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LIMITED CURRENT AND UNDERWATER BIOLOGICAL SURVEYS OF PROPOSED SEWER OUTFALL SITES IN THE MARSHALL ISLAND DISTRICT: EBEYE, KWAJALEIN ATOLL

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Ebeye

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UNIVERSITY OF GUAM MARINE LABORATORY

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Prepared for

ENVIRONMENTAL PROTECTION BOARD

TRUST TERRITORY OF THE PACIFIC ISLANDS

As per

TRUST TERRITORY CONTRACT NO. 76-9

University of Guam

The Marine Laboratory

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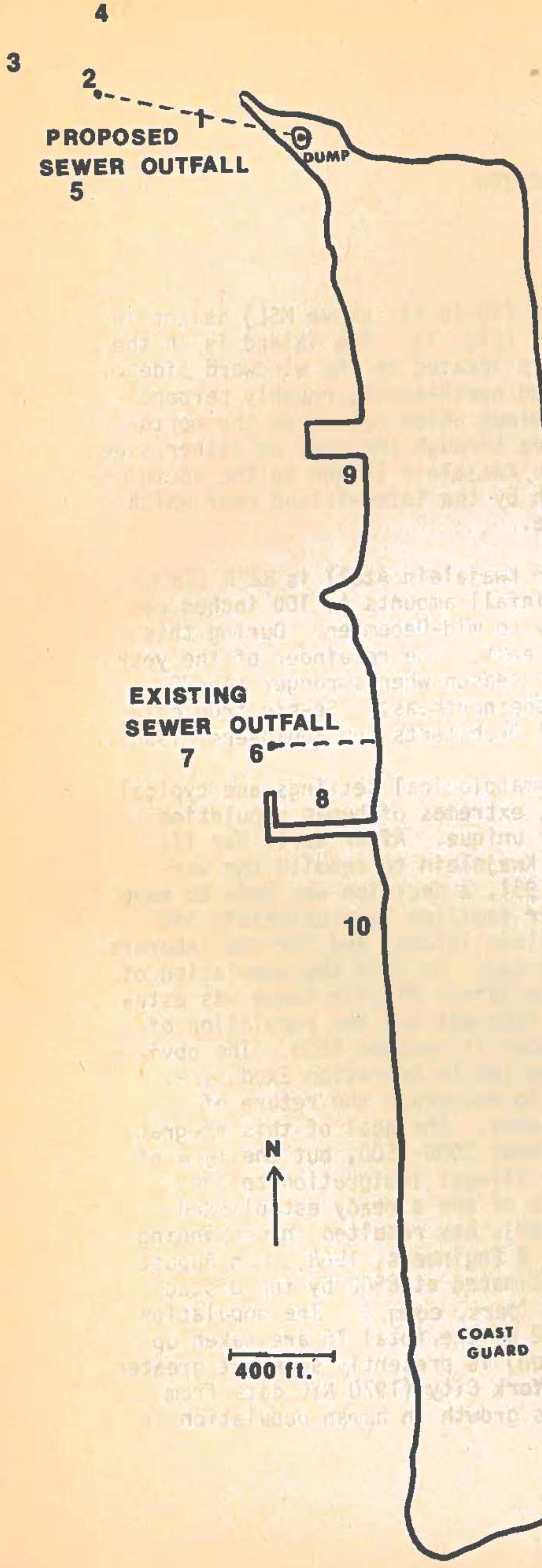
INTRODUCTION

Description of Island

Ebeye is a small (76 acre), low (10-15 ft. above MSL) island in the southern part of Kwajalein Atoll (Fig. 1). The island is in the shape of an elongate rectangle and is located on the windward side of the atoll with its long axis oriented north-south, roughly perpendicular to the direction of the tradewinds which come from the northeast. There are no deep water passes through the reef on either side of Ebeye; the island is connected to Kwajalein Island to the south and neighboring islands to the north by the inter-island reef which is only barely submerged at low tide.

The mean annual temperature for Kwajalein Atoll is 82°F (28°C) with little seasonal variation. Rainfall amounts to 100 inches per year, falling primarily from mid-May to mid-December. During this period winds are light and from the east. The remainder of the year (mid-December to mid-May) is the dry season when stronger (15-20 knots) tradewinds are blowing from the northeast. Severe tropical storms are rare in this area (Hawaii Architects and Engineers, 1968).

Although its geological and climatological settings are typical of a great many Micronesian islands, extremes of human population density have made Ebeye ecologically unique. After World War II, Marshallese workers were brought to Kwajalein to rebuild the war-damaged military installation. In 1951, a decision was made to move all the Marshallese workers and their families (approximately 550 people) to Ebeye, 4 miles from Kwajalein Island, and for the laborers to commute to Kwajalein to work each day. By 1954 the population of Ebeye was about 1000. In 1961 the Kwajalein Missile Range was established, requiring more Marshallese laborers and the population of Ebeye continued to grow until 1967 when it reached 4500. The obviously overcrowded conditions on Ebeye led to Operation Exodus, a program to prohibit immigration and to encourage the return of Marshallese people to their home islands. The goal of this program was to stabilize the population at about 3000-3500, but the lure of high wages and urban life has led to illegal immigration to the island. This, and the natural growth of the already established population (approximately 200 per year), has resulted in continuing population growth (Hawaii Architects & Engineers, 1968). In August 1975, the population of Ebeye was estimated at 8500 by the Distad Representative Mr. W. "Murph" Ownbey (pers. comm.). The population density on the 64 available acres (12 of the total 76 are taken up by the U. S. Coast Guard Loran Station) is presently somewhat greater than three times the density of New York City (1970 NYC data from Golenpaul, 1974). The result of this growth in human population is



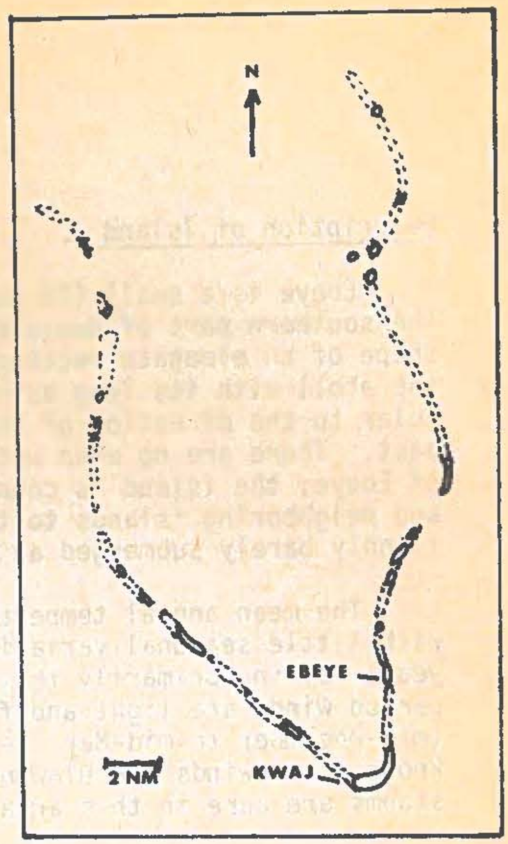


Fig. 1. Map of Ebeye showing location of proposed and existing sewer outfalls. Numbers represent the 10 stations where chemical, physical, and coliform samples were taken. Insert shows Ebeye in relation to Kwajalein Island.

an environment scarely recognizable as a Micronesian atoll island. The vegetation has been cleared for buildings, streets and a refuse dump; only scattered trees remain. Topsoil is virtually absent, as are native animals.

The extraordinary population density dictates that public health be a major concern on Ebeye. Most of the houses are provided with salt-water flushed plumbing, and most of the sewer lines are joined to a single outfall which releases untreated sewage into the lagoon adjacent to the boat dock (Fig. 1). A sewage treatment facility is being planned for Ebeye and will be located on the north end of the island at the present site of the refuse dump.

Originally proposed was a type of activated sludge secondary treatment plant, but this plan has been revised, and present planning is for the construction of an oxidation (stabilization) ditch. The treated effluent from this facility will be released into the atoll lagoon, approximately 650 ft. (203 m) from shore where the bottom topography begins its drop down to about 75 ft. (23.4 m).

Scope of Work

In view of the recommendations for current and biological studies to be performed at the proposed outfall site at Ebeye, the Environmental Protection Board of the Trust Territory of the Pacific Islands contracted with the University of Guam Marine Laboratory to carry out investigations on Ebeye's proposed wastewater outfall which will discharge treated, brackish effluent into nearshore waters of the Kwajalein Lagoon in an area believed to be under considerable environmental stress from untreated sewage discharges and construction activities.

The University of Guam Marine Laboratory biologists were to address themselves to the following questions.

1. What effect, if any, the discharge of treated effluent will have on the ecological condition and water quality at the proposed outfall site.

2. The extent and magnitude of surface and sub-surface currents at the proposed outfall diffuser site, so that reliable predictions on plume dispersion and dilution can be developed.

3. Define potential alternate sites for outfall/diffuser location, should currents/tidal flushing at the proposed site be found inadequate, or result in excessive biological impact.

4. Baseline ecological data that can be utilized for future comparison, evaluation and determination of deleterious effects or impacts on biota and water quality.

Personnel

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ACKNOWLEDGEMENTS

We acknowledge Mr. Nachsa Siren, Executive Officer of the Trust Territory Environmental Protection Board, and the Board members for providing the funds to carry out this study; Mr. William A. Brewer, Environmental Specialist, for his aid in obtaining oxygen, temperature, salinity and coliform data from the study area; Mr. W. "Murph" Ownbey, Distad Representative for Kwajalein, Mr. J. S. Beavers, Army Liaison Officer for Kwajalein, Mr. Kurma Korak, Sanitarian on Ebeye, and Mr. Mike Capelle, Administrative Assistant for Public Works on Ebeye, for logistic support. We are deeply indebted to Messrs. Paul Gustin, Chris Bangart and Bill William, all of Public Works on Ebeye, for their immense cooperation during our stay on Ebeye. Dr. Masashi Yamaguchi, University of Guam Marine Laboratory, provided help in the identification of some of the corals.

METHODOLOGY

Study Site

The outfall site on Ebeye was visited August 19 to 22, 1975. The location of the proposed sewage treatment plant and outfall pipe was determined from maps drawn by Metcalf and Eddy, Engineers (1975), and provided to us by the Trust Territory Environmental Protection Board (TTEPB). The treatment facility is to be constructed on the northwest corner of the island, and some initial construction has been done. The outfall pipe is to extend west-southwest approximately 650 feet (203 m) into the lagoon with the diffuser at a depth of 17 feet (5.3 m). At this point, the lagoon bottom begins a rapid descent to a maximum depth of approximately 75 feet (23.4 m). Plankton samples were taken in the vicinity of the proposed sewer outfall. Water samples for the determination of temperature, salinity, dissolved oxygen, NO_3-N, PO_4-P, and coliforms were taken from the sites indicated in Fig. 1. The proposed location of the diffuser was used as the starting point for the current studies.

Water Chemistry and Microbiology

All water samples, except for oxygen, were collected in 500 ml polyethylene bottles by opening the tightly fitted caps while the bottle was held underwater. The bottles were brought onto the boat where temperature and salinity were recorded with a YSI S-C-T meter. Sample bottles for NO_3-N and PO_4-P were immediately placed in ice and taken to a freezer as soon as possible to be frozen for later analyses (Strickland and Parsons, 1968) on Guam. Water for oxygen analyses were collected with a Van Dorn Sampler. Water samples for coliform analyses were taken on the last day and held in cold water until processed the following day on Majuro, since laboratory facilities were not available on Ebeye. The membrane filter method was used (A.P.H.A. 1971). Fecal coliforms were cultured on Difco M-FC medium at 44.5 ± 0.5°C; total coliforms were cultured on Difco M-Endo medium at 35.0 ± 0.5°C.

Water Circulation

Periodically, during rising and falling tides, pairs of drogues, 1 m and 5 m deep, were released from the position of the proposed sewer outfall diffuser. After appropriate time intervals, depending upon the speed of the current, the positions of the drogues were determined and plotted. Wind speed and direction were recorded during the current studies to assess the possible effects of the wind on the movements of the drogues. Predicted tides for the time periods under study were obtained for Ebeye from the Distad

Representatives Office.

Biota

Transects - Three transects were established at the study site (Fig. 2). Transect A, extending to the south of the proposed outfall pipeline was 200 m in length; Transect B, which followed the proposed outfall pipeline, was 265 m in length and extended to the edge of the lagoon slope; and Transect C, extended to the north of the proposed outfall pipeline and was 200 m long.

Algae - Since the algae in the study area were distinctly zoned, the algal associations in each zone were defined. Quantitative analysis was restricted to only the dominant species. The point-quadrat method (Tsuda et al., 1975) was used along the transects. However, for those species which could be counted, e.g., Halimeda cylindracea, density values were obtained by actually counting the number of thalli within a quadrat (25 cm X 25 cm).

Coral - The coral community was analyzed by using a point-center quarter technique (Cottam et al., 1953). For this technique a series of 10 points, 10 m apart, were selected along a 100 m transect line. The area around each point was divided into four equal quadrants. The coral nearest the transect point in each quadrant was located and its specific name, diameter or basal area, and the distance from the center of the corallum to the transect point was recorded. If no coral was observed within a maximum distance of 5 m from the transect point, the collection point was recorded as no coral with a transect point to organism distance at 5 m and a diameter of zero.

The Average Dominance Value for each species was defined as the average areal coverage of the specimens of that species encountered on the transect. The following relationships were used to calculate various population and community parameters of the corals:

$$\text{Total Density of All Species} = \frac{\text{Unit Area}}{(\text{Mean point-to-point distance})^2}$$

$$\text{Relative Density} = \frac{\text{Individuals of Species}}{\text{Total Individuals of All Species}} \times 100$$

$$\text{Density} = \frac{\text{Relative Density of Species}}{100} \times \text{Total Density of all Species}$$

$$\text{Percent Coverage} = \text{Density of Species} \times \text{Average Dominance Value for Species}$$

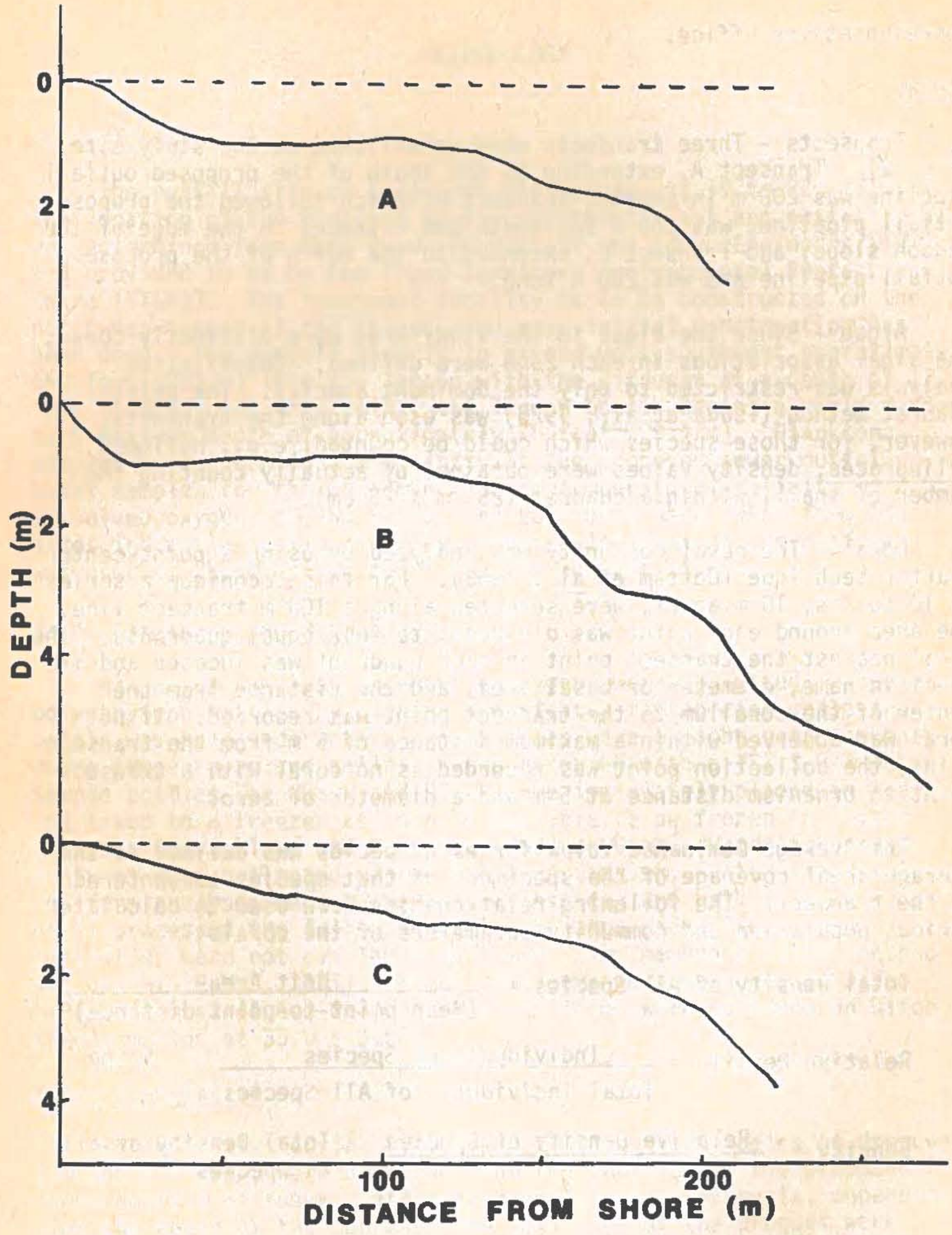

Fig. 2. Depth profile of the three transects established in the study area at Ebeye.

$$\text{Relative Percent Coverage} = \frac{\text{Percent Coverage for Species}}{\text{Total Coverage for All Species}}$$

$$\text{Frequency} = \frac{\text{Number of Points at which Species Occurs}}{\text{Total Number of Points}}$$

$$\text{Relative Frequency} = \frac{\text{Frequency Value for Species}}{\text{Total Frequency Values for All Species}} \times 100$$

Importance Value = Relative Density + Relative Percent Coverage + Relative Frequency

A more detailed analysis of the overall species diversity was achieved by making a collection in the general area on both sides of the transect line.

Other Macroinvertebrates - A general search for other macroinvertebrates was made in the study area, and their distribution and abundance were noted.

Fish - A diver equipped with scuba or snorking gear, depending upon the water depth, swam the length of the transect, taking approximately 20 minutes to cover the 100 m distance, and recorded all fish sighted within one meter to either side of the transect line. Transect A was run in two separate 100 m segments: A1 from the shore to 100 m and A2 from 100 m to 200 m. Transect B was run in three segments: B1 - shore to 100 m, B2 - 100 m to 200 m, and B3 - 200 m to 265 m. Transect C was run in two segments: C1 - shore to 100 m and C2 - 100 m to 200 m.

Plankton - Plankton were collected in paired tows with nets of two different mesh sizes: a #1 mesh net (.4 mm apperatures) with a mouth diameter of 52 cm, and a #15 mesh net (.094 mm apperatures) with a mouth diameter of 23.5 cm. Two paired tows of 5 minutes duration were made. Starting and ending positions were determined so that towing distance could be computed. Samples were preserved with 10% formalin in sea water, and subsample counts were made in the laboratory with a binocular microscope.

RESULTS AND DISCUSSION

Physico-Chemical Characteristics of the Water

Temperature was virtually uniform at all stations sampled (Table 1). Surface salinity is low at all the stations (28.5-29.9^{0}/oo), but

Table 1. Physical, chemical and microbiological characteristics of the lagoon water at the proposed outfall site and at selected locations at Ebeye. Station locations are shown in Figure 1. Lowest values for each characteristic with dashed underlining; highest value with solid underlining.

Station	Temperature (°C)	Salinity (o/oo)	D.O (ppm)	pH	NO_3-N (µg-at/l)	PO_4-P (µg-at/l)	Fecal Coliform (per 100 ml)
1	28.0	29.2	5.50	7.20	.2	.2	270
2	27.5	28.8	5.90	7.18	.2	.2	**
3	28.0	29.9	6.25	7.30	.2	.2	**
4	28.0	29.6	6.50	7.30	.3	.2	0
5	28.0	29.7	6.50	7.35	.3	.2	10
6	28.0	29.0	6.10	7.85	2.1	1.9	52,400
7	28.0	28.5	6.10	7.31	.3	.3	110
8	28.0	28.6	6.10	7.31	.4	.2	1,720
9							25,100
10							980,000
11*							70

*tap water, Ebeye Hotel
**confluent non-coliform

this seems due to salinometer inaccuracy; a similar range of salinities were measured in open ocean water off Majuro where salinities are expected to be in the range of 34-35^{0}/oo.

Despite the high nutrient levels and high coliform counts indicative of sewage input, dissolved oxygen levels in the immediate area of the present sewage outfall are not markedly low. They are, in fact, lower at the proposed outfall site, decreasing toward the shore. This end of the island is a sanitary land fill and there is ample evidence from the trash in and under the water that much of the trash is being carried into the lagoon. The oxidation of organic debris from the dump may be reducing dissolved oxygen levels in the immediate offshore waters. The high pH at the present sewer outfall is probably a result of the input of fresh water (Table 2) of a very high pH (9.15-9.20). The high nitrate and phosphate levels at the present outfall are obviously the result of the input of high nutrient effluent. The nutrient values at the other stations are within the normal range for lagoon waters in the Pacific and are similar to those recorded in Truk Lagoon (Tsuda *et al*., 1975).

Table 2. Ebeye municipal water quality data. Measurements performed August 20, 1975, by Mr. William A. Brewer, TTEPB. The three measurements of each parameter were made, from top to bottom, at 1100-1145, 1300-1320, and 1645-1715 hrs, respectively.

Sampling location	Temperature (°C)	Salinity (o/oo)	pH
1. Municipal rainwater storage tank	27.1	0.1	9.15
	27.3	0.1	9.15
	27.3	0.1	9.15
2. Tap water, Ebeye Hotel	27.1	0.1	9.20
	27.0	0.1	9.15
	27.0	0.1	9.20
3. Seawater flush system (toilet tank, Ebeye Hotel)	26.7	25.1	7.40
	28.1	26.5	7.30
	28.1	26.6	7.35
4. Sewer water from pump station on main	28.1	21.5	----
	28.2	20.2	----
	28.5	19.3	----

Microbiological Characteristics of the Water

U. S. Public Health Service water quality standards for fecal coliform concentrations (200 per 100 ml) are exceeded at the present outfall and in several other inshore locations (Table 1). The presence of a number of small outfalls not connected to the main pipe and the general use of the beach areas for toilets are responsible for the high coliform counts at areas away from the main outfall. The need for proper treatment and disposal of sewage is abundantly clear, as these inshore waters are heavily used for recreation and boating by the residents of Ebeye.

Water Circulation

Drift patterns of the drogues indicate that the general direction of water movement at the end of the proposed outfall is offshore, into the lagoon (Table 3, Fig. 3). With the exception of one high reading, currents at 5 meters depth are slow (.005-06 knots) and are not affected by tidal fluctuations. Currents at 1 meter depth are faster (.01-.22 knots) than the deeper ones, and there is a tendency (though not statistically significant) for the water to move more rapidly when the tide is high; as the tide rises, more water can move across the inter-island reef flat around the north end of the island into the lagoon. Water movement is, in general, in the same direction as the wind, but there is no significant relationship between the speed of the wind and the speed of the currents.

Kwajalein Atoll lies in the path of the westwardly flowing North Equatorial Current, and the consistent westward direction of the movement of the drogues suggests that this current system is largely responsible for water circulation around Ebeye. The period of time during which these studies were done was the period of relatively strong flow of the North Equatorial Current (Wyrtki, 1974) and it may be that during the spring time, water movement around Ebeye is weaker and may be more subject to the influence of other factors.

Table 3. Distance and speed of 1-meter and 5-meter drift drogues as well as direction and speed of wind.

			1 METER		5 METER			
Drogue	Start	ΔT (hrs)	Dist. (NM)	Speed (Knots)	Dist. (NM)	Speed (Knots)	Wind Dir.	Knots
Aug. 20								
1	0900 (1 m)	1.0	.17	.17			112°	7.0
	0930 (5 m)	0.5			.14	.28		
2	1000	2.0	.25	.12	.08	.04	125°	7.5
3	1200	2.0	.20	.01	.12	.06	114°	9.0
4	1400	2.0	.44	.22	.07	.03	108°	6.0
5	1600	2.0	.30	.15	.01	.005	101°	8.5
Aug. 21								
6	0940	2.2	.15	.07	.01	.005	066°	3.0
7	1200	3.3	.14	.04	.02	.006	066°	2.0

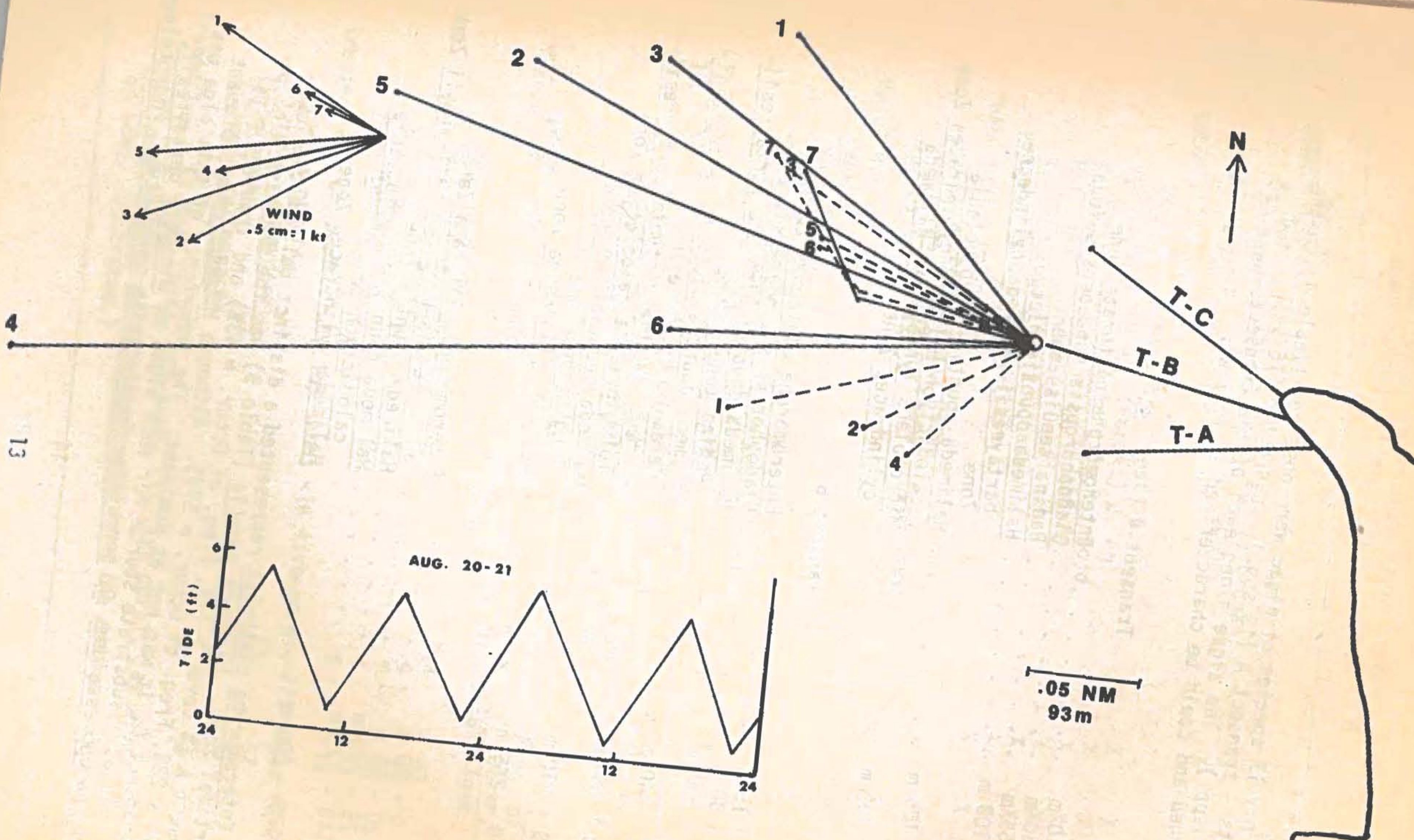

Fig. 3. Location of transect stations (T-A, T-B, and T-C), and direction of drift drogues, August 20-21, 1975. 1-meter drogues = solid lines, 5-meter drogues = dashed lines.

Biota

Algae - Only 17 species of algae were observed (Table 4) on the three transects - transect A (13 spp.), transect B (16 spp.), and transect C (9 spp.). The algae along each of the transects were distinctly zoned and could be characterized as follows.

Transect A

0 - 10 m	Enteromorpha clathrata Zone
10 - 30 m	Cladophoropsis sundanensis Zone
30 - 55 m	Padina tenuis Zone
55 - 100 m	Halimeda opuntia-Dictyota bartayresii-Halimeda cylindracea Zone
100 - 185 m	Halimeda opuntia-Tolypiocladia calodictyon-Halimeda cylindracea Zone
185 - 200 m	Microcoleus lyngbyaceus-Halimeda cylindracea Zone

Transect B

0 - 15 m	Enteromorpha clathrata Zone
15 - 30 m	Cladophoropsis sundanensis Zone
30 - 100 m	Halimeda opuntia-Dictyota bartayresii-Padina tenuis Zone
100 - 140 m	Halimeda opuntia-Dictyota bartayresii-Ceramium sp. Zone
140 - 160 m	Halimeda opuntia-Dictyota bartayresii-Tolypiocladia calodictyon Zone
160 - 210 m	Halimeda opuntia-Microcoleus lyngbyaceus Zone
210 - 265 m	Halimeda cylindracea Zone

Transect C

0 - 20 m	Enteromorpha clathrata Zone
20 - 75 m	Padina tenuis-Dictyota bartayresii Zone
75 - 140 m	Halimeda opuntia Zone
140 - 175 m	Halimeda opuntia-Tolypiocladia calodictyon Zone
175 - 200 m	Halimeda cylindracea Zone

Enteromorpha clathrata represented a distinct belt in the lower intertidal zone. Halimeda opuntia (Table 5) was the dominant alga on transect A (% Cover = 14%, Freq. of Occur. = 43%) and transect B (% Cover = 23%, Freq. of Occur. = 57%). Although H. opuntia was present in transect C, it was not as dominant. The importance of this alga was its role as a substrate source for such algae as Dictyota bartayresii, Caulerpa cupressoides, C. serrulata, Toypiocladia calodictyon, Microcoleus

Table 4. Checklist of algae along three transects at the proposed sewer outfall site on Ebeye, August 1975.

Species	Transects A	B	C
CYANOPHYTA (blue-greens)			
Microcoleus lyngbyaceus (Kutz.) Crouan	X	X	
Schizothrix calcicola (Ag.) Gomont	X	X	
Schizothrix mexicana Gomont		X	
CHLOROPHYTA (greens)			
Caulerpa cupressoides (West) C. Ag.	X	X	
Caulerpa serrulata (Forsk.) J. Ag.	X	X	X
Cladophoropsis sundanensis Reinbold	X	X	
Enteromorpha clathrata (Roth) Ag.	X	X	X
Halimeda cylindracea Decaisne	X	X	X
Halimeda opuntia (L.) Lamx.	X	X	X
Neomeris annulata Dickie	X	X	X
PHAEOPHYTA (browns)			
Dictyota bartayresii Lamx.	X	X	X
Lobophora variegata (Lamx.) Womersley	X	X	
Padina tenuis Bory	X	X	X
RHODOPHYTA			
Ceramium sp.		X	
Hypnea esperi Bory			X
Polysiphonia sp.		X	
Tolypiocladia calodictyon (Harv.) Silva	X	X	X
Total Number of Species	13	16	9

Table 5. Percent cover and frequency of occurrence of dominant benthic algae (>5% cover) present on transects A and B. Algae arranged in order of percent cover.

Species	Percent Cover	Freq. of Occur.
Transect A - 20% dead coral, 21% sand, <1% live coral, 58% algae (N=68)		
Halimeda opuntia	14	43
Tolypiocladia calodictyon	9	26
Halimeda cylindracea	7	38
Dictyota bartayresii	7	32
Padina tenuis	5	13
Transect B - 6% dead coral, 16% sand, <1% live coral, 77% algae (N=26)		
Halimeda opuntia	23	57
Dictyota bartayresii	17	41
Ceramium sp.	6	18
Halimeda cylindracea	5	25
Transect C - 5% dead coral, 80% sand, <1% live coral, 14% algae		
(Halimeda opuntia and H. cylindracea were the dominant algae on sandy substratum.)		

lyngbyaceus, and the immature stages of Padina tenuis.

Transect C consisted of a sand-silt substrate and served as an ideal habitat for Halimeda cylindracea which reached densities of ca. 50 thalli per m^2 in water 2-3 m deep. Of all the benthic organisms found in the study site, the algae were, by far, the most dominant organism in this area.

Corals - The three transects at Ebeye were similar in species of corals present and in the low percentage of coral cover (<.01%) as seen in Tables 6 and 7. Pocillopora damicornis and Porites lutea dominated the sparse coral community. The former species is commonly found in coral communities in silt-stressed environments (R. H. Randall, pers. comm.). A single rock outcropping near the lagoon slope on transect B possessed 50% of the observed coral species in the Ebeye study area, and none of these species were observed elsewhere.

Other Macroinvertebrates - Twenty-seven Strombus luhuanus, three Lambis sp., and 18 Diadema sp. were counted along a 50-m segment (between 150 and 200 m from shore) at transect A. The densest community of invertebrates was found on a large dead coral mound which measured about 4-m in diameter and .5-m high. Aside from the 17 Pocillopora damicornis present on this mound, the following invertebrates were counted - 78 Diadema sp., 26 Echinometra mathaei, and 1 Trochus niloticus. The holothurians Thelenota ananas and Holothuria hilla, and numerous hermit crabs were also encountered in the study area.

Fishes - A moderate diversity of fishes is found in the area of the proposed sewer outfall (Table 8). Except for roving schools of silversides (Atherinidae), ponyfish (Leiognathidae), and mullets (Mugilidae), no large concentrations of fishes are found in this area. This is no doubt due to the lack of suitable hard substrate and topographic relief, as almost all those fishes seen were associated with scattered rocks, coral formations, or pieces of metal and other stationary pieces of trash. It is unlikely that the construction of a sewer outfall pipe across the reef flat area will cause significant damage to the fish life. More likely the presence of the outfall pipe will provide additional substrate relief and additional fish habitats, as observed at the sewer outfall pipe at Moen, Truk (Tsuda et al., 1975).

Plankton - Zooplankton was very abundant in the lagoon waters in the vicinity of the proposed outfall site (Table 9). Phytoplankton was not adequately sampled by our nets. Gerber and Marshall (1974) have shown that detritus derived from the reef constitutes a major food source for lagoon zooplankton. The large schools of atherinid fishes observed on the transects are, in turn, probably supported by the zooplankton, as those species of atherinids which

Table 6. Checklist of coral species observed at proposed sewer outfall site, Ebeye, August 1975.

Species	TRANSECTS A	B	C
Acropora corymbosa (Lamarck)	X		
Acropora humilis (Dana)	X		
Acropora syringodes (Brook)			X
Acropora valida (Dana)	X		
Favites abdita (Ellis & Solander)	X		
Fungia fungites (Linnaeus)		X	
Lobophylla costata (Dana)	X		
Montipora caliculata (Dana)	X	X	
Montipora conicula Wells	X		
Montipora ramosa (Bernard)	X		
Montipora tuberculosa (Lamarck)	X		
Oulophylla crispa (Lamarck)	X		
Pavona (Polyastra) sp.	X	X	
Pavona clavus (Dana)	X	X	X
Pavona varians Verrill	X	X	X
Pocillopora damicornis (Linnaeus)	X	X	X
Pocillopora verrucosa (Ellis & Solander)	X	X	
Porites lichen Dana	X		
Porites lutea Milne Edwards & Haime	X	X	X
Symphylla nobilis (Dana)	X		

Table 7. Living coral density, percent of substratum coverage, frequency of occurrence, and importance value for dominant coral species at the Ebeye study area.

Species	Density/m^2	Rel. Density	Percent Coverage	Rel. Percent Coverage	Freq.	Rel. Freq.	I. V.
TRANSECT A (overall density = .044/m^2, overall coverage = <.01)							
Porites lutea	.009	20.00	<.01	86.05	.05	20.00	126.05
Pocillopora damicornis	.026	60.00	<.01	.19	.15	60.00	120.19
Montipora caliculata	.019	20.00	<.01	13.76	.05		
TRANSECT B (overall density = .066/m^2, overall coverage = <.01)							
Pocillopora damicornis	.064	97.70	<.01	99.00	.62	94.11	290.81
Pavona (Polyastra) sp.	.002	2.30	<.01	1.00	.04	5.89	9.19
TRANSECT C (overal density = .059/m^2, overall coverage = <.01)							
Pocillopora damicornis	.056	95.46	<.01	93.75	.35	87.50	282.52
Acropora syringodes	.003	4.54	<.01	6.25	.05	12.50	17.48

have been studied are primarily zooplankton feeders (Hiatt and Strasburg, 1960; Randall, 1967; Hobson and Chess, 1973; Hobson, 1974). The most numerous group in the plankton collections was larval crustaceans. Johnson (1954) reported concentrations of zooplankton inside lagoons in the Marshall Islands to be two to four times as abundant as outside the atoll. This is attributed to greater food abundance and slower circulation and longer residence time of the water inside the lagoon. He also noted a large proportion of larval and juvenile stages inside lagoons, the result of reproduction of slowly dispersed forms inside the lagoon in addition to recruitment from outside the atoll. The extent to which nutrient enrichment directly attributable to the Ebeye sewage outfall is responsible for high plankton concentrations cannot be assessed without more extensive collections from elsewhere in Kwajalein Lagoon.

Table 8. Fishes observed at the proposed sewer outfall site, Ebeye, August 1975.

Species	TRANSECT A1	A2	B1	B2	B3	C1	C2
Acanthuridae							
Acanthurus mata (Cuvier & Valenciennes)							1
A. nigrofuscus Forskal				1			
A. olivaceous Bloch & Schneider		3		2	3		2
A. c.f. thompsoni (Fowler)							4
A. triostegus (Linnaeus)	1		1				
unidentified juveniles			3		2		
Apogonidae							
Apogon novae-guineae Valenciennes							1
Atherinidae							
unidentified	500*	500*		500*			
Balistidae							
Rhinecanthus aculeatus Linnaeus							2
Blenniidae							
Runula tapeinosoma (Bleeker)		2		3			
unidentified					15		
Canthigasteridae							
Canthigaster margaritatus (Ruppell)					2		
C. solandri (Richardson)						1	1
Carangidae							
Caranx melampygus Cuvier			2				
Chaetodontidae							
Chaetodon citrinellus Cuvier				1			
Fistulariidae							
Fistularia petimba Lacepede	1	2				1	
Gobiidae							
Amblygobius albimaculatus (Ruppell)		1			4		
Oplopomus oplopomus (Cuvier & Valenciennes)	1						
unidentified					8		2

Species	TRANSECT A1	A2	B1	B2	B3	C1	C2
Labridae							
Cheilinus trilobatus Lacepede				1			
Coris aygula Lacepede							1
C. gaimardi (Quoy & Gaimard)				1	1		
Halichoeres margaritaceus (Cuvier & Valenciennes)	5		2	6			
H. marginatus Ruppell		3	5	4	1		
H. trimaculatus (Quoy & Gaimard)		5		15	16		5
Labroides dimidiatus (Cuvier & Valenciennes)		1					
Stethojulis bandanensis (Bleeker)	2	1	1	3			
Thalassoma purpureum (Forskal)		1					
T. quinquevittata (Lay & Bennett)			1	12			
Leiognathidae							
Gerres c.f. *oblongus* Cuvier & Valenciennes		50*					
Lutjanidae							
Scolopsis cancellatus (Cuvier & Valenciennes)		7					1
Mugilidae							
unidentified		50*					
Mugiloididae							
Parapercis cephalopunctata (Seale)			2	1			
Mullidae							
Parupeneus barberinus (Lacepede)		1			1		
P. trifasciatus (Lacepede)		1	1	1			
Pomacentridae							
Abudefduf leucopomus (Lesson)	1	11	12	7			
A. leucozona (Bleeker)	13	5	1	16			
Chromis caeruleus (Cuvier & Valenciennes)					30		
Dascyllus reticulatus (Richardson)							2
Pomacentrus albofasciatus (Schlegel & Muller)	1						
P. pavo (Bloch)		3					27
Scaridae							
juveniles	10		25				
Scorpaenidae							
Pterois antennata (Bloch)							1

Species	A1	A2	B1	TRANSECT B2	B3	C1	C2
Serranidae							
<u>Epinephelus</u> <u>merra</u> Bloch		1		1			1
Siganidae							
<u>Siganus</u> <u>spinus</u> (Linnaeus)	6			27			
Total Number	541	648	56	587	83	2	51
Total Number Residents**	41	48	56	87	83	2	51
Total Species	11	19	12	18	11	2	14
Total Species all Transects:	45						

*occurred in schools; counts are approximate
**excluding counts marked with asterisk

Table 9. Relative abundance of planktonic organisms collected at the proposed sewer outfall site, Ebeye, August 1975.

Plankton	Coarse Net	Fine Net
dinoflagellates		5%
foraminifera	16%	2%
radiolarians		1%
medusae	<1%	
siphonophores	2%	
mollusks	1%	7%
crustacean:		
larvae	59%	30%
mysids	<1%	
ostraeods	<1%	
copepods	12%	40%
euphausiids	<1%	
chaetognaths	1%	3%
salps	1%	
larvaceans	5%	12%
fish eggs	3%	
fish larvae	<1%	
Total plankton abundance (organisms/m^3):	617	850

CONCLUSIONS

Suitability of the Proposed Site

With the exception of the south end of Ebeye which is occupied by the U. S. Coast Guard Loran Station, the proposed treatment facility site at the north end of the island is probably the area of least dense housing on Ebeye. It is presently the site of a trash dump which will have to be relocated (perhaps to the other end of the island as suggested by Hawaii Architects and Engineers, 1968). The present dump is contributing a considerable amount of trash to the lagoonward reef flat, and any future land fill should be designed to minimize this.

Although the proposed outfall pipe will carry treated effluent to the edge of the drop off to deeper lagoon waters, the effluent itself will be of low salinity (even though salt water flushed toilets are used) and will rise to the surface. The proposed diffuser depth is only 17 feet and so the expected dilution of the effluent during its rise to the surface is small.

Once in the surface waters, the effluent will be subject to the currents characteristic of the surface waters. Our measurement show these currents to be between .005 and .28 knots and in an offshore, lagoonward direction. Thus, at least during this time of year, the effluent should move away from the island. Wyrtki (1974) has indicated that the general oceanic circulation in this area may be much weaker during the spring, and Hawaii Architects and Engineers (1968) indicate that during the spring, tradewinds are stronger and from the northeast. It is difficult to predict the likely effects of these seasonal meteorological and oceanographic changes: the stronger tradewinds may act to keep the water moving lagoonward; on the other hand, the more southward direction of the winds may move the effluent south along the lagoonward side of Ebeye. The possibility of eddies forming on the leeward (lagoonward) side of Ebeye, and trapping the effluent should not be overlooked.

Impact of Outfall Construction

It is not anticipated that the construction of the outfall across the lagoonward reef flat will result in any permanent environmental deterioration from its present condition. There may well be some enhancement of fish abundance from the shelter provided by the outfall pipe itself.

Impact of Treated Effluent

A properly functioning oxidation ditch should produce a good quality effluent. The addition of a chlorinator will reduce the levels of coliforms and pathogenic organisms. With the possible exception of the chlorine, the effluent is not expected to have any deleterious environmental effects, particularly at the anticipated low volume of output. The appropriate disposal of any accumulated sludge should be given proper consideration.

The proposed treatment facility should be a vast improvement over present conditions, both in the relocation of the outfall away from the heavily used public dock and in the proper treatment of the sewage.

RECOMMENDATIONS

1. Construction of the treatment plant at the north end of Ebeye is recommended.

2. Current studies should be made during the spring (March - June) to determine whether water circulation around Ebeye is markedly different than was indicated by our current studies. This is the period of weak North Equatorial Current flow. These studies need not be elaborate. Fluorescein dye could be placed into the water above the proposed diffuser site during ebb and flood tides, and the direction of movement of the dye observed. If dye movement is consistently offshore during this part of the year then it would probably be safe to assume that the future effluent will be carried away from the island.

3. Expansion or relocation of the trash dump should be designed to minimize the movement of trash into the lagoon.

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PLATE I

Fig. 1. Associations of fishes with submerged trash at proposed outfall site.

Fig. 2. Coris aygula associated with submerged trash at Transect C.

PLATE II

Fig. 1. School of atherinids (silversides) in the area of the proposed sewer outfall.

Fig. 2. Dense stand of Halimeda cylindracea on sandy-silty substrate on Transect C.