CI		X
East Kukum	2520m E of Pt Cruz	1968	6,500	54 R.U.		6	40	1.5	CI		X
West Kukum	2340m E of Pt Cruz	1968	8,000	67 R.U.		9	42	1.5	CI		X
Bahia	2120m E of Pt Cruz	1969	2,600	22 R.U.		6	30	1.1			X
St Nicholas	2100m E of Pt Cruz	1969	5,700	47 R.U.		6	30	0.9	CI	X	
Point Cruz	Point Cruz	1972	18,700	mixed R.U. & ind.	X	12	92	1.7	CCP		X
Rove	1800m W of Pt Cruz	1968	9,600	80 R.U.		6	36	1.7	CI		
			131,700								
			Other discharges								
Hospital Septic Tank Overlow	1500m E of Pt Cruz		unknown								
Septic tank overflow to Mataniko R.			unknown								
Septic tank effluent discharged by truck	into Vura outfall	-	800								
			Proposed Outfalls								
Naha alterna-tives	2760m E of Pt Cruz		30,000	250 R.U.							
			36,000	300 I.U.							
			78,000	650 R.							

Footnotes: 1. R.U. = residential units; 2. HWL = high water line; 3. I = cast iron; CCP = concrete pipe

TABLE 8: Factors to be considered in assessing results of Coliform bacteria analysis

I. Discharge characterists
   - A. Average rate
   - B. Coliform concentration in effluent
   - C. Time of day
   - D. Amount of recent rainfall

II. Outfall characteristics
   - A. Distance offshore
   - B. Terminus depth
   - C. Diffuser characteristics

III. Water Sample location
   - A. Distance from outfall terminus
   - B. Depth below surface
   - C. Salinity of sample

IV. General oceanographic characteristics
   - A. Currents
     - 1. speed and direction at time of collection
     - 2. speed and direction during preceding hours
   - B. Winds
   - C. Waves
   - D. Tides
     - 1. daily stage
     - 2. fortnightly stage
   - E. Stratification
   - F. Salinity

V. Geometry of receiving waters
   - A. Depth
   - B. Shoreline configuration
   - C. General circulation patterns
   - D. Distance of outfall terminus from shore
   - E. Distance from other waste water outfalls

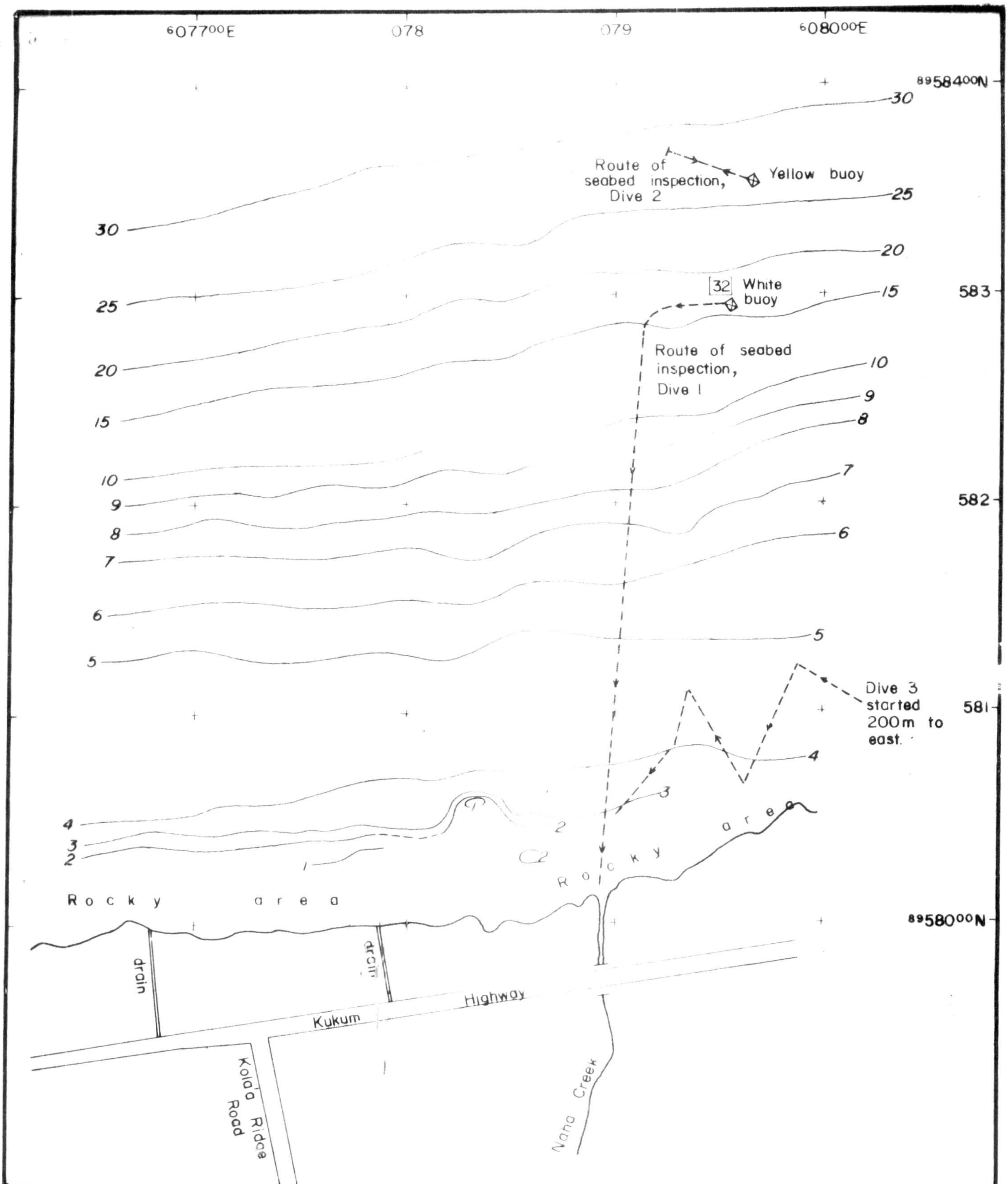
APPENDIX I

TABLE 9: Results of coliform bacteria analysis of water samples collected off Honiara shoreline, June 30 to July 8, 1981

SAMPLE NO.	DATE	LOCATION	DISPERSIVE CONDITIONS SUMMARY	DESCRIPTION	Results (mpn count per 100ml) Total Coliform	Faecal Coliform	E. Coli	Ave. dis-charge gal/day x 1000
1	30 June	38m seaward of Vura outfall	rapid	all samples collected between 1200 and 1217. Wind estimate E-NE 10-25kts; significant wave 60cm, maximum wave 1.0m; white caps abundant; tide: low; current: not known.	550	40	40	40
2	30 June	46m seaward of Mbua outfall	rapid		900	275	275	22
3	30 June	46m seaward of E Kukum outfall	rapid		900	40	35	6
4	30 June	30m seaward of W Kukum outfall	rapid		350	25	25	8
5	30 June	38m seaward of Bahia outfall	rapid		350	25	8	2.6
6	1 July	30m west of Bahia outfall	slow	all samples collected from shore between 0715-0815; no wind; no whitecaps; no sea waves; slight swell or surge causes considerable aeriation of near shore waters due to periodic submergence and subsequent draining of emergent reefs and intertidal flats; tide: mid level and dropping; current: changing from east to west.	1600	17	17	2.6
7	1 July	30m west of W Kukum outfall	slow		250	130	130	8
8	1 July	30m west of E Kukum outfall	slow		550	20	20	6
9	1 July	30m west of Mbua outfall	slow		1800+	175	175	22
10	1 July	30m west of Vura outfall	slow		1800+	275	275	40
11	1 July	30m off Vura outfall	moderate	all samples collected between 1230 and 1247. 5-10kt wind from NE, following direction shift from NW; no whitecaps; swell and sea about 1.0ft; tide: low; current: shifting from east to west.	900	40	40	40
12	1 July	30m off Mbua outfall	moderate		1600	55	55	22
13	1 July	30m off E Kukum outfall	moderate		550	55	55	6
14	1 July	30m off W Kukum outfall	moderate		170	110	110	8
15	1 July	30m off Bahia outfall	moderate		20	20	17	2.6

TABLE 9: Results of coliform bacteria analysis of water samples collected off Honiara shoreline, June 30 to July 8, 1981

SAMPLE NO.	DATE	LOCATION	DISPERSIVE CONDITIONS SUMMARY	DESCRIPTION	Results (mpn count per 100ml) Total Coliform	Faecal Coliform	E. Coli	Ave. discharge gal/day x 1000
16	6 July	60m E of Vura outfall	slow to very slow	all samples collected between 0950 and 1010. Wind 0-5kts; no white caps; waves height 0.5ft; very little surge; tide: mid level and dropping; current: to East 12-17cm/sec.	1800 +	175	175	40
17	6 July	120m E of Vura outfall			350	20	20	40
18	6 July	60m W of Vura outfall	"		900	25	25	40
19	6 July	60m N of Vura outfall	"		1600	275	275	40
20	6 July	60m W of Mbua outfall	"		1600	1600	1600	22
21	6 July	60m E of Mbua outfall	"		1600	1600	1600	22
22	6 July	60m N of Mbua outfall	"		275	250	200	-
23	6 July	Mataniko River near mouth	-		250	250	200	-
24	8 July	115m N of Vura outfall	very slow	all samples collected between 0850 and 0932; wind 0-5kts; no waves; no swell; tide: 2-3 hours after high (dropping); current: changed from 18cm/s to W to 4cm/s to east	40	25	25	40
25	8 July	115m E of Vura outfall	very slow		17	11	11	40
26	8 July	115m W of Vura outfall	very slow		1800+	900	900	40
27	8 July	115m W of Mbua outfall	very slow		1800+	45	45	22
28	8 July	115m N of Mbua outfall	very slow		1800+	200	200	22
29	8 July	115m E of Mbua outfall	very slow		350	35	35	22
30	8 July	115m N of Bahia outfall	very slow		1600	1600	1600	2.6
31	8 July	20m N of Station 141 (about 210m E (up current) from Vura outfall	very slow		550	12	12	-
32	8 July	270m to the NNE of Vura outfall and 240m offshore	very slow		25	14	14	-



NOTES: shoreline, coastal detail and metric grid have been taken from Honiara sheet XK0657

LEGEND

Seabed depth contour, metres 5

Contour interval: 1m for depths 0-10m
5m for depths 10m+

Datum: Honiara Chart Datum

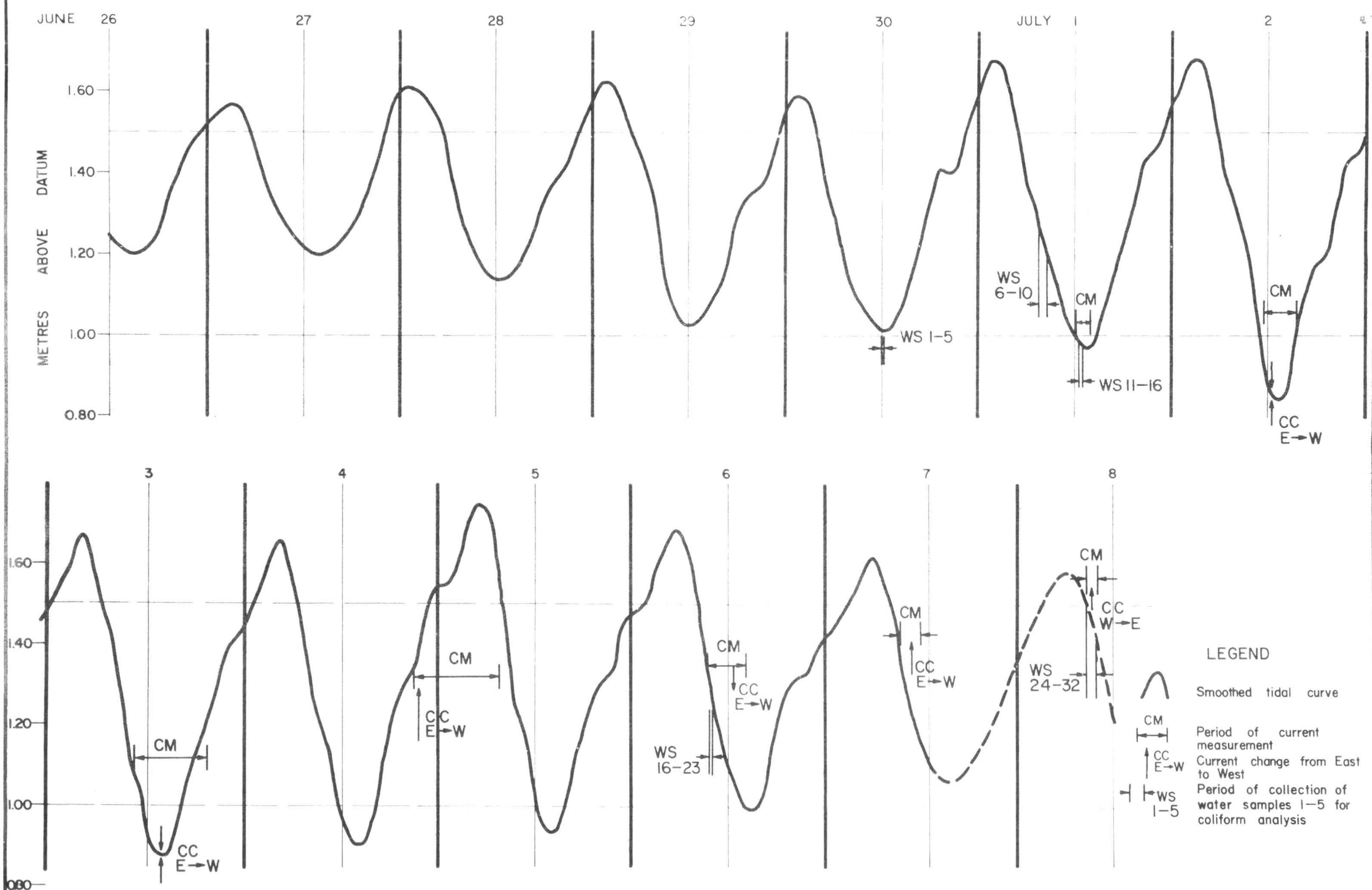
Coliform bacteria sample [32]

NAHA WASTE WATER OUTFALL

Bathymetric Chart
Naha Creek Area

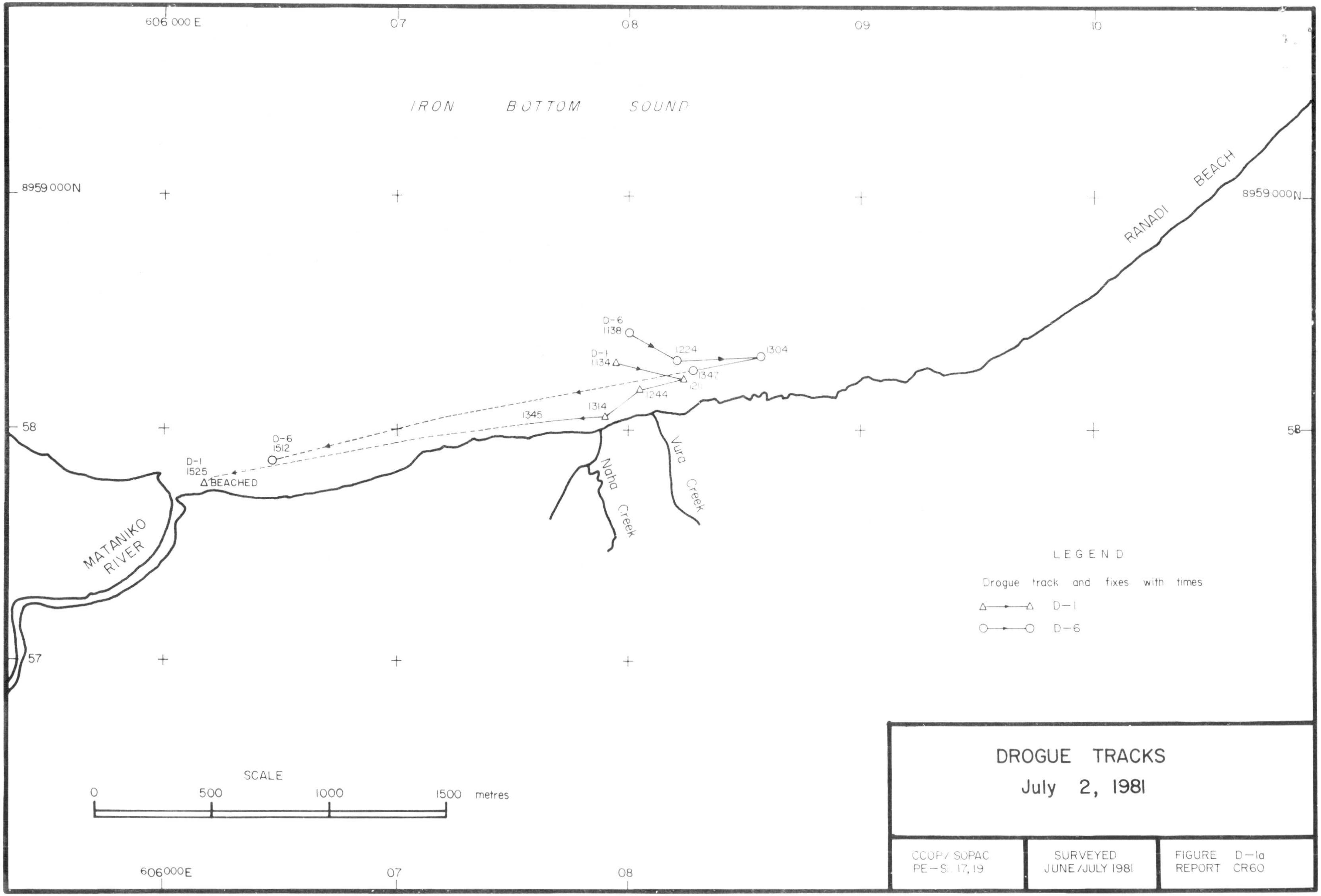
Scale 1:2500

CCOP/SOPAC	SURVEYED	FIGURE 1
PE-SI/17,19	JUNE/JULY 1981	REPORT CR60



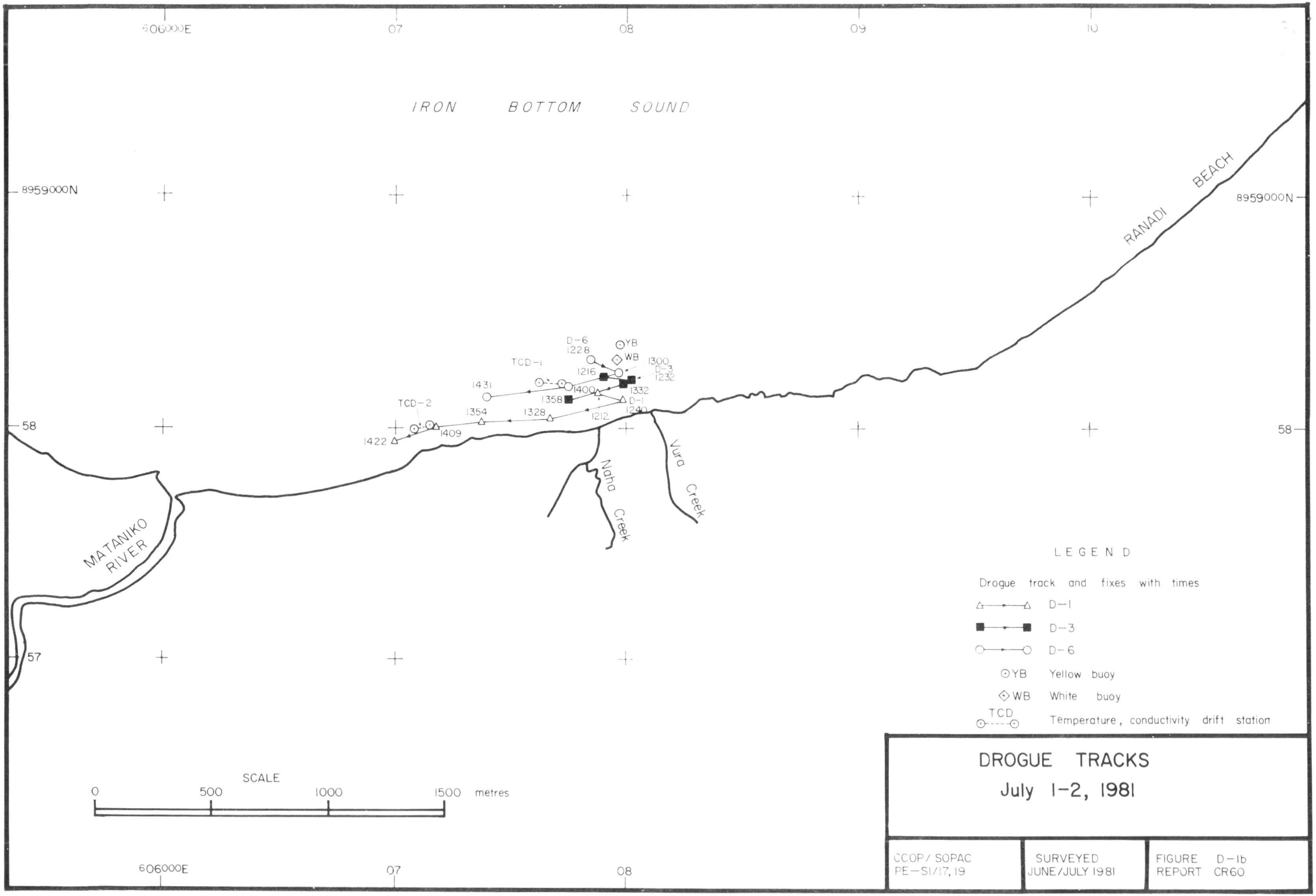
HONIARA TIDE RECORDS, JUNE 26 – JULY 8, 1981

CCOP/SOPAC PE. SI/17,19	Surveyed June/July 1981	FIGURE 2 Report CR60



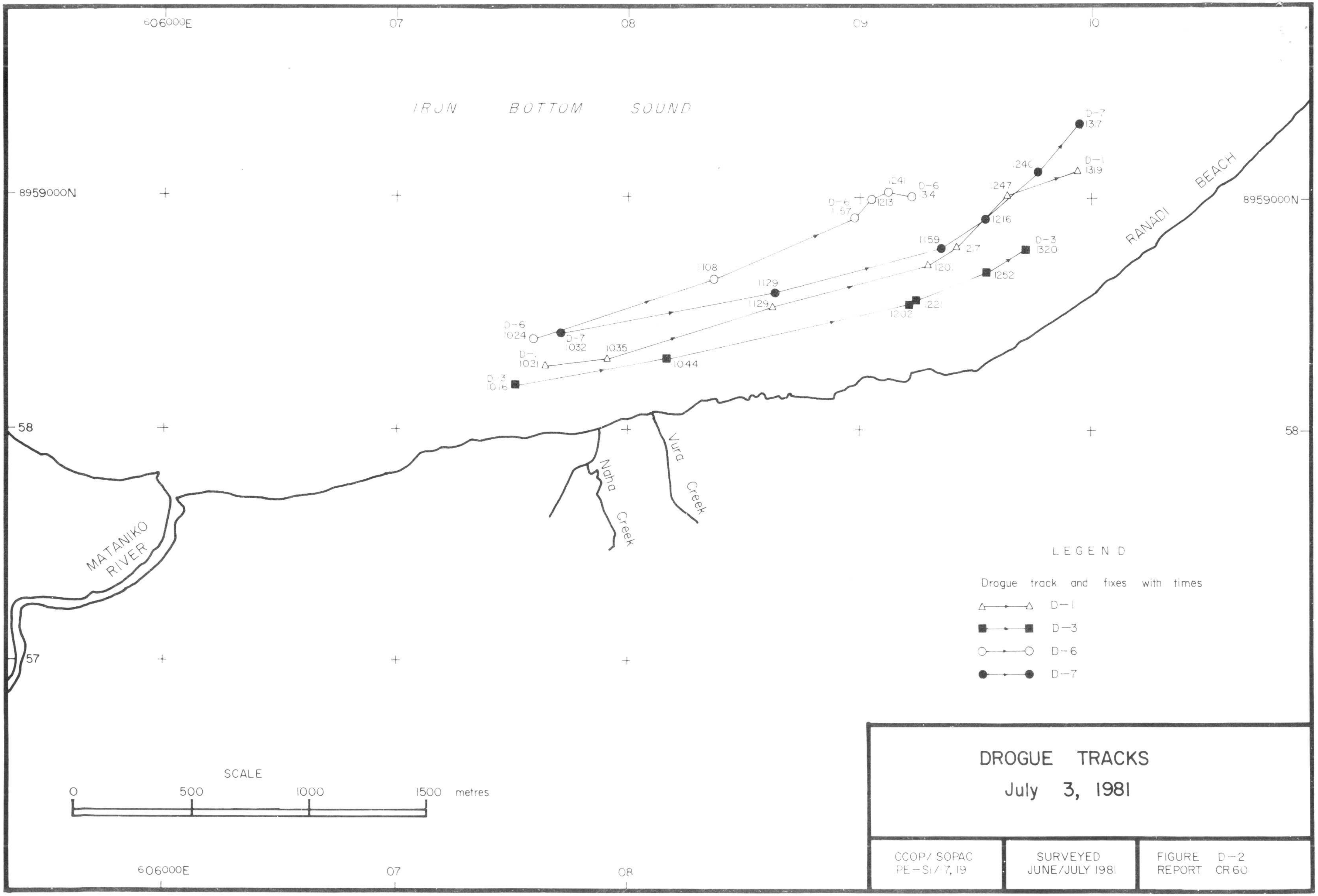
DROGUE TRACKS
July 2, 1981

CCOP/SOPAC PE-S. 17, 19	SURVEYED JUNE/JULY 1981	FIGURE D-1a REPORT CR60



DROGUE TRACKS
July 1-2, 1981

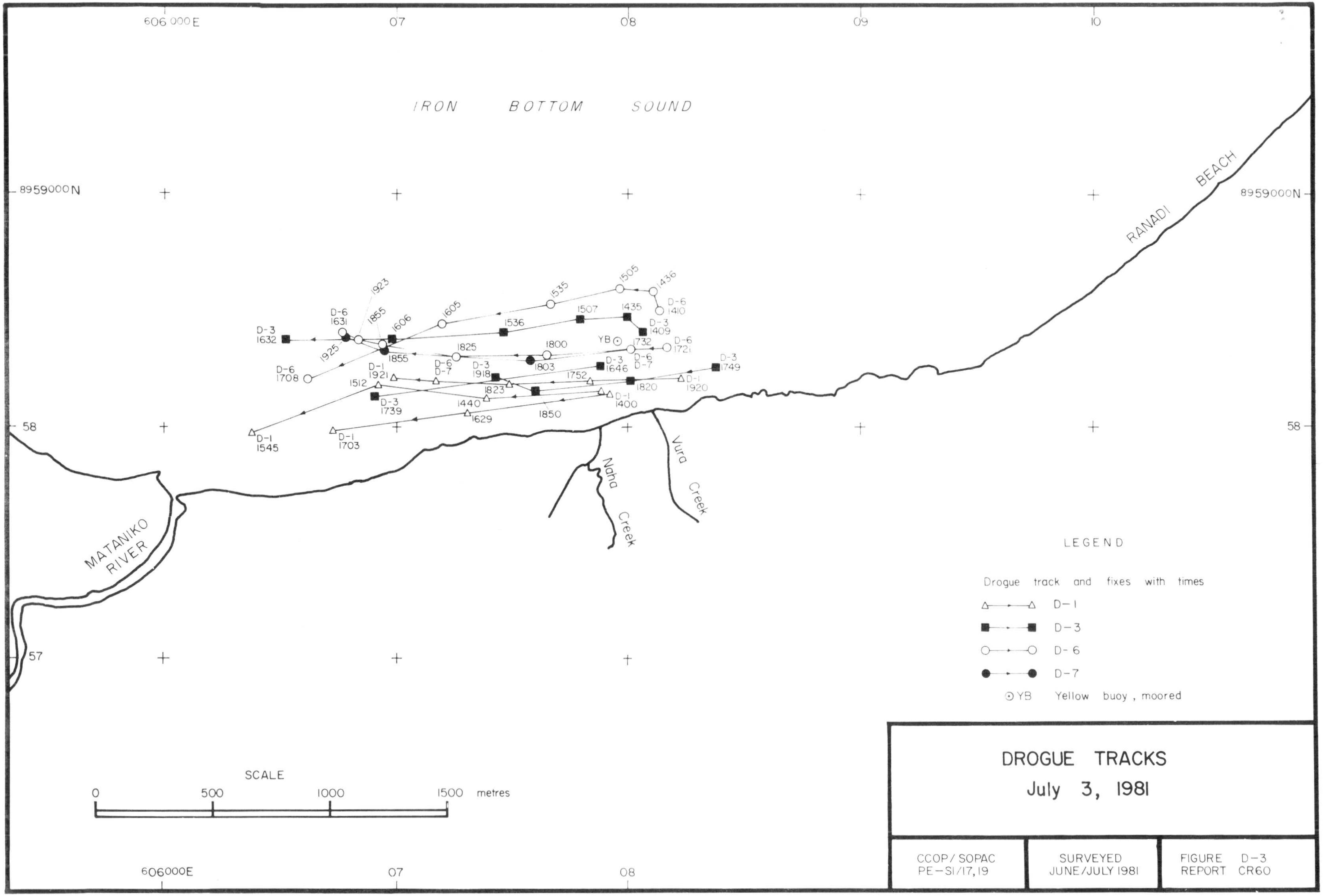
CCOP/ SOPAC PE-SI/17, 19	SURVEYED JUNE/JULY 1981	FIGURE D-1b REPORT CR60



DROGUE TRACKS

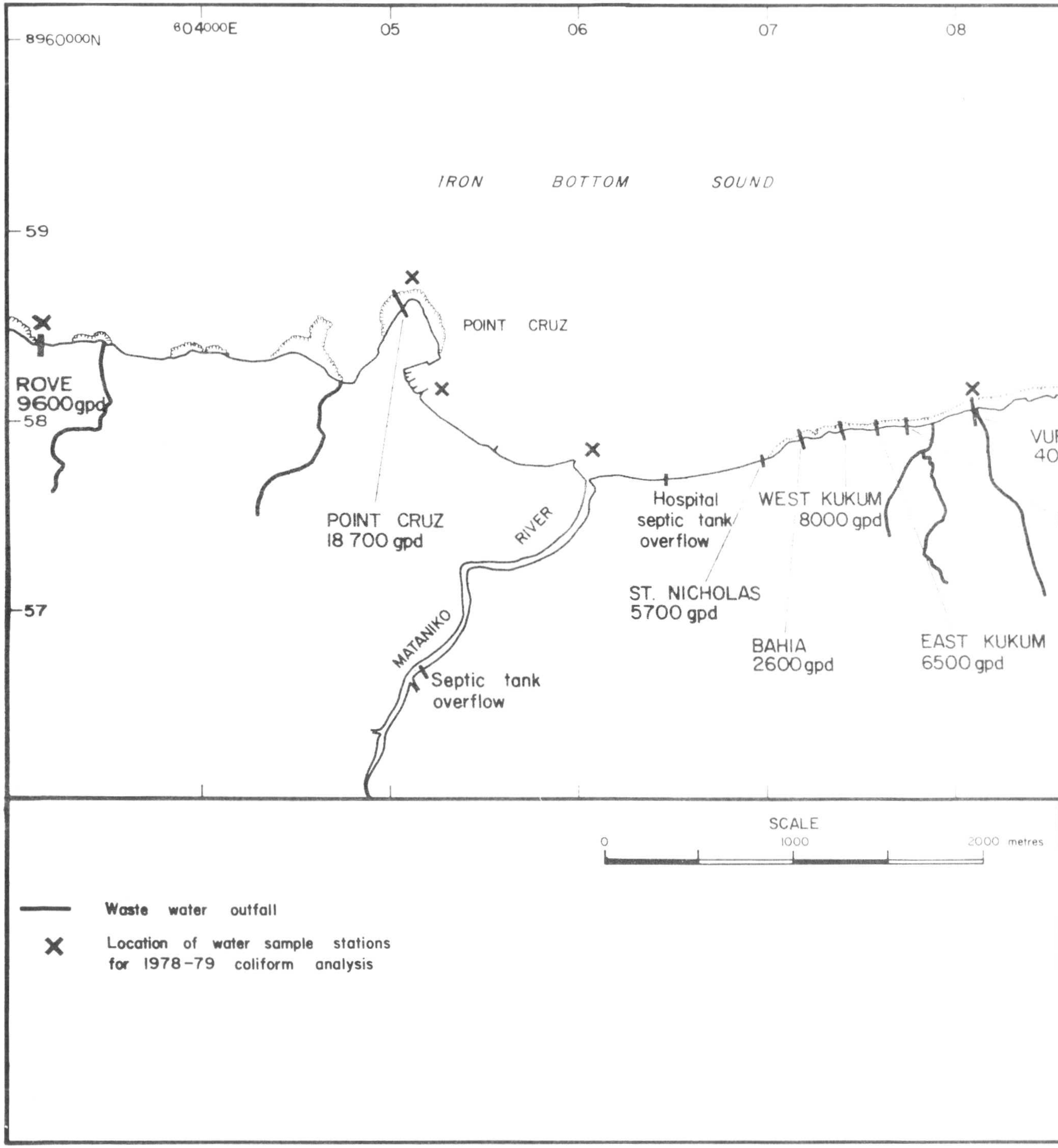
July 3, 1981

CCOP/SOPAC PE-SI/7,19	SURVEYED JUNE/JULY 1981	FIGURE D-2 REPORT CR60



DROGUE TRACKS
July 3, 1981

CCOP/SOPAC PE-SI/17,19	SURVEYED JUNE/JULY 1981	FIGURE D-3 REPORT CR60



LOCATION OF WASTE WATER OUTFALLS

Honiara, Solomon Islands

CCOP/SOPAC PE. SI/17,19	Surveyed June/July 1981	FIGURE 4 Report CR60

Location of Water Sample Stations for Coliform Bacteria Analysis
June – July 1981, Honiara, Solomon Islands

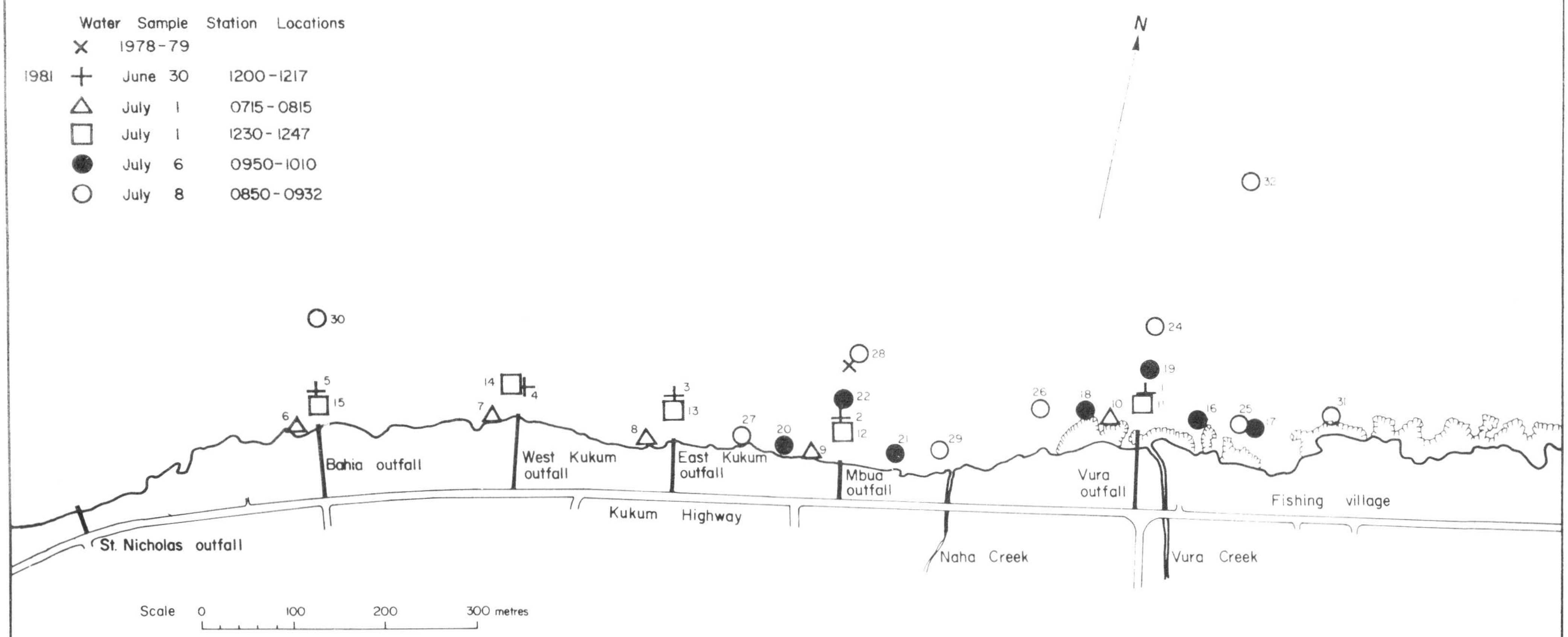


FIGURE 5