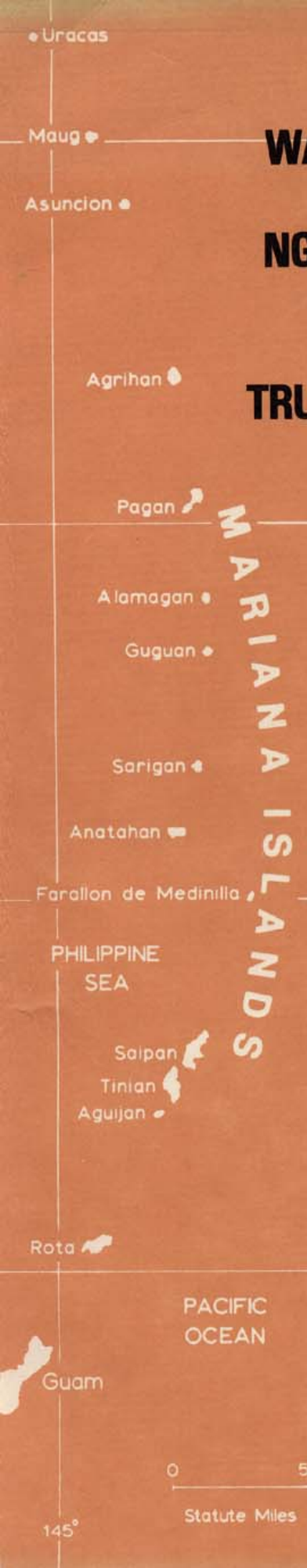

WATER QUALITY MONITORING PROGRAM PALAU AIRPORT PROJECT NGURUSAR BAY – TOAGEL MID CHANNEL BABELTHAUP AND KOROR ISLANDS PALAU DISTRICT TRUST TERRITORY OF THE PACIFIC ISLANDS PART B CONSTRUCTION

William J. Zolan

Water and Energy Research Institute of the Western Pacific

UNIVERSITY OF GUAM

Technical Report No. 46

November, 1983

WATER QUALITY MONITORING PROGRAM

PALAU AIRPORT PROJECT

NGURUSAR BAY - TOAGEL MID CHANNEL

BABELTHAUP AND KOROR ISLANDS

PALAU DISTRICT

TRUST TERRITORY OF THE PACIFIC ISLANDS

PART B

CONSTRUCTION

By

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Technical Report No. 46

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Completion Report for

Contract No. N62742-80-C-0002

Department of the Navy

Pacific Division

Naval Facilities Engineering Command

EXECUTIVE SUMMARY

The Palau Airport located at Babelthaup Island, Palau District, Trust Territory of the Pacific Islands (TTPI), is being improved and developed. The actual construction phase requiring dredging of coral fill material has been completed. It was required that dredging activity be controlled and that protection be provided so that waters outside the Water Quality Boundary, defined as 200 feet outside of the dragline limits, not be degraded below the water quality standards of the TTPI.

To satisfy this requirement (in accordance with U.S. Navy Contract No. N62742-80-5-0002) eight water quality stations and one control station were established along the outer perimeter of the Water Quality Boundary at the Ngurusar Bay dredge site. Part B Construction phase monitoring of these waters commenced in August 1980 and ended in January 1982 after dredge activity ceased in Ngurusar Bay. The site was replaced by a Trust Territory Environmental Protection Board approved dredge location on the reef adjacent and southeast of the Renrak Bridge. Nine new stations and one control station were selected in areas likely to be affected by uncontrolled dredging in areas outside the Water Quality Boundary at this new site. This site, designated as the Toagel Mid Channel dredge site was monitored from January 1982 until June 1983 when Part B Construction phase of the project was completed. The later monitoring program included two monitoring stations at Ngurusar Bay to monitor possible siltation pollution caused by land grading in the Gihmel River watershed.

Each monthly sample period consisted of determining the pH, salinity, temperature, dissolved oxygen, suspended solids and turbidity levels at each of the monitoring stations. Annually, samples were analyzed for total soluble nitrogen, total phosphorus, arsenic, cadmium, chromium, copper, lead, mercury, nickel and zinc.

Results of the monitoring program show that the dredge activity at both sites was controlled adequately. Only two turbidity readings (one at each site) exceeded the 5.0 NTU tubidity limit established during the Part A Pre-Construction monitoring program. One of these readings took place after a tropical storm which washed material from the sides of protective berms surrounding the construction area dredge works. Nephelometric turbidity (NTU) at Ngurusar Bay monitoring stations ranged from 0.60 to 5.10 NTU with an overall mean of 1.89 NTU. The Toagel Mid Channel monitoring stations recorded turbidity ranging from 0.05 to 8.80 NTU with an overall mean of 0.64 NTU. All other monthly parameter test results fell within ambient conditions as determined by the control stations and the Part A Pre-Construction monitoring program.

Total phosphorus and total soluble nitrogen concentrations were within the TTPI standards of .025 mg/l for total phosphorus and 0.400 mg/l for total nitrogen. The metals arsenic, cadmium, chromium, copper, lead, nickel and zinc were also within TTPI numerical standards. Several of the mercury analyses (7 out of 23) showed detectable mercury in samples above the 0.1 µg/l standard. The scattered location of the sample stations recording the higher than standard concentrations seems to indicate that the results are of natural origin (or possible contamination of samples) rather than a result of dredging activity.

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INTRODUCTION

Part B of the water quality monitoring program for the construction of the Palau International Airport commenced August 1980 and terminated with the June 1983 monthly water sampling and analyses. Normal aircraft landing operations on the runway and use of the parking apron began in May 1983. Dredging operations at the Toagel Mid Channel dredge site were completed the same month. This report completes the two part report of the water quality monitoring program which was contracted to the Water and Energy Research Institute of the University of Guam by the United States Naval Facilities Engineering Command under contract number N62742-80-C-0002. A completion report for Part A Pre-Construction was published in January 1981 (Romeo et al., 1981).

The initial estimate of the amount of coral fill dredging material needed for airport runway and road construction was 230,000 cubic meters. It was stipulated that the dredging activity be controlled and that protection be provided for adjacent waters and reefs so that waters 200 feet outside the dragline limits (the water quality boundary) would not be degraded below water quality standards established by the Trust Territory of the Pacific Islands (TTPI).

Utilizing TTPI water quality standards and a turbidity standard derived from Part A data, a monitoring program was placed into effect starting in August of 1980 in Ngurusar Bay where initial dredging operations had been planned (see Part A report). Unfortunately, the preselected site in Ngurusar Bay failed to provide the quality of coral fill needed. It was decided to terminate dredging operations in Ngurusar Bay during the summer of 1981 and a new site was selected and approved that fall on the southeast side of the Toagel Channel reef adjacent to the old works used in construction of the Renrak Bridge. Five water quality stations were selected along the reef margin of the Toagel Mid Channel (TMC) to monitor water quality during dredging operations. Besides the reef margin stations, three were selected in the middle of the channel and one on the reef southeast of the water quality boundary of the dredging site. One control station was established on the reef margin 2 kilometers to the south at the opening of the Toagel Mid Channel. This total of ten stations was monitored monthly as at Ngurusar Bay. The waters of the Toagel Channel and environs were determined on initial sampling to be much clearer and contained less suspended solids than Ngurusar Bay waters. It was recommended that the 5 NTU turbidity standard (a measurement of light scattering caused by suspended particles) established for Ngurusar Bay be lowered to 2 NTU. However, no official action was taken on this recommendation. Official monitoring of the TMC sites commenced in January 1982 and were completed with the end of Part B. Two sites in Ngurusar Bay most likely to be affected by river-borne sediment were retained to monitor the runoff effects on water quality since substantial earth moving in the Gihmel River watershed had occurred. Fortunately (in this case), the worst drought in Micronesia on record started in the fall of 1982 and lasted for the duration of the monitoring program. A reseeding program using the grass Digitaria decumbens had gotten off to a good start and as this report is written, no serious silt runoff problems are expected in Ngurusar Bay.

OBJECTIVES

The objectives of the Part B study were to:

1) collect monthly water quality data on selected parameters controlled by TTPI water quality standards during the construction phase (dredging operations) of the Palau Airport construction program with particular emphasis on monitoring turbidity levels.

2) determine where and which, if any, monitored parameters exceed TTPI water quality standards or are significantly affected by dredging operations of the Palau Airport construction program.

SCOPE

In order to accomplish these objectives, the Water and Energy Research Institute was directed to do the following:

1) In coordination with the Trust Territory Environmental Protection Board (TTEPB), collect once monthly a set of water samples from each of the water quality monitoring stations and analyze them for turbidity, suspended solids, dissolved oxygen, temperature, salinity and pH. On a yearly basis, one set of water samples is to be analyzed for total nitrogen, total phosphorus, lead, mercury, zinc, copper, arsenic, nickel, cadmium and chromium.

2) Prepare and submit semi-annual letter reports summarizing the water quality measurements conducted during the semi-annual period. The letter report shall identify any trends, observations, and exceedences of the limits established in Part A.

3) Report immediately to the Project Design Engineer (PDE) designated by the Naval Facilities Engineering Command when the turbidity limits established by Part A have been exceeded.

METHODS

The Part A report (Romeo et al., 1981) contains a detailed description of the station selection rationale and locations for the nine Ngurusar Bay stations which were included in Part B from August 1980 through December 1981 (Figures 1 and 2).

To accommodate the shift in the dredge location to the Koror side of the Toagel Mid Channel (TMC), southeast of the bridge, a new series of stations was selected consisting of nine stations and control. Since it was initially known that strong tidal currents take place in the channel and shift directions (east or west) on ebbing or flooding tides and that the reef flat surrounding the construction site is exposed on spring low tides, the nine stations (one exception) were arrayed around the construction zone in waters just off the reef margin of the reef flat surrounding the construction area (Figure 3 and 4) or in the middle of the channel (under the assumption that

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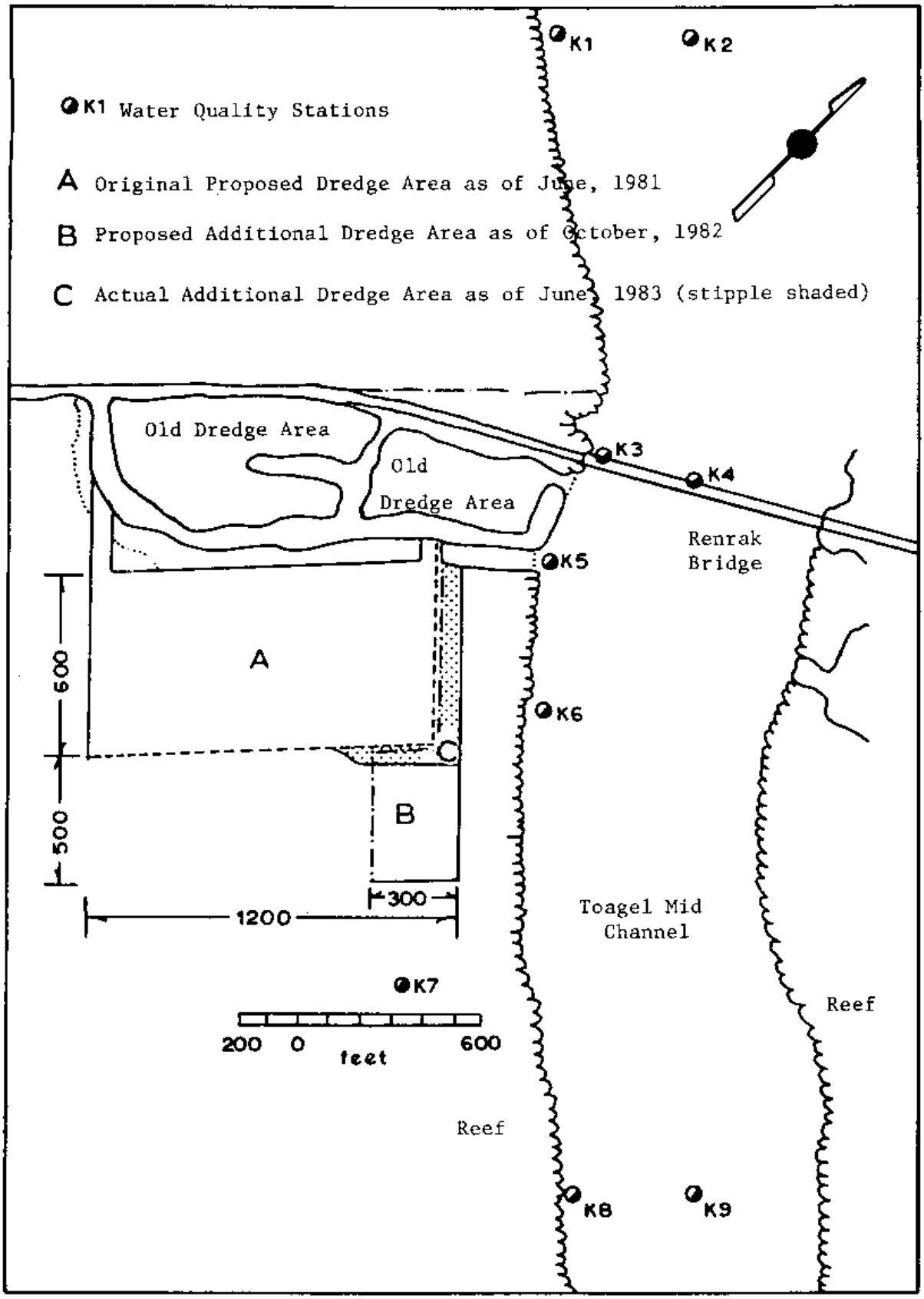

Figure 3. The Toagel Mid Channel dredge site showing the locations of nine water quality monitoring (station 7 after December 1982), and the proposed and actual areas dredged for coral fill.

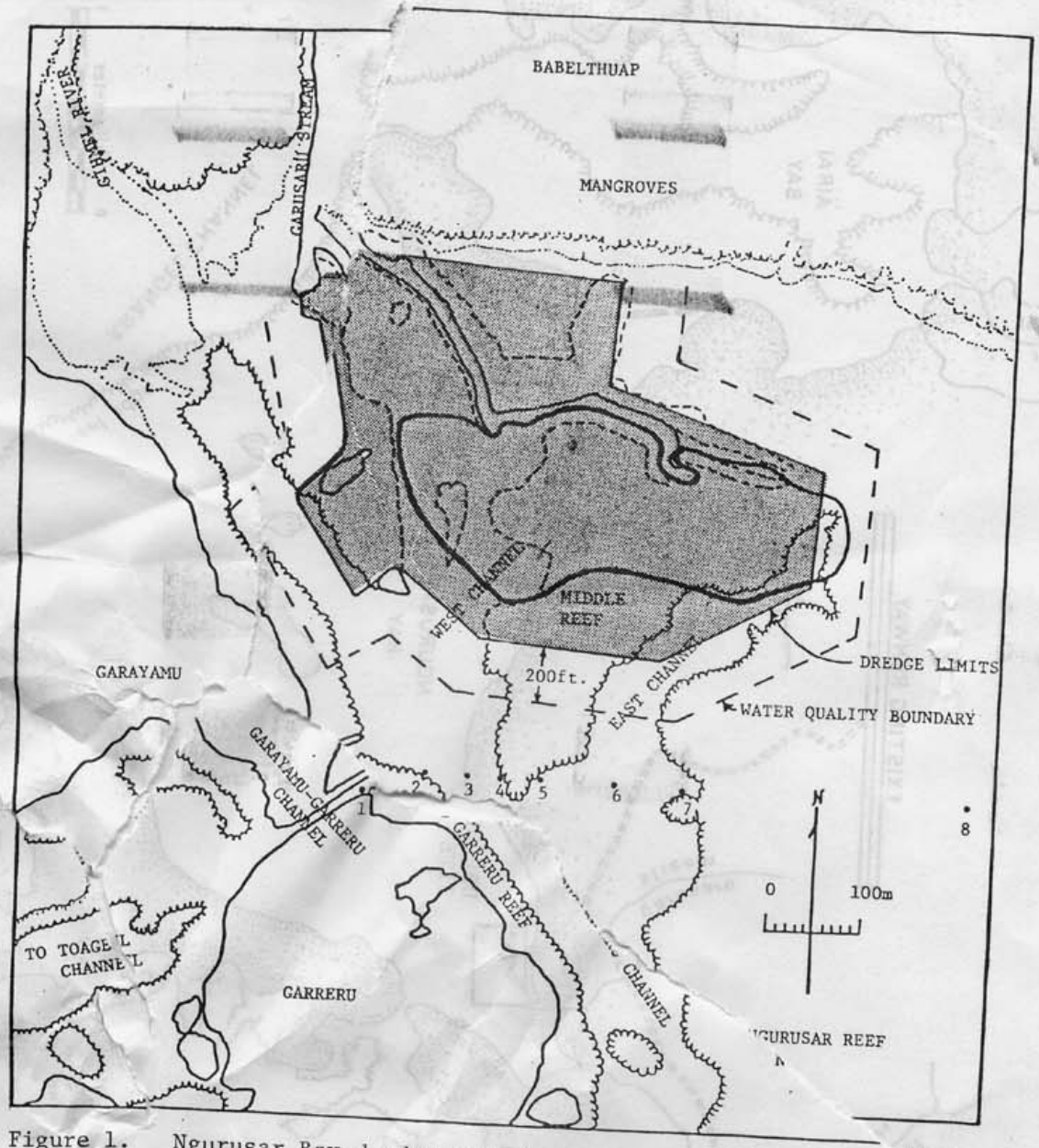

Figure 1. Ngurusar Bay dredge site location showing the water quality monitoring stations numbered 1 through 8. The area enclosed by the shading is the construction zone. The reef area actually dredged is enclosed by the inner heavy line.

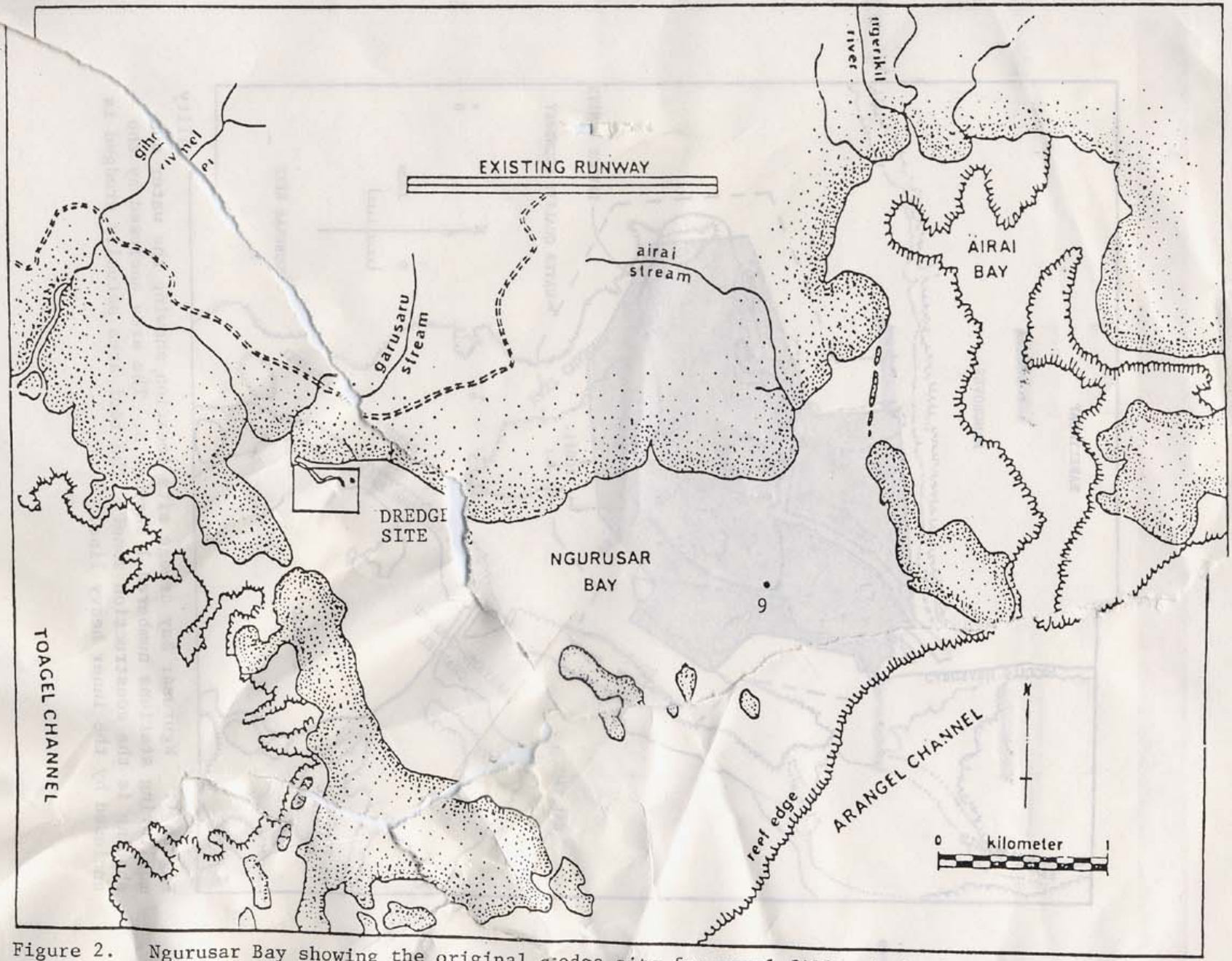

Figure 2. Ngurusar Bay showing the original dredge site for coral fill and the location of the control station(No. 9)[adopted from Environmental Consultants, Inc.(1978)].

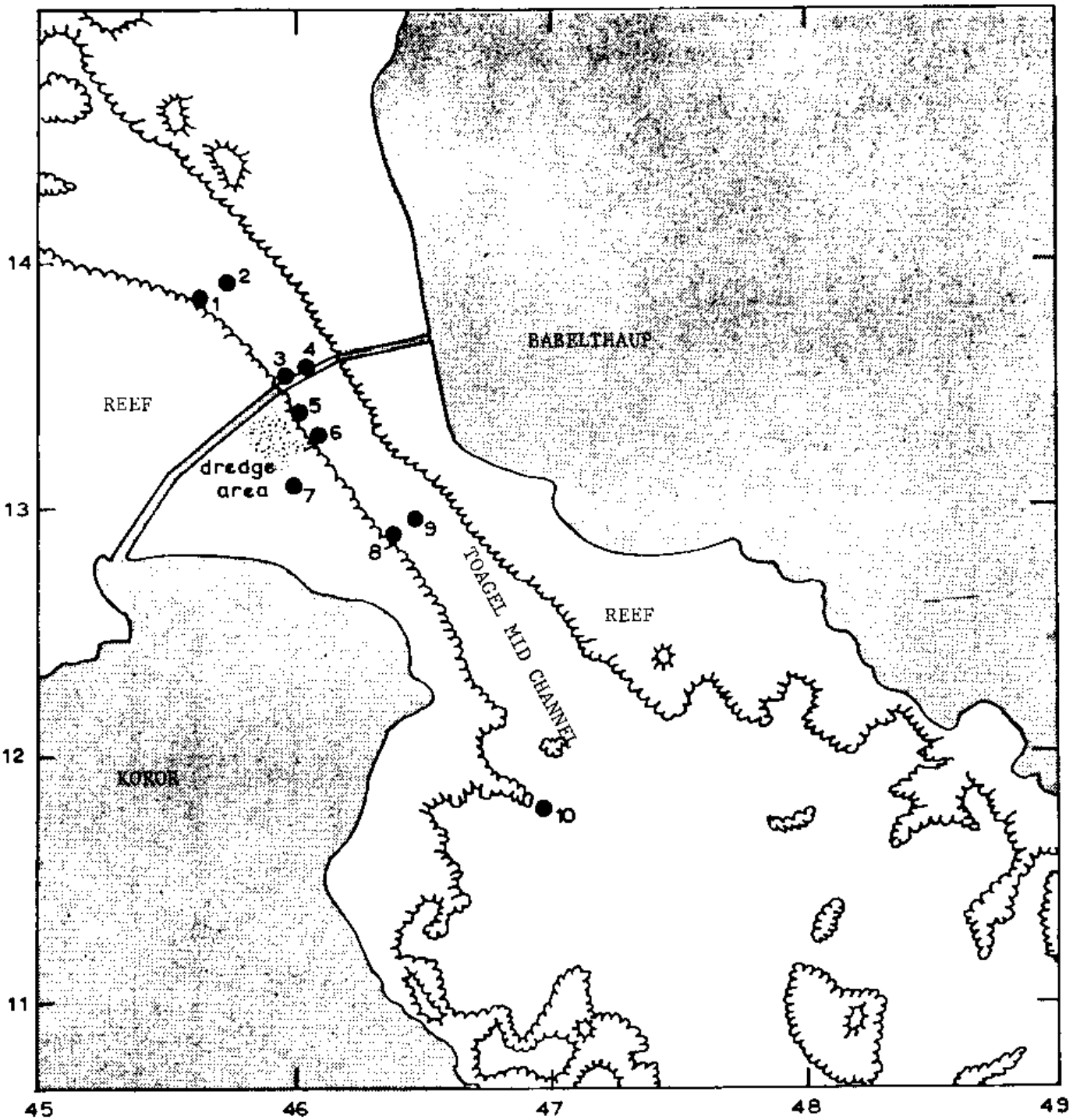

Figure 4. Overview of Toagel Mid Channel showing the location of station 10, the control station, in relation to the other water quality monitoring stations.

any sediment plume carried to the channel would concentrate in the channel proper). Additionally, stations 2 and 3s in Ngurusar Bay were retained to monitor possible runoff effects from earthmoving and grading in the watershed area affected by the airport construction. The following is a description of the stations as they were monitored from January 1982 through June 1983.

Station N2s - formerly Station 2 - is in Ngurusar Bay off the margin of fringing reef of Garreru Island (Figure 1).

Station N3s - formerly Station 3 - is in Ngurusar Bay in the middle of Garusaru channel between Garreru Reef and the southern end of Middle Reef (Figure 1).

Station K-1 - is located in the Toagel Mid Channel (Figure 3) off the reef margin in about 3 m of water and lies approximately 500 m northwest of the Renrak Bridge (also referred to as the K-B bridge).

Station K-2 - is located at mid-channel approximately 175 m northeast from K-1 and 500 m northwest from the Renrak Bridge.

Station K-3 - is located directly below the west side of the Renrak Bridge approximately 20 m from the west bridge support.

Station K-4 - is located at mid-channel directly below the Renrak Bridge.

Station K-5 - is located just inside the reef margin at the mouth of the shallow channel cutting the reef flat to the south and parallel to the old dredge works on the west side of the Toagel Mid Channel. The station is approximately 120 m southeast of the west Renrak Bridge support.

Station K-6 - is located approximately 160 m southeast of K-5 in 3 m of water, just off the reef margin in the Toagel Mid Channel.

Station K-7 - is located on the reef flat approximately 230 m due south of Station K-6 and approximately 100 m southeast of the proposed exterior retaining berm surrounding the Airport dredge site. A later expansion of the dredge site to the southeast and to the northeast (Figure 3) necessitated moving this station some 150 m to the southeast in December 1982.

Station K-8 - is located approximately 750 meters southeast of the Renrak Bridge in 3 m of water just off west reef margin in the Toagel Mid Channel.

Station K-9 - is located at mid-channel approximately 175 m northeast of K-8.

Station K-10 - is the control station located 2 km southeast of the Renrak Bridge at the Pipiroi Inlet (Figure 4). The station lies just off the pointed ridge of reef jutting into the Toagel Mid Channel from the west.

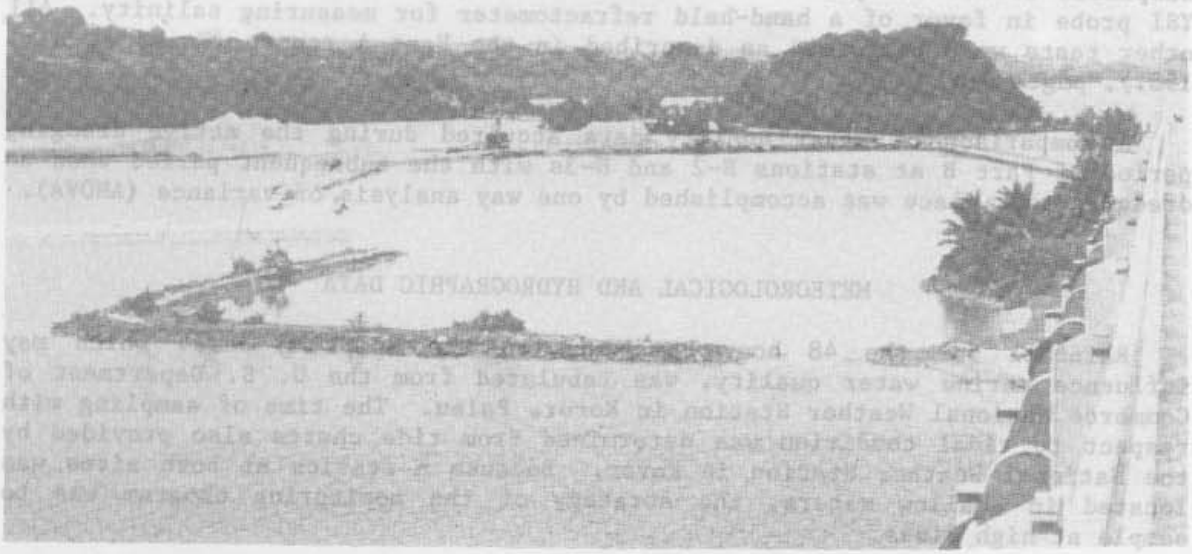

Figure 5a. The Toagel Mid Channel dredge as it appeared in June 1983 at projects completions. The lagoon in the center of the photo is the old dredge site (see Figure 3).

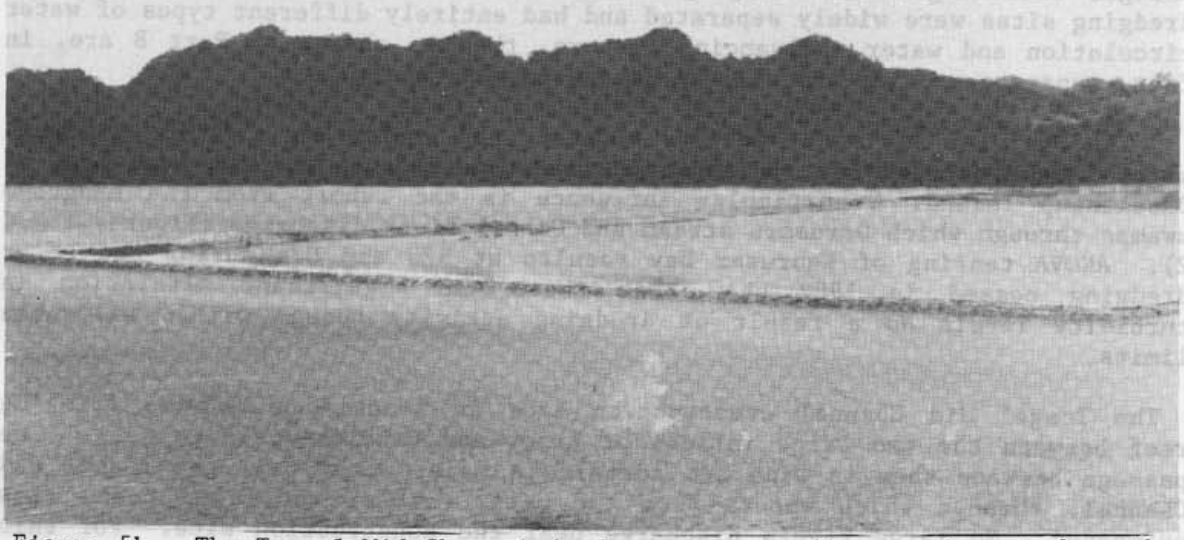

Figure 5b. The Toagel Mid Channel dredge site extending south east from the area shown above.

In summary, stations N2s, K-1, K-3, K-5, K-8, and K-10 are all located in about 3 m of water off reef margins. Stations N3s, K-2, K-4, and K-9 are located in mid-channel positions. Station K-5 and K-7 are located on the reef flat areas close to the water quality boundary.

Because increased numbers of stations were included (12 overall, versus 9 previous to January 1982) and no depth stratification of water masses was expected in the Toagel Mid Channel, only surface samples (collected at one meter from the surface) were collected from January 1982 through the remaining portion of the study. This kept the total number of samples analyzed to 12 as in the earlier portion of Part B. Figures 5a and 5b show the Toagel Mid Channel dredge site as it appeared at the project's completion in June, 1983.

Although no quantification of corals or other biological data was accumulated during Part B, it was evident that stations along the reef margin of the Toagel Mid Channel were all quite similar in possessing an extensive and diverse hermatipic coral community and otherwise an essentially hard calcareous substrate interspersed with biogenic sand deposits. Fish life is abundant and likewise diverse. Station K-5 was located on a disturbed portion of reef flat (from the construction of the Renrak Bridge) and the bottom consisted entirely of loose and fixed calcareous rock and sand with occasional thin and sparse covering of fine filamentous blue-green algae. Station K-7 was located in the dense turtle grass (Enhalis acroides) beds of this reef flat. The transferance of K-7 to the southwest brought this station closer to the reef margin and to the outer periphery of the Enhalis acroides zone. The bottom characteristics of Station N3s, is unknown since N3s lies in very turbid water and was not investigated. The Toagel Mid Channel stations K-3, K-4, and K-9 lie at points in excess of 30 m deep, the limit of the sounding line used and likewise were not observed. Ngurusar Bay Station N2s is over a living coral community that thrives along the margins of Garreru Channel. Although the community here also appears diverse, it appears to favor large, round coral heads of Porites in contrast to the foliaceous, encrusting or branching colonies of Acropora, Pocillopora and others commonly seen at the margins of the Toagel Mid Channel.

CHEMICAL AND PHYSICAL ANALYSES

Water quality parameters were measured once monthly, from August 1980 through June 1983 for the following: turbidity (NTU), suspended solids, dissolved oxygen, temperature, salinity, and pH, for a total of 34 monthly analyses sets. A sample set for October 1980 was not collected. Additionally, once each year, an additional set of samples from each station was collected and analyzed for total soluble nitrogen, total phosphorus, and the metals: arsenic, cadmium, copper, chromium, lead, mercury, nickel and zinc.

All water samples were collected by a PVC Van Dorn water sampler (3.2 liter capacity) at 1 m depths at all stations from January 1982 to December 1983. In the earlier period, from August 1980 through December 1981, stations N3, N6 and control station N9 were also sampled at one meter above the bottom in addition to the surface sample.

Sample handling once collected was identical to Part A (Romeo et al., 1981) except for the following. Instead of collecting 750 ml in two bottles,

one liter size bottles are utilized for the monthly required parameters (excepting dissolved oxygen which was obtained and analyzed as previously). The extra volume was beneficial in providing more measurable solids in the suspended solids analyses. An additional change was the abandonment of the YSI probe in favor of a hand-held refractometer for measuring salinity. All other tests were performed as described in the Part A report (Romeo et al., 1981), pages 4-5.

A comparison of water quality data acquired during the active dredging period of Part B at stations N-2 and N-3s with the subsequent period when no dredging took place was accomplished by one way analysis of variance (ANOVA).

METEOROLOGICAL AND HYDROGRAPHIC DATA

Rainfall for the 48 hours previous to the sampling date, which may influence marine water quality, was tabulated from the U. S. Department of Commerce National Weather Station in Koror, Palau. The time of sampling with respect to tidal condition was determined from tide charts also provided by the National Weather Station in Koror. Because a station at both sites was located in shallow waters, the strategy of the monitoring program was to sample at high tides.

RESULTS

The Part B water quality monitoring program can be divided into two parts of nearly equal length, that occurring from August 1980 through January 1982 when Ngurusar Bay was the focus of dredging activity and that occurring from January 1982 through June 1983 when dredging operations were relocated to the Koror side of the Toagel Mid Channel. The month of January 1982 was the only month when complete sets were collected from both water quality monitoring sites. Stations N2s and N3s of the Ngurusar Bay monitoring program were retained in the second portion to monitor subsequent changes occurring after dredging ceased in Ngurusar Bay. Because the two dredging sites were widely separated and had entirely different types of water circulation and water influencing factors, the two phases of Part B are, in fact, separate studies and will be discussed separately.

The Ngurusar Bay water quality boundary and monitoring stations lie well within the protected bay, adjacent to limestone islands and the land mass of Babelthaup Island. A particular influence is the runoff from the mangrove swamps through which Garusaru stream and Gihmel River discharge (Figures 1 and 2). ANOVA testing of Ngurusar Bay results at N2s and N3s during and after dredging ceased in 1982 show that there was significant alteration in turbidity levels as a result of dredging activity though within allowable limits.

The Toagel Mid Channel construction area is located on a wide fringing reef between the two large islands of Koror and Babelthaup (Figure 4). The passage between them is wide and contains a major water way, the Toagel Mid Channel, through which waters from the outer barrier reefs and ocean flow unimpeded. No large rivers discharge near the construction site. For this reason, the Toagel Mid Channel has inherently clearer, more oceanic type water than Ngurusar Bay. The results of the study reflect this basic

difference. The water quality monitoring program results show that any effects on water quality caused by dredging operations at the Toagel Mid Channel were minimal or too insignificant to measure on the dates sampling was conducted. Other than during storm conditions, or prolonged drought, rainfall and tidal conditions (Table 1) during the sampling did not appear to affect the water quality observed. Trust Territory of the Pacific Islands water quality standards for the parameters monitored are shown in Table 2.

pH

The pH of the Ngurusar Bay monitoring stations ranged from a low of 7.70 to a high of 8.60 (Table 3). Mean pH of the monitoring stations ranged from 8.10 to 8.17. Fluctuations in pH were dependent upon day of sampling and are reflected at all the stations for that particular sampling date. In comparison to the data obtained in December 1979 and January 1980 for Part A, the Part B mean pH is higher by approximately 0.2 pH units though the range for Part B would include Part A pH readings as well. Stations N2s and N3s were kept in the monitoring program till its conclusion. The mean recorded pH at these stations dropped during the no dredging period from 8.11 to 8.00 and from 8.12 to 8.04 at N2s and N3s, respectively. Because Part B covered a wider time period and included more variable climatological conditions, it is not surprising that the data from Part B should have greater variability (compare standard deviations) around the means.

The Toagel Mid Channel monitoring stations exhibited pH ranging from 7.85 to 8.41 (Table 4). Mean station pH ranged from 8.13 to 8.18. The standard deviation of pH around mean station pH was generally less, 0.1 pH units, indicating how constant and relatively unchanging were conditions at these stations. As seen in Ngurusar Bay, differences in pH were on a day to day basis with the lower or higher tendency observed across all stations for that particular sampling day. No trends toward higher or lower pH over time were observed.

Temperature

Temperatures in Ngurusar Bay for Part B ranged from 27.5 to 32.0°C (Table 5). Mean station temperatures ranged from 29.3°C (recorded at the control station) to 30.0°C (recorded at stations N-5 and N-6s). The rest of the Ngurusar Bay monitoring stations recorded mean temperatures of 29.8 to 29.9°C. The cooler waters of control station 9 may be due to its more distant location from shore and increased water circulation in comparison to the other Ngurusar Bay stations. In comparison to Part A measurements, temperatures during Part B were approximately 1°C higher. This pattern occurs also at the control station.

Temperatures at the Toagel Mid Channel ranged from 27.5°C to 30.5°C (Table 6). Mean station temperatures ranged from 28.7 to 29.1°C. Since control station temperatures did not vary from other monitoring station temperatures, there was no relationship of temperature at the water quality stations to dredging activity.

Table 1. Precipitation recorded for the 48 hours previous to the sampling date and tidal conditions at the time of sampling during Part B. Rainfall totals are rounded to the nearest tenth of an inch. The time of the first sample collection in hours:minutes prior (-) or after (+) the tidal height is given in the last column. N.A. means data not available.

Date	Precipitation (in.) (48 hours previous)	Tidal Height (ft.)	Time to Tide (hrs:min.)
8/19/80	1.0	4.7	+2:30
9/18/80	0.0	4.8	-1:28
11/20/80	0.0	5.9	+1:23
12/11/80	0.1	5.8	-1:30
1/27/81	0.1	5.1	+1:37
2/22/81	0.1	5.6	+0:27
3/23/81	0.0	5.8	+0:21
4/16/81	1.4	5.2	+2:00
5/29/81	1.9	4.8	-0:20
6/25/81	0.5	2.2	+1:21
7/29/81	8.5	6.0	+3:25
8/27/81	0.1	6.0	+2:11
9/29/81	1.1	6.7	+0:28
10/30/81	2.4	5.5	-0:45
11/24/81	0.2	1.9	+1:03
12/17/81	0.1	5.4	+0:53
1/21/82	2.3	5.0	-2:44
2/18/82	0.1	5.8	+1:24
3/18/82	0.0	4.7	-2:22
4/7/82	0.3	0.9	-3:05
5/13/82	N.A.	5.5	+1:39
6/10/82	1.0	5.8	+0:03
7/15/82	0.4	4.6	+0:03
8/10/82	N.A.	5.9	-0:25
1/11/83	N.A.	5.4	-2:42
2/16/83	N.A.	5.6	-0:15
3/16/83	0.1	5.8	+0:11
4/22/83	N.A.	4.8	-1:24
5/23/83	N.A.	1.3	-0:18
6/17/83	N.A.	5.4	-0:43

Table 2. Trust Territory of the Pacific Islands water quality standards for parameters included in the Part B water quality monitoring program for the Palau airport construction project.

Parameter	TTPI Water Quality Standard (class AA waters)
Temperature °C	Ambient ± 0.9° - all waters
Turbidity (NTU)	Ambient ± 5%, 5 NTU[1]
Salinity °/₀₀	Ambient ± 10% - all waters
pH, units	Ambient ± 0.2 units
Dissolved Oxygen (mg/ℓ)	Ambient ± 25% - all waters
Total Phosphorus (mg/ℓ)	0.025
Total Nitrogen (mg/ℓ)	0.400
Arsenic (ug/ℓ)	10
Cadmium (ug/ℓ)	5
Chromium (ug/ℓ)	50
Copper (ug/ℓ)	10
Lead (ug/ℓ)	10
Mercury (ug/ℓ)	0.1
Nickel (ug/ℓ)	2
Zinc (ug/ℓ)	20

[1]The turbidity standard in this study is 5.0 NTU.

Table 3. Monthly pH readings at the Ngurusar Bay monitoring stations sampled August 1980 through January 1982. Station, mean, standard deviation, number of samples, median, and the range of pH are listed below each column. N.S. indicates not sampled.

Station	N-1	N-2	N-3s	N-3b	N-4	N-5	N-6s	N-6b	N-7	N-8	N-9s	N-9b
Date												
8/19/80	8.10	8.10	8.10	8.10	8.10	8.10	8.05	8.05	8.10	N.S.	8.00	8.00
9/18/80	8.10	8.10	8.10	N.S.	8.10	8.10	8.10	8.15	8.10	N.S.	8.15	8.20
10/80	N.S.	----------										
11/20/80	8.00	8.10	8.10	8.10	8.10	8.10	8.10	8.10	8.10	N.S.	8.20	8.20
12/11/80	8.10	8.10	8.10	8.20	8.20	8.10	8.10	8.10	8.10	8.10	8.20	8.20
1/27/81	8.25	8.20	8.20	8.20	8.20	8.20	8.20	8.20	8.20	8.20	8.20	8.20
2/23/81	8.10	8.00	8.10	8.20	8.20	8.20	8.10	8.20	8.20	8.10	8.20	8.20
3/19/81	8.30	8.20	8.20	8.20	8.20	8.30	8.20	8.30	8.20	8.10	8.40	8.40
4/13/81	8.10	8.20	8.20	8.20	8.10	8.20	8.20	8.20	8.20	N.S.	8.20	8.20
5/29/81	8.10	8.30	8.25	8.25	8.25	8.30	8.40	8.20	8.25	8.50	8.60	8.30
6/25/81	8.40	8.30	8.30	8.40	8.40	8.30	8.30	8.40	8.40	8.50	8.40	8.40
7/29/81	8.10	8.20	8.20	8.20	8.20	8.20	8.20	8.20	8.20	8.15	8.00	8.10
8/27/81	8.00	8.00	8.04	8.25	8.10	8.10	8.00	8.05	8.05	8.10	8.20	8.10
9/29/81	7.80	7.80	7.80	N.S.	7.80	7.80	7.80	N.S.	7.80	7.80	7.80	7.80
10/30/81	8.00	7.90	7.90	7.90	7.90	7.90	8.00	7.90	8.00	7.70	8.00	8.00
11/24/81	8.00	7.90	8.00	7.90	7.90	7.90	7.90	7.90	7.80	N.S.	8.00	8.00
12/17/81	8.20	8.12	8.14	8.22	8.16	8.26	8.24	8.24	8.28	8.30	8.13	8.13
1/21/82	8.27	8.26	8.26	8.30	8.00	8.24	8.22	8.22	7.90	N.S.	8.07	8.10
Mean	8.11	8.10	8.12	8.17	8.11	8.14	8.13	8.16	8.11	8.14	8.16	8.15
Standard Deviation	0.14	0.14	0.13	0.13	0.15	0.15	0.14	0.13	0.16	0.23	0.19	0.15
Number of Samples	17	17	17	15	17	17	17	16	17	11	17	17
Median	8.00	8.10	8.10	8.20	8.10	8.10	8.15	8.20	8.10	8.10	8.15	8.20
Range	7.80-8.30	7.80-8.30	7.80-8.30	7.90-8.40	7.80-8.40	7.80-8.30	7.80-8.40	7.90-8.30	7.80-8.40	7.70-8.50	7.80-8.60	7.80-8.40

Table 4. Monthly pH readings at the Toagel Mid Channel monitoring stations sampled January 1982 through June 1983. Station mean, standard deviation, number of samples, median, and the range of pH are listed below each column. N.S. indicates not sampled.

Station	K-1	K-2	K-3	K-4	K-5	K-6	K-7	K-8	K-9	K-10	N-2s	N-3s
Date												
1/21/82	8.18		8.18		8.18	8.19		8.19		8.19		
2/18/82	8.05	8.05	8.05	8.05	8.13	8.17	8.20	8.20	8.16	8.15	7.96	7.95
3/18/82	8.22	8.22	8.24	8.26	8.21	8.22	8.23	8.26	8.18	8.19	8.05	8.11
4/7/82	8.17	8.11	8.14	8.14	8.11	8.15	N.S.	8.14	8.17	8.16	7.89	7.86
5/13/82	8.16	8.12	8.14	8.18	8.16	8.16	N.S.	8.22	8.24	8.24	7.85	8.16
6/10/82	8.02	8.06	8.04	8.02	8.04	8.06	8.08	8.08	8.04	8.11	7.98	8.02
7/15/82	8.33	8.11	8.21	8.28	8.18	8.17	8.22	8.18	8.10	8.12	7.98	8.00
8/10/82	8.13	8.14	8.09	8.02	8.18	8.10	8.10	8.04	8.06	8.08	8.04	7.99
9/21/82	8.30	8.18	8.15	8.20	8.20	8.20	8.24	8.30	8.30	8.30	8.20	8.20
10/13/82	8.03	8.05	8.00	8.04	7.99	7.93	N.S.	7.98	7.97	7.99	7.80	7.92
11/19/82	8.01	8.06	8.05	8.06	8.04	8.18	8.19	8.21	8.21	8.21	8.19	8.16
12/22/82	8.20	8.20	8.20	8.20	8.21	8.21	8.24	8.25	8.18	8.24	8.30	8.15
1/11/83	8.24	8.21	8.25	8.21	8.24	8.23	N.S.	8.22	8.20	8.20	8.05	8.04
2/16/83	8.01	N.S.	8.05	8.00	8.08	8.41	8.20	8.20	8.20	8.20	8.00	8.01
3/16/83	8.00	8.05	8.02	8.05	8.01	8.06	8.10	8.10	8.08	8.14	7.90	7.97
4/22/83	8.15	8.17	8.16	8.18	8.18	8.19	8.18	8.18	8.18	8.18	8.15	8.17
5/23/83	8.22	8.22	8.20	8.26	8.27	8.26	N.S.	8.26	8.26	8.14	7.93	8.00
6/17/83	8.18	8.20	8.10	8.20	8.20	8.20	8.20	8.20	8.20	8.22	7.90	7.90
Mean	8.14	8.14	8.13	8.14	8.14	8.17	8.18	8.18	8.16	8.17	8.00	8.04
Standard Deviation	0.10	0.06	0.08	0.09	0.08	0.10	0.06	0.08	0.08	0.07	0.13	0.10
Number of Samples	18	16	18	17	18	18	12	18	18	18	17	17
Median	8.16	8.14	8.14	8.16	8.14	8.19	8.20	8.20	8.17	8.18	7.98	8.00
Range	8.00-8.33	8.05-8.22	8.00-8.25	8.02-8.28	7.99-8.27	7.93-8.41	8.08-8.24	7.98-8.26	7.97-8.30	7.99-8.30	7.85-8.20	7.86-8.17

Table 5. Monthly centigrade temperature readings for Ngurusar Bay monitoring stations sampled August 1980 through January 1982. Mean, standard deviation, number of samples, median and the range of temperatures are listed below the monthly readings. N.S. indicates units not sampled.

Station	N-1	N-2	N-3	N-3b	N-4	N-5	N-6s	N-6b	N-7	N-8	N-9s	N-9b
Date												
8/19/80	30.3	30.6	30.3	28.9	30.0	30.6	30.0	28.9	30.0	N.S.	28.9	28.9
9/18/80	29.4	29.4	30.0	N.S.	30.0	29.4	29.4	28.9	29.4	N.S.	28.9	28.3
10/80	N.S	----------										
11/20/80	30.5	30.5	30.5	30.5	31.0	31.0	31.5	31.0	3..0	N.S.	30.5	30.0
12/11/80	31.0	31.0	31.0	30.5	30.5	30.5	31.0	30.5	31.0	31.0	30.0	30.0
1/27/81	29.0	30.0	29.5	29.5	29.5	30.0	30.0	29.5	29.5	N.S.	29.0	29.0
2/23/81	29.0	30.0	30.0	29.0	30.0	30.0	30.0	30.0	30.0	30.0	29.0	29.0
3/19/81	29.5	30.0	30.5	30.0	30.5	31.0	30.5	30.5	31.0	30.0	29.0	29.0
4/13/81	28.0	28.0	28.0	28.0	28.0	28.5	28.5	28.0	28.0	N.S.	27.5	27.5
5/29/81	31.0	31.0	31.0	30.0	30.5	31.0	31.0	30.0	30.5	32.0	30.5	29.5
6/25/81	29.0	29.0	29.0	29.0	29.0	29.0	29.0	29.0	29.0	29.0	29.0	29.0
7/29/81	28.0	29.0	28.5	30.0	28.5	29.0	28.0	30.0	28.0	28.0	28.0	29.0
8/27/81	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.5	30.0
9/29/81	29.0	29.0	29.0	29.0	29.0	29.0	29.0	N S.	29.0	28.0	28.0	28.5
10/30/81	30.5	31.0	31.0	30.5	31.0	31.5	31.0	31.0	31.0	30.5	30.0	30.5
11/29/81	30.5	31.0	30.5	31.0	31.0	31.0	31.0	31.0	31.0	N. S.	31.0	31.0
12/81	Thermometer lost at station 1.											
1/27/82	29.5	29.5	29.5	29.7	29.7	29.7	29.7	29.5	29.8	N.S.	29.2	29.3
Mean	29.6	29.9	29.9	29.7	29.9	30.0	30.0	29.8	29.8	29.8	29.3	29.3
Standard Deviation	0.9	0.9	0.9	0.8	0.9	0.9	1.0	0.9	1.1	1.3	1.0	0.9
Number of Samples	16	16	16	15	16	16	16	15	16	9	16	16
Median	29.5	30.0	30.0	29.8	30.0	30.0	30.0	30.0	30.0	30.0	29.0	29.0
Range	28.0-31.1	28.0-31.0	28.0-30.0	28.0-30.5	28.0-31.0	28.5-31.5	28.0-31.5	28.0-31.0	28.0-31.0	28.0-32.0	27.5-30.5	27.5-31.0

Table 6. Monthly centigrade temperature readings for the Toagel Mid Channel monitoring stations sampled January 1982 through June 1983. Mean, standard deviation, number of samples, median, and the range of temperatures are listed below the monthly readings. N. S. means not sampled.

Station	K-1	K-2	K-3	K-4	K-5	K-6	K-7	K-8	K-9	K-10	N-2s	N-3s
Date												
1/21/82	29.4		29.4		29.1	29.3		29.4		29.4	29.5	29.5
2/18/82	29.2	28.7	29.1	29.1	29.5	29.2	3.00	29.3	29.3	29.3	29.9	29.8
3/18/82	28.6	28.6	28.6	Thermometer lost at station K-4								
4/7/82		Thermometer broken in shipment										
5/13/82		Thermometer lost at station N2s										
6/10/82	28.3	28.3	28.3	28.3	28.0	28.3	28.0	28.3	28.0	28.0	28.3	28.6
7/15/82	30.0	29.5	30.0	29.0	29.5	29.5	30.0	30.0	29.5	29.0	31.0	30.0
8/10/82	27.2	27.5	27.8	27.5	27.5	27.8	27.8	27.8	27.8	27.8	28.0	27.8
9/21/82	28.8	28.7	28.3	28.4	28.4	28.6	29.0	28.3	28.2	28.5	29.7	29.6
10/13/82	28.7	28.5	28.7	28.5	28.5	29.0	N.S.	28.7	28.6	28.5	29.0	28.6
11/19/82	29.9	30.1	29.7	29.9	29.5	29.5	30.3	29.0	30.3	30.2	27.2	27.6
12/22/82	28.7	28.7	28.8	28.8	29.5	29.5	29.4	29.0	28.9	29.2	29.4	30.5
1/11/83	27.5	27.2	27.3	27.6	27.6	27.8	N.S.	27.9	27.8	27.8	29.4	28.6
2/16/83	28.3	N.S.	27.9	28.8	28.4	28.4	28.6	28.4	28.5	28.2	29.5	28.9
3/16/83	27.7	28.0	27.7	28.4	27.8	27.7	28.1	28.7	27.9	28.0	29.4	28.7
4/22/83	30.3	29.0	29.1	29.1	29.0	28.8	29.0	28.8	28.7	28.8	30.3	30.4
5/23/83	28.9	28.7	28.9	29.0	29.4	29.0	N.S.	29.0	29.0	29.2	30.4	30.2
6/17/83	30.1	30.5	30.4	30.4	30.5	30.2	30.3	30.1	30.4	30.4	29.4	29.7
Mean	28.8	28.7	28.8	28.8	28.8	28.8	29.1	28.8	28.8	28.8	29.3	29.2
Standard Deviation	0.9	0.9	0.9	0.8	0.9	0.7	0.9	0.7	0.9	0.8	0.9	0.9
Number of Samples	16	14	16	14	15	15	11	15	14	15	16	16
Median	28.8	28.6	28.8	28.6	28.5	29.0	29.0	28.8	28.6	28.9	29.4	29.6
Range	27.5-30.3	27.2-30.5	27.3-30.4	27.5-30.4	27.5-30.5	27.7-30.2	27.8-30.3	27.8-30.1	27.8-30.4	27.8-30.4	27.2-31.0	27.8-30.5

Salinity

Salinity concentrations (°/$_{oo}$) ranged from 27.8 to 36.1 at the Ngurusar Bay monitoring stations (Table 7). The extreme high and low readings were recorded from station N-8 which was located on the reef flat in shallow water (usually less than 1 meter). This factor may have attributed to the greater range in salinity concentrations observed there. The remaining stations generally ranged from 29.0°/$_{oo}$ to 34.4°/$_{oo}$. Mean station salinity ranged from 32.6 to 33.4°/$_{oo}$. The control station means were slightly higher at 33.5 and 34.0°/$_{oo}$ for surface and bottom depths respectively. In comparison to Part A, mean station salinity averaged 1.0 to 2.0°/$_{oo}$ higher during Part B, including the control station.

At the Toagel Mid Channel monitoring stations, salinity ranged from 31.1 to 35.8°/$_{oo}$ (Table 8). Mean station salinity ranged from 34.2 to 34.5°/$_{oo}$, including the control station. The median salinity was 34.4°/$_{oo}$ for all Toagel Mid Channel stations. The consistency in salinity readings at the Toagel Mid Channel monitoring stations reveals the earlier mentioned homogeneity of the water mass in the channel and also reflects its distance from any major fresh water input, in contrast to Ngurusar Bay. Toward the end of the monitoring program concurrent with the persistent drought, an increase in salinity was observed at all stations. Dredging activity at either site did not measureably affect salinity concentrations.

Suspended Solids

Suspended solids along with turbidity were expected to be the key parameters for observing any degradation of water at the water quality boundary surrounding the construction zone. In Ngurusar Bay, suspended solids (which is referred to as total non filtrable residue in recent water testing manuals), ranged from 0.7 to 5.9 mg/1. Station mean suspended solids ranged from 2.6 to 4.1 mg/1 (Table 9). The control station mean suspended solids concentrations were lower, 1.8 to 2.0 mg/1, for surface and bottom depths respectively. In comparison to Part A, mean station suspended solids were higher at eight stations and lower at four. Stations 1, 2, 7, and 9s were the same or had lower mean concentrations in Part B than Part A. The other 8 stations were slightly higher though well within one standard deviation of the Part A mean concentration. Stations N2s and N3s which were retained in the Part B monitoring program after January 1982 had nearly the same suspended solid concentrations as the August 1980 to January 1982 period. ANOVA testing showed no statistical difference between the two time periods at the .05 level of significance.

Toagel Mid Channel monitoring stations had suspended solids ranging from 0.1 to 4.4 mg/1 (Table 10). The control station (K-10) recorded a mean suspended solid concentration of 1.8 mg/1 which fell within the overall range (1.6 to 2.3 mg/1) of mean suspended solids concentrations for the monitoring stations. Station 5 which was located on the reef flat, at the berm opening of the old dredge site for the Renrak Bridge construction, had the highest mean suspended solids concentration. No ill effects from dredging on suspended solids are observable for Ngurusar or the Toagel Mid Channel dredge sites. There was one sampling in November 1980 at Station 6b which is

Table 7. Monthly salinity (parts per thousand) concentrations at the Ngurusar Bay monitoring stations August 1980 through January 1982. Mean, standard deviation, number of samples, median, and range of concentrations at each station are listed at the bottom of each column. N. S. indicates not sampled.

Station	N-1	N-2	N-3s	N-3b	N-4	N-5	N-6s	N-6b	N-7	N-8	N-9s	N-9b
8/19/80	32.2	32.2	37.2	31.6	32.8	31.6	31.6	32.8	32.2	N.S.	32.2	33.3
9/18/80	32.2	32.2	32.2	N.S.	32.2	32.2	32.2	32.2	32.2	N.S.	33.3	33.3
10/80	N.S.	----------										
11/20/80	32.2	32.2	32.2	32.8	32.8	32.8	32.8	32.8	32.8	N.S.	33.3	33.3
12/11/80	33.3	31.6	34.4	34.4	33.3	34.4	35.5	35.0	33.3	36.1	34.4	35.5
1/27/81	33.3	32.8	34.4	33.3	33.9	33.3	33.9	33.9	33.3	N.S.	34.4	33.9
2/23/81	34.4	33.9	33.3	33.3	32.8	32.8	33.3	33.3	33.3	32.2	33.9	34.4
3/19/81	33.9	33.3	33.9	33.9	33.9	34.4	33.9	33.9	33.9	33.9	34.4	34.4
4/13/81	34.4	33.3	33.9	33.3	34.4	33.9	34.4	33.3	34.4	N.S.	34.4	34.4
5/29/81	33.0	33.0	33.0	34.0	34.0	33.0	32.0	34.0	33.0	31.0	33.0	34.0
6/25/81	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0
7/29/81	28.9	30.5	30.5	32.8	30.0	31.1	29.4	32.8	28.9	27.8	30.0	33.3
8/27/81	33.9	33.3	33.6	33.6	33.9	33.9	34.4	33.9	33.9	34.2	33.9	34.4
9/29/81	32.8	32.2	32.2	N.S.	32.8	32.8	32.2	N.S.	32.8	32.2	33.3	33.3
10/30/81	33.3	33.3	33.3	33.3	33.3	33.3	33.3	33.3	33.9	33.3	33.9	34.4
11/24/81	34.4	33.3	33.3	33.9	33.3	33.3	33.3	33.9	33.3	N.S.	34.4	34.4
12/17/81	33.3	33.9	33.3	34.4	33.9	33.3	33.3	33.3	33.3	33.3	33.9	34.4
1/21/82	34.4	33.3	31.1	33.3	32.8	32.8	32.2	32.2	32.2	N.S.	33.3	34.4
Mean	33.1	32.8	32.9	33.4	33.0	33.0	33.0	33.3	32.9	32.6	33.5	34.0
Standard Deviation	1.3	0.9	1.1	0.7	1.0	0.9	1.6	0.8	1.2	2.3	1.1	0.7
Number of Samples	17	16	16	14	17	17	16	16	17	10	17	17
Median	33.3	33.0	33.0	33.3	33.0	33.0	33.3	33.33	33.3	32.6	33.9	34.4
Range	28.9-34.4	30.5-33.9	30.5-34.4	31.6-34.4	30.0-34.4	31.1-34.4	29.4-35.5	32.2-35.0	28.9-34.4	27.8-36.1	30.0-34.4	33.0-34.4

Table 8. Monthly salinity (parts per thousand) concentrations at the Toagel Mid Channel monitoring stations January 1982 through June 1983. Mean, standard deviation, number of samples, median, and range of concentrations for each station are listed below of each column. N.S. indicates not sampled.

Station	K-1	K-2	K-3	K-4	K-5	K-6	K-7	K-8	K-9	K-10	N-2s	N-3s
Date												
1/21/82	34.4		34.4		33.9	34.4		33.9		34.4	33.3	31.1
2/18/82	34.4	34.4	34.4	34.4	34.4	34.4	34.4	34.4	34.4	34.4	33.9	33.3
3/18/82	34.4	34.4	34.4	34.4	34.4	34.4	34.4	34.4	34.4	34.4	33.3	33.3
4/7/82	35.0	35.5	35.0	35.0	35.5	35.0	N.S.	34.4	35.0	34.4	33.9	35.0
5/13/82	34.4	34.4	34.4	34.4	34.4	34.4	N.S.	34.4	34.4	34.4	33.9	33.3
6/10/82	33.9	34.4	33.9	33.3	34.4	34.4	33.9	33.9	33.3	34.4	32.2	33.3
7/15/82	32.4	32.4	33.1	32.4	N.S.	33.1	33.8	33.8	33.5	33.8	30.9	32.0
8/10/82	34.4	33.9	31.1	33.3	34.4	34.4	34.4	34.4	33.3	33.9	32.8	33.3
9/21/82	35.0	35.0	34.4	34.4	34.4	34.4	34.4	34.4	34.4	34.4	34.4	34.4
10/13/82	34.4	34.4	33.9	34.4	33.9	33.9	N.S.	33.9	33.3	33.9	33.3	33.3
11/19/82	33.3	33.3	33.3	33.3	33.3	33.3	33.3	33.3	33.3	33.3	34.4	34.4
12/22/82	34.4	34.4	34.4	34.4	34.4	34.4	34.4	34.4	34.4	34.4	33.3	33.3
1/11/83	35.0	35.0	35.0	35.0	35.0	35.0	N.S.	35.0	35.0	35.0	34.5	34.5
2/16/83	35.0	N.S.	35.0	35.0	35.0	35.0	35.0	35.5	35.5	35.5	35.5	35.5
3/16/83	34.3	33.9	33.6	34.0	33.9	34.7	34.3	33.9	33.7	33.6	33.6	33.9
4/22/83	35.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	33.5	35.5
5/23/83	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	34.4	34.4
6/7/83	35.5	35.5	35.5	35.5	35.5	35.5	34.7	35.5	35.5	35.5	33.3	33.3
Mean	34.5	34.5	34.4	34.2	34.2	34.5	34.4	34.4	34.4	34.5	33.7	33.7
Standard Deviation	0.8	0.8	0.7	1.1	1.1	0.6	0.6	0.6	0.8	0.6	1.1	1.1
Number of Samples	18	16	18	17	17	18	13	18	17	18	18	18
Median	34.4	34.4	34.4	34.4	34.4	34.4	34.4	34.4	34.4	34.4	33.8	33.3
Range	32.4-35.5	32.4-35.8	33.1-35.5	31.1-35.5	33.3-35.5	33.1-35.5	33.3-35.5	33.3-35.5	33.3-35.5	33.3-35.5	30.9-35.5	31.1-35.5

Table 9. Monthly suspended solids concentrations in milligrams per liter recorded at the Ngursuar Bay monitoring stations August 1980 through January 1982. Mean, standard deviation, number of samples, median, and the range of concentrations recorded at each station is listed below each column. N. S. indicates units not sampled.

Station	N-1	N-2	N-3s	N-3b	N-4	N-5	N-6s	N-6b	N-7	N-8	N-9s	N-9b
Date												
8/18/80	3.3	3.1	2.9	2.6	2.7	2.8	2.2	2.4	3.0	N.S.	1.0	2.2
9/18/80	4.5	4.3	3.8	N.S.	4.5	3.6	3.5	3.8	4.5	N.S.	3.7	3.2
10/80	N.S.	----------										
11/20/80	3.7	3.1	2.0	2.9	3.7	2.3	4.9	12.9	2.0	N.S.	2.3	2.3
12/11/80	3.8	2.5	3.3	3.1	4.4	3.2	3.6	3.8	3.7	4.4	2.3	2.3
1/27/81	0.7	1.3	0.6	1.5	2.1	1.0	0.8	1.1	1.9	N.S.	0.4	0.4
2/23/81	2.0	2.2	2.6	1.3	3.0	2.0	2.1	3.1	2.8	4.0	1.7	2.6
3/19/81	1.9	1.5	3.0	3.0	2.9	2.9	2.7	2.9	3.1	2.7	1.4	1.7
4/13/81	3.5	3.6	5.0	3.3	1.9	2.3	3.2	3.2	3.3	N.S.	2.7	1.8
5/29/81	2.7	2.6	2.6	3.4	2.9	2.1	2.6	2.8	2.8	4.8	2.6	2.6
6/25/81	2.7	3.8	4.6	4.2	5.2	3.5	4.5	4.1	2.8	4.8	3.6	3.6
7/29/81	1.9	2.4	2.6	1.3	2.0	2.6	3.9	1.4	3.3	2.5	1.3	2.0
8/27/81	4.2	4.2	3.6	5.5	2.6	2.7	2.0	2.2	1.9	3.3	1.0	1.5
9/29/81	1.4	2.4	2.8	N.S.	2.6	2.6	4.1	N.S.	2.9	5.9	1.6	2.7
10/30/81	2.5	3.3	2.6	2.2	2.6	3.0	3.0	2.3	3.5	4.4	0.8	0.6
11/24/81	1.8	3.6	2.5	2.8	2.6	2.9	3.1	2.7	2.6	N.S.	1.9	0.9
12/17/81	3.0	2.5	5.2	3.3	2.1	3.2	3.2	1.5	2.5	4.6	2.1	1.2
1/21/82	2.8	2.8	2.2	5.3	2.3	3.2	1.8	1.4	2.7	N.S.	1.1	2.1
Mean	2.7	2.9	3.0	3.0	3.0	2.7	3.0	3.2	2.9	4.1	1.8	2.0
Standard Deviation	1.0	0.8	1.1	1.3	0.9	0.6	1.0	2.7	0.7	1.0	0.9	0.9
Number of Samples	17	17	17	15	17	17	17	16	17	10	17	17
Median	2.7	2.8	2.7	3.0	2.6	2.8	3.0	2.8	2.8	4.4	1.6	2.2
Range	0.7-4.5	1.3-4.3	0.6-5.2	1.3-5.5	1.9-5.2	1.0-3.6	0.8-4.9	1.1-12.9	1.9-4.5	2.5-5.9	0.4-3.7	0.4-3.6

Table 10. Monthly suspended solids concentrations in milligrams per liter recorded at the Toagel Mid Channel monitoring stations January 1982 through June 1983. Mean, standard deviation, number of samples, median, ana the range of concentrations at each station is listed below each column. N. S. indicates units not sampled.

Station	K-1	K-2	K-3	K-4	K-5	K-6	K-7	K-8	K-9	K-10	N-2s	N-3s
Date												
1/21/82	1.3		2.8		3.1	1.6		1.9		2.2	2.8	2.2
2/18/82	2.9	2.5	2.8	1.1	3.0	1.0	2.5	0.8	1.5	1.6	1.3	0.8
3/18/82	0.3	1.1	1.0	1.1	0.9	1.1	2.1	1.4	0.7	0.5	2.7	1.5
4/7/82	1.2	1.3	1.5	1.0	2.7	1.6	N.S.	1.3	0.7	1.0	7.8	2.2
5/13/82	2.3	1.7	1.4	1.3	1.5	1.6	N.S.	3.0	2.3	2.3	3.5	4.5
6/10/82	1.0	1.8	1.5	1.1	2.2	1.3	1.9	1.5	1.3	1.6	2.2	2.5
7/15/82	<0.1	1.5	1.4	1.9	1.7	2.3	1.3	0.9	0.4	<0.1	1.9	2.0
8/10/82	1.8	2.4	1.8	3.2	3.3	2.7	N.S.	2.1	1.3	1.3	2.7	1.6
9/21/82	2.2	1.7	1.9	2.3	1.8	1.9	2.0	1.6	1.3	0.2	3.2	2.3
10/13/82	0.1	<0.1	2.4	1.7	2.2	1.7	N.S.	2.7	0.1	1.8	3.8	2.8
11/19/82	3.7	3.3	4.0	3.9	4.6	2.7	2.0	3.2	4.4	5.1	4.0	3.4
12/22/82	1.6	0.9	2.1	0.9	2.1	2.1	1.2	1.5	0.9	3.8	1.3	4.4
1/11/83	2.5	1.5	0.3	0.5	0.7	1.3	N.S.	0.9	1.8	1.0	2.3	3.2
2/16/83	3.0	N.S.	2.8	2.9	1.8	1.6	1.8	1.9	1.7	1.6	3.1	5.0
3/16/83	1.0	0.9	1.2	1.9	1.5	1.7	1.6	1.3	0.8	1.4	2.8	1.8
4/22/83	4.0	2.0	2.4	0.3	2.3	4.3	2.7	2.5	2.4	3.0	3.3	3.1
5/23/83	2.5	2.3	0.8	1.0	3.3	1.7	N.S.	1.0	2.0	2.0	2.0	3.1
6/17/83	1.5	0.8	0.9	1.1	2.9	2.8	3.1	4.0	2.7	1.7	1.9	3.4
Mean	1.8	1.6	1.8	1.6	2.3	1.9	2.0	1.9	1.5	1.8	2.9	2.8
Standard Deviation	1.2	0.8	0.9	1.0	1.0	0.8	0.6	0.9	1.0	1.2	1.4	1.1
Number of Samples	18	16	18	17	18	18	11	18	17	18	18	18
Median	1.7	1.7	1.6	1.1	2.2	1.7	2.0	1.9	1.3	1.6	2.7	2.6
Range	<0.1-3.7	<0.1-3.3	0.3-4.0	0.7-3.9	1.0-3.3	1.0-4.3	1.2-3.1	0.8-4.0	<0.1-4.4	<0.1-5.1	1.3-7.8	0.8-5.0

believed erroneously high and caused by inadvertently hitting the channel bottom with the sampler just prior to collecting the sample. This reading has been excluded from analysis of the data.

Turbidity

Turbidity levels at the Ngurusar Bay monitoring stations ranged from 0.70 to 7.50 NTU (Table 11). Two readings exceeded the 5 NTU limit established on Part A turbidity data. One reading was suspected of being faulty as was brought out in the previous section on suspended solids and in the first semi-annual letter report. The other reading, believed valid, occurred on October 21, 1981 at Station 8 and coincided with work and observable silt in that area of the construction zone nearest the station. No other turbidity readings exceeded 5 NTU. Only one other reading exceeded 4 NTU and it occurred at Station N-3s on August 27, 1981. Mean station turbidity at the Ngurusar Bay monitoring stations ranged from 1.50 at N-1 to 2.76 NTU at Station N-8. Similar to Part A, the control station (9s and 9b) recorded much lower turbidity readings than regular monitoring stations (Table 11).

Mean Part A turbidity for Ngurusar Bay monitoring stations ranged from 1.10 to 1.40 NTU, well below the mean levels of Part B. The control station mean turbidity also rose, but only slightly. Stations N2s and N3s turbidity during active dredging operations were 1.99 and 2.06, respectively. During the last 15 months when dredging had ceased, mean turbidity levels fell to 1.09 and 1.13 NTU which compare favorably with Part A. From these observations it appears that dredging raised turbidity levels in Ngurusar Bay but to a small extent, about 0.5 NTU. The one way test of variance (ANOVA) on comparison of turbidity readings at the two stations during the active and non-active dredging periods shows the drop in turbidity to be statistically significant (.05 level). This is in contrast to the suspended solids results which were not significantly different between time periods.

The Toagel Mid Channel stations were not monitored prior to dredging for any length of time to establish a baseline for a comparison to non-dredging periods. However, turbidity levels were constantly very low at all stations, usually less than 1.0 NTU (Table 12). Only four readings outside of the October 13, 1982 sampling exceeded 1.0 NTU. Overall mean station turbidity at the TMC stations ranged from 0.51 NTU at Station 3 to 0.98 at Station 5. The October 13, 1982 sampling occurred after a storm and seas had been unusually rough the week prior to sampling. For this date all stations recorded NTU readings of 1.10 or higher (including the control station). The only NTU reading exceeding 5.0 NTU (8.80 NTU) occurred on the date at Station K-6. Median turbidities (Table 11) at the stations ranged from 0.42 to 0.72 NTU.

Dissolved Oxygen

Dissolved oxygen concentrations at the Ngurusar Bay monitoring stations ranged from 3.4 mg/l to 9.5 mg/l (Table 13). Dissolved oxygen at the control station ranged from 4.3 to 9.0 mg/l at the surface and 4.4 to 5.5 mg/l at this bottom. No evidence of oxygen depletion was noted. Station N-8, which was

Table 11. Monthly turbidity (NTU) readings at the Ngurusar Bay monitoring stations sampled August 1980 through January 1982. Mean, standard deviation, number of samples, median, and the range of turbidity values are listed below each column. N. S. indicates not sampled.

Station	N-1	N-2	N-3s	N-3b	N-4	N-5	N-6s	N-6b	N-7	N-8	N-9s	N-9b
Date												
8/19/80	1.20	1.80	1.30	1.10	1.30	1.60	1.10	1.20	1.20	N.S.	0.45	0.55
9/18/80	1.40	1.60	1.60	N.S.	1.10	0.80	1.10	0.80	1.20	N.S.	0.50	0.30
10/80	N.S.	----------										
11/20/80	2.60	1.80	1.50	1.90	1.60	1.70	1.90	7.50	1.20	N.S.	0.70	0.50
12/11/80	1.50	1.30	1.50	1.70	1.40	1.30	1.20	1.60	1.50	2.00	0.60	0.70
1/27/80	0.90	2.10	1.60	1.60	1.70	2.00	1.50	1.40	1.20	N.S.	0.80	0.70
2/23/81	0.90	1.70	1.60	1.40	1.30	1.20	1.20	1.70	1.40	2.40	0.90	0.70
3/19/81	0.90	1.50	1.80	1.80	1.60	1.70	1.50	1.50	2.10	2.80	0.70	0.90
4/13/81	2.10	2.00	2.00	2.10	1.90	1.00	1.80	1.50	1.50	N.S.	0.60	0.60
5/29/81	1.20	1.20	1.60	2.00	1.70	1.20	2.00	1.30	1.50	3.20	0.60	0.70
6/25/81	0.70	1.20	1.80	1.60	1.20	0.70	1.40	1.40	1.30	2.00	0.80	0.60
7/29/81	2.80	2.60	2.80	1.70	2.60	3.10	2.80	1.90	3.20	3.50	0.90	0.50
8/27/81	3.30	3.40	4.70	3.10	2.60	1.90	1.40	1.60	1.40	0.60	1.30	0.60
9/29/81	1.90	2.20	2.70	N.S.	2.30	2.00	2.60	N.S.	2.60	5.10	0.70	1.00
10/30/81	1.10	2.40	2.30	1.80	2.20	2.90	2.00	1.50	2.50	3.00	0.70	0.60
11/24/81	0.80	3.00	2.40	1.80	2.10	2.10	2.60	2.10	2.50	N.S.	1.10	0.70
11/17/81	0.75	2.00	1.81	1.75	1.62	1.36	1.80	1.60	1.66	3.00	0.82	0.69
1/21/82	0.72	1.49	1.72	2.00	1.70	1.48	1.10	0.98	1.82	N.S.	0.60	0.22
Mean	1.50	1.99	2.06	1.81	1.76	1.66	1.74	1.91	1.75	2.76	0.76	0.65
Standard Deviation	0.81	0.63	0.83	0.45	0.48	0.67	0.55	1.57	0.63	1.17	0.21	0.16
Number of Samples	16	16	16	14	16	16	16	15	16	10	16	16
Median	1.20	1.90	1.80	1.80	1.66	1.65	1.77	1.50	1.58	2.90	0.70	0.60
Range	0.70-3.30	1.20-3.40	1.30-4.70	1.10-3.10	1.10-2.60	0.70-3.10	1.10-2.80	0.80-7.50	1.20-3.20	0.60-5.10	0.45-1.30	0.22-1.00

Table 12. Monthly turbidity (NTU) readings at the Toagel Mid Channel monitoring stations sampled January 1982 through June 1983. Mean, standard deviation, number of samples, median, and the range of of turbidity values are listed at the bottom of each column. N.S. indicates not sampled.

Station	K-1	K-2	K-3	K-4	K-5	K-6	K-7	K-8	K-9	K-10	N-2s	N-3s
Date												
1/21/82	0.39	N S.	0.60	N.S.	0.80	0.50	N.S.	0.34	N.S.	0.40	1.49	1.72
2/18/82	0.55	0.53	0.62	0.50	0.88	0.57	0.85	0.47	0.43	0.41	0.74	0.72
3/18/82	0.26	0.41	0.24	0.23	0.26	0.22	0.40	0.31	0.26	0.29	0.89	0.76
4/7/82	0.40	0.33	0.53	0.32	1.80	0.43	N.S.	0.39	0.39	0.40	0.97	1.70
5/13/82	0.47	0.57	0.49	0.38	0.47	0.37	N.S.	0.69	0.44	0.27	0.96	1.30
6/10/82	0.49	0.32	0.36	0.43	0.65	0.26	0.64	0.50	0.43	0.27	0.49	0.40
7/15/82	0.44	0.45	0.54	0.67	0.69	0.54	0.61	0.65	0.42	0.50	1.21	1.40
8/10/82	0.49	0.42	0.64	1.25	1.60	0.79	0.95	0.63	0.80	0.63	1.55	1.30
9/21/82	0.33	0.28	0.25	0.26	0.23	0.22	0.49	0.25	0.21	0.17	0.54	0.53
10/13/82	1.35	2.93	1.85	1.55	4.40	8.80	N.S.	2.50	1.50	1.10	2.80	3.10
11/19/82	0.60	0.43	0.38	0.35	0.29	0.52	0.87	0.27	0.23	0.19	0.82	0.86
12/22/82	0.47	0.43	0.35	0.44	0.65	0.45	0.35	0.52	0.34	0.40	0.82	0.74
1 11/83	0.80	0.39	0.32	0.67	0.75	0.80	N.S.	0.65	0.52	0.51	1.40	1.30
2/16/83	0.34	N.S.	0.27	0.32	0.40	0.36	0.52	0.45	0.35	0.28	0.74	0.58
3/16/83	0.53	0.64	0.72	0.64	0.86	0.42	0.95	0.43	0.42	0.52	1.10	1.40
4/22/83	0.48	0.48	0.44	0.61	0.83	0.60	0.56	0.54	0.41	0.42	0.89	0.75
5/23/83	0.63	0.37	0.42	0.45	1.70	0.39	N.S.	0.44	0.42	0.39	1.40	1.20
6/17/83	0.26	0.19	0.08	0.18	0.47	0.13	0.47	0 69	0.05	0.09	0.85	0.57
Mean	0.52	0.57	0.51	0.54	0.98	0.91	0.64	0.60	0.45	0.40	1.09	1.13
Standard Deviation	0.25	0.64	0.37	0.36	0.97	1.98	0.21	0.49	0.31	0.22	0.53	0.64
Number of Samples	18	16	18	18	18	18	12	18	18	18	18	18
Median	0.48	0.42	0.43	0.44	0.72	0.44	0.58	0.48	0.42	0.40	0.96	0.94
Range	0.26- 1.35	0.19- 2.93	0.08- 1.85	0.18- 0.55	0.23- 4.40	0.13- 8.80	0.35- 0.95	0.25- 2.50	0.05- 1.52	0.09- 1.10	0.49- 2.80	0.40- 3.10

Table 13. Monthly dissolved oxygen concentrations in milligrams per liter at the Ngurusar Bay monitoring stations August 1980 through January 1982. Mean, standard deviation, number of samples, median, and the range of concentrations are listed below each column. N. S. indicates units not sampled.

Station Date	N-1	N-2	N-3s	N-3b	N-4	N-5	N-6s	N-6b	N-7	N-8	N-9s	N-9b
8/19/80	5.1	6.2	6.1	5.4	6.2	6.7	5.2	6.1	8.0	N.S.	5.5	5.4
9/18/80	5.8	5.5	5.5	N.S.	5.8	4.7	4.4	5.1	4.4	N.S.	4.8	4.7
10/80	N.S.	--	--	--	--	--	--	--	--	--	--	--
11/20/80	4.9	5.0	5.2	5.1	5.2	4.7	5.3	5.0	5.3	N.S.	5.0	5.3
12/11/80	4.8	4.9	5.0	4.7	5.0	4.9	4.8	4.5	4.8	4.8	5.0	5.3
1/27/81	N.S.	--	--	--	--	--	--	--	--	--	--	--
2/3/81	5.9	5.7	5.4	5.6	5.5	5.4	5.3	5.4	5.6	5.4	5.7	5.5
3/19/81	5.2	4.9	4.8	4.9	5.1	5.6	5.1	5.1	5.2	5.2	5.3	5.2
4/13/81	4.6	4.8	4.8	4.4	4.6	5.1	4.9	4.5	4.6	N.S.	4.8	4.4
5/29/81	6.5	6.3	6.2	5.2	5.6	6.1	8.0	4.6	6.0	9.5	9.0	5.4
6/25/81	5.6	5.3	4.7	5.4	5.3	5.3	4.9	5.5	5.0	6.0	5.4	4.6
7/29/81	5.0	4.6	4.6	4.8	4.9	4.7	4.4	4.9	5.0	4.7	--	--
8/27/81	4.3	4.0	4.6	4.5	N.S.	4.6	4.5	4.4	4.7	3.9	4.3	4.8
9/29/81	4.7	4.9	4.8	N.S.	5.0	5.0	4.6	N.S.	4.5	4.2	5.1	5.0
10/30/81	5.4	5.0	5.1	5.0	5.0	5.6	5.4	5.4	5.6	3.4	5.1	5.3
11/24/81	5.0	5.0	5.0	5.0	5.0	5.4	5.2	5.0	5.2	N.S.	5.3	5.4
12/17/81	6.0	5.6	5.8	5.8	7.1	6.0	5.8	5.8	5.4	5.9	5.7	5.5
1/21/82	6.0	4.9	5.5	4.9	5.0	5.1	5.5	5.8	5.1	N.S.	5.7	4.8
Mean	5.3	5.2	5.2	5.0	5.4	5.3	5.2	5.2	5.3	5.3	5.4	5.1
Standard Deviation	0.6	0.6	0.5	0.4	0.6	0.6	0.8	0.5	0.8	1.7	1.1	0.4
Number of Samples	16	16	16	14	15	16	16	15	16	10	15	15
Median	5.2	5.0	4.9	5.0	5.1	5.4	5.2	5.1	5.2	5.0	5.2	5.3
Range	4.3- 6.5	4.6- 6.3	4.6- 6.2	4.4- 5.8	4.6- 7.1	4.6- 6.7	4.4- 8.0	4.5- 6.1	4.4- 8.0	3.4- 9.5	4.3- 9.0	4.4- 5.5

Table 14. Monthly dissolved oxygen concentrations in milligrams per liter at the Toagel Mid Channel monitoring stations January 1982 through June 1983. Mean, standard deviation, number of samples, median, and the range of concentrations are listed below each column. N. S. indicates units not sampled.

Station Date	K-1	K-2	K-3	K-4	K-5	K-6	K-7	K-8	K-9	K-10	N-2s	N-3s
1/21/82	5.8		5.8		5.6	5.8		6.1		5.6	4.9	5.5
2/18/82	5.8	5.8	5.8	5.6	5.8	5.9	6.8	5.9	5.9	6.0	5.7	5.6
3/18/82	5.2	5.3	5.5	5.3	5.3	5.3	5.2	5.3	5.4	5.4	4.5	4.7
4/7/82	6.8	5.4	5.9	5.4	5.2	5.1	N.S.	5.2	5.3	5.5	4.5	4.6
5/13/82	6.7	5.8	5.6	6.0	5.6	5.4	N.S.	5.3	5.9	6.1	4.6	4.9
6/10/82	4.7	5.2	4.9	4.6	5.2	5.1	5.4	5.5	4.7	5.3	4.1	4.7
7/15/82	7.3	6.5	7.5	6.3	7.1	7.0	8.1	6.5	6.4	6.2	5.8	6.5
8/10/82	6.3	6.0	5.8	5.7	7.4	4.1	6.1	5.8	6.0	5.5	5.1	5.2
9/21/82	5.8	5.5	5.6	5.7	5.7	5.6	6.2	5.7	5.7	5.6	5.0	5.0
10/13/82	6.4	6.0	5.9	6.0	5.5	5.5	N.S.	5.8	6.0	6.0	5.4	6.4
11/19/82	6.0	6.4	5.7	6.4	5.4	6.0	6.3	5.6	5.5	5.6	5.0	5.2
12/22/82	6.0	5.8	5.8	6.6	6.0	6.4	7.2	5.9	5.6	5.7	5.4	5.5
1/11/83	5.9	6.1	6.0	5.9	6.1	6.1	N.S.	6.1	6.0	6.1	6.9	6.3
2/16/83	6.0	N.S.	5.4	5.9	5.3	5.5	6.0	5.6	5.9	5.7	5.1	5.4
3/16/83	5.4	7.2	6.9	5.5	5.5	5.4	6.1	5.5	5.9	5.8	5.3	3.5
4/22/83	5.6	5.3	5.7	5.7	5.4	5.6	5.9	5.8	5.9	5.6	6.1	5.9
5/23/83	5.1	5.2	5.4	5.2	5.6	5.3	N.S.	5.4	5.4	5.3	4.8	4.9
6/17/83	5.2	5.1	5.2	5.2	5.4	5.2	5.6	5.7	5.1	5.1	4.2	4.4
Mean	5.9	5.8	5.8	5.7	5.7	5.6	6.2	5.7	5.7	5.7	5.1	5.2
Standard Deviation	0.6	0.6	0.6	0.5	0.6	0.6	0.8	0.3	0.4	0.3	0.7	0.8
Number of Samples	18	17	18	17	18	18	12	18	17	18	18	18
Median	5.8	5.8	5.8	5.7	5.6	5.5	6.1	5.7	5.8	5.6	5.0	5.2
Range	4.7-7.3	5.1-7.2	4.9-7.5	4.6-6.6	5.2-7.4	4.1-7.0	5.2-8.1	5.2-6.5	4.7-6.4	5.1-6.2	4.1-6.7	3.5-6.5

the most variable station with regard to most parameters, had both the highest and lowest DO concentration measured during the study. Mean station DO concentrations ranged from 5.2 to 5.4 mg/l. Fluctuation in DO from day to day in the data reflects the effect of differences in time of sampling during the day, tidal state and, less importantly, temperature of the water. Part A DO concentrations were notably higher with station means ranging from 5.7 to 6.3 mg/l. A higher proportion of samples were collected in late morning and afternoon hours during the pre-construction study when diurnal DO concentrations are highest.

At the Toagel Mid Channel stations mean station DO concentrations ranged from 5.6 to 6.2 mg/l (Table 14). Station K-7 which was located on the reef flat had the highest mean DO concentration. The July 15, 1982 sampling had appreciably higher DO than the station mean concentrations. Samples were collected on that day from 14:55 to 15:10 when DO concentrations were higher than in the usual sampling time of 09:00 to 12:00. No differences in DO concentrations between control stations and water quality boundary monitoring stations were observed at either dredge sites.

Total Soluble Nitrogen

Five separate sample sets were analyzed for various nitrogen components (Table 15) during Part B. Because the methodology for determining total nitrogen includes total Kjeldahl analysis it was decided that total soluble nitrogen, comprised of ammonia-nitrogen, nitrite-nitrogen and nitrate-nitrogen would yield a better indication of actual nitrogen concentrations since the accuracy and precision of these techniques at lower concentrations is superior. One set of total Kjeldahl nitrogen analyses was run (April, 1983) and the results are presented for comparison to the total soluble nitrogen concentrations determined earlier.

The results of all tests show that all waters surrounding the construction sites were consistently low in nitrogen. Cowan and Clayshulte (1980) found that waters surrounding Koror had total soluble nitrogen concentrations ranging from 0.006 to 0.079 mg/l. All but four analyses in Part B fell within 0.100 mg/l (Table 16). The established total nitrogen water quality standard for these waters (as Class AA waters) is 0.400 mg/l. The highest total nitrogen concentration measured in the water quality boundary was 0.220 mg/l (4/23/83, station K-2). The higher concentrations observed were not related to any other higher parameter readings (e.g., turbidity) that would indicate a relationship to a general degradation of the water quality at the water quality monitoring stations. In comparison to Part A, there was no siginificant change in nitrite plus nitrate concentrations measured during Part B for Ngurusar Bay.

Total Phosphorus

The same sets of samples collected for total soluble nitrogen were analyzed for total phosphorus (Table 15). Part A total phosphorus concentrations ranged from 0.005 to 0.187 mg/l (excluding the control station). The median total phosphorus concentration was 0.007 mg/l. During Part B, total phosphorus concentrations in Ngurusar Bay ranged from 0.001 to

Table 15. Total soluble nitrogen, total kjeldahl nitrogen, and nitrite plus nitrate nitrogen concentrations determined during Part B of the Palau airport construction project water quality monitoring program. Concentrations are in milligrams per liter.

Station	1/27/81 NO_2-N plus NO_3-N	1/21/82 Total Soluble N	2/18/82 Total Soluble N	3/18/82 Total Soluble N	4/23/83 Total Kjeldahl N
Ngurusar Bay					
N-1	.010	.035	-----	-----	-----
N-2	.014	.040	.070	.061	.101
N-3s	.010	.055	.053	.027	.087
N-3b	.013	.053	-----	-----	-----
N-4	.106	.109	-----	-----	-----
N-5	.009	.109	-----	-----	-----
N-6s	.018	.046	-----	-----	-----
N-6b	.017	.079	-----	-----	-----
N-7	.013	.037	-----	-----	-----
N-8	-----	-----	-----	-----	-----
N-9s	.011	.044	-----	-----	-----
N-9b	.004	.043	-----	-----	-----
Koror-Toagel Mid Channel					
K-1		.084	.044	.026	<.010
K-2		-----	.045	.011	.220
K-3		.064	.042	.046	.039
K-4		-----	.032	.025	.137
K-5		.033	.030	.018	.011
K-6		.146	.034	.054	.036
K-7		-----	.034	.039	.053
K-8		.039	.055	.048	.010
K-9		-----	.062	.024	.011
K-10		-----	.022	.102	.013

Table 16. Total phosphorus concentrations determined for Part B of the Palau Airport Construction project water quality monitoring program. Concentrations are in milligrams per liter.

Station	1/21/81	1/21/82	2/18/82	3/18/82	4/23/82
Ngurusar Bay					
N-1	0.010	0.008	---	---	---
N-2	0.009	0.007	0.005	0.006	0.003
N-3s	0.014	0.001	0.005	0.006	0.003
N-3b	0.010	0.003	---	---	---
N-4	0.007	0.010	---	---	---
N-5	0.009	0.004	---	---	---
N-6s	0.009	0.005	---	---	---
N-6b	0.016	0.006	---	---	---
N-7	0.007	0.007	---	---	---
N-8	---	---	---	---	---
N-9s	0.012	0.009	---	---	---
N-9b	0.008	0.009	---	---	---
Koror-Toagel Mid Channel					
K-1	---	0.010	0.006	0.002	0.003
K-2	---	---	0.006	0.022	0.004
K-3	---	0.009	0.005	0.008	0.006
K-4	---	---	0.006	0.010	0.004
K-5	---	0.006	0.006	0.006	0.003
K-6	---	0.011	0.006	0.005	0.004
K-7	---	---	0.008	0.008	0.006
K-8	---	0.008	0.007	0.010	0.003
K-9	---	---	0.008	0.014	0.004
K-10	---	---	0.007	0.009	0.006

0.016 mg/l with a median concentration of 0.008 mg/l, essentially no difference from Part A except for the one unusual reading at station N3b obtained during Part A.

At the Toagel Mid Channel total phosphorus concentrations remained consistently at 0.010 mg/l or below. Out of the 25 samples analyzed only two (excluding the control station) exceeded 0.010 mg/l. The highest concentration recorded was 0.022 mg/l at station K-2. The specified Trust Territory of the Pacific water quality standard for total phosphorus is 0.025 mg/l for Class AA waters.

Heavy Metals

Annual metal analyses during Part B were performed on samples collected 1/27/81 and 2/9/82 (Tables 17 and 18). With the exception of mercury analyses, all metal analyses results (for arsenic, cadmium, chromium, copper, nickel, lead and zinc) yielded concentrations well below the TTPI standards. Mercury test results showed the presence of mercury in detectable quantitites in seven of the twenty three samples collected. The TTPI water quality standard for mercury is 0.1 µg/l. The detection limit of mercury methods in use during the study is 0.1 µg/l. All control stations had mercury concentrations less than the detectable limit. Waters of Station K-9 reportedly had 1.2 µg/l mercury in the 2/9/82 sampling. K-9 lies in the middle of Toagel Mid Channel well to southeast of the construction site. Stations K-8 and K-7, although much closer to construction activity, had less than detectable quantities of mercury (0.2 µg/l at K-6). Most likely, the K-9 value was due to contamination of the sample and does not reflect accurate mercury concentrations in the surrounding waters. A similar reason is believed to explain the reported 80 µg/l Pb concentration at K7. In Ngurusar Bay, the Part A metals testing revealed some samples with mercury concentrations ranging from 0.1 to 1.7 µg/l. A few samples in the Part B sampling revealed a similar pattern. Stations 1, 2, and 6 all recorded mercury present in the 0.3 to 0.8 µg/l range in both Part A and Part B samplings. More frequent and numerous samplings would have been required to pin point the source of the mercury. Surface collection of samples (collected from one meter below the surface) may increase the likelihood of picking up contaminated water since the surface waters are more easily contaminated from fuel oil by boats and/or construction related activities.

Comparison of Water Quality with TTPI Water Quality Standards for Class AA Waters

TTPI water quality standards for those parameters monitored in the monthly and annual monitoring regimen were not exceeded by any measurements taken during Part B excepting a single turbidity sample and some mercury analyses. Other variations in the measured parameters are attributable to normal fluctuations or the effects of drought as observed by control station results. The standards (Table 2) are listed for Class AA waters which cover all waters in Palau other than those specifically listed in the water quality standards, Public Law 4C-78 of the Trust Territory Code, as Class B or Class A. Because Part A covered a relatively short time (samples were collected from December 19, 1979 to January 11, 1980), it is debateable whether natural

Table 17. Heavy metal analyses of water collected February 9, 1982 at the Toagel Mid Channel water quality monitoring stations. Analyses were completed during April 1982. All concentrations are in ug/l.

Station	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
N2s	0.8	<0.1	<1	<1	<0.1	0.4	0.9	4.1
N3s	0.7	0.1	<1	<1	<0.1	0.8	0.1	2.3
K-1	0.6	0.1	<1	<1	<0.1	1.0	0.1	1.5
K-2	1.3	0.1	<1	<1	<0.1	0.7	2.7	2.2
K-3	1.6	0.3	<1	1	<0.1	0.8	0.1	12.2
K-4	1.0	0.1	1	2	0.1	0.6	0.8	5.4
K-5	1.3	<0.1	<1	<1	<0.1	0.6	0.1	1.5
K-6	1.2	<0.1	1	<1	0.2	0.1	4.9	4.4
K-7	0.9	0.1	1	1	0.1	0.1	80*	5.0
K-8	1.4	0.1	1	1	0.1	0.6	0.8	2.3
K-9	0.8	<0.1	4	<1	1.2*	0.2	0.1	2.6
K-10	1.0	<0.1	1	<1	<0.1	0.1	0.1	16
TTPI Standard	10	5	50	10	0.1	2	50	20

*These high concentrations are suspected to have resulted from contamination of water samples and not to enviromental pollution.

Table 18. Heavy metal concentrations (ug/l) of samples collected at the Ngurusar Bay water quality monitoring stations, January 27, 1981.

Station	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
1	0.5	3.7	1.8	<1	0.3	0.8	1	6
2	1.0	2.0	0.8	1	0.5	0.9	1	5
3b	1.0	1.6	0.5	<1	<0.1	0.5	<1	6
3s	1.1	1.8	1.1	<1	0.2	1.1	<1	5
4	1.0	<0.2	1.1	1	<0.1	0.7	<1	5
5	1.2	1.5	1.5	<1	0.2	0.8	<1	5
6b	0.8	0.3	<0.5	1	<0.1	0.7	<1	6
6s	1.1	0.8	<0.5	4	0.6	0.6	<1	6
7	0.8	1.1	<0.5	1	<0.1	0.8	1	13
8	---	---	---	---	---	---	---	---
9b	1.2	1.8	0.5	1	<0.1	1.6	3.6	6
9s	1.1	0.7	<0.5	<1	<0.1	3.5	2.4	5
TTPI Standard	10	5	50	10	0.1	2	50	20

conditions as stipulated in TTPI regulations were adequately determined since natural conditions will vary from season to season given Palau's wet and dry season and the effects of drought. The effect of little or no rainfall, a condition that occurred between November 1982 and the last sampling in June 1983, would naturally effect such parameters as turbidity, suspended solids, pH, nutrient concentrations, salinity, and perhaps metals. It would be expected that all concentrations would decrease excepting salinity and pH.

Analyses of pH exhibited a wider range, 0.8 pH units, in Ngurusar Bay and 0.48 units in TMC than specifically allowed by Class AA water quality standards except if caused by natural conditions. Because the control stations in both sites exhibited a similar range of pH, the observed range fluctuation is a natural phenomenon and not due to construction activities. Cowan and Clayshulte (1980) have compiled the best TTPI marine baseline water quality measurements to date, including all seven TTPI districts. Their recommendation based on 225 pH measurements of waters covered by all three water quality classifications is that the TTPI adopt a 8.10 pH standard for all waters that allows 0.4 pH variability in either direction.

Measurements of temperature at the TMC stations fall within the standard deviation for temperatures allowed for all marine waters. However, given the effects of sunshine-rainfall exposure, tide, current, and time of sampling on temperature measurement it is not suprising that the difference between low and high temperatures for individual stations average 3 to 4°C. Such differences occurred at the control stations and are natural.

Salinity measurements show a natural fluctuation (based on readings at the control stations) that exceeded the specified numerical variations (10%) allowed for Class AA waters. Salinity measurements appeared to be especially susceptable to drought effects in the last months of the monitoring program. This was especially the case in Ngurusar Bay where normal freshwater flow into the area normally keeps salinity around 31 to 32°/$_{oo}$. The TMC monitoring stations, less effected by freshwater runoff, fell within the 10% allowable variation (excepting K-4) throughout the monitoring program.

TTPI standards do not specify times which samples for dissolved oxygen must be taken. Dissolved oxygen concentrations normally vary with time of day so that specified times of sampling should be stipulated in water quality standards. Low DO concentrations (e.g. 8/27/81) coincide with collection of samples before 10:00. There was no evidence of DO being below the 25% differential allowed for natural conditions based on control station DO concentrations.

Suspended solids concentrations are not covered by TTPI water quality standards. Turbidity in nephelometric turbidity units was covered by a turbidity standard derived from Part A data for Ngurusar Bay. The standard, 5 NTU, was exceeded twice (once at each dredge location). The violation occurring in the TMC was definitely related to storm conditions that raised turbidity levels generally throughout the area.

The established total nitrogen water quality standard for Class AA waters is 0.400 mg/l. The highest total nitrogen concentration measured was 0.220 mg/l at station K-2 on the April 23, 1983 sampling set. The higher concentrations observed were never related to higher readings of other

parameters (e.g. turbidity) that would indicate a relationship to degradation of the water quality. The same held true of total phosphorus concentrations at both dredge sites. The specified TTPI water quality standard for total phosphorus is 0.025 mg/l, but of twenty five samples only two exceed 0.010 mg/l. No sample exceeded the total phosphorus water quality standard during Part B.

SUMMARY

Results of the Part B water quality monitoring program show that, during construction, waters outside the water quality boundary at both dredge sites were minimally affected by construction activities. Slight increases or decreases in parameter concentrations that are believed to have been caused by construction activities in Ngurusar Bay were increased turbidity and pH. The monitoring of N2s and N3s after dredging operations ceased in January 1982 revealed that these parameters slowly returned to levels observed in Part A. Only one turbidity reading in excess of 5.0 NTU (5.10) was recorded during the 17 month period of active dredging operations in Ngurusar Bay. Similarly, one turbidity reading, 8.80, exceeded the 5.0 NTU turbidity standard at the Toagel Mid Channel Station from January 1982 through June 1983. Both high readings were at stations closest to dredging operations at the time of sampling.

Other differences noted in parameter concentrations, particularly DO, temperature and salinity between Part A and Part B for Ngurusar Bay are believed due to time of day differences in sampling and the more restrictive time period of the Part A study. Nutrient concentrations were not substantially different in any of the sets collected. Concentrations of total phosphorus were generally less than 0.010 mg/l regardless of station or dredge site. Total soluble nitrogen concentrations generally remained below 0.100 mg/l. Trust Territory of the Pacific Islands (TTPI) water quality standards allow .025 mg/l total phosphorus and 0.400 mg/l total nitrogen in class AA waters.

All analyses results for arsenic, cadmium, chromium, copper, lead, nickel and zinc in Part B were below TTPI water quality limits. Mercury appeared detectable in isolated samples from both Part A and Part B in quantities of a few tenths part per billion which exceed the 0.1 ug/l mercury standard. Because the same pattern appeared in Parts A and B, it is felt that the mercury in the samples is a result of natural occurrence or possible contamination of samples.

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