BASIC DESIGN STUDY REPORT
ON
BETIO-BAIRIKI CAUSEWAY-FISHERIES CHANNEL PROJECT
IN
THE REPUBLIC OF KIRIBATI

August 1985

Japan International Cooperation Agency

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PREFACE

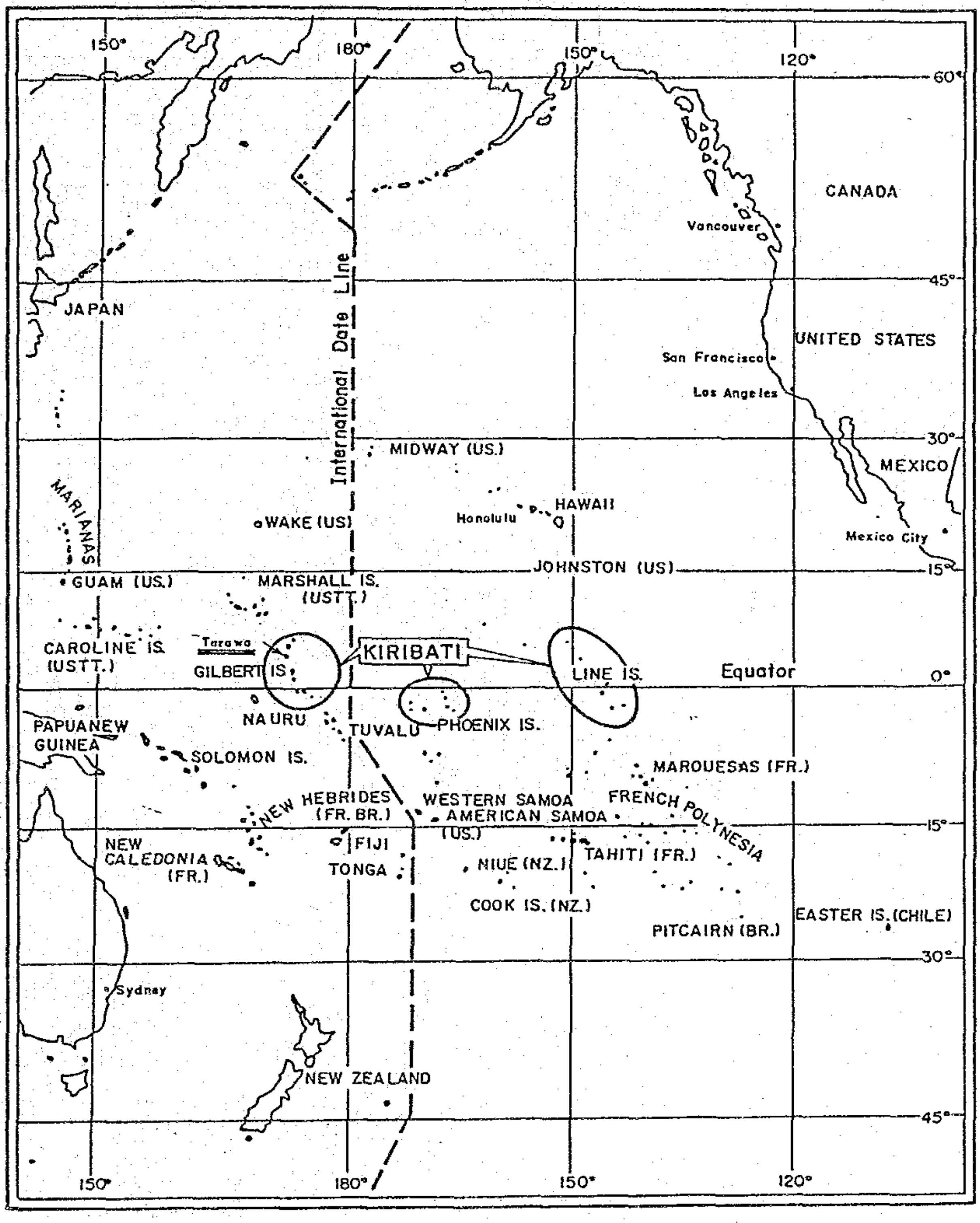
In response to the request of the Government of the Republic of Kiribati, the Government of Japan decided to conduct a Basic Design Study on the Betio-Bairiki Causeway & Fisheries Channel Project and entrusted the study to the Japan International Cooperation Agency (JICA). JICA sent to Kiribati a study team headed by Mr. Takeshi KAWAGUCHI, Deputy Director, Fishing Port Construction Division, Fisheries Agency, from April 5th to May 4th, 1985. The team had discussions on the Project with the officials concerned of the Government of Kiribati and conducted a field survey. After the team returned to Japan, further studies were made and the present report has been prepared.

I hope that this Report will serve for the development of the Project and contribute to the promotion of friendly relations between our two countries.

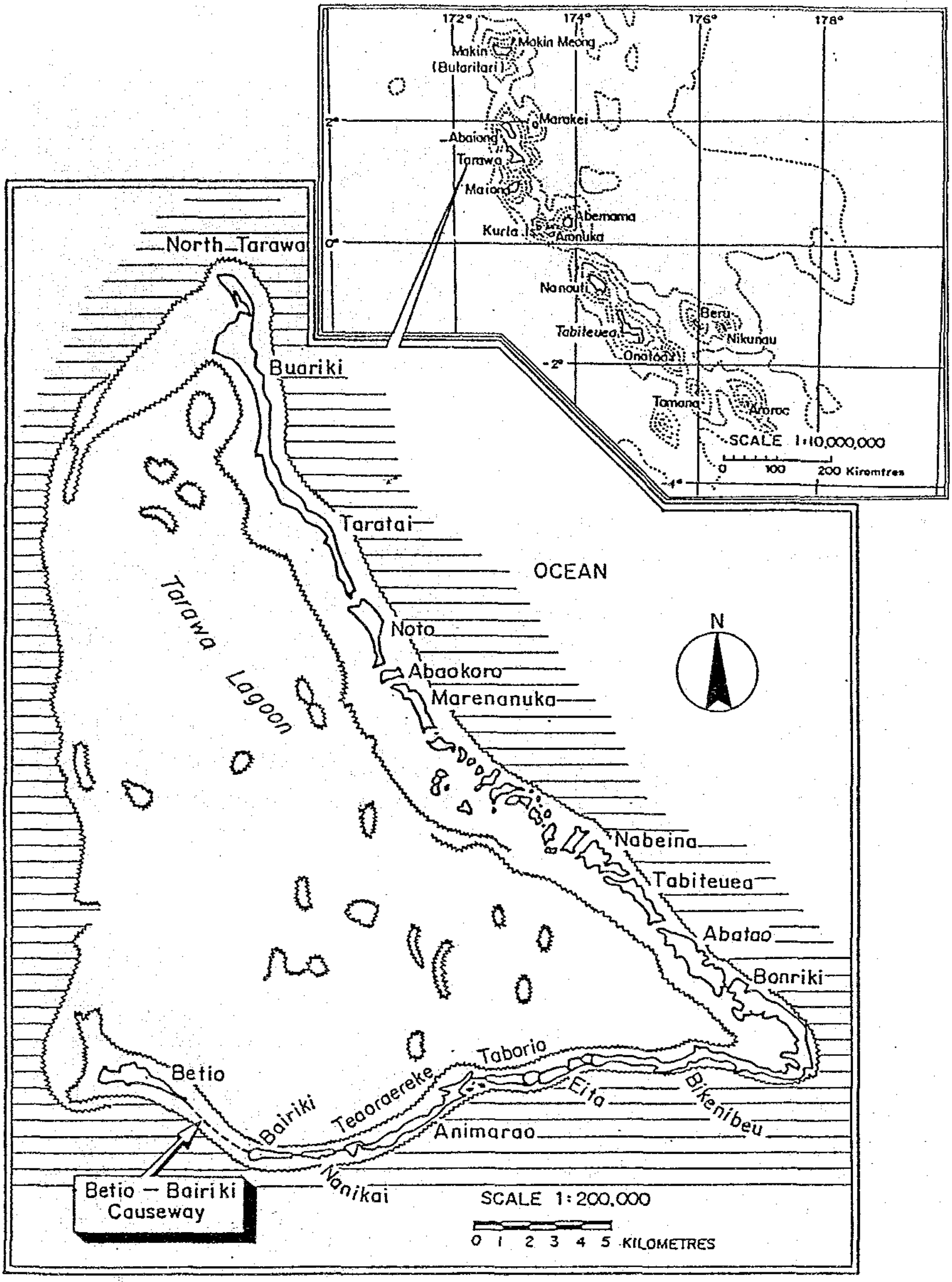
I wish to express my deep appreciation to the officials concerned of the Government of the Republic of Kiribati for their close cooperation extended to the team.

August 1985

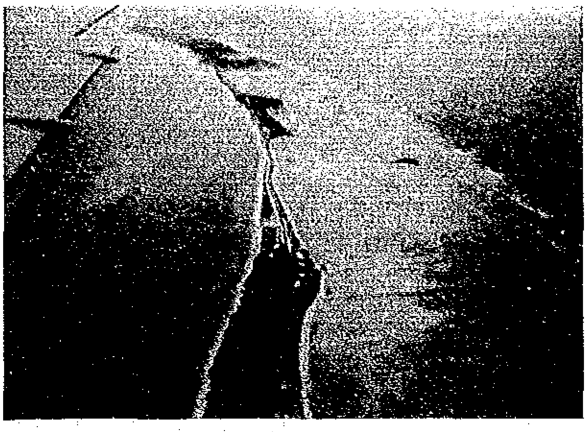
Keisuke ARITA
President
Japan International Cooperation Agency



MAP OF THE REPUBLIC OF KIRIBATI AND TARAWA ATOLL



LOCATION MAP OF THE PROJECT



Existing Nanikai Causeway

Proposed Construction Site of
Betio-Bairiki Causeway
(From Betio Side)

Existing Taborio Causeway
(Ocean Side)

Proposed Construction Site at
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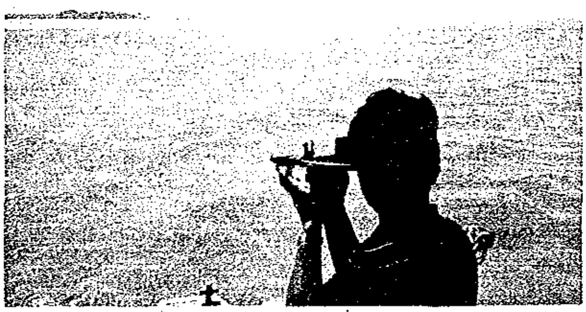
telephone cable)

Existing Taborio Causeway
(Lagoon Side)



High Tide Currents at Reef
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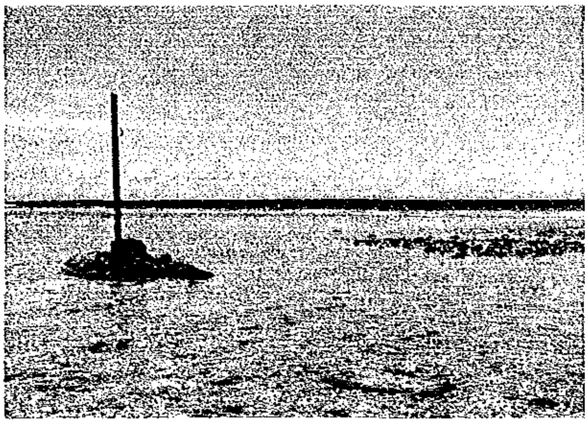
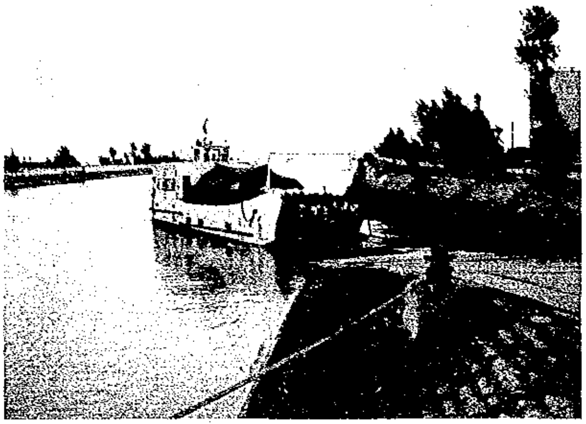
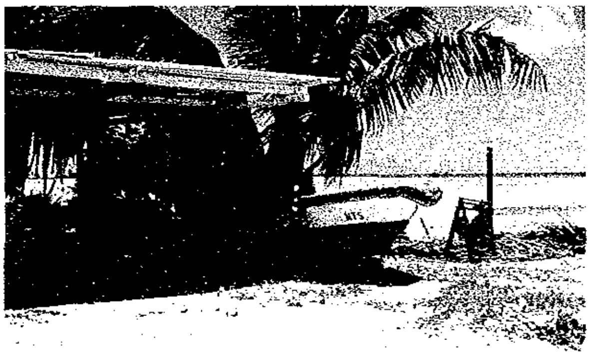


Proposed Site of Fisheries Channel at the Outer End of the Coral Reef (Ocean Side)

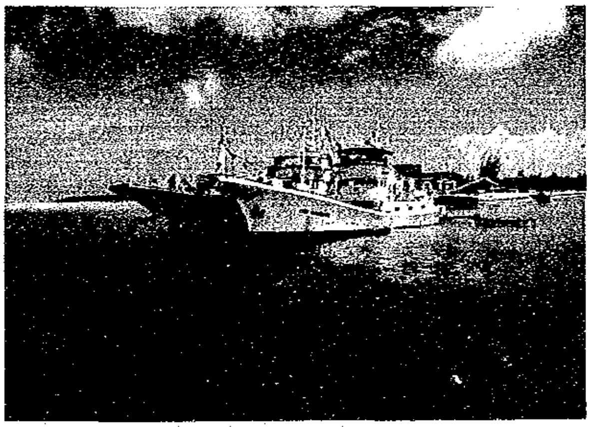


Ferry Boat Carrying Passengers Between Betio and Bairiki, and Ferry Terminal at Betio (crowded to limits by passengers)

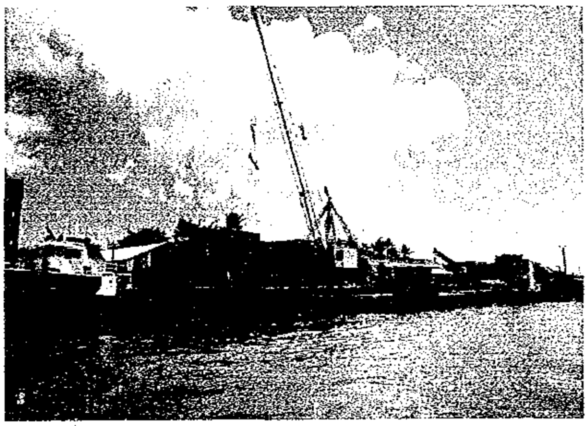


Typical Fishing Boat with Outboard Motor

Typical Micro Bus of Main Land Transport Facility



Ocean Fishing Boats Mooring Off Betio Port



Landing Facility at Betio Port

SUMMARY

SUMMARY

The Republic of Kiribati consists of three groups of islands, namely the Gilbert Group, the Line Group and the Phoenix Group which are scattered in the central part of the Pacific Ocean. The total land area of the country is about 719km^2, most of which is about 1.0 meter above sea level, except for Banaba Island. Since the nature of the soil is very poor, the planting of coconuts trees is the only industry on land. On the other hand, the vast waters surrounding the country are good fishing grounds for Bonito and Tuna fish.

The Government of the Republic of Kiribati has laid great emphasis on developing export industries after the exhaustion of the country's phosphate ore, which took place about the same time her independence was gained in 1979. These export industries, which are being established as a part of the government's National Development Plans of 1979-1982 and 1983-1986, include increased production of copra by replanting of coconut trees and expansion of Bonito and Tuna fishing. In response to a request by the Government of the Republic of Kiribati, the Government of Japan has, since 1979, provided two boats for Bonito & Tuna fishing, one mother-ship to support small fishing boats, one passenger/cargo boat to operate between the various islands, and a cold storage/freezing plant with related facilities and equipment as well as technical cooperation by dispatching Japanese experts to train local fishermen concerning the modern techniques of fishing and so on.

The Tarawa Atoll is the capital of the country and it has about 20,000 people out of a total population of 64,000 according to the census taken in 1985. Betio and Bairiki Islands are the main islands of the Tarawa Atoll, functioning as the economic and administrative centers of the country. Since the country's only port for fishing and trade is on Betio Island, the facilities related to these activities are principally located on this island, while facilities pertaining to the Government and the Public Affairs are mostly on Bairiki Island. These two islands are separated by a shallow sea and are presently connected by a ferry service which has been causing a significant bottleneck regarding the development of the nation's economy.

The Government of Kiribati has therefore requested assistance from the Government of Japan to construct a causeway with fisheries channel between Betio and Bairiki Islands. Based on this, the Government of Japan entrusted the Japan International Cooperation Agency (JICA) with making a study of the viability of such a project and preparing an optimum plan for it. JICA sent a survey team to Kiribati in April 1985 for the Basic Design Study and again in July 1985 to explain its draft final report. The results of the field study that was performed in Kiribati and the analysis that was made in Japan are summarized as follows:

1. Situations Pertaining to Ferry Operations and Fishing Boats Crossing the Shallow Sea between Betio and Bairiki Islands

The existing ferry system between Betio and Bairiki Islands is operated by the Public Shipping Corporation (financed by the government) using three small boats with a one-way ferry trip between the islands taking 45 minutes. The annual transportation of passengers, cargo and vehicles amounts to about 400,000 each, about 4,000 tons and about 10,000 each, respectively. 80 percent of the vehicles being transported are motorcycles with the transportation of other vehicles being limited due to the small capacities of the ferries. The ferry traffic has been decreasing due to the economic depression which started after the country's independence was gained in 1979; however, the ferry traffic demand is expected to increase in proportion to the recovery of the country's economy. The existing ferry facilities will not meet the requirement of the traffic demand in the near future; therefore, the procurement of new ferry boats and the improvement of the ferry terminals will be needed.

Out of total number of fishing boats (373) in South Tarawa, the number of skiffs with outboard motors which are operated in the ocean by crossing the shallow sea between Betio and Bairiki Islands is 20 in Betio Island and 17 in Bairiki Island. The catch by these skiffs is estimated to be 1,300 tons a year. The skiffs do not use ice for keeping the catch cool and therefore their fishing cycles are limited to about five hours in order to maintain the freshness of the fish and to get them to the market while they are still edible. At low neap tide when the tide level between Betio and Bairiki Islands is low, the fishing boats in Betio Island are sometimes unable to go to fishing, while those in Bairiki Island have to get to the fishing grounds by making a detour to the west of Betio Island. This occurs about 4 days a month. As such, once the fisheries channel is constructed, the number of hours available for fishing will be increased with a corresponding increase in fish catch.

2. Basic Design

(1) Causeway

The important items to be considered for the structural design of the causeway and the fisheries channel are to protect those structures from high waves and tidal currents that enter into the shallow sea between Betio and Bairiki Islands. Taking into consideration of the importance of the causeway as a fundamental infrastructure, the dimensions of the causeway structures are determined based on the design wave height (wave height: 0.7m at water level: DL +2.5m) expected to occur once in 50 years, as well as taking into account technical and economical studies.

The design speed of the causeway is to be 65 km/hr, considering the existing national trunk road system and topographic conditions. Based on the future traffic demand amounting to an average daily traffic of about 1,000 vehicles, the carriageway width will be 6 meters (2 lanes for 2 directions), while the width of each shoulder is to be 2.5 meters in order to provide parking and walkway.

(2) Fisheries Channel

The fisheries channel is designed so as to enable the maximum size (length: 6.4m, width: 2.0m and max draft: 0.78m) of the existing boats with outboard motors to sail safely through it at mean low water spring tide. Besides, in order to minimize the interference of the breaking waves at the end of the reef in regard to the operation of the fishing boats, the dimensions of the approach portion of the fisheries channel are designed to enable the fishing boats to safely enter the fisheries channel except when exceptionally high waves cross the reef, but this is expected to occur only several times a year.

(3) Principal Features

Principal features of the basic design of the proposed Betio-Bairiki causeway and its fisheries channel are listed below:

Causeway

Design speed	: 65 km/hr
Length	: 3.4 kms
Height of fill	: 2.7 meters (Average)
Top width	: 11 meters
Formation level at top	: DL + 3.3 meters
Cross-sectional composition	

Shoulder + Carriageway + Shoulder
(2.5m) (6.0m) (2.5m)

Roadway

Shoulder	: Soil-cemented
Carriageway	: Double Bituminous Surface Treatment (DBST)
Grade of side slope	: 1 : 1.5
Slope protection	: Concrete covering

Fisheries Channel

Length	: 800 m
Width (bottom)	: 10.0 m
Elevation (bottom)	: DL - 1.70 meter
Type	: Open channel without lining
Navigation clearance (Vertical)	: 2.6 meters above MHWS (DL + 1.80 m)

Bridge over Channel

Length	: 10.0 m
Width	: 10.0 m
Type of structure	: Reinforced concrete rigid frame

Incidental Works

Electric power cable	: Installation of 3.4 km
Telephone circuits (50 pairs/0.9 mm)	: Replacement of 4.3 km

3. Project Evaluation

The economic benefits to be expected from the project were derived from the difference of benefits resulting from "with-project" and "without-project".

In this study, the economic benefits to be expected from the Project were divided into the following categories:

Direct Tangible Benefits

i) Reduced operating expenses resulting from vehicle transportation which will replace the slow moving and expensive ferry services, and eliminating having to invest funds for the proposed construction of the Takoronga ferry terminal.

ii) Benefits from induced traffic which are expected to occur as a result of lowering the transport costs after the construction of the causeway.

iii) Savings in both operating expenses and time by the fishing boats being able to make use of the fisheries channel, resulting in an increase of the fish catch.

Indirect Benefits

i) Savings by being able to make better use of certain public facilities which now exist separately in both Betio and Bairiki Islands.

ii) Benefits to the public by providing easy access to such public facilities as the police station, hospital and schools.

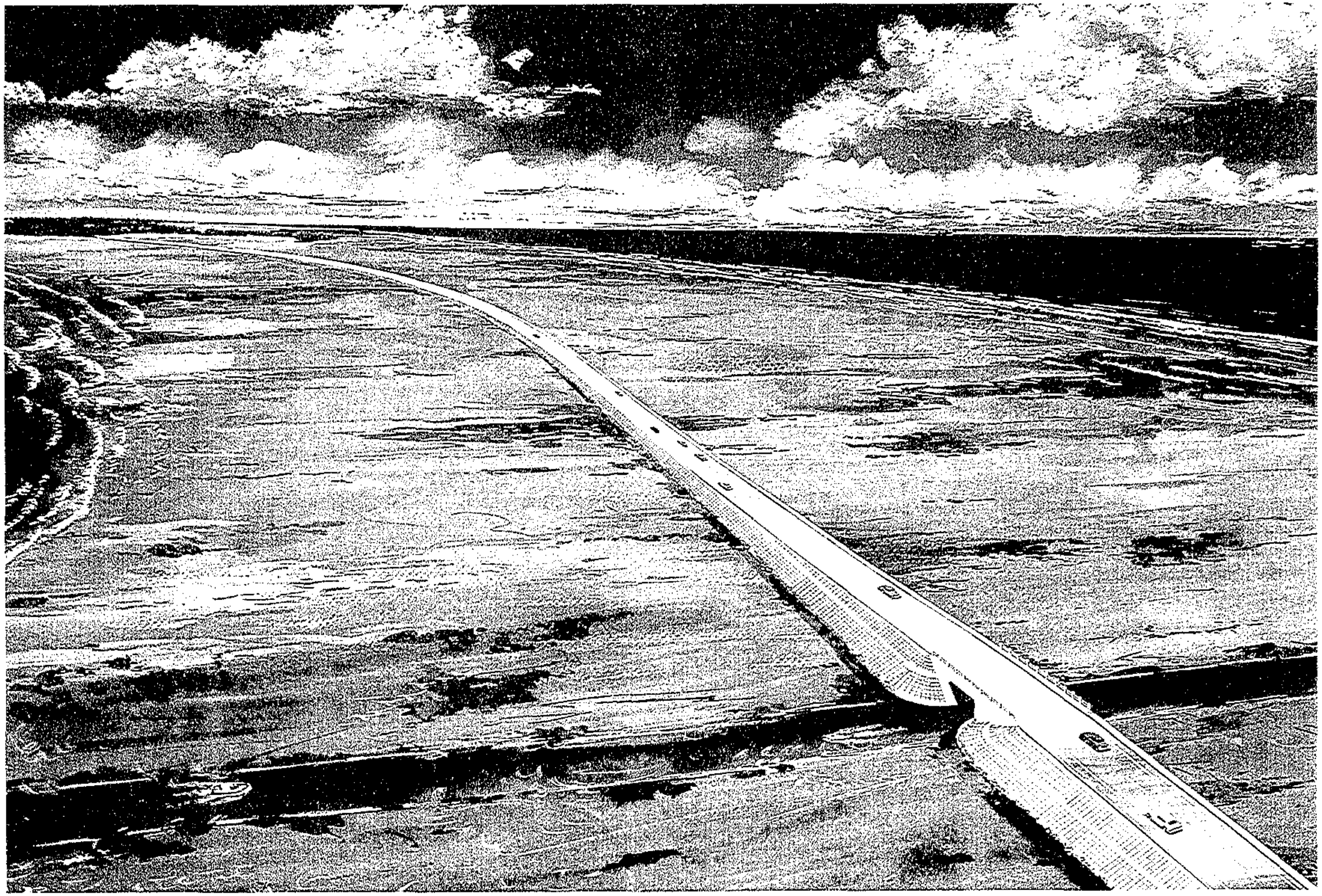
iii) Savings due to the improved administration and management of government, corporations and private businesses.

iv) Savings due to a lessening of the congestion at Betio harbour, thus allowing the port handling facilities to be utilized by others and enabling the Bairiki ferry terminal to be used by the local fishing boats.

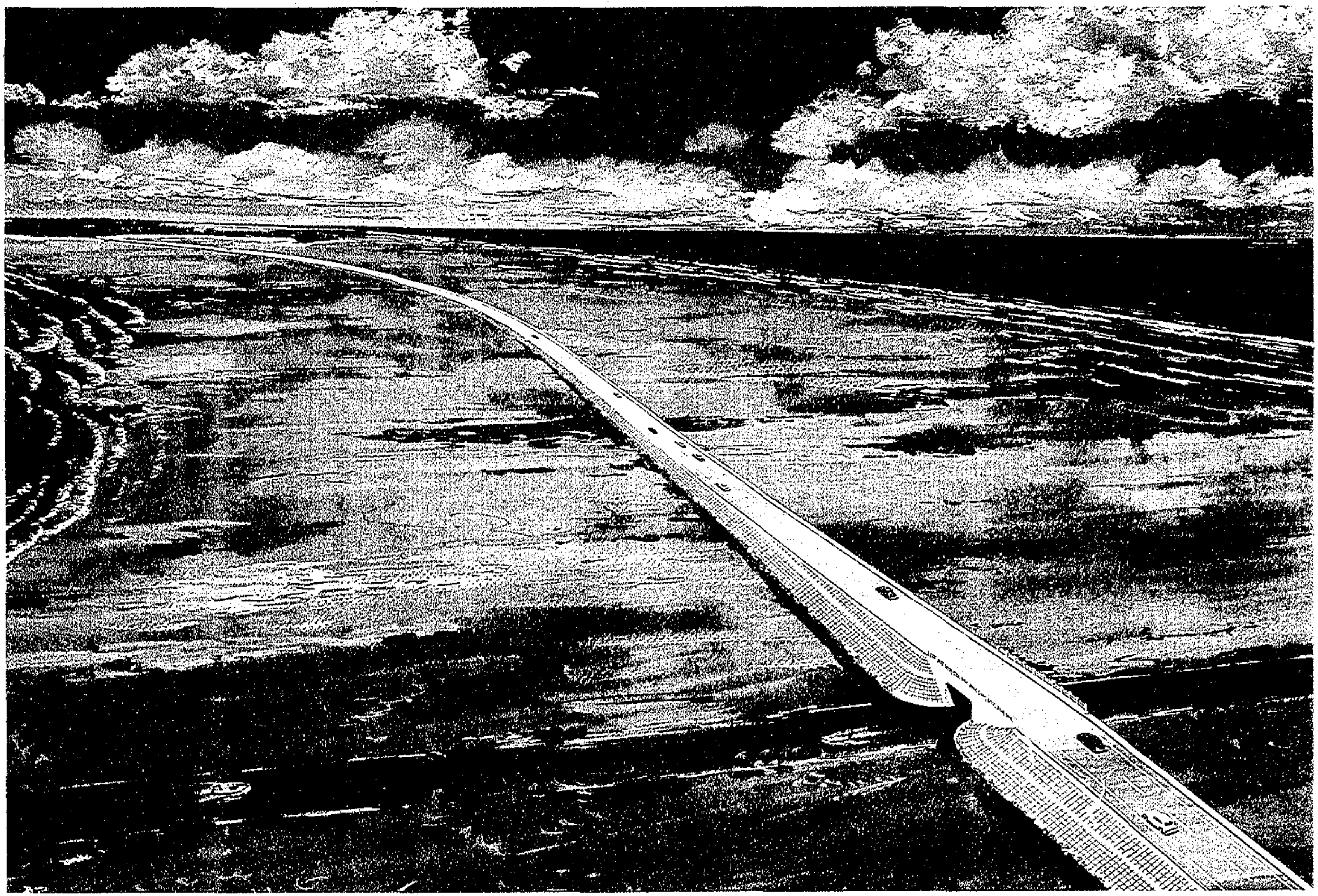
v) Decreasing the congestion now existing throughout Betio Island.

In comparing the direct benefits against the construction and maintenance costs by means of the Internal Rate of Return Method, the results amounted to 7.9 percent. Although this percentage does not seem to be high, when the indirect benefits are also taken into account it is judged that this Project will greatly contribute to the social, economic and fisheries developments of the Republic of Kiribati.

Taking into consideration that this Project has the highest priority in the National Development Plan (1983 - 1986), in addition to the benefits cited above, it is concluded that this Project is highly eligible for a Grant Aid Assistance Project by the Government of Japan.



ARTIST'S CONCEPT OF PROPOSED CAUSEWAY AND BRIDGE WITH FISHERIES CHANNEL



ARTIST'S CONCEPT OF PROPOSED CAUSEWAY AND BRIDGE WITH FISHERIES CHANNEL

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ABBREVIATIONS

AASHTO	American Association of State Highway and Transportation Officials
ADB	Asian Development Bank
ADT	average daily traffic
A$	Australian dollar(s)
BRG	bridge
°C	Degree Celsius (centigrade)
chn	channel
c/w	causeway
D B S T	double bituminus surface treatment
D/D	detailed design
D L	datum level
E	east
E E C	European Economic Community
EIRR	economic internal rate of return
Fig., Figs	figure, figures
F/S	feasibility study
ft	feet
gal/hr	gallons per hour
GDP	gross domestic product
h, hr	hour(s)
H H W L	highest high water level
HP	horce power
IRR	internal rate of return
Isl	Island
JICA	Japan International Cooperation Agency
JIS	Japanese Industrial Standards
KCWS	Kiribati Corporation Wholesale Society
kg	kilogramme(s)
kg/m^2	kilogramme(s) per square metre
KHC	Kiribati Housing Corporation

km	kilometre(s)
KV	kilo-volt
m	metre(s)
m^3	cubic metre(s)
max	maximum
M.H W N	mean high water neap
M H W S	mean high water spring
min	minutes, minimum
M L W.N	mean low water neap
M L W S	mean low water spring
MSL	mean sea level
mm	millimetre(s)
MOC	Ministry of Communication
m/s	metre(s) per second
N	north
No	number
PWD	Public Work Division
R L	ruduced levels (R.L) relating to Chart Datum. Negative R.L indicates below Chart Datum
S	south
S.C R	Solid Core Recovery (%)
SMB	Sverdup, Munk and Bretschneider Consultants
STA	Station
t	ton(s)
T	time
T C R	Total Core Recovery (%)
TL	truck load
t/m^2, $tons/m^2$	ton(s) per square metre
t/m^3	ton(s) cubic metre
UN	United Nations
US$	US dollar(s)
W	west
Yen (¥)	Japanese Yen

Note: Chart Datum Level (C.D.L.) is quoted as 0.3 ft below M.L.W.S. (Admiralty Chart)

CHAPTER 1

INTRODUCTION

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In earlier years, the main economic resource of the Republic of Kiribati was its phosphate ore but this had been exhausted by 1979. Therefore the Government has laid great emphasis on developing the export of copra, the potential of the fishery resources etc., aiming to realize economic independence. This is in accordance with the Government's National Development Plans of 1979 - 1982 and 1983 - 1986.

In response to a request by the Government of the Republic of Kiribati, the Government of Japan, since 1979, has provided two training boats for Bonito and Tuna fishing, one mother-ship to support small fishing boats, one passenger/cargo boat to operate between the various islands and and a cold storage/freezing plant with related facilities and equipment as well as technical cooperation by sending Japanese experts to train local fishermen concerning the modern techniques of fishing.

The capital of the Republic of Kiribati is located in the Tarawa Atoll. Betio and Bairiki Islands are the main islands of the country functioning as the economic and administrative centers of the country; however, these islands are separated by a shallow sea which causes a significant bottleneck in regard to the economic development of the country.

Therefore the Government of the Republic of Kiribati has requested the Japanese Government to assist in construction of a causeway with fisheries channel between Betio and Bairiki Islands. In response to this request, the Government of Japan had the Japan International Cooperation Agency (JICA) send a survey team to prepare the Basic Design Study for the Causeway and Fisheries Channel Construction Project during the period from 5 April to 4 May 1985.

When the study team arrived in Kiribati, they explained the aims and schedules of the study to the concerned authorities of the Government. The team then started getting the necessary pertinent data and performing the requested surveys concerning the geology and topography where the causeway is expected to be constructed, traffic studies of both vehicles and ferry services, data on tides/currents and even locations of un-exploded ordinance left over from World War II.

After performing the above mentioned work at the site, the team discussed with the representatives of the concerned ministries regarding the guideline for the Basic Design and came to an agreement with the Government concerning the basic plan for the Basic Design of the Project.

After the team returned to Japan, an analysis of the data obtained at the site was made. Then, the basic design of the causeway and fisheries channel was made based on the analysis and the agreed basic plan. The results of the analyses and performances are compiled in the draft final report.

The team again visited the project site from 16 July to 27 July 1985 for the purpose of presenting and explaining the draft final report to the concerned officials of the Government of Kiribati and then completed this final report with their consent.

The team members which were engaged in the study, as well as their assignment and organizations, are listed in Table 1-1.

Table 1-1 Team Members and Their Assignments/Organizations

1st Visit (From 5 April to 4 May 1985)

Name	Assignment	Organization
Mr. Takeshi Kawaguchi	Team Leader/Supervisor for Coastal Engineering	Fisheries Agency Ministry of Agriculture, Forestry and Fisheries
Mr. Koji Kurihara	Supervisor for Highway Engineering	Japan Highway Public Corporation
Mr. Hirotsugu Yoshitake	Project Coordinator	Japan International Cooperation Agency
Mr. Shinji Arisaka	Highway Planner	Nippon Koei Co., Ltd.
Mr. Katsumi Naito	Coastal Civil Engineer	Ditto
Mr. Hiroki Shinkai	Highway & Traffic Engineer	Ditto
Mr. Katsufumi Matsuzawa	Bridge Engineer	Ditto
Mr. Takuji Hirota	Fishery & Environmental Analyst	Ditto

2nd Visit (From 16 July to 27 July 1985)

Name	Assignment	Organization
Mr. Takeshi Kawaguchi	Team Leader	Fisheries Agency, Ministry of Agriculture, Forestry and Fisheries
Mr. Hirotsugu Yoshitake	Project Coordinator	Japan International Cooperation Agency
Mr. Shinji Arisaka	Highway Planner	Nippon Koei Co., Ltd.
Mr. Katsumi Naito	Coastal Civil Engineer	Ditto

The request for the study that was made by the Government of the Republic of Kiribati, schedules of the study team and Minutes of Discussions and Minutes of Meeting concerning the agreement made between the Government and the Team are attached in the Appendices 1-1 through 1-7.

CHAPTER 2

BACKGROUND OF THE PROJECT

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2.1 General Situation of Kiribati

The country consists of many scattered islands in a large area between lat. 4° N and 12° S and between long. 168° E and 147° W in the middle of the Pacific Ocean. These islands are divided into the Gilbert Group (17 islands), the Line Group (8 islands) and the Phoenix Group (8 islands), total of 33 islands. Most of all islands are about 1.0 meter above the sea level, except for Banaba Isl. which is at 86.6 meters high above sea level.

The total land area of the country is about 719 km^2, with Christmas Isl. being about 388 km^2 which is more than a half of the total area of the country.

The nature of the soil is relatively poor because it mostly consists of coral sand and rock which is suitable only for the planting of coconuts and pandanus. The country has no particular mineral resources except for the phosphate ore, however, this was exhausted by mining in 1979.

The annual rainfall in the country ranges from 1,000 mm to 3,000 mm. There are no fresh water lakes, marshes or rivers in the country.

For the most part, the country is located outside the areas where cyclones usually form and pass, therefore, the influence of cyclones on the country is relatively small.

The temperature ranges between 26°C and 32°C with, an annual mean of 28.3°C. Kiribati was the original name of the Gilbert Islands which was under the control of the United Kingdom for 87 years until it became self-governing in domestic affairs in 1977. The country gained full independence from the United Kingdom as the Republic of Kiribati on July 12th, 1979.

The people of the country consist mainly of Micronesians (98%) and Polynesians (1.5%), in addition to a small number of Europeans and Chinese.

2.2 Natural Conditions of Tarawa Atoll

2.2.1 Meteorology

(1) Temperature

The climate of South Tarawa is of the tropical islands type. The mean annual temperature is 28.3°C as seen below in Table 2-1, with no remarkable change in temperature occuring throughout the year.

Table 2-1 Temperature in South Tarawa Atoll

1947 - 1978 Betio

Temperature \ Month	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec	Annual
Mean Daily Max °C	30.9	30.8	30.7	30.9	31.2	31.1	31.1	31.2	31.3	31.5	31.5	31.2	31.1
Mean Daily Min °C	25.4	25.4	25.3	25.4	25.7	25.5	25.3	25.4	25.4	25.6	25.3	25.4	25.4
Mean °C	28.2	28.1	28.0	28.2	28.5	28.3	28.2	28.3	28.4	28.6	28.4	28.3	28.3
Max °C	34.5	33.6	33.1	34.3	34.3	33.6	33.2	34.3	33.5	33.8	35.0	34.4	35.0
Min °C	21.7	22.2	21.2	22.5	21.3	21.2	21.2	21.2	21.2	22.2	20.7	21.7	20.7

Source: Meteorological Division

(2) Rainfall

The mean annual rainfall on Tarawa Atoll is about 1,900 mm/year. The monthly rainfall varies greatly from month to month with a maximum difference of 800 mm. The highest rainfall occurs during the period of December to March. The rainfall record of Tarawa Atoll is shown below in Table 2-2.

Table 2-2 Rainfall in Tarawa Atoll

in mm

	Month	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec	Annual
1947-1978 1983-1984	Mean	309	215	212	168	134	124	154	109	102	100	114	186	1927
"	High	824	542	724	525	421	373	374	507	361	402	480	432	3452
"	Year	1966	1965	1958	1953	1972	1972	1949	1972	1972	1965	1957	1972	1972
"	Low	14	4	4	0	4	1	1	3	2	0	3	14	395
"	Year	1950	1950	1971	1968	1964	1954	1973	1949	1970	1978	1978	1970	1970
1983	Mean	21	170	68	120	375	282	394	110	59	149	69	79	1896
1984	Mean	110	53	33	148	122	97	37	114	39	101	19	125	998

Source: Meteorological Division

(3) Winds

The prevailing winds of Tarawa Atoll are generally from the northeast, the east and the southeast, and they account for about 78% of the total winds. The winds from the southwest and the northwest do not blow so often but when they occur, they are quite strong. The winds are generally calm throughout the year and in most cases the wind speed are less than 8 meters per second. The wind directions and velocities recorded at Tarawa Atoll are listed in the following Table 2-3:

Table 2-3 Wind Records in Tarawa Atoll

1970 - 1974
1975 - 1977 No record
1978 - 1981

All Years Combined — Unit: days

Direction	Beaufort Force 0	1	2-3	4	5	6	7	Total	%
Calm	225							225	
N		16	81	30	4	-	-	131	4.6
NE		28	254	97	7	-	-	386	13.6
E		39	771	467	99	1	-	1377	48.4
SE		24	237	146	39	2	-	448	15.8
S		17	51	12	1	1	-	82	2.9
SW		4	31	17	3	1	1	57	2.0
W		2	30	12	7	2	-	53	1.9
NW		7	48	22	3	4	1	85	3.0
Totals	225	137	1503	803	163	11	2	2844	
Percentage (%)	7.9	4.8	52.8	28.2	5.7	0.4	0.1		100.0

Source: Meteorological Division

The relationship between wind speed and Beaufort Force is shown in the following Table 2-4:

Table 2-4 Relationship between Wind Speed and Beaufort Force

Beaufort Force N°	0	1	2	3	4	5	6	7	8
Wind Speed (knots)	< 1	1-3	4-6	7-10	11-16	17-21	22-27	28-33	34-40
Wind Speed (m/sec)	0.0-0.5	0.6-1.5	1.6-3.3	3.4-5.4	5.5-7.9	8.0-10.7	10.8-13.8	13.9-17.1	17.2-30.7

2.2.2 Marine Meteorology

(1) Tides

Betio Port is designated as the standard port for tidal observations in this country and the tidal data obtained at this port have been sent for analysis to the College of Technology of the University of Hawaii. The tidal data for Betio Port are shown below in Table 2-5, with the most common tidal range being between 0.55 and 1.71 meters.

Table 2-5 Tidal Elevations at Betio Port

H H W L	8.05 ft (2.45 m)
M H W S	5.90 ft (1.80 m)
M H W N	4.00 ft (1.22 m)
M S L (Z)	3.08 ft (0.94 m)
M L W N	2.20 ft (0.67 m)
M L W S	0.30 ft (0.09 m)
Datum	0.00 ft (0.00 m)

(2) Wave

Tarawa Atoll is located near the equator and is slightly influenced by cyclones. The maximum wind speed has been recorded at about 20 meters per second and the wind duration is relatively long causing relatively large surges in the ocean. These surges in the ocean sometimes affect the waves in Tarawa Lagoon because the west part of the lagoon is opened widely to the ocean. The waves from the ocean initially break the outer edges of coral reefs and then decrease their height while moving on to the reefs around the lagoon. The maximum height of waves recorded near Tarawa Atoll is 5 meters according to the Pilot Chart of the North Pacific Ocean (1972).

(3) Currents

The currents around Tarawa Atoll are influenced by the South Equatorial Current with the main currents being from the east to the west at speeds of 1.0 to 1.5 knots. The speeds of the currents between Betio and Bairiki Islands and inside the lagoon which observed by the Team were between 0.00 and 1.67 knots and between 0.31 and 0.51 knots, respectively (refer to Appendix 2-12 and 4-5).

(4) Drift Sand

There are sand banks on the coral reefs which have been deposited by drifting sand over the years. According to the report "Coastal Erosion in Kiribati" by R. Carter in 1983, the deposits of drift sand are in a direction from the northeast to the southwest. Furthermore, there are deposite of drift sand near Anderson Causeway, Eita and Bangantebure. These deposits give the suggestion that the drafting sand is mainly in a direction from east to west. On the other hand, concerning the development of sand spit on the coral reef between the two Islands, that of the south of Betio Island is bigger than that of Bairiki Island.

After the Nanikai Causeway was constructed in 1950, sand deposition have been occured predominantly on the coral reefs to the south of Betio Island and to the north of Bairiki Island in comparison to the north of Betio Island and the south of Bairiki Island. Nanikai Causeway has been widened from it constructed width of 7.1 meters to 25 meters along a length of 350 meters by drift sand being deposited on its north side with the total quantity of drift sand estimated to be about 17,500 m^3. It seems that this quantity has been created over a period of about 20 years. So the quantity of sand drift per year is estimated to be 250 m^3.

2.2.3 Topography and Geology

(1) Topography

The terrain of the islands is composed of flat coral reefs, standing about 1.0 meter above sea level. The shape of the lagoon resembles a great size tray with a maximum depth of 24 meters and an average depth of about 8 meters. The base of the lagoon is quite rough, consisting of a great number of massive coral rocks which are scattered all over the base. At the west side of the lagoon, the reef are discontinuously extended over 31 kms, and only some of them rise above the water surface at ebb tide. The edges of the coral reefs drop downward at the steep slope.

(2) Geology

Tarawa Atoll consists of a thin sand surface layer over a comparatively thick layer of sand with coral rock, both of which cover the coral base rock. The sand in the surface layer is comparatively fine, while the sand with coral rock in the second layer is well compacted solid. According to a sub-soil survey made through borings, the coral base rock is about 3 to 6 meters below the surface of coral reefs and about 10 meters below the bed of the lagoon.

2.3 General Situation of the Project Area

2.3.1 Project Area

The project area is located at the southern part of Tarawa Atoll. South Tarawa consists mainly of the islands of Betio at the west end, Bairiki located to the east of Betio and Bonriki at the east end. Betio and Bairiki Islands are separated by a shallow sea that is 3.4 km wide. Islands between Bairiki and Bonriki are already connected to each other by the existing three causeways.

2.3.2 Socio-Economic Situation

The key economic indicators of the Republic of Kiribati are summarized in Table 2-6.

(1) Population (refer to Appendices 2-1 thru 2-5)

According to the 1985 census, the country has a population of about 64,000. About 20,000 people live in South Tarawa and this consists of 32% of the country's total population. In accordance with the Family Planning Program established by the Government, the annual growth rate in population is estimated to be 2.2 percent up to 1990 and then to be 1.8 percent in and after 1991.

According to the 1978 census, the percentage of the economically active population older than 15 years of age to the whole population is 51%, while the percentage of the actual population directly involved in monetary economy is only 26%. The total working population was about 6,400, 43 percent of whom are working in the public service sector. The economic activities are concentrated only in South Tarawa and thus 60 percent of the total working population is in this area.

(2) Economy (refer to Appendices 2-6 thru 2-8.)

The Gross Domestic Product (GDP) in 1977 was A$34.9 million in market price but after the phosphate ore was exhausted, the GDP declined to A$20.8 million in 1980 and A$23.0 million in 1981 (about 60 percent of the GDP in 1977). The actual GDP after 1981 is not available and accordingly the annual growth rate in GDP has only been estimated at 3.2 percent based on the 1980 and 1981 data, modified by the rate of inflation of 7.1 percent during the same period (estimated in United Nations, Statistical Yearbook for Asia and the Pacific dated 1982).

The Government has been placing importance on increasing the copra output and marine products such as Bonito and Tuna fish for export purposes. After the exhaustion of its phosphate ore in 1979, the country's imports have been exceeding its exports by a great amount in value, causing on adverse effect on the national economy. 60 percent of imports in monetary terms are for food from Australia although import of industrial products such as machinery have been increasing from Japan and the United State.

2.3.3 Social Conditions

Since the administration and economic centers are divided between both Bairiki and Betio Islands, the end result is a duplication of governmental activities. Such situation is causing problems in coordination as well as communications between various government agencies. For example, the government offices such as the Ministry of Finance, the Ministry of Home Affairs, the Ministry of Natural Resource Development and the Ministry of Trade Industry and Labour are located on Bairiki Isl., while the headquarters of the police and the Ministry of Public Works and Energy are on Betio Isl. with the Ministry of Welfare and the Ministry of Education being on Bikenibeu Isl.

Also, the Ministry of Communications is situated on both Betio and Bairiki Isls. Public Works Division which is on Betio Isl. has its construction equipment and vehicle yards on both Betio and Bairiki Islands. Moreover government conferences are often held at Bairiki Isl., but the actual time available for use during the conferences is very limited because of the time lost in the persons having to travel between these islands by ferry.

Table 2-6 Key Economic Indicators of the Republic of Kiribati

1. Area 719 km^2

The Gilbert Group	17 isls.	278 km^2
The Line Group	8 isls.	412 km^2
The Phoenix Group	8 isls.	29 km^2

2. Population

64,000 in the whole country (Census of 1985)

Density of population: 89 per km^2 (in the islands with permanent residents)

3. Gross Domestic Product (GDP) (Million A$ in market price)

1977	1978	1979	1980	1981
34.9	39.4	38.3	20.8	23.0

4. Price Indices

Consumers' Price Index in 1975: 100

1978	1979	1980	1981	1982	1983	1984
136.1	145.0	170.8	180.7	192.1	206.4	213.1

5. Income and Expenditure in Foreign Trade (A$1,000)

	1977	1978	1979	1980	1981	1982	1983
Export	18,212	21,396	21,209	2,426	3,534	1,934	3,661
Import	11,693	14,115	15,545	18,263	22,830	22,508	19,807
Balance	6,519	7,281	5,664	-15,837	-19,296	-20,574	-16,146

Major Export Items (1981, %): Copra 74.6, Fishes 19.7 and Others 5.7 (folk handcraft)

Major Import Items (1981, %):

Machinery and Transportation Equipment and Vehicles	32.8
Food	24.9
Industrial Products	12.5
Fuel	12.0
Others	17.8

6. Governmental Budget (A$1,000)

	1982	1983	1984
Income	12,302	11,803	13,973
Expenditures	15,889	15,389	16,722
Balance	-3,587	-3,586	-2,749
Foreign Aid (from UK)	4,000	3,500	2,750

7. Currency

Australian Dollar

Source: Statistics Division

Te Mautari Ltd., which is the government corporation for fisheries development, is located in Betio Isl. where the only fishing port is, but the Ministry of Natural Resources Development (which is the controlling authority of the corporation) is situated on Bairiki Isl. Furthermore, the Fishery Division which administers fisheries activities is located in Tanaea Isl. The police headquarters was located on Betio Isl. from the view point the causeway between Betio and Bairiki Islands was to have been constructed by about 1980, but the delay in such construction has caused problems in the police activities pertaining to security, fire fighting and operations at the airport.

The Ministry of Finance is located on Bairiki Isl. but its Supply Division is situated on both Betio and Bairiki Isls.

Betio Isl. has a primary school but does not have enough land space for a secondary school. Accordingly, the secondary school students on Betio Isl. have to go to school at Teoraereke, Eita or Bikenibeu Islands by using the ferry service. As to medical activities, the Central Hospital at Bikenibeu Isl. is the only one which has beds for the care of inpatients while the hospital on Betio Isl. is only for outpatients.

2.4 Development Plans

2.4.1 Fisheries Industry Development Plan

According to the Fifth National Development Plan (1983 - 1986) the Fisheries Development Plan consists of the following four major items:

1) Development of the industrial fishery complexes for exporting Bonito and Tuna fish

2) Development of offshore fishing activities of foreign countries in the Kiribati's Sea Zones

3) Development of self-sufficient fisheries and small scale fisheries for fish catches of independent fishermen

4) Development of other marine resources

Much expectation has been put on developing the Tuna and Bonito resources in order to replace the exhausted phosphate ore resources.

The Government established Te Mautari Ltd. (the national public fisheries corporation) in 1981 at Betio Isl., and has been puting a lot of emphasis on developing the industrial Tuna and Bonito fisheries so that their products can be exported. Te Mautari Ltd. has four large fishing boats and cold storage units on land with a total capacity of 313 tons. Two of the fishing boats were provided by the United Kingdom and the other two were provided by Japan. The development plan for Te Mautari Ltd. is outlined below:

1985	Procurement of one mothership granted by the Government of Japan
1986	Building of two fishing boats (50 - 100 ton capacities) for Bonito and Tuna fishing with the assistance of financial aids from the EEC.
1986 - 1987	Construction of cold storage complex (one unit of cold storage with a capacity of 250 tons at -30°C and one unit of freezing plant) which is proposed financial aid from Japan.
	Extension of the fishing boat jetty by 100 meters with financial aid from the United Kingdom.
1988	Building of two fishing boats for Bonito and Tuna fishing (proposed financial aid from EEC).

On the other hand, most of the private fishermen in the country are engaged in self-sufficient type of fishing or in small-scale artisanal fishing. Accordingly, the Government has formulated a plan for fishermen to increase their catches which will then be purchased by Te Mautari Ltd.

Another plan for development of marine resources is the culture of milk fish. The culture of milk fish is being undertaken in a fish farm within the lagoon for the purpose of supplying prey to attract Bonito fish. A milk fish farm covering 80 hectars has already been constructed.

2.4.2 Transport Facilities Development Plan

Since the Republic of Kiribati consists of a number of atolls, the existing transportation system involves many serious problems. The ferry services connecting the islands are very important in order to provide access for the travelling public and therefore the National Development Plan includes the following:

- Construction of a new ferry terminal at Taronga at the east end of Betio Isl.
- Procurement of a new ferry boat for strengthening the transport system between Betio and Bairiki Islands.
- Procurement of a ferry boat for the smaller islands within Tarawa Atoll.

Of particular importance are the traffic demands between economically developed Betio island and the administrative center located in Bairiki island in South Tarawa. These demands are quite high with the ferry services between the two islands being used for transporting many passengers as well as a large quantity of cargo.

The disadvantages of a ferry system such as waiting time, inconvenience, slow speed, payment of fares, etc. has come to be a considerable problem for the people of both islands.

In the past, plans have been made to build a causeway connecting Betio and Bairiki Islands but it has not yet been realized. There is no doubt that a causeway connecting the political and economic centers of the country will provide a definite economic and social improvement for the country. Accordingly, it has been listed as an important pending project and has been given a high priority for being taken up in the National Development Plan, with the people in both islands as well as the government expecting the project to be realized in the near future.

2.5 Fisheries Industry of South Tarawa

2.5.1 Marine Resources

Surrounded by coral reefs, and with it's suitable depth (average 8 meters) and natural condition, the lagoon forms an excellent habitat for marine life. They are rich in many different kinds and quantities of fish. Such fish as grown queen fish, flying fish, horse mackerel fish, snapper fish and goat fish are found in abundant numbers around the reefs of the atoll. Also, schools of the silver biddy family, halfbeak family, round herring family and mullet family often migrate in the lagoons. Migratory fishes such as bonito, yellowfin tuna, mongrel seerfish, common dolphin and rainbow lunor are found in abundance offshore. (The type of fish suitable for exports are mentioned in Appendix 2-9).

2.5.2 Fisheries Industry

There is remote possibility in Kiribati for animal husbandry or stock breeding because of the nature of the soils being composed mostly of coral. Most of the protein intake of the people comes from fish and fishery products. As such, fisheries activities in Kiribati are an esstential element in the lives of the people. The fishereis in South Tarawa are divided into four groups. They differ according to their respective purpose.

(1) Self-sufficient Fishing

This type of fishing is performed by household units for self-consumption. They use simple fishing gear such as gill net and casting net along various point of the reefs in the lagoon or on the ocean sides.

(2) Semi-artisanal Fishing

This is a small-scale type of fishing for the dual purpose of self-consumption as well as cash income. Usually, people with some fixed occupation perform such fishing during holiday or vacation periods. They perform various types of fishing using a gill net, hand line, pole and line and fly fishing, on their sailing canoes or skiffs equipped with outboard motors both in the lagoon and in the ocean. This type of fishing has noticeably increased recently.

(3) Artisanal Fishing

This style of fishing is conducted by artisanal fishermen's units for their daily work using sailing canoes or skiff boats equipped with outboard motors both in the lagoons and in the ocean. This type of fishing consists of skipjack and tuna pole and line fishing and longline fishing in deep water and angling fishing around the reef edge on the ocean side. One unit usually consists of about three fisherman.

(4) Export Fishing

This fishing is performed by four pole and line fishing boats which are owned by Te Mautari Ltd., a government corporation. These fishing boats, which are equipped with modern facilities, catch tuna in waters around the Gilbert Isls. Fish catch are quick-frozen on board, and then processed for exports.

2.5.3 Fishing Boat and Catches

(1) Fishing Boats

According to research of the Fisheries Division in 1982, the number of fishing boats was 255 canoes and 118 skiffs for a total of 373. There are 37 skiffs equipped with outboard motors which are able to go out to the ocean through a shallow sea betwen Betio and Bairiki Isls, of which 20 artisanal fishing boats are in Betio Island and about 17 in the main island.

The out-board motors being used on skiffs are commonly about 40HP which allow a sailing speed of about 13 knots/hr. The standard skiff equipped with an outboard motor has an overall length of about 5 meters, a maximum width of 1.9 meters and a maximum depth of 0.73 to 0.9 meters.

The fishing boats, which sail to the ocean fishing grounds usually leave their home in the early morning. Sometimes it is not possible to pass through a shallow sea at ebb tide, so they have to get to the fishing grounds by making a detour to the west of Betio Isl. This occurs about four days a month. The fishing boats in the main islands are not used when they cannot pass through a shallow sea. These fishing boats do not use ice for freezing the catch, and therefore their fishing cycles are limited to about five hours to keep the catch fresh and to get it to the market at the earliest possible.

On the way back, the fishing boats usually anchor at the reef on the ocean side at ebb tide waiting for a higher tide, and such cases often occures about eight days a month.

(2) Fish Catches

Data collection systems on catch results have not yet been established so no annual figures of catch results are available. Two interview surveys were held. The first interview survey was conducted with 180 fishermen's households all round South Tarawa from January to February 1982. The second interview survey with 240 fishermen's households in the South Tarawa (except Betio Isl.) was held in September 1984. The fish catch in 1984 as shown below was estimated based on the results mentioned above.

Area	Daily Local Consumption (1)	Population (2)	Total Yearly Consumption (3)
Main Islands (Local Consumption)	310 g	11,594	1,311 tons
Betio Island (Local Consumption)	270 g	8,875	874 tons
Betio Island (for Export)	-	-	381 tons
Total			2,566 tons

Note: (3) = (1) x (2) x 365 days/year (excluding export item)

The yearly fish catch in 1984 was estimated to be about 2,600 tons, as derived from the above figures. The offshore fishing catches by skiffs with outboard motors are as follows:

Area	Number of Skiffs	Estimated Fish Catch (tons)
South Tarawa Island Main Isl.	17	530
Betio Island	20	800
Totals	37	1,330

2.5.4 Market for Fishing Products

(1) There is a market facility for fish products in Betio Island which is under the control of the Betio Town Council. Fish greater than 4 pounds in weight are purchased by Te Mautari Ltd. at a fixed unit price of A$0.30 per pound, which is a competitive price in the international market. For fish less than 4 pounds in weight, the fishermen are free to sell them for a retail price fixed at A$

0.50 per pound, regardless of the type of fish. In such case the sellers have to pay a sales commission of A$0.02 per pound to the government.

(2) In South Tarawa island, fish sales are not regulated. The fishermen either consume their catches or sell them at stores, on the road or by hawking. The average sale price is about A$0.48 per pound, which is a little cheaper than in Betio Island.

2.5.5 Te Mautari Ltd.

Te Mautari Ltd. was established in 1981 as a governmental corporation (fully financed by the Government) and is the implementation agency for the Fisheries Development Program of the Government with the main object being the development of tuna and bonito resources and earning foreign currency. The corporation has about 150 employees and four fishing boats of 20 to 60 gross tons, a 500-ton freezing carrier which is under charter, and cold storage units on shore having a total capacity of 313 tons.

In 1984, the total catch by the Te Mautari Ltd. fishing boats amounted to 2,257 tons plus a fish catch of 381 tons purchased from private fishermen, all of which was exported (refer to App. 2-10).

2.6 Existing Transport Facilities and Traffic

Transportation facilities on Tarawa Atoll have been developed mainly in the southern islands with the international airport being located at the eastern end of Bonriki Isl. This airport is connected with Bairiki Island by means of the existing causeway and paved roads of 30 kms long and having a width of 5.5 to 6.5 meters.

Ferry services are operated between Betio and Bairiki Islands, the economic and administrative centers of the country, respectively.

2.6.1 Ferry System between Betio and Bairiki Islands

The ferry system is operated by the Public Shipping Corporation (financed by the Government) using three small boats. The daily operational hours are from six o'clock in the morning to nine o'clock in the evening, at intervals of one or two hours. The sailing time takes about 45 minutes for a one-way trip. The maximum loading capacity of the ferry boat is about 150 passengers. The particulars of the ferry fleet are shown in Table 2-7. Fig. 2-1 illustrates the existing ferry routes.

Figure 2-1 Ferry Route between Betio and Bairiki Islands

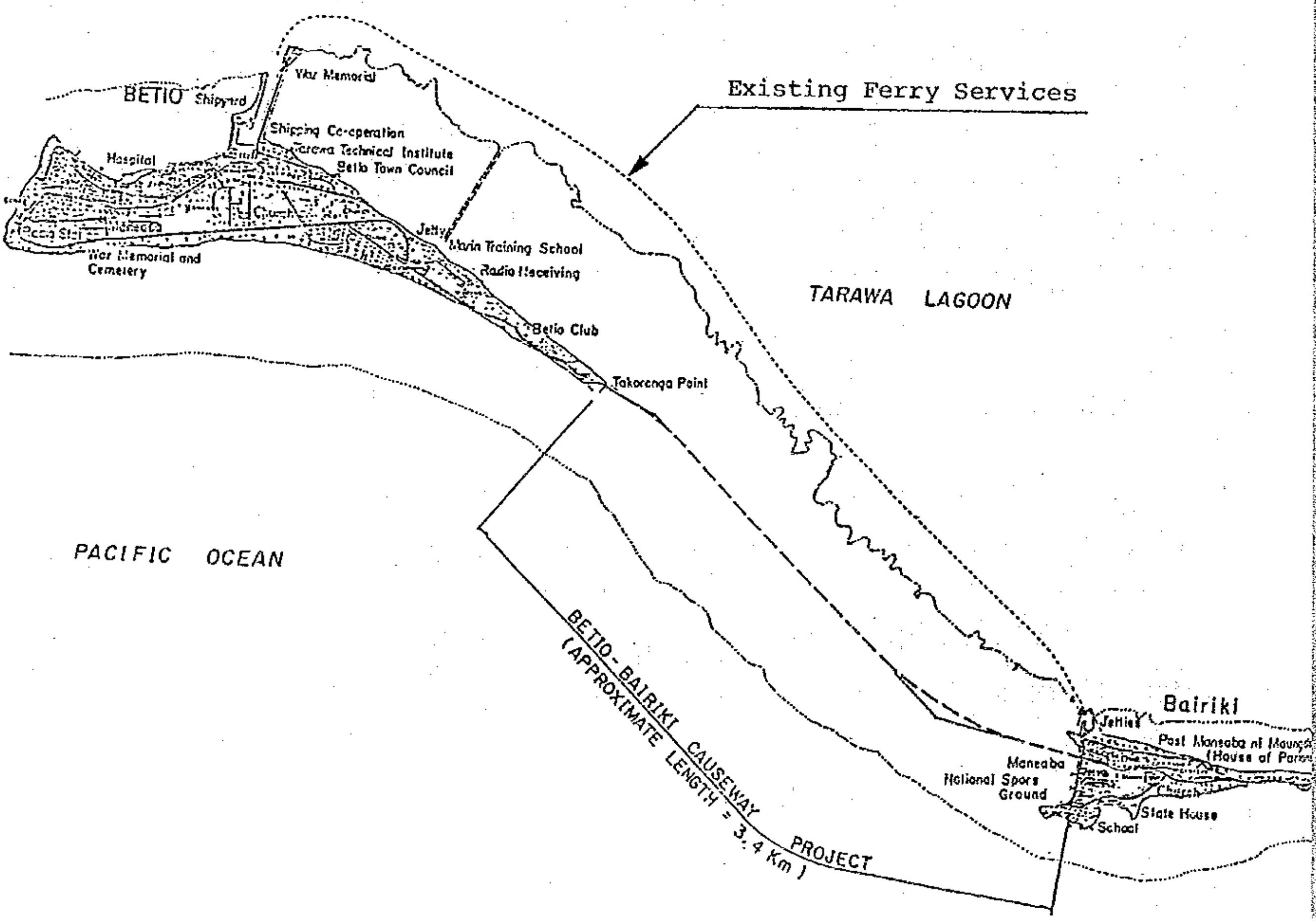


Table 2-7 Particulars of the Ferry Fleet

	Nei Auti	L.C. Tabakea	L.C. Nei Tebaa
Length, Overall	14.04 mtrs	19.20 mtrs	19 mtrs
Breadth Moulded	3.28 mtrs	5.18 mtrs	4.91 mtrs
Depth Moulded	1.86 mtrs	1.22 mtrs	1.22 mtrs
Loaded Draft	1.22 mtrs	11.48 mtrs	11.48 mtrs
Engine type	Gardner 2x6L3	Gardner 2x6L3	GM 6-71 In Line
Horsepower	2x168 HP	2x168 HP	2x250 HP
Fuel Consumption	7-1/2 gal/hr	7-1/2 gal/hr	15 gal/hr
Date Built	1968	1967	1972
Builder	E.C. Jones & Sons Brentford	Thames Launch Works London	Carpenters Industrial Ltd Fiji
* Passenger Capacity	50	150	150
* Vehicle Capacity	0	2	2

Note: * Capacity estimated by the JICA Team.

Source: Shipping Corporation

The daily ferry runs amount to 12 round trips per day from Monday to Friday, 9 round trips on Saturday and only 4 round trips on Sunday (refer to Appendix 2-13).

The actual transportation of passengers, cargo and vehicles over the past ten years by the ferry service between Betio and Bairiki Islands have been consolidated and are shown in Table 2-8 (refer to Appendix 2-14).

Table 2-8 shows that the volumes of passengers, cargo and vehicles have had a tendency to decrease over the last 3 years since this is reflecting the economic depression after the

Table 2-8 Statistics of Ferry Traffic Between Betio and Bairiki Islands

Year	Passengers carried by ferry		General cargo carried by cargo lighter and ferry				Vehicles carried by ferry	
	Nos	Increase Ratio	Betio/Bairiki	Bairiki/Betio	Total (Tons)	Increase Ratio	Nos.	Increase Ratio
1975	314,500	-	-	-	-	-	-	-
1976	356,000	-	-	-	-	-	-	-
1977	Not Recorded	-	3,331.5	1,351.7	4,683.2	-	-	-
1978	Not Recorded	-	Not Recorded	Not Recorded	Not Recorded	-	-	-
1979	411,784	100	2,961.8	976.7	3,938.5	100	-	-
1980	371,025	90	5,323.0	832.3	6,155.3	156	-	-
1981	411,077	99	4,072.3	646.1	4,718.4	120	-	-
1982	408,849	98	2,978.0	483.0	3,461.0	87	11,596	100
1983	379,609	92	3,847.0	611.0	4,458.0	113	10,108	87
1984	394,117	96	No Breakdown	No Breakdown	3,459.0	88	8,221	71

Source: Shipping Corporation

exhaustion of phosphate ore. The decrease in the volume of traffic during these three years is especially notable with respect to passengers and vehicles as each has gone down to about 95% and 70% respectively when compared to the traffic volume before exhaustion.

The actual transport of vehicles in 1983 totalled 10,108 (average of 27.6 vehicles per day) with 8,115 (80%) being motorcycles and 2,021 (20%) being cars, trucks and buses.

This means that the existing ferry service is transporting an average of only 5.5 vehicles (excluding motorcycles) per day and this seems to be caused by the following reasons:

1) The sizes of the ferry boats are small, having a capacity of carrying only 2 passenger cars.
2) During the morning and evening rush hours, the boats are crowded to their limits by passengers, so there is no space for vehicles.
3) The capacities of the ferry boats are so small that a two or three days in advance reservation is needed for vehicles.
4) The crossing cost is somewhat high.

As shown in Appendix 2-15, there are no remarkable monthly differences in the traffic statistics concerning passengers, vehicles and cargo.

In connection with the management of the Public Shipping Corporation, incomes exceed expenditures, so they are well balanced as shown in the following Table 2-9:

Table 2-9 Balance Sheet of the Public Shipping Corporation of Kiribati

FERRY DIVISION

		INCOME STATEMENT IN A$ FOR YEAR ENDING	
INCOME	31/12/82	31/12/83	31/12/84
Fares	-	245,728	232,278
Freight	-	113,585	103,619
Charter Hire	-	6,511	6,041
TOTAL INCOME	390,328	365,824	341,938
EXPENSES			
Staff Costs	99,963	102,221	107,443
Fuel & Lubricants	96,849	77,082	75,750
Operating Expenses	9,381	7,965	7,960
Maintenance & Repairs	40,685	27,756	42,716
Depreciation	27,410	21,308	23,610
Miscellaneous	1,333	1,236	1,825
TOTAL EXPENSES	270,621	237,568	259,304
SURPLUS	119,707	128,256	82,634

Source: Shipping Corporation

The percentages of income from passenger's fares, freight and charter fees to the whole income are 68%, 30%, and 2%, respectively. The percentages of the expenses for payroll, fuel consumption maintenance repairs and depreciation to the total expenses are 41%, 29%, 16% and 9%, respectively.

The fare for one-way ferry trip between Betio and Bairiki Islands for adults is A$0.70 while children receive a special discounted fare of A$16.0 per school semester. (Refer to Appendix 2-15.)

The ferry fare for vehicles varies from A$10.0 to 20.0 per one-way trip depending on the size and loading conditions.

2.6.2 Existing Roads, Causeway and Traffic

(1) Roads

The roads in the country have been developed around South Tarawa as it is the main center of activities. There is only one national trunk road, having a length of 30 kms and a width of 5.5 to 6.5 meters. It connects (by means of causeways) Bonriki Island where the international airport is located to Bairiki Island. A comparatively well maintained paved road network exists on Betio Isl. having a width of 5.5 to 6.0 meters. In general, the roads seem to be in fairly good condition due to the comparatively small traffic volumes (ADT 1,000 - 1,500). The proposed causeway is to be connected to the trunk roads on both Betio and Bairiki Islands and it will become a part of the national trunk road system.

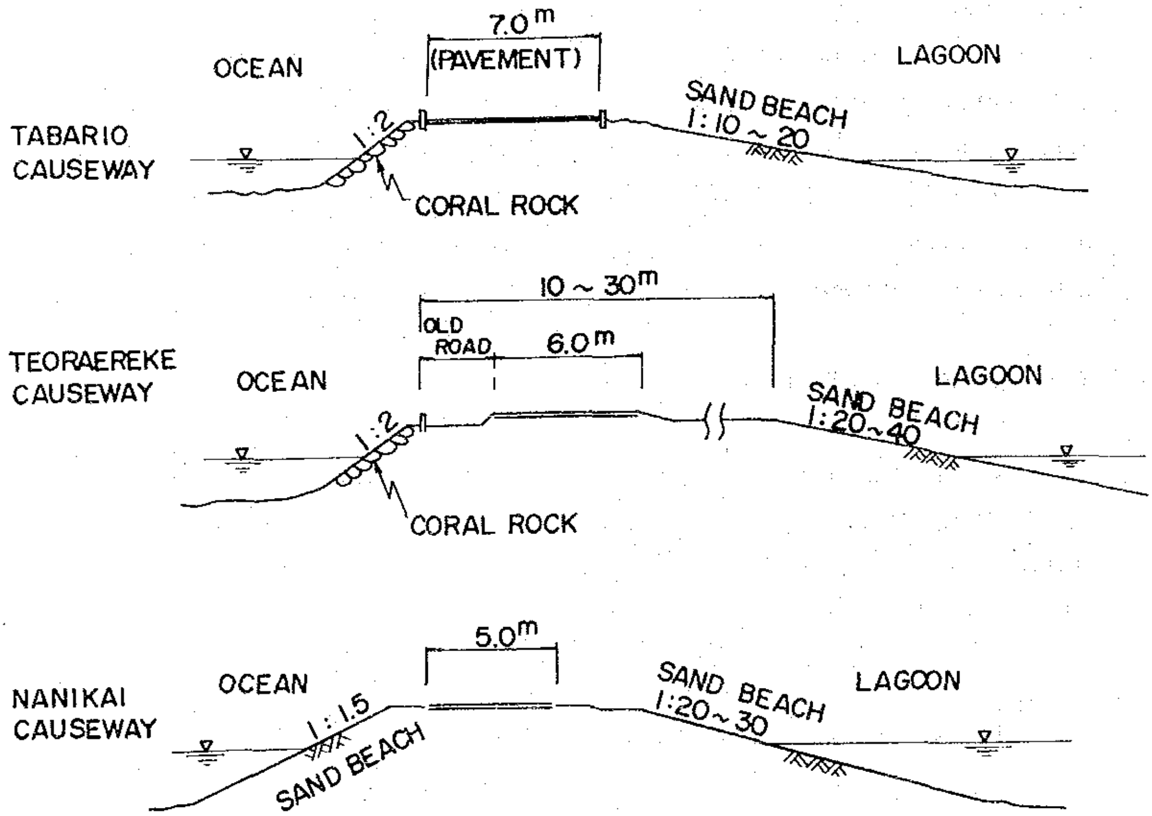
(2) Condition of Existing Causeways

As mentioned earlier, the islands in South Tarawa (between Bonriki and Bairiki Islands) are connected by existing causeways. Following is dimensions of the existing causeway.

Item		Taborio Causeway	Terareke Causeway	Nanikai Causeway
Elevation	(m)	2.65	3.05	3.05
Width	(m)	8.0	11.0	9.0
Length	(m)	200	900	400
Pavement				
Surface		Treated	Treated	Treated
Width	(m)	7.0	6.0	5.0

Some of the causeways side slopes are protected by covering structures and others are without any type of protection. The cross-sectional composition of each causeway are illustrated in the following Figure 2-2:

Figure 2-2 Cross-sectional Composition of Existing Causeways



The existing causeways have the following local characteristics:

(i) The surface level is DL + 3.0 meters and this elevation is almost the same as the land elevation of the connecting islands. The crushed waves may come over the top of the causeway, but only several times a year on windy days during spring tide.

(ii) The side slope on the lagoon side has a tendency to be covered with deposited drift sand, and usually does not used side slope protection. On the other hand, parts of the side slope of the Taborio and Teaoraereke Causeways on the ocean side must be protected by the use of large coral rocks.

(iii) The slopes on the ocean side of Taborio and Teaoraereke Causweays are protected against erosion from waves by means of coral rocks; however it should be noted that the finer particles of the protected side slope of the Teaoraereke Causeway were washed out by wave action which in turn resulted in damaging the fill and pavement of this causeway. For this reason, the route of the Teaoraereke Causeway had to be relocated (See Fig. 2-2).

(iv) Since the population and the economic activities are mostly concentrated in South Tarawa, most of the vehicles are located there. Betio Town Council and Teinainano Urban Council take charge of the registration of vehicles in Betio Isl. and in South Tarawa, respectively. The numbers of registered vehicles in Betio and South Tarawa Islands are seen in the following Table 2-10, and it is noted that their number is decreasing because of the economic depression now affecting the country.

Table 2-10 **Number of Registered Vehicles in Betio and South Tarawa Islands**

Year	1982	1983	1984
1. Buses			
Betio	No record	13	13
S. Tarawa	22 (2%)	24	24
Subtotal (1)	-	37 (3%)	37 (3%)
2. Passenger Cars and Trucks			
Betio	No record	76	76
S. Tarawa	403 (32%)	270	361
Subtotal (2)	-	364 (27%)	437 (36%)
3. Motorcycles			
Betio	No record	408	301
S. Tarawa	832 (66%)	486	441
Subtotal (3)	-	894 (70%)	742 (61%)
Total			
Betio	No record	501	390
S. Tarawa	1,257(100%)	780	826
Grand total (1)+(2)+(3)	-	1,281(100%)	1,216(100%)

Source: Betio Town Council and Teinainaino Urban Council

The registered number is between 1,200 and 1,300 and 60 to 70 percent are motorcycles.

(3) Bus Services

The bus services for Betio and South Tarawa Islands are separately operated by small private companies with only 1 to 3 buses. These bus companies do not have their own repair shops.

The bus services operate from and to the ferry terminals in line with the departures and arrivals of the ferries. After the proposed causeway is constructed, an overall revision of the fare systems, service levels, etc. will be needed and it may even be necessary to have some of the bus companies combined into larger ones. These bus companies are beeing managed privately and they do not have any records concerning the number of passengers, income and expenditures. A traffic survey (discussed in the next paragraph) estimated there are about 14 persons per bus and this occupancy rate seems to be rather high. The management of the bus services appears to be satisfactory. The bus service system for Betio and South Tarawa Islands is listed in the following Table 2-11.

Table 2-11 Bus Service System for Betio and South Tarawa Islands

Area	Number of Company	Number of Buses	Fare	Operation Schedule	Service Hours
Betio Isl.	3	8 (18-24 seats)	Flat fare A$ 0.25	NO	6:00 AM - 10:00 PM
S. Tarawa (Bairiki - Bonriki)	13	20 (18-24 seats)	Fare depending upon the distance (A$ 0.30 - A$ 0.60)	YES	6:00 AM - 10:00 PM

2.6.3 Traffic Survey and Analysis

Traffic surveys concerning the traffic characteristics, daily traffic volume and conditions of the ferry service in South Tarawa were made as listed below:

(i) Traffic count survey

(ii) Roadside interview survey

(iii) Interviewing ferry passengers

Date of survey:

April 25th, 1985 (Thusday)

Survey points:

(i) Nanikai Causeway : traffic counter survey and roadside interviews

(ii) Aboad ferry: interviewing passengers

Survey hours:

(i) Traffic count survey and roadside interviews:

12 hours from 6:00 a.m. to 6:00 p.m.

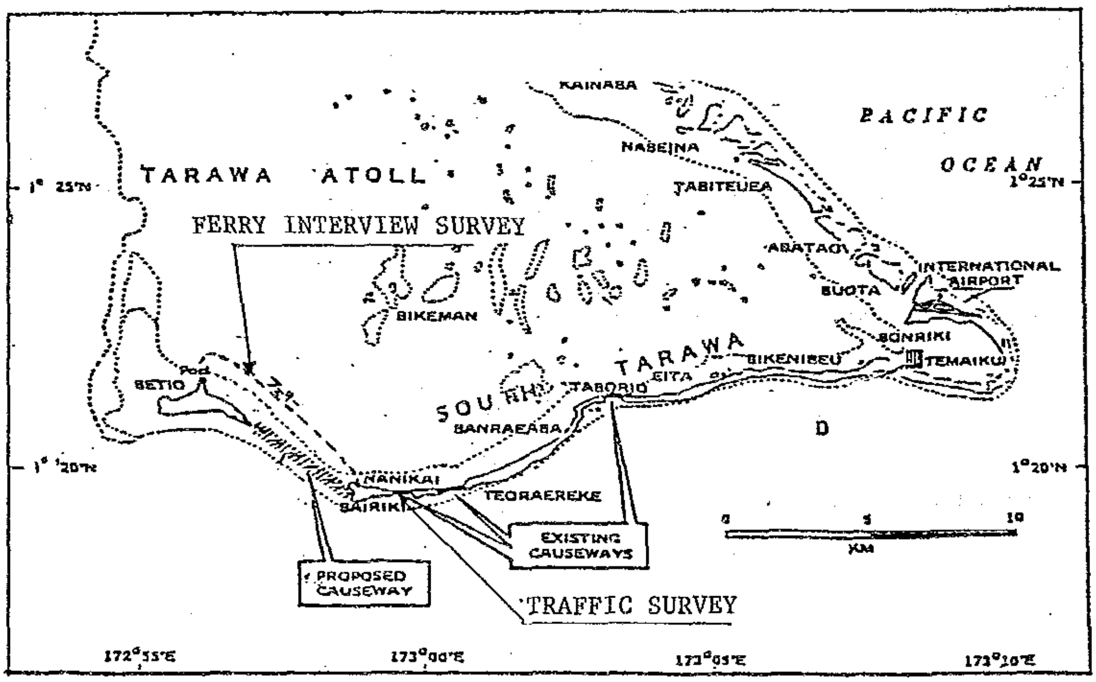
(ii) Interviewing passengers on ferries:

departing from Bairiki: 5 runs

departing from Betio : 3 runs

The survey points are shown in Figure 2-3.

Figure 2-3 Location of Survey Points



(1) Traffic Counting

The traffic counting was continued for 12 hours from 6:00 a.m. to 6:00 p.m. at the existing Nanikai Causeway on Thursday, in which the weekly traffic fluctuation is relatively small. The results of the survey are summarized below:

(i) The number of vehicles per 12-hour period is shown in Table 2-12. The total number of vehicles on the existing causeway in both directions was counted at 1,323. The traffic volume in daytime (12 hours) would be 70 to 80 percent of the daily traffic volume (24 hours); however, considering the relatively small socio-economic activities at night in this area, the 12-hour traffic volume is assumed to be 90 percent of the 24-hour traffic volume. The average daily traffic volume therefore is estimated as followd:

ADT = 1,323/0.9 = 1,470 (inlcuding motorcycles)

(ii) More than 90 percent of the total traffic volume is motorcycles while the traffic volume of heavy vehicles share is extremely small.

(iii) There are no record concerning traffic survey being held in the past in this country; however, it can be assumed that the traffic volumes in earlier years has not changed remarkably, taking into account the decrease in number of registered vehicles and the economic depression.

Table 2-12 12-Hour Traffic Volume (25 April 1985)

(1) Traffic in the Direction from Bairiki to Bonriki

Hour	Micro Buses	Passenger cars	Small Trucks	Motorcycles	Total
6 - 7	4	2	13	7	26
7 - 8	6	9	18	15	48
8 - 9	4	5	30	28	67
9 - 10	3	4	22	20	49
10 - 12	2	3	48	41	100
12 - 2	12	8	57	55	132
2 - 4	5	8	49	45	107
4 - 5	5	6	30	37	78
5 - 6	3	1	18	24	46
Total	50	46	285	272	653
(%)	8%	7%	43%	42%	100%

Unit: Vehicle

(2) Traffic in the Direction from Bonriki to Bairiki

Hour	Micro Buses	Passenger Cars	Small Trucks	Motorcycles	Total
6 - 7	7	0	15	16	38
7 - 8	4	12	34	42	92
8 - 9	7	5	33	35	80
9 - 10	3	5	31	33	62
10 - 12	14	12	61	59	146
12 - 2	7	1	23	29	60
2 - 4	7	7	47	36	97
4 - 5	3	5	23	17	48
5 - 6	5	2	19	21	47
Total	57	49	286	278	670
(%)	9%	7%	42%	42%	100%

Unit: Vehicle

(2) Roadside Interview Survey

The roadside interview survey was conducted at the same place where the traffic count survey was held in order to obtain data on vehicles going to Bairiki Island. The purpose of the survey was:

- To estimate future quantities of vehicles by type which will be used for estimating traffic volume by type diverted from the ferries after construction of the causeway.
- to estimate the average occupancy of passengers for each type of vehicle.
- to estimate the direction of traffic to Betio Island and to Bririki Island.

Survey Results

(i) The total number of passengers passing over Nanikai Causeway toward the direction of Bairiki Island was counted at 2,157, and 556 persons or 25% out of them were planning to go to Betio Island by means of ferry system. See Table 2-13 below.

Table 2-13 Roadside Interview Results at Nanikai Causeway

	Number of Passengers Going to Betio and Bairiki	Number of Passengers (1) Going to Betio using ferry
Buses	802 (36%)	295 (53%)
Trucks	919 (42%)	171 (31%)
Passenger cars	99 (5%)	26 (5%)
Motorcycles	337 (16%)	64 (12%)
Total	2,157 (100%)	556 (100%)

(ii) More than 90 percent of the passengers were estimated to have their origins in the area east of Nanikai Causeway while the remaining ten percent of the passengers were estimated to be those from the area west of the causeway (Bairiki Isl.). The percentage of vehicles by type were estimated based on the figures in Table 2-12 taking into account people travelling on foot from their homes to the ferry terminal and the results are shown in Table 2-14 below.

Table 2-14 Percentage of Vehicles by Type

Buses	45%
Trucks	25%
Passenger Cars	14%
Motorcycles	16%
Total	100%

The above percentage of vehicle by type was used for estimating the traffic volume by type that is expected to be diverted from the ferries after construction of the proposed causweay.

(iii) The average number of passengers per behicle type are shown in Table 2-15.

Table 2-15 Average Number of Passengers per Vehicle Type

Vehicle Type	Average number of passenger
Bus	14.1
Truck	3.2
Passenger car	2.0
Motor cycle	1.2

(3) Interviewing Ferry Passengers

The interviewing the ferry passengers was conducted in the same manner.

Ferry boats on which the interview survey was conducted:

Departing from	Nos.	Departure Times
Betio	3 boats	7:00AM, 8:00AM & 1:00PM
Bairiki	4 boats	7:00AM, 8:00AM, 1:00 PM & 2:00PM

Survey Categories:

Sex, age, purpose of trip, occupation, means of access to the ferry terminals, means of land transportation from ferry terminal to destination point and expected means of land transportation to be used after the construction of the causeway

Number of Answers Obtained:

passengers departing from Betio:	237
passengers departing from Bairiki:	267
Total	504

Ratio of extraction

passengers departing from Betio	35%
passengers departing from Bairiki:	44%
Average	39%

Questionaire sheet   Written in English and Kiribati (refer to Appendices 2-16 & 2-17)

Following are the resutls of the analysis made of interview survey:

(i) Composition of passengers and purposes of trip

More than 80% of passengers ferried are students and employees. In 60% of the cases, the purpose of the trip was to commute between Betio and Bairiki Islands. Thus, the traffic between Betio and Bairiki is considered to be closely related to the daily activities. The occupation of the passengers and the purpose of trip listed below in Table 2-16.

Table 2-16 Occupation of Passengers and Purpose of Trip

Occupation		Purpose of Trip	
Students	41%	Commuting	60%
Government or Private Employees	26%	Business	18%
Fishermen	6%	Temporary Visit	15%
Jobless	13%	Others	2%
Others	2%	No Answer	4%
No Answer	2%	Total	100%
Total	100%		

(ii) Means of Access to the Ferries

It is found that the passengers use different means from their origin to the ferry terminal in each island as shown in Table 2-17 below

Table 2-17 Percentage of Passengers by Vehicle Type (Betio and Bairiki)

Type of Vehicle	Percentage of Passengers	
	from Betio	from Bairiki
Buses & trucks	82.4%	76.8%
Passenger cars	4.3%	12.1%
Motorcycles	10.3%	9.1%
Bycycles	3.0%	2.0%
Total	100 %	100 %

2.6.4 Problems of Existing Ferry System

The existing ferry system between Betio and Bairiki has several problems as mentioned below:

(1) Three ferry boats are now in service, but all of them are small in size and usually crowded only with passengers and they have very limited space for the transport of vehicles. It is impossible to expect an efficient operation of a ferry system that has insufficient capacity for transporting vehicles and this results in bottleneck for the transportation system between Betio and Bairiki Islands. The existing ferry boats are obsolete and their maintenance and repair costs are increasing. The procurement of new ferry boats and the improvement of ferry terminals will therefore be needed in the near future.

(2) The average loading and unloading time for each ferry run is about 10 to 15 minutes and the sailing time across a strait between Betio and Bairiki Islands averages 45 minutes per trip, while it would take about 10 minutes by vehicle after the causeway has been constructed. Thus, a significant savings in travelling time will be realized by constructing the causeway.

(3) The daily operational hours of the ferry services are between 6.00 a.m. and 10.00 p.m., and intervals of the ferry runs are one hour during peak hour in the morning and evening, while two hours interval during day time and night time. Total ferry runs are 12 round trips per day from Monday to Friday, 9 runs on Saturday and only 4 runs on Sunday. It is quite clear that the social and economic activities of both islands are restricted due to the insufficient ferry services.

(4) The jetty at Betio port will be extended by 150 meters in the near future with assistance from the United Kingdom which is expected to increase the sailing time of ferry boats from 45 minutes at present to about 60 minutes.

(5) The traffic demand between Betio and Bairiki Islands is expected to be increased in proportion to the economic recovery of the country. The existing ferry facilities will not, however, meet the requirements of the traffic demands expected in near future.

(6) The transport systems on both islands have been developed independently; therefore, the bus services and their repair shops have to be provided separately on each island.

(6) The travellers between Betio and Bairiki Islands must bear relatively high transport cost due to the fact that they must use transport facilities such as bus services, ferry services and private cars.

CHAPTER 3

PROJECT FEATURES

CHAPTER 3 PROJECT FEATURES

3.1 History of the Project

There has, for a long time, been a strong desire to connect the island of Betio and the island of Bairiki by means of a causeway and a very high priority has been given to this project in the current National Development Plan.

This causeway project has a long history. The first study was made in 1966 to 1969 by Welton & Bell, Consulting Engineers of Sydney, Australia who prepared reports on the proposed Betio - Bairiki Causeway. Following this study, geological investigations, a feasibility study and detailed design were made by the same Consultant under financial aid from ADB, and the construction work was started in August 1978 by an Australian contractor. However, the construction work was halted in February 1979 due to technical difficulties. Several studies were made to determine how to overcome the technical difficulties and alternative plans were prepared for the continuation of the Project, but the construction work has been left as it was when stopped.

Under these circumstances, the Government of Kiribati, which is putting the highest priority on this project as it has a direct impact on the economic development of the country, has requested the Government of Japan to extend technical and financial assistance on a grant basis for the implementation of the Project.

3.2 Objective of the Project

The Project, by constructing a causeway on the shallow reef between the island of Betio and the island of Bairiki as well as to construct a fisheries channel to cross the causeway with a bridge at the crossing, aims at:

(1) Saving of transportation cost and travelling time between the two islands,

(2) Saving of access cost and time of fishering boats to ocean,

(3) Mitigation of traffic congestion in Betio, and

(4) Vitalization of social, economic and administrative activities by uniting the two islands.

3.3 Project Features in the Request

The proposed Project features in the request from the Government of Kiribati, are summarized as follows (refer to Appendix 1-3):

- Location: The Republic of Kiribati, South Tarawa
- Implementation Authority: Ministry of Communication (MOC)
- Implementation Organization:
  - Project Coordinator: Senior Assistant Secretary of MOC
  - Project Adviser : Chief Engineer of Ministry of Works and Energy
- Project Features

(i) Betio-Bairiki Causeway (refer to Fig. 3-1)

Length	: About 3.4 km
Formation (top width)	: 10 m
Formation Level	: D.L. + 3.0 m
Slope, ocean side	: 1:15
lagoon side	: 1:8
Embankment volume	: 285,000 m^3
Slope protection	: not provided

(ii) Fisheries channel

Width of channel	: 5.0 m
Clearance under bridge	: 1.5 m about MHWS

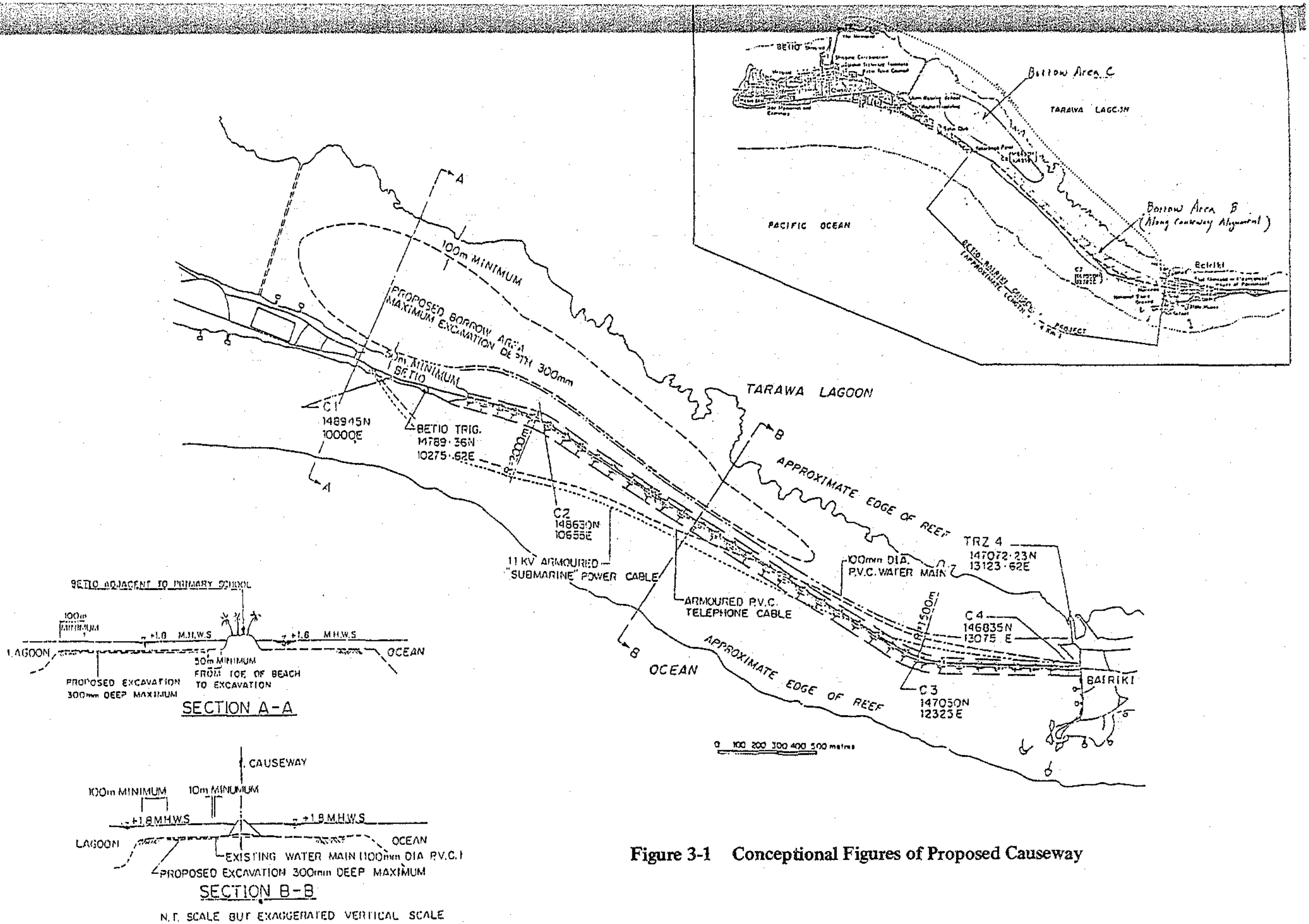


Figure 3-1 Conceptional Figures of Proposed Causeway

(iii) Bridge

Width : 10.0 m

Length : 5.0 m

3.4 Comments on the Project

Based on the preliminary review of the technical, economical and social aspects of the Project as listed in the request of the Government of Kiribati, the Study Team considered that special attention should be given to the following matters:

(1) The construction work of the Project was started by an Australian contractor with a financial aid of ADB, but was halted due to technical difficulties related to the method of embankment materials. Therefore, the construction plan should be prepared based on a exhaustive study covering selection of borrow areas, method of obtaining borrow material and the type of equipment to be used.

(2) As a result of the construction of the causeway, sea water circulation in the lagoon may be changed and it might cause some adverse effects on aquatic resources. Therefore, sea water circulation before and after construction of the causeway should be studied and its effects on aquatic resources shall be investigated.

(3) The causeway is a part of the trunk road in South Tarawa, and therefore it should have sufficient width as a trunk road and it should be the type of structure which can easily be maintained.

(4) Unexploded ordnances from World War II might still be found in the reef in and around Betio.

As such, soundings to determine the locations of unexploded ordnances should be made carefully at the borrow areas and at the causeway site before construction is started. Also a plan should be made for handling any ordnances which may be found during construction.

(5) Main direct benefits are savings in the transportation cost and travelling time between the two islands and savings in the access cost and sailing time of fishing boats to ocean. Besides, indirect benefits such as vitalization of economic activities by uniting the two islands, avoidance of double investments in public facilities and activation of suitable social activities are expected.

CHAPTER 4

BASIC DESIGN

CHAPTER 4 BASIC DESIGN

4.1 Design Criteria

The basic design of causeway and fisheries channel was carried out taking into consideration the natural environment and the existing transport system of the Republic of Kiribati as described in Chapter 2, and the proposed features in the request from its government described in Chapter 3. It was also based on the following policies:

(1) The causeway is to be designed to sufficiently meet the future transport demand, since it will be constructed in the sea and any future widening would therefore be rather difficult.

(2) The causeway is to be designed based on acceptable standards of the existing road system in the area, since it will form a part of a single trunk road in South Tarawa.

(3) Attention is to be paid to the easier and cheapest type of operation and maintenance of the structures.

(4) Use of local resources is to be maximized reasonably as much as possible, depending on the results of the investigation concerning the present condition of the construction business in the country, including locally available material, equipment, work forces, etc.

(5) The basic design is to be prepared in accordance with the design policies, standards and criteria which were established through discussions with and agreed to by the Government of the Republic of Kilibati.

4.2 Study of Design Conditions

4.2.1 Procedures for Estimation of the Design Waves

The dimensions of the design wave by direction and the ocean waves corresponding to the maximum wind speed for a 50-year return period as derived by the Gumbel method, were estimated based on the relationship between wind speed and distance to the seashore as well as that between wind speed and wind duration using the SMB method. As for the waves which propagate on the reef, their deformations were analyzed for two cases of which wave breaking on the edge of the reef at the tide level of DL+1.80 m, and without the wave breaking. Based on the above results, the wave height and setup were estimated at the proposed location of the causeway.

The detailed procedures for estimation of the design wave are described in Appendix 4-1 and itemized below:

(1) Collection of data of annual maximum wind speed by wind direction

(2) Probability calculations of wind speed by wind direction by the Gumbel method (refer to Appendix 4-2)

(3) Calculation of shallow water waves (by N wind for the lagoon side) as follows:

- (i) Calculation of the effective fetch
- (ii) Calculation of wave height for high water level by Bretschneider's method based on effective fetch, water depth in lagoon and wind speed with 50-year return period

(4) Calculation of deep water waves (by SW, S and SE winds for the ocean side and by N wind for lagoon side) as follows:

(i) Calculation of the effective fetch and wind duration on the ocean as follows:

Wave dimensions were calculated by the SMB method for the maximum wind speed with 50-year return period, referring to the pilot chart of the Maritime Safety Agency of Japan below listed cases:

a) Calculation of the effective fetch, a wave period and wind duration using the maximum wave height and the maximum wind speed recorded.

b) Calculation of the effective fetch, significant wave height and wind duration using the maximum wave and the maximum wind speed recorded.

Based on the results of the above two cases and taking into account the zonal characteristics, the effective fetch and wind duration were determined.

(ii) Calculation of deep water waves by wind direction as detailed below:

Wave dimensions for high water level were calculated for the following two cases, with the smaller value being taken:

a) Based on the effective fetch and wind speed (50-year probability)

b) Based on wind duration and wind speed (50-year probability)

(5) Calculation of wave deformation on the reef and its setup, outlined as follows:

Deformations of shallow water waves and deep water waves on the reef flat were calculated at various stages untill they reached the location of the planned causeway, the details of which are listed below:

(i) In case that wave breaking on the reef (refer to Appendix 4-3), then:
The breaking wave height at the edge of reef was calculated using Goda's equation and deformation of breaking waves on the reef and wave setup are calculated using Takayama's fomula for the following three type of waves (for the wave of 50-year probability):

- Deep water wave which reaches the ocean side of the causeway (by SW wind).
- Deep water wave which reaches the lagoon side of the causeway (by NW wind).
- Shallow water wave which reaches the lagoon side of the causeway (by N wind).

(ii) In case that the wave passes over the reef without breaking (refer to Appendix 4-4). then:
Wave attenuation by bottom friction on flat floor was calculated based on the method of "Shore Protection Manual, Volume II, USA." for the following three type of waves:

- For the deep water wave which reaches the ocean side of the causeway (by SW wind).
- For the deep water wave which reaches lagoon side of the causeway through western reef.
- For the wave which is generated in the lagoon and reaches the causeway.

(6) Design wave

Based on the results of above analysis, the design wave was determinied as summarized in Table 4-1.

Table 4-1 Design Wave

	Ocean Wave (direction)	Tidal Height above DL (m)	Ocean Wave (in front of reef) Wind Speed (m/s)	Wave Height (m)	Period (sec)	Setup by Ocean Wave (m)	Wave to Reach Causeway Wave Height (m)	Period (sec)	Design Wave Wave Height (m)	Period (sec)	Water Level above DL (m)
With Wave Breaking	Deep Water Wave on Ocean Side (SW)	+1.800	23.5	6.10	9.3	0.70	0.70	9.3	0.70	9.3	+2.500
	Deep Water Wave on Lagoon Side (NW)	+1.800	23.3	6.10	9.3	0.69	0.66	9.3	0.66	9.3	+2.490
	Shallow Water Wave on Lagoon Side (N)	+1.800	15.1	1.14	4.1	0.08	0.46	4.1	0.46	4.1	+1.880
Without Wave Breaking	Deep Water Wave on Ocean Side (SW)	+1.800		1.01	9.3	0	0.42	9.3	0.42	9.3	+1.800
	Deep Water Wave on Lagoon Side (NW)	+1.800		3.27	9.3	0	0.49	9.3	0.49	9.3	+1.800
	Shallow Water Wave on Lagoon Side (N)	+1.800		1.01	4.1	0	0.52	4.1	0.52	4.1	+1.800

Note : Deep water wave on ocean side = Ocean wave which occurs in open sea

Deep water wave on lagoon side = Ocean wave which occurs in open sea and penetrates into lagoon over western reef

Shallow water wave on logoon side = Ocean wave which occurs in the lagoon

4.2.2 Tidal Currents

In order to be able to analyze the change of the tidal currents between Betio and Bairiki Islands after the construction of the causeway, site investigations were conducted and observations of tidal current speeds were made. The observations were made at the existing fisheries channel on the proposed center line of the causeway. Based on the relationships between the current speed observed and the tidal height forecasted, the sea water levels on ocean side and lagoon side of the causeway were estimated by a water level trace calculation of non-uniform flow. The expected flow volume of the tidal current through the fisheries channel after construction of the causeway was then calculated based on the above estimated water levels. The procedures, conditions and equations used for the estimation and the results are detailed in Appendix 4-5. The results are summarized below.

Table 4-2 Tidal Currents between Betio and Bairiki Islands

			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

As shown in the above table, it is estimated that the flow volume will be reduced to 1/30 after completion of the causeway, while, the maximum speed of the current in the fisheries channel is estimated to reach around 3 m/sec.

The change of the tidal current was also analyzed for the whole area of the Tarawa Atoll. The flow volume of the current on the western reef is estimated at 26 times that of between Batio and Bairiki Islands, based on the following consideration.

Western reef: - average depth (high tide) = 4.2 m
- length = 24 km

Betio - Bairiki: - average depth (high tide) = 1.3 m
- length = 3 km

(24 x 4.2)/(3 x 1.3) = 26

Betio - Bairiki = $\frac{1}{26+1} = \frac{1}{27}$ (about 4% of the whole Tarawa Atoll)

As shown in the above calculations, it seems that the inflow volume and outflow volume for the total area of the Tarawa Atoll will be reduced by 4% after construction of the causeway, however, such reduction is presumed to be compensated by the increase of the flow volume on the western reef. Therefore, it is predicted that the construction of the causeway between Betio and Bairiki will cause little effect on the environment such as water quality and the ecosystem inside the area of the lagoon of the Tarawa Atoll.

In order to confirm the above, the change of tidal currents in the lagoon before and after construction of the causeway is examined by the simulation of tidal currents based on a two-dimensional model. The details of the simulation and the results are shown in Appendix 4-11. These results show the change is insignificant in the neap tide, while during the spring tide it is considerable; but only in the direction (not the velocity) of the tidal currents near the causeway. Since one of main reasons for pollution of sea water in the lagoon is a lack of the tidal currents, this project, in which no significant change of current velocity is expected to occur, will not cause an adverse effect in the quality of the sea water within the lagoon.

4.2.3 Soil Conditions

(1) For Construction of the Causeway

In the past, 9 bore holes were drilled along the proposed causeway with a depth from DL - 1.45 m to DL - 4.50 m. According to these boring data, the uppermost layer is coral sand widely extended with a thickness of 0.65 - 3.10 m, and underneath the uppermost layer there exist irregularly alternate sand layers with coral fragments.

According to the penetration test results, the underlying layers with coral fragment extend deeply. These layers are well consolidated compared with the uppermost coral sand layer with large penetration resistance. Their penetration rates[/1] are less than 0.05 m/min. The typical boring logs are shown in Fig. 4-1.

Material test results are also available for sand and coral which are to be used for embankment. According to the shear test results, the internal friction angles of sand and coral are 33°

/1 Rotary drilling penetration rates

Rapid	:	over 0.3 m/min.
Medium	:	0.05 - 0.3 m/min.
Slow	:	less than 0.05 m/min.

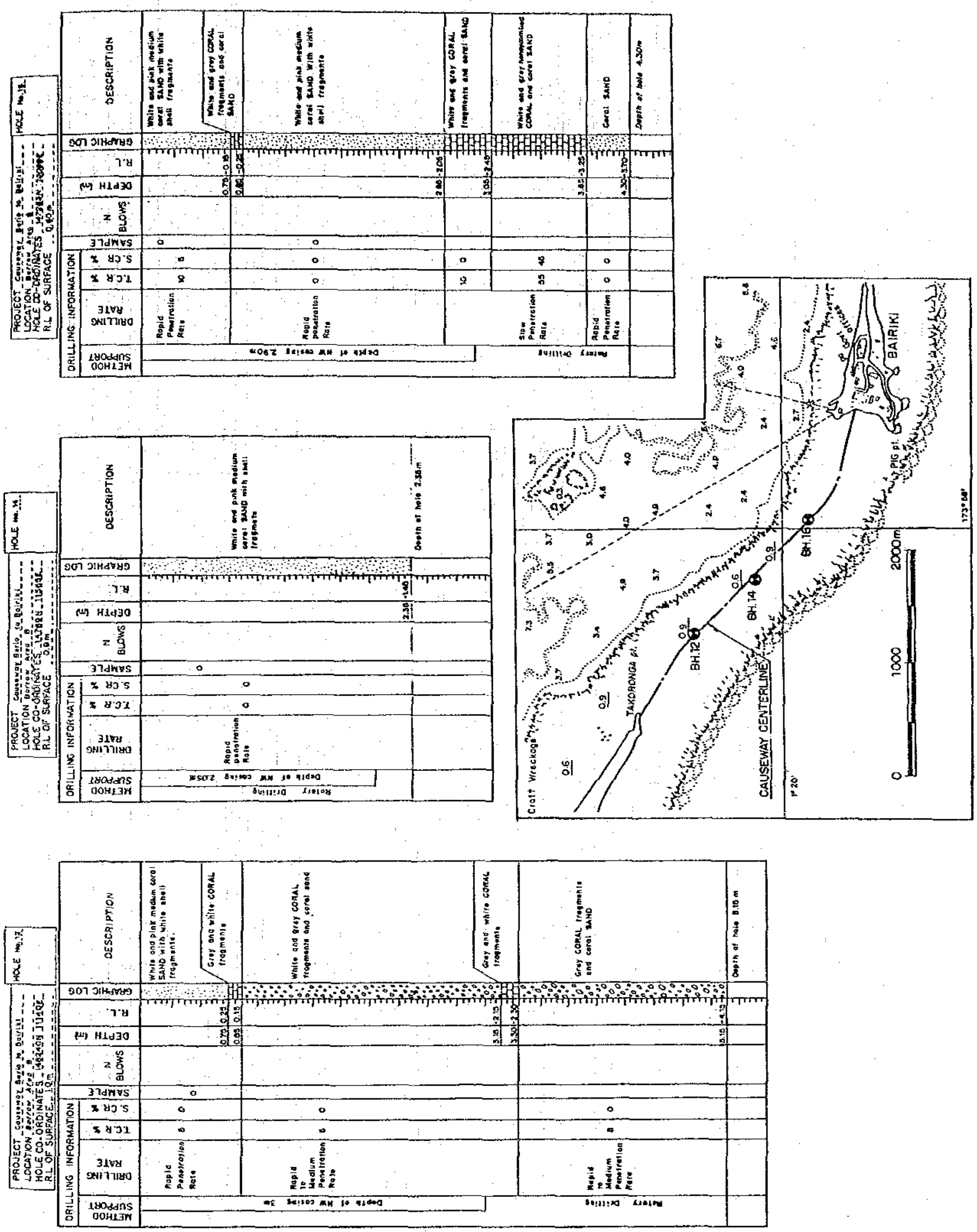
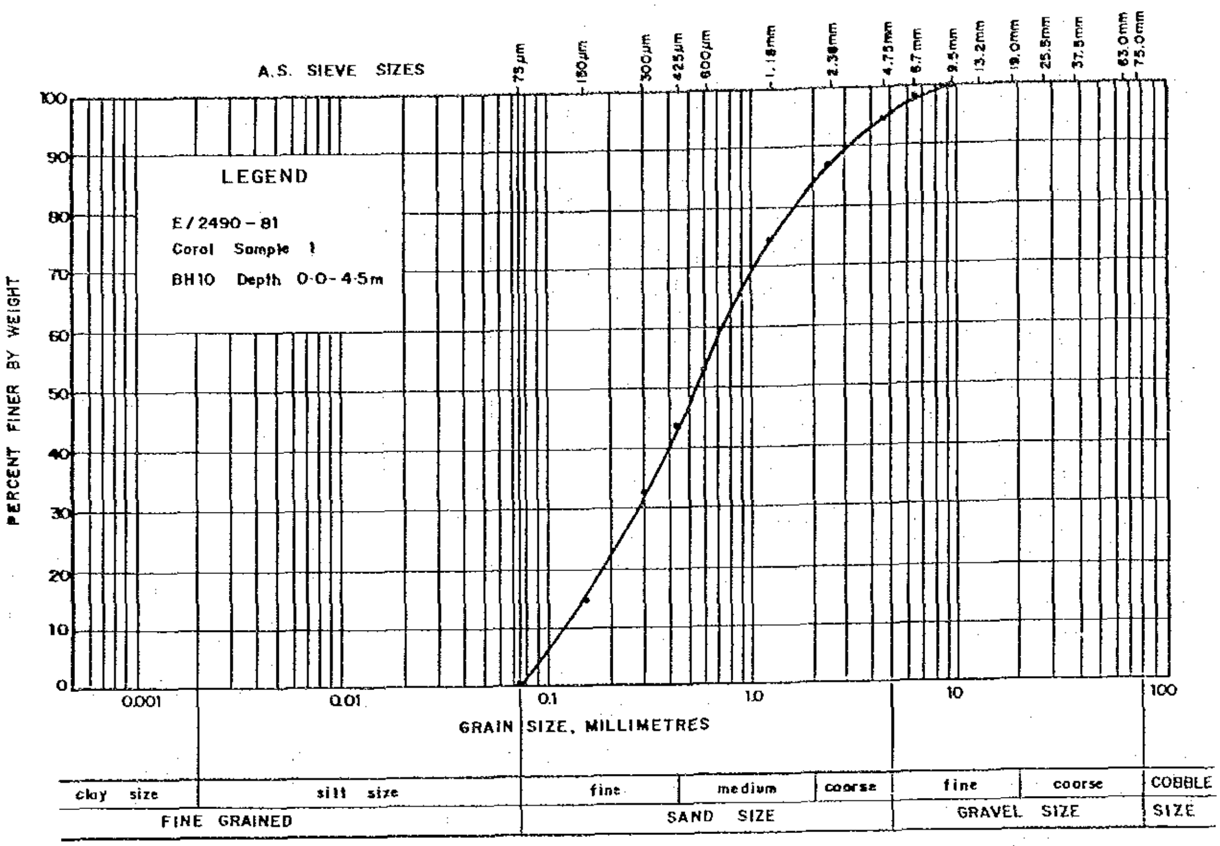


Figure 4-1 Boring Logs



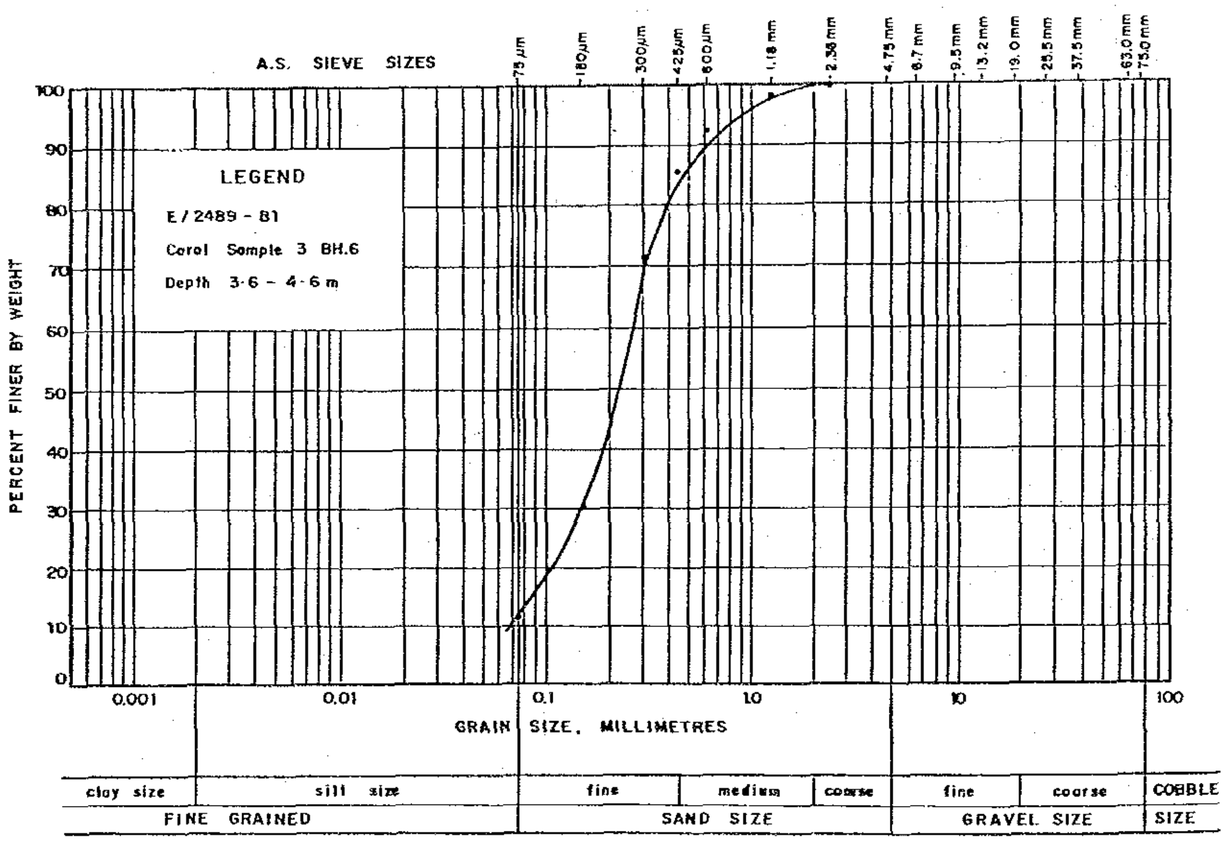


Figure 4-2 Grain Size Accumulation Curve of Sand

and 38°, respectively. In case that the slope is 1:1.5 with sand material having an internal friction angle of 33°, the critical embankment height should be around 5 meters. The compacting test results show that the maximum dry densities of sand and coral are 1.58 t/m^3 and 1.60 t/m^3 with their corresponding optimum water contents of 13.1% and 17.5%, respectively. The grain gize accumulation curve of sand is shown in Fig. 4-2.

(2) For Construction of the Bridge and Channel

Since there were no bore holes taken at the proposed locations of the bridge and channel, the soil conditions at the these locations were estimated based on the results of adjacent borings. The layer in a depth from DL - 1.45 m to DL - 2.95 m is of dense honeycombed coral rock with lens-shaped insertion of coral sand. The layers underneath the coral rock consist of a thin sand layer and a coral layer.

According to the results of the boring and penetration test, the penetration rate of coral rock is less than 0.05 m/min., and the total core recovery of core sample is 56%.

Judging from the results of the borings at the adjacent location to the proposed channel, the uppermost layer from the ground level to a depth of DL - 1.45 is non-consolidated coral sand with shell fragments.

At the ocean side and lagoon side tips of the reef, the existence of hard coral rock was confirmed by field investigation. This coral rock is judged to have a speed of elastic wave (P-wave) of 2,500 - 3,400 m/sec, and will need to be lasted for excavation.

4.3 Basic Design

4.3.1 Design Standards

The design standards of causeway, fisheries channel and bridge are established as described below:

(1) Design Standard of Causeway

(i) Design speed : 65 km/hr.
The volume of diverted traffic from the ferry and induced traffic is predicted to be a total of 500 - 1,000 vehicles per day upon construction of the causeway. For such a low traffic level, a high design speed is not required. However, since the causeway forms a part of the country's single trunk road which passes over flat topography, and actual travelling speed of vehicles is estimated to be 60 - 70 km/hr. As such, the design speed was set at 65 km/hr.

(ii) Carriageway width : 6.0 m (2 lanes for 2 directions)
The lane width was determined to be 3.0 m which is the minimum width required to maintain the standrds of the national road. Two lanes were provided for two opposite directions taking into account its function as a national road and the future traffic level. Therefore, the carriageway width was designed to be 6.0 m.

(iii) Shoulder width: 2.50 m x 2
Shoulder space will be needed as a car parking strip and a side walk. Thus, the shoulder width was determined at 2.50 m as that is the minimum width required for car parking without disturbing the traffic passing on the carriageway.

(iv) Formation width : 11.0 m

The formation width of the causeway is 11.0 m in total, 6.0 m of carriageway plus 2.5 m x 2 for the shoulders. Since the slope protection has been designed for the embankment slopes, no protection for the shoulder was provided.

(v) Slopes of the causeway

The slopes of the causeway is protected against ocean wave erosion by concrete structures on both the ocean side and the lagoon side.

(vi) Pavement

The whole formation width is paved to minimize damage by wave overtopping. Double bituminous surface treatment, the standard types of pavement structure in the country, is employed for the carriageway and the soil-cement for the shoulder..

(vii) Alignment

The following standards are used for the design of horizontal and vertical alignments, (determined for a design speed of 65 km/hr), referring to the Japanese Geometric Standard.

Min. radius of horizontal curve	:	100 m
Min. radius of vertical curve	:	1800 m
Min. length of vertical curve	:	55 m
Max. grade	:	5 %

(2) Design Standard of Fisheries Channel

(i) Fishing boats

The largest existing outboard motorboat running through the present fisheries channels in the Project area is

considered as the standard boat for channel design.
Its dimensions are:

boat length : 6.4 m (21 ft)
boat width : 2.0 m (6.6 ft)
max. draft : 0.78 m

(ii) Channel width

Since the channel is rather short and frequent passings of fishing boats are presumed, the channel width is 10 m, based on the following calculation.

Required width = boat length x 1.5
= 6.4 x 1.5 = 9.6 ≑ 10 m

(iii) Channel depth

The channel depth was determined as follows so as to allow the passing of fishing boat at low water level:

- max. draft	: 0.78 m
- allowance from bottom of boat (according to Japanese Standard)	: 1.00 m
Total depth	: 1.78 m

Therefore, the bottom level of the channel shall be DL-1.69 m or less (MLWS-1.78 = DL+0.09 - 1.78 = DL=1.69).

(iv) Vertical navigation clearnace

The navigation clearnace of 2.6 m as detailed below is kept above the M.H.W.S. (DL+1.80 m):

- Setup in the reef area by the breaking of an ocean wave : 0.70 m
- Wave height in reef area x ½ : 0.35 m
- Free board, trim, sitting height of fisherman, etc. : 1.55 m

Total	2.60 m

(v) Slope of channel

The slope of the proposed channel is designed to be 1:3, since the material along the channel is composed of coral sand and rocks.

(vi) Others

The entrance of the channel at the edges of the reef will be widened for safe navigation, taking into account the propagating direction of the waves.

(3) Design Standard of Bridge and Other Structures

(i) Loading

The "Specifications for Highway Bridges, Japan Road Association" was used as the basis for the loading. Such loads relating to natural conditions such as earthquakes, wind and temperature were determined taking into account the specific local characteristics of the Project area. Consideration was given to plans for future installation of electric cable, telephone cable and water supply pipe in estimating the dead load. The design load applied for the design of the bridge are compared with those in AASHTO's standard and those in the Japanese Standards (refer to Appendix 4-6). Details perteining to various type of loading are listed as follows:

a) Dead load

The dead load consists of the weight of the complete structure, including pavement, sidewalks, railing and any additions. The unit weights used in computing dead load were taken from Japanese Standards. The following unit weights were used for cables and pipe:

electeric cable	: 9 kg/m
telephone cable	: 2 kg/m
water supply pipe	: 47 kg/m

b) Live load

TL-20 according to Japanese Standards

c) Impact

$$i = \frac{20}{50 + L} \text{ (for T load)}$$ Note: T = Truck

$$i = \frac{10}{25 + L} \text{ (for L load)}$$ Note: L = Line

where, i = impact coefficient
L = span length (m)

d) Pedestrian load

350 kg/m^2 according to Japanese Standards

e) Wind load

Design wind velocity = 23.2 m/sec = 84 km/hr,
(return period = 50 years)

Basic wind load = 244 kg/m^2 (AASHTO 1.2.14)

Basic wind velocity = 160.9 km/hr (AHSHTO 1.2.14)

Horizontal wind load was calculated at 70 kg/m^2, by multiplying the square of the design wind velocity/ basic wind velocity to the basic load.

f) Seismic load

In the past 11 years between 1973 and 1983, earthquakes with a magnitude more than 5.8 occurred 5 times in Kiribati. The epicenters of these earthquakes were situated in the area of 3.4°S - 3.5°S and 177.6°E - 177.8°E (to the southeast of Arorae Island), more than 700 km distant from Tarawa. Their hypocenter were situated at a depth of 31 km to 33 km underground.

The expected acceleration of bedrock at the project site was estimated based on the method in "Manual for Earthquake Resistant Design, Japan Road Association", as detailed in Appendix 4-7. The expected acceleration of bedrock was calculated at 1%. In the design, 0.05 (the minimum value used in the design in Southeast Asian countries), was taken as the horizontal seismic coefficient, and the seismic load was calculated based on the following equation.

$$HE = 0.05\ W$$

where, HE = Horizontal seismic force (ton) of earthquake

W = Total dead weight of structure (ton)

g) Thermal forces

Not applicable for the type of bridge.

h) Wave force

The following equation of the Japanese Standards was used to calculate the wave force:

$p = 1.5\ WxH$

where, p : wave force by breaking (ton/m^2)

W : unit weight of seawater (ton/m^3)

H : Wave height (m)

i) Earth pressure

Based on Coulomb's earth pressure theory

(ii) Materials

- Reinforced concrete

  28 days compressive strength
  (cylinder specimen) : 210 kg/cm^2

  Cement : ordinary portland cement (JIS R 5210) or blast furnace slag cement (JIS R 5211)

  Aggregate: to be collected in Tarawa Island

- Sealing concrete (underwater concreting)

  28 days compressive strength
  (cylinder specimen) : 180 kg/cm^2

  Materials are same as those for reinforced concrete

- Reinforcing bar (deformed bar)

  SD 30 (JIS G 3112)

  Yield point : more than 30 kg/mm^2

  Max. tensile stress: 49 to 63 kg/mm^2

  Allowable stress : 1,400 kg/cm^2
  (for concrete slab bridge with a span less than 10 m)

4.3.2 Alternative Study

The type of slope protection for the causeway embankment, embankment height, parapet height and type of temporary protection of slope against erosion of embankment materials during construction were determined based on a comparative study of alternatives. The results of the comparative study are outlined below.

(1) Slope Protection Work

Taking into account the scale of ocean waves at the site, construction ease and available material, three alternative plans were made: i) concrete structure, ii) gabion and iii) riprap. Considering the structural stability of the embankment body itself, wave runup and cost, the plan using a concrete structure was selected. The slope of the concrete structure is to be 1:1.5 and its foundation shall be embedded into the reef for a depth of 50 cm from ground level, with protection by rubble stone at its front.

(2) Embankment Height and Parapet Height

According to the wave runup along the causeway slope, as calculated for the wave having 50-year probability (refer to Appendix 4-8), the required parapet height is up to DL + 3.80 on both the ocean side and lagoon side. For the formation level of the causeway embankment, two alternative plans were prepared: i) at DL + 3.00 m and ii) at DL + 3.30 m. Based on the results of a cost comparison study, the formation level was set at DL + 3.30 m.

(3) Temporary Protection Work

In order to protect the causeway embankment against erosion of materials by tidal currents during construction, a temporary protection was designed. As of the 2 types considered (sand bags and sand mat), the use of sand bags was selected as the technically more reliable.

4.3.3 Design Features

(1) Causeway

(i) Horizontal alignment

The horizontal alignment was designed in the right angle to the direction of the waves which move from the open sea towards the atoll, in order to lossen the adverse effects of the wave force.

(ii) Formation level

Though the minimum height required is DL + 3.20 m, which is the same as the road levels in Betio and Bairiki Islands, the formation level was set at DL + 3.30 m in order to reduce the volume of concrete for the parapet walls which are to be constructed as a protection against overtopping of waves. At the crossing point with the fisheries channel, the formation level was raised to DL + 5.38 m in order to maintain the navigation clearance.

(iii) Pavement

In order to minimize possible damage to the causeway by wave overtopping, the causeway will be paved for its full formation width. Double Bitumiuons Surface Treatment, the standard type of pavement structure in the country, will be used for the carriageway. Both shoulders will be paved with soil cement in order to make them easily distinguishable from the carriageway.

(iv) Parapet walls

In order to minimize possible damage to the causeway embankment by overtopping of waves, parapet walls will be constructed on the edge of both shoulders.

(v) Slope protection

The causeway slopes will be covered by a concrete mat to avoid erosion by waves. A concrete mat, pressure injection of concrete into mat, will be used, as it was found to be the most economical type of slope protection.

(vi) Sand bags

Sand bags will be installed at the toe of the embankment in order to secure embankment work and prevent materials from being carried away by tidal current and wave induced current. This work will be carried out in advance of the embankment fill being placed.

(vii) Stairs on embankment slope

The design slope of the causeway embankment is rather steep at 1:1.5 since the slope will be covered by a concrete mat. Therefore, stairs are provided on the slope at intervals of 200 - 300 m to facilitate fishermen's access to the seashore.

(viii) Relocation of existing water pipe and cables

Presently, an underground water pipe, telephone cable and electric cable exist along the proposed alignment of the causeway. As such, care will have to be exercised during the construction stage so as not to cause damage to the pipe and cables. Eventually, they will be relocated to areas under the shoulder portion of the causeway.

A typical cross section of the causeway is shown in Fig. 4-3.

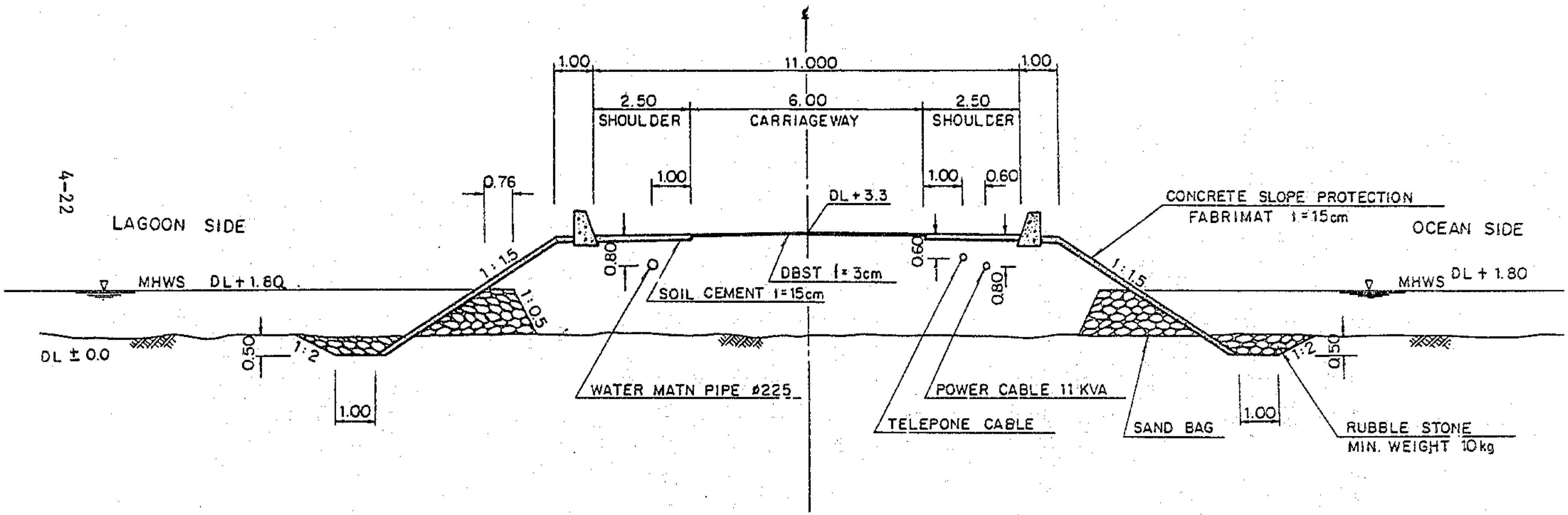


Figure 4-3 Typical Cross Section of Causeway

(2) Fisheries Channel

(i) Location of channel

The fisheries channel will be constructed to cross the causeway at Sta. 15 + 45 as shown in Fig. 4-4.

Its length will be 800 meters from the reef edge on the lagoon side the reef edge on the ocean side.

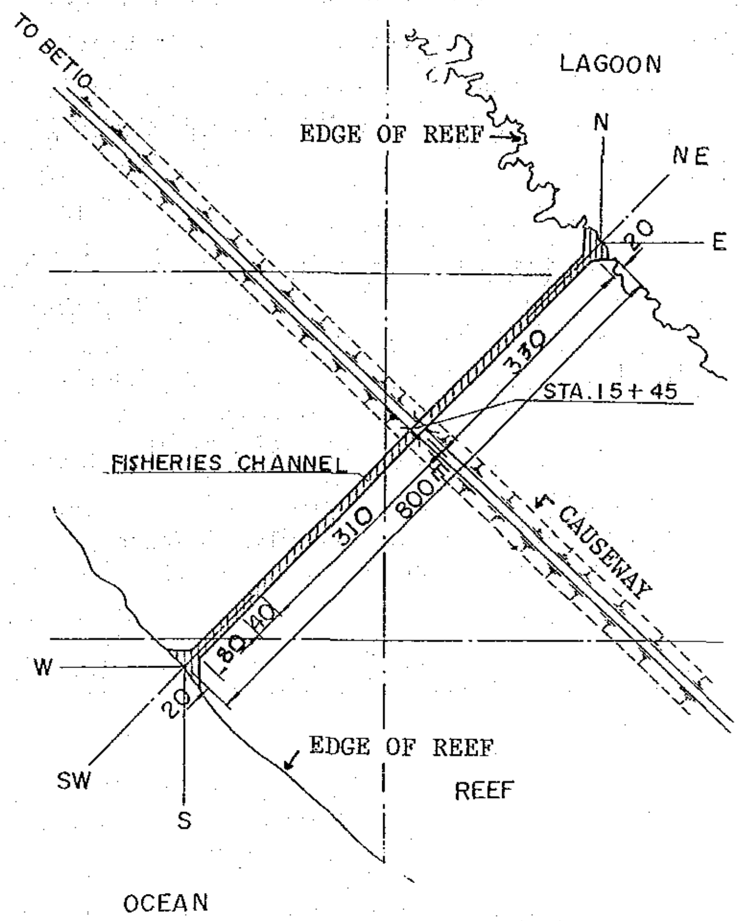


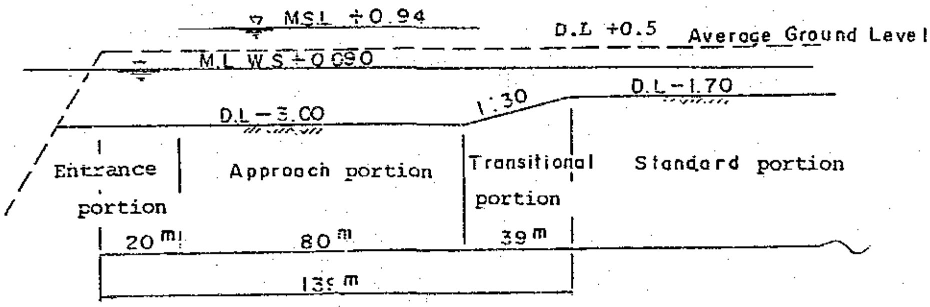
Figure 4-4 Layout of the Fisheries Channel

(ii) Width, depth and slope of channel

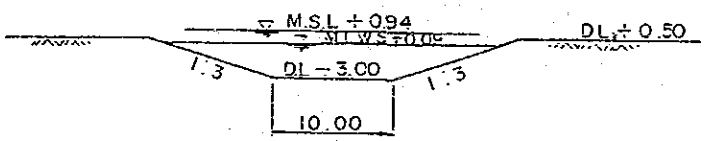
According to the design standards described in section 4.3.1., the width, depth and slope of channel are listed below:

Width	: 10 m	(at the bottom)
Depth	: DL - 1.70 m	(Standard section)
Slope	: 1:3	

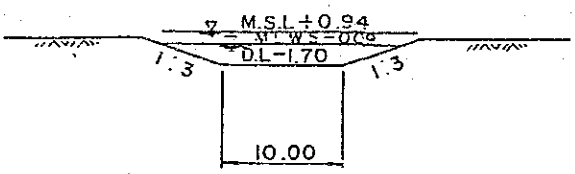
(iii) Entrance, approach & standard portion of the channel
The entrance portions, 20 meters from edges on both ocean and lagoon sides, will be widened not to cause wave breaking for easy entrance of fishing boats. The approach portion, 80 meters from the end of entrance section on the ocean side, was designed to have its bed elevation at DL-3.0 m not to cause wave breaking and from there its bed elevation will be gradually heightened to the elevation of the standard portion as shown below:



Longitudianl Section of the Approach Section of the Fisheries Channel (Ocean Side)



Cross Section of Approach Portion



Cross Section of Standard Portion

Figure 4-5 Profile and Cross Sections of the Approach Portions of the Fishery Channel on the Ocean Side

The approach portion on the lagoon side will be the same as that of the standard portion (i.e., no transition portion).

The design calculations for the channel bed elevations are described in Appendix 4-9 and is summarized below.

Table 4-3 Summary of Study Results on Water Depth of the Fisheries Channel

Tide	Tidal Level	Design Wave Height Enterance		Approach Portion		Standard Portion		Remarks
		Begin-ning	End	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 Wave
M.S.L	+0.94	1.80	1.80	2.75	3.94	2.28	2.64	Non-Breaking Wave
M.H.W.S	+1.80	1.80	1.80	2.75	4.80	1.67	3.50	Non-Breaking Wave

Based on the above results, ocean waves will not break at the approach portion of the fisheries channel (under the design condition) when these waves are lower than 0.8 m at MLWS. In order to prevent the breaking of a design wave of 1.8 m at MLWS, the approach channel would have to be excavated to a depth of 4.13 m but such a deep excavation will be uneconomical.

Moverover, according to the results concerning the study of water depth needed in the approach portion of the fisheries channel, waves (0.8 to 1.8 m in height) which are entering in a straight line from a southwestern direction to the channel