5－1　プロジェクト便益

5－1－1　フェリーからの転換交通量による便益

(1)　将来交通需要予測

現行フェリー輸送の1984年における実績をベースにし，ベシオ，バイキリ間の将来交通需要を予測した結果次表5－1の様になった。

表5－1　将来交通需要予測（ベシオ・バイリキ間）

年	旅客輸送（人）	車両輸送（台）	貨物輸送（トン）フェリー	はしけ	合計（トン）
1984	394,117	8,221	3,496	3,570	7,066
1987	420,705	9,036	3,842	3,924	7,766
1992	465,400	10,577	4,497	4,593	9,090
1997	508,821	12,381	5,265	5,377	10,642
2002	556,293	14,493	6,163	6,294	12,457
2007	608,195	16,965	7,214	7,367	14,581

旅客輸送の伸びに関しては第2章に示した南タラワの人口増と等しく増加するものとして次の増加率を適用した。

1984年～1990年　　年間 2.2%

1991年以降　　年間 1.8%

車両及び貨物輸送の伸びに関しては第2章2－3－2(2)で求めた実質経済成長率と等しく増加するものとして3.2%の増加率を適用した。

(2)　フェリーからの転換交通量

連絡路完成後には現行のフェリー（はしけを含む）は廃止され，ベシオ・バイリキ間の人及び物資の移動は車両による陸上交通によって行われる。フェリーからの転換交通量は大きく分けて（ｉ）旅客と（ii）車両および貨物の2グループに分けられる。

（ｉ）旅客の転換交通量

転換交通量は表5－1で得られたフェリー旅客の将来輸送量を，交通調査のフェリー利用アンケート調査及び交通量調査の結果得られた車種別の分担率及び車種別

平均乗員数（表５－２）をもとにして車両台数に換算した。その結果を表５－３に示す。

但し，転換交通量を推移するにあたっては次の前提条件がある。即ち

－連絡路完成後にはバスサービスシステムの再編成が行われ，ベシオ・バイリキ間には現行と同様なサービスが行われる。

－従って連絡路利用の車種分担率は現行と同じとする。

表５－２　車種別の分担率と平均乗車人数

	Type of Vehicle (%)	Average No. of Passengers (person/vehicle)
Motorcycles	16	1.2
Passenger Cars	14	2.0
Mini Buses	45	14.1
Trucks	25	3.2

表５－３　フェリー旅客輸送からの転換交通量

(Unit: vehicle/year)

Year	Motor-Cycle	Passenger Car	Mini Bus	Truck	Total	(%)
1987	56,094	29,449	13,427	32,868	131,838	(100)
1992	62,053	32,578	14,853	36,359	145,844	(111)
1997	67,843	35,617	16,239	39,752	159,451	(122)
2002	74,172	38,941	17,754	43,460	174,327	(135)
2007	81,093	42,574	19,410	47,515	190,592	(148)

（ii）車両及び貨物の運転交通量

現在フェリーによって運ばれている車両の構成はモーターサイクルが80％，トラックが20％となっている。コーズウェイ完成後においてもこの構成比は変化しないものとして車種別台数を求めた。

貨物についてはすべてトラック輸送に転換されるものとし，又一台当たりの平均積載量を２トンとして転換車両台数を求めた。その結果を表５－４に示す。

（iii）転換交通量の合計

旅客による転換交通量（表５－３）と車両及び貨物による転換交通量（表５－４）を合計した総転換交通量を表５－５に示す。

表５－４　フェリーからの車両及び貨物の年間転換交通量

(Unit: vehicle/year)

Year	Motor-cycles	Passenger Cars	Mini Buses	Trucks	Total
1987	7,229	-	-	5,690	12,919
1992	8,462	-	-	6,661	15,123
1997	9,905	-	-	7,797	17,702
2002	11,594	-	-	9,127	20,721
2007	13,572	-	-	10,684	24,256

表５－５　フェリーからの総転換交通量

(Unit: vehicle/year)

Year	Motor-cycles	Passenger Cars	Mini Buses	Trucks	Total
1987	63,323	29,449	13,427	38,558	144,757
1992	70,515	32,578	14,853	43,020	160,966
1997	77,748	35,617	16,239	47,549	177,153
2002	85,767	38,941	17,754	52,587	195,049
2007	94,665	42,574	19,410	58,199	214,848

(3) 連絡路による輸送費用節約便益

連絡路完成に伴う輸送費用節約便益には走行費用節約便益と時間費用節約便益の２つが考えられる。これらの費用算出にあたっての前提条件は以下の通り。

＜前提条件＞

－フェリーの運行頻度は現行と同じとし，交通量の増加に対応して新船購入時に大型化する。

－新船は1987年に２隻，1988年に１隻を購入する。
船の耐用年数は15年とし，新船の容量は現行フェリーの５割増とする。

－新ターミナルはベシオ島の東端近くの TAKORONGAに建設されるものとし，着工1986年，供用開始は1987年と仮定する。

－新ターミナル開港後のベシオ・バイリキ間の所要時間は現行の45分から30分になると仮定。

上記の前提条件をもとに走行費用節約及び時間費用節約便益を求める。

（ｉ）走行費用節約便益

フェリーによる海上輸送費用（将来の投資費用を含む）と，コーズウェイに転換した車輌による陸上輸送費用の差として走行費用節約便益を求める。

ａ．フェリーの輸送費用

イ　フェリーの運行費用（人件費，維持修理費，燃料費）

ロ　新船購入費

ハ　新フェリーターミナル建設費

ニ　新フェリーターミナル維持管理費

これらの費用の内訳，詳細は附属資料５－１に示す。下記（表５－６）に今後20年間のフェリーの運行，維持管理費用を推計した。

表 5 - 6　フェリーの運行，維持管理費用

(1000 A$)

Year	New Port Const-ruction Cost	Port Mainte-nance Cost	Ferry Invest-ment Cost	Staff Costs	Ferry Mainte-nance and Repair Costs	Ferry Fuel and Lubri-cants Costs	Lighter Operat-ing Costs	Total Ferry Transport Costs
1986	526	-	-	-	-	-	-	526
1987	0	1	1,170	94	37	76	19	1,397
1988	0	1	585	94	37	76	19	812
1989	0	1	0	94	37	76	20	228
1990	0	1	0	94	37	76	20	228
1991	0	1	0	94	37	76	21	229
1992	0	1	0	94	37	76	21	229
1993	0	1	0	94	37	76	22	230
1994	0	1	0	94	37	76	22	230
1995	0	1	0	94	37	76	22	230
1996	0	1	0	94	37	76	23	231
1997	0	1	0	94	37	76	23	231
1998	0	1	0	94	37	76	24	232
1999	0	1	0	94	37	76	24	232
2000	0	1	0	94	37	76	25	233
2001	0	1	0	94	37	76	25	233
2002	0	1	1,404	94	37	76	26	1,638
2003	0	1	702	94	37	76	26	936
2004	0	1	0	94	37	76	27	235
2005	0	1	0	94	37	76	27	235
2006	0	1	0	94	37	76	28	236
2007	0	1	0	94	37	76	28	236
Salvaged Value			-1,498					-1,498
Total	526	21	2,363		777	1,596	492	7,749

b．車両の輸送（走行）費用

車両の走行費用は，燃料費，潤滑油，タイヤチューブ費，減価売却費及び利子，維持修理費，乗務員費及び管理費（バス，トラックのみ）から構成される。車種別のこれらの走行費用単価を表５－７にまとめた。

表５－７　車種別走行費用単価

(A¢/KM)

	Fuel Cost	Oil Cost	Tire and Tube Cost	Deprecia-tion and Intrest Costs	Repair and Main-tenance Costs	Operator and Over-head Costs	Total
Motorcycles	2.2	.05	.04	1.73	.16	0	4.18
Passenger Cars	4.4	.09	.35	6	.85	0	11.69
Mini Buses	6.9	.15	.98	12.96	5.17	11.4	37.56
Trucks	6.2	.13	.89	6.7	2.62	4.1	20.64

上記走行費用単価に走行距離（4.0 km），将来交通量（表５－４参照）を乗じて総走行費用を求めたのが表５－８である。

表５－８　転換交通の総走行費用

(A$)

Year	Motor-cycles	Passenger Cars	Mini Buses	Trucks	Total
1987	10,588	13,771	20,172	31,833	76,364
1992	11,790	15,233	22,315	35,518	84,856
1997	12,999	16,655	24,397	39,256	93,308
2002	14,340	18,209	26,674	43,416	102,639
2007	15,828	19,907	29,162	48,049	112,947

c、走行費用節約便益

走行費用節約便益は上記で求めたフェリー輸送費用(a)と車両の輸送（走行）費用(b)の差によって求める。その結果を表5－9に示す。

表5－9　走行費用節約便益

(1000A$)

YEAR	Without Project (1) Transport Cost by Ferry	With Project (2) Vehicle Operating Cost	(1)-(2) Transport Cost Savings with Causeway
1986	526	-	526
1987	1,397	76	1,321
1988	812	78	734
1989	228	80	148
1990	228	81	147
1991	229	83	146
1992	229	85	144
1993	230	87	144
1994	230	88	142
1995	230	90	140
1996	231	92	139
1997	231	93	138
1998	232	95	137
1999	232	97	135
2000	233	99	134
2001	233	101	132
2002	1,638	103	1,535
2003	936	105	831
2004	235	107	128
2005	235	109	126
2006	236	111	125
2007	236	113	123
SALVAGE VALUE	-1,498	-	-1,498
TOTAL	7,749	1,972	5,777

(ii) 時間費用節約便益

フェリーによる所要時間と車による所要時間との時間差を時間費用節約便益として求める。ベシオ・バイリキ間の所要時間は次の様に設定する。

- 現行フェリーの所要時間（ Withou Project ）
  - ・ベシオ（タコロンガ新フェリーターミナル）・バイリキ間
    フェリー所要時間 ………………………………………… 30分
  - ・フェリー乗降，荷役時間 ……………………………… 15分
  - ・合計所要時間 …………………………………………… 45分
- 車両による所要時間
  - ・コーズウェイ及びアクセス ………………… 総延長 4.0km
  - ・平均走行速度 …………………………………………… 40km/hr
  - ・所要時間 ………………………………………………… 6分
- 時間節約（1トリップ当たり） 45分 − 6分 = 39分

時間節約の対象になるのは旅客のみとし，車両や貨物については考えない。又，時間節約の対象となる旅客のうち学生や失業者等の非就業者は節約された時間を生産にまわす事はできないので対象からはずす。就業者の平均時間価値は，給与所得者の40%を占める公務員の平均的な賃金を参考にし，A$1.20／hrとする（附属資料5－2参照）。

従って，車種別の1台当り時間費用は次の様になる。

表5－10 車種別の1台当たり時間費用

	Motor-Cycle	Passenger Car	Mini Bus	Truck
(1) Average Occupancy (Persons/Vehicle)	1.2	2	14.1	3.2
(2) Employed Persons per Vehicle /1 (1)*0.4	0.48	0.80	5.64	1.28
(3) Passenger Time Value (A$/Vehicle) /2	0.58	0.96	6.77	1.54

/1 Estimated to be 40% of total occupant per vehicle

/2 Estimated to be A$1.20 per hour

この一台当たり時間費用に，節約時間（39分）及び車両台数（表５－３）を乗じてトータルの時間費用節約便益を求める。その結果を下表５－11に示す。

表５－11　車種別時間節約便益（転換交通）

(A$ 1000)

Year	Motor-cycles	Passenger Cars	Mini Buses	Trucks	Total
1987	21	18	59	33	132
1992	23	20	65	36	145
1997	26	22	71	40	159
2002	28	24	78	44	174
2007	31	27	85	48	190

５－１－２　誘発交通量による便益

（ｉ）誘発交通量の推計

誘発交通量はコーズウェイ開通に伴う運賃の低下，所要時間の短縮による利便性の向上に起因して発生する。

誘発交通の対象となるのは旅客交通と貨物輸送であるが，貨物については地域経済の大きさに制約される事から予測を行うのは困難であり，推計の対象としない。

旅客交通の誘発要因としては運賃と時間の二つの要因が考えられるが，同地域の低い所得水準を考えると運賃の低減による効果が交通誘発の主要因として考えられる。

誘発交通量は以下に示す式によって推計する。

$$IT = IR \times NT$$

ＩＴ：誘発交通量

ＩＲ：誘発率

ＮＴ：通常交通（この場合コーズウェイが完成した初年度の転換交通量）

誘発率ＩＲは次式によって求める

$$IR = \left(\frac{FC}{CC} - 1\right) \times DE$$

ＦＣ：フェリーの旅客運賃（A$0.70／人）

ＣＣ：コーズウェイ利用時の輸送費用（A$0.40／人）

ＤＥ：需要弾性値　(1.0)

ＦＣは現行フェリーの大人料金を代表値とし，ＣＣについては現行のバス料金から連絡路内バス料金を40セントと推定し，この値を代表値とした。ＤＥについては他国の実績から 1.0と仮定した。その結果誘発率ＩＲ＝ 0.75 を得た。又，フェリー利用者アンケート調査の結果，旅客の６割は誘発交通の期待できない通勤，通学者である事から，通常交通（ＮＴ）は表５－３で得られたフェリー乗客による転換交通量の40％のみ計上し，これを誘発交通量算出のベースとする。

誘発交通量は転換交通量と同じ伸び率で増加していくものとし，下表の様に推定した。

表５－12　年間誘発交通量の推定

(Unit: vehicle/year)

Year	Motor-cycles	Passenger Cars	Mini Buses	Trucks	Total
1987	16,828	8,835	4,028	9,860	39,551
1992	18,616	9,773	4,456	10,908	43,753
1997	20,353	10,685	4,872	11,925	47,835
2002	22,252	11,682	5,326	13,038	52,298
2007	24,328	12,772	5,823	14,255	57,178

(ⅱ) 誘発交通量による便益

誘発交通量による便益は，通常交通（転換交通）の便益の 1/2を計上してよい事が経験的に認められている。従って誘発交通による輸送費用節約及時間節約便益は次のようになる。

表５－13　誘発交通による輸送用節約及び時間節約便益

(A$1000)

Year	Cost Saving Benefits	Time Saving Benefits	Total
1987	34	20	54
1988	35	20	55
1989	36	21	57
1990	36	21	57
1991	37	22	59
1992	38	22	60
1993	39	22	61
1994	39	23	62
1995	40	23	63
1996	41	23	64
1997	41	24	65
1998	42	24	66
1999	43	25	68
2000	43	25	68
2001	44	26	70
2002	45	26	71
2003	46	26	72
2004	47	27	74
2005	47	27	74
2006	48	28	76
2007	49	29	78
TOTAL	870	504	1,374

5－1－3　漁船用水路による便益

漁船用水路建設による節約便益としては次の二つが考えられる。

（ｉ）燃料の節約

（ii）漁場への時間節約に伴う漁獲高の増加

現行の外洋漁業は次の様なシステムで行われている。

－　操業漁船数

　ベシオ島　20　隻

　南タラワ本島　17　隻

－　操業日数

　ベシオ島漁船

　漁場まで直行できる日数　22日／月

　干潮時に迂回する日数　4日／月

　南タラワ本島漁船

　漁場まで直行できる日数　22日／月

　干潮時に操業しない日数　4日／月

－　漁場への距離

　ベシオ島漁船

　直行できる場合（片道）　14.0マイル

　迂回する場合（片道）　19.5マイル

　南タラワ本島漁船　14.0マイル

－　1航海に要する所要時間　5.0時間

－　帰路における潮の待ち時間

　小潮時における待ち時間　1.0時間／日×8日／月

－　漁船の性能

　船外機　40ＨＰ

　燃料消費　1ℓ／マイル×A$0.77／ℓ＝A$0.77／マイル

　航走速力　13マイル／時間

－　迂回に要する時間（1トリップ当り）

（19.5－14.0）マイル÷13.0マイル／時間×２（往復）＝0.85時間

－ 漁場へ直行できる場合の操業時間

5時間－｛14.0マイル÷13マイル／時間×２（往復）｝＝ 2.85 時間

－ 漁場へ行くのに迂回しなければならない場合の操業時間

＝ 2.85 － 0.85

＝ 2.0時間

（ｉ）燃料費の節約

南タラワ本島の漁船は小潮の干潮時には出漁しないので漁船用水路ができる事によって燃料費節約の対象となるのは小潮の干潮時に迂回して漁場に向うベシオ島の漁船のみである。

ベシオ島漁船の燃料節約は年間１隻当たり次のようになる。

S_0 ＝（ 1.95 マイル－14.0マイル）×２（往復）×A$ 0.77 ／マイル

×４日／月×12月／年

＝A$406.56／隻・年

ベシオ島には20隻の漁船があるので年間当りの燃料節約便益は

S_B ＝A$406.56／隻・年×20隻＝A$8.131／年

ベシオ島の冷凍施設の容量は限界があり漁船数の伸びは制限される。従ってここでは過大評価を避ける為に漁船数の伸びはないものとし，現行のままとする。

（ii）時間費用節約による便益

漁船用水路の建設により，漁船は迂回時間及び帰途の待ち時間を解消できる。節約された時間は漁の操業時間の増加に使われるものとし，それによる漁獲高の増加を便益と考える（附属資料５－１－３参照）。

ａ．節約時間

ベシオ島漁船の節約時間

＝迂回時間の節約（４日間／月）＋帰途待ち時間の節約（８日／月）

＝ 0.85 時間（往復）／日×４日／月×12ヶ月／年＋ 1.0時間／日×８日／月×12ヶ月／年

= 136.6時間／年

南タラワ本島漁船の節約時間

=帰途待ち時間の節約（8日／月）+干潮時に操業できなかった日が操業可能となる日（4日間／月）

= 1.0時間／日×8日／月×12ヶ月／年+ 2.85 時間／日×4日／月×12月／年

= 184.8時間／年

b．時間当り漁獲高

現在漁船の操業時間は魚の鮮度を維持する為，往復時間を含め一航海時間は最大5時間程度に制約されている。従って漁船一隻が漁獲に従事できる時間は漁場迄の往復に要する時間を差引くと次のようになる。

ベシオ島漁船の年間操業時間（現況）

=漁場へ直行できる日（22日／月）+迂回する日（4日／月）

= 2.85 時間／日×22日／月×12月／年+2時間×4日／月×12月／年

= 752時間+96時間

= 842時間

南タラワ本島漁船の年間操業時間（現況）

= 2.85 時間／日×22日／月×12月／年

= 752時間

ベシオ島及び南タラワ本島の漁船の年間の漁獲高はそれぞれ 800トン（20隻）及び 530トン（17隻）であるから，時間当たり漁獲高は次のようになる。

ベシオ島漁船の時間当たり漁獲高

800トン／年÷20隻÷ 842時間／年= 0.048トン／時間・隻

南タラワ本島漁船の時間当たり漁獲高

530トン／年÷17隻÷ 752時間／年= 0.041トン／時間・隻

c．時間節約に伴う漁獲高増加による便益

節約された時間が操業時間に費やされる事により，漁獲高は次のように増加し便益が発生する。

ベシオ島漁船（20隻）の漁獲増加高（年間）

136.6時間／年× 0.048トン／時間・隻×20隻= 131トン

南タラワ本島漁船（17隻）

184.8時間／年× 0.041トン／時間・隻×17隻＝ 129トン

漁獲増加高　合計 260トン

この増加した漁獲量すべてが全量売れると仮定するのは危険であるので安全側にたち初年度は漁獲量の1/2 を漁業公社が買取るものとし，以後毎年経済成長の伸び（ 3.2%／年）と同じ率で販売量は増えるものと仮定する。買取りは全量漁業公社が行い買取り価格は現行のA$0.66／kgとする。

漁獲高増加による便益は次のようになる。

1987年	260トン×1/2 ×A$ 660／トン	＝A$ 85,800
1992年	3.2%の伸び率	＝A$100,435
1997年		＝A$117,567
2002年		＝A$137,620
2007年		＝A$161,095

5－1－4　その他の便益（間接便益）

項目5－1－1から5－1－3まで延べた直接便益の他に，計量化が容易でない次のような間接便益かある。

(1) 社会施設費用節約による便益

(2) 公共施設が受ける社会的便益

(3) 行政の簡素化による便益

(4) ベシオ港，バイリキ港の利用改善による便益

(5) ベレオ島の過密緩和

これらの間接便益は内部収益率法による評価の中には含めないが，その内容は以下の通りである。

(1) 社会施設費用節約による便益

ベシオ島及びバイリキ島に事務所を持つ主要な政府機関及び企業に連絡路完成による費用節約について聴取した結果は次の通りである。

表5－14　主要政府機関及び企業の連絡路完成後の費用節約

	節約費用		備考
	項目	A$／年	
PVB	電気 水道	100,000 45,000	ビケニベウに配置してある緊急用260kw2台が不要になる。 連絡路に水道管を埋設する事による水道施設の維持修理費用の節約
	合計	145,000	
PVU	人件費 修理工場 輸送	(45,500) 10,000 (29,349)	バイリキ修理工場を閉鎖し，ベシオ修理工場に整理統合する事による節約費用
	合計	84,849	
KHC	輸送	(3,500)	フェリーの運賃
SUPPLY DIVISION MINISTRY OF FINANCE	輸送 機械 人件費	(60,000) 36,000 (10,500)	バイリキの倉庫を閉鎖しベシオの倉庫に整理統合する事による節約費用
	合計	106,500	
KCWS	輸送	(14,000)	フェリーの運賃
ABAMARKORO TRADING	輸送	(10,500)	フェリーの運賃
TARAWA MOTORS	輸送	(32,000)	フェリーの運賃
ATOLL AVTOSTORE	輸送	15,600	自家船の費用
合計 (　)含まず		411,449 206,600	

上記の節約費用の内容輸送費用の節約便益は5－1－1に述べた連絡路による輸送費用節約便益に含まれる。人件費の節約費用については雇用機会の少ない南タラワにおいてはむしろマイナスになる可能性もあり，ここでは，節約費用と考えない。残った節約費用は社会施設からのものである。その節約費用はA$200,000／年に達し，社会経済活動に大きなインパクトを与えると考えられる。

(2) 公共施設が受ける社会的便益

その他交通が便利になる事により公共的な機関が受ける社会的な便益がある。警察・病院・学校に聴取した結果を表5－15に示す。

表5－15 連絡路完成後の社会的便益

	現在の問題点	社会的便益
警察	ベシオに本部があり，各支所との連絡が不便。 空港警備，消火作業に対して早期対処が出来ない。 警察活動がフェリーに左右される。 警察官の訓練が十分出来ない。	現在の問題点を解消し，警察活動の近代化を計る事が出来る。
病院	ベシオの病院は入院施設がなく入院患者はビケニベウの中央病院に送る。フェリー経由のため，救急患者の輸送に不安がある。 バイリキに診療所がありベシオの医師が担当しているがフェリーのため十分な診療時間がない。	現在の問題点を解消し，ビケニベウの中央病院の医療活動がベシオにも及び，住民が安心出来る。
学校	ベシオには小学校だけで中学校がない。 中学生はフェリーを経由してテアオライレケアイタ・ビケニベウの中学に通学しなければならない。	現在の問題を解消し，学校活動の時間が増え人材育成に寄与する。

(3) 行政の簡素化による便益

両島がコーズウェイで結ばれる事により政府，公共事業体民間会等は行政，運営面での効率を著しく向上できる。

(4) ベシオ港，バイリキ港の利用改善による便益

フェリーがなくなる事によりベシオ港の混雑緩和が可能になり，荷揚げ作業の効率化が期待できる。又，バイリキ港は漁船専用港として利用が可能になりバイリキ側の水産業拡大に役立つ。

(5) ベシオ島の過密緩和

5－2　プロジェクト費用

プロジェクト費用としては，第４章でもとめた建設費および維持管理費を見込む。

(1)　建設費

建設費は1985年現在の価格をもとに積算した。

工事は1986年度より開始され１年の工期を見込んである。

建設費は￥ 1,154,000千円　となった。

(2)　維持管理費

舗装に関しては５年に一度オーバーレイを行う必要があり，この費用として A＄120,000を1992年，1997年，2002年，2007年度にそれぞれ計上する。

従って維持管理費用は次のようになる。

維持管理費	A＄15,000	（各年度）
舗装オーバーレイ	A＄120,000	（1992，1997，2002，2007年度のみ）

5－3　プロジェクト評価

算定されたプロジェクト便益及びプロジェクト費用をもとにし，プロジェクトライフ20年間の費用及び便益を年度別にまとめると表5－16のようになる。

この結果をもとに内部収益率を算定した結果ＥＩＲＲ＝ 7.9％を得た。

ＩＲＲ 7.9％の値は決して高い値でないが，ＩＲＲの計算に含めていない水産業拡大による便益や，社会施設費用の節約による便益，さらに社会・文化活動に与えるインパクト等非常に大きなものがあり，本事業による開発効果は十分であると考えられる。

表 5 − 16　年度別費用・便益

(A$1,000)

Year	Economic Cost			Economic Benefit							
	Construction Cost of Causeway	Maintenance Cost of Causeway	(1) Total Cost	Diverted Traffic		Induced Traffic		Fishery		(2) Total Benefits	(2)-(1) Net Cash Flow
				Cost Savings	Travel Time Savings	Cost Savings	Travel Time Savings	Cost Savings	Time Savings		
1986	6836	-	6836	526	-	-	-	-	-	526	6310
1987	0	15	15	1321	132	34	20	8	86	1601	1586
1988	0	15	15	734	134	35	20	8	89	1020	1005
1989	0	15	15	148	137	36	21	8	92	442	427
1990	0	15	15	147	139	36	21	8	95	446	431
1991	0	15	15	146	142	37	22	8	98	453	438
1992	0	135	135	144	144	38	22	8	101	457	322
1993	0	15	15	144	147	39	22	8	104	464	449
1994	0	15	15	142	150	39	23	8	107	469	454
1995	0	15	15	140	153	40	23	8	111	475	460
1996	0	15	15	139	155	41	23	8	114	480	465
1997	0	135	135	138	158	41	24	8	118	487	352
1998	0	15	15	137	161	42	24	8	122	494	479
1999	0	15	15	135	164	43	25	8	126	501	486
2000	0	15	15	134	167	43	25	8	130	507	492
2001	0	15	15	132	170	44	26	8	134	514	499
2002	0	135	135	1535	173	45	26	8	138	1925	1790
2003	0	15	15	831	176	46	26	8	142	1229	1214
2004	0	15	15	128	179	47	27	8	147	536	521
2005	0	15	15	126	183	47	27	8	152	543	528
2006	0	15	15	125	186	48	28	8	156	551	536
2007	0	135	135	123	189	49	29	8	161	559	424
Salvage Value	-	-	-	-1498	-	-		-	-	-1498	-1498
Total	6836	795	7631	5777	3339	870	504	168	2523	13181	5550

Economic Internal Rate of Return was calculated at 7.9%.

第６章　結論と提言

第6章　結論と提言

キリバス共和国の首都タラワ環礁において，行政の中心地であるバイリキ島と，同国の経済の中心であり又，唯一の漁港をもち水産業の基地であるベシオ島を連絡路で一体化する計画は，過去にＡＤＢの援助により実施が試みられたが完成に至らずに今日に至っており，その実現はキリバス国民にとって長い夢であった。

本調査団は，キリバス政府より日本政府に対し協力の要請がなされた，上記連絡路の建設と共に，その途中に漁船用水路を開削する計画を調査・検討した。この結果リン鉱石の枯渇後水産業の振興と経済の効率化を図っているキリバス国にとって，本計画の実施が持たらす社会経済的インパクトは水産業を始め，社会経済活動の活性化に大きく貢献するものであると共に技術的にも潮流・波泊等の影響に充分留意すれば建設・維持管理は可能であると判断した。かかる観点から本調査団は日本政府の無償資金協力案件として妥当なものであると結論すると共にその早急な実施を切に望むものである。

本プロジェクトが実現した後，連絡路及び漁船用水路が効果的かつ安全に機能していく様，キリバス国に対して次の様な提言を行う。

(1) 連絡路は線形がよく比較的車のスピードが出やすい為，速度制限（65km／hr）を行い事故防止に対する交通管理を十分に行う。

(2) 連絡路の道路，堤体及び漁船用水路の維持管理については，維持補修項目，定期検査の時期，補修方法等を明記したマニュアルを作成し十分な管理を行う。

(3) 連絡路は海上のリーフ上に建設されるものであり，一度破壊されるとその復旧は容易にできるものではない。従って維持管理に十分な留意をし財政的な面での支障がない様努力する。

以　上

図表リスト

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第2章　計画の背景

附属資料

附　属　資　料

LIST OF APPENDICES

調査日程（第1次）

日 順	月／日	曜 日	調 査 日 程
1	4/5	金	成田21：55発 JL-775便にて調査団ナンディに向けて出発
2	6	土	ナンディ着 9：15着
3	7	日	休日
4	8	月	ナンディ9：00発 DK-301便にてタラワ着 16：00
5	9	火	キリバス関係各省表敬訪問
6	10	水	キリバス関係各省代表者と調査日程内容便宜供与の打合せ
7	11	木	関係各省にて事情聴取・資料収集
8	12	金	同 上
9	13	土	現場調査
10	14	日	不発弾調査・潮流調査
11	15	月	公共事業省Engineerと意見交換
12	16	火	設計条件の検討
13	17	水	関係各省代表者と打合せ，プロジェクト基本設計のガイドライン調印
14	18	木	土取場調査・潮流調査
15	19	金	内部ミーティング
16	20	土	不発弾調査
17	21	日	休日
18	22	月	内部ミーティング・気象データー収集
19	23	火	交通量調査の準備・潮位／潮流観測
20	24	水	交通量調査（12時間）・潮位／潮流観測／川口団員・栗原団員・吉竹団員 タラワ出発
21	25	木	関係公社にて事情聴取・潮流観測／川口団員・栗原団員・吉竹団員 フィジー大使館訪問
22	26	金	関係公社にて資料収集／川口団員・栗原団員・吉竹団員 ナンディ経由シドニィ到着
23	27	土	内部ミーティング・資料収集／川口団員・栗原団員・吉竹団員 シドニィ経由成田帰国
24	28	日	休日
25	29	月	中心線測量・潮流観測
26	30	火	帰国準備
27	5/1	水	タラワ発10：00 ON301便にてナウル経由 OV921便にてスバ着18：00
28	2	木	在フィジー日本大使館訪問 JICA訪問 スバ発13：00（タクシー）ナンディ着16：30 発17：35 QF094 シドニー着20：00
29	3	金	シドニー発21：45 QF201便にて成田向け
30	4	土	成田着6：10帰国

LIST OF PERSONS INTERVIEWED (From 5 Apr 1985 To 4 May 1985)

Ministry of Communications

Minister	Hon. Taomati T Iuta
Secretary	Mr John I Tonganibeia
Senior Assistant Secretary	Mr Inatoa Tebania
Marine Superintendent, Marine Division	Capt Beiaiti Highland
Senior Customs Officer	Mr Patric Barey

Ministry of Works and Energy

Secretary	Mr Koraubara Tetabea
Chief Engineer, Public Works Division	Mr Bill Young
Senior Assistant Secretary, Mobil Oil Agency	Mr Tekire Tamuera

Ministry of Foreign Affairs

Acting Secretary	Mr Peter T Timeon

Ministry of Finance

Secretary	Mr Beniamina Tinga
Economist	Mr Peter Poulsen
Chief Supplies Officer, Supply Division	Mr Temoai Tuakai
Stock Controller, Supply Division	Mr Raurenti Taake
Senior Storekeeper, Supply Division	Mr Teinai
Chief Statistics Office	Mr Charles McFadden

Ministry of Natural Resource Development

Secretary	Mr Teken C Tokatake
Chief Fisheries Officer	Mr Barerei Onorio
Senior Fisheries Officer	Mr Teekabu Tiikai
Assistant Fisheries Officer	Mr Maruia Kamatie
Boat Builder, Fisheries Office at Tanaea	Mr Nelson Reiti

<u>Ministry of Home Affairs</u>

Chief Lands Officer	Mr N Papps

<u>Betio Town Council</u>

Town Clerk	Mr Rubetake Taburuea

<u>Teinaninano Urban Council</u>

Urban Clerk	Mr David Yee-Ting

<u>Plant and Vehicle Unit</u>

Manager	Mr Manraoi Kaiea

<u>Public Utilities Board</u>

General Manager	Mr Nataara T Biribo

<u>Te Mautari Ltd</u>

General Manager	Mr Brendan Dalley
Fishing Master	Mr Pikia Tiroba

<u>Police</u>

Commissioner	Mr P J Somerville

<u>Betio Hospital</u>

Doctor	Dr Eritane Kamatie

.E NO: W.17/30, C5/1/1 SUBMISSION DATE: 8/11/84
.E NO.MF: DP 25/2 PLANNING OFFICE CONTACT: C.P.O.

DEVELOPMENT PROJECT FUNDING SUBMISSION

1. TITLE OF PROJECT: Betio-Bairiki Causeway - Fisheries Channel Project.
2. LOCATION: South Tarawa
3. IMPLEMENTING AUTHORITY: Ministry of Works and Energy
   Public Works Division
4. PROJECT COORDINATOR: PWD. Chief Engineer
5. PROFESSIONAL ADVICE: PWD Chief Engineer
   Previous consultant's reports
6. OBJECTIVES OF PROJECT:

   (i) the local construction of a permanent causeway between the island of Betio and the rest of South Tarawa; (Full technical details are given in Appendix I)

   (ii) to ease access and communication within the capital of Kiribati;

   (iii) to greatly reduce the recurrent costs of linking Betio and the rest of South Tarawa;

   (iv) to aid the consolidation of government, other public and private sector services;

   (v) to aid the administration and management of all South Tarawa institutions; and

   (vi) to construct a channel over the reef connecting the lagoon with the ocean to allow fish and fishermen's access.

This project has been given a very high priority by Cabinet as stated in the current National Development Plan (Further details are given in Appendix IV).

7. BACKGROUND:

The project has a long and unfortunate history, details of which are given in Appendix II.

All preparatory work has been completed i.e. surveys, cost studies and feasibility studies and technical documents are held by the PWD Chief Engineer.

Other projects and public investments are dependent on this project. These are listed in Appendix III.

8. BENEFITS:

   (i) Cost savings due to the displacement of the Ferry and Lighterage services;

   (ii) Removal of the need for a new Ferry Terminal at Takoronga;

   (iii) Cost savings due to the improved administration and management of all sectors of the economy;

   (iv) Cost savings due to a lessening of congestion on Betio;

(v) Time savings and social benefits due to more convenient communications within South Tarawa;

(vi) Time and cost savings as the local fishermen's access to the ocean is greatly enhanced; and

(vii) The maintenance of the marine ecology.

Further details are given in the Appendix covering Economic Viability - Appendix IV.

APPENDIX I : TECHNICAL PROPOSALS

Following the failure of the first attempt to construct a causeway between Betio and Bairiki various alternative designs were put forward by the contractor, consultant engineer and the Asian Development Bank consultant.

These suggestions were under consideration when the idea of a causeway/runway was put forward and they were subsequently discarded in favour of the causeway/runway. The causeway/runway suggestion was also rejected, on the grounds of excessive costs in late 1982 and the project has not moved any further forward since then.

The Public Works Division (PWD) believe that the suggestion for a minimum capital cost causeway put forward by Mr. B. D. Robertson of Sinclair Knight and partners Pty Ltd. for the Asian Development Bank had merit and could be accepted by us in a slightly modified form. The construction of this causeway could be carried out by the P.W.D. using our existing equipment.

The dimensions of this minimum causeway are taken as crest Elevation R.L. + 3.0metres crest width 10 metres, beach slope on the lagoon side of 1 in 8 and beach slope on the ocean side of 1 in 15. The quantity of material required for this embankment is 285,000 cubic metres. The Bridge over the Fisheries channel would be 10 metre wide and have a span of 5m. The approximate deck level would be R.L. +4.0 metres.

There is an estimated quantity of 90,000 cubic metres of material occurring naturally on the reef flat in the form of relatively stable sandbanks. This material can be pushed into the causeway shape by construction plant working at low tide. This leaves a deficiency of 195,000 cubic metres which would be excavated from the reef flat wo on the lagoon side between Bairiki and Betio Harbour.

It is envisaged that the 90,000 cubic metres of sand at present on the causeway location could be pushed up into the causeway cross section using a Bulldozer operating at low tides. The material to be excavated from the reef flat would be pushed into stockpiles by a Bulldozer and would then be loaded by two loaders into 5 No. Nissan 5.5 cubic metre capacity tipper trucks and one 19.6 cubic metre Dumptruck. These trucks would then haul the material approximately 3.2.km to the causeway site where it would be spread by a Bulldozer and a Motor Grader.

To facilitate the continuance of the present ecological movement of fish and other marine life between ocean and lagoon and to allow small local craft to reach their fishing grounds from their lagoon moorings an opening between the two islands has to be maintained.

The type of works required would be a channel across the reef which is 5 metres wide and has a minimum depth of 0.3 metres below a spring low tide (say - 0.4 metres). The roadway would have to bridge that gap and the structure recommended for that is a single span bridge of concrete encased steel beams with a reinforced concrete deck. The abutments of the bridge are to be 5 metres apart, the approximate clearance under the bridge should be 1.5 metres above a spring high tide. Suggest underside of Bridge beams to be at 3.5 metres..

All excavation work for the channell can be carried out using locally available equipment.

Design

The design is very much a combination of some of the designs already put forward. The crest elevation of 3.0 metres above chart datum has been chosen by Wilton and Bell for their Causeway/Runway proposal and also by B.D. Robertson of Sinclair Knight and Partners in their report of March 1980. This height compares with Nanikai-Teaoraereke causeway of +3.05m and Ambo-Taborio causeway of +2.65. The road on the present sandspit has an elevation of +2.6 metres and looks perfectly adequate. The finished height of the causeway is not the significant factor in assessing safety from storm damage.

The crest width of 10m is considered to be the minimum desirable width to accommodate a road of 5½ metres together with footpaths and an area for services, and also maintain a small margin for safety. It is anticipated that some acretion will occur on the northern side of the causeway, mainly caused by the deposition of lime muds which at present are held in suspension and then lost on the ebb tide to the ocean. It is not considered necessary to construct the road surfacing immediately following completion of the causeway.

The lagoon beach slope of 1 in 8 and the ocean beach slope of 1 in 15 allows for a run-up on one day in 100 years but for no beach flattening. It is not anticipated that any beach flattening will occur as the particle size of the fill is expected to be well in excess of 1.0mm grain size, the vast bulk being coral rubble.

Borrow Area

Previous advice has been against the removal of material from the coral reef. Holmes in his report of 1976 states "Removal of significant amounts of material from a reef would modify the refraction of waves over the reef and would change their direction of incidence on the Island's shore. Potentially disastrous erosion of the narrow land could occur".

It is considered that this statement is ill advised and unsubstantiate Temaiku Bund, Ambo-Taborio, Nanikai-Teaoraereke and Nanikai-Bairiki causeways have all been constructed by excavating material from the lagoon reef flats and there have been no serious after effects.

The rosive effect of the reef excavation can be kept to a minimum by shallow dredging over large areas in sections of similar width, parallel to the shoreline. This reduces the reflection of incident waves and restricts any changes to the ends of the excavation. The proposed site for excavation is on the lagoon flat between Bairiki Harbour and the Marine Training School (M.T.S.) channel on Betio and it is intended to excavate a long wide section of reef to a depth of 250mm to provide the causeway fill. (see sketch). With an excavation of this shape the vulnerable areas will be at the ends and at any change in the excavation width. The eastern end is the Bairiki Harbour mole and the new causeway itself. The Bairiki harbour mole could not be eroded and the new causeway will have a high degree of resistance to erosion due to the particle size of the fill. The western end which could be affected is the area between the M.T.S. channel and Betio harbour east mole. It is not anticipated that any material will be lost from this section as the sand beaches are "locked in" by the M.T.S. Jetty and the harbour mole, but some movement may take place. It is anticipated that any erosion that occurs could be dealt with quite easily by conventional methods (sand replacement, stone wall or gabion baskets.)

Resources

The Public Works Division has at present cadre very experienced and highly skilled plant operators who have proved their capabilities on the Outer Islands Airfield construction and the Outer Island Road upgrading projects. These men are at present employed on South Tarawa by P.W.D. but not necessarily on tasks commensurate with their skills. They can be made available to work under the direction of the contractor appointed by the donor.

The Plant and Vehicle Unit has all the necessary equipment for the construction of the causeway in its possession. This equipment is at present being under-utilised. The plant should be utilised by the contractor appointed to do the work.

The existing management of P.W.D. Civil Engineering Section could manage and carry out the work provided funding is made available.

APPENDIX II : SUMMARY OF BACKGROUND INFORMATION TO 1984

1966 and 1969	Reports on proposed Betio-Bairiki causeway. Wilton and Bell, Consulting Engineers, Sydney
1969	Borehole and probe survey of the proposed adjacent lagoon bed as a possible source of embankment fill material. George Wimpey & Co. Australia (Full report and cores etc. with Wilton and Bell.)
1974	Evaluation of causeway project by UNDP Advisory Team (B. Injac. Suva).
1976 (March)	Wilton and Bell engaged as consulting engineer.
1976 (July/aug)	Asian Development Bank pre-appraisal/appraisal mission to site.
1976 (Aug/Oct)	Wilton and Bell asked to carry out further coastal engineering studies etc.
1976 (Oct)	Wilton and Bell asked to proceed with pre-qualification of interested contractors.
1976 (Nov)	ADB approval
1977 (Feb)	Wilton and Bell design report issued
1977 (March)	Report by Wilton and Bell on pre-qualification of contractors.
1977 (March)	ADB and Kiribati Government sign loan agreement.
1977 (Aug)	Pre-tender conference on site and issue of tender documents.
1977 (Oct)	Wilton and Bell advise K.G. on lowest tender bid.
1977 (Nov)	Contract awarded by K.G. to P.D.C. Ltd. Value A$1.936 million.
1978 (Jan)	Contractor on site. Dredging due to start May 1978 and estimated completion of dredging August 1978.
1978 (Aug)	Dredging started.
1978 (Dec)	Dredging stopped. Contractor claimed extra costs due to shortage of dredgeable material and or material being more compacted "than might reasonably have been anticipated".
1979 (March)	K.G. brought in independent Dutch dredging expert for report on P.D.C. dredger and recommendation.
1979 (April)	Report - Analysis of Dredging Works at Tarawa by J.H. Van Koeverigne of Royal Volker Stevin.
	P.D.C. dredger condemned - impossible to complete contract.

1979	Protracted negotiations and discussions between K.G., Consultant, P.D.C. and their legal advisers.
1979 (July)	Contractor (P.D.C.) expelled from site by K.G. on advice of Consultant.
1979 (Dec)	P.D.C. Initiated arbitration proceedings.
1980 (July)	Agreement between K.G. and P.D.C. resolving distribution of site plant and equipment and postponing arbitration proceedings.
1980 (Dec)	A.D.B. (Robertson) Technical Assistance report on proposed further Geotechnical Investigations for the causeway project. Proposal for "minimum dimension" single causeway.
1981 (Oct)	ADB Report TANo 383 KIR - "Kiribati Causeway Geotechnical Investigations" - John Connell. Consulting Engineers, Melbourne, Australia Report covers borehole and probe investigations of A) original borrow area in lagoon bed B) borrow area along centre line of causeway C) borrow area on lagoon reef flat N.E. of Betio D) borrow area on lagoon reef flat near Bonriki runway and confirmed adequate quantity of material suitable for dredging available in original area.
1982 (July)	Report on feasibility of constructing a proposed Betio-Bairiki Causeway/Runway by dredged fill embankment. (John Connell). The proposal was to combine the requirement for a new and bigger runway with the causeway to justify the mobilisation/demobilisation costs of a medium large cutter/suction dredger. The report indicated the costs would be excessive.
1982	KG gave up Causeway/Runway proposal and decided to proceed with dual causeway project enquiries.
1983	Arbitration proceedings between P.D.C. and K.G. abandoned by mutual agreement.
1984	PWD proposal for "minimum dimension" - Causeway - Fisheries Channel Project

APPENDIX III : RELATED PROJECTS/EXERCISES

Consolidation of Supplies Division

Consolidation of Plant and Vehilce Unit

The PVU have identified the following benefits which would arise from the construction of a causeway:

(i) closure of Bairiki Mechanical Workshop;
(ii) centralisation of vehicle hiring on Bairiki;
(iii) centralisation of government fuel outlet on Bairiki;
(iv) easing of repairs to heavy equipment on Betio;

These "benefits" would realise savings in vehicles, staff, spares and electricity;

Consolidation of Kiribati Housing Corporation

Tarawa Water Supply Project - Betio-Bairiki pipe Laying.

Takoronga Ferry Terminal - unnecessary of Causeway proceeds.

Replacement Ferries - unnecessary if Causeway proceeds.

Repositioning of Betio-Bairiki Submarine electricity cable.

Public Service Review.

APPENDIX IV : ECONOMIC VIABILITY

This project has been agreed by the Kiribati Government and accepted as a top priority project. The Ministry of Finance has been asked to pursue finance.

The alternative to the Causeway/Fisheries Channel is to continue and try to improve the existing ferry service. A new ferry terminal at Takoronga, Betio has been proposed by the Ministry of Communications ~~at~~ at a cost estimate of A$605,000. An alternative ferry terminal on Betio will prove all the more necessary once the Betio fisheries jetty is constructed. The Causeway and the ferry terminal are mutually exclusive projects. National development must be seen to be far better served by a Causeway. The initial investment costs and negligible maintenance costs of a Causeway/Fisheries Channel must be preferred to the annual and increasing operating costs of a ferry service.

Demand

Statistics of ferry traffic are presented below in Tables 1 and 2. A total of 8,115 motorcycles and 2,191 other vehicles were also ferried between Betio and Bairiki in 1983. There is obviously a high demand for traffic between Betio and Bairiki which is quite

*number travelling from Betio to Bairiki and Bairiki to Betio.

TABLE 1

FERRY PASSENGERS *

1973	219,000
1974	260,000
1975	314,500
1976	356,000
1979	411,784
1980	371,025
1981	411,077
1982	409,462
1983	379,611

likely to substantially increase with the construction of a more convenient causeway/Fisheries Channel.

TABLE 2

CARGO LIGHTERED (TONS)

	BETIO/BAIRIKI	BAIRIKI/BETIO	TOTAL
1977	3331.5	1351.7	4683.2
1978	n.a.	n.a.	n.a.
1979	2961.8	970.7	3938.5
1980	5323.0	832.3	6155.3
1981	4072.3	646.1	4718.4
1982	2977.8	545.8	3523.6
1983	3847.0	606.7	4453.7

Economic Costs

The original ADB economic appraisal and subsequent reappraisals described the Causeway Economic costs as:

(i) Capital
(ii) Maintenance
(iii) Additional Vehicle Operating Costs

If locally constructed, capital costs are estimated to total A$920,000 only, this represents a great reduction over previous estimates.

Maintenance costs were set by ADB in 1976 at A$15,000 then A$30,000. These are a gross over-estimate, even for 1984, and exceed PWD's total South Tarawa causeway maintenance allowance of A$2,500 for 1985. An annual allowance of A$2,000 would be more realistic. The additional vehicle operating costs are also unrealistic, as such costs would be more than outweighed by the vehicle operating costs-savings, due to reductions in the size of both the public and private vehicle fleets. These are partially duplicated at present because of the lack of a permanent roadlink between Betio and Bairiki.

Economic Benefits

Economic benefits can be listed as follows:

(i) Cost savings due to the displacement of the Ferry and Lighterage services (including fuel transportation), and the removal of the need for a new ferry Terminal at Takoronga, resulting in lower costs of imports;

(ii) Costs savings due to the consolidation of government services avoiding the present duplication of some government staff, buildings as well as vehicles. PVU and Supplies Division could be reorganised;

(iii) Cost savings due to the improved administration and management of Government, Corporations and private businesses;

(iv) Cost savings due to a lessening of the congestion at Betio harbour, easing the port handling of other users, and enabling Bairiki harbour to be used by Local fishing boats; and

(v) Time and Cost savings associated with the local fishermen's easier access to the ocean.

The permanent roadlink would also be of great social benefit to the pupulations of Betio and the rest of South Tarawa easing their respective access to: the hospital; airport; TTC; Hotel; for Betio and the harbour; TTI; and High Court for the rest of South Tarawa. The Causeway/Fisheries Channels would ease Betio's dense population. The Causeway would undoubtedly lead to a large increase in the traffic between Betio and the rest of South Tarawa.

Unfortunately few of the above benefits are directly and immediately quantifiable. Also, the ADB appraisal over-estimated the benefits due to the Causeway by entering Ferry Cost savings from project year 1, (and possibly double accounting ferry depreciation). These are more realistically entered after completion of construction.

Rate of Return

An economic analysis should be based on the careful assessment of social, as opposed to financial, prices. To date, hardly any work has been undertaken to assess social (shadow or accountancy) prices for Kiribati. The Kiribati economy is however fairly open, using an international currency with next to no foreign exchange control, and few other controls other than domestic taxes. The economy is however artificially stimulated by aid. On balance Kiribati social prices and financial or market prices should be close. Causeway costs and benefits (cost savings) are similar - i.e. machinery, fuel, labour and any price distortions could be assumed to effect both costs and benefits equally.

The Causeway/fisheries Channel project is undoubtedly economic with a repayment of capital costs within two years and an estimated internal rate of return of over 50%. This can be illustrated by the following cost comparison:

CAUSEWAY

COSTS	A$	BENEFITS	A$
Construction (1)	920,000	Ferry cost savings (3)	477,754
Annual maintenance:	2,000	Lighterage cost savings	22,246
			500,000
		Salvage value (4)	81,359

There is little if any need for a "what if" analysis of sensitivity. However if:

(i) construction costs are doubled and spread over two years which allows for the importation of equipment;

(ii) net cost-savings are reduced to A$290,000 which equates to the 1982 Shipping Corporation Accounts cost estimates for the ferry service

With these two major cost/benefit adjustments the project still returns an IRR of 15%.

---

(1) All in 1984 prices

(2) Estimated total construction cost of A$920,000 in 1984 prices - (See Appendix V for details)

(3) Revision of December 1982 Management Report data by a factor of 10% to allow for inflation to 1984

	A$
Staff Costs	177,972
Maintenance and slipping	66,932
Fuel	96,000
Insurance	6,006
Depreciation	163,000
Other	27,844
	477,754

Additional A$22,246 for savings in lighterage operations

= A$500,000

Note

Ferry replacement and major overhaul costs included under depreciation and maintenance and slipping cost elements of ferry operation.

(4) Salvage Value at 10% of capital investment.

On the benefits side of the equation, we have not as yet been able to provide quantification of the further benefits due to the construction of a causeway/fisheries channel i.e.:

(i) cost savings due to the consolidation of government services avoiding the present duplication of some government staff, buildings and vehicles. PWD, FVU and Supplies Division could be reorganised;

(ii) Cost savings due to the improved administration and management of government, Corporations and private business;

(iii) cost savings due to a lessening of the congestion at Betio harbour, easing the port handling of other users; and

(iv) cost savings due to improved fishermen's access to the ocean.

MINUTES OF DISCUSSION ON BASIC DESIGN STUDY FOR BATIO - BAIRIKI CAUSEWAY , FISHERIES CHANNEL PROJECT IN THE REPUBLIC OF KIRIBATI

In response to a request made by the Government of the Republic of Kiribati, the Government of Japan through Japan International Cooperation Agency(JICA), the governmental agency responsible for implementation of economic &technical cooperation programme of the Government of Japan, dispatched the Basic Design Study Team on Betio - Bairiki Causeway, Fisheries Channel Project.

The Team headed by Mr.Takeshi KAWAGUCHI, Fisheries Agency, Ministry of Agriculture, Forestry & Fisheries, has carried out a field survey, held a series discussions and exchanged views with Kiribati government officials concernd from 8th to 28th April,1985.

Both parties confirmed following points mentioned in attachment.

April 19, 1985
Betio

Mr. Takeshi KAWAGUCHI
Team Leader
Basic Design Study Team on Betio-Bairiki Causeway, Fisheries Channel Project
Japan International Cooperation Agency

Mr. John Ikakeau Tonganibeia
Secretary
Ministry of Communications
The Republic of Kiribati

ATTACHMENT

1. The objective of the Japanese Grant Aid required for the Project is to construct a causeway between Betio and Bairiki islands, a navigation channel for local small fishing boats and a bridge at the crossing of the causeway and the channel.

2. Executing Authority of the Project in the Republic of Kiribati : Ministry of Communications

3. The Basic Design Study shall be completed in line with the Design Guidline attached in ANNEX 1., which was agreed to between the Team and the Inter-Ministerial Committee of the Government of the Republic of Kiribati.

4. The result of the Basic Design Study shall be compiled as a draft of the Basic Design Study Report, which shall be submitted and explained to the Government of the Republic of Kiribati by JICA mission to be dispatched at the beginning of July, 1985.

5. The Kiribati side has understood Japan's Grant Aid System explained by the Team which includes a principle of use a Japanese consultant firm and a Japanese general contractor.

6. The Government of the Republic of Kiribati will take necessary measures listed in ANNEX 2. on condition that the Grant Aid by the Government of Japan will be extended to the Project.

ATTACHMENT TO THE MINUTES

ANNEX I – DESIGN GUIDELINE FOR THE BASIC DESIGN STUDY ON BETIO-BAIRIKI CAUSEWAY AND FISHERIES CHANNEL PROJECT

I-1 Project Length (See Figure No. 1)

Beginning point:	STA 0+00 near junction with existing road at Bairiki
Ending point:	STA 30+00 near the eastern end of Betio
Causeway length:	3,000 m

I-2 Alignment of Causeway

Horizontal alignment:	As proposed by PWD
Vertical alignment	
Causeway:	Level
Approach to the bridge:	2.5%

I-3 Design Speed: 50 km/hr

I-4 Typical Cross Section of Causeway

(1) Crest elevation: RL + 3.0 (lowest)

(2) Crest width: 10.0m

(3) Roadway with pavement: 6.0m

(4) Alternatives of causeway embankment to be studied.

Type	Slope of Embankment: Ocean side	Slope of Embankment: Lagoon side
Type 1	1 : 15	1 : 8
Type 2 /2	1 : 2 1 : 3 /1	1 : 8
Type 3 /2	1 : 2 1 : 3 /1	1 : 2 1 : 3 /1

Note/1: Slope Protection

Slope protection with grout filled fabric mat or other suitable measures will be provided on the fill slope of causeway.

O.K.

/Y.

Note 2: Alternative cross sections (Type 2 and Type 3) are established by the Study Team to:

(1) minimize erosion of fill slope

(2) maintain durability of embankment

(3) minimize environmental problems which might be caused by excavating fill material from the lagoon reef flat.

I-5 Fisheries Channel

(1)	Approximate location of channel to be constructed	: STA 19 + 00
(2)	Width of channel:	10.0m
(3)	Depth of channel:	1.0m below a MLWS or R.L - 1.0m

I-6 Bridge across channel

(1)	Clear span:	10.0m
(2)	Width of bridge:	1[illegible]
(3)	Clearance from MLWS:	[illegible].6m
(4)	Deck elevation:	R.L + 5.
(5)	Type of Bridge:	Reinforced [illegible]

I-7 Borrow Area

Borrow areas [illegible] avation proposed by [illegible] Study [illegible]

(i) the l[illegible] of flat within Borrow area [illegible]
(ii) the [illegible] on the ocean side near B[illegible]ki

I-8 Quarry Si[illegible]

Coral r[illegible] be used for aggregate of concrete structure and pavemen[illegible] be obtained from the quarry on the ocean side of Bon[illegible] Coral rubble for slope protection will also be obtaine[illegible] there.

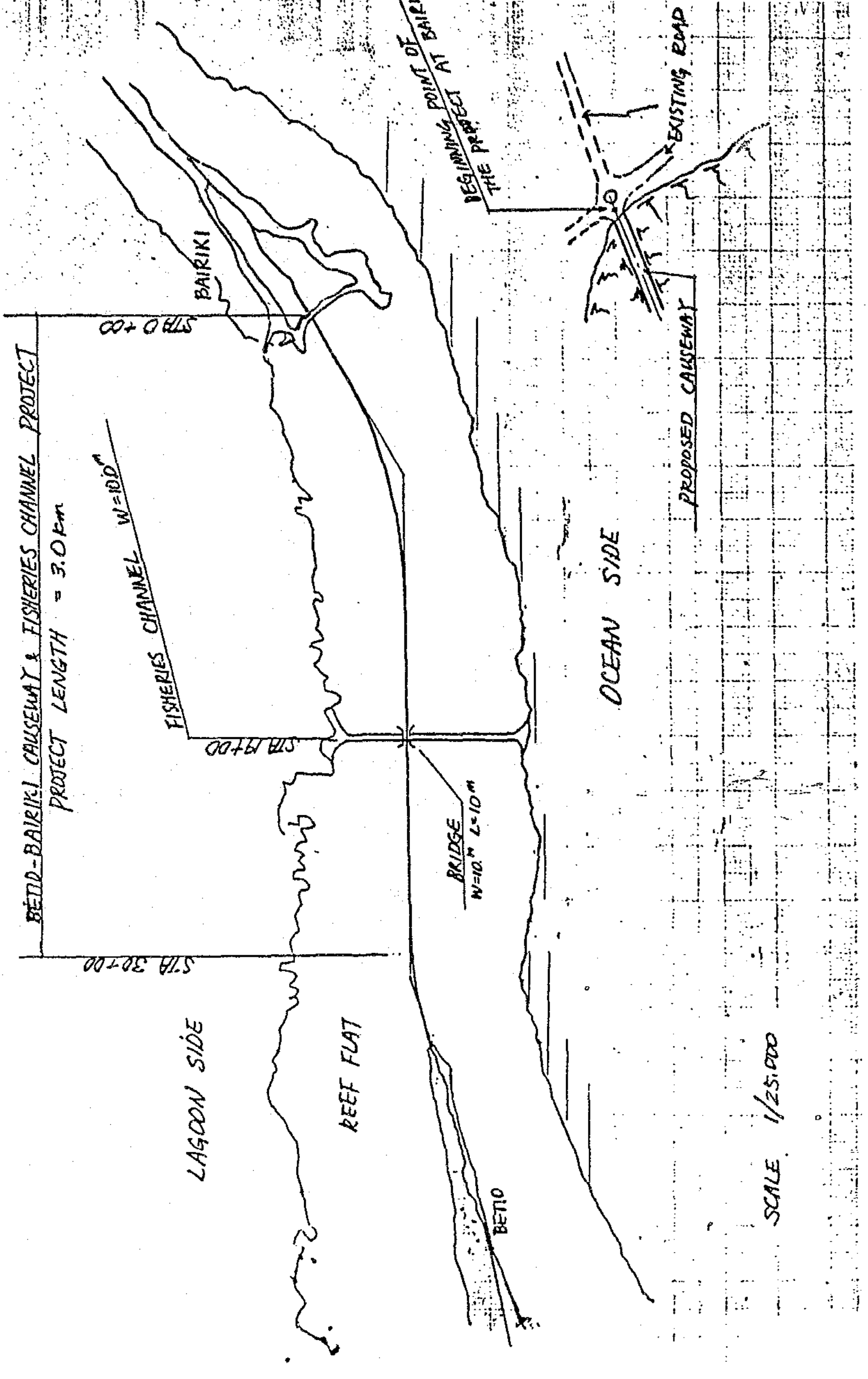
Comments:

The followi[illegible] comments are raised by the Government of Kiribati in connecti[illegible] with the design guideline:

(1) the necessity of additional opening be studied taking into consideration marine life in the lagoon

(2) Slope protection of the causeway might be necessary if borrow area for the excavation are selected near to the causeway.

Fig. No.1 LAYOUT OF THE PROJECT



Annex 2

Major undertakings to be taken by the Government of the Republic of Kiribati

1. To secure lots of land necessary for the Project.

2. To provide and accord necessary permissions, licences and other authorizations required for the execution of the Project.

3. To ensure prompt unloading, customs clearance for the goods imported by the contracted Japanese firms for the Project.

4. To exempt Japanese nationals from customs duties, internal taxes and other fiscal levies which may be imposed in the Republic of Kiribati with respect to the supply of the products and services under the Verified Contracts.

5. To accord Japanese nationals whose services may be required in connection with the supply of the products and services under the Verified Contracts such facilities as may be necessary for their entry into the Republic of Kiribati and stay therein for the performance of their work.

6. To maintain and use properly and effectively the facilities constructed under the Grant.

7. To bear all the expenses other than those to be borne by the Grant.

MINUTES OF MEETING

The Basic Design Study Team of Japan International Cooperation Agency on Betio - Bairiki Causeway, Fisheries Channel Project and the Inter-Ministerial Committee of the Government of the Republic of Kiribati held a meeting on 17th April, 1985.

At the meeting, a draft of the Design Guidline for the Basic Design on the Project was submitted and explained by the Team based on findings of reviewing the existing data & information and of the preliminary field survey.

As a result of discussion, the Design Guidline was confirmed by both parties as per attached in Annex 1..

Meanwhile, Kiribati side made an additional request that supplementary works relating to the Project would be covered in the scope of the Japanese grant aid requested.
(The contents of the additional request is shown in Annex 2. herein attached.)

While pointing out the difficulty to satisfy the request on account of the demarcation principle on works of the Japanese grant aid system, the Team expressed its intention, in consideration of Kiribati side's ardent hope for the request, to convey the request to the Government of Japan and to make efforts toward realization of the request.

At the end of the meeting, the Team expressed its appreciation and paid its respect for the effort taken by Mr. Inatoa TEBANIA to organize and chair the meeting.

April 17, 1985
Betio

Mr. Takeshi KAWAGUCHI
Team Leader
Basic Design Study Team on Betio-Bairiki Causeway, Fisheries Channel Project
Japan International Cooperation Agency

Mr. Inatoa TEBANIA
Senior Assistant Secretary
Ministry of Communication
Chairman of Inter-Ministerial Committee of the Government of the Republic of Kiribati

ATTACHMENT TO THE MINUTES

ANNEX I – DESIGN GUIDELINE FOR THE BASIC DESIGN STUDY ON BETIO-BAIRIKI CAUSEWAY AND FISHERIES CHANNEL PROJECT

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Ending point: STA 30+00 near the eastern end of Betio

Causeway length: 3,000 m

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Horizontal alignment: As proposed by PWD

Vertical alignment
- Causeway: Level
- Approach to the bridge: 2.5%

I-3 Design Speed: 50 km/hr

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(3) Depth of channel: 1.0m below a MLWS or R.L - 1.0m

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(2) Width of bridge: 1[illegible]m

(3) Clearance from MHWS: [illegible].6m

(4) Deck elevation: R.L + 5.

(5) Type of Bridge: Reinforced

L-7 Borrow Area

Borrow areas [illegible] vation proposed by [illegible]

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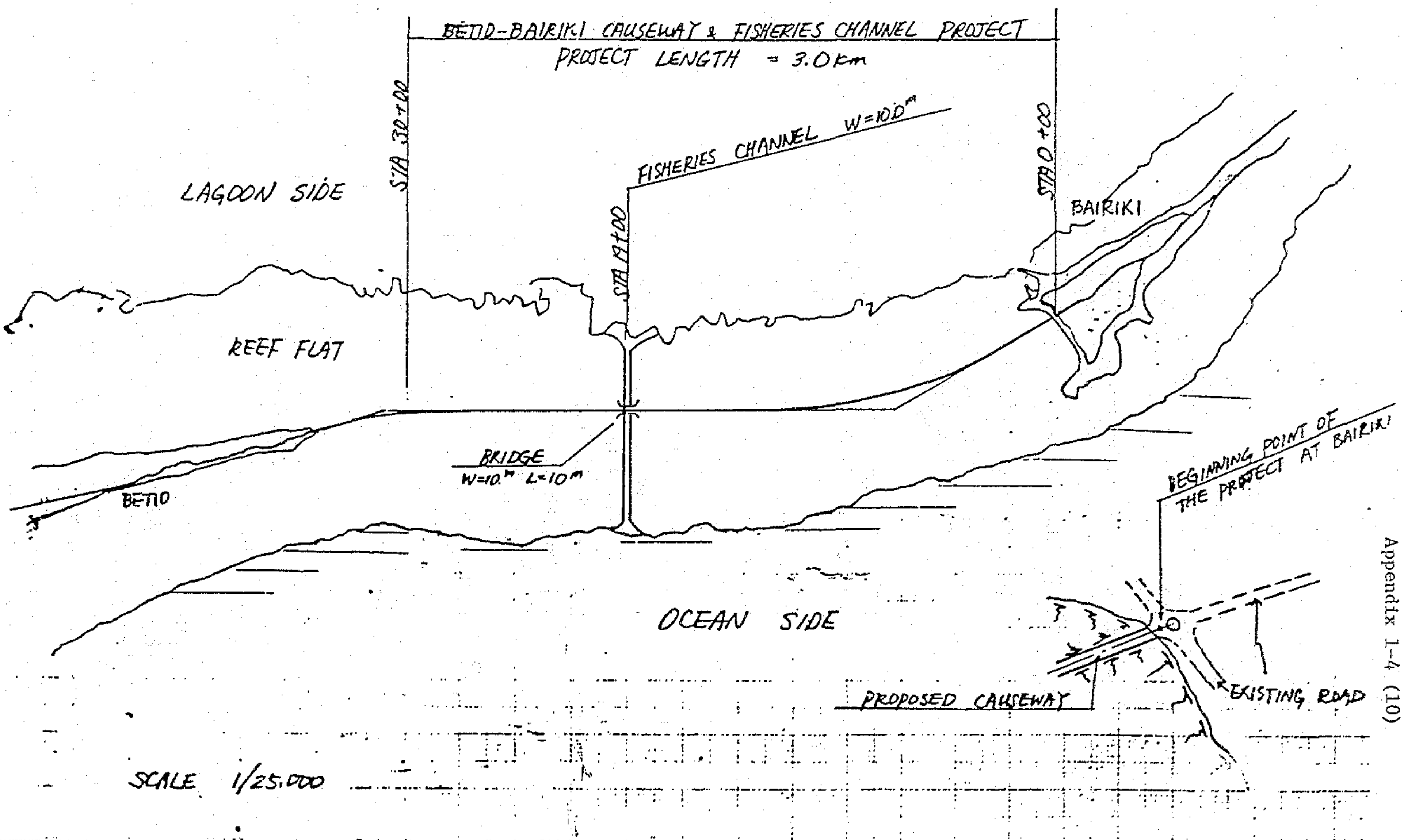


ANNEX 2

BETIO-BAIRIKI CAUSEWAY AND FISHERIES CHANNEL PROJECT

MEETING HELD ON 17 APRIL 1985 BETWEEN THE BASIC DESIGN SURVEY STUDY TEAM OF JAPAN INTERNATIONAL COOPERATION AGENCY AND THE INTER MINISTERIAL COMMITTEE OF THE GOVERNMENT OF KIRIBATI

The following additional works are requested by Kiribati Government:

(1) That both the causeway and approach roads be surfaced with Double Bituminous Surface Treatment. (Total length approximately 4,200m)

(2) That two parking lots be provided, one on each side of the proposed bridge

(3) That removal of unexploded ordnance over the area of the causeway and borrow areas be included

(4) That the existing power cable be relocated in the proposed causeway

(5) That a new 50 pr/0.93mm telephone cable is provided over the causeway and approach roads between the relevant junction boxes (total length 4,500m approximately).

T.E.   [signature]

BACKGROUND INFORMATION TO ADDITIONAL WORK REQUESTS

1) The sealing of the road over the length of the causeway proper (Sta 0+00 to Sta 30+00) has always been considered as part and panel of the causeway project. The access roads should also be considered part of the project.

At present the sealed road on Betio terminates outside Takoronga Primary School and there is a rough track from this point to the end of the island, a distance of 1,050 metres. More than half of this distance is land that was reclaimed by the first causeway attempt in 1978.

On the Bairiki side the main road at present goes to the wharf and there is an unsurfaced road 170m from Bairiki Police Station to the point where the proposed causeway will commence.

Kiribati Government will be adjusting the alignment of both these road sections and will construct the roads up to the underside of final surfacing level. It is considered that the final surfacing should be done by one contractor as this will give a uniform appearance to the work and will reduce the costs.

The level of road surfacing skills at present available within P.W.D. is not not very high.

2) The Parking Lots (lay-by's) are to be provided so that vehicles do not stop on the highway. It is intended to make the causeway a Clearway but some provision must be made for breakdown and also vehicles who want to stop on the causeway for fishing or site seeing.

3) Kiribati Governments expertise with unexploded ordnance is limited to identifying the probable risk and disposing of the smaller material by hand over the reef. Large or potentially dangerous shells are disposed of by overseas experts. No equipment or expertise for locating ordnance is available locally.

The detonation of shells in-situ is not recommended as the present across-reef water pipeline is in poor condition. The work of locating and disposing of unexploded ordnance on the line of the works, borrow pits and haul roads should be carried out at a pre-contract stage.

/...

4. There are two 11K.V.A. power cables running across the reef. One has extensive damage to it and is located on the line of the proposed causeway, the cable will be recovered by P.U.B. prior to the commencement of the contract. The other cable carries the main power supply from the power house on Betio to the other urban centres of South Tarawa.

Owing to its position on the reef this cable is constantly at risk. Kiribati Government would like this cable to be relocated in the proposed causeway where it will be adequately protected. If the cable is not relocated it has to be lowered and protected over the width of the channel.

5. At present all junction telephone circuits, telex and telegraph circuits between Betio and Bairiki/Bikenibeu are carried by the 20/0.9 submarine cable. To increase its capacity phantom circuits have been derived giving us a total capacity of 28 circuits. All 28 circuits are in-use.

With the anticipated completion of the Radio System this year the junction telephone circuits will be transferred to it. However, it is not possible to transfer the telex and telegraph circuits. Also associated with the anticipated completion of the Automatic Telephone Exchanges and Subscribers Private Exchange a demand has arisen for private circuits between Betio and Bairiki/Bikenibeu. This demand will increase over the next 10 years.

Based on the above and our current requests for private circuits a 20/0.9 cable is insufficient, recommended that a 50/0.9 cable be installed.

調査日程（第2次）

日順	月／日	曜日	調査日程
1	7/16	火	成田11：00発　CO-564便にてガム経由ナウルに向け出発
2	17	水	ナウル8：00発　ON-320便にてタラワに向け出発9：10到着
3	18	木	キリバス関係者表敬訪問，MOCと日程打合せ
4	19	金	キリバス関係各省代表者にドラフトファイナルレポートの説明
5	20	土	調査団内部調整
6	21	日	休日
7	22	月	キリバス関係各省代表者とレポートに関する質疑応答
8	23	火	キリバス政府と議事録調印
9	24	水	タラワ発10：00　ON-319便にてナウル経由ON-921経由にてスバ着16：45
10	25	木	在フィジー日本大使館訪問，JICA事務所訪問プロジェクト報告 スバ16：00発　FJ-113便にてナンディへ　ナンディ17：35発QF-094便にてシドニィへ向け出発　シドニーへ20：00到着
11	26	金	シドニィ14：45発　CX-100便にて香港へ向け出発　香港21：45到着
12	27	土	香港16：30発　CX-500便にて東京へ向け出発　成田21：30帰国

LIST OF PERSONS INTERVIEWED (From 16 July 1985 To 27 July 1985)

Ministry of Communications

Minister	Hon. Taomati T Iuta
Secretary	Mr John I Tonganibeia
Senior Assistant Secretary	Mr Inatoa Tebania

Ministry of Works and Energy

Chief Engineer, Public Works Division	Mr Bill Young

Ministry of Foreign Affairs

Acting Secretary	Mr Peter T Timeon

Ministry of Finance

Secretary	Mr Beniamina Tinga
Economist	Mr Peter Poulsen

Ministry of Natural Resource Development

Secretary	Mr Teken C Tokatake
Chief Fisheries Officer	Mr Barerei Onorio

Ministry of Home Affairs

Lands Officer	Mr Paul Taylor

Public Utilities Board

General Manager	Mr Nataara T Biribo

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

Japan International Cooperation Agency (J.I.C.A.) sent a study team to the Republic of Kiribati from July 17th to 24th July 1985 for the purpose of presenting and explaining the Draft Final Report of the Basic Design Study (the Report) on Betio-Bairiki Causeway-Fisheries Channel Project.

The team held meetings with the Inter-Ministerial Committee of the Government of Kiribati chaired by Mr Inatoa Tebania, Senior Assistant Secretary, Ministry of Communications. As a result of discussions, both parties confirmed the following points attached herewith.

Betio, July 23rd 1985

Mr Takeshi KAWAGUCHI Team Leader JICA Study Team	Mr John Ikakeati TONGANIBEIA Secretary Ministry of Communications The Republic of Kiribati

Witness

Mr Inatoa TEBANIA
Senior Assistant Secretary
Ministry of Communications
Chairman of the Inter-Ministerial
Committee of the Government
of the Republic of Kiribati

ATTACHMENT

1. The Kiribati side has agreed to the Basic Design proposal in the Draft Final Report.

2. The Final Report (10 copies in English) on the Project shall be submitted to the Kiribati side by the end of September 1985.

3. The Kiribati side understood the system of Japan's Grant Aid Programme and the arrangement to be taken by the Kiribati side which includes undertakings to secure the necessary quarry site and the necessary infrastructural facilities such as distribution of electricity, water supply, etc. for the Japanese contractor.

4. Kiribati side will secure the provision of underground power cable to be installed in the causeway with adequate length and quality as mentioned in the Annex.

ANNEX

Appendix 1-7 (3)

[...]rams: MINCOM, TARAWA

MINISTRY OF COMMUNICATIONS
P.O.Box 487
Betio,Tarawa
Republic of Kiribati

[In] reply please quote)
CS/6/2

Date...

23 July 1985

Mr T Kawaguchi
BETIO

Dear Sir

Attached is the formal request from the Public Utilities Board relating to the installation of the ground cable for electricity to be included in the construction of the causeway.

The request receives the support of the Ministry of Communications for the kind consideration of the Japanese Government.

Yours faithfully

I TEBANIA
for Secretary for Communications

Encl

T.K

Public Utilities Board

ESTABLISHED 1st JULY 1977

CABLES: P.U.B. TARAWA

SERVICES
ELECTRICITY SUPPLY
WATER SUPPLY &
SEWAGE DISPOSAL

PHONE: 743 & 749

P.O. BOX 443
BETIO, TARAWA
REPUBLIC OF KIRIBATI
CENTRAL PACIFIC

OUR REF. PUB 4/44

DATE 23/7/85

Secretary
Ministry of Communications
Betio

Dear Sir (Attn: Project Co-ordinator)

RE: CABLE FOR CAUSEWAY

Following our letter even referenced to the Chief Engineer and subsequently to our discussion Tebania/Biribo. We would again confirm that:

PUB has enough underground cable 11KV (8 drums, each 500m total 4.0km) to go into the causeway and has responsibility of cable quality thereof.

Six joints for cable and cable jointing would also be provided by PUB including delivery of cable to site.

We request that installation of cable in the causeway be carried out by Government of Japan through their site engineers during construction of the causeway.

Yours faithfully

NATAARA T. BIRIBO
General Manager

AREA AND POPULATION OF KIRIBATI BY ISLAND

Area	Area in km^2	Population		
		Dec. 1978 (Census)	Dec. 1982 (Estimated)	per km^2
The Gilbert Group				
Banaba	6.2	2,201	73	11.6
Makin	7.9	1,419	1,555	196.8
Butaritari	13.5	3,149	3,470	257.0
Marakei	14.1	2,335	2,580	183.0
Abaiang	17.5	3,447	3,775	215.7
North Tarawa	15.3	2,227	2,450	160.1
South Tarawa (Urban area)	15.7	17,921	20,050	1,277.1
Maiana	16.5	1,688	1,900	113.8
Abemama	27.4	2,411	2,710	98.9
Kuria	15.5	803	900	58.1
Aranuka	11.6	850	1,005	86.6
Nonouti	19.9	2,284	2710	136.2
North Tabiteuea	25.8	2,975	3,320	128.7
South Tabieuea	11.8	1,182	1,315	111.4
Beru	17.6	2,212	2,480	140.9
Nikunau	19.1	1,829	2,100	109.9
Onotoa	15.6	2,034	2,310	148.1
Tamaroa	4.7	1,349	1,585	337.2
Arorae	9.5	1.527	1,735	182.6
The Line Group				
Washington	9.6	416	450	46.9
Phaninog	33.7	434	470	13.9
Christmas	388.4	1,265	1,360	3.5
The Phoenix Group				
Canton, Phenox & others				
Others (estimated)		255		
T O T A L	717.1	56,213	60,302	84.1

Source: Ministry of Finance

Note: The population in Bonaba Isl. is decreasing sharply due to the exhaustion of the phosphate ore in 1979

TREND IN POPULATION AND NUMBER OF HOUSEHOLDS

	1931	1947	1963	1968	1973	1978	1982
Male	15,395	15,762	21,460	23,748	25,606	27,726	
Female	14,356	15,751	21,876	23,987	26,320	28,487	
Total	29,751	31,513	43,336	47,735	51,926	56,213	60,302
Number of households		7,144	7,770	8,187	8,518	9,068	
Average number of persons per household		4.41	5.58	5.83	6.10	6.20	
Growth rate of population, %		0.4	2.0	1.9	1.7	1.6	2.0
Growth rate of household, %			0.5	1.0	0.8	1.3	
Growth rate of number of persons per household, %			1.5	0.9	0.9	0.3	

COMPOSITION OF POPULATION BY AGE

Age	1973		1978	
	Male	Female	Male	Female
0 ∿ 4	3,787	3,704	3,900	3,876
5 ∿ 9	4,151	3,916	3,670	3,488
10 ∿ 14	3,771	3,571	4,216	3,935
15 ∿ 19	2,484	2,674	3,337	3,397
20 ∿ 24	2,036	2,370	2,318	2,600
25 ∿ 29	1,626	1,669	1,976	2,172
30 ∿ 34	1,458	1,567	1,626	1,614
35 ∿ 39	1,249	1,294	1,451	1,508
40 ∿ 44	1,212	1,139	1,057	1,180
45 ∿ 49	1,026	1,077	1,203	1,129
50 ∿ 54	832	872	863	986
55 ∿ 59	562	659	693	744
60 ∿ 64	551	627	550	688
65 ∿ 69	338	423	393	488
70 and more	523	758	473	682
Total	25,606	26,320	27,726	28,487

Source: 1978 Census of Population

ECONOMICALLY ACTIVE POPULATION (NATIVE PEOPLE)

(Unit: per...)

	Total	Male	Female
Population older than 15 years of age	32,858	15,776	17,082
Economically active population	28,859 (100%)	13,769 (100%)	15,090 (100%)
Monentary economic sector	7,375 (25.6%)	5,882 (42.7%)	1,493 (9.9%)
Employer	60	52	8
Employee	6,296	4,963	1,333
Private Concern	184	127	57
Unemployed	835	740	95
Non-monentary economic sector	21,484 (74.4%)	7,887 (57.3%)	13,597 (90.1%)
Non-economically active population	3,999	2,007	1,992

Source: Report on the 1978 Census of Population and Housing

EMPLOYMENT POPULATION BY INDUSTRY (NATIVE PEOPLE)

(Unit: Person)

Industry	Total	Male	Female
	6,432	5,045	1,387
Agriculture & Fisheries	480	464	16
Agriculture	(375)	(365)	(10)
Fisheries	(105)	(99)	(6)
Mining	293	281	12
Manufacturing Industry	183	131	52
Food	(58)	(20)	(38)
Textile	(5)	(1)	(4)
Furniture	(15)	(15)	(0)
Printing	(23)	(15)	(8)
Ship Building	(82)	(80)	(2)
Welfare	192	185	7
Construction	954	917	37
Commerce & Service	902	607	295
Wholesale	(148)	(127)	(21)
Retail Trade	(599)	(405)	(194)
Hotel & Restaurant	(155)	(75)	(80)
Transport & Communication	662	590	72
Transport	(518)	(474)	(44)
Communication	(144)	(116)	(28)
Financial Business	28	21	7
Public Service	2,730	1,844	886
Administration	(994)	(824)	(170)
Education	(639)	(381)	(258)
Others	(1,097)	(639)	(458)
Indefinite	8	5	3

Source : Report on the 1978 Census of Population and Housing

TREND OF COMPOSITION OF FOREIGN TRADE BY ITEM

(Unit: 1,000 A$, %)

Year	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
Amount of Export (Ratio of increase to previous year, %)	24,054 (+10.57)	27,734 (+15.3)	18,147 (-34.6)	18,212 (+0.4)	21,396 (-17.5)	21,209 (-0.9)	2,426 (-89.6)	3,534 (+45.7)	1,934	3,661	6,978
Ogisogate ore	79.4	96.4	94.5	86.4	88.3	84.7					
Copra	20.3	3.4	5.3	13.3	11.6	14.5	89.2	74.6	75.1	58.9	
Fish						0.7	9.9	19.7	15.7	35.0	
Shark's Fin				0.1	0.1	0.1	0.8				
Handcraft	0.1	0.2	0.2	0.2			0.1	5.7	6.1		
Others	0.2										
Amount of Import (Ratio of increase to previous year, %)	7,546 (+10.7)	9,281 (+23.0)	10,062 (+8.4)	11,692 (+16.2)	14,115 (+20.7)	15,545 (+10.1)	18,263 (+8.4)	22,830 (+18.2)	22,508	19,807	
Food	38.7	32.7	29.2	27.4	27.2	30.2	32.3	24.9	23.1	27.6	
Beverage & Tobacco	5.6	5.8	6.6	6.3	6.3	9.7	7.7	5.6	5.2	6.0	
Raw Materials	3.0	1.5	2.1	1.7	2.0	1.7	1.8	2.0	1.7	2.7	
Fuels	7.0	10.1	13.5	18.1	10.5	14.5	10.8	12.0	14.1	11.1	
Chemicals	6.6	5.4	6.4	5.2	5.3	5.5	5.3	2.0	4.1	4.0	
Industrial Products*	16.8	13.9	11.9	15.5	19.2	11.6	13.7	12.5	12.6	17.5	
Machinery, Transport Equipment & Vehicles	12.5	17.7	19.2	15.6	18.6	16.8	17.2	32.8	27.9	23.1	
Sundries	9.6	11.2	9.9	9.2	10.0	9.3	9.7	8.0	10.5	7.4	
Others	0.1	1.5	1.0	0.9	0.8	0.6	1.4	0.1	0.6	0.5	
Balance of Foreign Trade	16,508	18,453	8,085	6,520	7,281	5,664	-14,422	-16,378	-20,574	-16,146	

* Except Machinery, Transport Equipment & Vehicles.

Source : Ministry of Finance

TREND OF FINANCIAL INCOME AND EXPENDITURE

(Unit: 1,000 A$)

	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
Ordinary Revenues	26,356	14,660	14,751	14,462	17,649	16,769	17,040	16,302	15,303	16,723
Taxes	25,232	12,844	12,028	11,682	13,727	6,755	5,672	4,467	4,509	5,763
Income Tax	547	699	885	927	1,309	1,359	1,020	919	1,020	1,080
Export Tax	1,761	2,460	2,431	2,439	3,315	3,380	3,483	3,428	3,195	3,800
Import Tax	128	109	387	6	47	77	4	2	15	
Phosphate Ore Tax	22,783	9,566	8,301	8,029	8,354	1,669				
Others	1,142	1,816	2,726	3,041	4,536	10,665	10,978	11,274	11,272	
Charge for Fishing			3	261	614	616	1,255			875
Trucking Station					154	241	204	316		183
RERF Interest						4,250	5,751	4,750	5,500	5,050
Postal Stamps			255	383	457	489	590	1,047	49	850
Financial Aid from UK						2,000	2,017	1,000	3,500	2,750
Ordinary Expenditures	30,405	12,251	13,442	13,270	16,687	14,362	16,235	15,889	15,389	16,722
Education & Welfare	2,755	2,503	2,907	3,152	3,760	4,513	4,812	4,803	4,599	
Natural Resources, Trade & Labour	2,304	824	155 646	433 64	686 1,774	740 167	608 341	1,099 446	1,362 734	
Communications, Energy &	2,310	2,153	2,237	4,586	3,464	4,137	4,438	4,481	3,454	
RERF Contribution	19,526	2,705	1,555		245					
Development Fund Contribution	549	512	1,517	1,434	1,976	593				
Balance	-4,049	2,409	1,309	1,192	962	2,407	805	413	86	1

Source : Ministry of Finance

TREND OF GROSS DOMESTIC PRODUCT (EXPENDITURE BASIS IN MARKET PRICE)

(Unit: 1,000 A$)

	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
Private Consumption	8,934	11,202	11,896	15,742	15,946	17,122	20,208	20,988	19,386	20,999
Governmental Consumption	4,396	5,979	5,760	7,574	8,511	9,435	7,603	7,890	7,592	8,211
Total Investment in Fixed Assets	1,281	1,778	1,460	2,020	2,220	2,236	8,154	8,196	9,173	10,373
Increase in Stock	458	311	730							
Export (goods & service)	6,973	11,691	25,324	28,444	18,973	19,498	21,626	21,218	2,434	2,990
Import (goods & service)	6,230	8,735	8,685	11,703	12,010	13,348	18,199	19,993	17,784	19,573
GDP in Market Price	15,812	22,226	36,490	42,077	33,641	34,943	39,392	38,300	20,800	23,000

Source : A D B, Key Indicators of Developing Countries, 1983

Note : GDP in Added Value Basis is not consolidated into Statistics.

NAME OF FISH IN KIRIBATI

Kiribati	Scientific	English
Ati	Katsuwonus pelamis	Skipjack
Aua	Mugilidae	Mullet (Adult)
Auamaran	Valamugil seheli	Bluetail mullet
Auataba	Liza vaigiensis	Diamondscale mullet
Awai	Aprion virescens	Green jobfish
Auan	Spratelloides delicatulus	Blue sprat
Arataba	Etelis carbunculus	Red snapper
Aonga	Caranx Iugubris	Black trevally
Awatai	Chanos chanos	Milkfish
Baiura	Thunnus albacares	Yellowfin tuna
Bakoa	Triaenodon obesus	Shark
Bureinawa	Holocentrus violanceus	Violet sqirrel fish
Baara	Acanthocybium solandri	Wahoo, Kingfish
Baua	Valamugil seheli	Bluespot mullet
Bawe	Lutjanus fulvus	Redtail snapper
Barebu	Caranx sexfasciatus	Dusky trevally
Buki iaro	Pristipomoides auricilla	Yellowtail snapper
Bukinrin	Aphareus rutilans	Jobfish
Buari	Gymnosarda	Dogtooth tuna
Barinua	Sphyraena barracuda	Great barracuda
Baiburoro	Carcharhinus melanopterus	Blacktip reefshark
Ingimea	Thunnus albacares	Yellowfin tuna
Ikanibeka	Ruvettus pretiosus	Coster oil fish
Ikanenea	Ruvettus pretiosus	Coster oil fish
Ikari	Albula vulpes	Bonefish
Ikabauea	Sphyraena	Forsters seapike
Ikanibong	Lutjanus gibbus	Humpback red snapper
Ingo	Lutjanus bohar	Red bass, two-spot red snapper
Ikanarina	Trachinotus bailloni	Black-spotted swallow tail
Imnai	Siganus argenteus	Silver spinefoot
Inai	Scarus ghobban	Five banded parrot fish

Kiribati	Scientific	English
Ikamatoa	Lethrinus elongatus	Longnose emperor
Ikamaikeke	Dussumieria sp.	Rainbow sardine
Kemaa	Elagatis bipinnulata	Rainbow lunar
Kika	Octopus unlgarris	Octopus
Kimokimo	Grammatorcynus bilineatus	Scad
Kabubu	Hyporhawphus	Garfish
Koinawa	Acanthurus triostegus	Convict surgeonfish
Kiroro	Gymnothorax fimbriatus	Green jobfish
Kuaubani	Epinephelus maculatus	Marbled rock cod
Kuau	Epinephelus merra	Honeycomb rock cod
Maebo	Upenous taenopterus	Bar-tailed goatfish
Matabareka	Carangoides orthogrammus	Gold-spot trevally
Mako	Acanthurus xanthopterus	Yellowfin surgeonfish
Matakore	Monotaxis grandoculis	Large-eyed bream
Morikoi	Lethrinus nebulosus	Spangled emperor
Ninimai	Gerres oyena	Silver biddy
Nari	Scomberoides lysan	Queenfish
Neia	Gnathodentex aurolineatus	Gold-line bream
Nimako	Cephalopholis urodelus	Flagtail rock cod
Nimanang	Cephalopholis argus	Peacock rock cod
Onauti	Cypselurus sp.	Flying fish
Okaoka	Lethrinus remak	Orange striped emperor
Rereba	Caranx melampygus	Bluefin travelly
Rou	Lethrinus miniatus	Long-faced emperor
Ree	Gnathanodom speciosus	Golden trevally
Rounaneawa	Lethrinus variegatus	Variegated emperor
Rakuriri	Istiophorus platypterus	Sail fish
Temon	Holocentridae	Squirrel fish
Tarabuti	Harengula ovalis	Sardines
Tau	Tyrosurus crocodilus	Longtom
Taa	Adioryx spinifer	Scarlet squirrel fish
Tiatiiu	Sardinella sirm	Blue sardine
Tawatawa	Euthynnus affinis	Mackerel tuna
Takua	Coryphaena hippurus	Dolphin fish
Tewe	Mulloidichthys	Goat fish
Urua	Caranx ignobilis	Great travelly

DETAILS OF MONTHLY PURCHASE OF FISH CATCHES
BY TE MAUTARI LTD. (1984)

1. Bonito and Tuna Fish

Month	Receiving Days	Receiving Number of boats	Purchase Quantity (kg)	Purchase Amount (A$)	Average Unit Price (A¢)	Purchase Q'ty per Boat (kg)	Purchase Amount per Boat (A$)
1	28	292	38,967	25,738	66.1	133.4	88.1
2	29	286	55,178	36,341	65.9	192.9	127.1
3	30	247	28,780	19,034	66.1	116.5	77.1
4	28	148	17,123	11,312	66.1	115.7	76.4
5	31	272	30,168	19,952	66.1	110.9	73.4
6	28	213	29,501	19,513	66.1	138.5	91.6
7	29	166	22,693	16,595	73.1	136.7	100.0
8	30	233	27,524	19,543	67.4	118.1	79.6
9	27	180	21,662	14,355	66.3	120.3	79.8
10	31	195	26,275	15,848	60.3	134.7	81.3
11	30	330	43,374	28,352	65.4	131.4	85.9
12	29	331	40,349	27,905	69.2	121.9	84.3
Total	350	2,893	381,594	253,489	66.4	131.9	87.6

2. Reef Fish

Month	Receiving Days	Receiving Number of Boats	Purchase Quantity (kg)	Purchase Amount (A$)	Average Unit Price (A¢)	Purchase Q'ty per Boat (kg)	Purchase Amount per Boat (A$)
9	4	6	133	132	99.2	22.1	22.0
10	19	54	2,551	2,530	99.2	47.2	46.9
11	24	52	2,773	2,751	99.2	53.3	52.9
12	10	12	1,423	1,412	99.2	118.6	117.7
Total	57	124	6,880	6,825	99.2	55.5	55.1

3. Total

Receiving Number of Boats	Purchase Quantity (kg)	Purchase Amount (A$)
3,017	388,474	260,314

Note: The figures in this table were consolidated from those in the Daily Purchase Report.

CHARACTERISTICS OF WATER IN LAGOON

The waters at the sea bottom were sampled at the following points and analyzed: 3 points in the ocean, 3 points offshore the lagoon, 10 points along the reefs around South Tarawa Main Isls., 8 points at the proposed site and along the reefs around Betio Isl. and 3 points in Betio Harbour totaling 27 points.

The characteristics were analyzed as mentioned below:

Area	Temperature at base	Specific gravity	Content of chlorine (‰)	Salt concentration (‰)	pH
Ocean	27.6	25.47	19.02	34.37	8.3
Offshore Lagoon	28.4	26.03	19.41	35.06	8.3
Main Isls. Reefs	29.0	26.62	19.83	35.82	8.3
Betio Reefs	29.1	26.47	19.72	35.63	8.3
In Betio Harbour	29.3	26.80	20.01	36.15	8.3
Average in Total	28.8	26.41	19.68	35.56	8.3

The characteristics seems to be that the temperature and specific gravity are lower in the ocean, and they come to be higher, the nearer the points are to the shoreline of the lagoon.

The hydrogen ion concentration index is of the standard type found in a tropical zone, and no tendency of water pollution was found. A tidal current was observed at the entrance of the sea route in the western reef, but only a slow flow of water toward the west along the edge of reefs was found in the lagoon.

OBSERVED MARINE METEOROLOGICAL DATA

Date	Time	Location No.	Depth (m)	Temperature at Base (°C)	Current Speed (kt)	Specific Gravity	Content of Chlorine (°‰)	Salt Concentration (°‰)	pH	Tide				Weather	Wind Direction & Speed
4/23	10.05	1	1.73	29.0	W'ly 0.20	1.02705	20.14	36.38	8.3	-	H.W	05.36	1.6m	Fine	E 3 m/sec
	10.30	2	4.30	28.8	SW 0.34	1.02698	20.09	36.29	8 3	-	L.W	12.00	0.5m		
	10.48	3	3.57	28.6	SW 0.36	1.02722	20.26	36.60	8.2	-	H.W	18.00	1.3m		
	11.18	4	5.14	28.9	SW 0.23	1.02702	20.12	36.34	8.3	-	L.W	23.48	0.6m		
	11.48	5	4.55	29.0	W'ly 0.20	1.02690	20.03	36.18	8.2	L					
	12.08	6	3.50	29.2	WSW 0.27	1.02765	20.57	37.16	[illegible]	L					
	13.01	7	3.28	29.4	WSW 0.17	1.02668	19.87	35.90	8.3	+					
	13.20	8	3.80	27.4	Nil	1.02702	20.12	36.34	8.3	+					
	13.43	9	6.00	29.0	W'ly 0.10	1.02655	19.78	35.73	8.3	+					
	13.56	10	4.00	29.4	W'ly 0.10	1.02700	20.10	36.31	8.3	+					
	14.15	11	4.75	29.2	W'ly 0.18	1.02692	20.04	36.21	8.3	+					
	14.35	12	5.40	29.2	W;ly 0.19	1.02710	20.17	36.44	8.3	+					
4/24	08.40	13	2.00	29.2		1.02662	19.83	35.82	8.3	-	H.W	06.06	1.5m	Fine	E 4.5m/sec
	08.45	14	1.40	29.2		1.02712	20.19	36.47	8.3	-	L.W	12.30	0.6m		
	12.48	15	9.60	27.6		1.02610	19.45	35.14	8.3	+	H.W	18.30	1.2m		
	14.15	16	10.50	27.9		1.02587	19.29	34.84	8.2	+					
4/25	13.17	17	5.60	27.6		1.02518	18.79	33.95	8.3	L	L.W	00.18	0.7m	Fine	
	14.15	18	10.60	27.8		1.02524	18.83	34.02	8.3	+	H.W	06.36	1.4m		
	15.05	19	13.00	28.3		1.02567	19.16	34.61	8.3	+	L.W	13.12	0.7m		
											H.W	19.12	1.1m		
4/26	07.35	20	4.06	29.6		1.02688	20.01	36.16	8.3	H	L.W	01.00	0.8m	Fine	E 1~2m/sec
	07.45	21	5.60	27.0	W 0.13	1.02577	19.22	34.71	8.3	H	H.W	07.30	1.3m		
	07.58	22	3.90	29.0	W'ly 0.11	1.02597	19.36	34.98	8.2	H	L.W	14.18	0.7m		
	08.18	23	1.10	28.0	WSW 0.35	1.02535	18.91	34.17	8.2	-	H.W	20.30	1.0m		
	08.37	24	4.20	28.8	W 0.29	1.02585	19.27	34.82	8.2	-					
	08.54	25	1.10	29.0	W'ly 0.23	1.02592	19.32	34.91	8.3	-					
	09.07	26	1.40	29.5	W'ly 0.23	1.02568	19.15	34.60	8.3	-					
	09.22	27	1.50	29.0	WSW 0.30	1.02592	19.32	34.91	8.3	-					
Average				28.8		1.02641	19.68	35.56	8.3						

SHIPPING CORPORATION OF KIRIBATI

CURRENT FERRY SCHEDULES

MONDAY TO FRIDAY

BETIO DEPARTURES	BAIRIKI DEPARTURES
0615 hrs. Mobil Tanker and Passengers from Bairiki	0700 hrs.
0700 hrs. Ferry Run	0800 hrs.
0800 hrs. Ferry Run and BP Tanker	0900 hrs.
0900 hrs. Ferry Run	1000 hrs.
1100 hrs. Ferry Run	1200 hrs.
1200 hrs. BP Tanker and School Children from Bairiki	1300 hrs.
1300 hrs. Ferry Run	1400 hrs.
1500 hrs. Ferry Run	1630 hrs.
1630 hrs. Ferry Run	1715 hrs.
1715 hrs. Ferry Run	1800 hrs.
1900 hrs. Ferry Run	2000 hrs.
2100 hrs. Ferry Run	2200 hrs.

Satuaday

0700 hrs. Ferry Run	0800 hrs.
0900 hrs. Ferry Run	1000 hrs.
1100 hrs. Ferry Run	1200 hrs.
1300 hrs. Ferry Run	1400 hrs.
1500 hrs. Ferry Run	1600 hrs.
1700 hrs. Ferry Run	1800 hrs.
1900 hrs. Ferry Run	2000 hrs.
2100 hrs. Ferry Run	2200 hrs.
2300 hrs. Ferry Run	2400 hrs.

Sunday

0700 hrs. Ferry Run	0800 hrs.
1100 hrs. Ferry Run	1200 hrs.
1500 hrs. Ferry Run	1600 hrs.
1900 hrs. Ferry Run	2000 hrs.

SHIPPING CORPORATION OF KIRIBATI

FERRY DIVISION

TRAFFIC STATISTICS

	YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	TOTAL
PASSENGERS	1982	33,113	34,634	35,347	34,441	37,371	35,857	37,436	32,058	32,547	33,259	29,253	33,533	408,849
	1983	29,329	28,884	30,131	33,064	32,999	33,100	34,936	32,319	31,336	31,888	30,032	31,591	379,609
	1984	30,465	33,663	34.188	32,140	34,413	32,759	34,716	33,898	32,872	32,834	33,781	28,388	394,117
VEHICLES	1982	1387	998	1108	1107	1279	800	956	858	861	717	504	1021	11,596
	1983	1008	794	767	794	638	759	916	1031	881	898	754	868	10,108
	1984	856	729	633	643	693	707	688	642	573	646	656	755	8,221
GENERAL CARGO (M^3)	1982	281	216	265	57	341	271	121	226	549	358	406	370	3,461
	1983	332	234	558	383	764	190	107	1146	105	167	327	145	4,458
	1984	442	162	198	194	194	268	765	167	335	61	474	199	3,459

K. Tabwebweiti
Financial Controller

SHIPPING CORPORATION OF KIRIBATI

TARAWA LAGOON FREIGHT RATES ON FERRIES

ITEMS		
Personal Baggage in excess of one piece	:	3.00 per cubic metre. (Minimum)
Animals	:	1.30 each
Chickens	:	.30 each
Timber	:	45.50 per cubic metre
Bicycle	:	0.80 each
Motor Cycle	:	1.50 each
Tractors Road, Rollers, Fork Lift and small mobil crane	:	12.50 each
Large Crane & Excavators	:	59.30 each
Empty 44 gallons drums	:	6.50 each
Full or part full 4 gals. drums	:	13.00 each
General freight rate per cubic metre	:	32.50
Special freight rate for films	:	0.60 each

Between Betio and Bairiki	Unladen	Full or Part Laden
Cars, truck, trailer Utilities and boats not exceeding 3.5 metres	6.00	10.00
exceeding 3.5 metres but not exceeding 4.5 metres	10.00	19.00
" 4.5 " " " " 6 "	13.00	24.00
" 6 " " " " 7.5 "	14.00	28.00
" 7.5 " " " " 9 "	24.00	47.00
Mobil Truck & B.P. Tankers	35.00	70.00
Over 9 metres - by special arrangement		

NOTE:

1. The above rate covers carriage only: Loading and discharging should be arranged separately by the Shipper or consignee.
2. Freight on vehicles does not include fares for drivers. It should be charged separately.

Charter Rates

Nei Auti	-	$20.00 per hour
Tabakea	-	$40.00 per hour
Nei Tebaa	-	$40.00 per hour

Plus 1½ hours overtime of $10 during non-working hours. (1½ hours is the time tallen for a trip from Betio/Bairiki/Betio).

Fares

Between Betio and Bairiki	-	0.70 per adult
	-	0.35 per child
Concession fare for students	-	$16.00 per term

Questionaire Sheet (English Version)
INTERVIEWS WITH PASSENGERS IN FERRY BOAT BETWEEN BETIO AND BAIRIKI ISLANDS

PERSON TRIP SURVEY IN THE FERRY BOAT BETWEEN B ~~& B~~

1. ☐ Male ☐ Female	2. Age ☐ Years old
3. Purpose of the trip to Betio 1. Commuting 2. Business 3. Temporary Visit 4. ☐	
4. What is your present status? 1. Student 2. Gov. Official 3. Employee 4. Fisherman 5. ☐ 6. Jobless	
5. How did you get to the Bairiki ferry terminal from your residence? 1. Walking 2. Bus 3. Passenger Car 4. Truck 5. Motorcycle 6. Bicycle 7. ☐	
6. How do you get to the destination from Betio ferry terminal? 1. Walking 2. Bus 3. Passenger Car 4. Truck 5. Motorcycle 6. Bicycle 7. ☐	
7. Which transport do you intend to use after the completion of causeway between Betio and Bairiki? 1. Bus 2. Passenger Car 3. Motorcycle 4. Bicycle 5. ☐ 6. Walking	

Questionaire Sheet (Kiribati Version)

TE MAMANANGA N TE MEERI BAIRIKI - BETIO

1. ☐ Mane ☐ Aine ☒

2. Roronga ☐ Te Ririki ☒

3. Bukin manangana nako Betio 1. Kakakibotu
2. Kaean te makuri 3. Karaoan te bitineti

4. Tera ae ko kakaraoia?
1. Ataein te reirei 2. Te ~~tia~~ makuri 3. Te tia akawa.
4. ☐ 5. Akea au makuri

5. Ko Kanga n roko ~~nte~~ Tabo Ni Meeri I-Bairiki man am Auti?
1. Rianna 2. N te Bati 3. N te Ka 4. N te Truck
5. N te rebwerebwe 6. N te Batika 7. ☐

6. Tera Baom ae Ko na toka iai ma I Tabon Te Uabu
I Betio nakon te tabo ane ko na Kawaria?
1. Te Rianna 2. N te Bati 3. Te Rebwerebwe 4. Te Batika
5. ☐

7. Tera te bao ae ko Kani Kamanena imwin tian te Kotiwei?
1. Te Bati 2. Te Ka 3. Te Rebwerebwe 4. Te Batika
5. Te Rianna 6. ☐

IT/mmk.

STUDY ON DESIGN WAVE

(1) Wind Speed by Direction

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

Table-1 Maximum Wind Speed by Direction

Year	All Directions	Direction				
		N	SE	S	SW	NW
1948	7					
1949	6 - 7					
1950	4 - 5					
1951	4 - 5					
1952	6 - 7					
1953	6 - 7					
1954	6 - 7					
1955	4 - 5					
1956	4 - 5					
1957	8					
1958	8					
1959	8					
1960	7					
1961	7					
1962	7					
1963	8					
1964	7					
1965	7					
1966	5					
1967	5					
1968	5					
1969	6 - 7					
1970	5	4	5	3		4
1971	5	4	5	4		4
1972	6	5	5	4	5	6
1973	5	5	5	4		4
1974	6	4	6	4	4	6
1979	7	5	5	5	7	6
1980	6	5	5	4	6	5
1981	5	4	5	4	5	5
1982	8	5	6	5	7	8
1983	6	6	6	6	5	6
1984	6	4	6	5		4

Note: No directional data during 1948 - 1969

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

Table-2

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

(2) Probability Analysis of Wind Speed

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

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

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

Table-3

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

(3) Shallow Water Wave

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

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

(i) Effective fetch of north wind

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

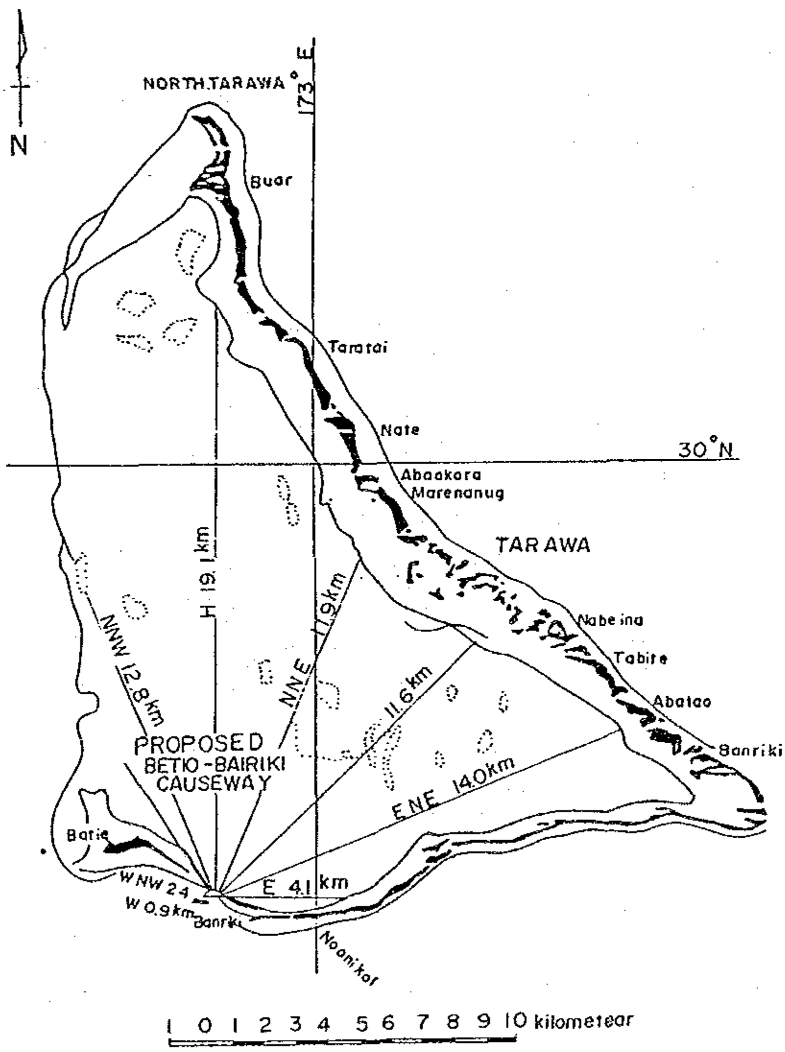


Fig.1 Effective fetch

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

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

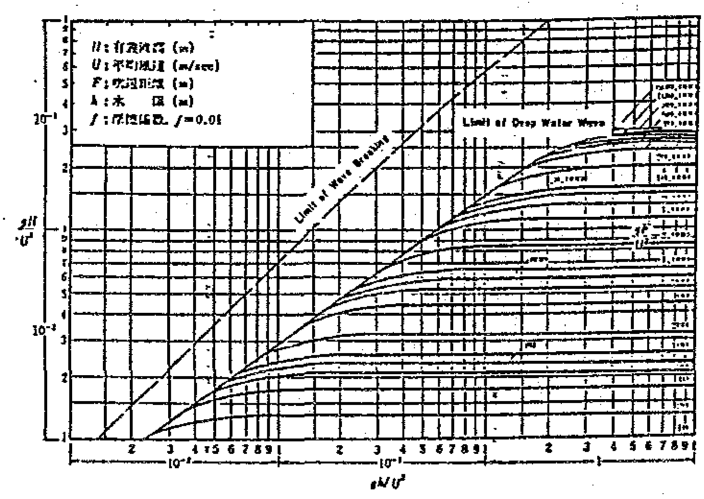
where, F_{eff} : Effective fetch

Θ : Main wind direction

Fi : Distance to the opposite shore in θ_i direction

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

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



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

Fig.2 Estimation of Fetch of Shallow Water Wave

$h = 8.0 + 1.8 = 9.8$ m

Average seabed level: DL - 8.00

Tide level (MHWS): DL + 1.80

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

$F = 12.7$ km

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

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

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

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

$H = 1.14$ m

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

(4) Deep Water Wave

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

(i) Effective fetch and wind duration

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

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

a) Method A

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

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

b) Method B

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

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

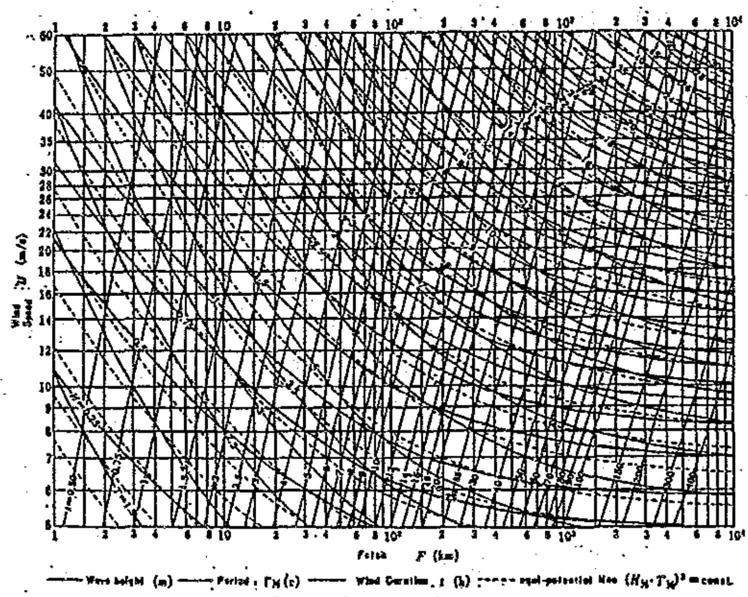


Fig.3 Curve of Wave Height by S-M-B Method

c) Effective fetch and wind duration

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

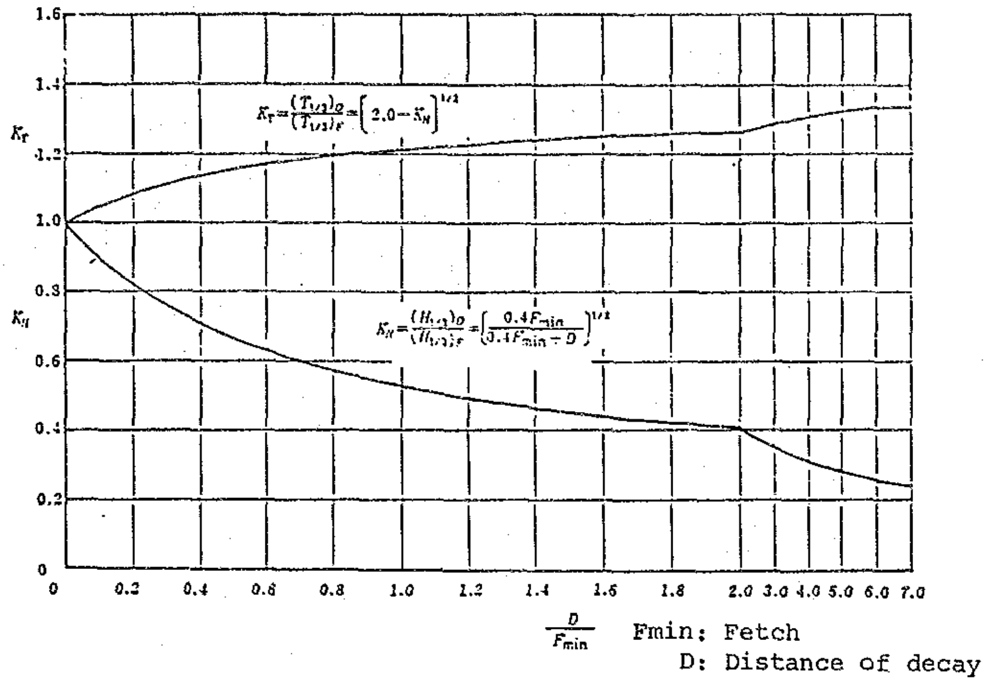


Fig.4 Attenuation Curve

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

(ii) Deep Water Wave by Direction

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

Table-4 Deep Water Waves by Direction

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

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

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

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

(5) Wave Transformation and Setup on Reef

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

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

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

<u>Takayama's equation</u>

a) Height of breaking wave on reef edge

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

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

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

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

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

H_0': Significant wave height

L_0 : Wave length

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

b) Attenuation of wave height and setup

Wave height

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

Setup

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

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

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

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

α = 0.33 (constant)

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

h_0 = Water depth

β = 0.56 (constant)

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

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

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

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

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

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

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

Table-5

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

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

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

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

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

Table-6

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

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

(6) Design Wave

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

Table-7

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

PROBABILITY ANALYSIS ON WIND VELOCITY

Probability analysis is made based on the following:

a) Applied Method

- Gumbel's Method in deriving the frequency curve

b) Wind Direction

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

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

(1) NORTH

PLOTTING POSITION

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

* NUMBER OF SAMPLES ; 11

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

CALCULATION METHOD ;GUMBEL METHOD

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

(1) NUMBER OF SAMPLES ; 11

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

NOTE : FORMULA OF PRESUMPTION

X=XO+(1/A)*VARIABLE

XO = 7.806
1/A = 1.880

Station :KIRIBATI, TARAWA

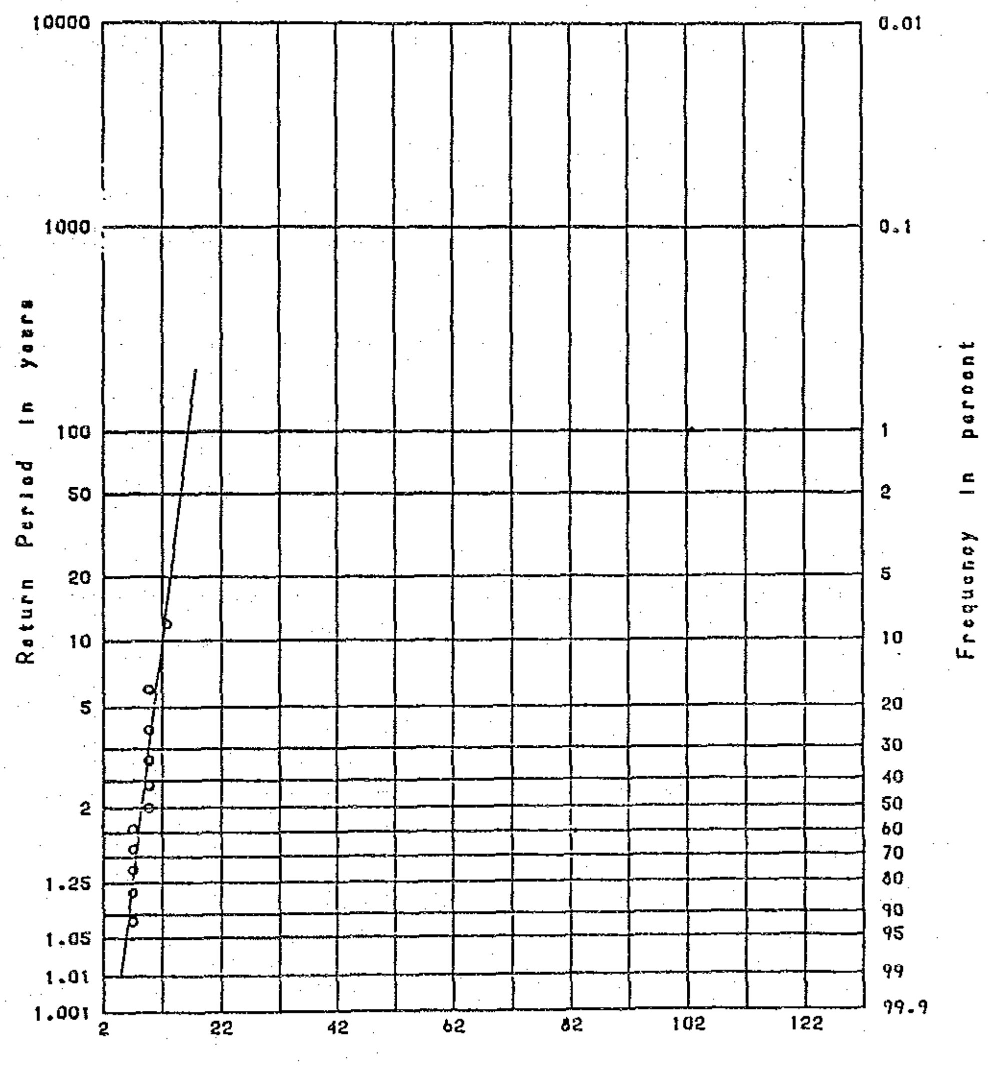
Region :BETIO-BAIRIKI

District :PACIFIC OCEAN

Altitude of Station :35.0 Meters

Kind of Record :WIND FORCE (N)

Period of Record :11 YEARS



BETIO-BAIRIKI CAUSEWAY-FISHERIES CHANNEL

Fig.-1 FREQUENCY CURVE

(2) NORTH WEST

PLOTTING POSITION

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

* NUMBER OF SAMPLES ; 11

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

CALCULATION METHOD ;GUMBEL METHOD

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

(1) NUMBER OF SAMPLES ; 11

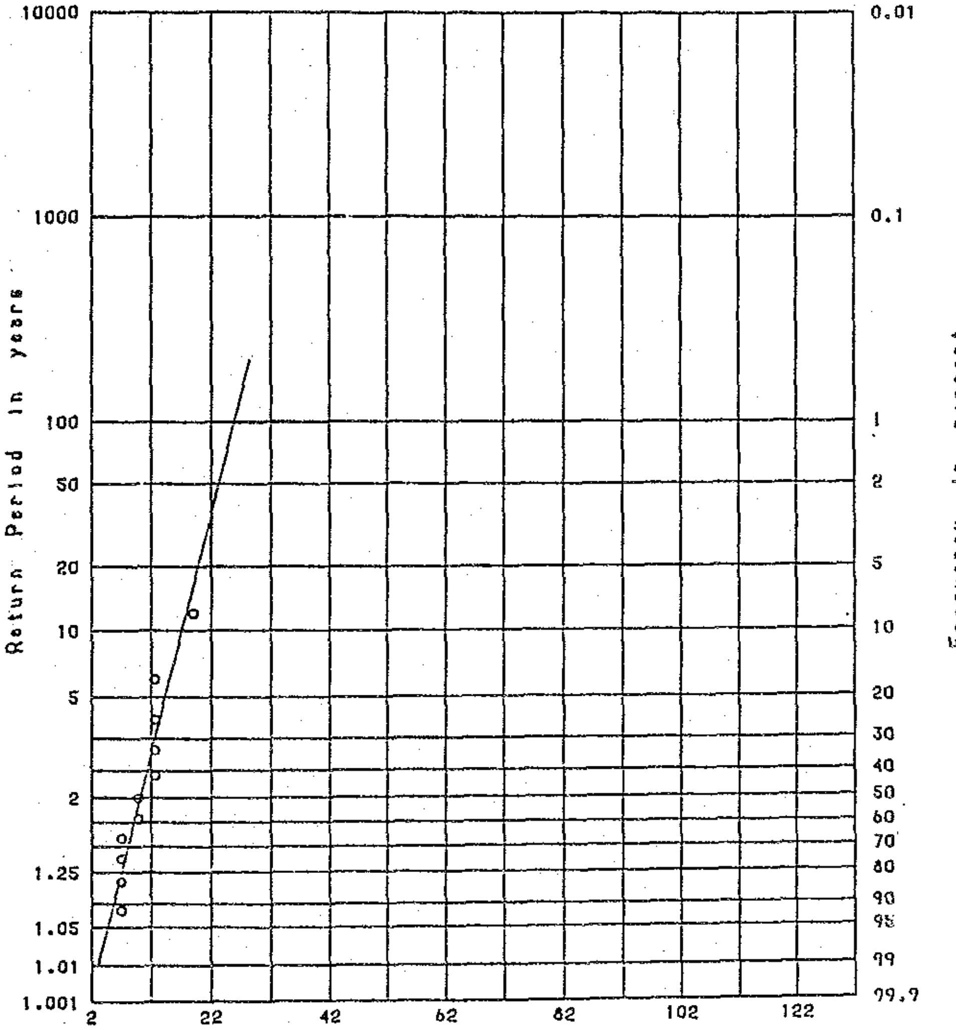
RETURN PERIOD	EXCESS PROB.	VARIABLE	WIND VELOCITY
1.01	0.9901	-1.5293	3.081
1.50	0.6667	-0.0940	8.411
2.	0.5000	0.3665	10.121
5.	0.2000	1.4999	14.330
10.	0.1000	2.2504	17.117
20.	0.0500	2.9702	19.790
30.	0.0333	3.3843	21.328
40.	0.0250	3.6762	22.412
50.	0.0200	3.9019	23.251
80.	0.0125	4.3757	25.010
100.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

NOTE : FORMULA OF PRESUMPTION

X=X0+(1/A)*VARIABLE

X0 = 8.760
1/A = 3.714

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



BETIO-BAIRIKI CAUSEWAY-FISHERIES CHANNEL

Fig.-2 FREQUENCY CURVE

(3) SOUTH WEST

PLOTTING POSITION

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

* NUMBER OF SAMPLES ; 7

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

CALCULATION METHOD ;GUMBEL METHOD

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

(1) NUMBER OF SAMPLES ; 7

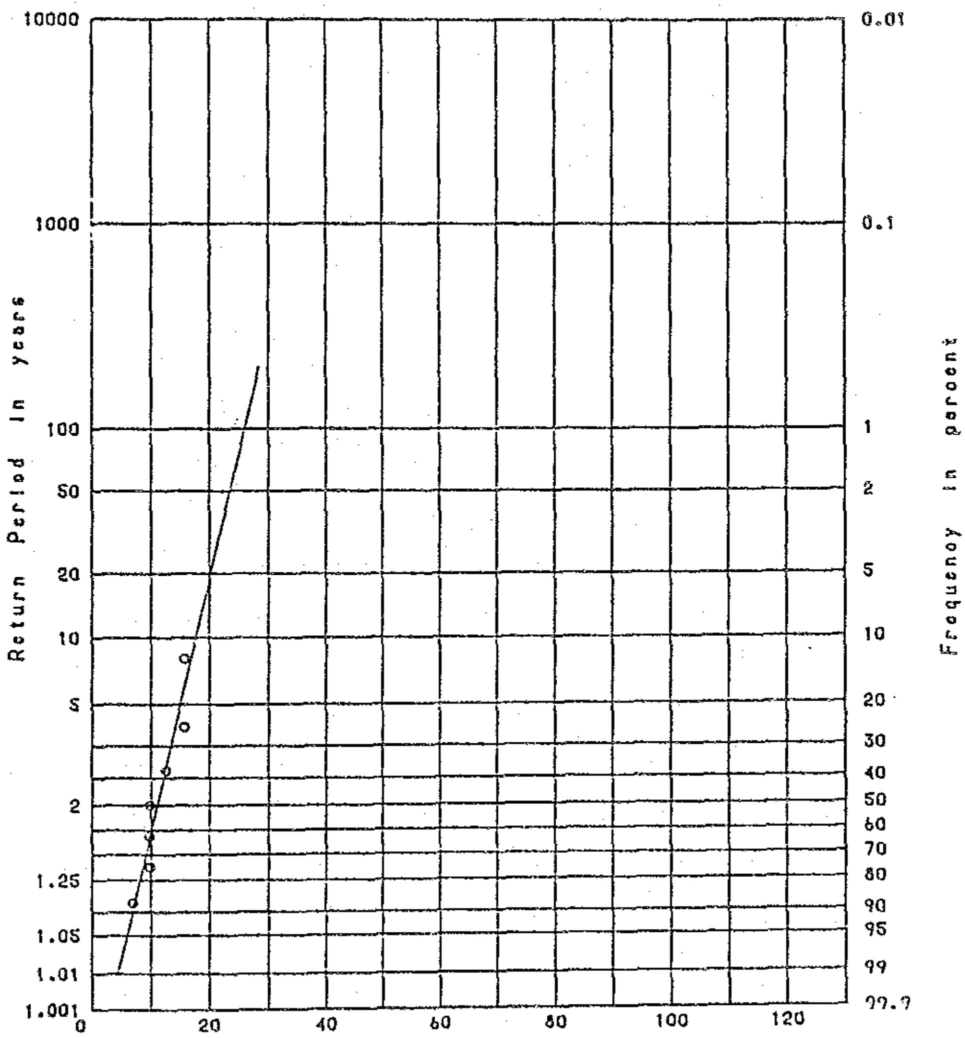
RETURN PERIOD	EXCESS PROB.	VARIABLE	WIND VELOCITY
1.01	0.9901	-1.5293	4.421
1.50	0.6667	-0.0940	9.459
2.	0.5000	0.3665	11.075
5.	0.2000	1.4999	15.053
10.	0.1000	2.2504	17.686
20.	0.0500	2.9702	20.212
30.	0.0333	3.3843	21.666
40.	0.0250	3.6762	22.690
50.	0.0200	3.9019	23.482
80.	0.0125	4.3757	25.145
100.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

NOTE : FORMULA OF PRESUMPTION

X=X0+(1/A)*VARIABLE

X0 = 9.789
1/A = 3.509

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



BETIO-BAIRIKI CAUSEWAY-FISHERIES CHANNEL

Fig.-3 FREQUENCY CURVE

(4) SOUTH

PLOTTING POSITION

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

* NUMBER OF SAMPLES ; 11

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

CALCULATION METHOD ;GUMBEL METHOD

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

(1) NUMBER OF SAMPLES ; 11

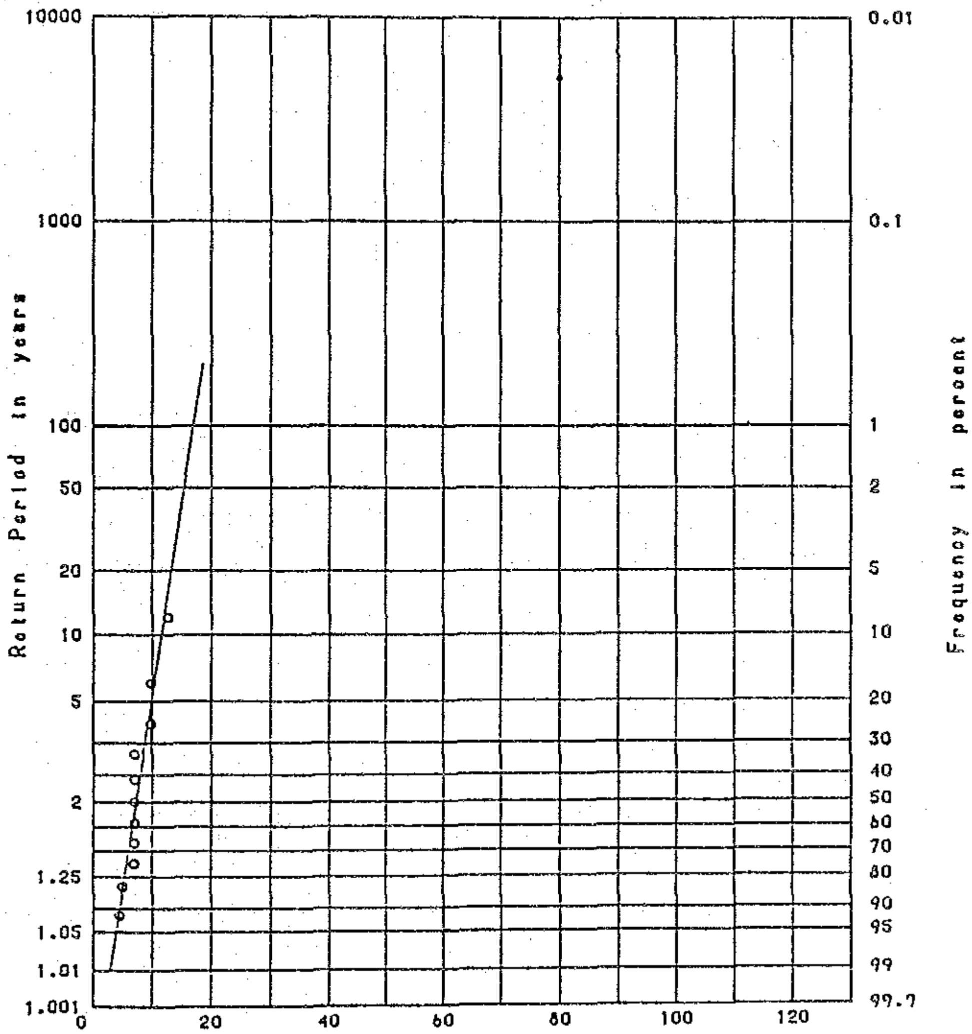
RETURN PERIOD	EXCESS PROB.	VARIABLE	WIND VELOCITY
1.01	0.9901	-1.5293	2.907
1.50	0.6667	-0.0940	6.200
2.	0.5000	0.3665	7.257
5.	0.2000	1.4999	9.858
10.	0.1000	2.2504	11.580
20.	0.0500	2.9702	13.232
30.	0.0333	3.3843	14.182
40.	0.0250	3.6762	14.852
50.	0.0200	3.9019	15.370
80.	0.0125	4.3757	16.457
100.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

NOTE : FORMULA OF PRESUMPTION

X=X0+(1/A)*VARIABLE

X0 = 6.416
1/A = 2.295

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



BETIO-BAIRIKI CAUSEWAY-FISHERIES CHANNEL

Fig.-4 FREQUENCY CURVE

(5) SOUTH EAST

PLOTTING POSITION

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

* NUMBER OF SAMPLES ; 11

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

CALCULATION METHOD ;GUMBEL METHOD

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

(1) NUMBER OF SAMPLES ; 11

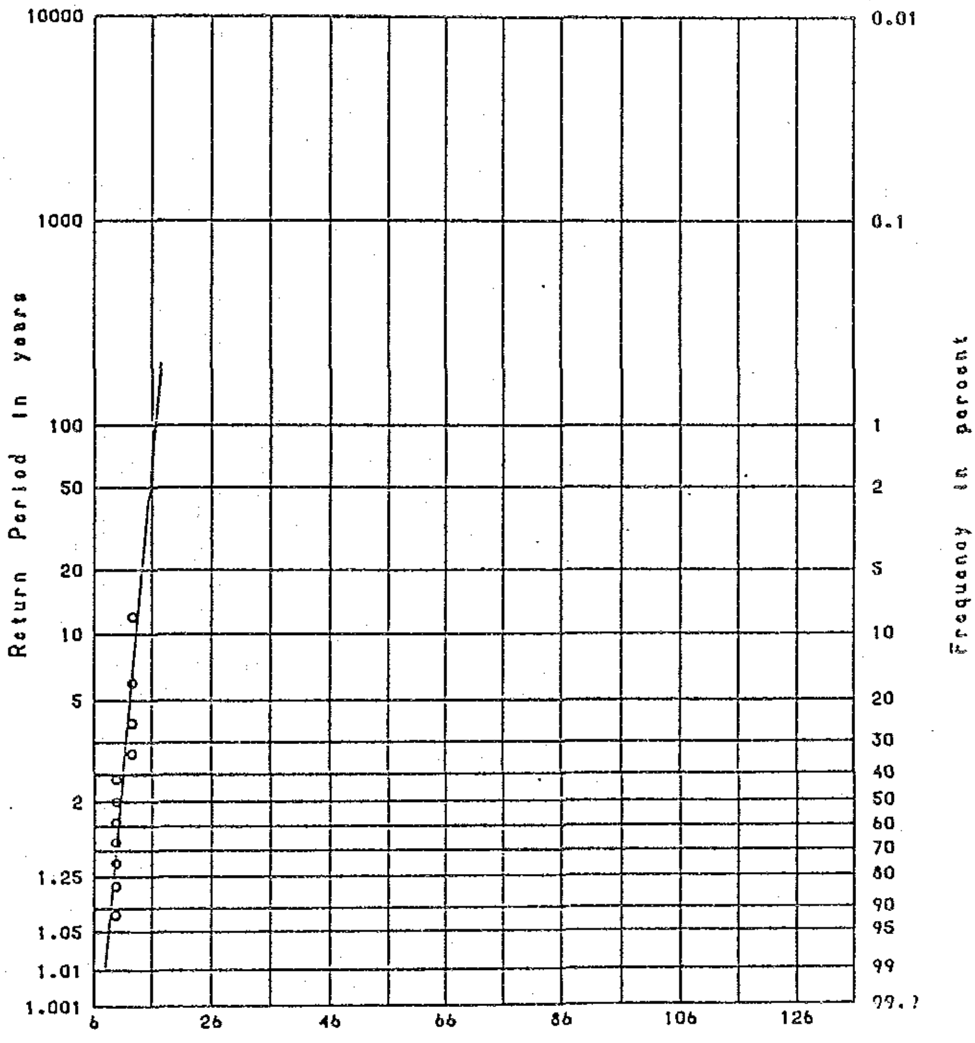
RETURN PERIOD	EXCESS PROB.	VARIABLE	WIND VELOCITY
1.01	0.9901	-1.5293	7.949
1.50	0.6667	-0.0940	9.968
2.	0.5000	0.3665	10.616
5.	0.2000	1.4999	12.210
10.	0.1000	2.2504	13.265
20.	0.0500	2.9702	14.278
30.	0.0333	3.3843	14.860
40.	0.0250	3.6762	15.271
50.	0.0200	3.9019	15.588
80.	0.0125	4.3757	16.254
100.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

NOTE : FORMULA OF PRESUMPTION

X=X0+(1/A)*VARIABLE

X0 = 10.100
1/A = 1.406

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



BETIO-BAIRIKI CAUSEWAY-FISHERIES CHANNEL

Fig.-5 FREQUENCY CURVE

(6) ALL DIRECTION

PLOTTING POSITION

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

* NUMBER OF SAMPLES ; 33

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

CALCULATION METHOD ;GUMBEL METHOD

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

(1) NUMBER OF SAMPLES ; 33

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

NOTE : FORMULA OF PRESUMPTION

X=X0+(1/A)*VARIABLE

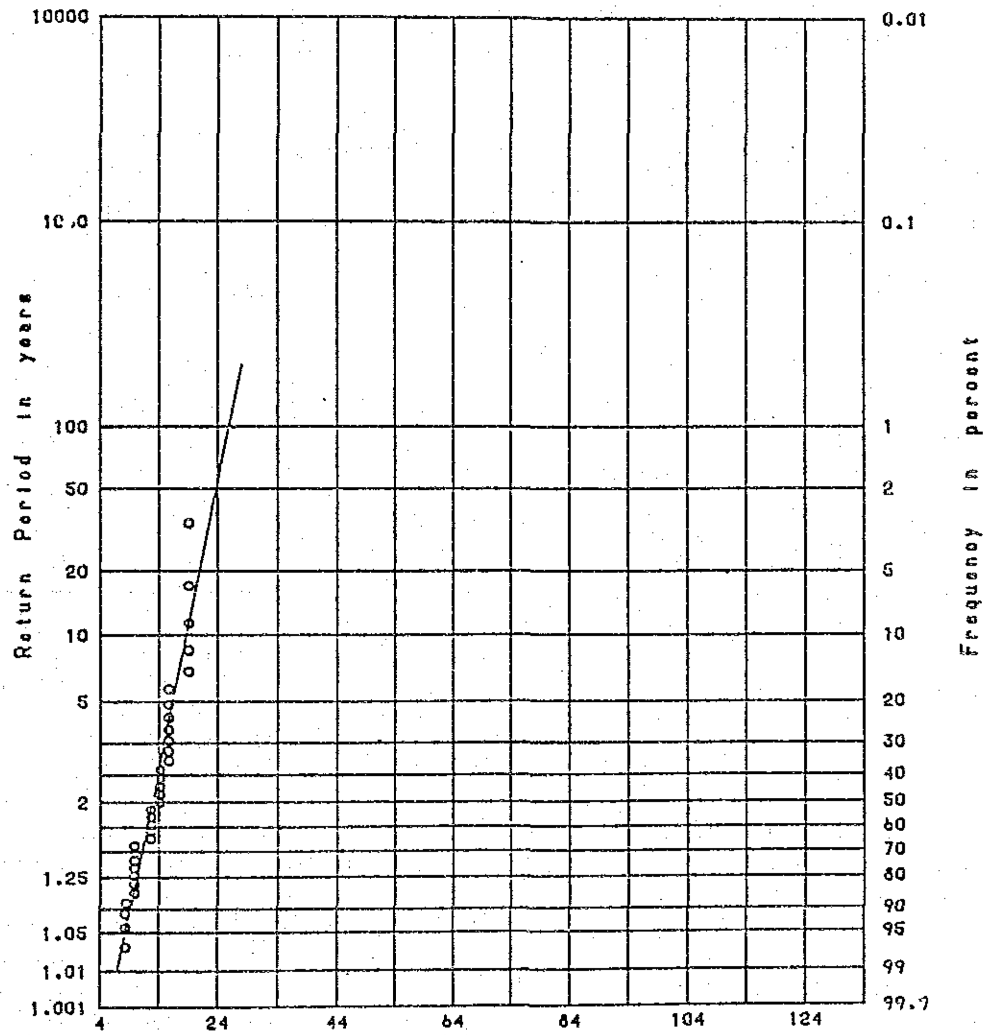
X0 = 11.691
1/A = 3.082

Station :KIRIBATI, TARAWA   Region :BETIO-BAIRIKI

District :PACIFIC OCEAN   Altitude of Station :35.0 Meters

Kind of Record :WIND VELOCITY (ALL)

Period of Record : 33 YEARS



BETIO-BAIRIKI CAUSEWAY-FISHERIES CHANNEL

Fig.-6 FREQUENCY CURVE

CALCULATION OF WAVE TRANSFORMATION OF BREAKING WAVES

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

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

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

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

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

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

a) Wave Breaking at Lagoon Tip

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

	Expression	Value
Lo	$1.56\ T^2$	134.9 m
H_o'/Lo	6.1/134.9	0.045
ho	M.H.W.S - h	8.000 m
ho/H_o'	8.0/6.1	1.311
β o	$0.028\ (H_o'/Lo)^{-0.38}\ \exp\ (20\ \tan^{1.5})$	0.158
β 1	0.52 exp (4.2 tan)	0.598
β max	$Max\ (0.92, 0.32\ (H_o'/Lo)^{-0.29}\ \exp\ (2.4\ \tan\ ))$	0.920

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

b) Wave Breaking at Reef Tip

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

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

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

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

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

CALCULATION OF WAVE DECAY IN CASE OF NON-BREAKING WAVES

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

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

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

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

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

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

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

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

a) Friction Loss on Lagoon

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

- Distance: Δx = 10,000 m = 32,809 ft
- Averaged water depth = 8.0 m = 26.248 ft

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

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

Kf = 0.3

H_T = 0.3 x 10.764 = 3.229 ft = 0.98 m

b) Friction Loss on Reef

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

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

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

Kf = 0.5

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

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

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

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

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

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

$Kf = 0.51$

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

CALCULATION OF TIDAL FLOW BETWEEN BETIO AND BAIRIKI

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

1-1 Objective

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

1-2 Calculation formula

Following equations for non-uniform flow will be adopted.

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

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

where; Z : flow bed height

H : flow depth

α : coefficient of energy

Q : discharge

g : acceleration of gravity

A : flow area

l : distance between sections

N : coefficient of roughness

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

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

1-3 Input Data

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

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

1-4 Order of Calculation

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

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

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

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

1-5 Results

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

Fig. 1 Location of Sections

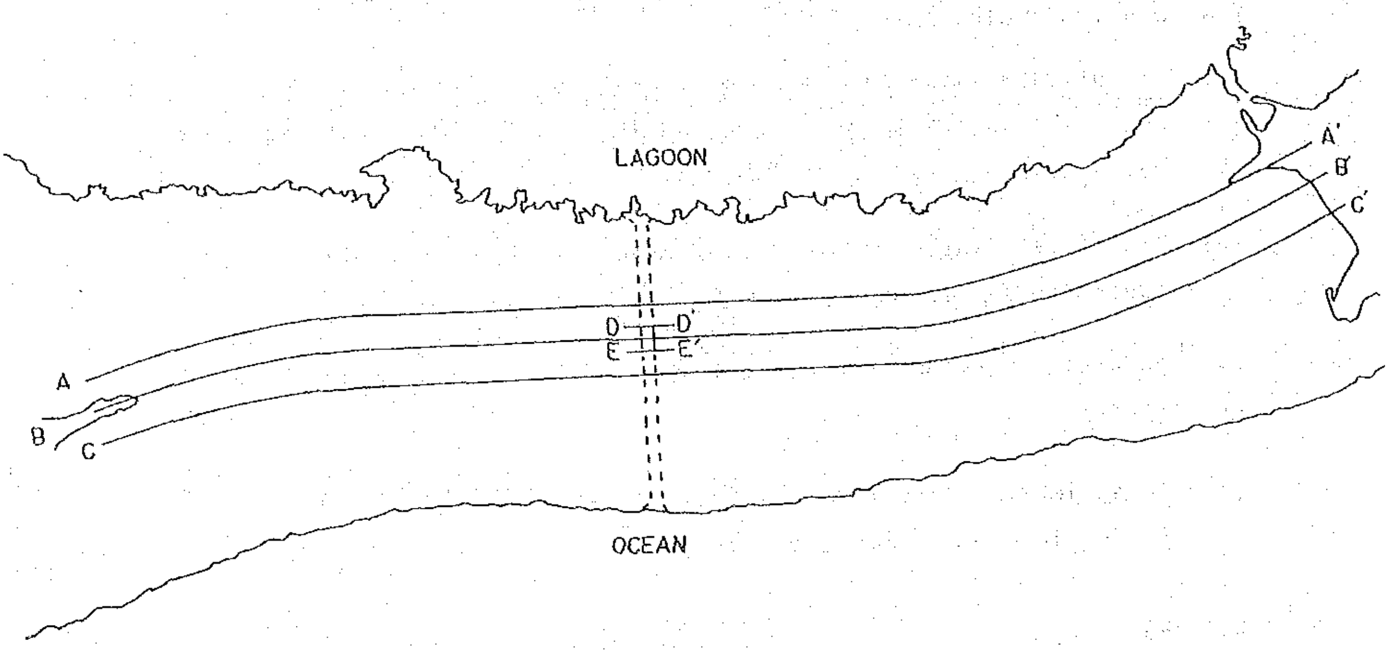


Fig. 2 Protiles of Sections

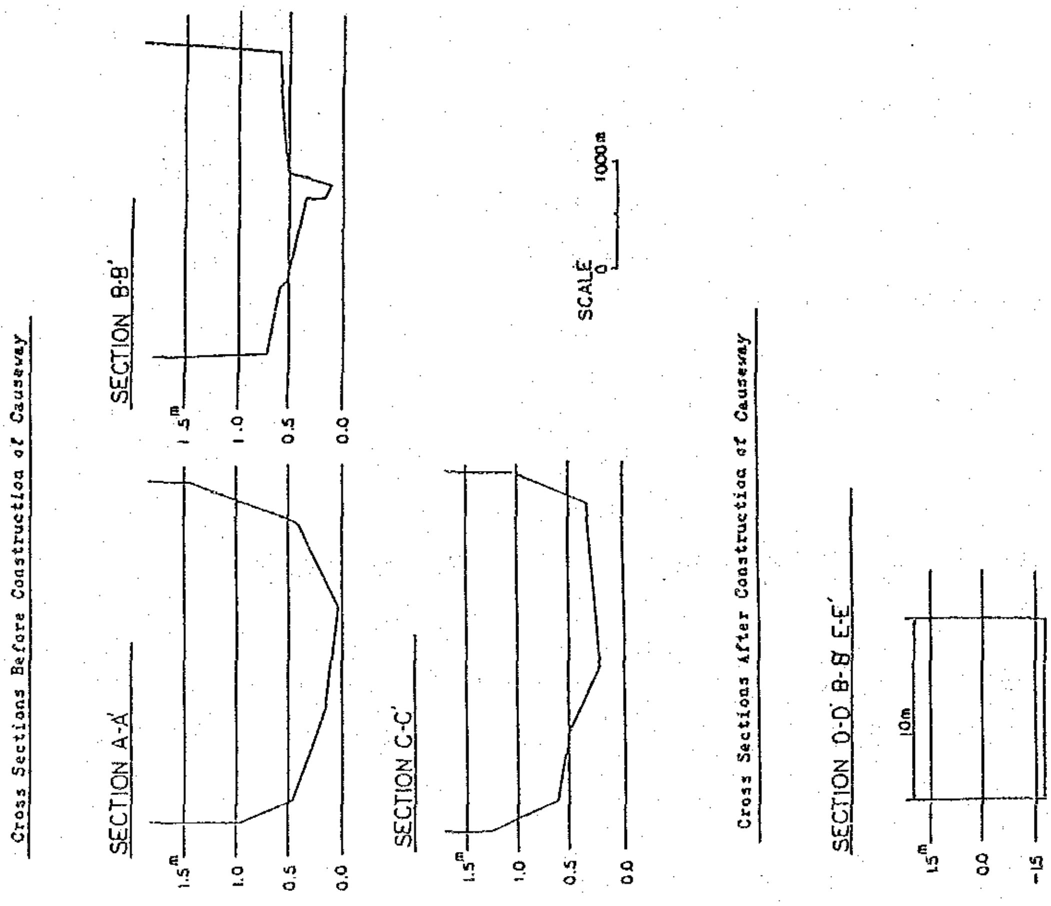
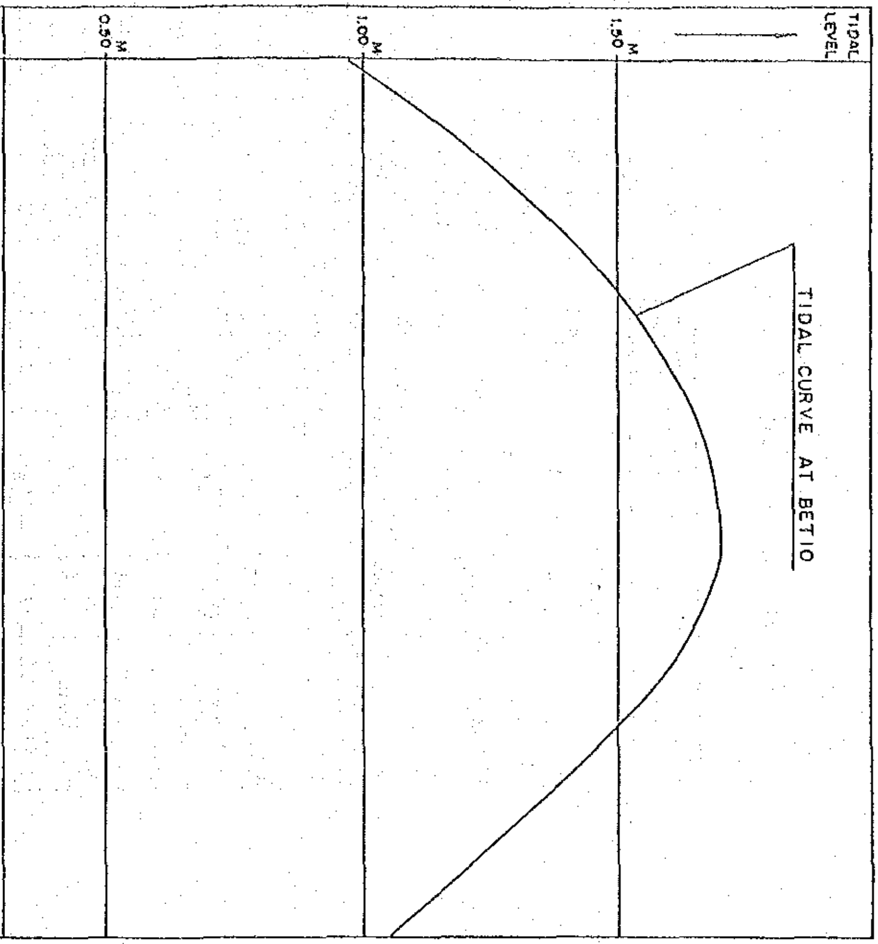


Fig. 3 Tidal Curve at Betio

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



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

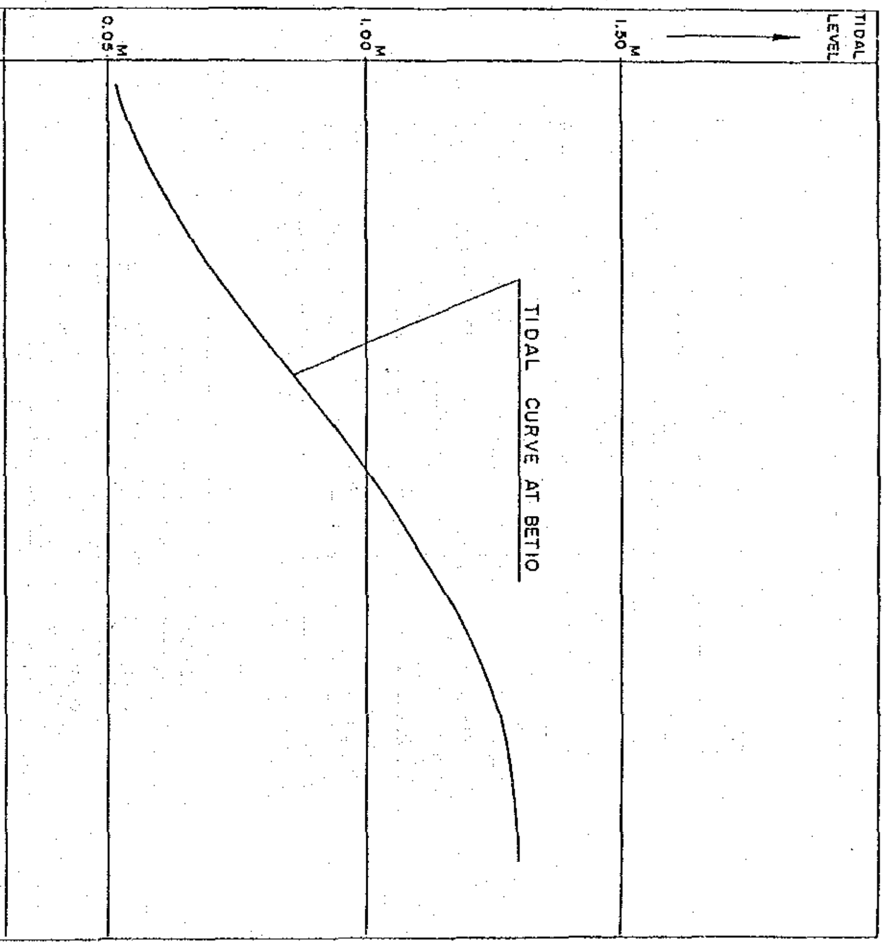


Table-1 Tidal Flow Analysis (Existing Condition)

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

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

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

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

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

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

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

Flow Direction: Ocean → Lagoon

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

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

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

Flow Direction: Lagoon → Ocean

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

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

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

Flow Direction	Time	Discharge (m^3/sec)	Averaged Discharge (m^3/sec)	Inflow (m^3)	Outline (m^3)
From Ocean to Lagoon	12:30	0			
			30.6	55,080	-
	13:00	61.2			
			60.7	109,260	-
	13:30	60.2			
			47.3	85,140	-
	14:00	34.3			
			32.2	57,960	-
	14:30	30.0			
			32.2	57,960	-
	15:00	34.3			
			17.2	20,640	-
	15:20	0			
From Lagoon to Ocean			16.9	-	10,140
	15:30	33.7			
			62.3	-	112,140
	16:00	90.8			
			75.0	-	135,000
	16:30	59.1			
			52.1	-	93,780
	17:00	45.0			
			22.5	-	13,500
	17:10	0			
From Ocean to Lagoon			12.1	14,520	-
	17:30	24.2			
			25.6	46,030	-
	18:00	26.9			
			13.5	24,300	-
	18:30	0			
Total			-	470,940	364,560

Table-7 Tidal Flow Analysis

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

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

Table-8 Summary of Tidal Flow Analysis

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

COMPARISON OF LOADING SPECIFICATIONS FOR HIGHWAY BRIDGES

COMPARISON OF LOADING SPECIFICATIONS FOR HIGHWAY BRIDGES

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

ESTIMATION OF EARTHQUAKE LOAD

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

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

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

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

TABLE-1 PAST EARTHQUAKES AND INDUCED GROUND ACCELERATION

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

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