APPENDIX 8. DESIGN OF DRAINAGE FACILITIES

A8.1 Analysis of Design Rainfall

The yearly maximum 10 minute rainfall data recorded at Majuro Weather Station in the last 10 years are as shown in Table A8-1. The design rainfall intensity which is the 10 minute duration intensity of a 2 year return period was derived as described as follows:

Table A8-1 THE YEARLY MAXIMUM 10 MINUTE RAINFALL

Year	Max Rainfall	Year	Max Rainfall
1983	18	1989	26
1984	N.A.	1990	28
1985	19	1991	27
1986	19	1992	12*
1987	15	1993	23
1988	18	1994	N.A.

Source : Majuro Weather Station

The 10 minute rainfall of a 2 year return period (X) was obtained by the following formula (Gambel's Method):

$$X = Xave + K \times \sigma = 21.444 - 0.164 \times 4.40 = 20.72 \text{ mm}$$

Where,

Xave : Average of the maximum 10 minute rainfalls (The minimum one was excluded.) = 21.40 mm

σ : Standard deviation of the maximum 10 minute rainfalls = 4.40

K : Frequency factor $= 0.7797 \times Y - 0.45 = -0.164$

Y : Reduced variation $= -\text{Ln}(-\text{Ln}(1 - P)) = 0.367$

P : Possibility = 1 / 2 = 0.5

Since the 10 minute rainfall of a 2 year return period is 20.72 mm, therefore, the design rainfall intensity is 130 mm/h.

A8.2 Calculation of Discharge, Infiltration, Velocity of Ditches

(1) Discharge from the surface

Discharge (Q) was computed by Rational Formula:

$$Q = (1 / 3.6) \times 10^{6} \times C \times r \times A$$

Where,

C : Ratio of runoff = 0.9 for paved road r : Intensity of rainfall = 130 mm/h

A: Catchment area (m2)

The discharge per linear meter of ditches by catchment width (Width of road shoulders and ditches vary by section) were computed as shown in Table A8-2.

Table A8-2 DISCHARGE BY CATCHMENT WIDTH

Catchment width (m)	Discharge (m3/sec/m)
4.0	0.000130
4.5	0.000146
5.0	0.000163
6.0	0.000195
7.0	0.000228

(2) Infiltration to the ground

A formula to compute infiltration from an infiltrate type ditch was proposed in "Design Manual for Infiltrate Type Ditches" issued by Ozawa Concrete Co., Ltd.

Infiltration (fc) of Ditch type-A was computed as follows:

$$fc = F \times y \times (1-D) \times (1-E) \times q$$
$$= 0.3 \times 0.35 \times (1-0.1) \times (1-0.33) \times 0.00022$$
$$= 0.000014 (m3/sec/m)$$

Where,

F : Factor of safety = 0.3

y : Factor of reduction of permeability = 0.35 (for 50 years use)

D: Factor of reduction of saturation= 0.1

E : Factor of reduction of high underground water=0.33 (in case water level is 0.3m beneath the bottom of porous concrete base.)

q : Unit infiltration of the soil obtained by test or calculated.

$$= (8.95 saturation \times k + 2.55 \times 10^{-4}) \times B \times H$$
$$= (8.95 \times 0.0001 + 2.55 \times 10^{-4}) \times 0.65 \times 0.30$$
$$= 0.00022 (m3/sec)$$

k : Permeability coefficient = 0.01(cm/sec) (assumed)

B : Width of the porous concrete base = 0.65m

H : Head = 0.30m (between the bottom of porous concrete base and design discharge water level)

Infiltration (fc) of Ditch type-B was computed as follows:

$$fc = 0.3 \times 0.35 \times (1-0.1) \times (1-0.33) \times 0.000092$$

= 0.0000058(m3/sec/m)

$q = (8.95 \times 0.0001 + 2.55 \times 10^{-4}) \times 0.40 \times 0.2$

= 0.000092(m3/sec)

(3) Discharge including Infiltration

The final discharge to the sea was obtained by reducing infiltration from discharge from the surface.

The final discharges per linear meter of ditches by catchment width and ditch type were computed as shown in Table A8-3.

Table A8-3 FINAL DISCHARGE BY DITCH TYPE (m3/sec/m)

Catchment width (m)	Ditch Type - A	Ditch Type - B
4.0	0.000116	0.000124
4.5	0.000132	0.000140
5.0	0.000149	0.000157
6.0	0.000181	0.000189
7.0	0.000214	0.000222

(3) Velocity and depth of discharge

Velocity (V) of discharge was computed by Maning's Formula

$$V = 1 / n \times R^{2/3} \times I^{1/2}$$

$$Q = V \times A$$

Where,

n : Coefficient of roughness of the ditch

= 0.015 : Smooth concrete surface,

= 0.017 : Rough concrete surface

R : Hydrauric radius =Sectional area / Wetted perimeter

I : Gradient of ditch

A : Sectional area of discharge

The discharge, velocity and depth of each span of ditch was computed and the results were tabulated as shown in Table A8-4.

A8.3 Calculation of Discharge of Culverts

The discharge, velocity and depth of each box culvert (to cross main road) is computed as tabulated in Table A8-5.

The discharge, velocity and depth of each pipe culvert (from road to the sea) is computed as tabulated in Table A8-6.

Table A8-4 CALCULATION OF DISCHARGE(Q), VELOCITY(V) AND DEPTH(H) OF SIDE DITHCES (1/2)

Intensity of rainfall : r 130.0 mm/h
Ratio of runoff : c 0.900

Infiltration of "U" ditch : Infu 0.00001400 m3/sec/m
Infiltration of "C" ditch : Infc 0.00000580 m3/sec/m

Ditch type "U" is TYPE-A in drawing.
Ditch type "C" is TYPE-B in drawing.

Outlet NO.	Side "O"or"L"	Chainage Crest (km)	Chainage Outlet (km)	Catchment length (m)	Catchment width (m)	Catchment area (m2)	Dithch type "U"or"C"	Discharge from road (m3/sec)	Infiltrate to ground (m3/sec)	Discharge final (m3/sec)	Elevation Crest (m)	Elevation Outlet (m)	Ditch gradient (%)	Velocity of dischrge (m/sec)	Depth of dischrge (m)	Depth of ditch (m)
2	O & L	0.060	0.000	60.0	5.0	300.0	U	0.00975	0.00084	0.00891	1.189	0.955	0.390	0.5217	0.068	0.150
2	O & L	0.060	0.000	60.0	4.5	270.0	U	0.00878	0.00084	0.00794	1.189	0.955	0.390	0.5005	0.063	0.150
3	O & L	0.060	0.160	100.0	5.0	500.0	U	0.01625	0.00140	0.01485	1.189	1.086	0.103	0.3656	0.162	0.400
3	O & L	0.300	0.160	140.0	5.0	700.0	U	0.02275	0.00196	0.02079	1.336	1.086	0.179	0.4877	0.171	0.400
6	O & L	0.300	0.430	130.0	5.0	650.0	U	0.02113	0.00182	0.01931	1.336	1.040	0.228	0.5264	0.147	0.400
6	O & L	0.560	0.430	130.0	5.0	650.0	U	0.02113	0.00182	0.01931	1.400	1.040	0.277	0.5264	0.147	0.400
8	O & L	0.720	0.560	160.0	5.0	800.0	U	0.02600	0.00224	0.02376	1.486	1.050	0.273	0.5924	0.160	0.500
10	O & L	0.720	0.830	110.0	5.0	550.0	U	0.01787	0.00154	0.01633	1.486	1.096	0.355	0.5982	0.109	0.400
10	O & L	0.910	0.830	80.0	5.0	400.0	U	0.01300	0.00112	0.01188	1.363	1.096	0.334	0.5365	0.089	0.400
12	O & L	0.910	1.000	90.0	5.0	450.0	U	0.01462	0.00126	0.01336	1.363	1.121	0.269	0.5107	0.105	0.400
12	O & L	1.060	1.000	60.0	5.0	300.0	U	0.00975	0.00084	0.00891	1.427	1.121	0.510	0.4964	0.072	0.300
13	O & L	1.060	1.090	30.0	5.0	150.0	U	0.00488	0.00042	0.00446	1.427	1.348	0.263	0.4051	0.044	0.200
13	O & L	1.240	1.090	150.0	5.0	750.0	U	0.02438	0.00210	0.02228	1.393	1.348	0.030	0.5003	0.178	0.400
14	O & L	1.240	1.370	130.0	5.0	650.0	U	0.02113	0.00182	0.01931	1.393	1.118	0.212	0.5119	0.151	0.400
14	O & L	1.570	1.370	200.0	5.0	1000.0	U	0.03250	0.00280	0.02970	1.635	1.118	0.259	0.6090	0.195	0.400
18	O & L	1.570	1.750	180.0	5.0	900.0	U	0.02925	0.00252	0.02673	1.635	1.190	0.247	0.5846	0.183	0.500
21	O & L	1.750	1.930	180.0	5.0	900.0	U	0.02925	0.00252	0.02673	1.550	1.105	0.247	0.5846	0.183	0.400
21	O & L	2.100	1.930	170.0	5.0	850.0	U	0.02762	0.00238	0.02524	1.506	1.105	0.236	0.5677	0.178	0.400
24	O & L	2.100	2.220	120.0	5.0	600.0	U	0.01950	0.00168	0.01782	1.506	1.105	0.334	0.5980	0.119	0.400
25	O & L	2.220	2.380	160.0	5.0	800.0	U	0.02600	0.00224	0.02376	1.455	1.095	0.225	0.5492	0.173	0.500
25	O & L	2.480	2.380	100.0	5.0	500.0	U	0.01625	0.00140	0.01485	1.508	1.195	0.313	0.5553	0.107	0.400
26	O & L	2.480	2.560	80.0	5.0	400.0	U	0.01300	0.00112	0.01188	1.508	1.377	0.164	0.5069	0.094	0.300
26	O & L	2.720	2.560	160.0	5.0	800.0	U	0.02600	0.00224	0.02376	1.468	1.077	0.244	0.5666	0.168	0.500
27	O & L	2.720	2.800	80.0	5.0	400.0	U	0.01300	0.00112	0.01188	1.468	1.155	0.391	0.5652	0.084	0.200
27	O & L	3.000	2.800	200.0	5.0	1000.0	U	0.03250	0.00280	0.02970	1.577	1.055	0.261	0.6112	0.194	0.300
29	O & L	3.000	3.120	120.0	5.0	600.0	U	0.01950	0.00168	0.01782	1.577	1.155	0.352	0.6083	0.117	0.400
29	O & L	3.290	3.120	170.0	5.0	850.0	U	0.02763	0.00238	0.02525	1.586	1.155	0.254	0.5836	0.173	0.400
32	O & L	3.290	3.460	170.0	5.0	850.0	U	0.02763	0.00238	0.02525	1.586	1.165	0.248	0.5836	0.173	0.500
32	O & L	3.600	3.460	140.0	5.0	700.0	U	0.02275	0.00196	0.02079	1.545	1.165	0.271	0.5720	0.145	0.500
38	O & L	3.600	3.750	150.0	5.0	750.0	U	0.02438	0.00210	0.02228	1.545	1.055	0.327	0.6248	0.143	0.350
38	O & L	3.940	3.750	190.0	5.0	950.0	U	0.03088	0.00266	0.02822	1.484	1.055	0.226	0.5652	0.200	0.350
43	O & L	3.940	4.130	190.0	5.0	950.0	U	0.03088	0.00266	0.02822	1.484	1.055	0.226	0.5716	0.197	0.500
43	O & L	4.250	4.130	120.0	5.0	600.0	U	0.01950	0.00168	0.01782	1.593	1.255	0.282	0.5612	0.127	0.300
49	O & L	4.250	4.450	200.0	5.0	1000.0	U	0.03250	0.00280	0.02970	1.593	1.105	0.244	0.5946	0.200	0.400
49	O & L	4.560	4.450	110.0	5.0	550.0	U	0.01788	0.00154	0.01634	1.611	1.205	0.369	0.6054	0.108	0.300
52	O & L	4.560	4.760	200.0	5.0	1000.0	U	0.03250	0.00280	0.02970	1.611	1.088	0.261	0.6105	0.195	0.400
52	O & L	4.890	4.760	130.0	5.0	650.0	U	0.02112	0.00182	0.01930	1.581	1.188	0.302	0.5871	0.131	0.300
53	O & L	5.130	4.890	240.0	7.0	1680.0	U	0.05460	0.00336	0.05124	1.655	1.181	0.197	0.6746	0.304	0.550
54	O & L	5.220	5.130	90.0	7.0	630.0	U	0.02047	0.00126	0.01921	1.634	1.365	0.299	0.5830	0.132	0.500
56	O & L	5.220	5.340	120.0	7.0	840.0	U	0.02730	0.00168	0.02562	1.634	1.185	0.374	0.6814	0.150	0.400
57	O & L	5.340	5.440	100.0	7.0	700.0	U	0.02275	0.00140	0.02135	1.435	1.095	0.340	0.6278	0.136	0.400
58	O & L	5.440	5.550	110.0	7.0	770.0	U	0.02503	0.00154	0.02349	1.345	1.015	0.300	0.6135	0.153	0.350
58	O & L	5.630	5.550	80.0	7.0	560.0	U	0.01820	0.00112	0.01708	1.293	0.990	0.379	0.6175	0.110	0.350
59-L	O & L	5.700	5.630	241.5	7.0	1690.5	U	0.05494	0.00338	0.05156	1.230	1.043	0.267	0.6828	0.302	0.400
59-R	O & L	5.700	5.630	70.0	7.0	490.0	U	0.01592	0.00098	0.01494	1.230	1.143	0.124	0.3936	0.152	0.250
60-1	O & L	5.700	5.880	180.0	7.0	1260.0	U	0.04095	0.00252	0.03843	1.285	1.015	0.150	0.5117	0.300	0.400
60-1	O & L	6.040	5.880	160.0	7.0	1120.0	U	0.03640	0.00224	0.03416	1.670	1.100	0.356	0.7117	0.192	0.400
62	O & L	6.040	6.120	80.0	7.0	560.0	U	0.01820	0.00112	0.01708	1.670	1.175	0.619	0.7387	0.092	0.300
62	O & L	6.320	6.120	200.0	5.0	1000.0	U	0.03250	0.00280	0.02970	1.440	1.075	0.182	0.5285	0.225	0.400
65	O & L	6.320	6.360	40.0	5.0	200.0	U	0.00650	0.00056	0.00594	1.430	1.185	0.613	0.5320	0.045	0.400
65	O & L	6.540	6.360	180.0	5.0	900.0	U	0.02925	0.00252	0.02673	1.587	1.085	0.279	0.6138	0.174	0.500
69	O & L	6.540	6.680	140.0	5.0	700.0	U	0.02275	0.00196	0.02079	1.587	1.235	0.251	0.5571	0.149	0.500
69	O & L	6.780	6.680	100.0	5.0	500.0	U	0.01625	0.00140	0.01485	1.587	1.235	0.352	0.5628	0.106	0.500
70	O & L	6.780	6.900	120.0	5.0	600.0	U	0.01950	0.00168	0.01782	1.557	1.205	0.293	0.5680	0.125	0.500
70	O & L	6.980	6.900	80.0	4.0	320.0	U	0.01040	0.00112	0.00928	1.615	1.305	0.388	0.5283	0.070	0.400
71	O & L	7.100	6.980	120.0	4.0	480.0	U	0.01560	0.00168	0.01392	1.629	1.240	0.324	0.5535	0.101	0.500
73	O & L	7.100	7.180	80.0	4.0	320.0	U	0.01040	0.00112	0.00928	1.629	1.263	0.458	0.5551	0.067	0.500
74	O & L	7.180	7.280	100.0	4.0	400.0	U	0.01300	0.00140	0.01160	1.613	1.291	0.322	0.5235	0.089	0.500
74	O & L	7.340	7.280	60.0	4.0	240.0	U	0.00780	0.00084	0.00696	1.644	1.291	0.588	0.5512	0.050	0.500
77	O & L	7.340	7.430	90.0	4.0	360.0	U	0.01170	0.00126	0.01044	1.644	1.270	0.416	0.5592	0.075	0.500
77	O & L	7.480	7.430	50.0	4.0	200.0	U	0.00650	0.00070	0.00580	1.600	1.270	0.660	0.5455	0.043	0.500
78	O & L	7.480	7.530	50.0	4.0	200.0	U	0.00650	0.00070	0.00580	1.600	1.270	0.660	0.5455	0.043	0.500
78	O & L	7.600	7.530	70.0	4.0	280.0	U	0.00910	0.00098	0.00812	1.645	1.270	0.536	0.5661	0.057	0.500
80	O & L	7.600	7.730	130.0	4.0	520.0	U	0.01690	0.00182	0.01508	1.645	1.250	0.304	0.5529	0.109	0.500
80	O & L	7.840	7.730	110.0	4.0	440.0	U	0.01430	0.00154	0.01276	1.621	1.250	0.337	0.5488	0.093	0.500
81	O & L	7.900	7.840	60.0	4.0	240.0	U	0.00780	0.00084	0.00696	2.834	1.521	2.188	0.8537	0.033	0.150
	BRIDGE															
84	O	8.020	8.130	110.0	4.0	440.0	C	0.01430	0.00064	0.01366	6.310	1.700	4.191	1.3173	0.036	0.250
86	O	8.130	8.330	200.0	4.0	800.0	C	0.02600	0.00116	0.02484	1.715	1.265	0.225	0.5621	0.120	0.700
86	O	8.450	8.330	120.0	4.0	480.0	C	0.01560	0.00070	0.01490	1.765	1.415	0.292	0.5338	0.084	0.550
90	O	8.450	8.530	80.0	4.0	320.0	C	0.01040	0.00046	0.00994	1.765	1.455	0.388	0.5226	0.061	0.500
92	O	8.530	8.630	100.0	4.0	400.0	C	0.01300	0.00058	0.01242	1.705	1.405	0.300	0.5103	0.075	0.550
92	O	8.640	8.630	10.0	4.0	40.0	C	0.00130	0.00006	0.00124	1.717	1.455	2.620	0.4619	0.010	0.500
93	O	8.640	8.730	90.0	4.0	360.0	C	0.01170	0.00052	0.01118	1.717	1.398	0.354	0.5295	0.067	0.500
94	O	8.730	8.830	100.0	4.0	400.0	C	0.01300	0.00058	0.01242	1.645	0.995	0.650	0.6675	0.060	0.300
94	O	8.930	8.830	100.0	4.0	400.0	C	0.01300	0.00058	0.01242	1.048	0.945	0.103	0.3507	0.101	0.350
95	O	9.100	8.930	170.0	4.0	680.0	C	0.02210	0.00099	0.02111	1.485	0.998	0.286	0.5874	0.102	0.300
98	O	9.280	9.100	180.0	4.0	720.0	C	0.02340	0.00104	0.02236	1.551	1.185	0.203	0.5275	0.116	0.550
100	O	9.460	9.280	180.0	4.0	720.0	C	0.02340	0.00104	0.02236	1.634	1.251	0.213	0.5344	0.115	0.550
102	O	9.600	9.460	140.0	4.0	560.0	C	0.01820	0.00081	0.01739	1.775	1.384	0.279	0.5517	0.092	0.500
104	O	9.680	9.600	80.0	4.0	320.0	C	0.01040	0.00046	0.00994	1.978	1.625	0.441	0.5456	0.059	0.400
107	O	9.680	9.840	160.0	4.0	640.0	C	0.02080	0.00093	0.01987	1.978	1.619	0.224	0.5293	0.106	0.500
107	O	9.920	9.840	80.0	4.0	320.0	C	0.01040	0.00046	0.00994	1.977	1.619	0.448	0.5479	0.059	0.500
111	O	9.920	10.090	170.0	4.0	680.0	C	0.02210	0.00099	0.02111	1.977	1.565	0.242	0.5535	0.107	0.500
113	O	10.090	10.280	190.0	4.0	760.0	C	0.02470	0.00110	0.02360	1.815	1.405	0.216	0.5478	0.117	0.500
113	O	10.320	10.280	40.0	4.0	160.0	C	0.00520	0.00023	0.00497	1.691	1.505	0.465	0.4447	0.039	0.400
117	O	10.320	10.470	150.0	4.0	600.0	C	0.01950	0.00087	0.01863	1.691	1.165	0.351	0.6079	0.090	0.300
117	O	10.510	10.470	40.0	4.0	160.0	C	0.00520	0.00023	0.00497	1.286	0.975	0.778	0.5421	0.032	0.500
119	O	10.510	10.580	70.0	4.0	280.0	C	0.00910	0.00041	0.00869	1.286	1.090	0.280	0.4515	0.062	0.500
119	O	10.690	10.580	110.0	4.0	440.0	C	0.01430	0.00064	0.01366	1.226	1.090	0.124	0.3850	0.101	0.400
121	O	10.760	10.690	70.0	4.0	280.0	C	0.00910	0.00041	0.00869	1.279	0.976	0.433	0.5190	0.055	0.400
124	O	10.760	10.920	160.0	4.0	640.0	C	0.02080	0.00093	0.01987	1.279	0.992	0.179	0.4883	0.112	0.350
124	O	11.120	10.920	200.0	4.0	800.0	C	0.02600	0.00116	0.02484	1.147	0.942	0.103	0.4219	0.148	0.400
126	O	11.120	11.210	90.0	4.0	360.0	C	0.01170	0.00052	0.01118	1.147	0.880	0.297	0.4956	0.070	0.150
126	O	11.310	11.210	100.0	4.0	400.0	C	0.01300	0.00058	0.01242	1.725	0.880	0.845	0.7386	0.055	0.150
128	O	11.310	11.410	100.0	4.0	400.0	C	0.01300	0.00058	0.01242	1.725	1.315	0.410	0.5694	0.068	0.400
129	O	11.410	11.570	160.0	4.0	640.0	C	0.02080	0.00093	0.01987	1.465	1.005	0.288	0.5768	0.099	0.300
129	O	11.630	11.570	60.0	4.0	240.0	C	0.00780	0.00035	0.00745	1.115	0.955	0.267	0.4193	0.058	0.350
130	O	11.630	11.730	100.0	4.0	400.0	C	0.01300	0.00058	0.01242	1.115	0.955	0.160	0.4107	0.089	0.350
130	O	11.970	11.730	240.0	4.0	960.0	C	0.03120	0.00139	0.02981	1.415	0.915	0.208	0.5751	0.135	0.350
133	O	11.970	12.160	190.0	4.0	760.0	C	0.02470	0.00110	0.02360	1.415	0.965	0.237	0.5165	0.123	0.350
133	O	12.380	12.160	220.0	4.0	880.0	C	0.02860	0.00128	0.02732	1.566	0.965	0.273	0.6175	0.120	0.350
137	O	12.380	12.600	220.0	4.0	880.0	C	0.02860	0.00128	0.02732	1.566	1.015	0.250	0.5987	0.123	0.500
137	O	12.720	12.600	120.0	4.0	480.0	C	0.01560	0.00070	0.01490	1.483	1.015	0.390	0.5908	0.077	0.500
				0.0		0.0		0.00000	0.00000	0.00000			ERR			

Note : Side "L" means lagoon side, "O" means ocean side.

Table A8-4 CALCULATION OF DISCHARGE(Q), VELOCITY(V) AND DEPTH(H) OF SIDE DITHCES (2/2)

Intensity of rainfall : r 130.0 mm/h
Ratio of runoff : c 0.900

Infiltration of "U" ditch : Infu 0.00001400 m3/sec/m
Infiltration of "C" ditch : Infc 0.00000580 m3/sec/m

Ditch type "U" is TYPE-A in drawing.
Ditch type "C" is TYPE-B in drawing.

Outlet NO.	Side "O"or"L"	Chainage Crest (km)	Chainage Outlet (km)	Catchment length (m)	Catchment width (m)	Catchment area (m2)	Dithch type "U"or"C"	Discharge from road (m3/sec)	Infiltrate to ground (m3/sec)	Discharge final (m3/sec)	Elevation Crest (m)	Elevation Outlet (m)	Ditch gradient (%/100)	Velocity of dischrge (m/sec)	Depth of dischrge (m)	Depth of ditch (m)
139	O	12.720	12.830	110.0	4.0	440.0	C	0.01430	0.00064	0.01366	1.483	1.015	0.425	0.5937	0.072	0.500
139	O	12.960	12.830	130.0	4.0	520.0	C	0.01690	0.00075	0.01615	1.715	1.115	0.462	0.5901	0.082	0.400
140	O	13.090	12.960	130.0	4.0	520.0	C	0.01690	0.00075	0.01615	2.015	1.565	0.346	0.5802	0.083	0.400
142	O	13.090	13.130	40.0	4.0	160.0	C	0.00520	0.00023	0.00497	2.015	1.665	0.875	0.5577	0.032	0.300
142	O	13.230	13.130	100.0	4.0	400.0	C	0.01300	0.00058	0.01242	2.305	1.715	0.590	0.6524	0.061	0.250
143	O	13.230	13.280	50.0	4.0	200.0	C	0.00650	0.00029	0.00621	2.305	1.585	1.440	0.6987	0.032	0.200
143	O	13.380	13.280	100.0	4.0	400.0	C	0.01300	0.00058	0.01242	1.678	1.265	0.413	0.5714	0.068	0.500
145	O	13.380	13.470	90.0	4.0	360.0	C	0.01170	0.00052	0.01118	1.678	1.005	0.748	0.6845	0.054	0.200
145	O	13.580	13.470	110.0	4.0	440.0	C	0.01430	0.00064	0.01366	1.230	0.955	0.250	0.4949	0.083	0.250
147	O	13.580	13.680	100.0	4.0	400.0	C	0.01300	0.00058	0.01242	1.230	0.890	0.340	0.5364	0.072	0.250
147	O	13.830	13.680	150.0	4.0	600.0	C	0.01950	0.00087	0.01863	1.631	0.890	0.494	0.6907	0.081	0.250
150	O	13.830	13.950	120.0	4.0	480.0	C	0.01560	0.00070	0.01490	1.631	1.085	0.455	0.6231	0.074	0.300
150	O	14.020	13.950	70.0	4.0	280.0	C	0.00910	0.00041	0.00869	1.598	1.135	0.661	0.6009	0.048	0.250
153	O	14.020	14.220	200.0	4.0	800.0	C	0.02600	0.00116	0.02484	1.598	1.035	0.282	0.6096	0.112	0.500
153	O	14.340	14.220	120.0	4.0	480.0	C	0.01560	0.00070	0.01490	1.760	1.185	0.479	0.6352	0.073	0.350
155	O	14.340	14.410	70.0	4.0	280.0	C	0.00910	0.00041	0.00869	1.860	1.325	0.764	0.5885	0.049	0.300
155	O	14.560	14.410	150.0	4.0	600.0	C	0.01950	0.00087	0.01863	1.642	1.125	0.345	0.6073	0.090	0.500
159	O	14.560	14.690	130.0	4.0	520.0	C	0.01690	0.00075	0.01615	1.642	1.125	0.398	0.6084	0.080	0.400
159	O	14.880	14.690	190.0	4.0	760.0	C	0.02470	0.00110	0.02360	1.645	1.025	0.326	0.6321	0.105	0.500
161	O	14.970	14.880	90.0	4.0	360.0	C	0.01170	0.00052	0.01118	1.735	1.345	0.433	0.5619	0.063	0.550
163	O	14.970	15.160	190.0	4.0	760.0	C	0.02470	0.00110	0.02360	1.735	1.015	0.379	0.6677	0.101	0.250
163	O	15.260	15.160	100.0	4.0	400.0	C	0.01300	0.00058	0.01242	1.101	0.915	0.186	0.4332	0.085	0.350
164	O	15.260	15.310	50.0	4.0	200.0	C	0.00650	0.00029	0.00621	1.101	0.915	0.372	0.4428	0.047	0.350
164	O	15.440	15.310	130.0	4.0	520.0	C	0.01690	0.00075	0.01615	1.615	0.965	0.500	0.6066	0.081	0.300
166	O	15.440	15.630	190.0	4.0	760.0	C	0.02470	0.00110	0.02360	1.615	1.065	0.289	0.6083	0.108	0.500
166	O	15.680	15.630	50.0	4.0	200.0	C	0.00650	0.00029	0.00621	1.421	1.065	0.712	0.5595	0.038	0.500
167	O	15.680	15.770	90.0	4.0	360.0	C	0.01170	0.00052	0.01118	1.421	0.965	0.507	0.5983	0.060	0.350
167	O	15.930	15.770	160.0	4.0	640.0	C	0.02080	0.00093	0.01987	1.515	0.965	0.344	0.6172	0.094	0.350
170	O	15.930	16.090	160.0	4.0	640.0	C	0.02080	0.00093	0.01987	1.515	1.055	0.288	0.5787	0.099	0.500
170	O	16.170	16.090	80.0	4.0	320.0	C	0.01040	0.00046	0.00994	1.523	1.055	0.585	0.6004	0.054	0.500
172	O	16.170	16.250	80.0	4.0	320.0	C	0.01040	0.00046	0.00994	1.523	1.065	0.573	0.6017	0.054	0.300
172	O	16.300	16.250	50.0	4.0	200.0	C	0.00650	0.00029	0.00621	1.247	0.965	0.564	0.5109	0.042	0.400
	BRIDGE															
84	L	8.020	8.130	110.0	4.0	440.0	U	0.01430	0.00154	0.01276	6.325	1.715	4.191	1.3183	0.039	0.250
86	L	8.130	8.330	200.0	4.0	800.0	U	0.02600	0.00280	0.02320	1.715	1.265	0.225	0.5472	0.170	0.550
86	L	8.450	8.330	120.0	4.0	480.0	U	0.01560	0.00168	0.01392	1.765	1.415	0.292	0.5321	0.105	0.450
90	L	8.450	8.530	80.0	4.0	320.0	U	0.01040	0.00112	0.00928	1.765	1.455	0.388	0.5246	0.071	0.500
92	L	8.530	8.630	100.0	4.0	400.0	U	0.01300	0.00140	0.01160	1.705	1.405	0.300	0.5106	0.091	0.400
92	L	8.640	8.630	10.0	4.0	40.0	U	0.00130	0.00014	0.00116	1.717	1.555	1.620	0.3973	0.012	0.300
93	L	8.640	8.730	90.0	4.0	360.0	U	0.01170	0.00126	0.01044	1.717	1.395	0.358	0.5283	0.079	0.400
94	L	8.730	8.830	100.0	4.0	400.0	U	0.01300	0.00140	0.01160	1.645	0.995	0.650	0.6748	0.069	0.200
94	L	8.930	8.830	100.0	4.0	400.0	U	0.01300	0.00140	0.01160	1.048	0.945	0.103	0.3451	0.134	0.250
95	L	9.100	8.930	170.0	4.0	680.0	U	0.02210	0.00238	0.01972	1.485	0.948	0.316	0.6002	0.131	0.250
98	L	9.280	9.100	180.0	4.0	720.0	U	0.02340	0.00252	0.02088	1.551	1.235	0.176	0.4892	0.172	0.400
100	L	9.460	9.280	180.0	4.0	720.0	U	0.02340	0.00252	0.02088	1.634	1.301	0.185	0.5003	0.167	0.400
102	L	9.600	9.460	140.0	4.0	560.0	U	0.01820	0.00196	0.01624	1.775	1.384	0.279	0.5441	0.119	0.400
104	L	9.680	9.600	80.0	4.0	320.0	U	0.01040	0.00112	0.00928	1.978	1.625	0.441	0.5480	0.068	0.300
107	L	9.680	9.840	160.0	4.0	640.0	U	0.02080	0.00224	0.01856	1.978	1.619	0.224	0.5190	0.143	0.400
107	L	9.920	9.840	80.0	4.0	320.0	U	0.01040	0.00112	0.00928	1.977	1.619	0.448	0.5504	0.067	0.400
111	L	9.920	10.090	170.0	4.0	680.0	U	0.02210	0.00238	0.01972	1.977	1.565	0.242	0.5423	0.145	0.400
113	L	10.090	10.280	190.0	4.0	760.0	U	0.02470	0.00266	0.02204	1.815	1.405	0.216	0.5325	0.166	0.400
113	L	10.320	10.280	40.0	4.0	160.0	U	0.00520	0.00056	0.00464	1.691	1.405	0.715	0.5142	0.036	0.400
117	L	10.320	10.470	150.0	4.0	600.0	U	0.01950	0.00210	0.01740	1.691	1.165	0.351	0.6039	0.115	0.200
117	L	10.510	10.470	40.0	4.0	160.0	U	0.00520	0.00056	0.00464	1.286	1.015	0.678	0.5060	0.037	0.350
119	L	10.510	10.580	70.0	4.0	280.0	U	0.00910	0.00098	0.00812	1.286	1.040	0.351	0.4898	0.066	0.350
119	L	10.690	10.580	110.0	4.0	440.0	U	0.01430	0.00154	0.01276	1.226	1.022	0.185	0.4403	0.116	0.350
121	L	10.760	10.690	70.0	4.0	280.0	U	0.00910	0.00098	0.00812	1.279	1.026	0.361	0.4907	0.066	0.350
124	L	10.760	10.920	160.0	4.0	640.0	U	0.02080	0.00224	0.01856	1.279	0.992	0.179	0.4762	0.156	0.250
124	L	11.120	10.920	200.0	4.0	800.0	U	0.02600	0.00280	0.02320	1.147	0.992	0.078	0.3577	0.259	0.250
126	L	11.120	11.210	90.0	4.0	360.0	U	0.01170	0.00126	0.01044	1.147	0.780	0.408	0.5553	0.075	0.150
126	L	11.310	11.210	100.0	4.0	400.0	U	0.01300	0.00140	0.01160	1.725	0.780	0.945	0.7700	0.060	0.150
128	L	11.310	11.410	100.0	4.0	400.0	U	0.01300	0.00140	0.01160	1.725	1.315	0.410	0.5706	0.081	0.300
129	L	11.410	11.570	160.0	4.0	640.0	U	0.02080	0.00224	0.01856	1.465	0.955	0.319	0.5917	0.125	0.250
129	L	11.630	11.570	60.0	4.0	240.0	U	0.00780	0.00084	0.00696	1.115	0.955	0.267	0.4214	0.066	0.250
130	L	11.630	11.730	100.0	4.0	400.0	U	0.01300	0.00140	0.01160	1.115	0.915	0.200	0.4421	0.105	0.250
130	L	11.970	11.730	240.0	4.0	960.0	U	0.03120	0.00336	0.02784	1.415	0.915	0.208	0.5505	0.202	0.250
133	L	11.970	12.160	190.0	4.0	760.0	U	0.02470	0.00266	0.02204	1.415	0.965	0.237	0.5518	0.160	0.250
133	L	12.380	12.160	220.0	4.0	880.0	U	0.02860	0.00308	0.02552	1.566	0.965	0.273	0.6023	0.169	0.250
137	L	12.380	12.600	220.0	4.0	880.0	U	0.02860	0.00308	0.02552	1.566	1.015	0.250	0.5813	0.176	0.400
137	L	12.720	12.600	120.0	4.0	480.0	U	0.01560	0.00168	0.01392	1.483	1.015	0.390	0.5909	0.094	0.400
139	L	12.720	12.830	110.0	4.0	440.0	U	0.01430	0.00154	0.01276	1.483	1.015	0.425	0.5945	0.086	0.400
139	L	12.960	12.830	130.0	4.0	520.0	U	0.01690	0.00182	0.01508	1.715	1.015	0.538	0.6802	0.089	0.400
140	L	13.090	12.960	130.0	4.0	520.0	U	0.01690	0.00182	0.01508	2.015	1.565	0.346	0.5782	0.104	0.300
142	L	13.090	13.130	40.0	4.0	160.0	U	0.00520	0.00056	0.00464	2.015	1.665	0.875	0.5498	0.034	0.200
142	L	13.230	13.130	100.0	4.0	400.0	U	0.01300	0.00140	0.01160	2.305	1.715	0.590	0.6496	0.071	0.150
143	L	13.230	13.280	50.0	4.0	200.0	U	0.00650	0.00070	0.00580	2.305	1.535	1.540	0.7249	0.032	0.150
143	L	13.380	13.280	100.0	4.0	400.0	U	0.01300	0.00140	0.01160	1.678	1.535	0.143	0.5729	0.081	0.400
145	L	13.380	13.470	90.0	4.0	360.0	U	0.01170	0.00126	0.01044	1.678	0.955	0.803	0.6999	0.060	0.150
145	L	13.580	13.470	110.0	4.0	440.0	U	0.01430	0.00154	0.01276	1.230	0.955	0.250	0.4923	0.104	0.150
147	L	13.580	13.680	100.0	4.0	400.0	U	0.01300	0.00140	0.01160	1.230	0.890	0.340	0.5363	0.087	0.150
147	L	13.830	13.680	150.0	4.0	600.0	U	0.01950	0.00210	0.01740	1.631	0.890	0.494	0.6847	0.102	0.150
150	L	13.830	13.950	120.0	4.0	480.0	U	0.01560	0.00168	0.01392	1.631	1.085	0.455	0.6239	0.089	0.200
150	L	14.020	13.950	70.0	4.0	280.0	U	0.00910	0.00098	0.00812	1.598	1.135	0.661	0.6335	0.054	0.150
153	L	14.020	14.220	200.0	4.0	800.0	U	0.02600	0.00280	0.02320	1.598	1.035	0.282	0.5973	0.155	0.400
153	L	14.340	14.220	120.0	4.0	480.0	U	0.01560	0.00168	0.01392	1.760	1.235	0.438	0.6180	0.090	0.200
155	L	14.340	14.410	70.0	4.0	280.0	U	0.00910	0.00098	0.00812	1.760	1.325	0.621	0.5915	0.055	0.200
155	L	14.560	14.410	150.0	4.0	600.0	U	0.01950	0.00210	0.01740	1.642	1.125	0.345	0.6014	0.116	0.400
159	L	14.560	14.690	130.0	4.0	520.0	U	0.01690	0.00182	0.01508	1.642	1.125	0.398	0.6101	0.099	0.300
159	L	14.880	14.690	190.0	4.0	760.0	U	0.02470	0.00266	0.02204	1.645	1.125	0.274	0.6226	0.142	0.400
161	L	14.970	14.880	90.0	4.0	360.0	U	0.01170	0.00126	0.01044	1.735	1.345	0.433	0.5641	0.074	0.450
163	L	14.970	15.160	190.0	4.0	760.0	U	0.02470	0.00266	0.02204	1.735	0.915	0.432	0.6939	0.127	0.250
163	L	15.260	15.160	100.0	4.0	400.0	U	0.01300	0.00140	0.01160	1.101	0.965	0.136	0.3836	0.121	0.200
164	L	15.260	15.310	50.0	4.0	200.0	U	0.00650	0.00070	0.00580	1.101	0.965	0.272	0.4036	0.057	0.200
164	L	15.440	15.310	130.0	4.0	520.0	U	0.01690	0.00182	0.01508	1.611	0.965	0.497	0.6609	0.091	0.200
166	L	15.440	15.630	190.0	4.0	760.0	U	0.02470	0.00266	0.02204	1.611	1.065	0.287	0.5956	0.148	0.400
166	L	15.680	15.630	50.0	4.0	200.0	U	0.00650	0.00070	0.00580	1.421	1.065	0.712	0.5549	0.042	0.400
167	L	15.680	15.770	90.0	4.0	360.0	U	0.01170	0.00126	0.01044	1.421	0.915	0.562	0.6222	0.067	0.300
167	L	15.930	15.770	160.0	4.0	640.0	U	0.02080	0.00224	0.01856	1.515	0.915	0.375	0.6304	0.118	0.300
170	L	15.930	16.090	160.0	4.0	640.0	U	0.02080	0.00224	0.01856	1.515	1.055	0.288	0.5711	0.130	0.400
170	L	16.170	16.090	80.0	4.0	320.0	U	0.01040	0.00112	0.00928	1.523	1.055	0.585	0.6080	0.061	0.400
172	L	16.170	16.250	80.0	4.0	320.0	U	0.01040	0.00112	0.00928	1.523	1.065	0.573	0.6017	0.062	0.200
172	L	16.300	16.250	50.0	4.0	200.0	U	0.00650	0.00070	0.00580	1.247	0.965	0.564	0.5177	0.045	0.300

Note : Side "L" means lagoon side, "O" means ocean side.

Table A8-5 CALCULATION OF DISCHARGE OF CULVERTS (DITCH TYPE-F; CROSSING MAIN ROAD)

Outlet No.	Width (m)	Roughnes n	Gradient (%/100)	Discharge (m3/sec)	Velocity (m/sec)	Depth (m)	A (m2)	R (m)	Outlet side	Culvert length	Elevation Inlet	Elevation Outlet
2	0.300	0.015	0.0046	0.0079	0.5154	0.051	0.0154	0.039	O	8.7	0.955	0.915
3	0.300	0.015	0.0046	0.0356	0.7997	0.148	0.0445	0.074	L	8.7	1.086	1.046
6	0.300	0.015	0.0046	0.0386	0.8171	0.157	0.0472	0.077	L	8.7	1.040	1.000
8	0.300	0.015	0.0046	0.0238	0.7211	0.110	0.0330	0.064	L	8.7	1.050	1.010
10	0.300	0.015	0.0046	0.0282	0.7550	0.125	0.0374	0.068	L	8.7	1.096	1.056
12	0.300	0.015	0.0046	0.0223	0.7550	0.125	0.0374	0.068	L	8.7	1.121	1.081
13	0.300	0.015	0.0046	0.0267	0.7550	0.125	0.0374	0.068	L	8.7	1.348	1.308
14	0.300	0.015	0.0046	0.0490	0.8632	0.189	0.0568	0.084	L	8.7	1.118	1.078
18	0.300	0.015	0.0046	0.0267	0.7416	0.120	0.0360	0.067	L	8.7	1.190	1.150
21	0.300	0.015	0.0046	0.0520	0.8747	0.198	0.0594	0.085	L	8.7	1.105	1.065
24	0.300	0.015	0.0043	0.0178	0.6444	0.092	0.0276	0.057	L	9.2	1.105	1.065
25	0.300	0.015	0.0043	0.0386	0.7966	0.162	0.0485	0.078	O	9.2	1.095	1.055
26	0.300	0.015	0.0043	0.0356	0.7798	0.152	0.0457	0.075	L	9.2	1.077	1.037
27	0.300	0.015	0.0043	0.0416	0.8114	0.171	0.0513	0.080	L	9.2	1.055	1.015
29	0.300	0.015	0.0043	0.0431	0.8167	0.176	0.0528	0.081	L	9.2	1.155	1.115
32	0.300	0.015	0.0043	0.0460	0.8301	0.185	0.0554	0.083	L	9.2	1.165	1.125
38	0.300	0.015	0.0043	0.0505	0.8479	0.199	0.0596	0.086	O	9.2	1.055	1.015
43	0.300	0.015	0.0043	0.0460	0.8293	0.185	0.0555	0.083	L	9.2	1.055	1.015
49	0.300	0.015	0.0043	0.0461	0.8293	0.185	0.0556	0.083	L	9.2	1.105	1.065
52	0.300	0.015	0.0043	0.0490	0.8421	0.194	0.0582	0.085	L	9.2	1.088	1.048
53	0.300	0.015	0.0043	0.0512	0.8494	0.201	0.0603	0.086	L	8.7	1.131	1.091
54	0.300	0.015	0.0030	0.0192	0.5819	0.110	0.0330	0.063	L	13.2	1.365	1.325
56	0.300	0.015	0.0030	0.0256	0.6290	0.136	0.0407	0.071	L	13.2	1.185	1.145
57	0.300	0.015	0.0030	0.0214	0.6011	0.119	0.0356	0.066	L	13.2	1.095	1.055
58	0.300	0.015	0.0030	0.0451	0.7176	0.209	0.0628	0.087	L	13.2	0.990	0.950
59	0.300	0.015	0.0030	0.0516	0.7395	0.232	0.0697	0.091	L	13.2	1.043	1.003
60-1	0.300	0.015	0.0030	0.0726	0.7934	0.305	0.0915	0.101	L	13.2	1.015	0.975
62	0.300	0.015	0.0043	0.0468	0.8325	0.187	0.0562	0.083	L	9.2	1.075	1.035
65	0.300	0.015	0.0043	0.0327	0.7631	0.143	0.0428	0.073	O	9.2	1.085	1.045
69	0.300	0.015	0.0043	0.0356	0.7812	0.152	0.0456	0.076	O	9.2	1.235	1.195
70	0.300	0.015	0.0043	0.0271	0.7283	0.124	0.0372	0.068	O	9.2	1.205	1.165
71	0.300	0.015	0.0056	0.0139	0.6593	0.070	0.0211	0.048	O	7.2	1.240	1.200
73	0.300	0.015	0.0056	0.0093	0.5791	0.054	0.0161	0.040	O	7.2	1.263	1.223
74	0.300	0.015	0.0056	0.0186	0.7190	0.086	0.0259	0.055	O	7.2	1.291	1.241
77	0.300	0.015	0.0056	0.0186	0.7190	0.086	0.0259	0.055	O	7.2	1.270	1.230
78	0.300	0.015	0.0056	0.0139	0.6586	0.070	0.0211	0.048	O	7.2	1.270	1.230
80	0.300	0.015	0.0056	0.0278	0.8054	0.115	0.0345	0.065	O	7.2	1.250	1.210
BRIDGE									O	0.0		
86	0.300	0.015	0.0053	0.0278	0.7900	0.117	0.0352	0.066	O	7.6	1.265	1.225
90	0.300	0.015	0.0053	0.0094	0.5706	0.055	0.0165	0.041	O	7.6	1.455	1.415
92	0.300	0.015	0.0053	0.0137	0.6421	0.071	0.0213	0.048	O	7.6	1.405	1.365
93	0.300	0.015	0.0053	0.0112	0.6032	0.062	0.0186	0.044	O	7.6	1.395	1.345
94	0.300	0.015	0.0053	0.0248	0.7630	0.108	0.0325	0.063	O	7.6	0.945	0.905
95	0.300	0.015	0.0053	0.0211	0.7305	0.096	0.0289	0.059	O	7.6	0.948	0.908
98	0.300	0.015	0.0053	0.0224	0.7408	0.101	0.0302	0.060	O	7.6	1.235	1.195
100	0.300	0.015	0.0053	0.0209	0.7266	0.096	0.0288	0.058	L	7.6	1.251	1.211
102	0.300	0.015	0.0053	0.0162	0.6764	0.080	0.0239	0.052	L	7.6	1.384	1.344
104	0.300	0.015	0.0053	0.0099	0.5753	0.057	0.0172	0.041	O	7.6	1.625	1.585
107	0.300	0.015	0.0053	0.0298	0.8048	0.123	0.0370	0.068	O	7.6	1.619	1.579
111	0.300	0.015	0.0053	0.0211	0.7315	0.096	0.0288	0.059	O	7.6	1.565	1.525
113	0.300	0.015	0.0053	0.0286	0.7931	0.120	0.0361	0.067	O	7.6	1.405	1.365
117	0.300	0.015	0.0053	0.0236	0.7541	0.104	0.0313	0.062	O	7.6	1.015	0.975
119	0.300	0.015	0.0053	0.0214	0.7311	0.098	0.0293	0.059	O	7.6	1.022	0.982
121	0.300	0.015	0.0053	0.0087	0.5560	0.052	0.0156	0.039	O	7.6	1.026	0.976
124	0.300	0.015	0.0053	0.0447	0.8914	0.167	0.0501	0.079	O	7.6	0.992	0.942
126	0.300	0.015	0.0053	0.0220	0.7368	0.100	0.0299	0.060	L	7.6	0.780	0.740
128	0.300	0.015	0.0053	0.0124	0.6187	0.067	0.0200	0.046	O	7.6	1.315	1.275
129	0.300	0.015	0.0053	0.0255	0.7711	0.110	0.0331	0.064	L	7.6	0.955	0.915
130	0.300	0.015	0.0053	0.0394	0.8621	0.152	0.0457	0.075	L	7.6	0.915	0.875
133	0.300	0.015	0.0053	0.0476	0.9032	0.176	0.0527	0.081	L	7.6	0.965	0.925
137	0.300	0.015	0.0053	0.0422	0.8771	0.160	0.0481	0.077	O	7.6	1.015	0.975
139	0.300	0.015	0.0053	0.0298	0.8044	0.123	0.0370	0.068	O	7.6	1.015	0.975
140	0.300	0.015	0.0053	0.0151	0.6581	0.076	0.0229	0.050	L	7.6	1.565	1.525
142	0.300	0.015	0.0053	0.0151	0.6581	0.076	0.0229	0.050	L	7.6	1.665	1.625
143	0.300	0.015	0.0053	0.0174	0.6882	0.084	0.0253	0.054	L	7.6	1.265	1.225
145	0.300	0.015	0.0053	0.0248	0.7620	0.108	0.0325	0.063	O	7.6	0.955	0.915
147	0.300	0.015	0.0053	0.0311	0.8114	0.128	0.0383	0.069	O	7.6	0.890	0.850
150	0.300	0.015	0.0053	0.0236	0.7546	0.104	0.0313	0.062	O	7.6	1.085	1.045
153	0.300	0.015	0.0053	0.0397	0.8635	0.153	0.0460	0.076	O	7.6	1.035	0.995
155	0.300	0.015	0.0053	0.0273	0.7858	0.116	0.0347	0.066	O	7.6	1.125	1.085
159	0.300	0.015	0.0053	0.0371	0.8494	0.146	0.0437	0.074	L	7.6	1.025	0.985
161	0.300	0.015	0.0053	0.0112	0.6036	0.062	0.0186	0.044	O	7.6	1.345	1.305
163	0.300	0.015	0.0053	0.0336	0.8303	0.135	0.0405	0.071	L	7.6	0.915	0.875
164	0.300	0.015	0.0053	0.0209	0.7303	0.095	0.0286	0.058	L	7.6	0.915	0.875
166	0.300	0.015	0.0053	0.0278	0.7867	0.118	0.0353	0.066	L	7.6	1.065	1.025
167	0.300	0.015	0.0053	0.0290	0.7958	0.121	0.0364	0.067	L	7.6	0.965	0.915
170	0.300	0.015	0.0053	0.0278	0.7893	0.117	0.0352	0.066	L	7.6	1.055	1.015
172	0.300	0.015	0.0053	0.0151	0.6604	0.076	0.0228	0.050	L	7.6	0.965	0.925

Table A8-6 CALCULATION OF DISCHARGE OF PIPE CULVERTS (FROM ROAD TO SEA)

Outlet No.	Dia. (m)	Roughnes n	Gradient (%/100)	Discharge (m3/sec)	Velocity (m/sec)	Depth (m)	A (m2)	R (m)	Outlet side	Pipe length	Elevation Inlet	Elevation Outlet
2	0.350	0.010	0.0020	0.01685	0.687	0.106	0.0245	0.060	O	28.0	0.915	0.859
3	0.350	0.010	0.0020	0.07128	0.988	0.246	0.0722	0.104	L	102.0	1.046	0.842
6	0.350	0.010	0.0020	0.07724	0.999	0.262	0.0773	0.106	L	95.0	1.000	0.810
8	0.350	0.010	0.0020	0.04752	0.906	0.187	0.0524	0.091	L	65.0	1.010	0.880
10	0.350	0.010	0.0020	0.05642	0.943	0.209	0.0598	0.097	L	31.0	1.056	0.994
12	0.350	0.010	0.0020	0.04454	0.892	0.180	0.0499	0.089	L	36.0	1.081	1.009
13	0.350	0.010	0.0020	0.05348	0.932	0.202	0.0574	0.095	L	33.0	1.308	1.242
14	0.400	0.010	0.0020	0.09802	1.073	0.273	0.0914	0.117	L	5.0	1.078	1.068
18	0.350	0.010	0.0020	0.05346	0.932	0.202	0.0574	0.095	L	20.0	1.150	1.110
21	0.400	0.010	0.0020	0.10394	1.083	0.286	0.0960	0.119	L	9.0	1.065	1.047
24	0.350	0.010	0.0020	0.03564	0.843	0.158	0.0423	0.082	L	31.0	1.065	1.003
25	0.350	0.010	0.0020	0.07722	0.999	0.262	0.0773	0.106	O	50.0	1.005	0.955
26	0.350	0.010	0.0020	0.07128	0.988	0.246	0.0722	0.104	L	107.0	1.037	0.823
27	0.350	0.010	0.0020	0.08316	1.005	0.281	0.0828	0.106	L	67.0	1.015	0.881
29	0.350	0.010	0.0020	0.08614	1.004	0.292	0.0858	0.106	L	50.0	1.115	1.015
32	0.400	0.010	0.0020	0.09208	1.060	0.261	0.0868	0.115	L	78.0	1.250	0.969
38	0.400	0.010	0.0020	0.10396	1.083	0.286	0.0960	0.119	O	55.0	1.015	0.905
43	0.400	0.010	0.0020	0.09208	1.060	0.261	0.0868	0.115	L	48.0	1.015	0.919
49	0.400	0.010	0.0020	0.09266	1.062	0.262	0.0873	0.116	L	20.0	1.065	1.025
52	0.400	0.010	0.0020	0.09800	1.073	0.273	0.0914	0.117	L	92.0	1.048	8.864
53	0.400	0.010	0.0020	0.10248	1.081	0.282	0.0948	0.119	L	107.0	1.091	0.877
54	0.450	0.010	0.0020	0.03842	0.848	0.147	0.0453	0.083	L	130.0	1.325	1.065
56	0.350	0.010	0.0020	0.05142	0.924	0.197	0.0557	0.094	L	47.0	1.145	1.051
57	0.350	0.010	0.0020	0.04270	0.883	0.176	0.0484	0.088	L	48.0	1.055	0.959
58	0.400	0.010	0.0020	0.04507	0.893	0.169	0.0505	0.089	L	80.0	0.950	0.790
59	0.400	0.010	0.0020	0.06654	0.986	0.212	0.0675	0.104	L	59.0	1.003	0.885
60-1	0.350	0.010	0.0020	0.01452	0.658	0.098	0.0220	0.056	L	0.0	(0.975)	
62	0.400	0.010	0.0020	0.09356	1.064	0.264	0.0880	0.116	L	112.0	1.035	0.811
65	0.350	0.010	0.0020	0.06534	0.972	0.230	0.0672	0.101	O	74.0	1.045	0.897
69	0.350	0.010	0.0020	0.07128	0.988	0.246	0.0722	0.104	O	93.0	1.195	1.009
70	0.350	0.010	0.0020	0.05420	0.935	0.203	0.0580	0.096	O	63.0	1.165	1.039
71	0.350	0.010	0.0020	0.02784	0.790	0.138	0.0353	0.074	O	12.0	1.200	1.176
73	0.350	0.010	0.0020	0.01856	0.706	0.111	0.0263	0.063	O	14.0	1.223	1.195
74	0.350	0.010	0.0020	0.03712	0.852	0.162	0.0436	0.083	O	15.0	1.241	1.200
77	0.350	0.010	0.0020	0.03248	0.823	0.150	0.0395	0.079	O	13.0	1.230	1.204
78	0.350	0.010	0.0020	0.02784	0.790	0.138	0.0353	0.074	O	15.0	1.230	1.200
80	0.350	0.010	0.0020	0.05568	0.940	0.207	0.0592	0.096	O	10.0	1.210	1.190
BRIDGE												
86	0.350	0.010	0.0020	0.07686	0.998	0.261	0.0770	0.105	O	16.0	1.225	1.193
90	0.350	0.010	0.0020	0.01872	0.708	0.112	0.0264	0.063	O	7.0	1.415	1.401
92	0.350	0.010	0.0020	0.02642	0.779	0.134	0.0339	0.073	O	32.0	1.365	1.301
93	0.350	0.010	0.0020	0.02162	0.737	0.121	0.0293	0.067	O	33.0	1.345	1.279
94	0.350	0.010	0.0020	0.04804	0.909	0.189	0.0529	0.092	O	32.0	0.905	0.841
95	0.350	0.010	0.0020	0.04803	0.909	0.189	0.0528	0.092	O	70.0	0.908	0.768
98	0.350	0.010	0.0020	0.02312	0.750	0.125	0.0308	0.069	O	71.0	1.185	1.043
100	0.350	0.010	0.0020	0.04324	0.886	0.177	0.0488	0.088	L	45.0	1.211	1.121
102	0.350	0.010	0.0020	0.04324	0.886	0.177	0.0488	0.088	L	58.0	1.344	1.228
104	0.350	0.010	0.0020	0.01922	0.713	0.113	0.0270	0.064	O	47.0	1.585	1.491
107	0.350	0.010	0.0020	0.05675	0.944	0.209	0.0601	0.097	O	63.0	1.579	1.453
111	0.350	0.010	0.0020	0.04083	0.873	0.171	0.0468	0.086	O	43.0	1.525	1.439
113	0.350	0.010	0.0020	0.05525	0.939	0.206	0.0589	0.096	O	8.0	1.365	1.349
117	0.350	0.010	0.0020	0.04564	0.898	0.183	0.0508	0.090	O	65.0	0.975	0.845
119	0.350	0.010	0.0020	0.04223	0.880	0.175	0.0480	0.087	O	55.0	0.982	0.872
121	0.350	0.010	0.0020	0.01281	0.635	0.092	0.0202	0.054	O	46.0	0.976	0.884
124	0.350	0.010	0.0020	0.08647	1.004	0.293	0.0861	0.106	O	41.0	0.942	0.860
126	0.350	0.010	0.0020	0.04564	0.898	0.183	0.0508	0.090	L	48.0	0.740	0.644
128	0.350	0.010	0.0020	0.02402	0.758	0.127	0.0317	0.070	O	120.0	1.275	1.035
129	0.350	0.010	0.0020	0.05284	0.929	0.200	0.0569	0.095	L	89.0	0.915	0.737
130	0.350	0.010	0.0020	0.08167	1.004	0.276	0.0814	0.106	L	35.0	0.875	0.805
133	0.400	0.010	0.0020	0.09848	1.074	0.274	0.0917	0.118	L	50.0	0.925	0.825
137	0.350	0.010	0.0020	0.08166	1.004	0.276	0.0813	0.106	O	68.0	0.975	0.839
139	0.350	0.010	0.0020	0.05765	0.948	0.212	0.0608	0.098	O	66.0	0.975	0.843
140	0.350	0.010	0.0020	0.03123	0.814	0.147	0.0384	0.078	L	138.0	1.525	1.249
142	0.350	0.010	0.0020	0.03365	0.831	0.153	0.0405	0.080	L	107.0	1.625	1.411
143	0.350	0.010	0.0020	0.03603	0.846	0.159	0.0426	0.082	L	74.0	1.225	1.077
145	0.350	0.010	0.0020	0.04804	0.909	0.189	0.0529	0.092	O	57.0	0.915	0.801
147	0.350	0.010	0.0020	0.06005	0.956	0.217	0.0628	0.099	O	22.0	0.850	0.806
150	0.350	0.010	0.0020	0.04563	0.898	0.183	0.0508	0.090	O	50.0	1.045	0.945
153	0.350	0.010	0.0020	0.07686	0.998	0.261	0.0770	0.105	O	39.0	0.995	0.917
155	0.350	0.010	0.0020	0.05284	0.929	0.200	0.0569	0.095	O	28.0	1.085	1.029
159	0.350	0.010	0.0020	0.07687	0.998	0.261	0.0770	0.105	L	65.0	0.985	0.855
161	0.350	0.010	0.0020	0.02162	0.737	0.121	0.0293	0.067	O	108.0	1.305	1.089
163	0.350	0.010	0.0020	0.06966	0.984	0.242	0.0708	0.103	L	13.0	0.875	0.849
164	0.350	0.010	0.0020	0.04324	0.886	0.177	0.0488	0.074	L	19.0	0.875	0.837
166	0.350	0.010	0.0020	0.05765	0.948	0.212	0.0608	0.098	L	18.0	1.025	0.987
167	0.350	0.010	0.0020	0.06005	0.956	0.217	0.0628	0.099	L	20.0	0.915	0.875
170	0.350	0.010	0.0020	0.05675	0.944	0.209	0.0601	0.097	L	24.0	1.015	0.967
172	0.350	0.010	0.0020	0.03123	0.814	0.147	0.0384	0.078	L	6.0	0.925	0.913

APPENDIX 9. DESIGN OF PAVEMENT REHABILITATION

Design of AC overlay and reconstruction was carried out according to the Asphalt Pavement Manual and the Road Maintenance and Rehabilitation Manual issued by the Japan Road Association. The procedure of the design is explained in Figure A9-1.

A9.1 Design of AC Overlay

(1) Assessment of Existing Pavement

The conversion ratio (C. ratio) of pavement materials by type and degree of deterioration was given by the Manuals. The C. ratio of materials employed in this design is shown in Table A9-1.

Table A9-1 CONVERSION RATIO OF PAVEMENT MATERIALS

Type of material	Degree of deterioration	Conversion Ratio
Hot-mixed AC	None (New)	1.0
	Level 1	0.9
	Level 2	0.7
	Level 3	0.5
Graded material (for base course)	None (New)	0.35
	Level 1	0.30
	Level 2	0.25
	Level 3	0.2
Granular material (for subbase course)	None (New)	0.2
	(Subbase is not included in the existing pave.)	

Note : Level 1 ; Deterioration is light (Crack ratio <15%) and it performs as if it were new. (For Km6.9-13.3 of the Project road)
Level 2 ; Deterioration is partial (Crack ratio is 15% to 35%) and it perform as if it were new. (For the Rairok Section)
Level 3 ; Deterioration needs overlay or reconstruction (Crack ratio>35%). (For DUD Section)

(2) Design CBR

The in-situ CBR test results and the design CBR by design section are shown in Table 2.3-2 in Chapter 2. It was obtained by the following calculations as specified in the Manual.

The Section CBR = CBRave — Standard deviation of CBR test results

Where, CBRave is the average of CBR test results in the design section.

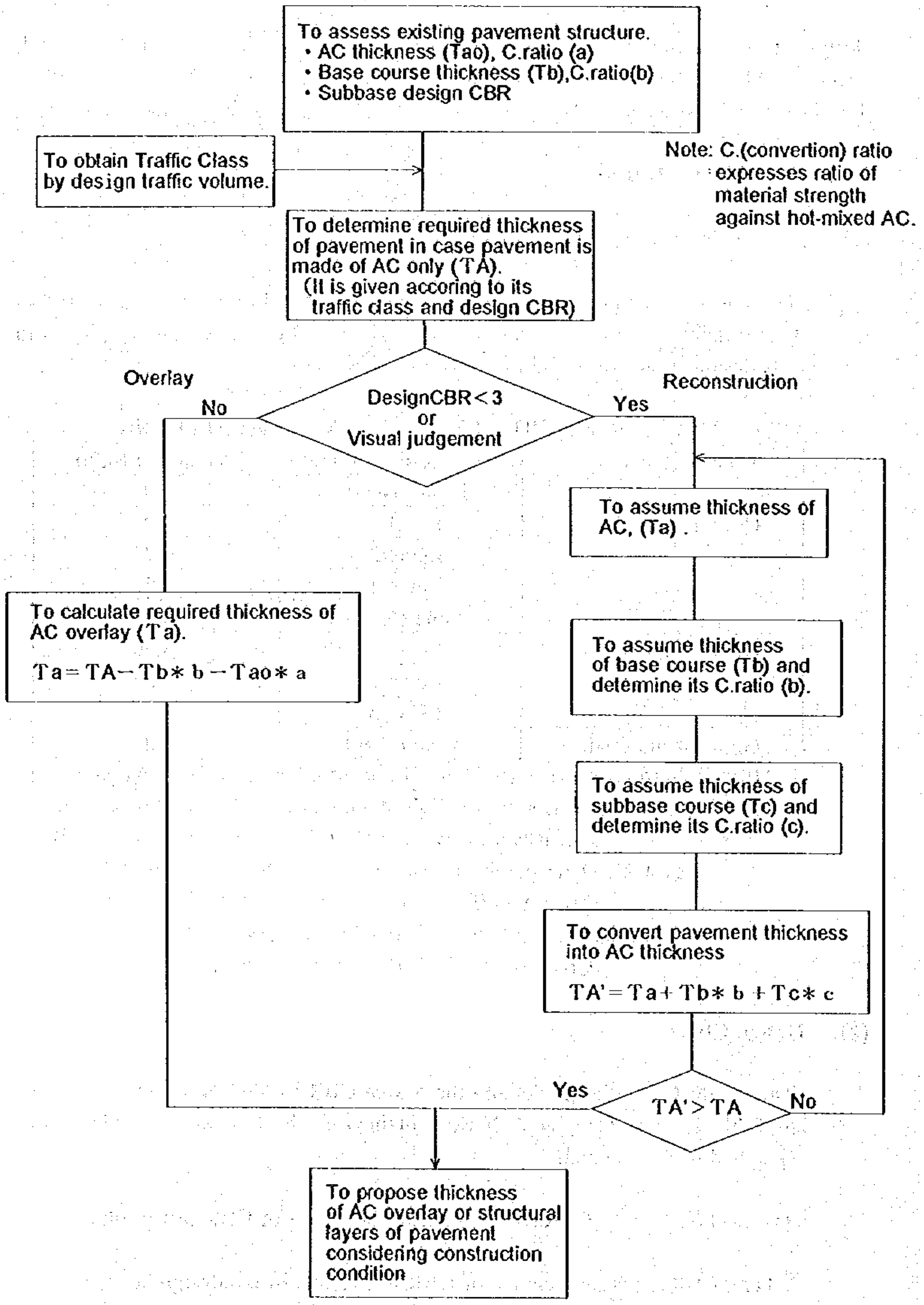

Figure A9-1 PROCEDURE OF AC OVERLAY / RECONSTRUCTION DESIGN

The Design CBR was obtained by the table given by the Manual as shown in Table A9-2.

Table A9-2 SECTION CBR VS. DESIGN CBR

Section CBR	Design CBR
2 ～ 3	2
3 ～ 4	3
4 ～ 6	4
6 ～ 8	6
8 ～ 12	8
12 ～ 20	12
20 or more	20

Source: Asphalt Pavement Manual by JRA

(2) Design Traffic Class

The Design Traffic Class was classified according to the table given by the Manual as shown in Table A9-3. The Design Heavy Traffic Volume to be used in pavement design is average of heavy traffic volume during the design span (10 years for this Project). The Design Heavy Traffic Volume (Heavy Vehicle ADT) was obtained by the design traffic volume shown in the Table 2.3-3 in Chapter 2, percentile of heavy vehicles, and the growth rate of 50% for 10 years (It is the average growth rate of vehicles registered for the last 10 years.)

Table A9-3 TRAFFIC VOLUME VS. TRAFFIC CLASS

Heavy Vehicle ADT	Design Traffic Class
100 or less (Veh./day/dir.)	L
100 ～ 250 (Veh./day/dir.)	A
250 ～ 1000 (Veh./day/dir.)	B
1000 ～ 3000 (Veh./day/dir.)	C
3000 or more (Veh./day/dir.)	D

Source: Asphalt Pavement Manual by JRA

Since all the Heavy Vehicle ADTs are less than 100, Design Traffic Classes are L for all sections.

(3) Required thickness of pavement (TA) in case pavement is made of hot-mixed AC only

The "TA" was obtained by the table given by the Manual as shown in Table A9-4 according to the Design CBR..

Table A9-4 DESIGN CBR VS. TA

Design CBR	TA (cm)
2	17
3	15
4	14
6	12
8	11
12	11
20	11

Source: Asphalt Pavement Manual by JRA

Based on above, the "TA" by design section was obtained as shown in Table A9-5.

Table A9-5 "TA" BY DESIGN SECTION

Section	Design CBR	Traffic Class	TA (cm)
DUD	8	L	11
Majuro Br.	8	L	11
Rairok	20	L	11
Km 15-16	4	L	14

(4) Required thickness (Ta) and proposed thickness of AC overlay

"Ta" was obtained by the following formula:

$$Ta = TA - Tb \times b - Tao \times a$$

Proposed thickness of the AC overlay by design section was determined as shown in Table A9-6 considering the construction condition.

Table A9-6 REQUIRED & PROPOSED THICKNESS OF AC OVERLAY

Section	TA	Tb	b	Tao	a	Required thickness	Proposed thickness (cm)
DUD	11	15	0.2	5	0.5	5.5	5.5
Majuro Br.	11	15	0.3	5	0.9	2.0	3.0
Rairok	11	15	0.25	5	0.7	3.8	4.0
Km15-16	14	15	0.2	5	0.5	8.5	8.5

A9.2 Design of Reconstruction

(1) Required thickness of pavement (TA) in case pavement is made of hot-mixed AC only.

The "TA" by reconstruction section was obtained as shown in Table A9-7. The data was obtained by the same procedures as AC overlay design.

Table A9-7 "TA" BY RECONSTRUCTION SECTION

Section	Design CBR	Traffic Class	TA (cm)
Km 2.5	8	L	11
Km 15-16	4	L	14
Grade rising (DUD)	20	L	11
Grade rising(Rairok)	20	L	11

(2) Proposed pavement layers and pavement thickness (TA') converted into thickness of hot-mixed AC.

Graded material is proposed for base course and granular material is proposed for subbase course. Based on the assumed thicknesses of layers, "TA'" was calculated using the following formula. The "TA'" is required to be grater than "TA".

$$TA' = Ta + Tb \times b + Tc \times c$$

Based on the above, the components of the pavements for reconstruction/ grade rising sections were proposed as shown in Table A9-7. The thickness of the AC surface courses were proposed to be same as adjacent AC overlay.

Table A9-8 PROPOSED PAVEMENT FOR RECONSTRUCTION

Section	Ta AC(cm)	Tb Base C.	b	Tc Subbase	c	TA' Conv'ted	TA Required
Km 2.5	5.5	10.0	0.35	15.0	0.2	12.0	11.0
Km15-16	4.0	10.0	0.35	25.0	0.2	14.3	14.0
Grade rising (DUD)	5.5	10.0	0.35	15.0	0.2	12.0	11.0
Grade rising(Rairok)	4.0	10.0	0.35	20.0	0.2	11.5	11.0

APPENDIX 10. REFERENCES

Maintenance plan for the road facilities to be constructed under the Project was proposed as shown in the Table A10-1. Timing, staff, equipment and cost required in each maintenance activity is explaiend in the plan.

As shown in the plan, no special equipment or technique is necessary in the maintenance, however, since the road drainage facilities will be constructed for the first time in the country, a maintenance manual was proposed to be prepared for the Project by the consultant to ensure that the maintenance will be executed properly.

Table A10-1 MAINTENANCE PLAN FOR THE PROJECT ROAD

1. INSPECTION

Facility	Inspection Item	Interval	Req'd Staff	Req'd material/equipment	Req'd days	Req'd Budget
Ditches	Soundness of covers, existence of deposit of mud, sand, obstacles	Once a month	2	Pickup, scoop, hammer, bar	5	10,200
Basins	Soundness of covers, existence of deposit of mud, sand, obstacles	Once a month	2	Pickup, scoop, hammer, bar	5	10,200
Culverts crossing road	Existence of deposit of mud, sand or obstacle	Once a month	2	Pickup, scoop, hammer, bar, light	3	6,120
PVC Pipes	Existence of deposit of mud, sand or obstacle	Once a month	2	Pickup, scoop, hammer, bar, light	5	10,200
Outlet Protections	Damage or dislocation of protections,	Once a month	2	Pickup, scoop, hammer, bar	3	6,120
AC pavement	Crack, deformation, potholes, etc.	Once a week	2	Pickup, measuring tape	3	24,480
Road Markings	Stain, discolor	Once a week	2	Pickup, measuring tape	0.5	4,080
Safety Sign Boards	Damage, deformation, stain, discolor	Once a week	2	Pickup, ladder	1	8,160
Median	Soundness of turf, erosion of fill	Once a week	2	Pickup, scoops	0.5	4,080
Lighting	Soundness of light and switch, damage, deformation	Once a week	2	Pickup, ladder	0.5	4,080
					Subtotal($/yr)	87,720

2. CLEANING

Facility	Cleaning Item	Interval	Req'd Staff	Req'd material/equipment	Req'd days	Req'd Budget
Ditches	Removal of deposit of mud, sand, obstacle	Once a year	5	Dump, pickup, scoops, hammer, bars	15	8,625
Basins	Removal of deposit of mud, sand, obstacle	Once a year	5	Dump, pickup, scoops, hammer, bars	15	8,625
Culverts crossing road	Removal of deposit of mud, sand, obstacle	Once a year	5	Pickup, scoops, bars, water jet pump	5	1,375
PVC Pipes	Removal of deposit of mud, sand, obstacle	Once a year	5	Pickup, scoops, bars, water jet pump	15	4,125
Outlet Protections	None					
AC pavement	Removal of dust, sand	Once a month	5	Dump, pickup, scoops, brooms	10	69,000
Road Markings	Removal of stain	Once a year	2	Pickup, scoops, brooms	5	850
Safety Sign Boards	Removal of stain, reformation	Once a year	2	Pickup, ladders	10	1,700
Median	Removal of foreign objects, adding fertilizer	Once a month	2	Pickup, scoops	5	10,200
Lighting	Removal of stain	Once a year	2	Lift truck	5	1,850
					Subtotal($/yr)	106,350

3. REPAIR

Facility	Repair Item	Expected quant'y	Req'd Staff	Req'd material/equipment	Req'd days	Req'd Budget
Ditches	Repair or exchange of covers	10 spots a year	4	Pickup, cover, concrete, motor, form	1days/spot	2,400
Basins	Repair or exchange of covers	3 spots a year	4	Pickup, cover, concrete, motor, form	1days/spot	960
Culverts crossing road	None					
PVC Pipes	None					
Outlet Protections	Repair of gabion, reformation	3 spots a year	4	Backhoe, gabions	3days/spot	3,960
AC pavement	Sealing, Patching, Leveling	50 spots a year	4	Asphalt, asphalt boiler, aggregate	1days/spot	22,000
Road Markings	Repaint	10 spots a year	3	Paint, brush, pickup, measuring tape	1days/spot	2,050
Safety Sign Boards	Repair of damage and deform, repaint	10 spots a year	3	Paint, brush, pickup, ladder	1days/spot	2,050
Median	Re-turfing	10 spots a year	3	Grass, dump, pickup, scoop	1days/spot	5,050
Lighting	Replacement of broken lamps	1 spot a year	2	Lamps, lift truck	1days/spot	370
					Subtotal($/yr)	38,840

Total ($/year)	232,910

APPENDIX 11. REFERENCES

- Marshall Islands Statistical Abstract, 1995
- Census of Population and Housing (Final Report), 1988
- Report on the Multi-Subject Household Survey, 1994
- Second Five Year Development Plan, 1991/92-1995/96
- First Five Year Development Plan, Rephased for 1986/87- 1990/91
- Majuro Development Plan, 1981
- Population and Development Policy, 1995
- Marshall Islands Transport Infrastructure Development Project (Final Report),1995
- Marshall Islands Transport Infrastructure Development Project (Appendix)
- Environmental Inpact Assessment Regulation (EPA, 1994)
- Marine Water Quality Regulations (EPA, 1992)
- Earthmoving Regulations (EPA, 1994)
- Solid Waste Regulations (EPA,1989)
- National Environmental Management Strategy (Action strategy for strengthening environmental management), 1992
- National Environmental Management Strategy (State of the environment), 1992
- Marshall Islands Information Book, Forum '96
- The People of Bikini: From Exodus to Resettlement
- Pacific, September/October 1996
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