STUDY ON DESIGN WAVE

(1) Wind Speed by Direction

The records of maximum wind speed expressed in Beaufort wind scale were available during the period 1948 - 1984 as shown below:

Table-1 Maximum Wind Speed by Direction

Year	All Directions	Direction				
		N	SE	S	SW	NW
1948	7					
1949	6 - 7					
1950	4 - 5					
1951	4 - 5					
1952	6 - 7					
1953	6 - 7					
1954	6 - 7					
1955	4 - 5					
1956	4 - 5					
1957	8					
1958	8	Note: No directional data during 1948 - 1969				
1959	8					
1960	7					
1961	7					
1962	7					
1963	8					
1964	7					
1965	7					
1966	5					
1967	5					
1968	5					
1969	6 - 7					
1970	5	4	5	3		4
1971	5	4	5	4		4
1972	6	5	5	4	5	6
1973	5	5	5	4		4
1974	6	4	6	4	4	6
1979	7	5	5	5	7	6
1980	6	5	5	4	6	5
1981	5	4	5	4	5	5
1982	8	5	6	5	7	8
1983	6	6	6	6	5	6
1984	6	4	6	5		4

The relationship between the Beaufort wind scale and wind speed is as follows:

Table-2

Beaufort Wind Scale	Wind Speed (m/sec)	Range (m/sec)
1	1.039	0.6 - 1.5
2	2.572	1.6 - 3.3
3	4.372	3.4 - 5.4
4	6.944	5.5 - 7.9
5	9.774	8.0 - 10.7
6	12.603	10.8 - 13.8
7	15.689	13.9 - 17.1
8	19.033	17.2 - 30.7

(2) Probability Analysis of Wind Speed

Based on the data of the wind speed as described above, a probability analysis was made. The data was plotted by the Thomas method and the probability was analyzed by the Gumbel method.

An analysis was made for each of six cases (directions) of winds, i.e., north (N), northwest (NW), southwest (SW), south (S), southeast (SE) and all directions, taking into account the winds corresponding to the waves which propagate to the proposed causeway.

The detailed calculations are presented in Appendix 4-2, of which the results are summarized as shown below:

Table-3

Return Period (Year)	Wind Speed by Direction (m/sec)					
	N	NW	SW	S	SE	All
2	8.5	10.1	11.1	7.3	10.6	12.8
5	10.6	14.3	15.1	9.9	12.2	16.3
10	12.0	17.1	17.7	11.6	13.3	18.6
20	13.4	19.8	20.2	13.2	14.3	20.8
50	15.1	23.3	23.5	15.4	15.6	23.7
100	16.5	25.8	25.9	17.0	16.6	25.9

(3) Shallow Water Wave

The scale of shallow water wave which is generated in the lagoon was estimated for a 50-year probability.

Judging from the location of the proposed causeway and topography of Tarawa, the shallow water wave generated by the north wind will have a larger effect on causeway than the others, and as such an estimation was made for it.

(i) Effective fetch of north wind

The distance between the proposed causeway and the reef edges on the opposite shore by direction is shown in the figure below:

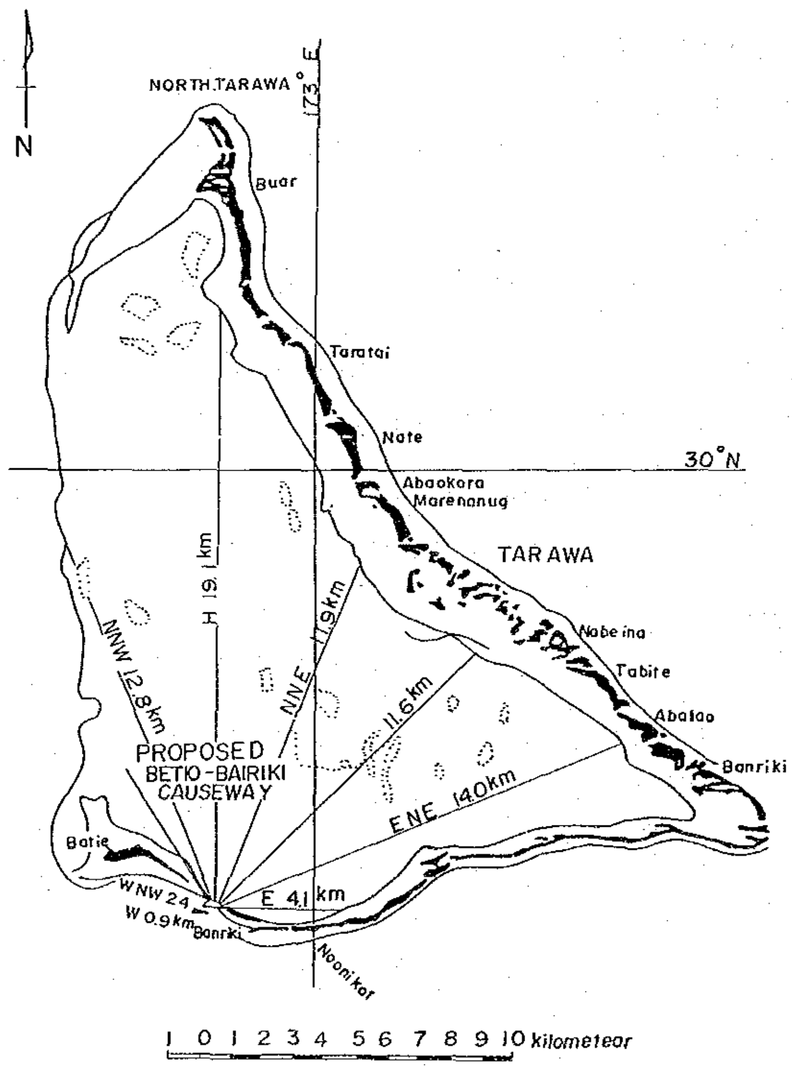


Fig.1 Effective fetch

Based on the above distance, the effective fetch was calculated by the following equation.

$$F_{eff} = \frac{\sum_{i=1}^{n} F_t \cos(\theta_i - \Theta)\Delta\theta_t}{\sum_{i=1}^{n} \cos(\theta_i - \Theta)\Delta\theta_t}$$

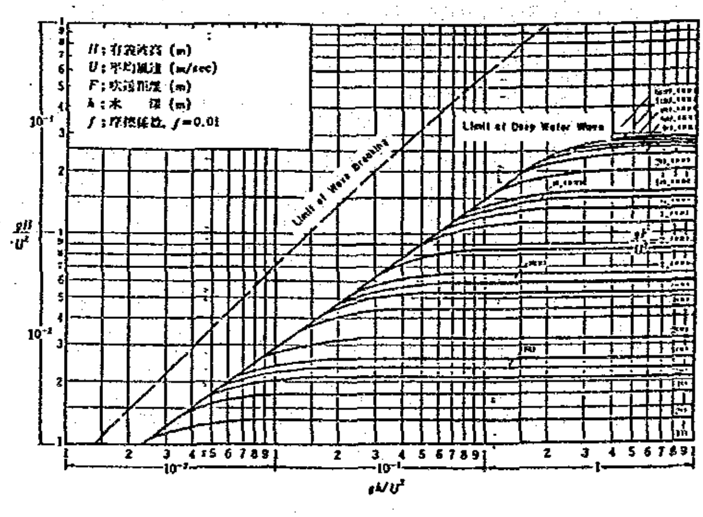
where, F_{eff} : Effective fetch

Θ : Main wind direction

Fi : Distance to the opposite shore in θ_i direction

Using this formula, the effective fetch for the north wind was calculated at 12.7 kilometers.

(ii) A shallow water wave generated by north wind. Significant wave height and wave period of shallow water wave generated by north wind were estimated based on the Bretschneider's method shown in the following figure.



H: Significant wave height
U: Average wind speed
F: Fetch
h: Water depth
f: Coefficient of friction, f = 0.01

Fig.2 Estimation of Fetch of Shallow Water Wave

$h = 8.0 + 1.8 = 9.8$ m

Average seabed level: DL - 8.00

Tide level (MHWS): DL + 1.80

$U = 15.1$ m/sec (50-year return period)

$F = 12.7$ km

$gh/U^2 = 9.8 \times 9.8/(15.1)^2 = 0.421$

$gF/U^2 = 9.8 \times 12{,}700/(15.1)^2 = 546$

$gH/U^2 = 0.049$ from the above figure

Therefore, the significant wave height (H) and the wave period (T) are calculated, as follows:

$H = 1.14$ m

$T = 3.86\sqrt{H} = 3.86 \times \sqrt{1.14} = 4.1$ sec

(4) Deep Water Wave

The scale of a deep water wave generated in the ocean was estimated for a 50-year probability. Four cases (wind directions), SW, S and SE winds which blow on ocean side of the proposed causeway and NW wind which blows on lagoon side, were analyzed.

(i) Effective fetch and wind duration

According to the pilot chart of the Maritime Safety Agency of Japan, the maximum height of ocean wave ($H_{1/3}$) is 5.0 m and the maximum wave period (T) is 9.0 sec. The maximum wind speed during the period when this ocean wave occurred was 8 in the Beaufort wind scale, equivalent to about 40 knots (20.56 m/sec).

The fetch and wind duration were estimated based on the above, as described below:

a) Method A

Based on the wave height and wind speed, the following values were obtained using the S-M-B method (refer to the chart below).

Effective fetch	: Fe = 250 km
Period	: T = 8.6 sec
Wind duration	: t = 13 hr

b) Method B

Based on the wave period and wind speed, the following values were obtained also using the S-M-B method.

Effective fetch	: Fe = 300 km
Significant wave height	: $H_{1/3}$ = 5.5 m
Wind duration	: t = 16 kt

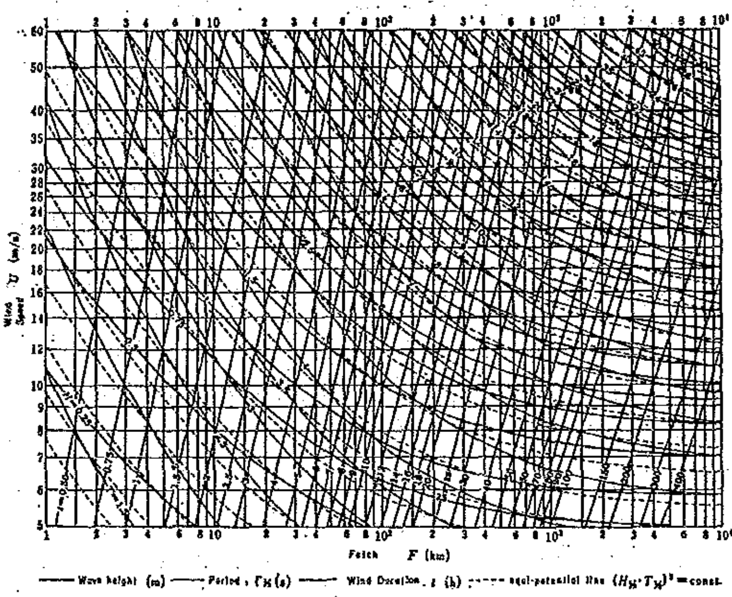
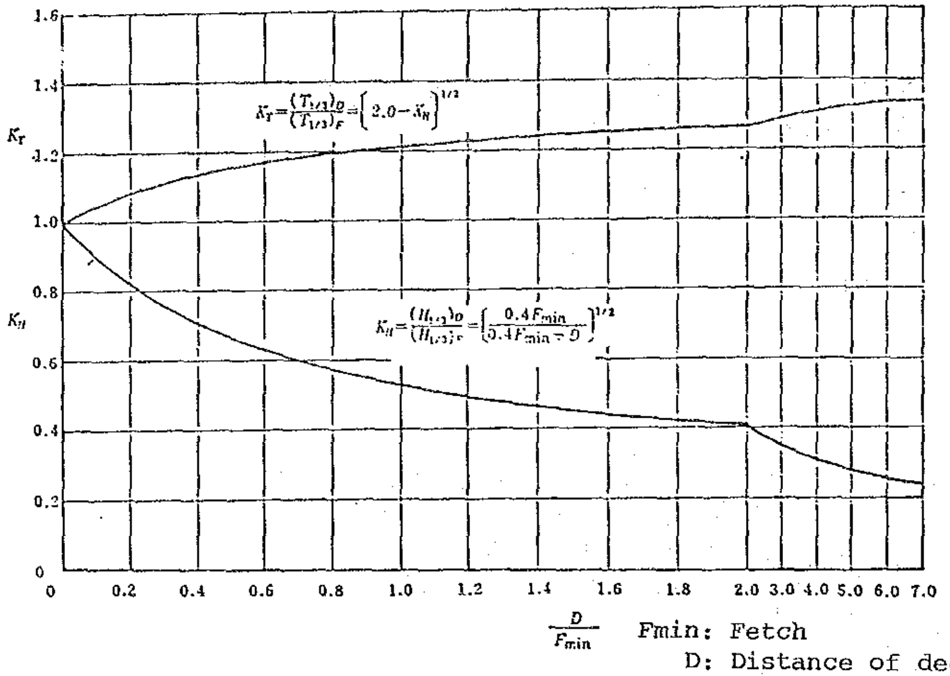


Fig.3 Curve of Wave Height by S-M-B Method

c) Effective fetch and wind duration

In general, if Bretschneider's method is applied in the case where there is an attenuation of well, the wave height decreases and the wave period increases in value as shown in the figure below. The difference between Method A and B is judged to be due to such attenuation and the attenuation distance was estimated at 20 - 30 km.



Fmin: Fetch
D: Distance of decay

Fig.4 Attenuation Curve

Based on the above results, the effective fetch and wind duration near Tarawa were estimated to be 250 km and 14 hours, respectively, which are considered to be appropriate for such area near the equator that have no extraordinary weather such as typhoon or hurricanes.

(ii) Deep Water Wave by Direction

The wave height and period were estimated, for a wind speed of a 50-year return period, calculated in (2), effective fetch of 250 km and wind duration of 14 hours, using the S-M-B method, as summarized in the table below: The results are a little bit different between those calculated based on effective fetch and wind speed and those calculated based on wind duration and wind speed. The smaller values were taken referring to the Manual for Wave Analysis, Japan.

Table-4 Deep Water Waves by Direction

			Wave on Ocean Side			Lagoon Side
Wind Direction			SW	S	SE	NW
Wind Speed		(m/sec)	23.5	15.4	15.6	23.3
Estimation based on Effective Fetch	Wave Height	$H_{1/3}$ (m)	6.2	3.5	3.5	6.2
	Period	T (sec)	9.5	7.5	7.5	9.3
Estimation based on Wind Duration	Wave Height	$H_{1/3}$ (m)	6.1	3.3	3.3	6.1
	Period	T (sec)	9.3	7.1	7.1	9.3
Used Values	Wave Height	$H_{1/3}$ (m)	6.1	3.3	3.3	6.1
	Period	T (sec)	9.3	7.1	7.1	9.3

Based on the above, the following waves were fixed for the subsequent studies

Wave on ocean side (SW): $H_{1/3}$ = 6.1 m, T = 9.3 sec

Wave on lagoon side (NW): $H_{1/3}$ = 6.1 m, T = 9.3 sec

(5) Wave Transformation and Setup on Reef

The transformation of a shallow water wave and a deep water wave were analyzed until they reached the proposed location of causeway and the wave height and wave setup in front of the causeway were then calculated.

(i) In the case of a wave breaking on the reef (wave of 50 years return period)

The height of breaking wave and wave transformation were estimated by the following Takayama's equations:

Takayama's equation

a) Height of breaking wave on reef edge

$$H_{1/3x\fallingdotseq 0} = \text{Min}\{(\beta_0 \cdot H_0' + \beta_1 \cdot h), \beta_{max} \cdot H_0', K_s \cdot H_0'\}$$

Where, $H_{1/3x=0}$ = Height of breaking wave

$\beta_0 = 0.028(H_0'/L_0)^{-0.38} \cdot \exp(20(\tan\theta)^{1.5})$

$\beta_1 = 0.52 \cdot \exp(4.2\tan\theta)$

$\beta_{max} = \mathrm{Max}\{0.92,\ 0.32\ (H_0'/L_0)^{-0.29} \cdot \exp(2.4\tan\theta)\}$

H_0': Significant wave height

L_0 : Wave length

$\tan\theta$: Seabed slope on reef edge

b) Attenuation of wave height and setup

Wave height

$$\frac{H_{1/3x}}{H_0} = B \cdot \exp(-0.05\frac{x}{H_0}) + \alpha\,\frac{h_0 + \bar{\eta}_\infty}{H_0}$$

Setup

$$\bar{\eta}_x/H_0' = \sqrt{C_0 - 3/8\beta(\frac{H_{1/3x}}{H_0})^2} - \frac{h}{H_0'}$$

$H_{1/3x}$ = Wave height at the distance of xm from reef edge

$\bar{\eta}_x$ = Setup at the distance of xm from reef edge

$$B = \frac{H_{1/3x=0}}{H_0} - \alpha\,\frac{h_0 - \bar{\eta}_\infty}{H_0}$$

α = 0.33 (constant)

$$\frac{h_0 + \bar{\eta}_\infty}{H_0} = \sqrt{\frac{C_0}{1 + 3/8\beta\alpha^2}}$$

h_0 = Water depth

β = 0.56 (constant)

$$C_0 = (\frac{\bar{\eta}_{x=0} + H_0}{H_0'})^2 + \frac{3}{8}\beta\,(\frac{H_{1/3x=0}}{H_0'})^2$$

$\bar{\eta}_{x=0}/H_0'$ = From Goda's estimation diagram

Using these equations, an analysis was made for the following 3 waves:

- Deep water wave to reach the ocean side of the causeway
  - Wave by SW wind
  - Significant wave height of ocean wave: 6.1 m
  - Period of ocean wave: 9.3 sec
  - Distance between the reef and the causeway (x) and water depth (h_0): x = 400 m, h_0 = 1.3 m

- Deep water wave to reach the lagoon side of the causeway
  - Wave by NW wind
  - Significant wave height of ocean wave: 6.1 m
  - Period of ocean wave: 9.3 sec
  - Distance between the reef and the causeway (x) and the water depth (h_0): x = 10,000 m, h_0 = 8.0 m, and x = 300 m, h_0 = 1.3 m

- Shallow water wave to reach the lagoon side of the causeway
  - Wave by N wind
  - Significant wave height of shallow water wave: 1.14 m
  - Period of shallow water wave: 4.1 sec
  - Distance between the reef and the causeway (x) and the water depth (h_0): x = 300 m, h_0 = 1.3 m

The detailed calculation is described in the subsequent pages, of which results are summarized below:

Table-5

		Ocean Side	Lagoon Side	
		Deep Water Wave		Shallow Water wave
Wind Direction		SW	NW	N
Wind Speed (m/sec)		23.5	23.3	15.1
Before Breaking	Wave Height $H_{0\,1/3}$ (m)	6.1	6.1	1.14
	Period T (sec)	9.3	9.3	4.1
After Breaking	Wave Height $H_{1/3x}$ (m)	0.70	0.66	0.46
	Period T (sec)	9.3	9.3	4.1
	Setup $\bar{\eta}$ (m)	0.7	0.69	0.08
	Tide Level (m)	1.8	1.8	1.8
	Water Level (DL + m)	+2.50	+2.49	+1.88

(ii) In case of passing over the reef without breaking

The wave height at the proposed causeway, attenuated by a friction loss, was estimated on the condition that the wave of limiting height passes over reef edge without breaking. Calculation of the limiting wave height was made based on the method proposed by Bredtschneider and Reid in "Shore Protection Manual, Volume I, USA" for the following 3 cases:

- Deep water wave to reach the ocean side of the causeway
- Deep water wave to reach the lagoon side of the causeway through Betio port
- Shallow water wave which occurs in the lagoon and reaches the lagoon side of the causeway

The detailed calculation is described in the subsequent pages, the results of which are summarized below: It is to be noted the same attenuation distance as explained in (i) above was used in calculation.

Table-6

		Ocean Side	Lagoon Side	
Kind of wave		Deep Water Wave		Shallow Water Wave
Before Attenuation by Friction Loss	Wave Height $H_{1/3}$ (m)	1.01	3.27	1.01
	Period T (sec)	9.3	9.3	4.1
After Attenuation by Friction Loss	Wave Height $H_{1/3}$ (m)	0.42	0.49*	0.52
	Period T (sec)	9.3	9.3	4.1

* This wave is dumped by the friction loss and then attenuated by shallow reef as it propagates.

(6) Design Wave

Based on all the results of the above studies, it was determined to use the waves shown in the table below for the design of the Project.

Table-7

		Wave Height (m)	Period (sec)	Water Level (DL + m)
With Breaking	Deep Water Wave Ocean Side (SW)	0.70	9.3	DL + 2.500
	Deep Water Wave Lagoon Side (NW)	0.66	9.3	DL + 2.490
	Shallow Water Wave Lagoon Side (N)	0.46	4.1	DL + 1.880
Without Breaking	Deep Water Wave Ocean Side (SW)	0.42	9.3	DL + 1.800
	Deep Water Wave Lagoon Side (NW)	0.49	9.3	DL + 1.800
	Shallow Water Wave Lagoon Side (N)	0.52	4.1	DL + 1.800

PROBABILITY ANALYSIS ON WIND VELOCITY

Probability analysis is made based on the following:

a) Applied Method

- Gumbel's Method in deriving the frequency curve

b) Wind Direction

- North
- North West
- South West
- South
- South East
- All Direction

The results are shown in the succeeding pages together with the annual maximum wind velocity records.

(1) NORTH

PLOTTING POSITION

STATION ; KIRIBATI, TARAWA
REGION ; BETIO-BAIRIKI
DISTRICT ; PACIFIC OCEAN
ALTITUDE OF STATION ; 35.0 METERS
KIND OF RECORD ; WIND FORCE (N)
PERIOD OF RECORD ; 11 YEARS

* NUMBER OF SAMPLES ; 11

NO.	WIND VELOCITY	HAZEN	THOMAS
1	6.94	0.9545	0.9167
2	6.94	0.8636	0.8333
3	6.94	0.7727	0.7500
4	6.94	0.6818	0.6667
5	6.94	0.5909	0.5833
6	9.77	0.5000	0.5000
7	9.77	0.4091	0.4167
8	9.77	0.3182	0.3333
9	9.77	0.2273	0.2500
10	9.77	0.1364	0.1667
11	12.60	0.0455	0.0833

CALCULATION METHOD ;GUMBEL METHOD

STATION ; KIRIBATI, TARAWA
REGION ; BETIO-BAIRIKI
DISTRICT ; PACIFIC OCEAN
ALTITUDE OF STATION ; 35.0 METERS
KIND OF RECORD ; WIND FORCE (N)
PERIOD OF RECORD ; 11 YEARS

(1) NUMBER OF SAMPLES ; 11

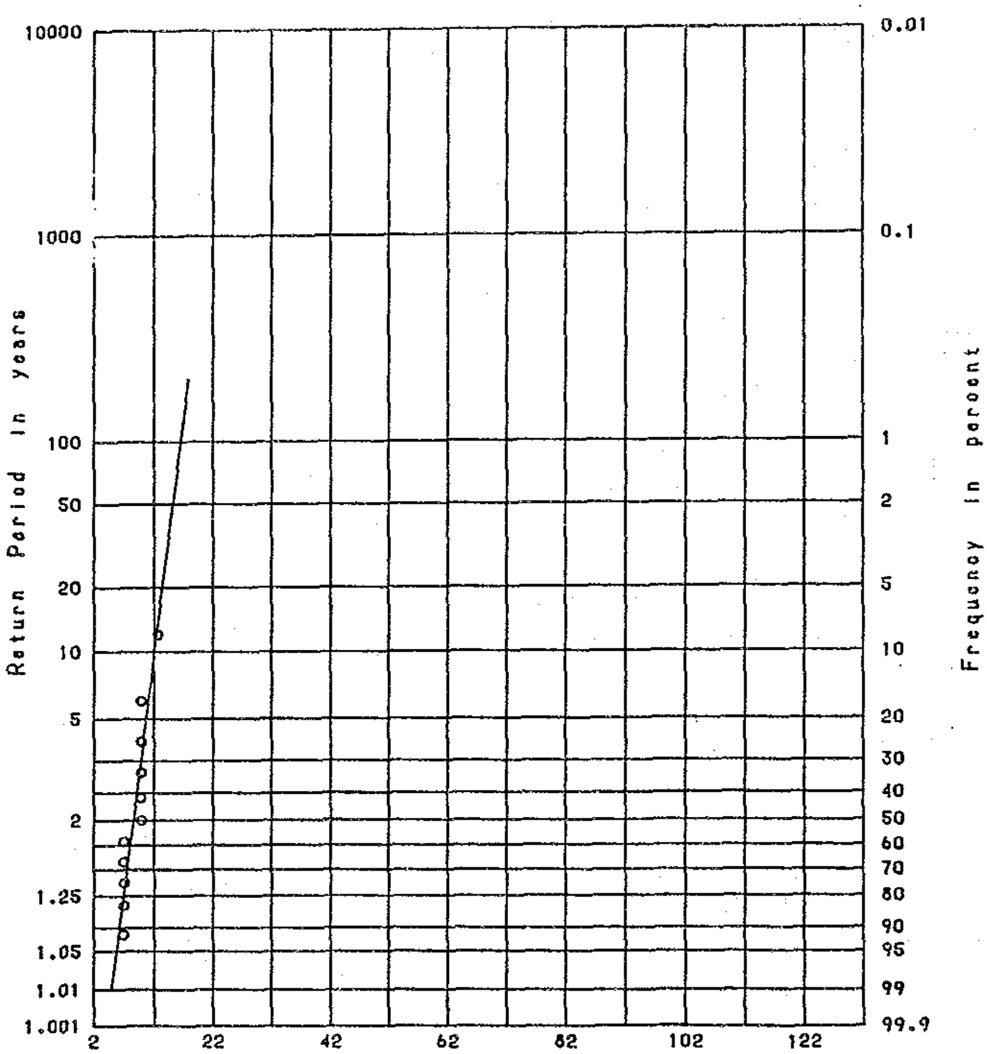
RETURN PERIOD	EXCESS PROB.	VARIABLE	WIND VELOCITY
1.01	0.9901	-1.5293	4.930
1.50	0.6667	-0.0940	7.629
2.	0.5000	0.3665	8.495
5.	0.2000	1.4999	10.625
10.	0.1000	2.2504	12.036
20.	0.0500	2.9702	13.389
30.	0.0333	3.3843	14.168
40.	0.0250	3.6762	14.717
50.	0.0200	3.9019	15.141
80.	0.0125	4.3757	16.032
100.	0.0100	4.6001	16.454
200.	0.0050	5.2958	17.761

NOTE : FORMULA OF PRESUMPTION

X=X0+(1/A)*VARIABLE

X0 = 7.806
1/A = 1.880

Station	:KIRIBATI, TARAWA	Region	:BETIO-BAIRIKI
District	:PACIFIC OCEAN	Altitude of Station	:35.0 Meters
Kind of Record	:WIND FORCE (N)		
Period of Record	:11 YEARS		



BETIO-BAIRIKI CAUSEWAY-FISHERIES CHANNEL

Fig.-1 FREQUENCY CURVE

(2) NORTH WEST

PLOTTING POSITION

STATION ; KIRIBAT1, TARAWA
REGION ; BETIO-BAIRIKI
DISTRICT ; PACIFIC OCEAN
ALTITUDE OF STATION ; 35.0 METERS
KIND OF RECORD ; WIND VELOCITY (NW)
PERIOD OF RECORD ; 11 YEARS

* NUMBER OF SAMPLES ; 11

NO.	WIND VELOCITY	HAZEN	THOMAS
1	6.94	0.9545	0.9167
2	6.94	0.8636	0.8333
3	6.94	0.7727	0.7500
4	6.94	0.6818	0.6667
5	9.77	0.5909	0.5833
6	9.77	0.5000	0.5000
7	12.60	0.4091	0.4167
8	12.60	0.3182	0.3333
9	12.60	0.2273	0.2500
10	12.60	0.1364	0.1667
11	19.04	0.0455	0.0833

CALCULATION METHOD ;GUMBEL METHOD

STATION ; KIRIBAT1, TARAWA
REGION ; BETIO-BAIRIKI
DISTRICT ; PACIFIC OCEAN
ALTITUDE OF STATION ; 35.0 METERS
KIND OF RECORD ; WIND VELOCITY (NW)
PERIOD OF RECORD ; 11 YEARS

(1) NUMBER OF SAMPLES ; 11

RETURN PERIOD	EXCESS PROB.	VARIABLE	WIND VELOCITY
1.01	0.9901	-1.5293	3.081
1.50	0.6667	-0.0940	8.411
2.	0.5000	0.3665	10.121
5.	0.2000	1.4999	14.330
10.	0.1000	2.2504	17.117
20.	0.0500	2.9702	19.790
30.	0.0333	3.3843	21.328
40.	0.0250	3.6762	22.412
50.	0.0200	3.9019	23.251
80.	0.0125	4.3757	25.010
100.	0.0100	4.6001	25.843
200.	0.0050	5.2958	28.427

NOTE : FORMULA OF PRESUMPTION

X=X0+(1/A)*VARIABLE

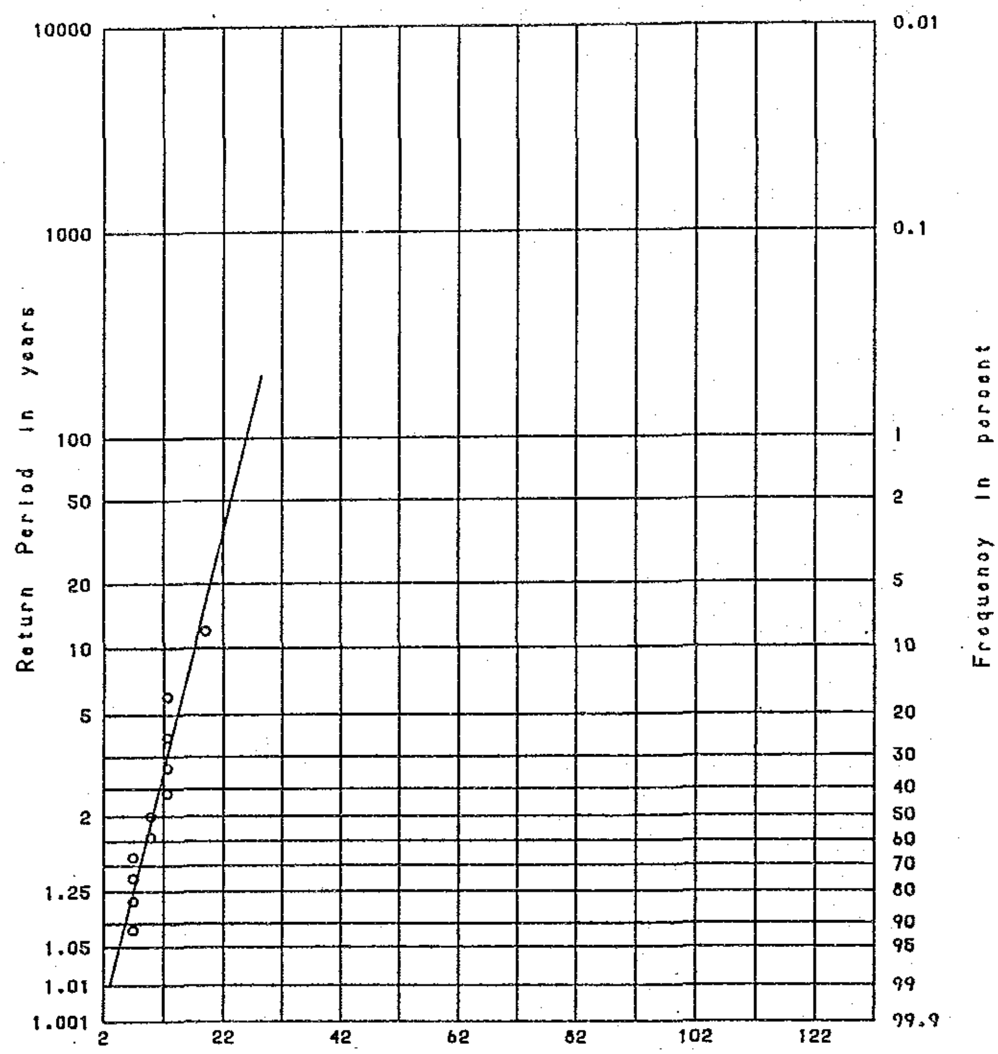
X0 = 8.760
1/A = 3.714

Station :KIRIBATI. TARAWA Region :BETIO-BAIRIKI

District :PACIFIC OCEAN Altitude of Station :35.0 Metre

Kind of Record :WIND VELOCITY (NW)

Period of Record : _ YEARS



BETIO-BAIRIKI CAUSEWAY-FISHERIES CHANNEL

Fig.-2 FREQUENCY CURVE

(3) SOUTH WEST

PLOTTING POSITION

STATION	; KIRIBATI, TARAWA		
REGION	; BETIO-BAIRIKI		
DISTRICT	; PACIFIC OCEAN		
ALTITUDE OF STATION	; 35.0	METERS	
KIND OF RECORD	; WIND FORCE (SW)		
PERIOD OF RECORD	; 7 YEARS		

* NUMBER OF SAMPLES ; 7

NO.	WIND VELOCITY	HAZEN	THOMAS
1	6.94	0.9286	0.8750
2	9.77	0.7857	0.7500
3	9.77	0.6429	0.6250
4	9.77	0.5000	0.5000
5	12.60	0.3571	0.3750
6	15.69	0.2143	0.2500
7	15.69	0.0714	0.1250

CALCULATION METHOD ;GUMBEL METHOD

STATION	; KIRIBATI, TARAWA	
REGION	; BETIO-BAIRIKI	
DISTRICT	; PACIFIC OCEAN	
ALTITUDE OF STATION	; 35.0	METERS
KIND OF RECORD	; WIND FORCE (SW)	
PERIOD OF RECORD	; 7 YEARS	

(1) NUMBER OF SAMPLES ; 7

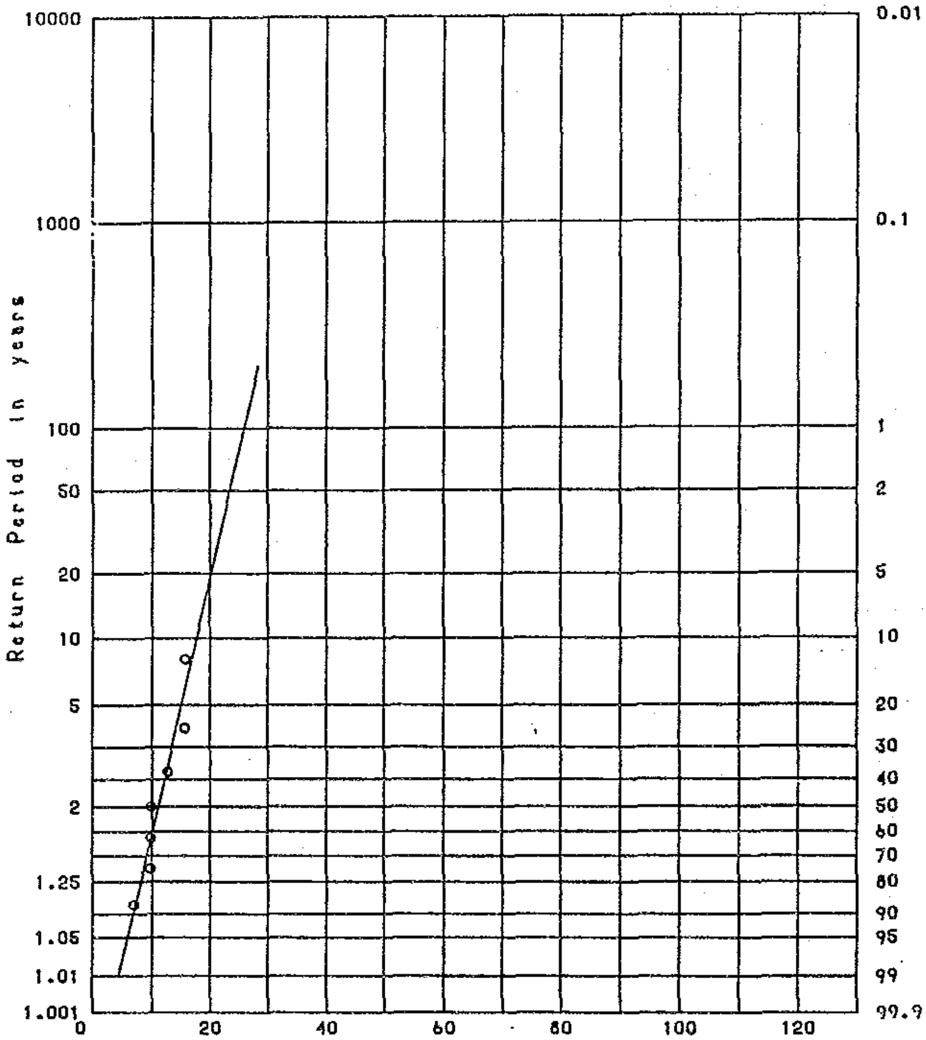
RETURN PERIOD	EXCESS PROB.	VARIABLE	WIND VELOCITY
1.01	0.9901	-1.5293	4.421
1.50	0.6667	-0.0940	9.459
2.	0.5000	0.3665	11.075
5.	0.2000	1.4999	15.053
10.	0.1000	2.2504	17.686
20.	0.0500	2.9702	20.212
30.	0.0333	3.3843	21.666
40.	0.0250	3.6762	22.690
50.	0.0200	3.9019	23.482
80.	0.0125	4.3757	25.145
100.	0.0100	4.6001	25.933
200.	0.0050	5.2958	28.374

NOTE : FORMULA OF PRESUMPTION

X=X0+(1/A)*VARIABLE

X0 = 9.789
1/A = 3.509

Station :KIRIBATI, TARAWA
Region :BETIO-BAIRIKI
District :PACIFIC OCEAN
Altitude of Station :35.0 Meters
Kind of Record :WIND (SW)
Period of Record : 7 YEARS



BETIO-BAIRIKI CAUSEWAY-FISHERIES CHANNEL

Fig.-3 FREQUENCY CURVE

PLOTTING POSITION

STATION ; KIRIBATI, TARAWA
REGION ; BETIO-BAIRIKI
DISTRICT ; PACIFIC OCEAN
ALTITUDE OF STATION ; 35.0 METERS
KIND OF RECORD ; WIND FORCE (S)
PERIOD OF RECORD ;

* NUMBER OF SAMPLES ; 11

NO.	WIND VELOCITY	HAZEN	THOMAS
1	4.37	0.9545	0.9167
2	5.00	0.8636	0.8333
3	6.94	0.7727	0.7500
4	6.94	0.6818	0.6667
5	6.94	0.5909	0.5833
6	6.94	0.5000	0.5000
7	6.94	0.4091	0.4167
8	6.94	0.3182	0.3333
9	9.77	0.2273	0.2500
10	9.77	0.1364	0.1667
11	12.60	0.0455	0.0833

CALCULATION METHOD ;GUMBEL METHOD

STATION ; KIRIBATI, TARAWA
REGION ; BETIO-BAIRIKI
DISTRICT ; PACIFIC OCEAN
ALTITUDE OF STATION ; 35.0 METERS
KIND OF RECORD ; WIND FORCE (S)
PERIOD OF RECORD ;

(1) NUMBER OF SAMPLES ; 11

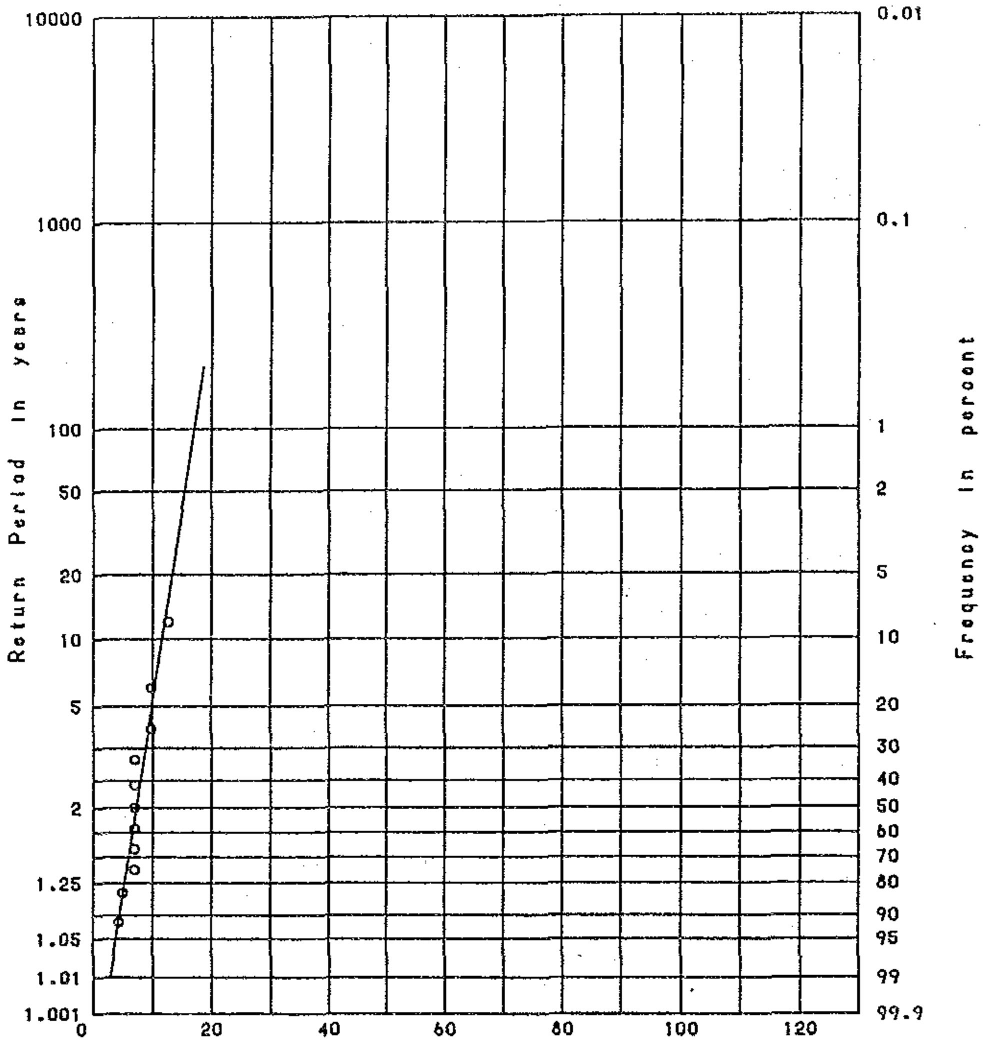
RETURN PERIOD	EXCESS PROB.	VARIABLE	WIND VELOCITY
1.01	0.9901	-1.5293	2.907
1.50	0.6667	-0.0940	6.200
2.	0.5000	0.3665	7.257
5.	0.2000	1.4999	9.858
10.	0.1000	2.2504	11.580
20.	0.0500	2.9702	13.232
30.	0.0333	3.3843	14.182
40.	0.0250	3.6762	14.852
50.	0.0200	3.9019	15.370
80.	0.0125	4.3757	16.457
100.	0.0100	4.6001	16.972
200.	0.0050	5.2958	18.568

NOTE : FORMULA OF PRESUMPTION

X=X0+(1/A)*VARIABLE

X0 = 6.416
1/A = 2.295

Station	:KIRIBATI. TARAWA	Region	:BETIO-BAIRIKI
District	:PACIFIC OCEAN	Altitude of Station	:35.0 Meters
Kind of Record	:WIND (S)		
Period of Record :			



BETIO-BAIRIKI CAUSEWAY-FISHERIES CHANNEL

Fig.-4 FREQUENCY CURVE

PLOTTING POSITION

STATION ; KIRIBATI, TARAWA
REGION ; BETIO-BAIRIKI
DISTRICT ; PACIFIC OCEAN
ALTITUDE OF STATION ; 35.0 METERS
KIND OF RECORD ; WIND FORCE (SE)
PERIOD OF RECORD ; 11 YEARS

* NUMBER OF SAMPLES ; 11

NO.	WIND VELOCITY	HAZEN	THOMAS
1	9.77	0.9545	0.9167
2	9.77	0.8636	0.8333
3	9.77	0.7727	0.7500
4	9.77	0.6818	0.6667
5	9.77	0.5909	0.5833
6	9.77	0.5000	0.5000
7	9.77	0.4091	0.4167
8	12.60	0.3182	0.3333
9	12.60	0.2273	0.2500
10	12.60	0.1364	0.1667
11	12.60	0.0455	0.0833

CALCULATION METHOD ;GUMBEL METHOD

STATION ; KIRIBATI, TARAWA
REGION ; BETIO-BAIRIKI
DISTRICT ; PACIFIC OCEAN
ALTITUDE OF STATION ; 35.0 METERS
KIND OF RECORD ; WIND FORCE (SE)
PERIOD OF RECORD ; 11 YEARS

(1) NUMBER OF SAMPLES ; 11

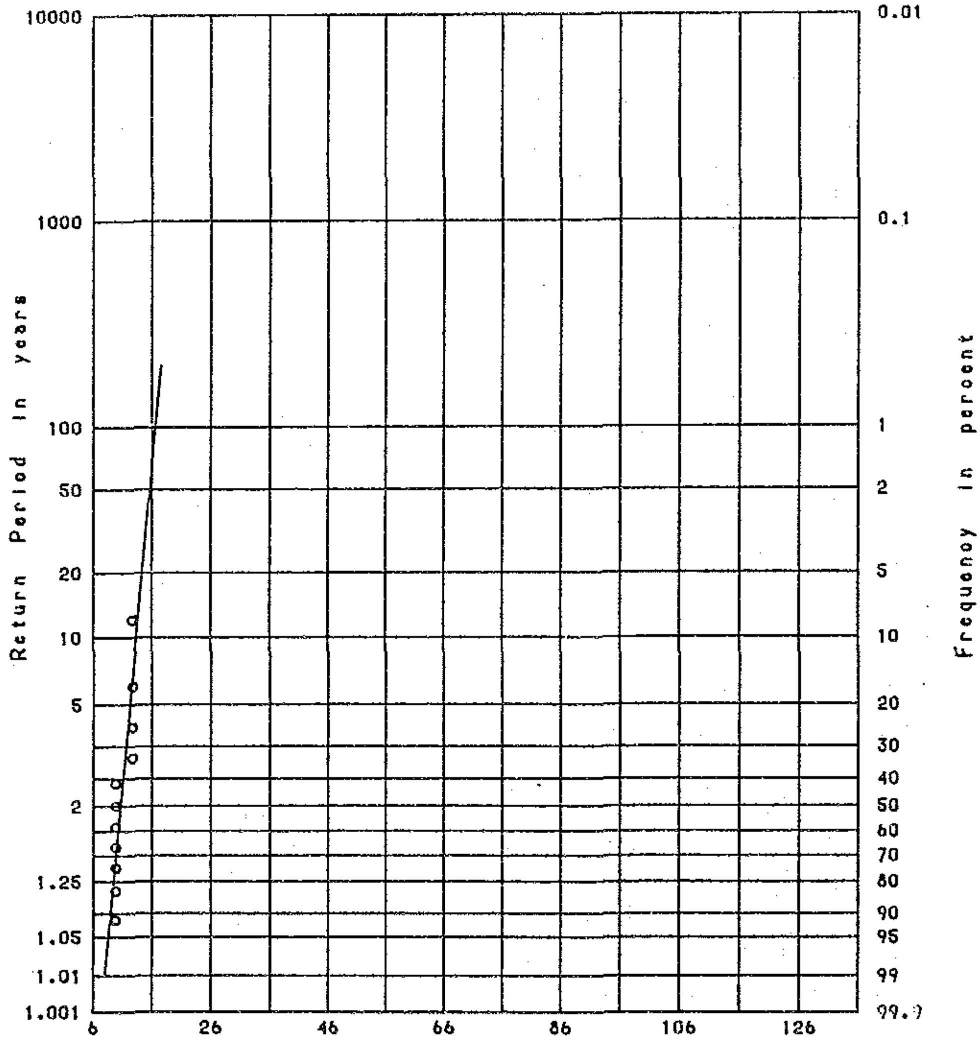
RETURN PERIOD	EXCESS PROB.	VARIABLE	WIND VELOCITY
1.01	0.9901	-1.5293	7.949
1.50	0.6667	-0.0940	9.968
2.	0.5000	0.3665	10.616
5.	0.2000	1.4999	12.210
10.	0.1000	2.2504	13.265
20.	0.0500	2.9702	14.278
30.	0.0333	3.3843	14.860
40.	0.0250	3.6762	15.271
50.	0.0200	3.9019	15.588
80.	0.0125	4.3757	16.254
100.	0.0100	4.6001	16.570
200.	0.0050	5.2958	17.548

NOTE : FORMULA OF PRESUMPTION

X=X0+(1/A)*VARIABLE

X0 = 10.100
1/A = 1.406

Station ;KIRIBATI, TARAWA
Region ;BETIO-BAIRIKI
District ;PACIFIC OCEAN
Altitude of Station ;35.0 Meters
Kind of Record ;WIND (SE)
Period of Record ;11 YEARS



BETIO-BAIRIKI CAUSEWAY-FISHERIES CHANNEL

Fig.-5 FREQUENCY CURVE

(6) ALL DIRECTION

PLOTTING POSITION

STATION	; KIRIBATI, TARAWA	
REGION	; BETIO-BAIRIKI	
DISTRICT	; PACIFIC OCEAN	
ALTITUDE OF STATION	; 35.0	METERS
KIND OF RECORD	; WIND VELOCITY (ALL)	
PERIOD OF RECORD	; 33 YEARS	

* NUMBER OF SAMPLES ; 33

NO.	WIND VELOCITY	HAZEN	THOMAS
1	8.36	0.9848	0.9706
2	8.36	0.9545	0.9412
3	8.36	0.9242	0.9118
4	8.36	0.8939	0.8824
5	9.77	0.8636	0.8529
6	9.77	0.8333	0.8235
7	9.77	0.8030	0.7941
8	9.77	0.7727	0.7647
9	9.77	0.7424	0.7353
10	9.77	0.7121	0.7059
11	9.77	0.6818	0.6765
12	12.60	0.6515	0.6471
13	12.60	0.6212	0.6176
14	12.60	0.5909	0.5882
15	12.60	0.5606	0.5588
16	12.60	0.5303	0.5294
17	14.15	0.5000	0.5000
18	14.15	0.4697	0.4706
19	14.15	0.4394	0.4412
20	14.15	0.4091	0.4118
21	14.15	0.3788	0.3824
22	15.69	0.3485	0.3529
23	15.69	0.3182	0.3235
24	15.69	0.2879	0.2941
25	15.69	0.2576	0.2647
26	15.69	0.2273	0.2353
27	15.69	0.1970	0.2059
28	15.69	0.1667	0.1765
29	19.03	0.1364	0.1471
30	19.03	0.1061	0.1176
31	19.03	0.0758	0.0882
32	19.03	0.0455	0.0588
33	19.04	0.0152	0.0294

CALCULATION METHOD ;GUMBEL METHOD

STATION	; KIRIBATI, TARAWA	
REGION	; BETIO-BAIRIKI	
DISTRICT	; PACIFIC OCEAN	
ALTITUDE OF STATION	; 35.0	METERS
KIND OF RECORD	; WIND VELOCITY (ALL)	
PERIOD OF RECORD	; 33 YEARS	

(1) NUMBER OF SAMPLES ; 33

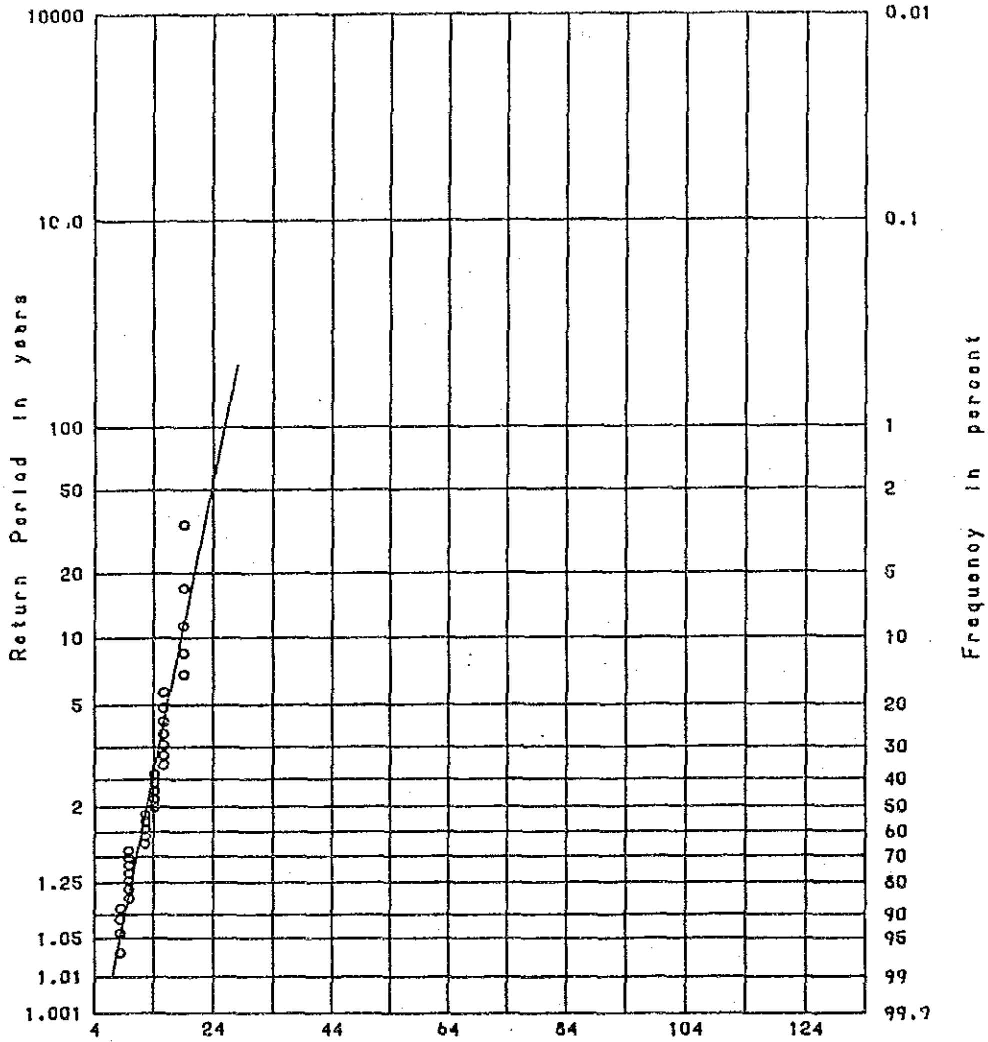
RETURN PERIOD	EXCESS PROB.	VARIABLE	WIND VELOCITY
1.01	0.9901	-1.5293	6.977
1.50	0.6667	-0.0940	11.401
2.	0.5000	0.3665	12.820
5.	0.2000	1.4999	16.313
10.	0.1000	2.2504	18.626
20.	0.0500	2.9702	20.844
30.	0.0333	3.3843	22.121
40.	0.0250	3.6762	23.020
50.	0.0200	3.9019	23.716
80.	0.0125	4.3757	25.176
100.	0.0100	4.6001	25.868
200.	0.0050	5.2958	28.012

NOTE : FORMULA OF PRESUMPTION

X=X0+(1/A)*VARIABLE

X0 = 11.691
1/A = 3.082

Station	:KIRIBATI, TARAWA	Region	:BETIO-BAIRIKI
District	:PACIFIC OCEAN	Altitude of Station	:35.0 Meters
Kind of Record	:WIND VELOCITY (ALL)		
Period of Record	: 33 YEARS		



BETIO-BAIRIKI CAUSEWAY-FISHERIES CHANNEL

Fig.-6 FREQUENCY CURVE

CALCULATION OF WAVE TRANSFORMATION OF BREAKING WAVES

(1) Deep Water Wave (SW-direction, Ocean Side)

- Significant wave height: $H_0' = 6.1$ m
  (SW & NW, Return period = 50 years)
- Period: T = 9.3 sec
- Sea bottom slope (at reef tip): $\tan\theta = 1/10$
- M.H.W.S = DL + 1.800 m
- Sea bed elevation: h = DL + 0.500 (average)
- Distance between the tip of reef and causeway: x = 400 m

Calculation is made using Takayama's Method and tabulated in the following.

	Expression	Value
Lo	$1.56\ T^2$	134.9 m
H_0'/Lo	6.1/134.9	0.045
ho	M.H.W.S - h	1.300 m
ho/H_0'	1.300/6.1	0.213
β_o	$0.028\ (H_0'/Lo)^{-0.38}\ \exp\ (20\ \tan\theta^{\ 1.5})$	0.171
β_1	$0.52\ \exp\ (4.2\ \tan\theta)$	0.791
β_{max}	$\mathrm{Max}\ (0.92,\ 0.32\ (H_0'/Lo)^{-0.29}\ \exp\ (2.4\ \tan\theta))$	1.000
$H_{1/3\ x=o}$	$\mathrm{Min}\ ((\beta_o \cdot H_0' + \beta_1 \cdot ho),\ \beta_{max} H_0',\ KS \cdot H_0')$	2.071 m
$H_{1/3\ x=o}/H_0'$	2.071/6.1	0.340
$\bar{\eta}_{x=o}/H_0'$	FIG. 3-24 of "Random Seas and Design of Maritime Structures"	0.080
Co	$\left(\frac{\bar{\eta}_{x=o} + ho}{H_0'}\right)^2 + \frac{3}{8} \cdot \beta \cdot \left(\frac{H_{1/3\ x=o}}{H_0'}\right)^2$, where $\beta = 0.56$	0.110
$\frac{\bar{\eta}_\infty + ho}{H_0'}$	$\sqrt{\frac{Co}{1 + \frac{3}{8}\beta\alpha^2}}$, where $\alpha = 0.33$	0.325

	Expression	Value
B	$\frac{H\ 1/3\ x{=}o}{H_o'} - \alpha \frac{ho + \bar{\eta}_\infty}{H_o'}$	0.233
$\frac{H\ 1/3\ x{=}400}{H_o'}$	$B \exp(-0.05 \frac{x}{H_o'}) + \alpha \cdot \frac{ho + \bar{\eta}_\infty}{H_o'}$	0.116
Wave Height H 1/3 x=400	0.116 x 6.1	0.70 m
$\bar{\eta}_{x=400}/H_o'$	$\sqrt{Co - \frac{3}{8}\beta \cdot (\frac{H\ 1/3\ x{=}400}{H_o'})^2} - ho/H_o'$	0.114
Wave Set-up $\bar{\eta}_{x=400}$	0.114 x 6.1	0.70 m

(2) Deep Water Wave (NW-direction, Lagoon Side)

a) Wave Breaking at Lagoon Tip

- Significant wave height: $H_o' = 6.1$ m (NW, return period = 50 years)
- Period: T = 9.3 sec
- Sea bottom slope (at lagoon tip): $\tan\theta = 1/30$
- Sea bed elevation = DL - 6.200 (Lagoon tip)
- Distance between the tip of lagoon and reef: x = 10,000 m

	Expression	Value
Lo	$1.56\ T^2$	134.9 m
H_o'/Lo	6.1/134.9	0.045
ho	M.H.W.S - h	8.000 m
ho/H_o'	8.0/6.1	1.311
β_o	$0.028\ (H_o'/Lo)^{-0.38} \exp(20 \tan^{1.5})$	0.158
β_1	$0.52 \exp(4.2 \tan)$	0.598
β_{max}	$Max(0.92,\ 0.32\ (H_o'/Lo)^{-0.29} \exp(2.4 \tan))$	0.920

	Expression	Value
$H_{1/3}\ x=o$	$\mathrm{Min}\ ((\beta_o \cdot H_o' + \beta_1 \cdot ho),\ \beta_{max} H_o',\ KS \cdot H_o')$	5.612 m
$H_{1/3}\ x=o / H_o'$	5.612/6.1	0.920
$\bar{\eta}_{x=o}/H_o'$	FIG. 3-24 of "Random Seas and Design of Maritime Structures"	0.018
Co	$\left(\frac{\bar{\eta}_{x=o} + ho}{H_o'}\right)^2 + \frac{3}{8} \cdot \beta \cdot \left(\frac{H_{1/3}\ x=o}{H_o'}\right)^2$, where $\beta = 0.56$	1.944
$\frac{\bar{\eta}_\infty + ho}{H_o'}$	$\sqrt{\frac{Co}{1 + \frac{3}{8}\beta\alpha^2}}$, where $\alpha = 0.33$	1.379
B	$\frac{H_{1/3}\ x=o}{H_o'} - \alpha \frac{ho + \bar{\eta}_\infty}{H_o'}$	0.465
$\frac{H_{1/3}\ x=10,000}{H_o'}$	$B \exp\left(-0.05 \frac{x}{H_o'}\right) + \alpha \cdot \frac{ho + \bar{\eta}_\infty}{H_o'}$	0.455
Wave Height $H_{1/3}\ x=10,000$	0.455 x 6.1	2.77 m
$\bar{\eta}_x=10,000/H_o'$	$\sqrt{Co - \frac{3}{8}\beta \left(\frac{H_{1/3}\ x=10,000}{H_o'}\right)^2} - ho/H_o'$	0.068
Wave Set-up $\bar{\eta}_x=10,000$	0.068 x 6.1	0.41 m

b) Wave Breaking at Reef Tip

- Significant wave height: $H_o' = 2.77$ m
- Period: T = 9.3 sec
- H.W.L = DL + 1.8 + 0.41 = DL + 2.21
- Sea bottom slope (at reef tip): $\tan\theta = 1/20$
- Sea bed elevation = DL + 0.500
- Distance between the tip of reef and causeway: x = 300 m

	Expression	Value
Lo	$1.56\ T^2$	134.9m
H_0'/Lo	2.77/134.9	0.020
ho	H.W.L - h	1.71 m
ho/H_0'	1.71/2.77	0.617
βo	$0.028\ (H_0'/Lo)^{-0.38}\ \exp\ (20\ \tan\theta^{\ 1.5})$	0.155
$\beta 1$	$0.52\ \exp\ (4.2\ \tan\ \ )$	0.642
$\beta\ max$	$\mathrm{Max}\ (0.92,\ 0.32\ (H_0'/Lo)^{-0.29}\ \exp\ (2.4\ \tan\theta\ ))$	1.122
H 1/3 x=o	$\mathrm{Min}\ ((\beta o \cdot H_0' + \beta_1 \cdot ho),\ \max H_0',\ KS \cdot H_0')$	1.527m
$H\ 1/3\ x{=}o/H_0'$	1.527/2.77	0.551
$\bar{\eta}\ x{=}o/H_0'$	FIG. 3-24 of "Random Seas and Design of Maritime Structures"	0.065
Co	$\left(\frac{\bar{\eta}x{=}o + ho}{H_0'}\right)^2 + \frac{3}{8}\beta \cdot \left(\frac{H\ 1/3\ x{=}o}{H_0'}\right)^2$, where $\beta = 0.56$	0.529
$\frac{\bar{\eta}_\infty + ho}{H_0'}$	$\sqrt{\frac{Co}{1 + \frac{3}{8}\beta\alpha^2}}$, where $\alpha = 0.33$	0.719
B	$\frac{H\ 1/3\ x{=}o}{H_0'} - \alpha \frac{ho + \bar{\eta}_\infty}{H_0'}$	0.314
$\frac{H\ 1/3\ x{=}300}{H_0'}$	$B \exp\ (-0.05 \frac{x}{H_0'}) + \alpha \frac{ho + \bar{\eta}_\infty}{H_0'}$	0.239
Wave Height H 1/3 x=300	0.239 x 2.77	0.66m
$\bar{\eta}x{=}300/H_0'$	$\sqrt{Co - \frac{3}{8}\beta\left(\frac{H\ 1/3\ x{=}300}{H_0'}\right)^2} - ho/H_0'$	0.102
Wave Set-up $\bar{\eta}x{=}300$	0.102 x 2.77	0.28 m

(3) Shallow Water Wave (N-direction, Lagoon Side)

- Significant wave height: $H_0' = 1.14$ m
  (N-direction, return period = 50 years)
- Period: T = 4.1 sec
- Sea bottom slope (at reef tip): $\tan\theta = 1/20$
- Sea bed elevation = DL + 0.500
- Distance between reef tip and causeway: x = 300 m

	Expression	Value
Lo	$1.56\ T^2$	26.22m
H_0'/Lo	1.14/26.22	0.043
ho	M.H.W.S - h	1.300m
ho/H_0'	1.300/1.14	1.140
βo	$0.028\ (H_0'/Lo)^{-0.38}\ \exp\ (20\ \tan\theta^{1.5})$	0.116
$\beta 1$	$0.52\ \exp\ (4.2\ \tan\theta)$	0.642
β max	$\mathrm{Max}\ (0.92,\ 0.32\ (H_0'/Lo)^{-0.29}\ \exp\ (2.4\ \tan\theta))$	0.920
H 1/3 x=o	$\mathrm{Min}\ ((\beta o \cdot H_0' +\ _1\ ho),\ \max H_0',\ KS\ H_0')$	0.967m
$H\ 1/3\ x{=}o/H_0'$	0.967/1.14	0.848
$\bar{\eta}\, x{=}o/H_0'$	FIG. 3-24 of "Random Seas and Design of Maritime Structures"	0.025
Co	$\left(\frac{\bar{\eta}_{x=o} + ho}{H_0'}\right)^2 + \frac{3}{8}\cdot\beta\cdot\left(\frac{H\ 1/3\ x=o}{H_0'}\right)^2$, where $\beta = 0.56$	1.508
$\frac{\bar{\eta}_\infty + ho}{H_0'}$	$\sqrt{\frac{Co}{1 + \frac{3}{8}\beta\alpha^2}}$, where $\alpha = 0.33$	1.214
B	$\frac{H\ 1/3\ x=o}{H_0'} - \alpha\frac{ho + \bar{\eta}_\infty}{H_0'}$	0.447
$\frac{H\ 1/3\ x=300}{H_0'}$	$B\ \exp\ (-0.05\ \frac{x}{H_0'}) + \alpha\frac{ho + \bar{\eta}_\infty}{H_0'}$	0.4006
Wave Height H 1/3 x=300	0.4006 x 1.14	0.46 m

CALCULATION OF WAVE DECAY IN CASE OF NON-BREAKING WAVES

Calculation is made based on "SHORE PROTECTION MANUAL Volume I" adopted by U.S. Army.

(1) WAVE DECAY FOR DEEP WATER WAVE (Ocean Side)

- Water level: DL + 1.800
- Sea bed elevation: DL + 0.500 (reef average)
- Water depth: d = 1.8 - 0.5 = 1.3 m = 4.265 ft
- Friction factor: Ff = 0.03 (assumed)
- Maximum stable wave height: Hi = 4.265 x 0.78 = 3.327 ft
- Wave period: T = 9.3 sec
- Distance related to friction loss: Δx = 400 m = 1,312 ft

$$\frac{Ff \cdot Hi \cdot \Delta x}{d^2} = \frac{0.03 \times 3.327 \times 1{,}312}{4.265^2} = 7.199$$

$$\frac{2\pi \cdot d}{g \cdot T^2} = \frac{2 \times \pi \times 4.265}{32.2 \times 9.3^2} = 0.00962$$

From Figure 3-24 in the MANUAL, Kf is obtained as 0.41.

H_T = Kf·Hi = 0.41 x 3.327 = 1.364 ft
= 0.42 m (wave height)

(2) WAVE DECAY FOR DEEP WATER WAVE (Lagoon Side)

a) Friction Loss on Lagoon

- Water level: DL + 1.800
- Sea bed elevation: DL - 2.4
- Water depth: d = 1.8 + 2.4 = 4.2 m = 13.800 ft
- Friction factor: Ff = 0.03 (assumed)
- Maximum stable wave height: Hi = 13.8 x 0.78 = 10.764 ft
- Wave period: T = 9.3 sec (NW-direction)

- Distance: Δx = 10,000 m = 32,809 ft

- Averaged water depth = 8.0 m = 26.248 ft

$$\frac{Ff \cdot Hi \cdot \Delta x}{d^2} = \frac{0.03 \times 10.764 \times 32.809}{26.248^2} = 15.378$$

$$\frac{2\pi \cdot d}{g \cdot T^2} = \frac{2 \times \pi \times 26.248}{32.2 \times 9.3^2} = 0.059$$

Kf = 0.3

H_T = 0.3 x 10.764 = 3.229 ft = 0.98 m

b) Friction Loss on Reef

- Water level: DL + 1.800
- Sea bed elevation: DL + 0.500 (reef average)
- Water depth: d = 1.8 - 0.5 = 1.3 m = 4.265 ft
- Friction factor: Ff = 0.03 (assumed)
- Wave height: Hi = 0.98 m = 3.229 ft
- Wave period: T = 9.3 sec
- Distance: Δx = 300 m = 984.3 ft

$$\frac{Ff \cdot Hi \cdot \Delta x}{d^2} = \frac{0.03 \times 3.229 \times 984.3}{4.265^2} = 5.242$$

$$\frac{2\pi \cdot d}{g \cdot T^2} = \frac{2 \times \pi \times 4.265}{32.2 \times 9.3^2} = 0.00962$$

Kf = 0.5

H_T = 0.5 x 3.229 = 1.615 ft = 0.49 m (Wave height)

(3) WAVE DECAY FOR SHALLOW WATER WAVE (Lagoon Side, N-direction)

- Water level: DL + 1.800
- Sea bed elevation: DL + 0.500 (reef average)
- Water depth: d = 1.8 - 0.5 = 1.3 m = 4.265 ft
- Friction factor: Ff = 0.03 (assumed)

- Maximum stable wave height: $Hi = 4.265 \times 0.78 = 3.327$ ft
- Wave period: $T = 4.1$ sec
- Distance related to friction loss: $\Delta x = 300$ m $= 984.3$ ft

$$\frac{Ff \cdot Hi \cdot \Delta x}{d^2} = \frac{0.03 \times 3.327 \times 984.3}{4.265^2} = 5.400$$

$$\frac{2\pi \cdot d}{g \cdot T^2} = \frac{2 \times \pi \times 4.265}{32.2 \times 4.1^2} = 0.0495$$

$Kf = 0.51$

$H_T = 0.51 \times 3.327 = 1.697$ ft $= 0.52$ m (Wave height)

CALCULATION OF TIDAL FLOW BETWEEN BETIO AND BAIRIKI

1. Tidal flow in the straight between the island of Betio and the island of Bairiki.

1-1 Objective

This study aims to analyze tidal flow in the straight between the island of Betio and the island of Bairiki in connection with construction of the causeway.

1-2 Calculation formula

Following equations for non-uniform flow will be adopted.

$$\Phi = Z + H + \frac{\alpha Q^2}{2gA^2} + \frac{Nu^2 Q^2\ lu}{2R^{4/3}A^2}$$

$$\Psi = Z + H + \frac{\alpha Q^2}{2gA^2} - \frac{Nd^2 Q^2\ ld}{2R^{4/3}A^2}$$

where; Z : flow bed height

H : flow depth

α : coefficient of energy

Q : discharge

g : acceleration of gravity

A : flow area

l : distance between sections

N : coefficient of roughness

lu, Nu : valves of N and l at upstream section from certain section

ld, Nd : valves of N and l at downstream section from certain section

1-3 Input Data

(1) Location and profiles of sections are shown in Fig. 1 and Fig. 2 respectively.

(2) Water level and flow velocity are shown in Fig. 3. Flow velocities are those observed this time, while water levels are those of tidal level forecast at Betio harbour.

1-4 Order of Calculation

(1) To estimate water levels at Sec. A-A' in the ocean side and at Sec. E-E' in the lagoon side, and then a difference between those water levels. (Refer to Table-1)

(2) To estimate inflow and outflow in the existing condition. (Refer to Table-2 and -3)

(3) To estimate velocity and discharge of flow in the fishery channel. (Refer to Table-4 and -5)

(4) To estimate inflow and outflow after completion of causeway. (Refer to Table-6 and -7)

1-5 Results

Tidal inflow and outflow before and after completion of causeway. (Refer to Table-8)

Fig. 1 Location of Sections

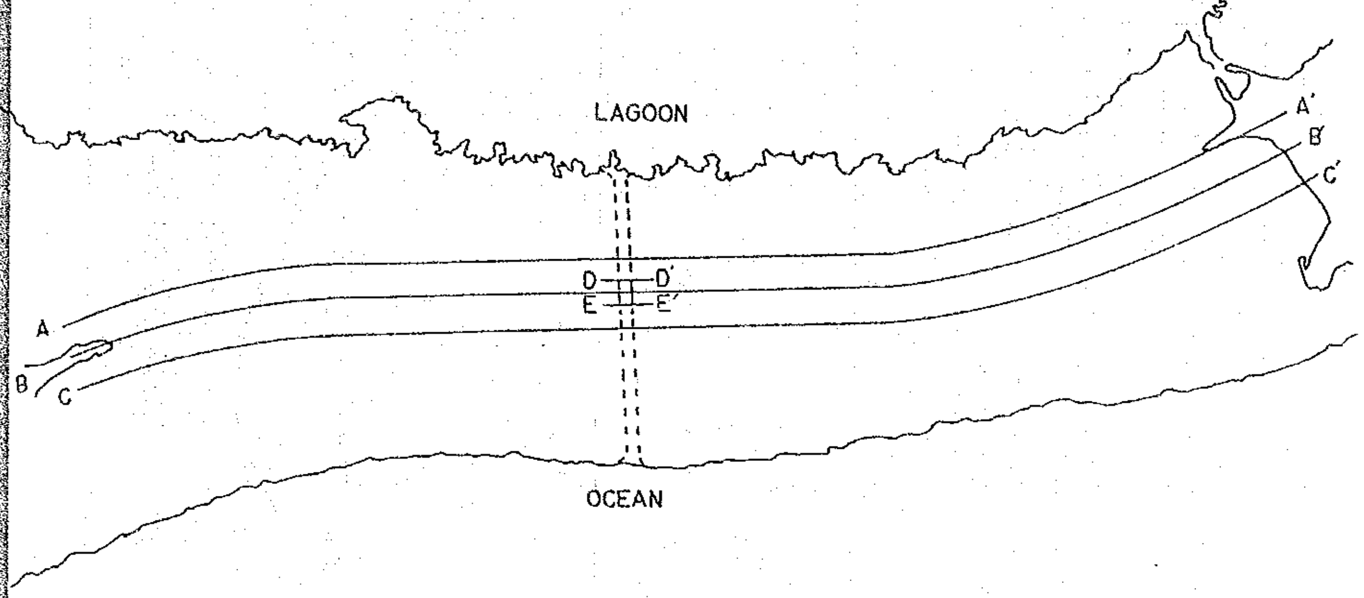


Fig. 2 Profiles of Sections

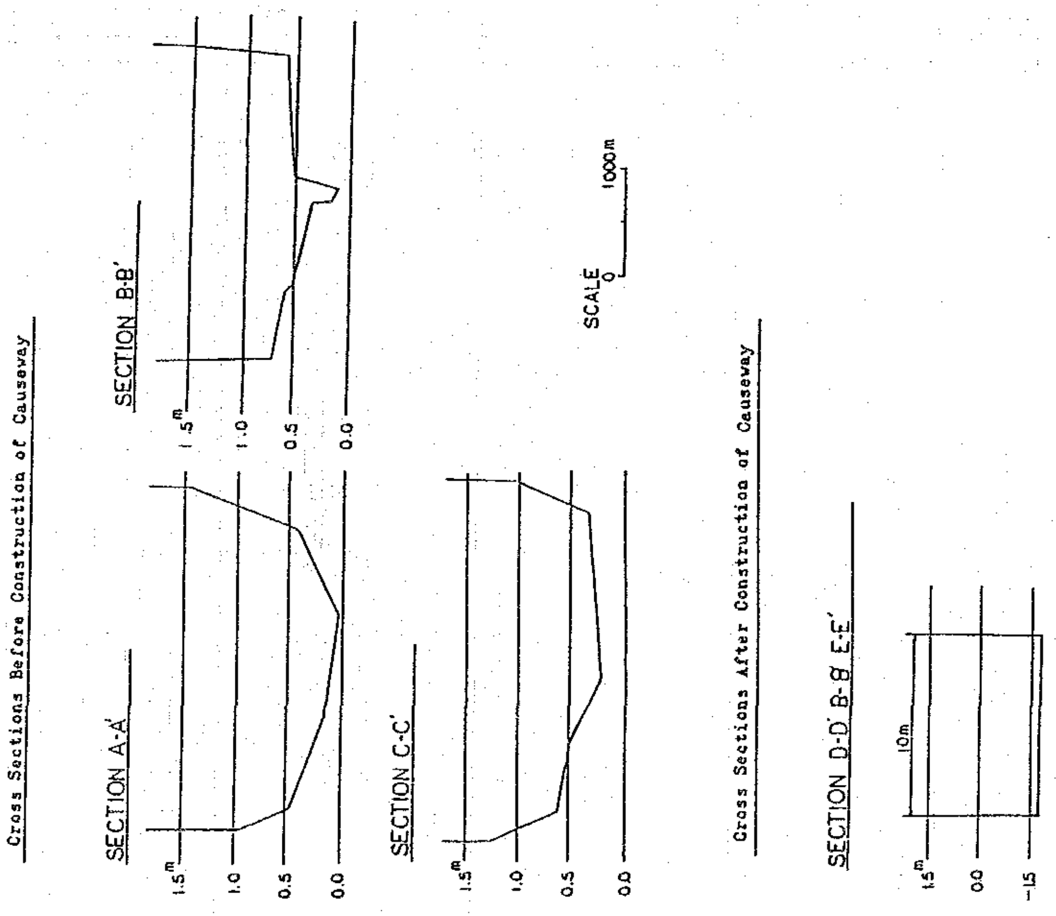
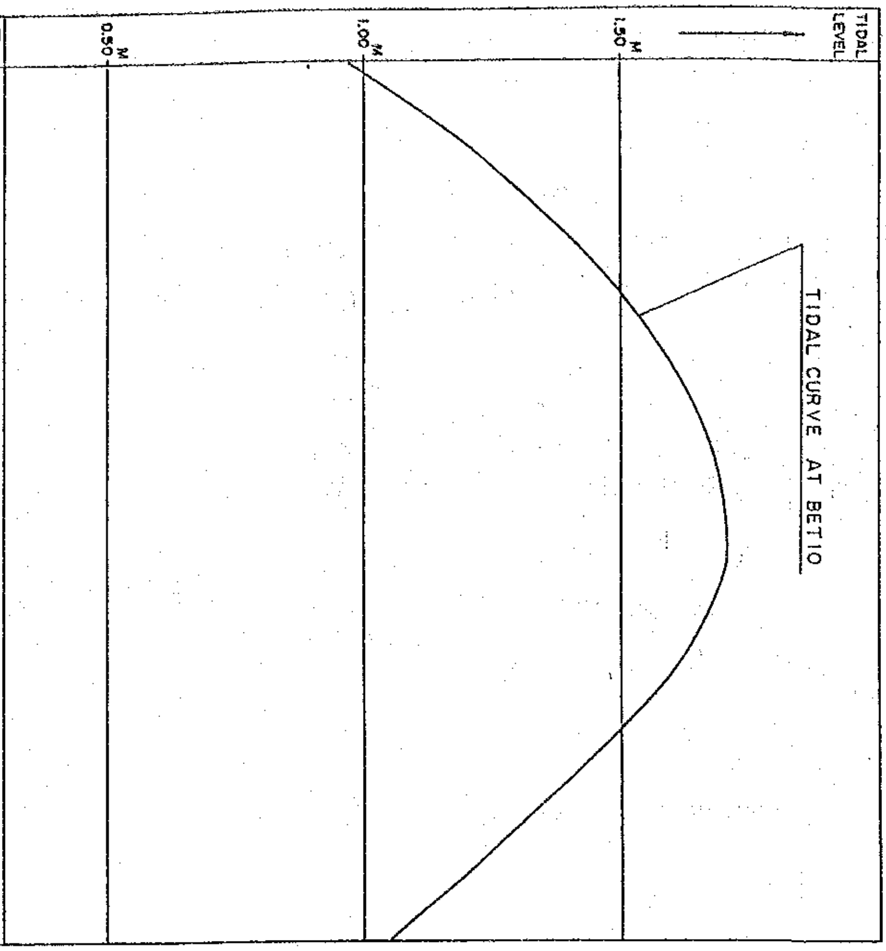


Fig. 3 Tidal Curve at Betio

TIME	SPEED (m/SEC)	DIRECTION OCN/LGN
12: 40		
50	0.38	N+10° →
13: 00	0.52	• →
10	0.43	• →
20	0.43	• →
30	0.38	• →
40	0.32	• →
50	0.32	• →
14: 00	0.29	N−10° →
10	0.33	• →
20	0.39	• →
30	0.43	N+5° →
40	0.33	• →
50	0.32	• →
15: 00	0.37	• →
10	0.22	• →
20	NOT RECORDED	• →
30	0.41	SE ↙
40	0.65	• ↙
50	0.61	• ↙
16: 00	0.86	• ↙
10	0.75	• ↙
20	0.73	• ↙
30	0.73	• ↙
40	0.73	• ↙
50	0.55	• ↙
17: 00	0.37	• ↙
10	—	—
20	0.15	E ↓
30	0.14	• ↓
40	0.14	N+10° →
50	0.30	• →
18: 00	0.21	• →



TIME	SPEED (m/SEC)	DIRECTION OCN/LGN
15:00		
10		
20	0.08	WSW ↖
30	0.10	NNW →
40	0.15	N →
50	0.23	• →
16:00	0.26	• →
10	0.21	• →
20	0.32	• →
30	0.31	• →
40	0.20	NNW →
50	0.12	W ↑
17:00	0.10	• ↑
10	0.09	SW ↗
20	0.12	• ↗
30	0.15	• ↗
40	0.24	S →
50	0.30	• →
18:00	0.25	SW ↗

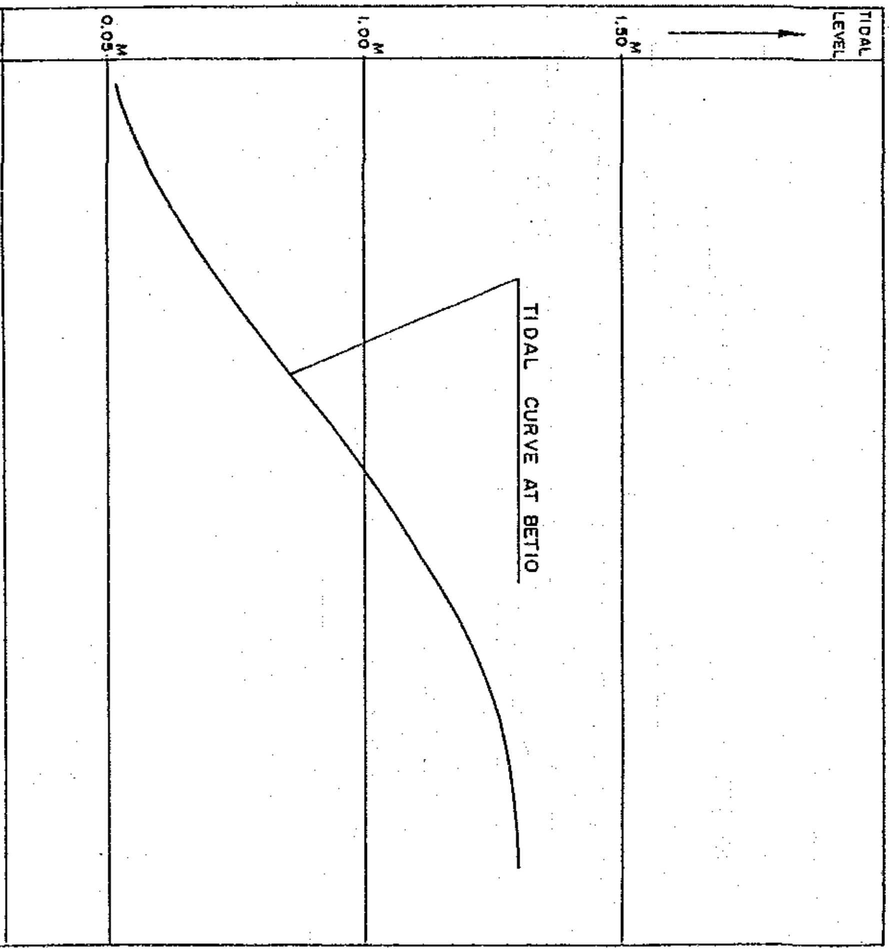


Table-1 Tidal Flow Analysis (Existing Condition)

	Flow Direction	OCEAN → LAGOON				
	Date	18 APR 13:00	18 APR 14:00	18 APR 15:00	18 APR 18:00	23 APR 17:00
	Observed Velocity (m/sec)	0.52	0.29	0.37	0.21	0.10
	Discharge (m/sec)	909	784	1,207	355	207
WATER LEVEL (M)	Sec. C-C'	1,191	1,489	1,679	1,139	1,263
	Sec. B-B'	1,150	1,480	1,670	1,130	1,260
	Sec. A-A'	1,122	1,477	1,667	1,127	1,259

	Flow Direction	LAGOON → OCEAN		
	Date	18 APR 16:00	18 APR 17:00	23 APR 18:00
	Ovserved Velocity (m/sec)	0.86	0.37	0.25
	Discharge (m/sec)	2,830	969	546
WATER LEVEL (M)	Sec. A-A'	1,739	1,466	1,309
	Sec. B-B'	1,680	1,450	1,300
	Sec. C-C'	1,646	1,441	1,297

Table-2 Tidal Flow Analysis
(Inflow and Outflow at Spring Tide in the Existing Condition)

Flow Direction	Time	Discharge (m^3/sec)	Averaged Discharge (m^3/sec)	Inflow (m^3)	Outflow (m^3)
From Ocean To Lagoon	12:30	0			
			455	819,000	-
	13:00	909			
			902	1,623,600	-
	13:30	895			
			840	1,512,000	-
	14:00	784			
			1,308	2,354,000	-
	14:30	1,831			
			1,519	2,734,200	-
	15:00	1,207			
			604	724,800	-
From Lagoon To Ocean	15:20	0			
			526	-	315,600
	15:30	1,051			
			1,941	-	3,493,800
	16:00	2,830			
			2,336	-	4,204,800
	16:30	1,841			
			1,405	-	2,529,000
	17:00	969			
			485	-	291,000
From Ocean To Lagoon	17:10	0			
			160	192,000	-
	17:30	320			
			338	608,000	-
	18:00	355			
			178	320,400	-
	18:30	0			
Total		-	-	10,837,000	10,834,200

Table-3 Tidal Flow Analysis
(Inflow and Outflow at Neap Tide in the Existing Condition)

Flow Direction	Time	Discharge (m^3/sec)	Averaged Discharge (m^3/sec)	Inflow (m^3)	Outflow (m^3)
From Ocean to Lagoon	15:20	0			
			135	81,000	-
	15:30	269			
			405	729,000	-
	16:00	541			
			612	1,101,600	-
	16:30	683			
			342	414,400	-
	16:50	0			
From Lagoon to Ocean			104	-	62,400
	17:00	207			
			292	-	525,600
	17:30	376			
			461	-	829,800
	18:00	546			
			273	-	327,600
	18:20	0			
			-	-	-
1: 15:20 - 18:20 Total			-	2,326,000	1,745,400
12:30 - 18:20 Total (1 x 2)			-	4,652,000	3,490,000

Table-4 Tidal Flow Analysis after Construction of Causeway
(Velocity and Discharge) ①

Flow Direction: Ocean → Lagoon

DATE/TIME		18 APR 13:00	18 APR 14:00	18 APR 15:00	18 APR 18:00	23 APR 17:00
WATER LEVEL AT OCEAN SIDE (m)		1,191	1,489	1,679	1,139	1,263
WATER LEVEL AT LAGOON SIDE (m)		1,122	1,477	1,667	1,127	1,259
WATER HEAD (m)		0.069	0.012	0.012	0.012	0.004
PREDICTED DISCHARGE (m^3/sec)		61.2	34.3	34.3	26.9	20.8
Sec. E-E'	W.L. (m)	1,191	1,489	1,679	1,139	1,263
	V. (m/sec)	2,117	1,075	1,015	0.947	0.701
Sec. B-B'	W.L. (m)	1,158	1,483	1,673	1,134	1,262
	V. (m/sec)	2,141	1,077	1,016	0.949	0.701
Sec. D-D'	W.L. (m)	1,122	1,477	1,667	1,127	1,259
	V. (m/sec)	2,168	1,075	1,018	0.951	0.703

Note: V. : Velocity
W.L.: Water Level

Table-5 Tidal Flow Analysis after Construction of Causeway
(Velocity and Discharge) ②

Flow Direction: Lagoon → Ocean

DATE/TIME		18 APR 16:00	18 APR 17:00	23 APR 18:00
WATER LEVEL AT LAGOON SIDE (m)		1,739	1,466	1,309
WATER LEVEL AT OCEAN SIDE (m)		1,646	1,441	1,297
WATER HEAD (m)		0.093	0.015	0.012
PREDICTED DISCHARGE (m^3/sec)		90.8	45.0	22.1
Sec. D-D'	W.L. (m)	1,739	1,466	1,309
	V. (m/sec)	2,640	1,421	1,032
Sec. B-B'	W.L. (m)	1,694	1,454	1,301
	V. (m/sec)	2,675	1,427	1,034
Sec. E-E'	W.L. (m)	1,646	1,441	1,297
	V. (m/sec)	2,713	1,432	1,036

Note: V. : Velocity
W.L.: Water Level

Table-6 Tidal Flow Analysis
(Inflow and Outflow at Spring Tide after Construction of Causeway)

Flow Direction	Time	Discharge (m^3/sec)	Averaged Discharge (m^3/sec)	Inflow (m^3)	Outline (m^3)
From Ocean to Lagoon	12:30	0			
			30.6	55,080	-
	13:00	61.2			
			60.7	109,260	-
	13:30	60.2			
			47.3	85,140	-
	14:00	34.3			
			32.2	57,960	-
	14:30	30.0			
			32.2	57,960	-
	15:00	34.3			
			17.2	20,640	-
	15:20	0			
From Lagoon to Ocean			16.9	-	10,140
	15:30	33.7			
			62.3	-	112,140
	16:00	90.8			
			75.0	-	135,000
	16:30	59.1			
			52.1	-	93,780
	17:00	45.0			
			22.5	-	13,500
	17:10	0			
From Ocean to Lagoon			12.1	14,520	-
	17:30	24.2			
			25.6	46,080	-
	18:00	26.9			
			13.5	24,300	-
	18:30	0			
Total			-	470,940	364,560

Table-7 Tidal Flow Analysis

(Inflow and Outflow at Neap Tide after Construction of Causeway)

Flow Direction	Time	Discharge (m^3/sec)	Averaged Discharge (m^3/sec)	Inflow (m^3)	Outflow (m^3)
From Ocean to Lagoon	15:20	0			
			8.6	5,160	-
	15:30	17.1			
			19.8	35,560	-
	16:00	22.4			
			23.2	41,760	-
	16:30	23.9			
			12.0	14,400	-
	16:50	0			
From Lagoon to Ocean			10.4	-	6,240
	17:00	20.8			
			20.9	-	37,620
	17:30	21.0			
			21.6	-	38,880
	18:00	22.1			
			11.1	-	13,320
	18:20	0			
1: 15:20 - 18:20 Total			-	96,880	96,060
12:30 - 18:20 Total (1 x 2)			-	193,760	192,120

Table-8 Summary of Tidal Flow Analysis

			Inflow		Outflow	
			Velocity (m /sec)	Discharge (m^3/day)	Velocity (m /sec)	Discharge (m^3/day)
Present Condition	SEC. A-A'	Spring Tide	0 - 0.382	21,774,000	0 - 0.650	21,668,000
		Neap Tide	0 - 0.074	9,304,000	0 - 0.279	6,931,000
	SEC. B-B'	Spring Tide	0 - 0.520	21,774,000	0 - 0.860	21,668,000
		Neap Tide	0 - 0.100	9,304,000	0 - 0.250	6,981,600
	SEC. C-C'	Spring Tide	0 - 0.357	21,774,000	0 - 0.691	21,668,000
		Neap Tide	0 - 0.074	9,304,000	0 - 0.191	6,981,000
After Completion of Causeway	SEC. D-D'	Spring Tide	0 - 2.168	941,880	0 - 2.640	729,120
		Neap Tide	0 - 0.703	387,520	0 - 1.032	384,240
	SEC. B-B'	Spring Tide	0 - 2.141	941,880	0 - 2.675	729,120
		Neap Tide	0 - 0.701	387,520	0 - 1.034	384,240
	SEC. E-E'	Spring Tide	0 - 2.117	941,880	0 - 2.713	729,120
		Neap Tide	0 - 0.701	387,520	0 - 1.036	384,240

COMPARISON OF LOADING SPECIFICATIONS FOR HIGHWAY BRIDGES

COMPARISON OF LOADING SPECIFICATIONS FOR HIGHWAY BRIDGES

DESCRIPTION	AASHTO (American Association of State Highway and Transportation Officials)	J.R.A. (Japan Road Association)	Adopted to the Betio-Bairiki Causeway Project	Remarks
Live Load	HS 20 - 44 (MS 18)	TL - 20	TL - 20	
Impact Fraction	$i = \frac{15.24}{L + 30}$ 30%	$i = \frac{20}{50 + L}$ (For T-Load.) $i = \frac{10}{25 + L}$ (For L-Load.)	$i = \frac{20}{50 + L}$ (For T-Load) $i = \frac{10}{25 + L}$ (For L-Load)	L: Span Length in Meters
Sidewalk Loading	415 kg/m^2	350 kg/m^2 (For $L \leq 80$) 430-L (For $80 < L \leq 130$) 300 (For $L > 130$)	350 kg/m^2 (For L = 10 m)	L: Span Length in Meters
Kerb Loading	744 kg/m	Nil	Nil	Lateral Force
Railing Loading	74.4 kg/m	250 kg/m	74.4 kg/m	Lateral Force
Longitudinal Forces	5% of Live Load	Nil	Nil	For Bridge Axis
Wind Load	V = 100 mph (160.9 km/h) W = 244 kg/m^2 (For Girder and Beam) W = 195 kg/m^2 (For Substructure)	V = 55 m/s (198 km/h) W = 300 kg/m^2 (For PC Girder and Beam) W = 300 kg/m^2 (For Substructure)	V = 23.2 m/s (84 km/h) W = 70 kg/m^2	V: Wind Velocity
Earthquake Load	- Equivalent Static Force Method - Response Spectrum Method	- Modified Static Force Method - Response Spectrum Method	EH = 0.05 WD	EH: Horizontal Force in tons WD: Dead Weight in tons
Thermal Forces	Rise 16.7°C Fall 22.2°C	± 15°C	± 10°C	
Stream Current Forces or Wave Forces	$P = 515\ k \cdot V^2$ V: Velocity of Water $K = 1 \cdot \frac{3}{8}$ (For Square End) $K = \frac{1}{2}$ (For Angle End, 30°) $K = \frac{2}{3}$ (For Circular Pier)	$P = k \cdot v^2$ v: Maximum Water Velocity k = 0.07 (For Square End) k = 0.04 (For Circular Pier) k = 0.02 (For Streamline Pier)	$p = 1.5\ w \cdot Ho$ p : Pressure of breaking wave (t/m^2) w : Unit Weight of sea water (t/m^3) Ho: Wave Height (m)	
Centrifugal Forces	$C = \frac{0.79}{R} \cdot S^2$ S: Design Speed (km/h) R: Radius of Curve (m)	C = 0.08 x W W: Vehicle Weight (t)	Nil	
Earth Pressure	Rankine's Formula	Coulomb's Formula	Coulomb's Formula	

ESTIMATION OF EARTHQUAKE LOAD

The following equation quoted from "Design Manual for Seismic Design" adopted by JRA, which shows good coincidence in case of long epicentral distance, is selected for estimating the ground acceleration caused by past earthquakes.

$$A = 40.3 \times 10^{0.2621 M} \times (d + 30)^{-1.208}$$

where: A = estimated maximum ground acceleration in % of g
M = magnitude of earthquake
d = epicentral distance in km

Past earthquake records and induced ground acceleration in Tarawa Island (01°21'N, 172°56'E) are summerised hereunder.

TABLE-1 PAST EARTHQUAKES AND INDUCED GROUND ACCELERATION

No	Occurence			Epicentre				d km	A %g
	Year	Month	Date	Latitude	Longitude	Depth	Magnitude		
1	1982	1	7	3.4 S	177.6 E	33 km	5.8 M	739	0.4
2	1982	5	23	3.4 S	177.4 E	32 km	6.1 M	724	0.5
3	1983	1	31	3.5 S	177.7 E	31 km	5.8 M	755	0.4
4	1983	2	5	3.5 S	177.8 E	33 km	5.8 M	763	0.4
5	1983	3	8	3.5 S	177.6 E	33 km	5.8 M	747	0.4

(Source of past earthquakes: "Chronological Table in Science" published by Marzen, Japan)

CALCULATION OF WAVE RUNUP

Wave runup is calculated by means of the following formula:

$$\frac{R}{Ho'} = \left(\sqrt{\frac{\pi}{2\theta}} + \left(\frac{\eta_s}{H_1} - 1\right)\right) \cdot Ks$$

$$\frac{\eta_s}{H_1} = 1 + \pi \cdot \frac{H_1}{Lo} \coth kh \cdot \left(1 + \frac{3}{4 \sin h^2 kh} - \frac{1}{4 \cos h^2 kh}\right)$$

where,

- R : Wave runup (m)
- H_1 : Wave height (m)
- Ho : Equivalent deep water height (m)
- θ : Slope angle (radian)
- η_s : Wave runup for vertical wall (m)
- h : Water depth (m)
- Lo : Wave length (m) = $1.56 \cdot T^2$; T: Period (sec)
- k = $\frac{2\pi h}{Lo}$

In this calculation, the following type of waves are taken into consideration, and the results are summarized in the succeeding pages.

(1) Shallow Water Wave

(i) Lagoon Side, Wind = N-direction

- breaking wave (return period = 50 years)

H_1 = 0.46 m
T = 4.1 sec

- non-breaking wave

H_1 = 0.52 m
T = 4.1 sec

(2) Deep Water Wave

(i) Ocean Side, Wind = SW-direction

- breaking wave (return period = 50 years)

H_1 = 0.70 m
T = 9.3 sec

- non-breaking wave

$H_1 = 0.42$ m
$T = 9.3$ sec

(ii) Lagoon Side, Wind = NW-direction

- breaking wave (return period = 50 years)

$H_1 = 0.66$ m
$T = 9.3$ sec

- non-breaking wave

$H_1 = 0.49$ m
$T = 9.3$ sec

TABLE-1 WAVE RUNUP FOR SHALLOW WATER WAVE

(Lagoon Side, N-direction)

DESCRIPTION	BREAKING	NON-BREAKING
H_1 (Return period = 50 years)	0.46 m	0.52 m
T (do.)	4.1 sec	4.1 sec
$Lo = 1.56 \cdot T^2$	26.224 m	26.224 m
Seabed elevation	DL + 0.500	DL + 0.500
Water level	DL + 1.880	DL + 1.800
h	1.380 m	1.300 m
h/Lo	0.053	0.0496
Ks (Wiegel's Table)	1.013	1.026
sin h kh (do.)	0.6499	0.6189
cos h kh (do.)	1.1926	1.1760
cot h kh	1.835	1.900
$\eta s/H_1$	1.263	1.328
Elevation of parapet top	DL + 3.800	DL + 3.800
RL + y	DL + 1.190	DL + 1.020
d = 3.8 - y	2.610 m	2.780 m
ℓ	3.165 m	3.420 m
$\theta = \tan^{-1} (d/\ell)$	39.5^o	39.1^o
Ho'	0.45 m	0.51 m
R/Ho'	1.80	1.89
R	0.81 m	0.96 m
Elevation of runup (50 years)	DL + 2.69 m	DL + 2.76 m

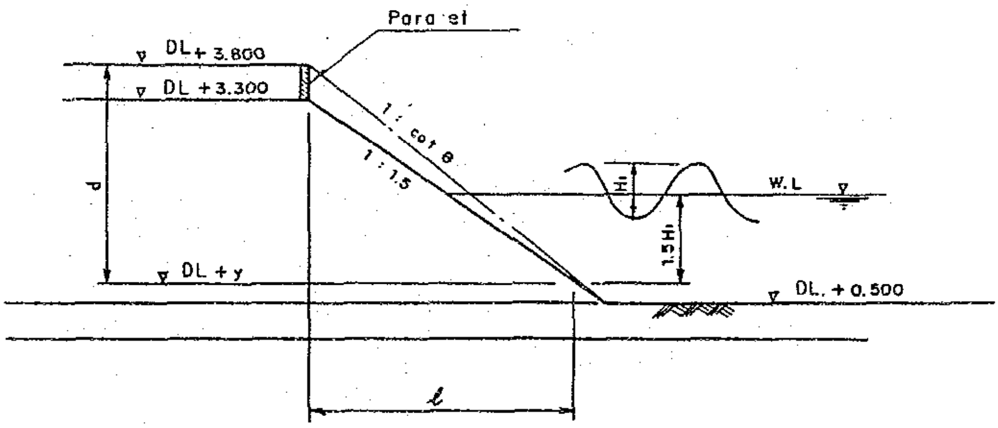


TABLE-2 WAVE RUNUP FOR DEEP WATER WAVE-1
(Ocean Side, SW-direction)

DESCRIPTION	BREAKING	NON-BREAKING
H_1 (Return period = 50 years)	0.70 m	0.42 m
T (do.)	9.3 sec	9.3 sec
$Lo = 1.56 \cdot T^2$	134.9 m	134.9 m
Seabed elevation	DL + 0.500	DL + 0.500
Water level	DL + 2.500	DL + 1.800
h	2.000 m	1.300 m
h/Lo	0.015	0.0096
Ks (Weigel's Table)	1.3070	1.4480
sin h kh (do.)	0.3170	0.2507
cos h kh (do.)	1.049	1.0309
cot h kh	3.309	4.112
η_s/H_1	1.449	1.510
Elevation of parapet top	DL + 3.800	DL + 3.800
RL + y	DL + 1.450	DL + 1.170
d = 3.8 - y	2.35 m	2.630 m
ℓ	2.775 m	2.745 m
$\theta = \tan^{-1} (d/\ell)$	40.3°	43.8°
Ho'	0.53 m	0.29 m
R/Ho'	2.45	2.81
R	1.30 m	0.82 m
Elevation of runup (50 years)	DL + 3.80 m	DL + 2.62 m

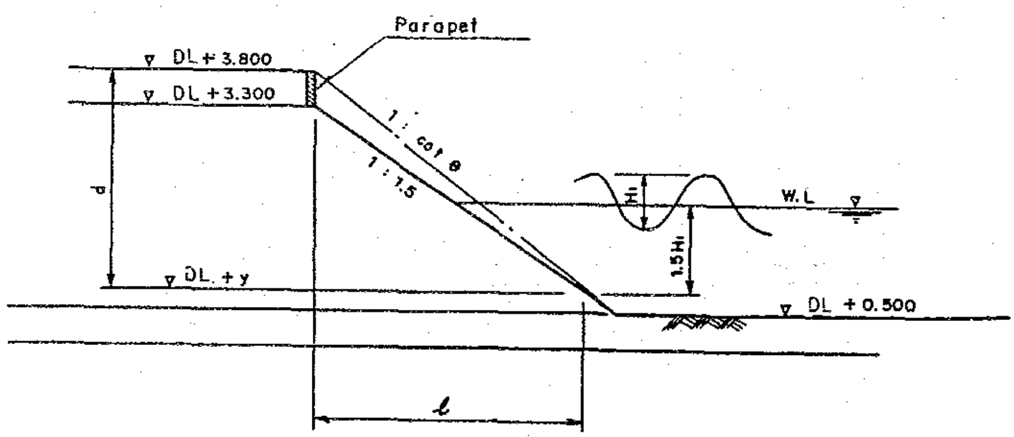
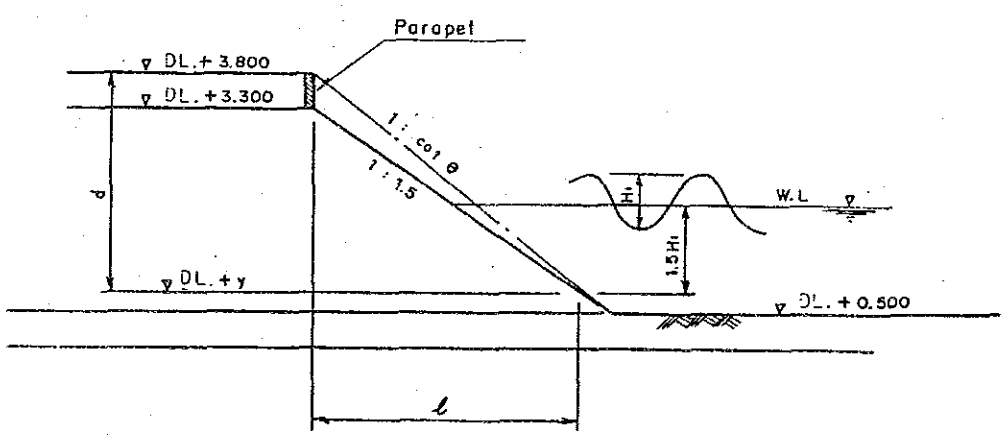


TABLE-3 WAVE RUNUP FOR DEEP WATER WAVE-2

(Lagoon Side, NW-direction)

DESCRIPTION	BREAKING	NON-BREAKING
H_1 (Return period = 50 years)	0.66 m	0.49 m
T (do.)	9.3 sec	9.3 sec
$Lo = 1.56 \cdot T^2$	134.9 m	134.9 m
Seabed elevation	DL + 0.500	DL + 0.500
Water level	DL + 2.490	DL + 1.800
h	1.99 m	1.30 m
h/Lo	0.015	0.0096
Ks (Wiegel's Table)	1.3070	1.4480
sin h kh (do.)	0.3170	0.2507
cos h kh (do.)	1.049	1.0309
cot h kh	3.309	4.112
$\eta s/H_1$	1.449	1.510
Elevation of parapet top	DL + 3.800	DL + 3.800
RL + y	DL + 1.500	DL + 1.065
d = 3.8 - y	2.30 m	2.735 m
ℓ	2.70 m	3.353 m
$\theta = \tan^{-1} (d/\ell)$	40.4°	39.2°
Ho'	0.50 m	0.34 m
R/Ho'	2.44	2.93
R	1.22 m	1.00 m
Elevation of runup (50 years)	DL + 3.71 m	DL + 2.80 m



DESIGN OF FISHERIES CHANNEL

1. Design of Approach Section of the Fisheries Channel from the Ocean Side

1.1 Design Wave

According to the information obtained about ordinary operations of fishing boats, they have to suspend their operations several days a year due to bad weather in the sea area and the wave height seems to be about 1.8 metre in such bad weather.

As such, the design wave for the approach section shall be the maximum wave height normally encountered during the year.

In the case of a maximum wind speed of 9.0 metre/sec and wind duration of 40 hours in a year, the wave height will be 1.8 meters with a wave period of 6 second.

1.2 Design Conditions

The elevation of the sea bottom of the approach section of the channel is D L -3.00 metres as shown in Fig. 1.

Typical cross section of the approach and standard portions of the fisheries channel on the ocean side are shown in Fig. 2.

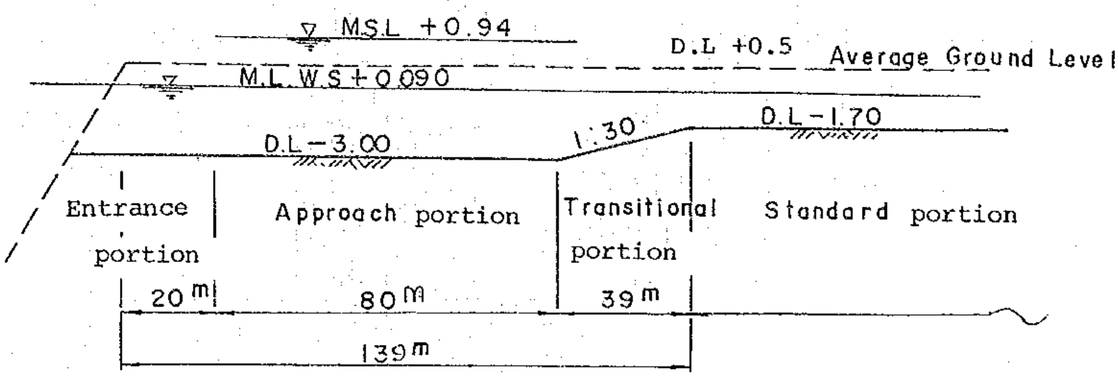
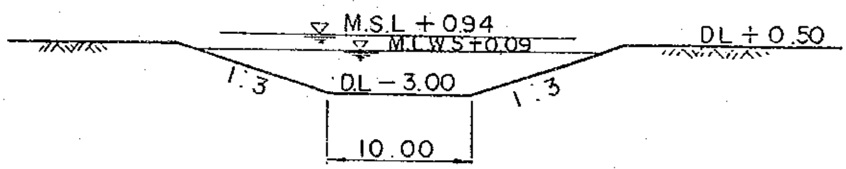
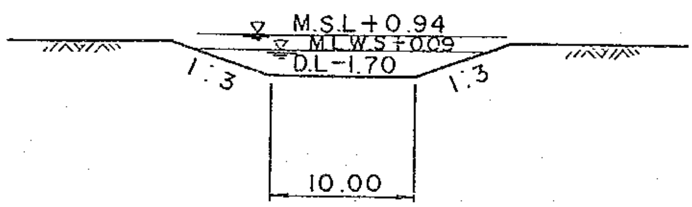


Fig. 1 Longitudinal section of the approach section of the channel on the Ocean side



Cross Section of Approach Portion



Cross Section of Standard Portion

Fig. 2 Profile and Cross Sections of Approach Portion of Fisheries Channel on Ocean Side

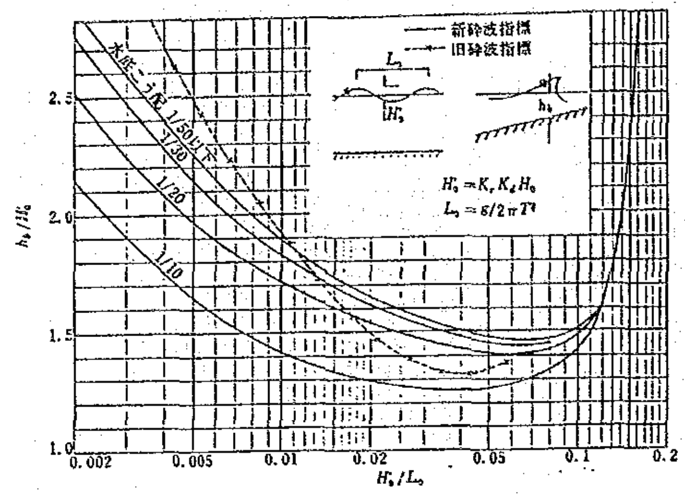


Fig 3 Relation between Depth of breaking and Equivalent deepwater wave height

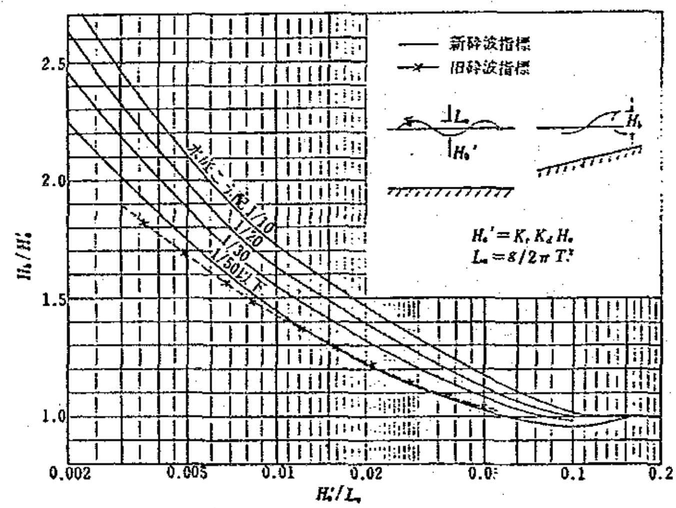


Fig 4 Relation between Breaking wave height and Equivalent deepwater wave height

1.3 Breaker depth of Wave

1) Relation between the depth of breaking and of the breaking wave height at the beginning point of the approach section.

The relation between depth of breaking and the equivalent deepwater wave height is shown in Fig. 3, while the relation between the breaking wave height and equivalent deepwater wave height is shown in Fig. 4.

The following assumptions are used for the design:

Deepwater wave height	$H_0 = 1.8$ m
Wave period	$T = 6.0$ sec
Wave length	$L_0 = 1.56\ T^2$
	$= 1.56 \times 6^2 = 56.16$ m

In this case, the deepwater wave height (H_0) and equivalent deepwater wave height (H_0') are almost the same when the bottom slope is not steeper than 1/50.

i.e. $H_0 = H_0'$

then, $$\frac{H_0'}{L_0} = \frac{1.8}{56.16} = 0.032$$

$$\frac{h_b}{L_0} = 1.53$$ is given in Fig. 3.

$$\therefore\ h_b = 1.53 \times 1.8 = 2.75$$

On the other hand, if both sides of the channel are dried up, tidal currents will flow only within the fisheries channel during low water tide.

Therefore the tidal current speeds will increase and the deepwater wave height will increase simultaneously due to the abrupt reduction of the channel width.

The relation between the wave height at the beginning point of the approach section (H_0') and the wave height at the ending point of the approach section (H_2) was calculated as follows (See Fig. 5 below):

$$\left(\frac{H2}{H_0'}\right)^2 = \left(\frac{B0}{B1}\right)$$

$$\therefore \quad H_2 = H_0'\sqrt{\frac{B_0}{B_1}} = 1.8\sqrt{\frac{68.54}{28.54}} = 2.79 \text{ m}$$

where: B_0: Width at the beginning point of entrance portion

B_1: Width at the ending point of entrance portion

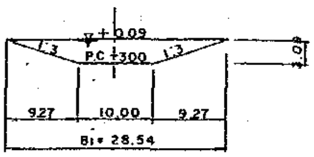
The water depth which does not break the wave height at H_2 (2.79m) was changed from H_2 to H_2' and for bottom slopes is not steeper than 1/50.

The breaking depth of a wave was calculated as follows (refer to Fig. 3):

$$\frac{h_b}{H_2'} = 1.48 \text{ m} \qquad \therefore\ h_b = 1.48 \times 2.79 = 4.13 \text{ m}$$

Accordingly, the sea bottom at the beginning point of the approach section was determined as shown below;

Tide	Tidal Elevation	Depth of Breaking wave	Required sea bottom elevation at Beginning point of the Approach Section
M L W S	DL + 0.09	4.13	-4.04
M S L	DL + 0.94	2.75	-1.81
M H W L	DL + 1.80	2.75	-0.95



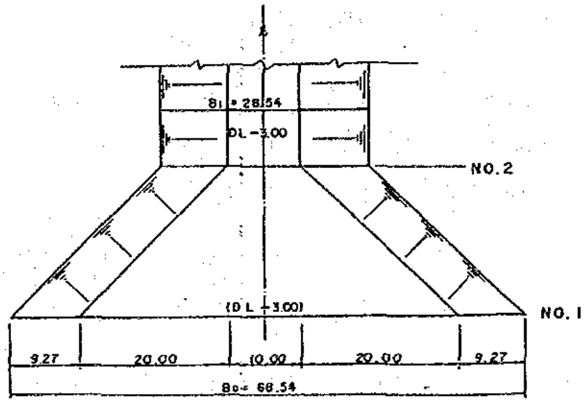


Fig.5 Beginning width and ending width at Approach of Channel

2) Deepwater wave height which does not break was calculated as follows, assuming that the tide at L.W.L. and the deepwater wave height are 0.80 m.

$$H_2 = H_1 \times \sqrt{\frac{B_0}{B_1}} = 0.8 \times \sqrt{\frac{68.54}{28.54}} = 1.24$$

As $H_2 = H_3'$

$$\frac{H_3'}{L_0} = \frac{1.24}{56.16} = 0.022$$

then by Fig. 3;

$$\frac{h_b}{H_3'} = 1.63 \qquad \text{i.e.} \quad h_b = 1.63 \times 1.24 = 2.02 \text{ m}$$

Here, the wave height attenuation at the approach section of the fisheries channel was calculated by using the Bretschneider & Reid Formula, as follows:

$$K_f = \frac{H_2}{H_1} = [1 + \frac{64}{3} \frac{\pi^3}{g^2} \frac{fH_1\Delta x}{d^2} (\frac{d}{T^2})^2 \frac{K_s{}^2}{\sinh^3(\frac{2\pi d}{L})}]^{-1}$$

here, f : Coefficient of sea bottom friction

H_1: Wave height

Δx: Distance of wave height attenuation

d : Water depth

T : Wave period

H_2: Wave height after attenuation

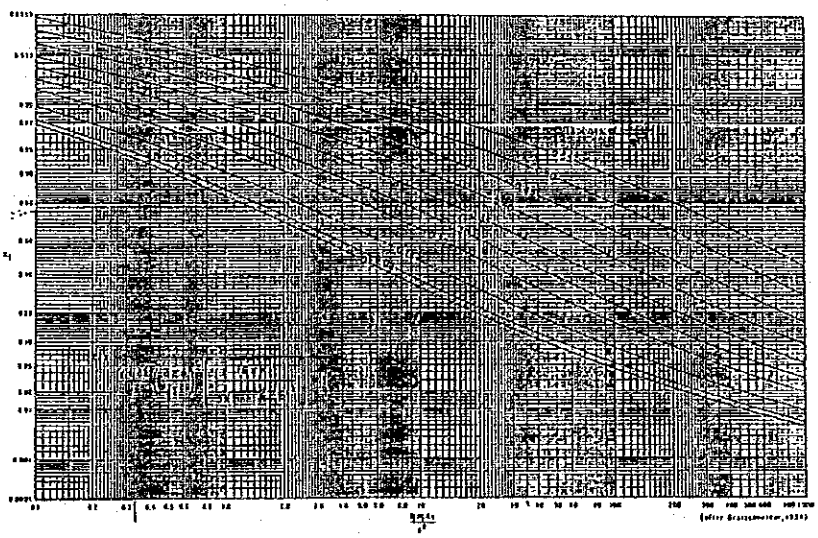


Fig. 6 Relationship for Friction Loss Over a Bottom of Constant Depth

$$\frac{f_f Hi \Delta x}{d^2} = \frac{0.03 \times 2.02 \times 139}{(3.09)^2} = 0.88$$

$$\frac{2\pi d}{gT^2} = \frac{2 \times 3.14 \times 3.09}{9.8 \times (6)^2} = 0.055$$

by Fig. 4,

$$Kf = 0.86 = \frac{H_2}{1.24} \qquad \therefore \; H_2 = 0.86 \times 1.24 = 1.07 \text{ m}$$

$$\Delta H = 1.24 - 1.07 = 0.17 \text{ m}$$

3) The attenuation of the deepwater wave (H_0') of 1.8 m in height caused by passing through the approach section of 139 meters long was calculated as follows:

a) $d = 3.09$ m $\ell = 139$ m at M L W S

$$\frac{f_f Hi \Delta x}{d^2} = \frac{0.03 \times 2.79 \times 139}{(3.09)^2} = 1.218$$

$$\frac{2\pi d}{gT^2} = \frac{2 \times 3.14 \times 3.09}{9.8 \times (6)^2} = 0.055$$

then by Fig. 4:

$$K_f = 0.82 = \frac{H_2}{2.79} \qquad \therefore \; H_2 = 0.82 \times 2.79 = 2.29 \text{ m}$$

$$\Delta H = 2.79 - 2.29 = 0.50 \text{ m}$$

b) $d = 3.94$ m $\ell = 139$ m in M S L

$$\frac{f_f \cdot Hi \cdot \Delta x}{d^2} = \frac{0.03 \times 1.80 \times 139}{(3.94)^2} = 0.484$$

$$\frac{2\pi d}{gT^2} = \frac{2 \times 3.14 \times 3.94}{9.8 \times (6)^2} = 0.070$$

then by Fig. 4:

$$Kf = 0.93 = \frac{H_2}{1.8} \qquad \therefore \; H_2 = 0.93 \times 1.8 = 1.67 \text{ m}$$

$$\Delta H = 1.80 - 1.67 = 0.13 \text{ m}$$

c) d = 4.80 m ℓ = 139 m in M.H.W.S.

$$\frac{f_f \cdot Hi \cdot \Delta x}{d^2} = \frac{0.03 \times 1.8 \times 139}{(4.80)^2} = 0.326$$

$$\frac{2\pi d}{gT^2} = \frac{2 \times 3.14 \times 4.80}{9.8 \times (6)^2} = 0.085$$

then by Fig. 4:

$$K_f = 0.97 = \frac{H_2}{1.8} \qquad \therefore H_2 = 0.97 \times 1.8 = 1.75 \text{ m}$$

$$\Delta H = 1.8 - 1.75 = 0.05 \text{ m}$$

The results of these calculations are summerized in Table 1, below:

Table 1. Summary of Calculation Results

in Metre

Tide	Tidal level	Design wave height		Approach Portion		Standard Portion	
		*1 No.1	*2 No.2	Water depth	Attenuated wave height	Necessary water depth	Design water depth
M L W S	+0.09	1.80	2.79	3.09	0.50	2.29	1.79
M S L	+0.94	1.80	1.80	3.94	0.13	1.67	2.64
M H W S	+1.80	1.80	1.80	4.80	0.05	1.75	3.50

*1 At the beginning point of the approach section

*2 At the ending point of the approach section

4) Study result of design condition

The study result pertaining to the deepwater wave height in the approach section are summerized in Table 2 at M L W S, M S L and M H W S, respectively.

Table 2. Summary of Study Results of Design Conditions

(in Metres)

Tide	Tidal level	Dewign wave height		Approach Portion		Standard Portion		Remarks
		*1 No.1	*2 No.2	Depth of breaking wave	Design water depth	Depth of breaking wave	Design water depth	
M L W S	+0.09	1.80	2.79	4.13	3.09			Breaking wave
M L W S	+0.09	0.80	1.24	2.02	3.09	1.74	1.79	Non-breaking
M S L	+0.94	1.80	1.80	2.75	3.94	2.28	2.64	Non-breking
M H W S	+1.80	1.80	1.80	2.75	4.80	1.67	3.50	Non-breaking

*1 At the beginning point of the approach section

*2 At the ending point of the approach section

Accordingly, the deepwater wave height (which is higher than 0.8 metre) will break within the fisheries channel at M L W S.

The required water depth of the approach section was calculated to be 4.13 metre in order to keep a wave of 1.8 m height (which was used in design) from breaking in the approach section, however, such a deep excavation does not seem economical. Therefore, it was assumed as a design condition that a deepwater wave of 1.8 metre in height will not break at M.S.L in the approach section.

2. Design of Approach Section of the Fisheries Channel from Lagoon Side

2.1 Design Wave

The longest fetch in Lagoon side is in the N direction.

The wave height and wave period were calculated by the using Bretschneider Formula as follows:

- Wave height at M H W S

Wind speed	:	8.50 m/s
Effective fetch	:	19.1 km
Average water depth	:	9.8 m (8 m + 1.8 m)
Tide level	:	+1.8 m

$$\frac{gh}{U^2} = \frac{9.8\ m/sec^2 \times 9.8\ m}{(8.5\ m/s)^2} = 1.33$$

$$\frac{gF}{U^2} = \frac{9.8\ m/sec^2 \times 19{,}100\ m}{(8.5\ m/s)^2} = 2{,}590.7$$

$$\frac{gH}{U^2} = \frac{9.8\ m/sec^2 \times H\ m}{(8.5\ m/s)^2} = 9.5 \times 10^{-2}$$

$$\therefore H = \frac{9.5 \times 10^{-2} \times 8.5^2}{9.8} = 0.70\ m$$

Wave period

$$T_{1/3} = 3.86\ \sqrt{H^{1/3}} = 3.86\ \sqrt{0.70} = 3.23 \doteq 3\ sec.$$

- Wave height at M L W S

Wind speed	:	8.50 m/s
Effective fetch	:	12.70 km
Average wave depth	:	8.09 m
Tidal level	:	+0.09 m

$$\frac{gh}{U^2} = \frac{9.8\ m/sec^2 \times 8.09\ m}{(8.5\ m/s)^2} = 1.10$$

$$\frac{gF}{U^2} = \frac{9.8\ m/sec^2 \times 12,700\ m}{(8.5\ m/s)^2} = 1,722.6$$

$$\frac{gH}{U^2} = \frac{9.8\ m/sec^2 \times H\ m}{(8.5\ m/s)^2} = 8.0 \times 10^{-2}$$

$$\frac{gH}{U^2} = \frac{8 \times 10^{-2} \times 8.5^2}{9.8} = 0.59\ m$$

Wave speed

$$T_{1/3} = 3.86\ \sqrt{H_{1/3}}$$

$$= 3.86\sqrt{0.59} = 2.96 \doteqdot 3.0\ sec.$$

The relation between the wave height at the beginning point (H_0') and wave height at the ending point (H_2) of the approach section was calculated as follows *(refer to Fig. 7, below)*:

$$\left(\frac{H_2}{H_0'}\right) = \left(\frac{B_0}{B_1}\right)$$

$$H_2 = H_0' \sqrt{\frac{B_0}{B_1}} = 0.6 \times \sqrt{\frac{60.74}{20.74}} = 1.03\ m$$

$$L_0 = 1.56T^2 = 1.56 \times 3^3 = 14.04\ m$$

The water depth which does not break the wave height H_2 (2.79m) was calculated as follows, where the sea bottom slope is not steeper than 1/50:

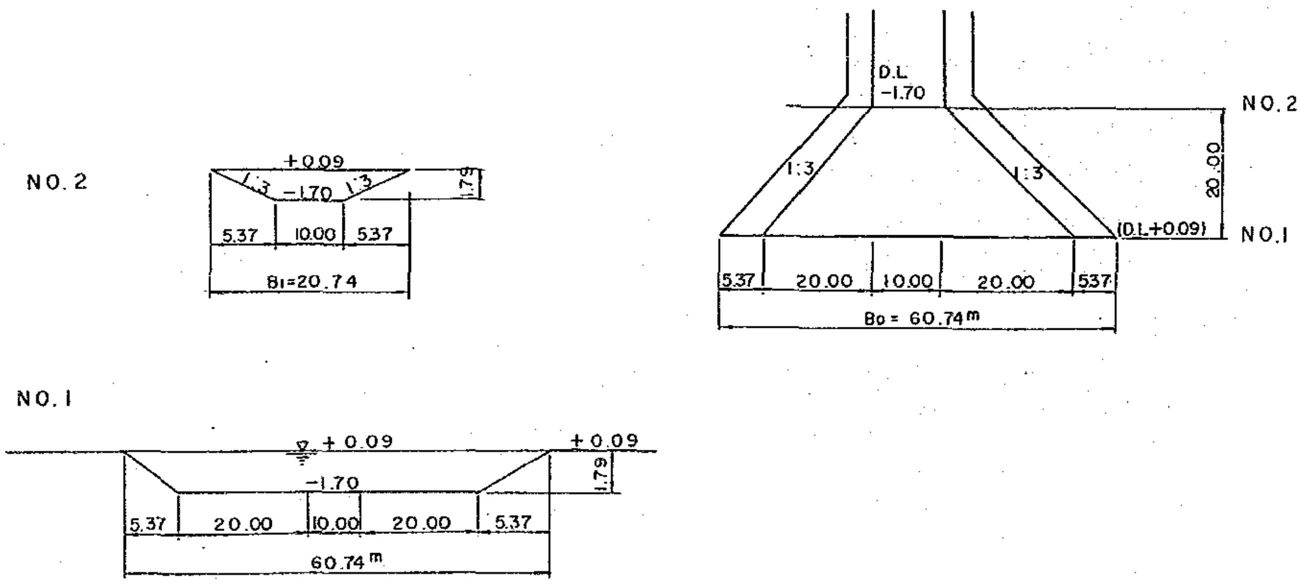


Fig.7 Beginning width and ending width at Approach of Channel

Received: 85.4.12
From Mr. Manrool Kaiea
(Manager: PVU)

Appendix 4-10 (1)

PLANT AND VEHICLE UNIT

Vehicle/Plant	Reg. No.	Date In Service	Remaining Value	Condition
Nissan Tipper	BTC 3184	Renewal 1983	34596.00	New-not yet put into service
" "	BTC 3024	14.9.82	12025	Good condition
" "	BTC 3025	20.9.82	12025	Good condition
" "	BTC 3026	29.9.82	12025	Good
" "	BTC 3022	14.9.82	16850	Good
930 Cat Loader	BTC 3063	1.11.82	57396	Good
" " "	BTC 2989	23.7.82	53405	Good Back-Up Machine
Dump Truck	BTC 3043	19.9.82	76503	Presentdy under repairs but good
Sykes 4" pump	No. 5	20.4.79	875	Good
Simplite 2" Pump	No. 6	5.2.81	1150	Good
" " "	No. 7	5.2.81	1150	Gaod
4" Johnson Pump	No. 2	3.3.75	Nil	Operational
4" " "	No. 3	3.3.75	Nil	Operational
Honda 2" Pump	No. 8	1.1.83	525	Good
Lister 15KVA	No. 2	2.1.67	137	Good
Powerlite 30KVA 3 Phase	No. 4	1.5.81	9000	Good
" "	No. 5	1.5.81	9000	Good
Meiko C/Mixer	Ex-Jap. Aid	(Mautari Project)		Good
Winget 7/5	No. 6	74	Nil	Operating
" "	No. 12	74	Nil	Operating
Holman Compressor	No. 2	8.10.79	1250	Good
Comp. Air 160 GV	No. 4	1.5.81	6328	Good
" " " "	No. 5	1.3.82	8925	Good
Moore Phuemat ic Tyred Roller	BTC 2630	28.4.81	18000	Good
Steel Tyred Roller Aveling Barford	BTC 2808	28.4.81	27334	Good
Cat D6D	BTC 1575	Rebuilt Fiji Jan81	55250	Good
" "	BTC 2218	20.6.79	47925	Good
Cat 130G Grader	BTC 2105	1.1.79	27215	Good
" " "	BTC 2165	23.5.79	27215	Good
12G	BTC 3137	1.1.83	87360	Good
22RB	BAN 23	EX BPC 11.3.80	2500	Good
"	BAN 24	11.3.80	2500	Good
" Piling	BTC 1368	1.3.74	2500	Good
22RB	BTC 1520	5.7.76	4000	Good
"	BTC 2042	27.10.78	35325	Good

Coles 911C 10ton	BTC 2105	4.7.81	72189	Good
York Container Trailer	BTC 2353	22.1.80	2125	Good
Tractor for Above Trailer	BTC 2353	22.1.80	4600	Good

SIMULATION OF TIDAL CURRENT IN THE LAGOON OF THE TARAWA ATOLL

1. Objective

This study aims to analyze a change of tidal flow in the lagoon of the Tarawa Atoll due to construction of the causeway between the island of Betio and the island of Bairiki.

2. Calculation Formula

(1) Basic Formula

i. Equation of Motion

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + w\frac{\partial u}{\partial z} = 2\Omega v \sin\phi$$

$$-\frac{1}{\rho}\frac{\partial p}{\partial x} + Vx\frac{\partial^2 u}{\partial x^2} + Vy\frac{\partial^2 u}{\partial y^2} + Vz\frac{\partial^2 u}{\partial z^2} \qquad \text{----- (1)}$$

$$\frac{\partial v}{\partial t} + u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} + w\frac{\partial v}{\partial z} = 2\Omega \sin\phi$$

$$-\frac{1}{\rho}\frac{\partial p}{\partial y} + Vx\frac{\partial^2 v}{\partial x^2} + Vy\frac{\partial v^2}{\partial y^2} + Vz\frac{\partial^2 v}{\partial z^2} \qquad \text{----- (2)}$$

$$0 = \frac{1}{\rho}\frac{\partial p}{\partial z} - g \qquad \text{----- (3)}$$

ii. Equation of Continuity

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0 \qquad \text{---- (4)}$$

where:

x, y = horizontal axis of x, y.
z = vertical axis
u, v, w = velocities for respective direction of s, y, z.
Ω = angle speed of rotation of the earth
ϕ = latitude
ρ = density
p = pressure
Vx, Vy, Vz = coefficient of eddy viscosity for respective direction of x, y, z.

(2) Equation for Calculation

Basic equations (1) to (4) will be integrated as regarding z direction as follows:

$$\frac{\partial Sx}{\partial t} + \frac{\partial}{\partial x}(Sx.\bar{u}) - \frac{\partial}{\partial y}(Sx.\bar{v}) = 2\Omega Sy \sin\phi$$

$$- g(\zeta - H)\frac{\partial \zeta}{\partial x} - r_b^2\ \bar{u}\sqrt{u^2 + v^2} + Vx\frac{\partial^2 Sx}{\partial x^2} + Vy\frac{\partial^2 Sx}{\partial y^2} \qquad \text{------ (5)}$$

$$\frac{\partial Sy}{\partial t} + \frac{\partial}{\partial y}(Sy.\bar{u}) - \frac{\partial}{\partial y}(Sy.\bar{v}) = 2\Omega Sx \sin\phi$$

$$- g(\zeta - H)\frac{\partial \zeta}{\partial y} - r_b^2\ \bar{v}\sqrt{u^2 + v^2} + Vx\frac{\partial^2 Sy}{\partial x^2} + Vy\frac{\partial^2 Sy}{\partial y^2} \qquad \text{------ (6)}$$

$$\frac{\partial \zeta}{\partial t} = \frac{\partial Sx}{\partial x} - \frac{\partial Sy}{\partial y} \qquad \text{------ (7)}$$

where:

$$Sx = \int_{-H}^{\zeta} Udz = (\zeta - H)\bar{u} \qquad Sy = \int_{-H}^{\zeta} Vdz = (\zeta - H)\bar{v}$$

ζ = water level above MSL

r_b^2 = coefficient of sea bed friction

Equations (5) to (7) will be calculated numerically.

3. Conditions of Calculation

Simulation of tidal flow will be made in the following 4 cases:

Case	Betio - Bairiki Entrance	Tide Flow	Tide Level CDL	
1	Closure	Spring tide	+0.09 - +1.80	MHWS
2	Closure	Neap tide	+0.67 - +1.22	MHWN
3	Open	Spring tide	+0.09 - +1.80	MLWS
4	Open	Neap tide	+0.67 - +1.22	MLWN

Conditions of calculations are as follows:

Topography :	Ocean sea bed	-20.0 CDL
:	Lagoon west entrance	-2.4 CDL
:	Betio - Bairiki entrance	+1.19 CDL*
:	Lagoon sea bed	-8.0 CDL

Mesh size : 1,000 m both directions of x, y.

Time step : 20 sec.

Calculation time : 3 tidal

Coriolis' coefficient : $2w \sin\varphi = 2 \times (360/3{,}600 \times 24) \times \sin 15^{\circ}$

Coefficient of viscosity : 10^{6} cm^{2}/sec

Coefficient of sea bed friction : 0.0026

Boundary condition :

Spring Tide :	Amplitude of spring tide at boundary	85.5 cm
:	Phase lag of east and west	4.2°
:	Water level of east boundary	2 cm
Neap Tide :	Amplitude of neap tide at boundary	27.5 cm
:	Phase lag of east and west	4.2°
:	Water level of east boundary	2 cm

4. Results

Tidal flow before construction of the causeway is shown in Appendix 4-11 (4) to 4-11 (10) and after in Appendix 4-11 (11) to 4-11 (17). As shown in the results, the change of tidal flow is none in the neap tide, while a little in the spring tide. The charge is a little occurred in the flow direction near the opening of Betio - Bairiki and none in the flow velocity.

* Average depth of the highest portion of the reef along the causeway. Existing two channels with elevation of +0.1 m to 0.5 m and width of 20 m to 30 m are not considered for calculation.

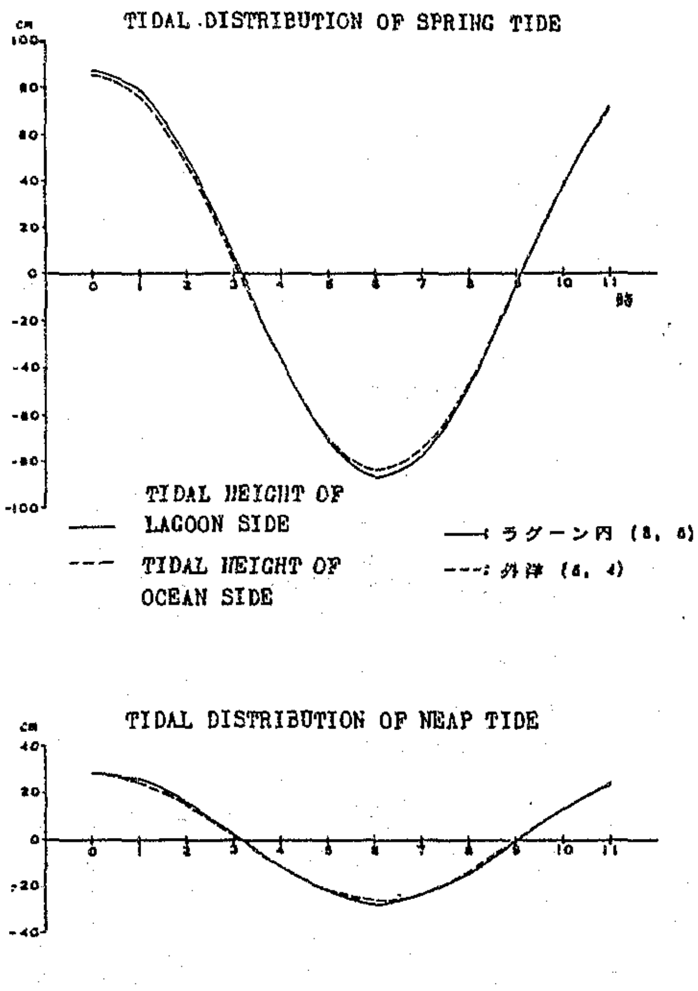
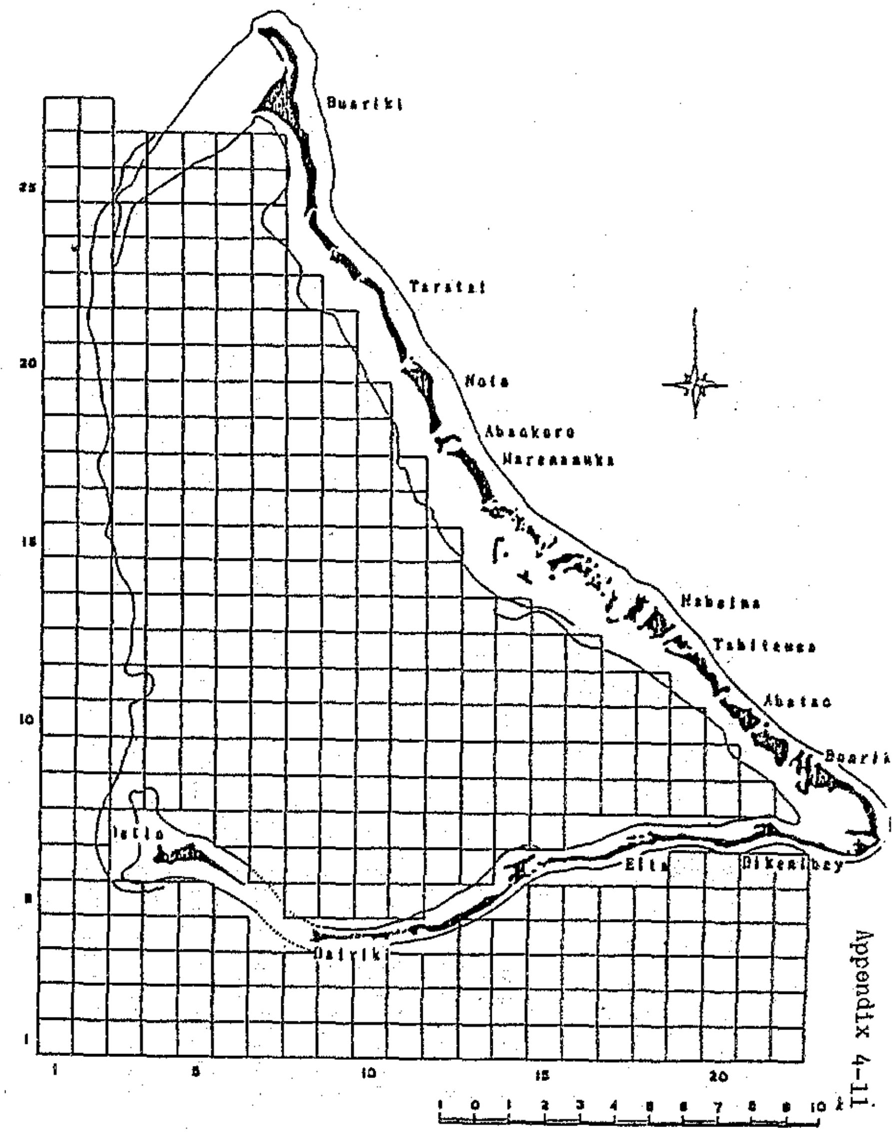
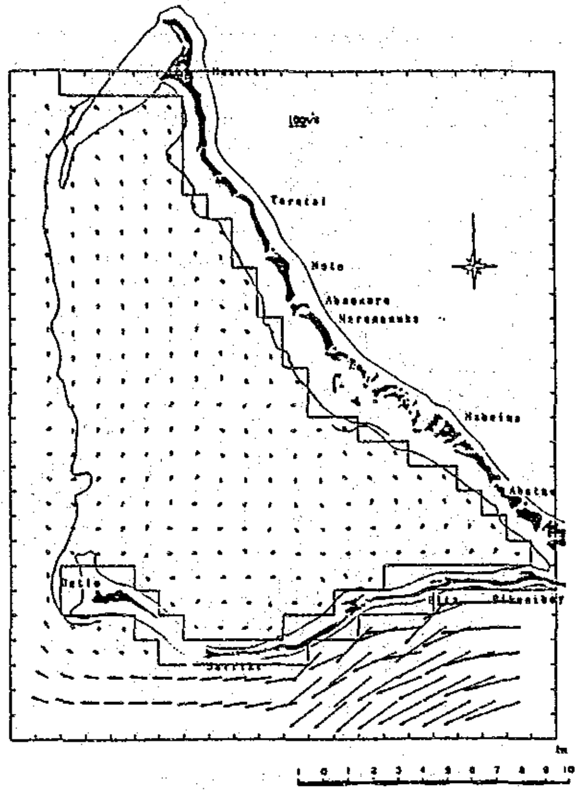


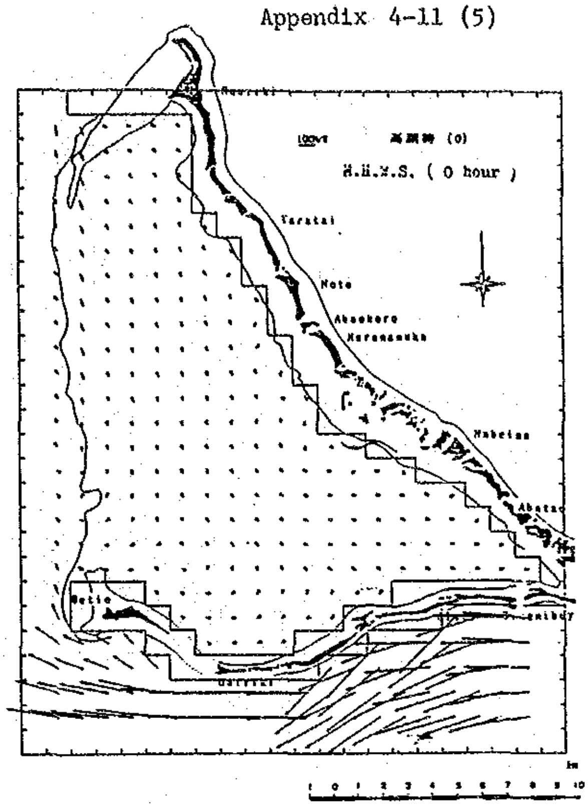
図 Tidal current (Closure)



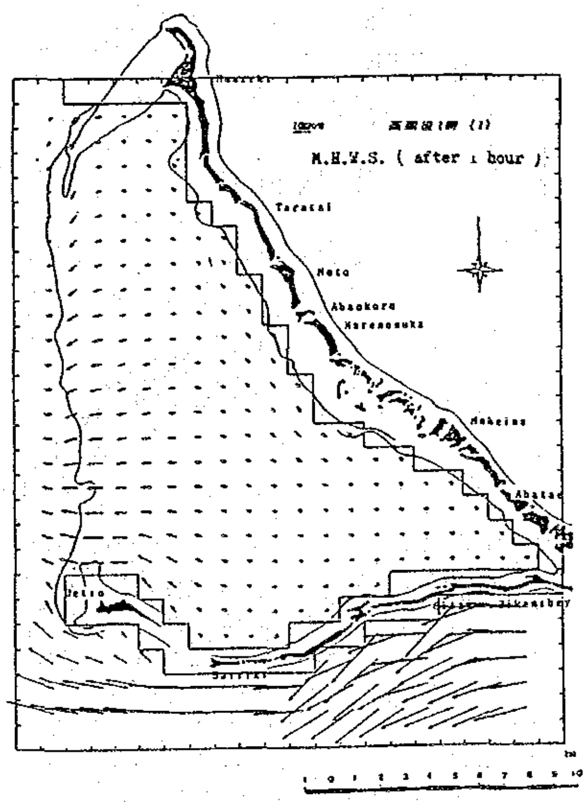
Grid for the simulation of tidal current
(Closure)



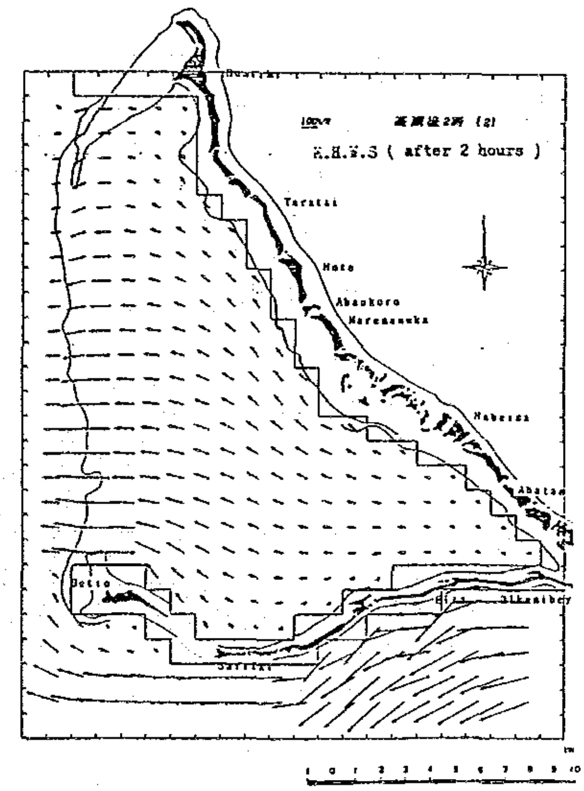
Permanent current (Closure)



Tidal current in Spring tide (Closure)



Tidal current in Spring tide (Closure)



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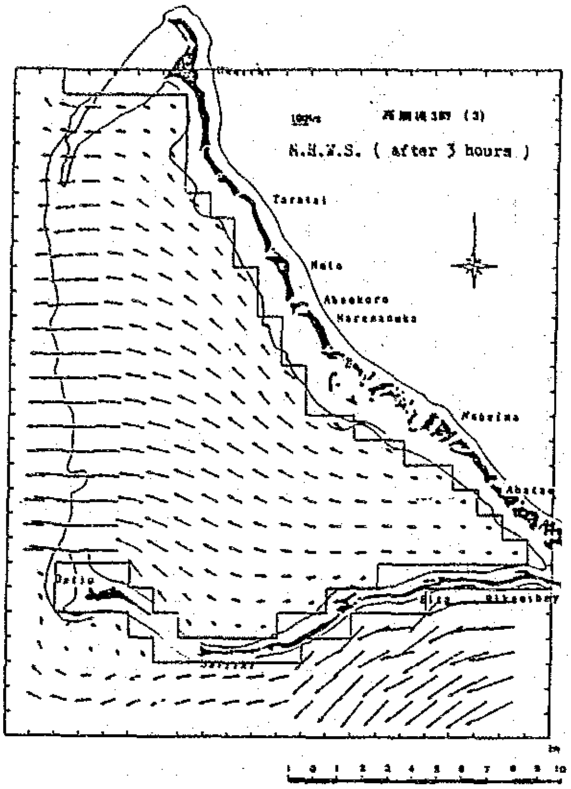

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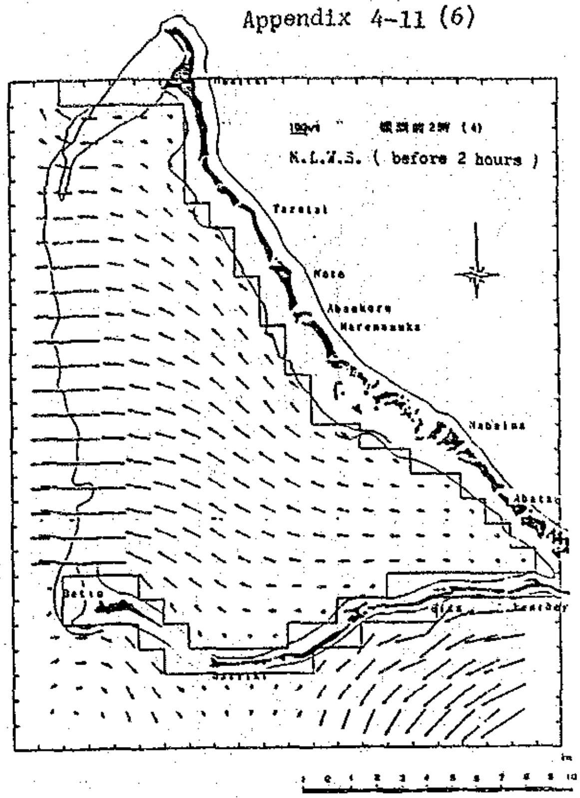

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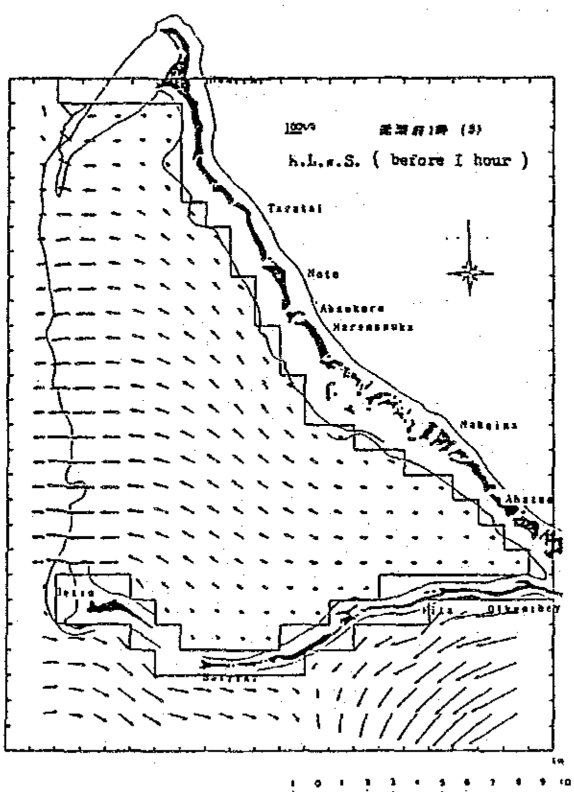

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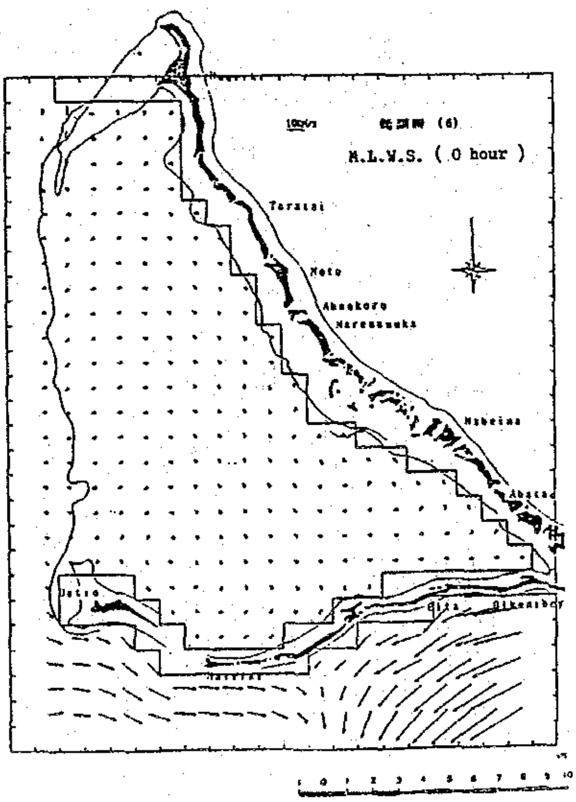
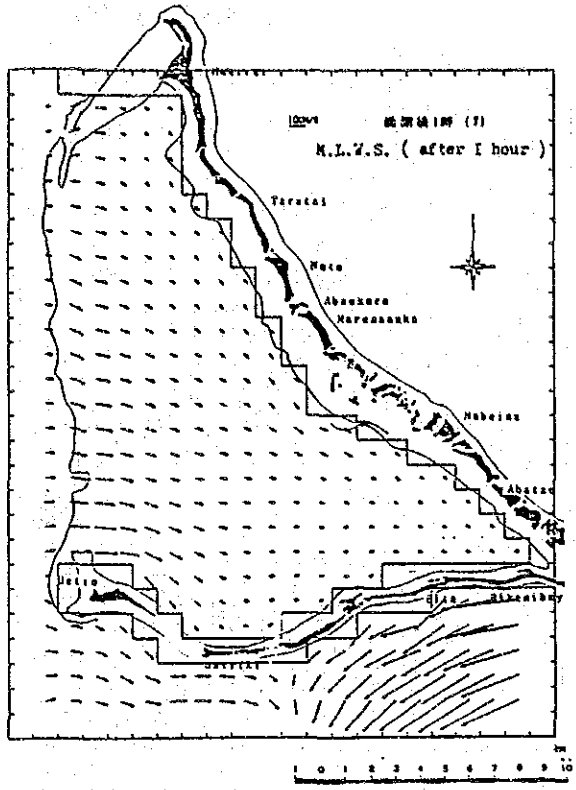
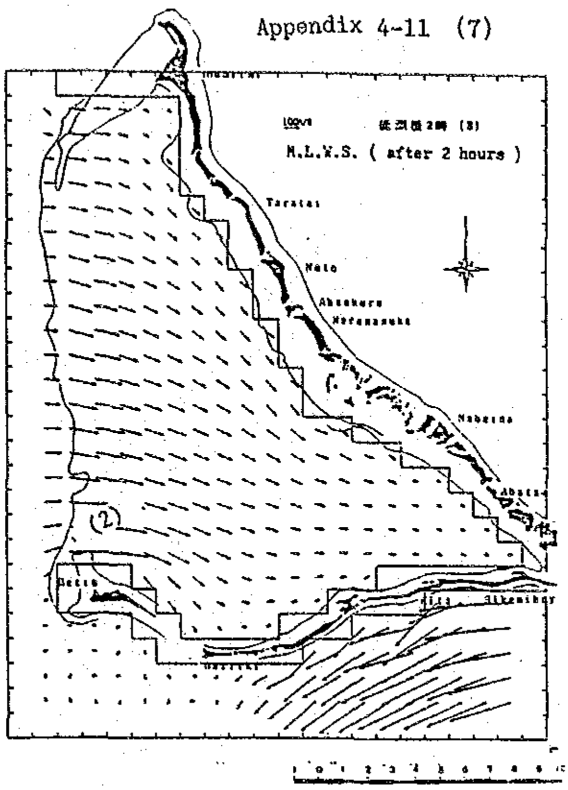


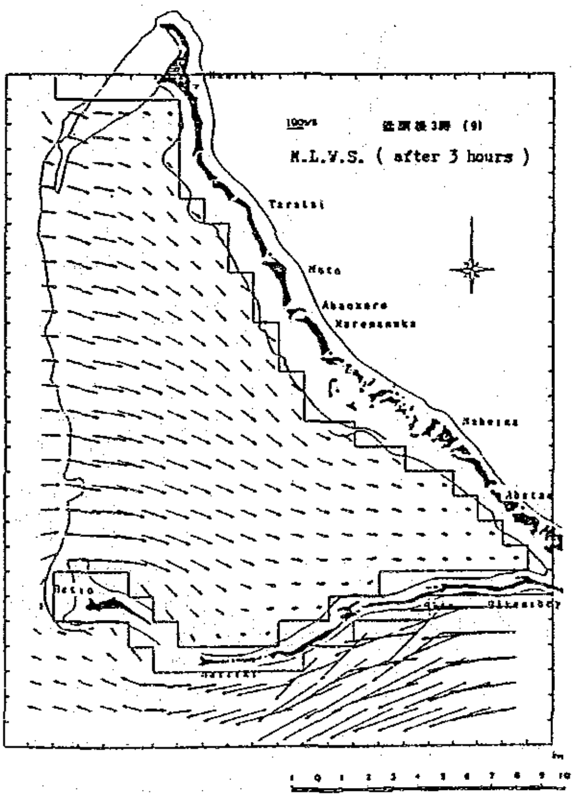
Tidal current in Spring tide (Closure)



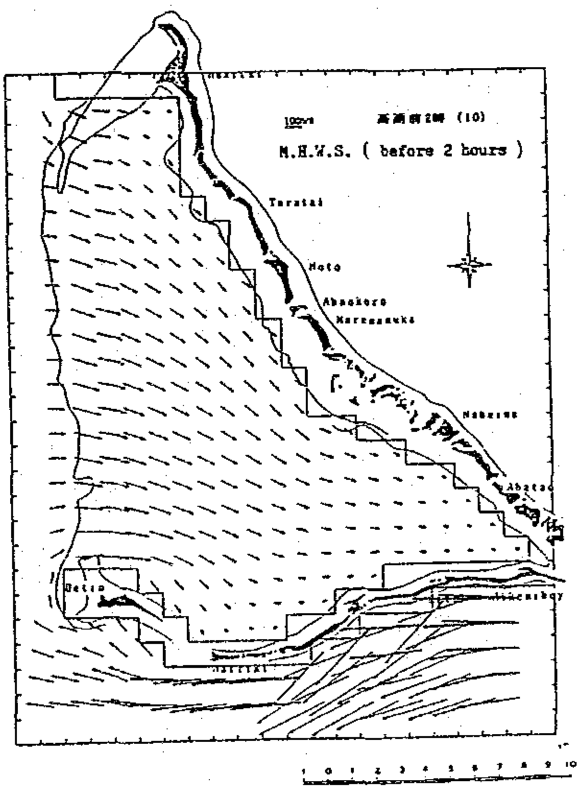
Tidal current in Spring tide (Closure)



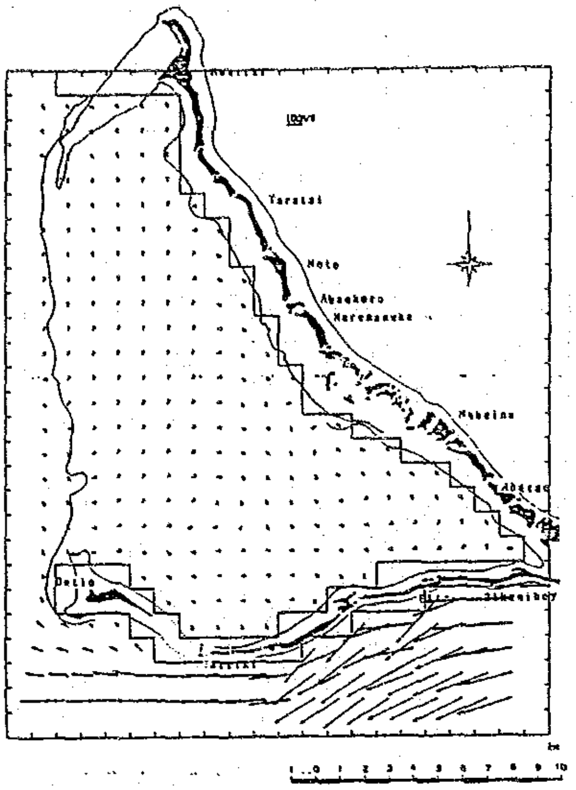
Tidal current in Spring tide(Closure)



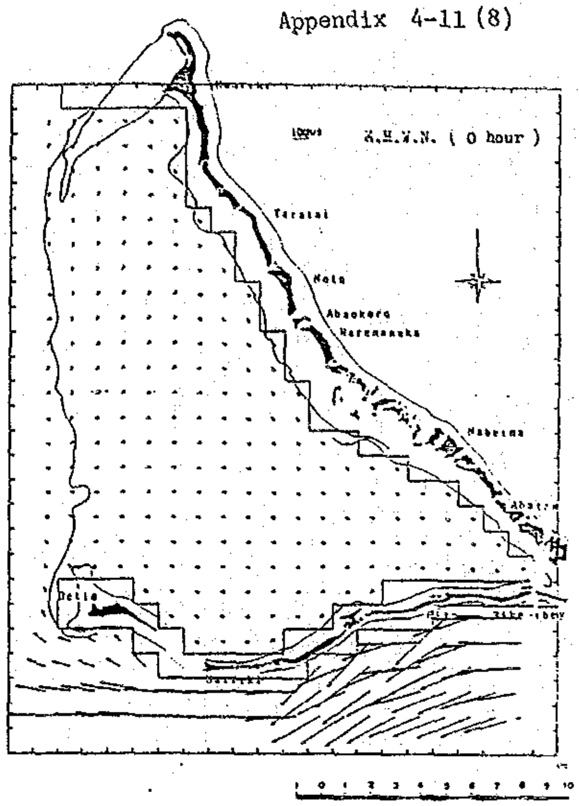
Tidal current in Spring tide(Closure)



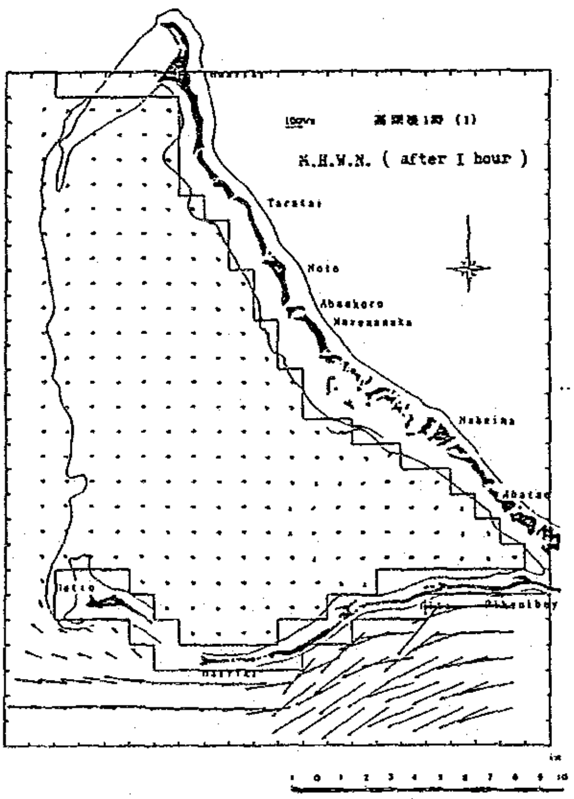
Tidal current in Spring tide (Closure)



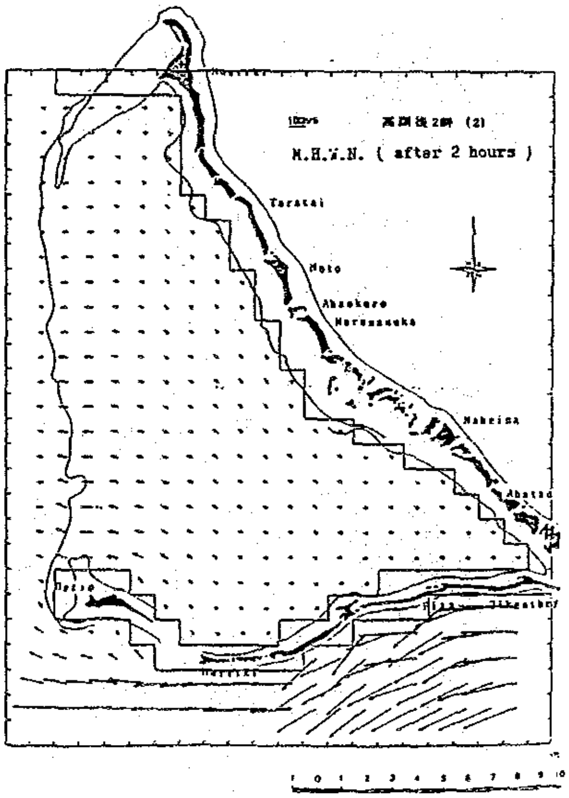
Permanent Current (Closure)



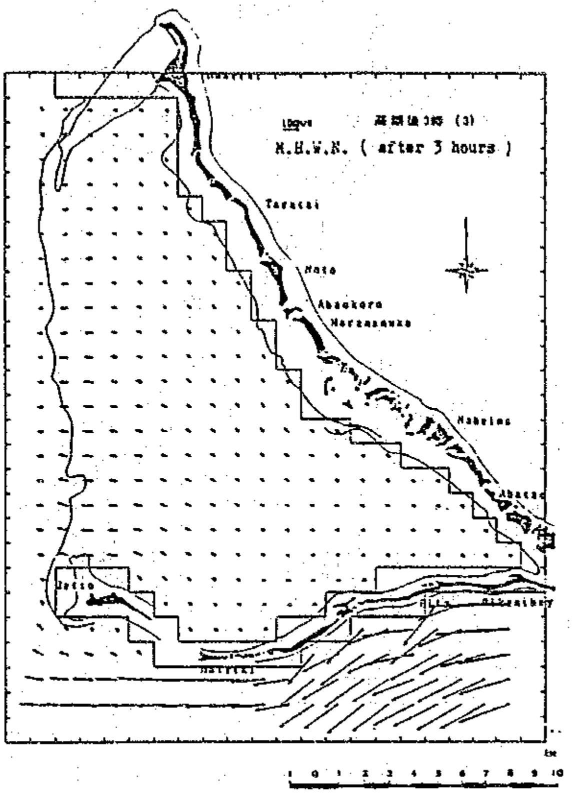
Tidal current in Neap tide (Closure)



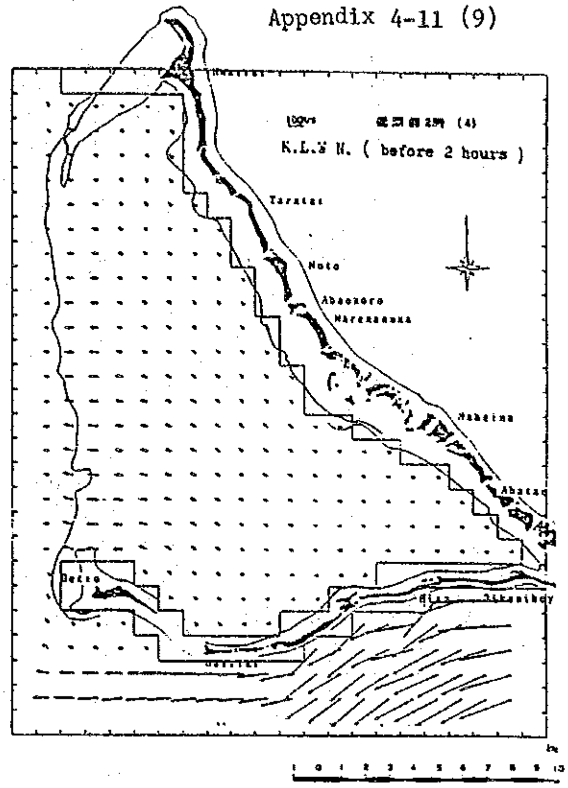
Tidal current in Neap tide (Closure)



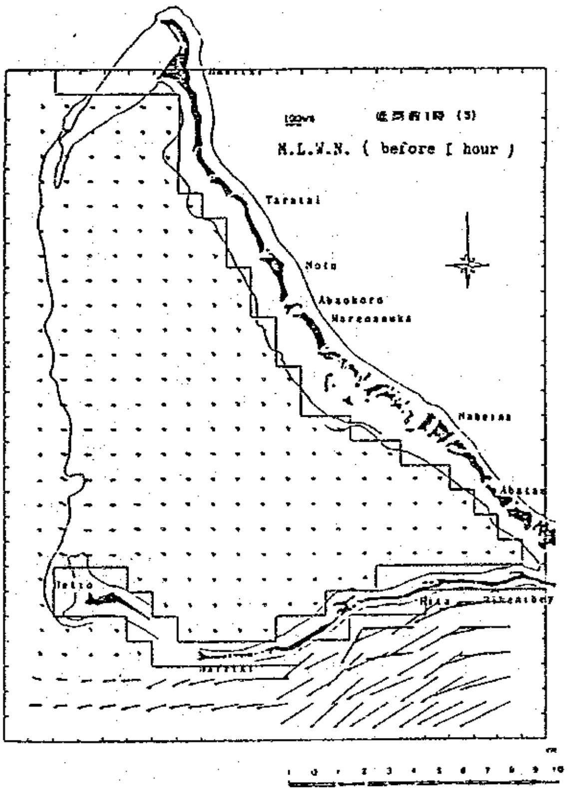
Tidal current in Neap tide (Closure)



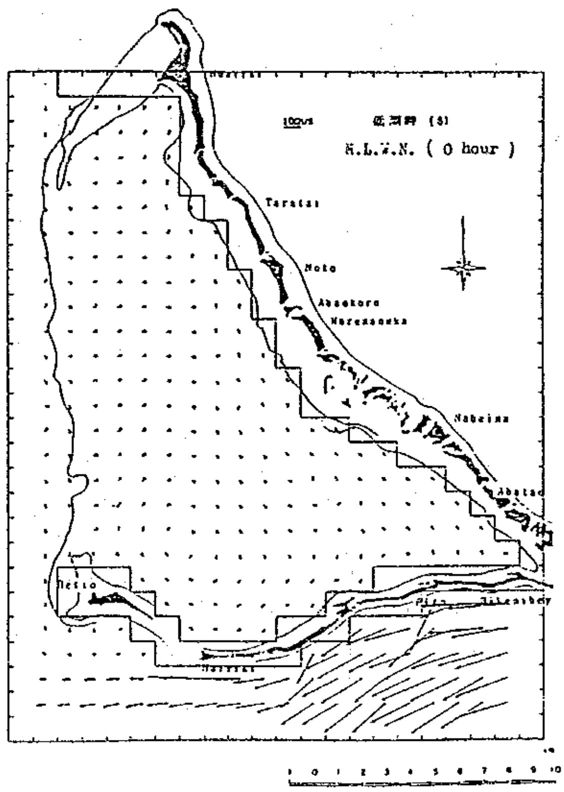
Tidal current in Neap tide (Closure)



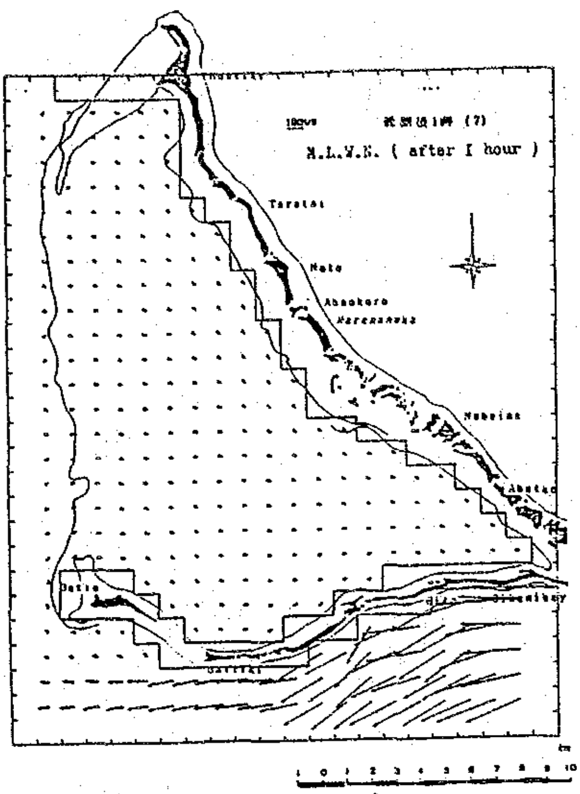
Tidal current in Neap tide(Closure)



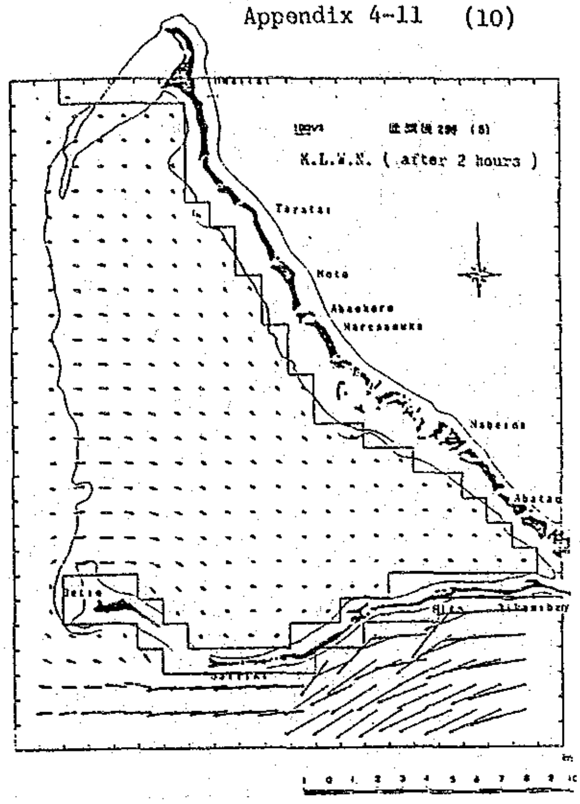
Tidal current in Neap tide(Closure)



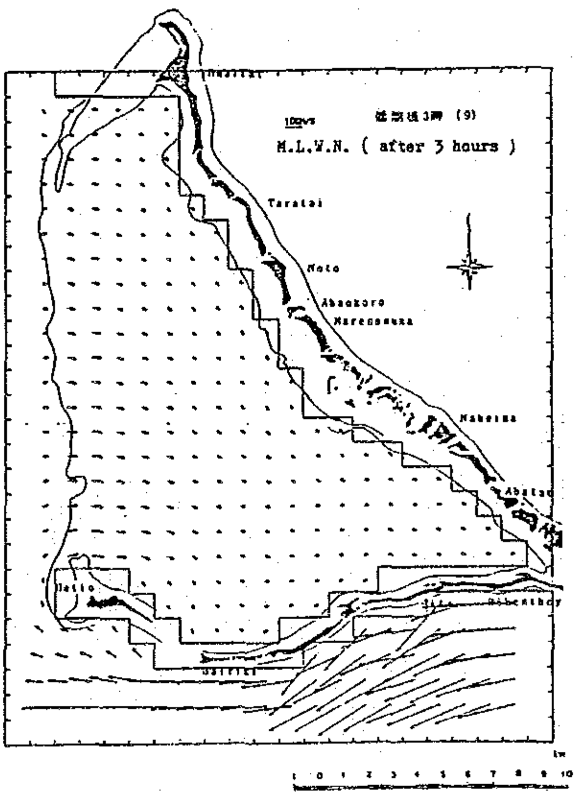
Tidal current in Neap tide (Closure)



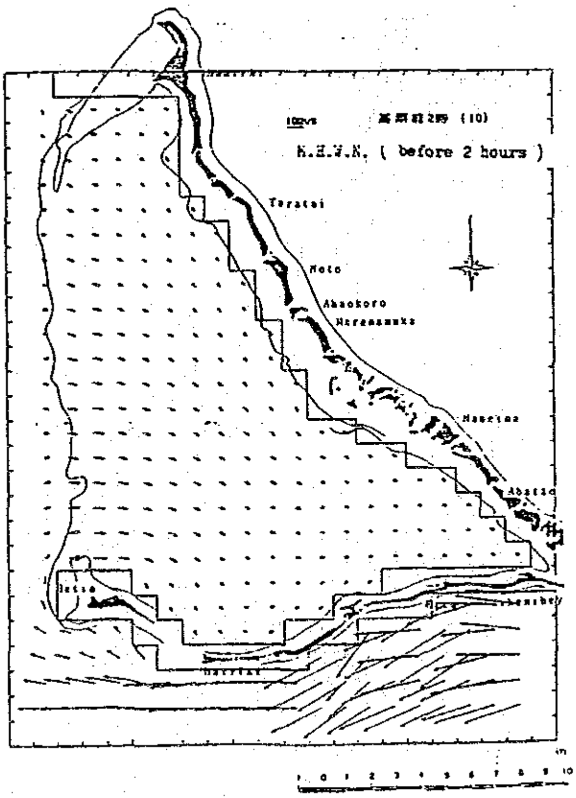
Tidal current in Neap tide (Closure)



Tidal current in Neap tide (Closure)



Tidal current in Neap tide (Closure)



Tidal current in Neap tide (Closure)

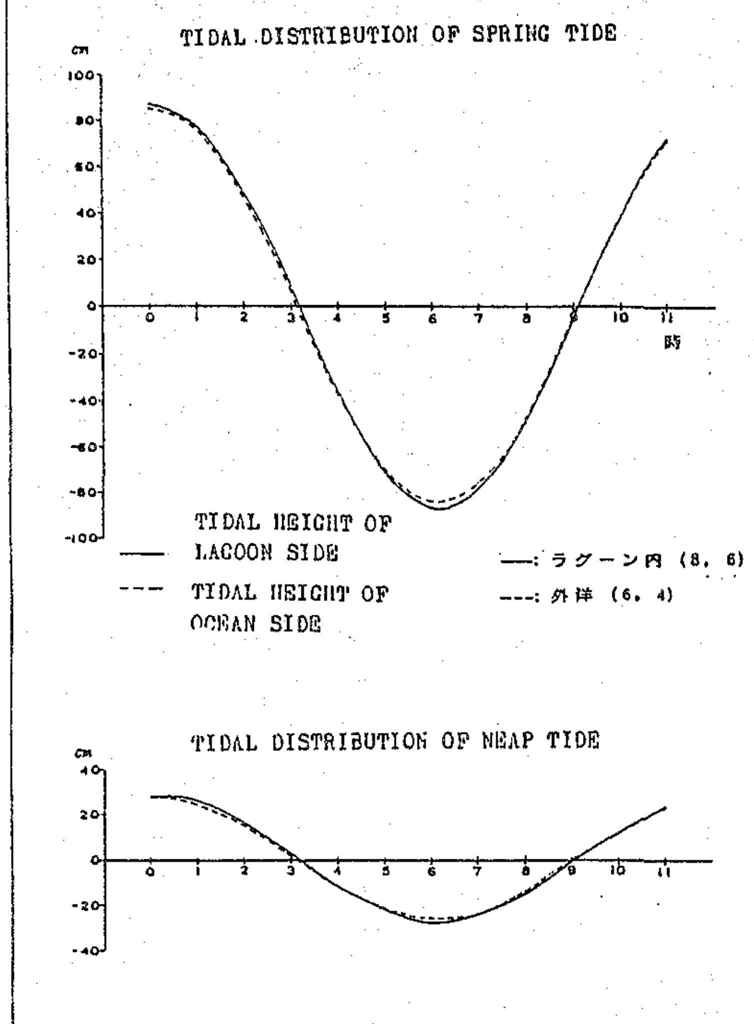
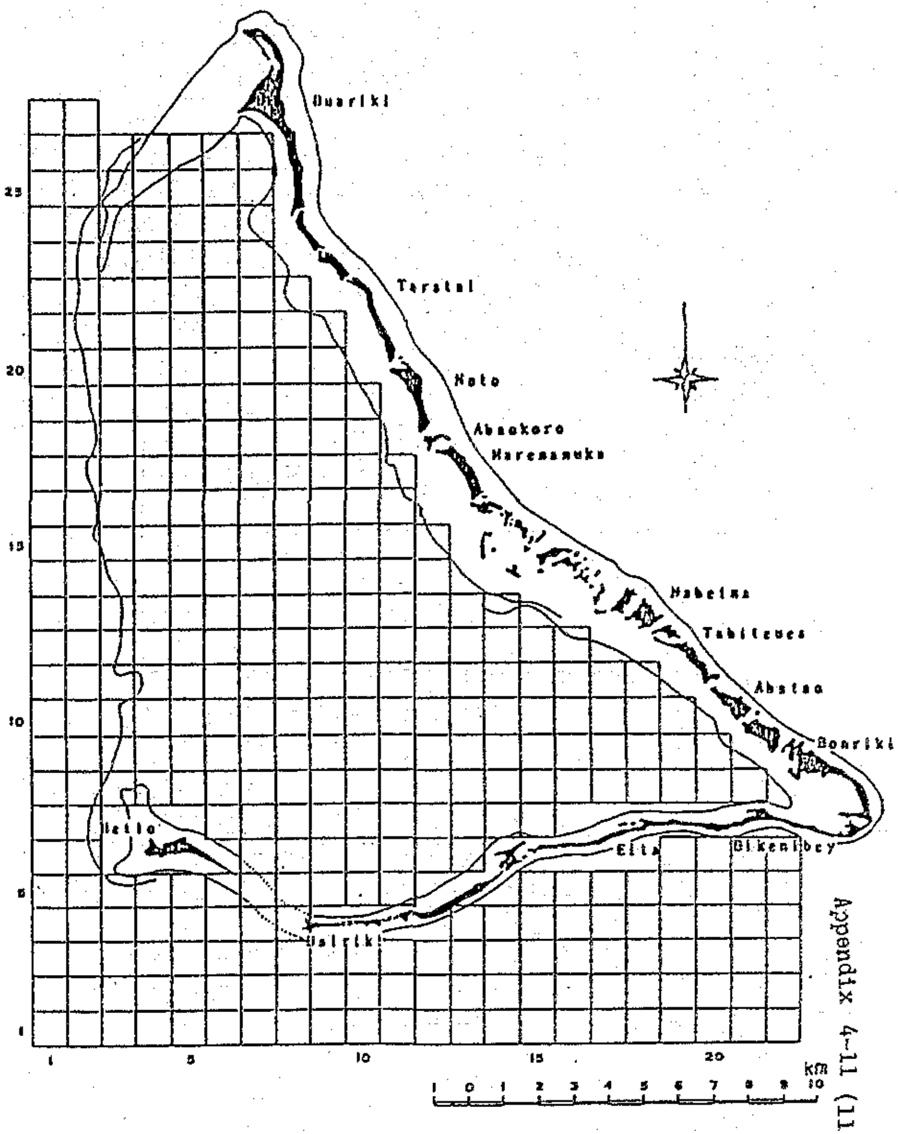
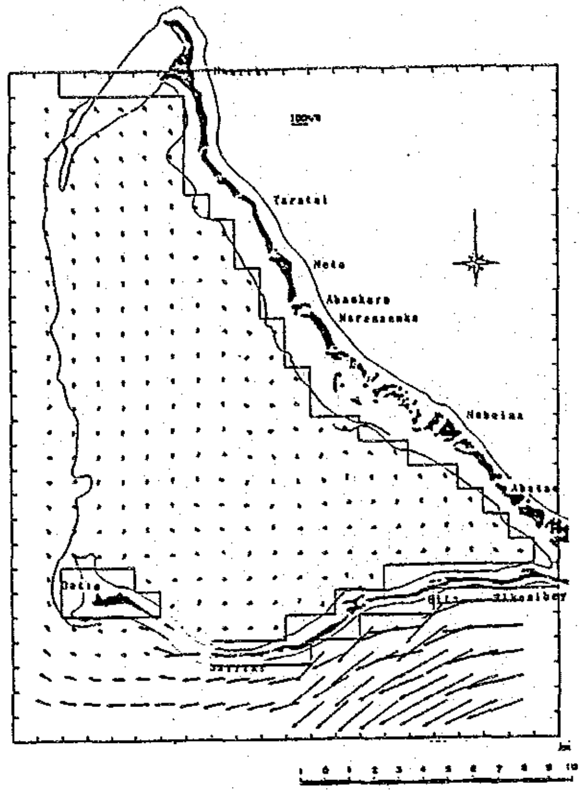


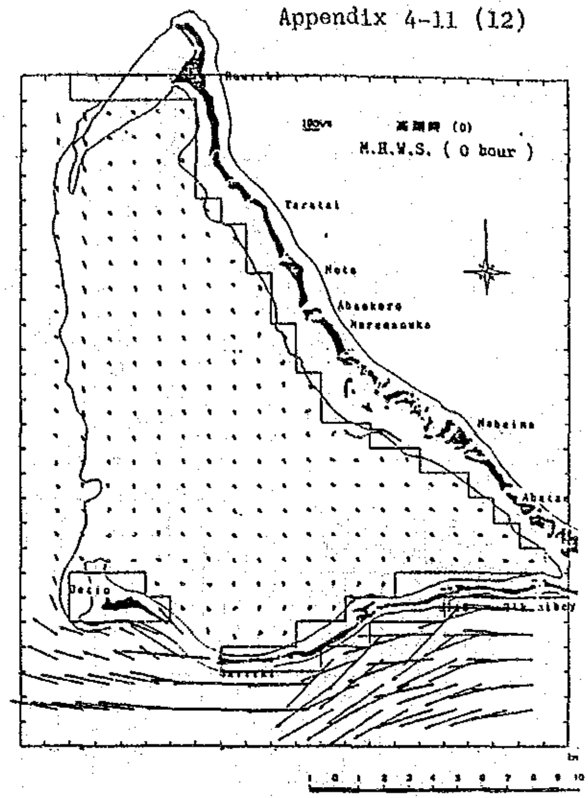
図 Tidal current (Opening)



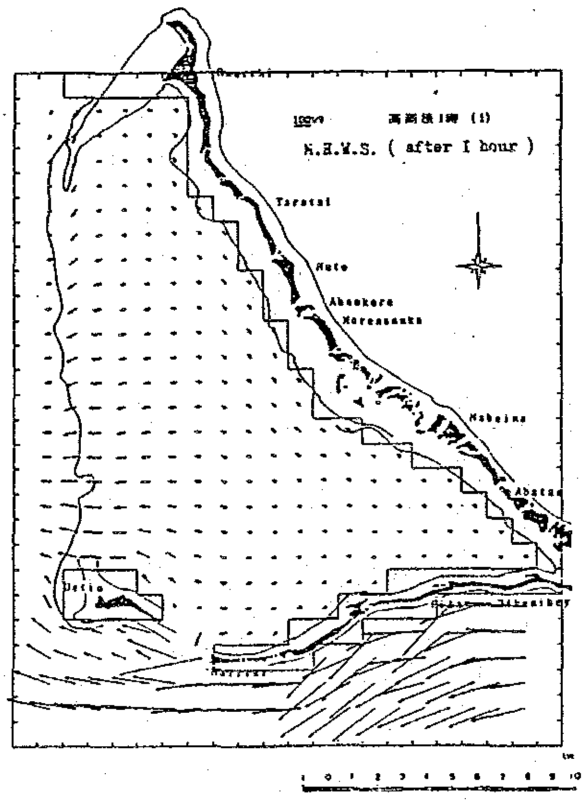
Grid for the simulation of tidal current
(Opening)



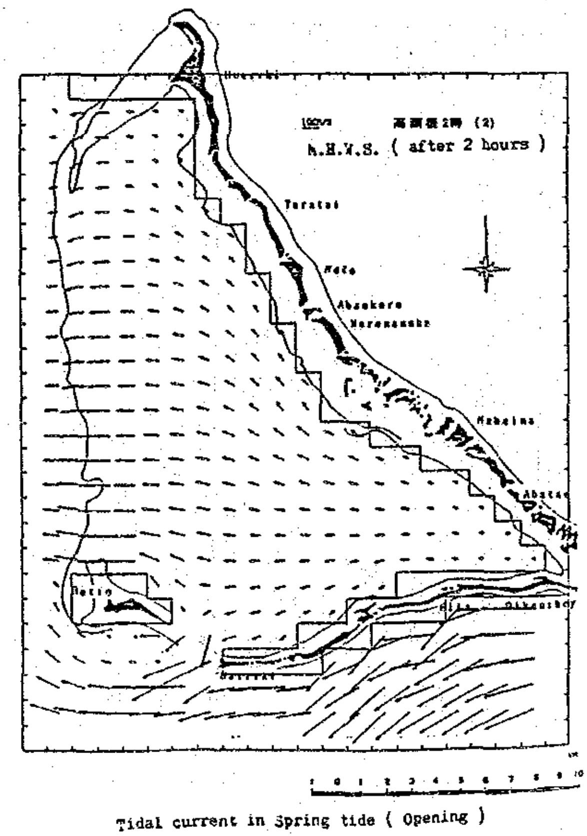
Tidal current in Spring tide (Opening)



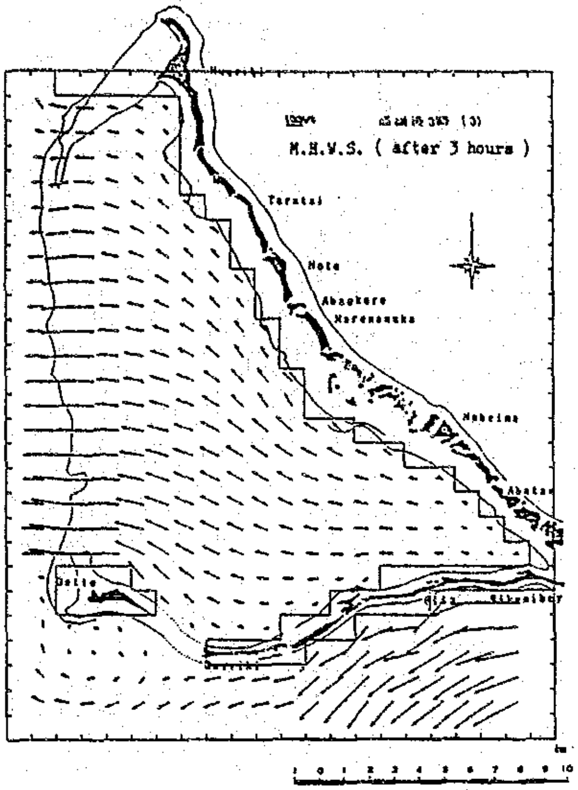
Tidal current in Spring tide (Opening)



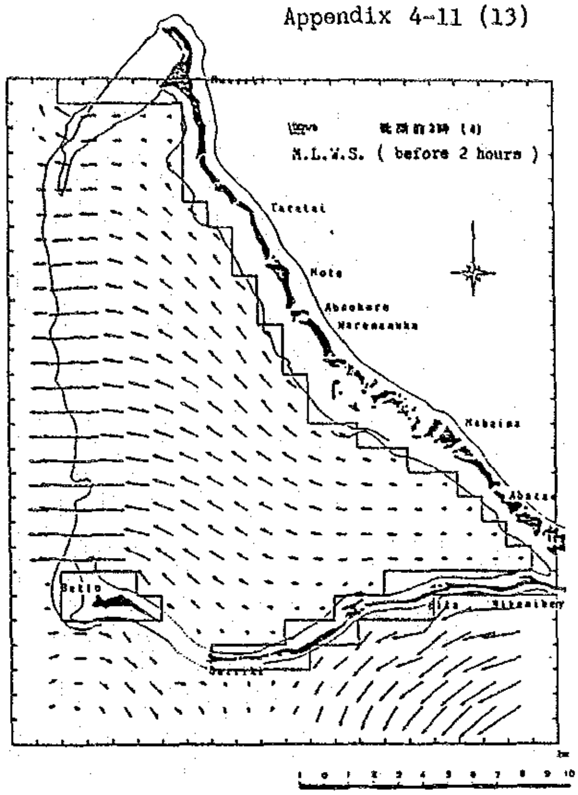
Tidal current in Spring tide (Opening)



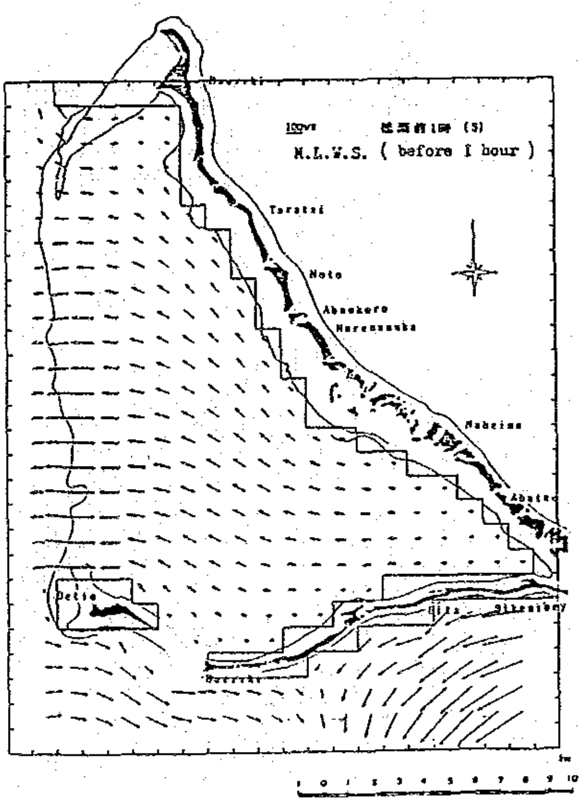
Tidal current in Spring tide (Opening)



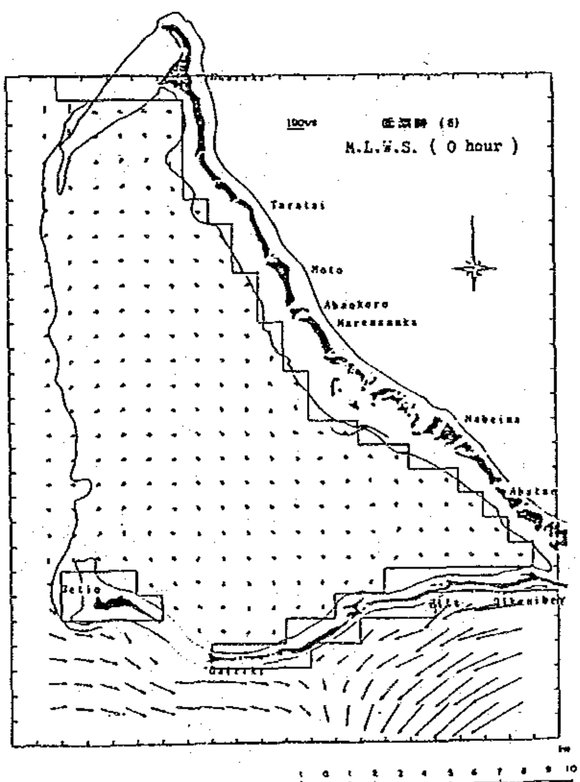
Tidal current in Spring tide (Opening)



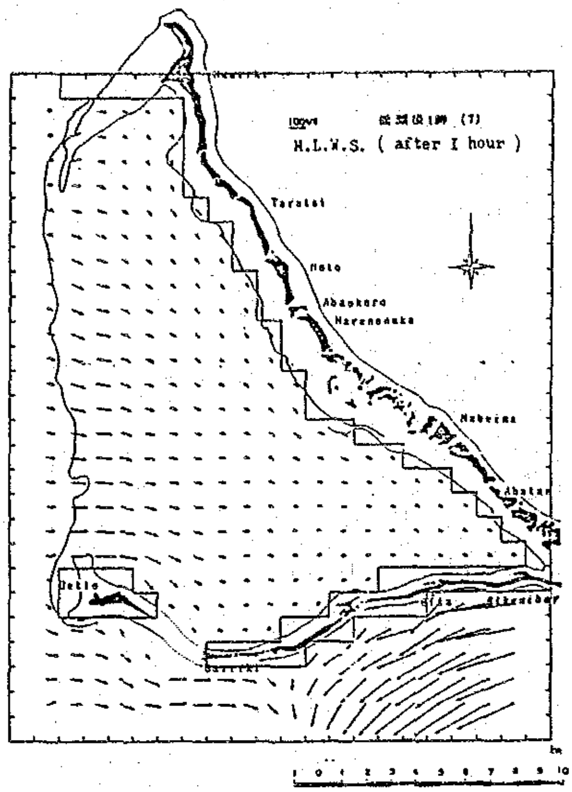
Tidal current in Spring tide (Opening)



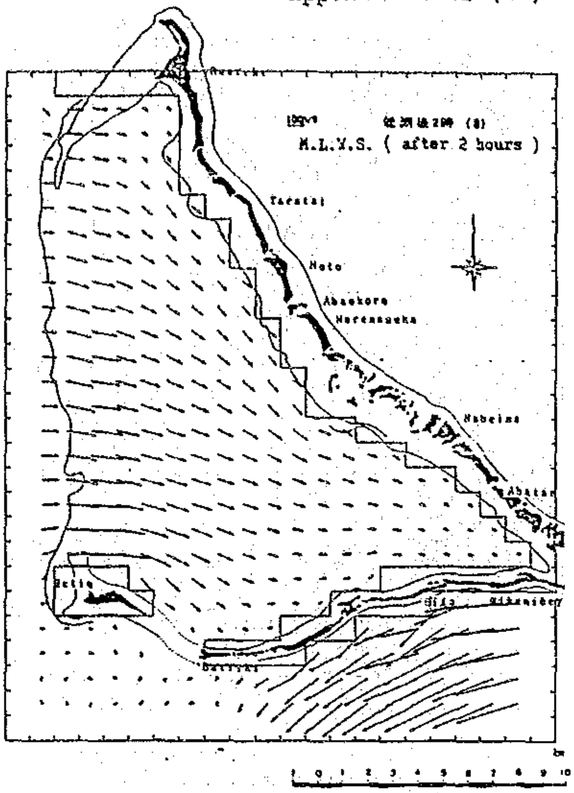
Tidal current in Spring tide (Opening)



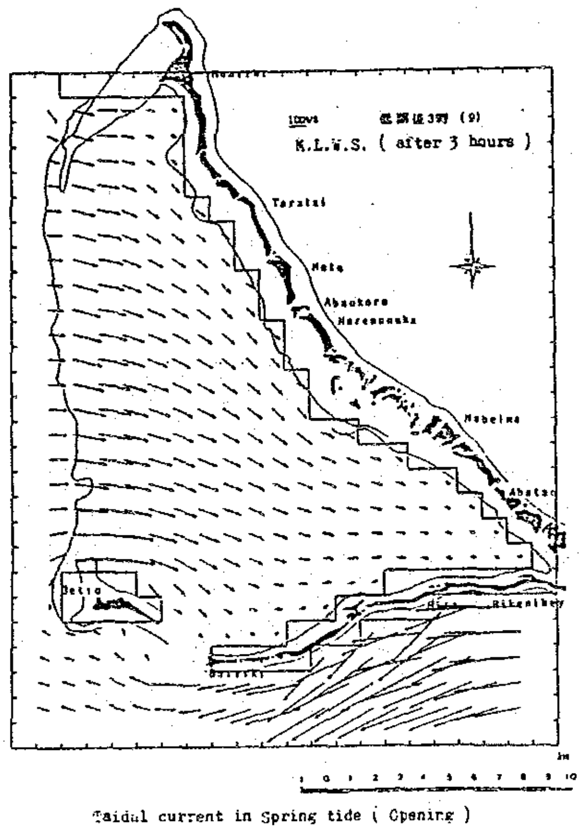
Tidal current in Spring tide (Opening)



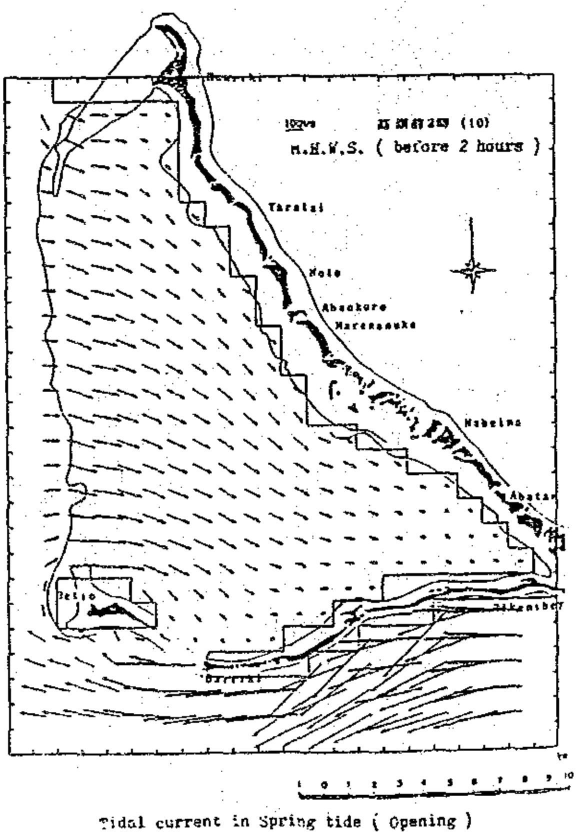
Tidal current in Spring tide (Opening)



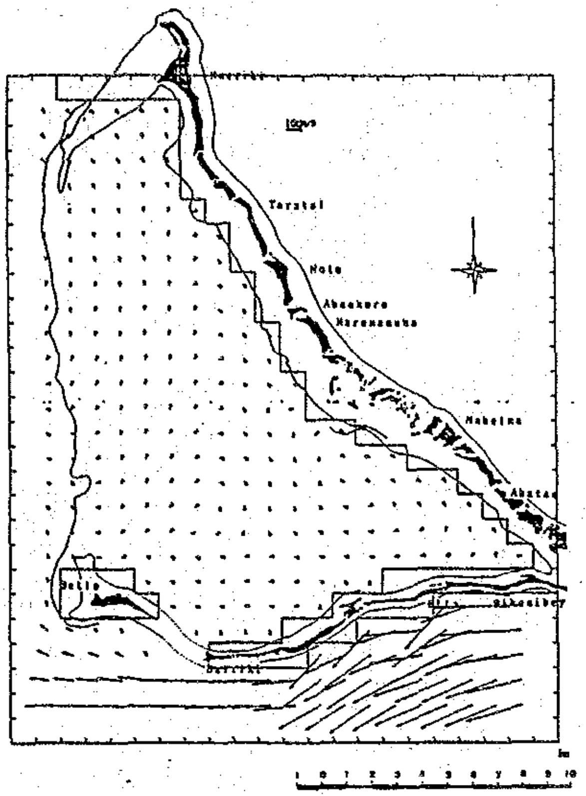
Tidal current in Spring tide (Opening)



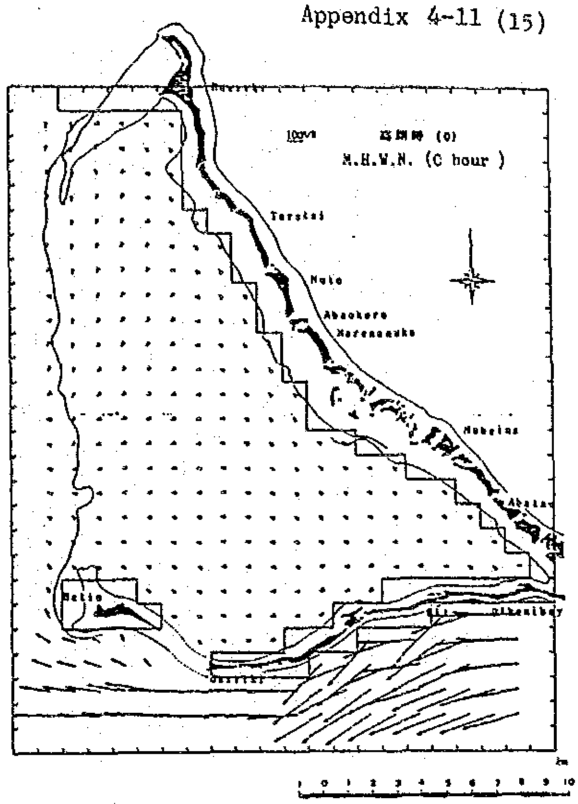
Taidal current in Spring tide (Opening)



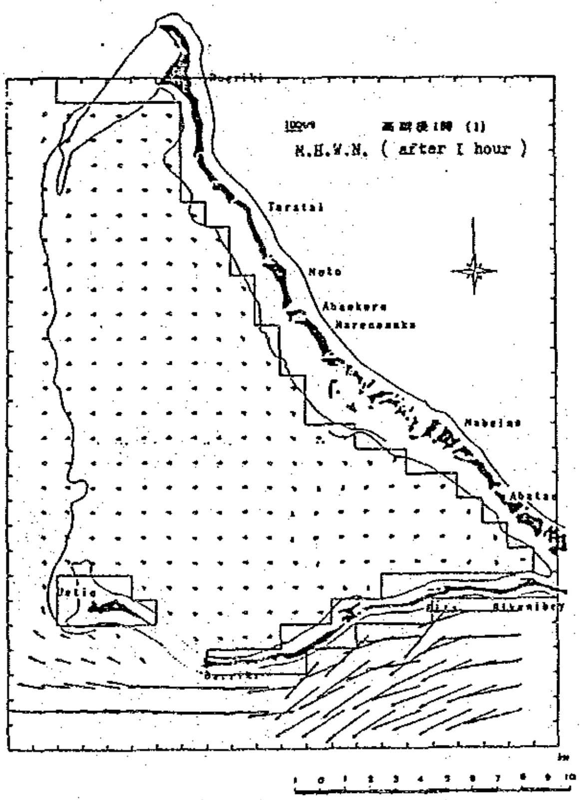
Tidal current in Spring tide (Opening)



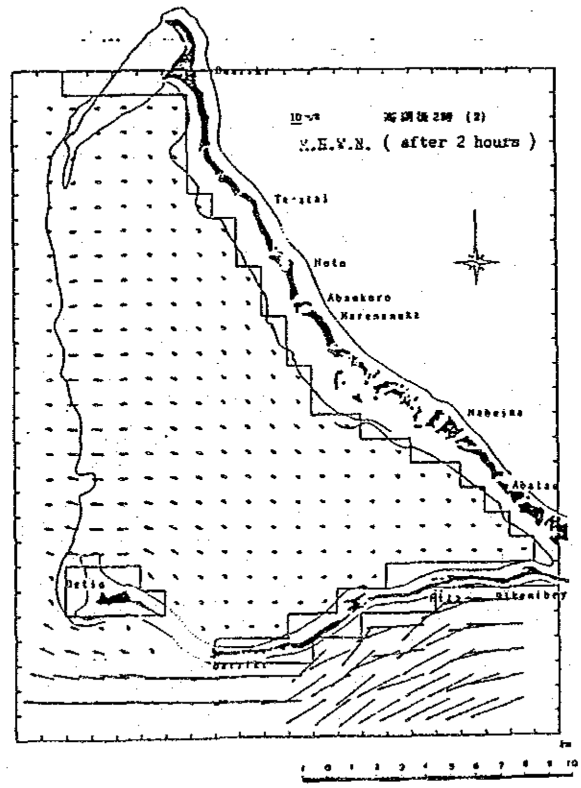
Tidal current in Neap tide (Opening)



Tidal current in Neap tide (Opening)



Tidal current in Neap tide (Opening)



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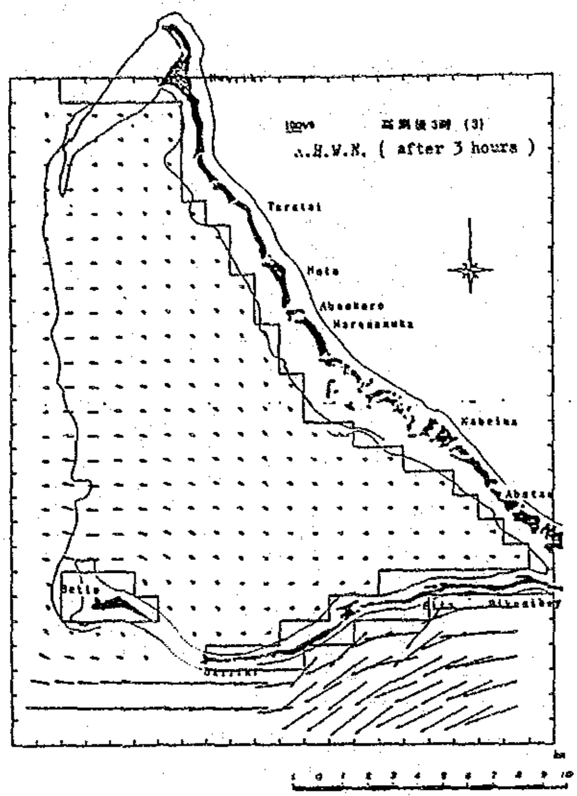
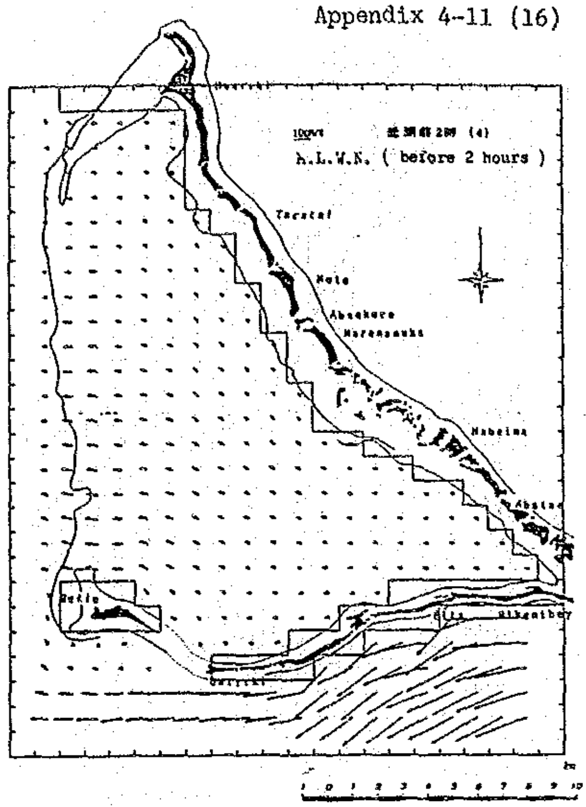
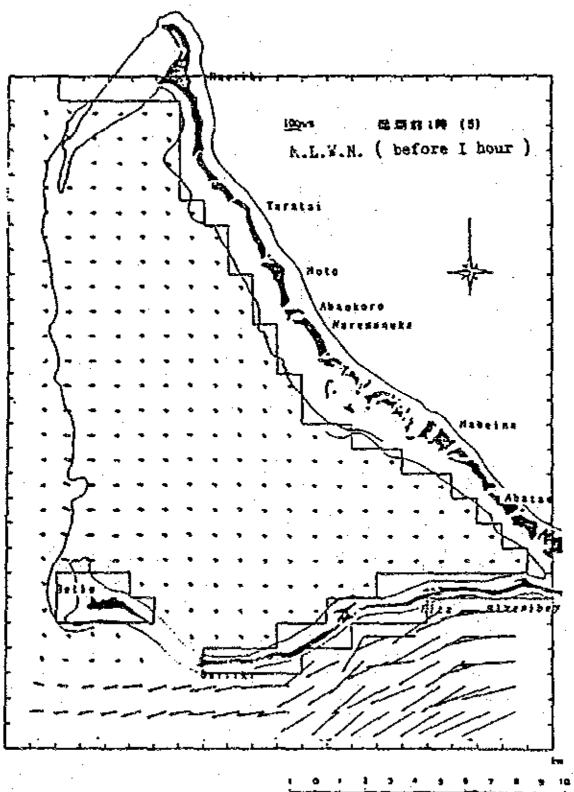


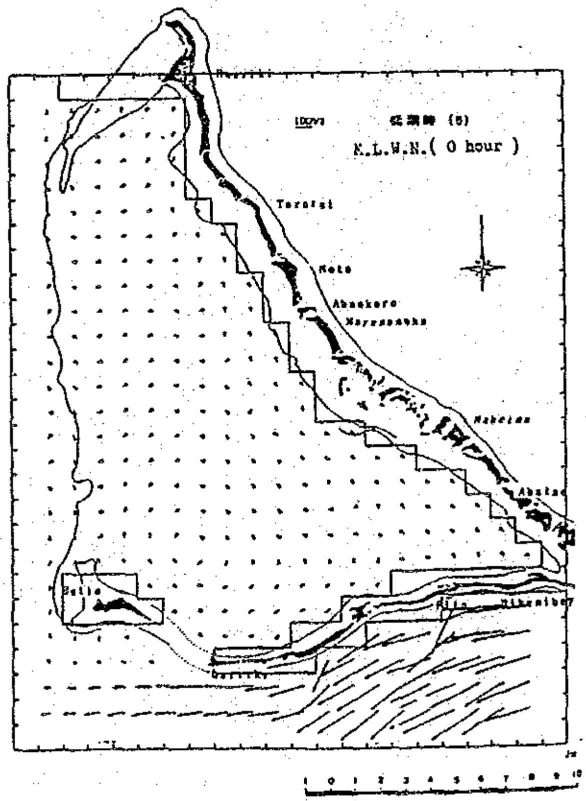
Tidal current in Neap tide (Opening)



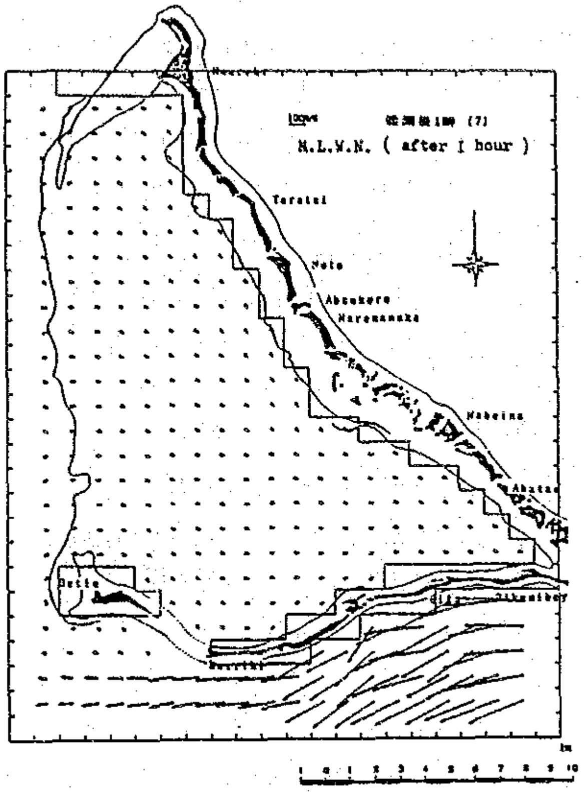
Tidal current in Neap tide (Opening)



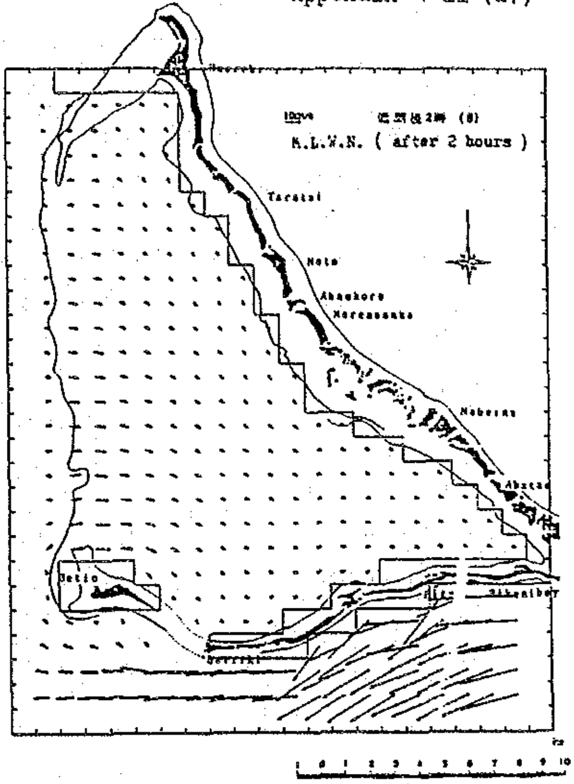
Tidal current in Neap tide (Opening)



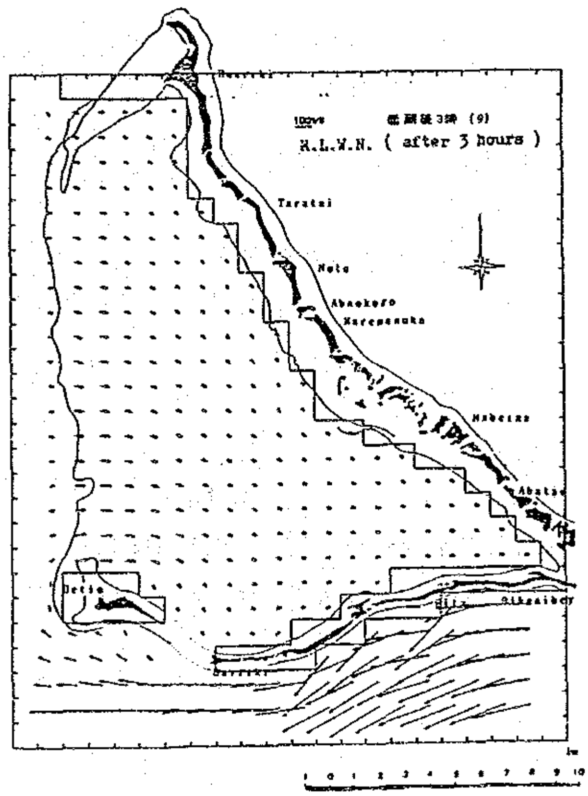
Tidal current in Neap tide (Opening)



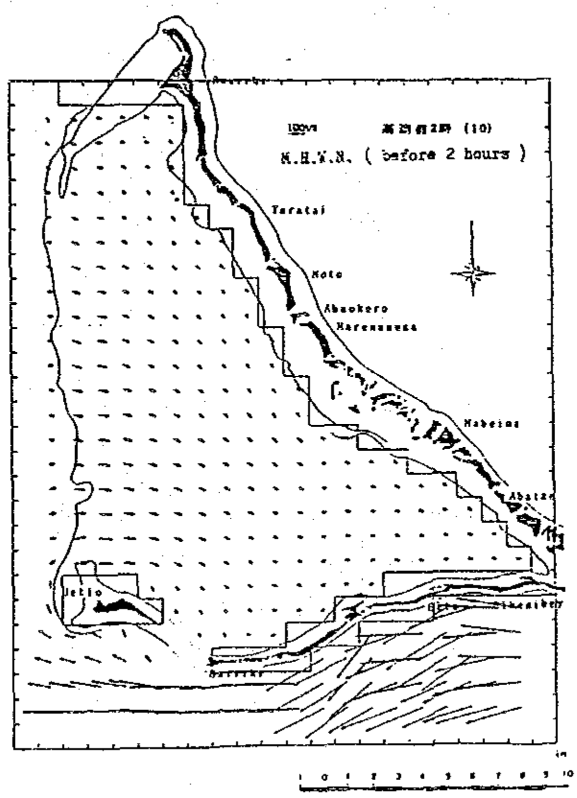
Tidal current in Neap tide (Opening)



Tidal current in Neap tide (Opening)



Tidal current in Neap tide (Opening)



Tidal current in Neap tide (Opening)

Transport Cost of Ferry and Lighter

1. Transport Cost of Ferry

1.1 Ferry Operating Cost

Ferry operating cost is estimated based on the present cost as of 1984. As for labor cost and maintenance cost is adjusted by shadow rate (0.87) as follows:

	Labor Cost	Maintenance Cost	Fuel
Cost as of 1984	107,443	42,716	75,750
Shadow-Rate	0.87	0.87	-
Adjusted Cost	93,475	37,163	75,750

1.2 Procurement Cost of New Ferry

At present, 3 nos of ferry boats are operated of which 2 nos will be replaced with new ones in 1987 and one in 1988 where they become at the end of durable period respectively. Transport capacity of new ferry boats shall meet future demand which will be estimated to be 140% of the present capacity. Purchase cost of new ferry is A$650,000 per one and then procurement cost will be A$585,000 excluding the residual value (10% of purchase cost). New ferry boats to be procured in 2002 and 2003 will be valued as 120% of the above procurement cost.

1987	2 nos	A$585,000 x 2 = A$1,170,000
1988	1 no	A$585,000
2003	2 nos	A$702,000 x 2 = A$1,404,000
2004	1 no	A$702,000

1.3 Construction Cost of New Terminal at Takoronga

The existing ferry terminal will be relocated to Takoronga from the Betio harbor according to the extension scheme of the Betio harboror. The construction cost of new ferry terminal at Takoronga is estimated to be A$605,000 according to the report published in 1983 from Ministry of Communication.

This new ferry terminal will not be required when the causeway is constructed. Accordingly the construction cost of new ferry terminal will be considered as transport cost saving which will be adjusted to be A$526,000 by shadow rate (0.87) for actual use of evaluation.

1.4 Maintenance Cost of New Ferry Terminal

Maintenance cost of new ferry terminal is estimated to be 0.2% of the construction cost.

2. Cost of Lighter

Lighterage consists of transportation cost on the sea and loading and unloading cost, of which only loading and unloading cost is used in this study. According to The Report on Development Program on Fisheries Jetty at Betio in The Republic of Kiribati prepared by JICA in 1981, loading and unloading cost is A$2.60/ton. Considering infration rate 5% per year, it is estimated to be A$3.3 ton as of 1985 price.

Time Value

1. Shadow Wage Rate

Shadow wage rate of domestic labor is estimated to be equal to standard conversion rate from domestic market price to border price on the assumption that domestic market price represents opportunity cost.

$$SCF = \frac{I + E}{(I + TI) + (E - TE)}$$

SCF : Standard Conversion Rate
I : Total Import Price
E : Total Export Price
TI : Total Import Duty Price
TE : Total Export Duty Price

According to trade statistics in 198. SCF is estimated to be 0.87.

2. Time Value

Time value is estimated by multiplying standard wage rate of domestic labor by shadow wage rate.

About 40% of employees in the South Tarawa consists of government officers. Ranking of government officer's wage is from 1 to 19 of which 11 to 16 occupies majority. Therefore averaged value of wages from 11 to 16 is adopted as representative wage in the South Tarawa.

GDP and the population of the Republic of Kiribati in 1985 is estimated to be A$37,000,000 and 70,000. Accordingly GDP per capita is estimated to be A$530 and GDP per household is also estimated be A$3,800 based on the average number of member per one household (7.2). Therefore the above average value of A$3,050 is not high as compared to the above value of A$3,800.

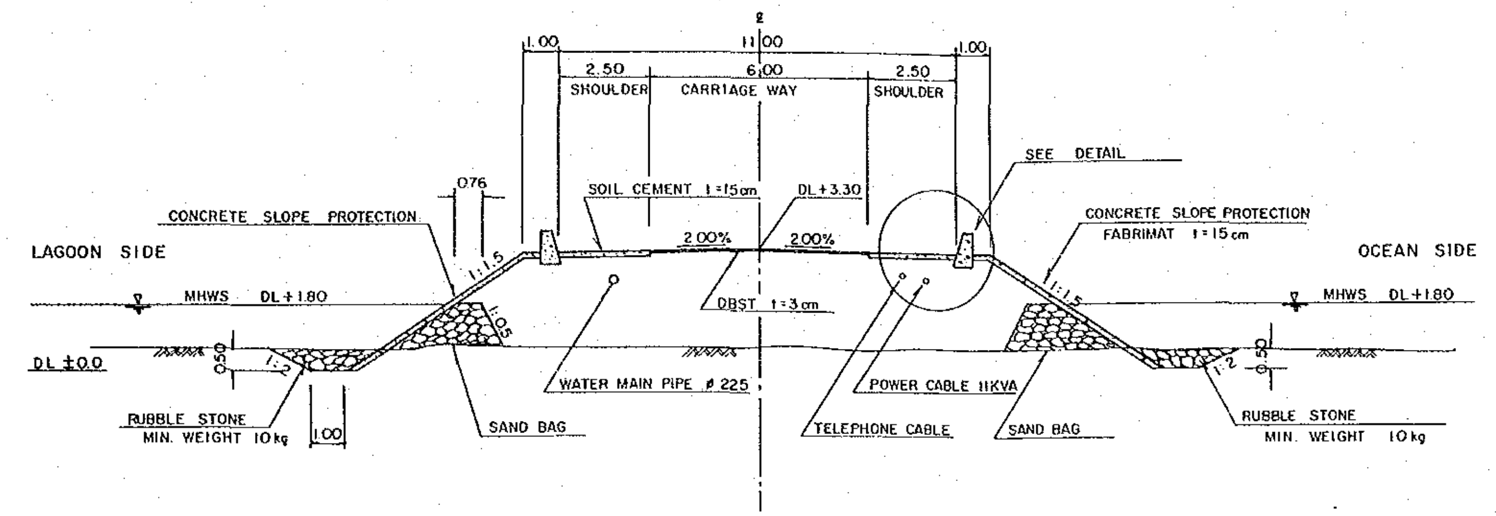
The wage per hour is calculated as shown below:

A$3,050/12 x 23 x 8 = A$1.38/hour

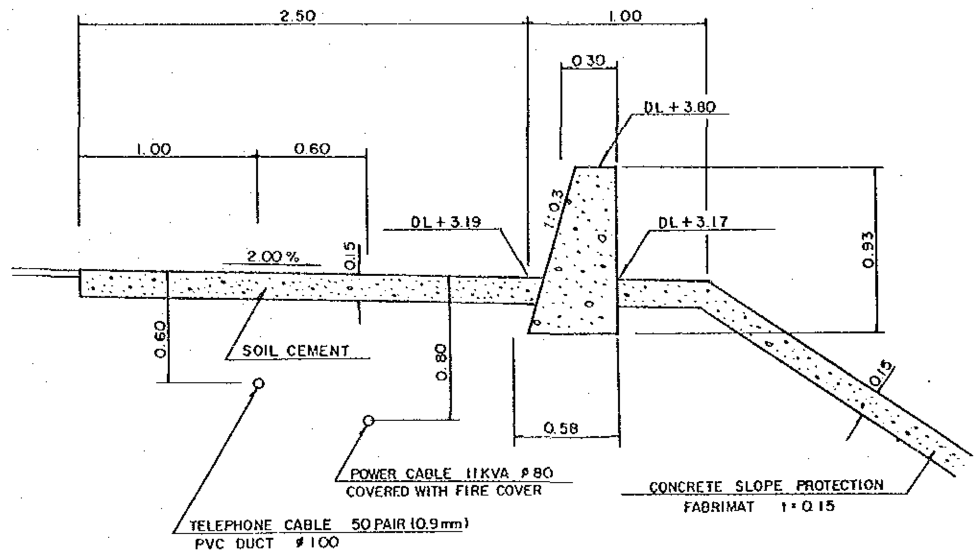
Therefore the time value is estimated by multiplying the above hourly wage by shadow wage rate of 0.87.

Time Value = A$1.38 x 0.87 = A$1.20/hour

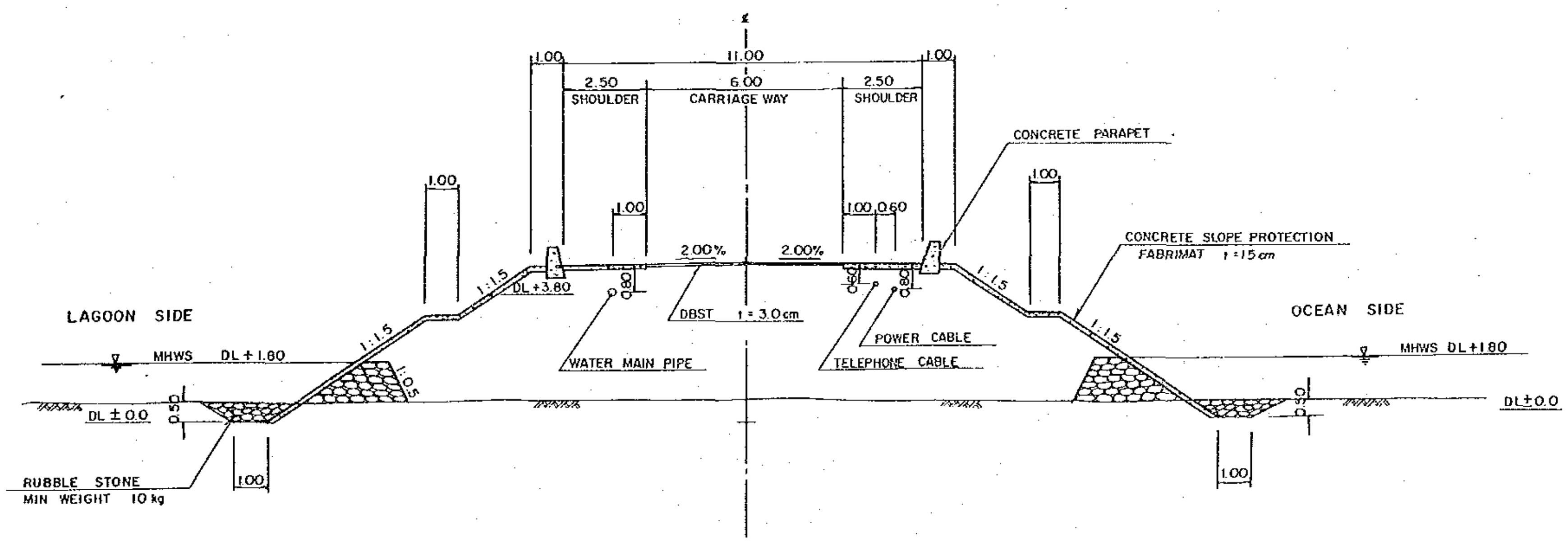
DRAWINGS



TYPICAL CROSS SECTION (I)
STA. 20+00
S=1/200



DETAIL
S=1/100

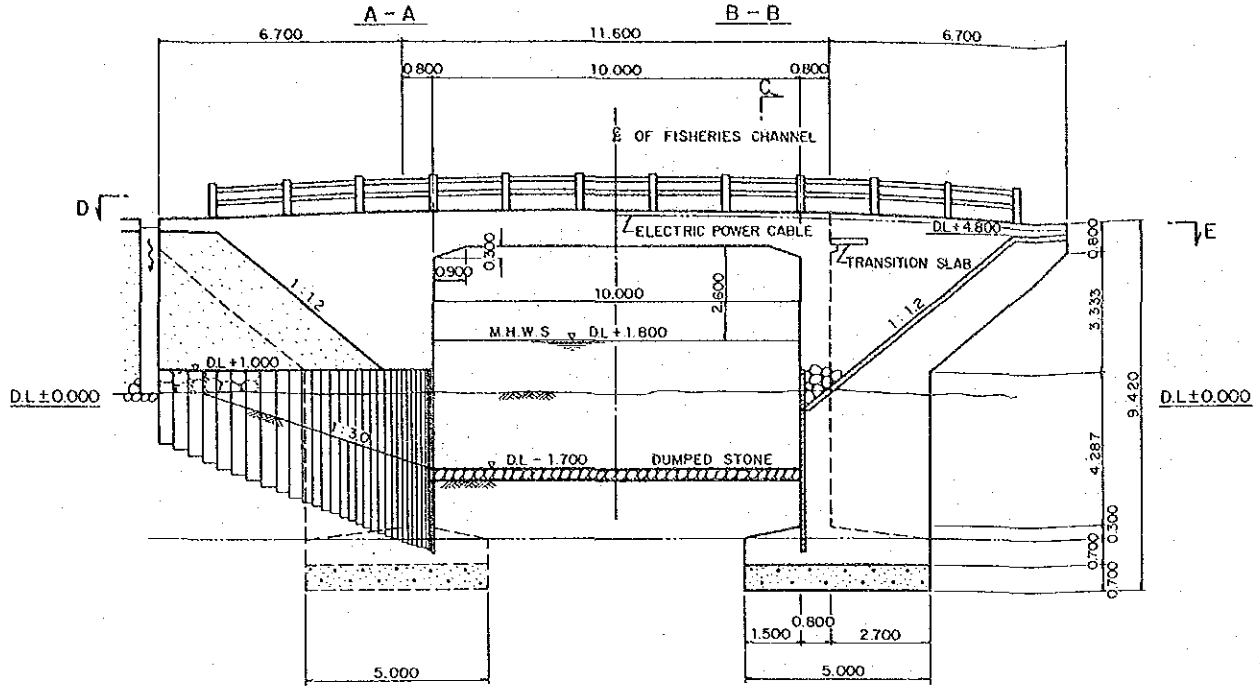


TYPICAL CROSS SECTION (II)
STA. 15+00
S=1/200

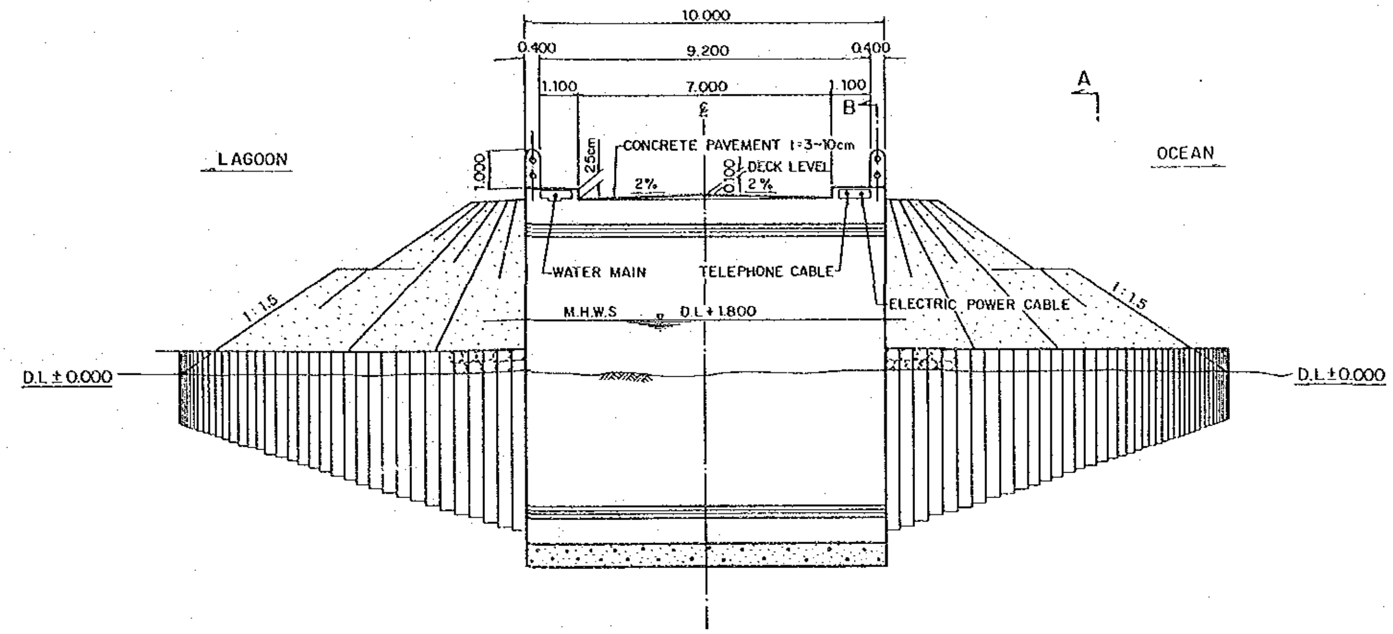
THE GOVERNMENT OF KIRIBATI
BETIO BAIRIKI CAUSEWAY AND FISHERIES CHANNEL PROJECT (BASIC DESIGN)
TYPICAL CROSS SECTION

SCALE : 1/100~1/200	DATE :
DRAWING NO. 2/5	

A - A　　B - B



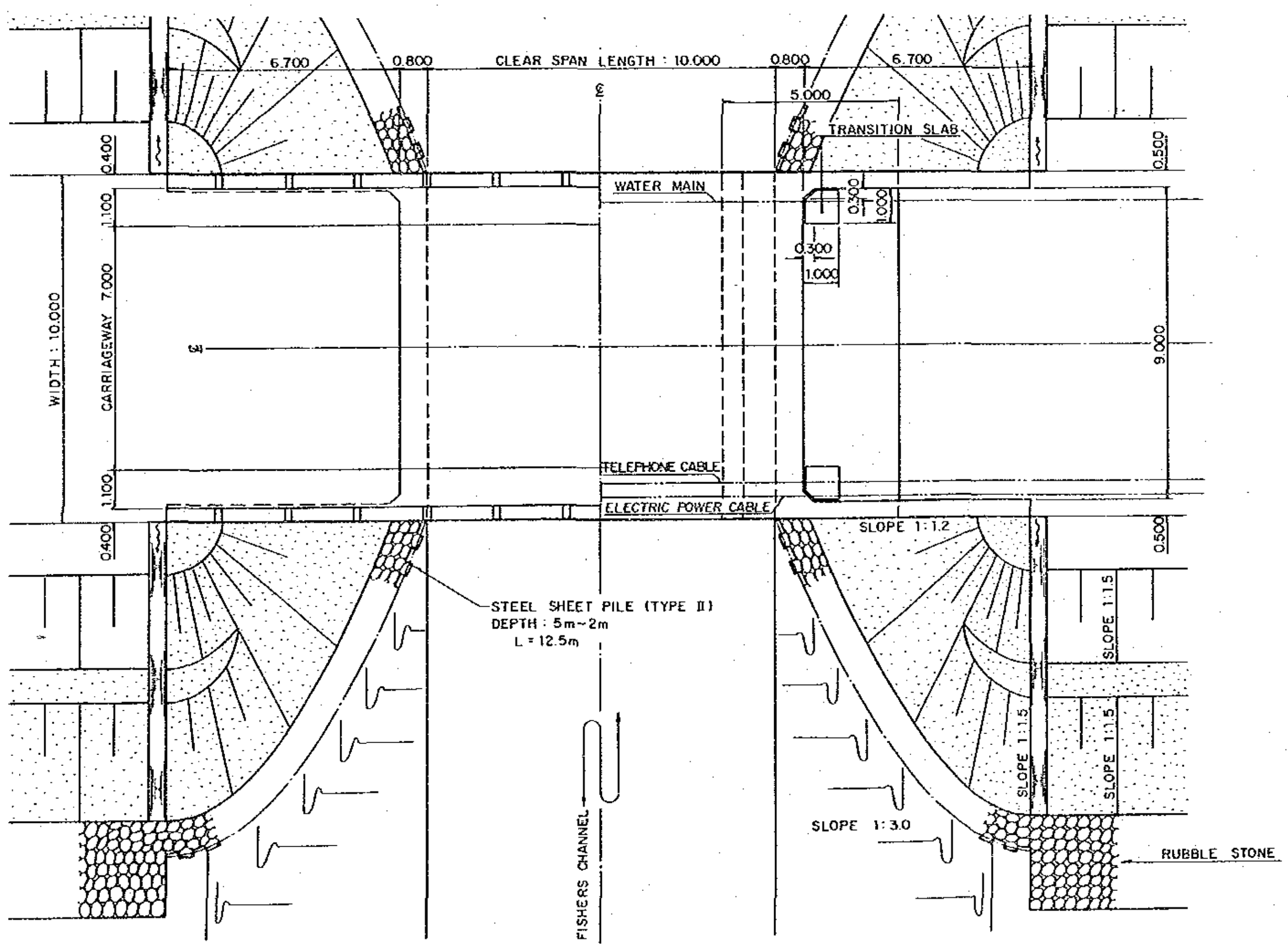
C - C



▽ D.L - 9.000

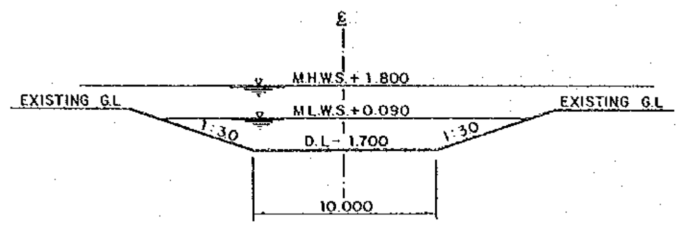
	(A1)	℄	(A2)
STATIONING	STA.15+40.000	STA.15+45.000	STA.15+50.000
DECK LEVEL ON BRIDGE ℄	D.L + 5.270	D.L + 5.280	D.L + 5.270
BOTTOM FACE OF FOUNDATION	D.L - 5.000	———	D.L - 5.000

D - D　　E - E

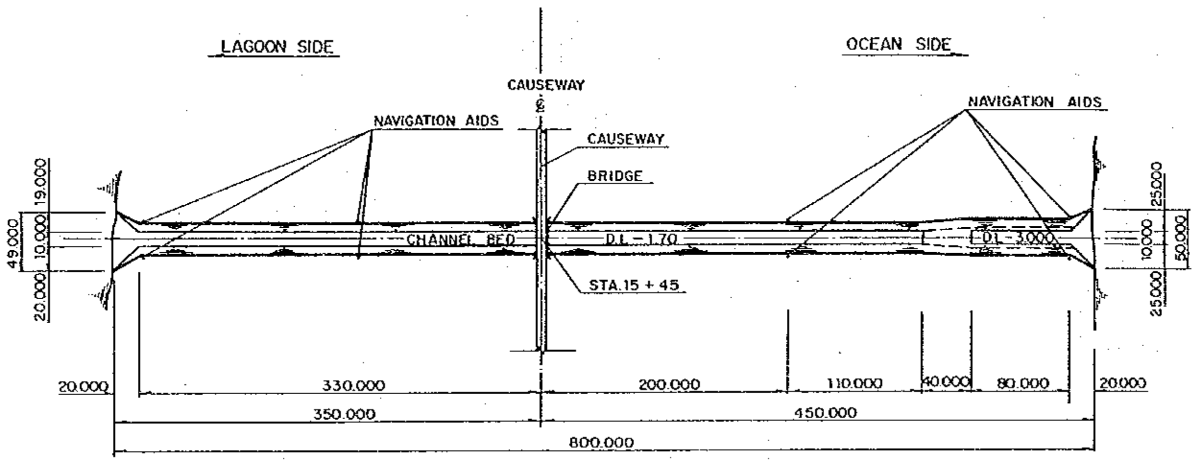


THE GOVERNMENT OF KIRIBATI
BETIO BAIRIKI CAUSEWAY AND FISHERIES CHANNEL PROJECT (BASIC DESIGN)
PLAN AND ELEVATION OF BRIDGE
SCALE : 1/200 — DATE :
DRAWING NO. 3 / 5

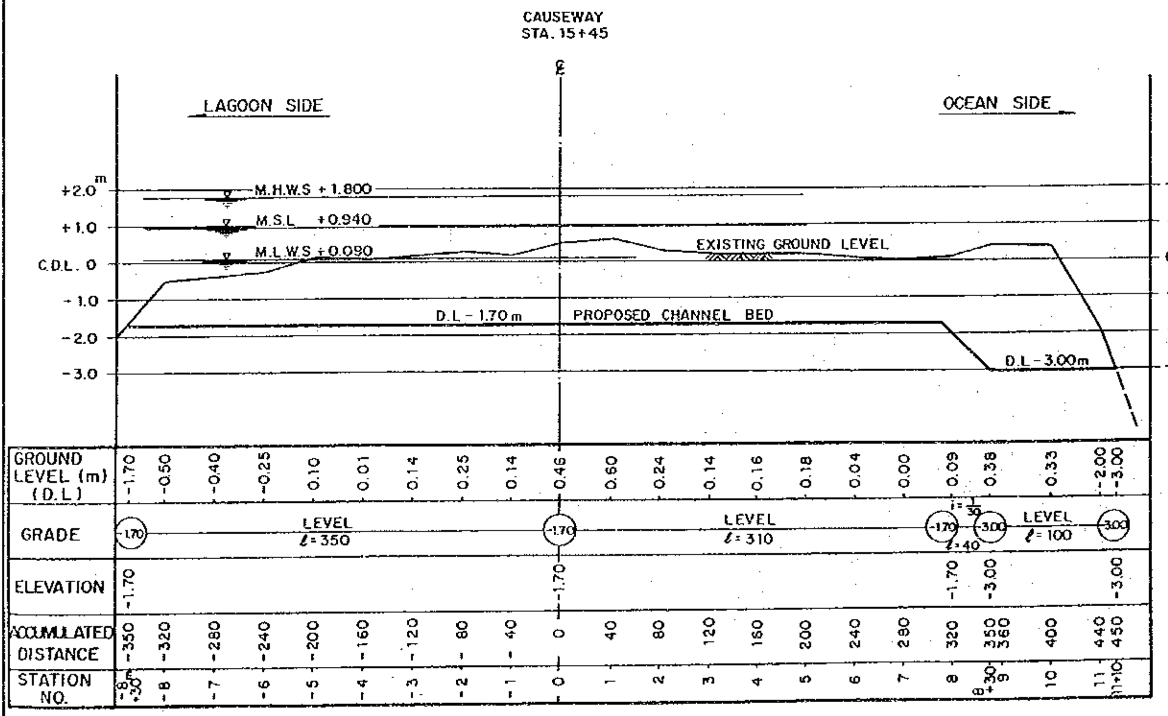
TYPICAL CROSS SECTION OF FISHERIES CHANNEL SCALE 1:400



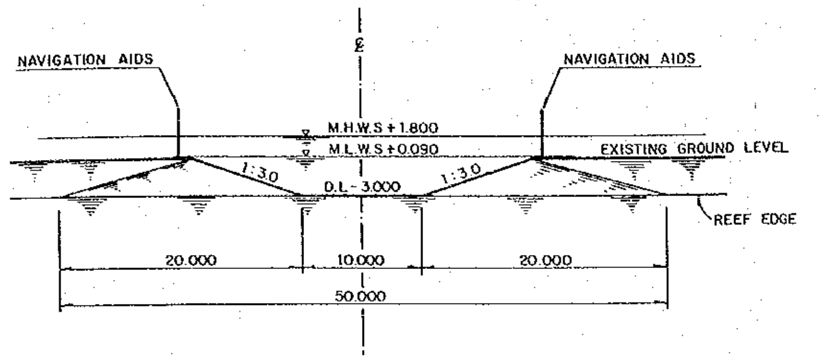
LAYOUT OF FISHERIES CHANNEL SCALE 1:600



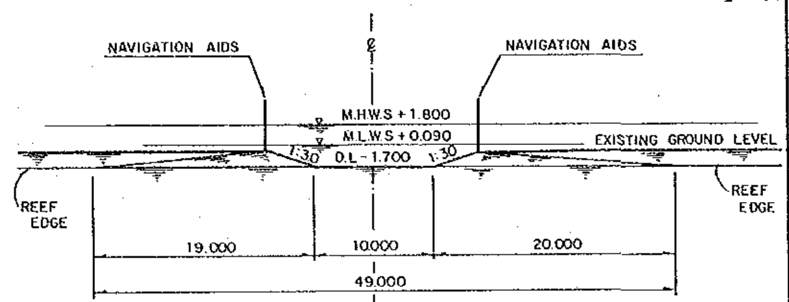
LONGITUDINAL SECTION OF FISHERIES CHANNEL SCALE H=1:6000 U=1:200



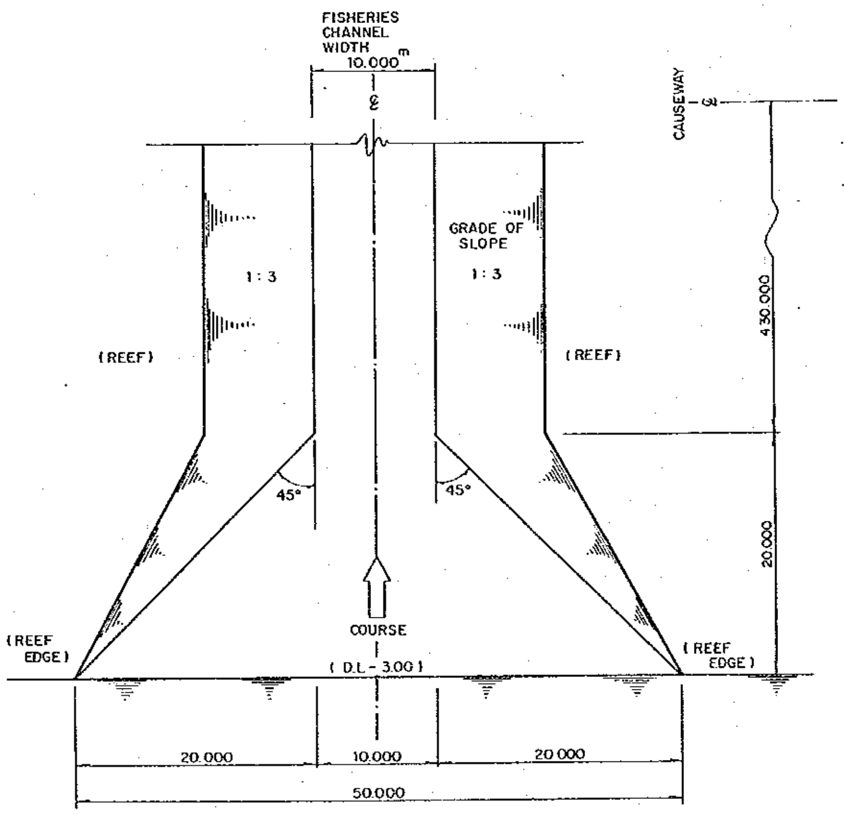
FRONT VIEW OF APPROACH CHANNEL AT OCEAN SIDE SCALE 1:600



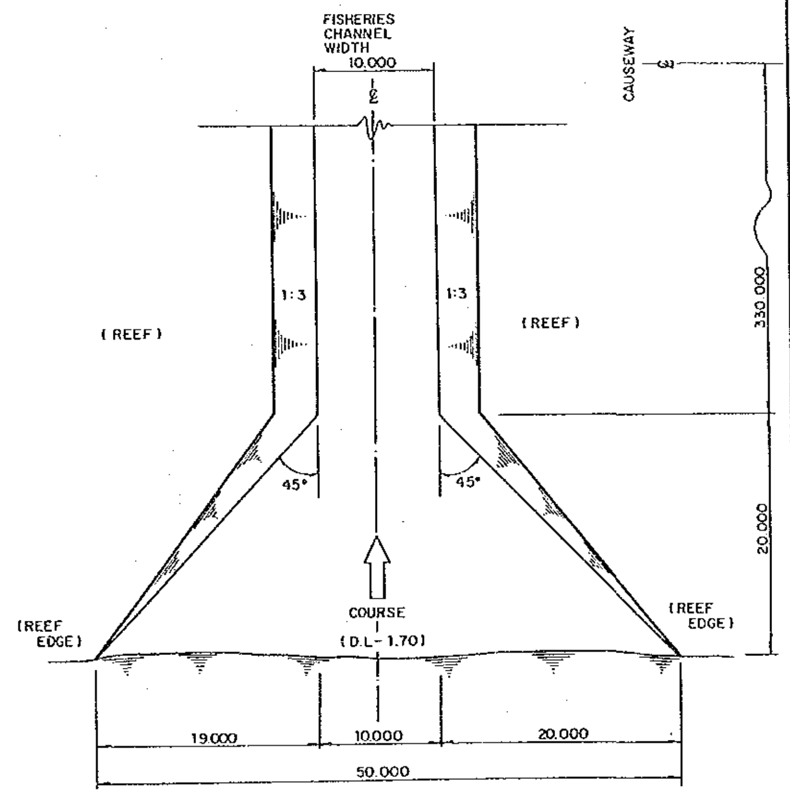
FRONT VIEW OF APPROACH CHANNEL AT LAGOON SIDE SCALE 1:600



PLAN OF APPROACH CHANNEL AT OCEAN SIDE SCALE 1:600



PLAN OF APPROACH CHANNEL AT LAGOON SIDE SCALE 1:600

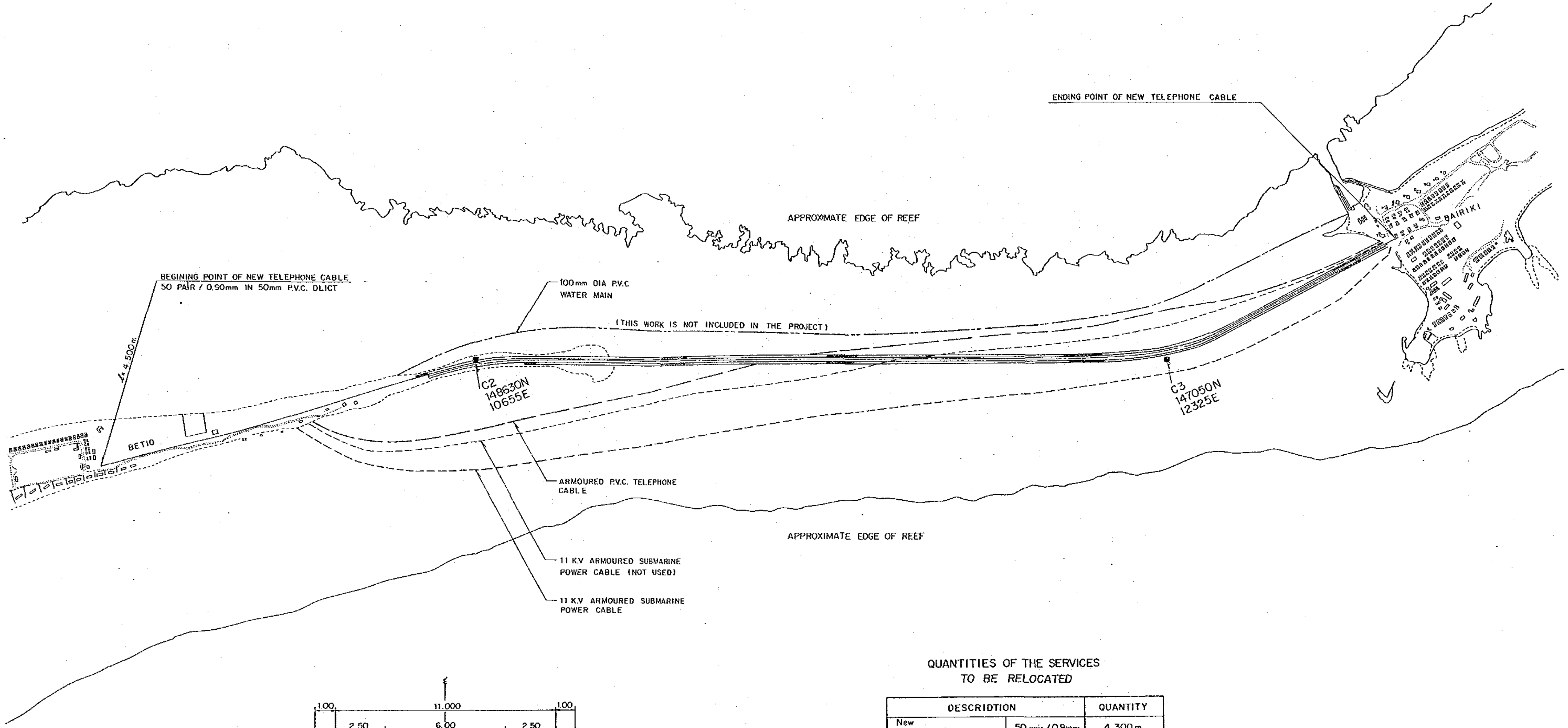


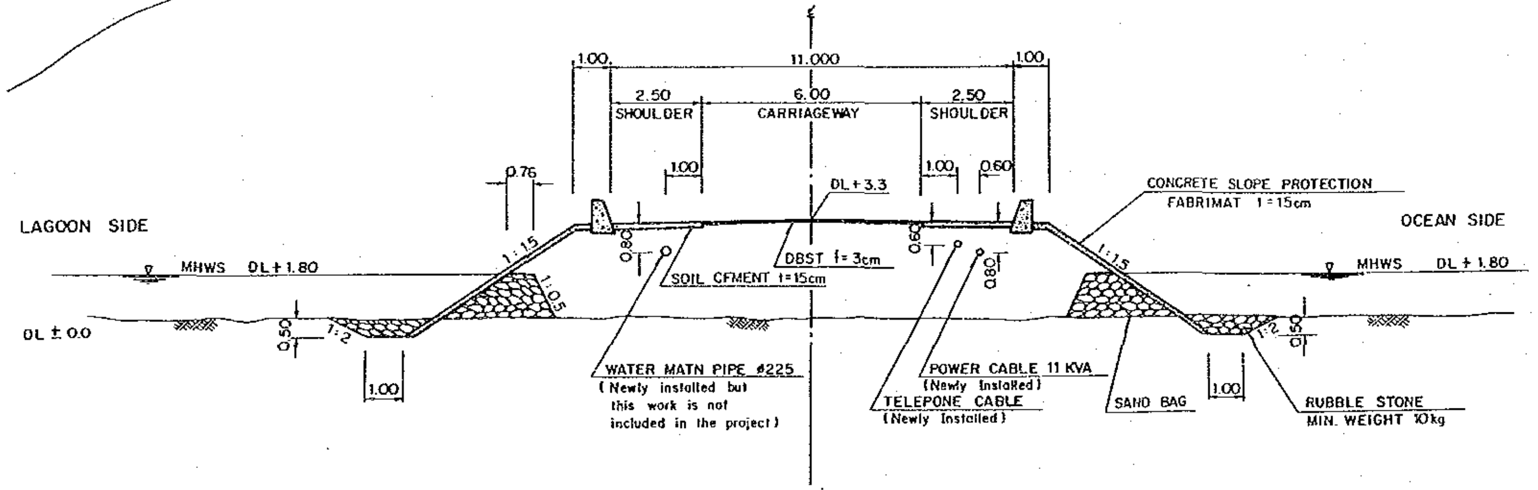
THE GOVERNMENT OF KIRIBATI

BETIO BAIRIKI CAUSEWAY AND FISHERIES CHANNEL PROJECT (BASIC DESIGN)

FISHERIES CHANNEL

SCALE : 1/6000 ~ 1/200	DATE : July, 1985
DRAWING NO. 4/5	





TIPICAL CROSS SECTION
S=1/200

QUANTITIES OF THE SERVICES
TO BE RELOCATED

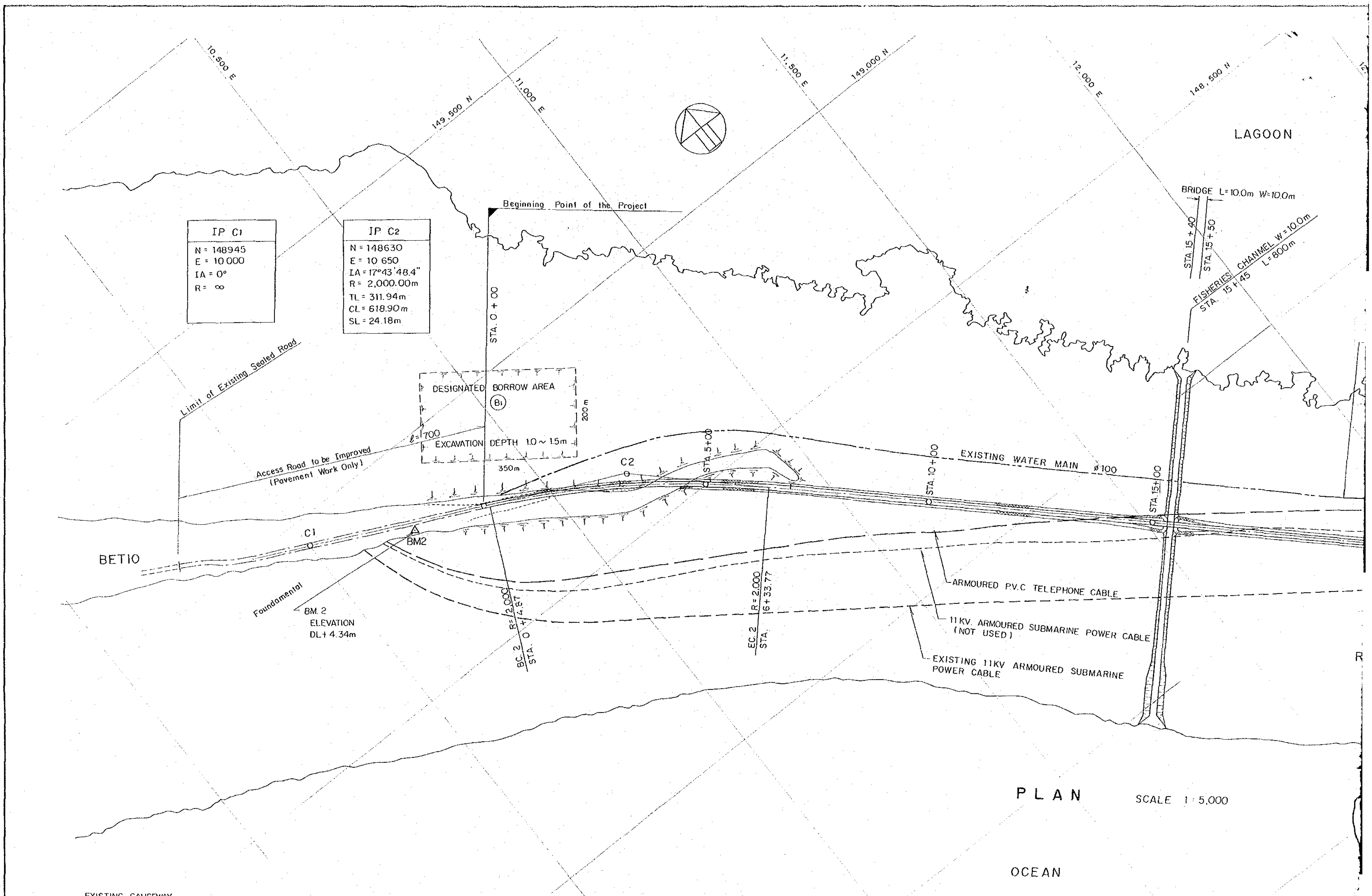
DESCRIDTION		QUANTITY
New TELEPHONE CABLE (Supply and placing)	50 pair / 0.9mm	4,300m
New POWER CABLE (Installation only)	11 KVA	3,400 m

THE GOVERNMENT OF KIRIBATI

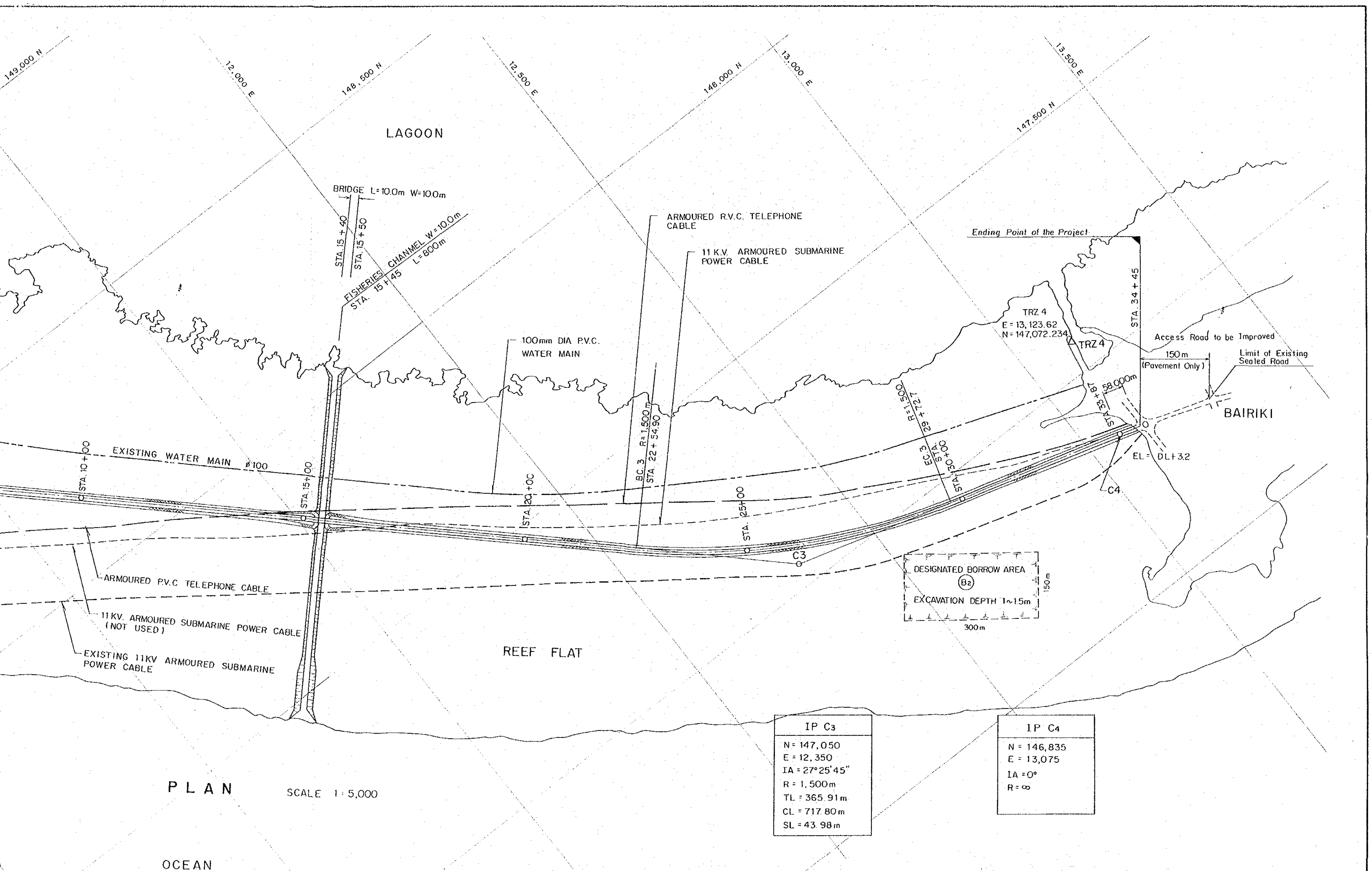
BETIO BAIRIKI CAUSEWAY AND
FISHRIES CHANNEL PROJECT
(BASIC DESIGN)

RELOCATION PLAN OF EXISTING SERVICES

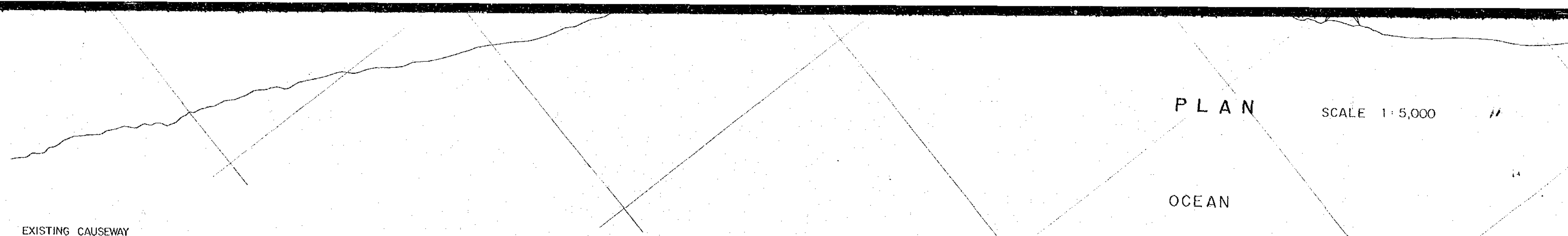
SCALE : 1/200 , 1/10,000	DATE :
DRAWING NO. 5/5	

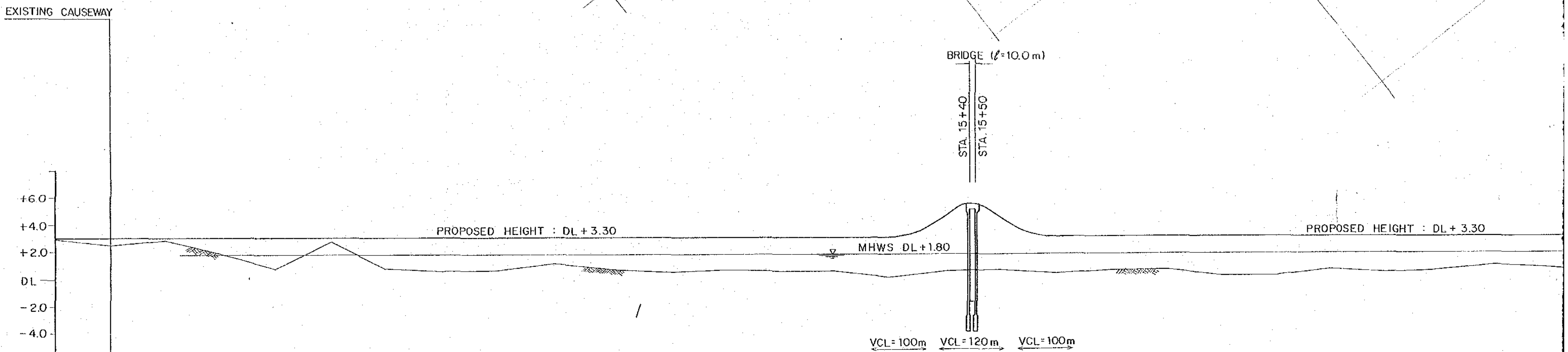


10,500 E
149,500 N
11,000 E
11,500 E
149,000 N
12,000 E
148,500 N
LAGOON
BRIDGE L=10.0m W=10.0m
STA 15+40
STA 15+50
FISHERIES CHANNEL W=10.0m L=800m
STA. 15+45
Beginning Point of the Project
IP C1
N = 148945
E = 10000
IA = 0°
R = ∞
IP C2
N = 148630
E = 10 650
IA = 17°43'48.4"
R = 2,000.00m
TL = 311.94m
CL = 618.90m
SL = 24.18m
STA. 0 + 00
Limit of Existing Sealed Road
DESIGNATED BORROW AREA
B1
200m
ℓ=1700
EXCAVATION DEPTH 1.0 ~ 1.5m
350m
Access Road to be Improved
(Pavement Work Only)
C2
STA.5+00
STA.10+00
EXISTING WATER MAIN ø100
STA 15+00
C1
BM2
BETIO
Foundamental
BM. 2
ELEVATION
DL+4.34m
R=2,000
BC.2 STA. 0+4.87
EC.2 R=2,000
STA. 6+33.77
ARMOURED P.V.C TELEPHONE CABLE
11KV. ARMOURED SUBMARINE POWER CABLE
(NOT USED)
EXISTING 11KV ARMOURED SUBMARINE
POWER CABLE
PLAN
SCALE 1:5,000
OCEAN
EXISTING CAUSEWAY



PLAN SCALE 1:5,000





PROFILE H = 1/100 V = 1/1,000

GRADIENT	(3.30) LEVEL									
PROPOSED HEIGHT	3.30	3.30	3.30	3.30	3.30	3.30	3.30		3.30	3.30
GROUND LEVEL	2.52	2.82	1.86	0.78	2.71	0.70	0.68		0.62	1.15
EMBANKMENT HEIGHT	0.78	0.48	1.44	2.52	0.59	2.60	2.72		2.68	2.15
CUMULATED DISTANCE	0 / 14.87	100	200	300	400	500	600	633.77	700	800
DISTANCE	0 / 14.87	100	100	100	100	100	100	33.77	100	100
STATION NO.	0+00 / 14.87	1+00	2+00	3+00	4+00	5+00	6+00	33.77	7+00	8+00

GRADIENT	LEVEL					(3.30) i=2.0% ℓ=130m		(5.90) i=2.0% ℓ=130m		(3.30)
PROPOSED HEIGHT	3.30	3.30	3.30	3.30	3.30	3.42 / 3.55	4.74	5.30	4.70	3.363
GROUND LEVEL	0.65	0.46	0.61	0.51	0.48	0.04	0.46		0.58	0.37
EMBANKMENT HEIGHT	2.65	2.84	2.69	2.79	2.82	3.26	4.27		3.89	2.93
CUMULATED DISTANCE	900	1,000	1 100	1 200	1 300	1 400	1500		1600	1700
DISTANCE	100	100	100	100	100	100	100		100	100
STATION NO.	9+00	10+00	11+00	12+00	13+00	14+00 / 14+15	15+00	15+45	16+00	16+75 / 17+00

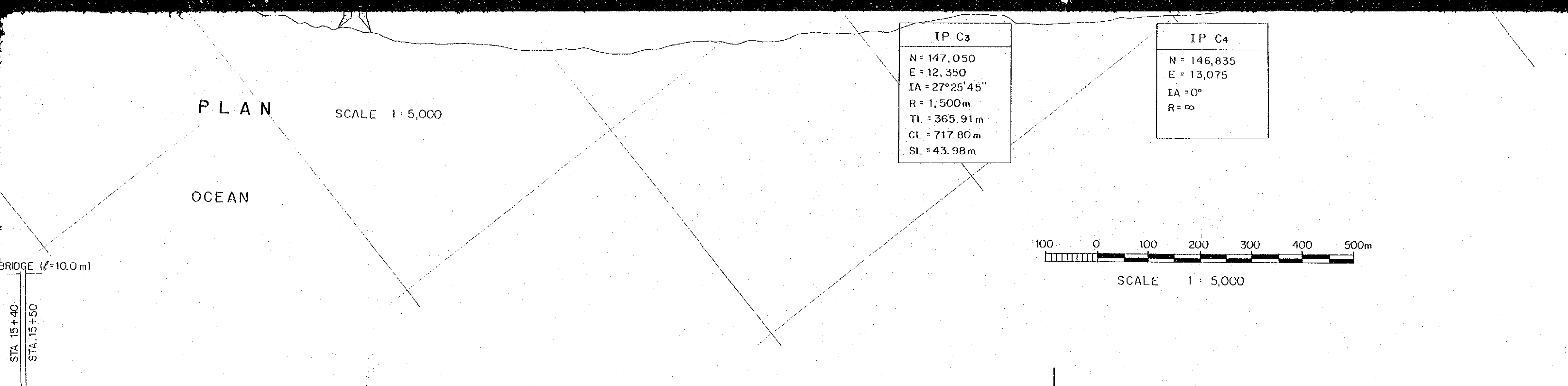
GRADIENT	LEVEL									
PROPOSED HEIGHT	3.30	3.30	3.30	3.30	3.30		3.30	3.30	3.30	3.30
GROUND LEVEL	0.60	0.64	0.18	0.10	0.61		0.39	0.58	0.87	0.73
EMBANKMENT HEIGHT	2.70	2.66	3.12	3.20	2.69		2.91	2.72	2.43	2.57
CUMULATED DISTANCE	1 800	1900	2000	2 100	2 200	2254.9	2 300	2 400	2 500	2600
DISTANCE	100	100	100	100	100	54.9	100	100	100	100
STATION NO.	18+00	19+00	20+00	21+00	22+00	54.9	23+00	24+00	25+00	26+00

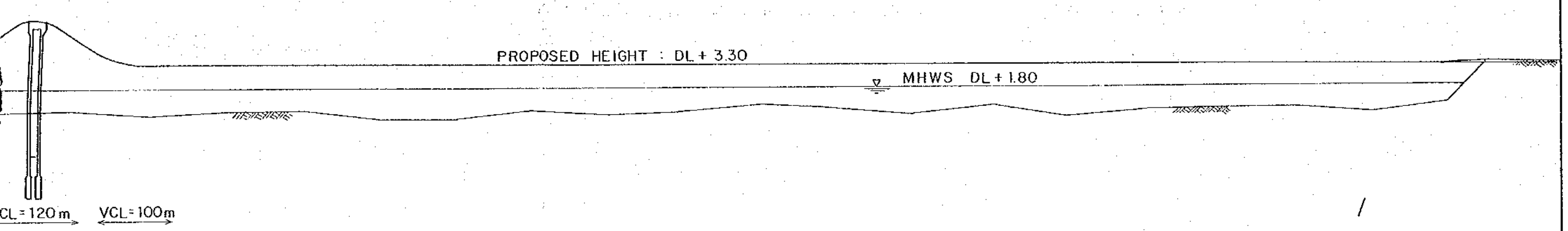
SUPER ELEVATION: 2%

CURVE BAND: IP.C2 IA 17°43'48.4" R=2,000 TL=311.94 CL=618.90 SL=24.18; IA=27°25'45" R=1,500 TL=365.91 IPC.3

PLAN

SCALE 1 : 5,000





PROFILE

H = 1 / 100
V = 1 / 1,000

i=2.0% ℓ=130m — 5.90 — 3.30 — LEVEL — i=0.2% — LEVEL

Height	Depth	Ground level	Chainage	Distance	Station
5.30					15+45
4.70	0.58	3.89	1600	100	16+00
					16+75
3.363	0.37	2.93	1700	100	17+00
3.30	0.60	2.70	1800	100	18+00
3.30	0.64	2.66	1900	100	19+00
3.30	0.18	3.12	2000	100	20+00
3.30	0.10	3.20	2100	100	21+00
3.30	0.61	2.69	2200	100	22+00
			22549	549	549
3.30	0.39	2.91	2300	100	23+00
3.30	0.58	2.72	2400	100	24+00
3.30	0.87	2.43	2500	100	25+00
3.30	0.73	2.57	2600	100	26+00
3.30	0.37	2.93	2700	100	27+00
3.30	0.84	2.46	2800	100	28+00
3.30	0.26	3.14	2900	100	29+00
			29729	729	729
3.30	0.58	2.72	3000	100	30+00
3.30	0.69	2.61	3100	100	31+00
3.30	0.65	2.65	3200	100	32+00
3.30	0.49	2.81	3300	100	33+00
3.30	0.98	2.32	3400	100	34+00
3.20	3.20	-0.10	3445	45	34+45
					35+00

IA = 27°25'45" R = 1,500 TL = 365.91 CL = 717.80 SL = 43.98
I.P.C.3

GENERAL NOTES

1. ALL DIMENSIONS IN METRES
2. GRID "TARAWA LOCAL GRID"
3. DATUM LEVELS (DL) REFER TO ADMIRALTY CHART DATUM.
4. LOCATION OF EXISTING SERVICES AS SHOWN

THE GOVERNMENT OF KIRIBATI	
BETIO BAIRIKI CAUSEWAY AND FISHERIES CHANNEL PROJECT (BASIC DESIGN)	
PLAN AND PROFILE	
SCALE 1 / 5,000	DATE :
DRAWING NO. 1 / 5	

JICA