Type of boring: mecanical drilling Apafor 22 Depth of water level : 4.80 m	SVAY PARK 30M FROM RN°5 PK 9 + LEFT SIDE

Depth , m	Water level , m	Legend	Description of soil	SPT N Blows N0	N1	N2	% recovery	AASHTO T206-81 N values	Unit weight, g/cm	Spe.gravity, g/cm	Type of samp
0											
1			Made ground - stiff of dark								
2			brown CLAY . A-7-6	3	5	6	62	11		2.574	D-1
3			3.00m								
4				6	8	9	66	17			D-2
5	▼		Stiff to very stiff , brownish	5	9	10	33	19		2.588	D-3
6	4.80		and dark brown CLAY .	4	7	8	66	15			D-4
7			A-7-6	4	5	7	84	12			D-5
8			8.20m	3	4	6	100	10			D-6
9				4	9	10	55	19			D-7
10				5	7	8	51	15		2.609	D-8
11				4	7	11	33	18			D-9
12				10	13	13	26	26			D-10
13				10	15	15	40	30		2.601	D-11
14				10	12	12	44	24			D-12
15				8	12	13	48	25		2.602	D-13
16			Medium to dense , grayish ,	11	15	17	55	32			D-14
17			greenish-gray , poorly	6	8	8	44	16			D-15
18			grained FINE SANDS .	8	11	13	66	24		2.594	D-16
19			A-3	8	13	13	62	26			D-17
20			Dmin<0.08mm=4.2%	12	16	19	66	35			D-18
21				10	12	14	48	26			D-19
22				10	15	15	66	30			D-20
23				10	15	22	55	37			D-21
24				5	10	18	44	28			D-22
25				13	17	8	33	25		2.596	D-23
26			26.00m	7	8	11	33	19	2.077	2.604	D-24
27			Very stiff to hard , greenish-	13	19	20	33	39		2.574	D-25
28			gray SANDY CLAYS . A-7-6	38	>50		0	>50			D-26
			END OF SPT-27.45m								

Elevation of borehole : EL.9.9m

The Study on Drainage Improvement and Flood Control in the Municipality of Phnom Penh JICA - CTIE International Co., Ltd. - Nippon Koei Co., Ltd.	Figure C5-2 Boring Logs (1/11) - No. BH-1-

Type of boring: mecanical drilling Apafor 22
Depth of water level : 1.00 m

KOP SROV DIKE
14M FROM DIKE CENTER
EAST TO WEST
RIGHT SIDE

Depth, m	Water level, m	Legend	Description of soil	SPT N.Blows N0	N1	N2	% recovery	AASHTO T206-81 N values	Unit weight, g/cm	Spe.gravity, g/cm	Type of sampl
0											
1	0.50										
2				2	2	4	62	6	2.079	2.640	D-1
3			Firm to very stiff, brownish								
			CLAY.	5	6	6	88	12			D-2
4			A-7-6								
			Dmin<0.08mm=97%	6	9	12	84	21			D-3
5											
				6	10	13	66	23			D-4
6											
				7	11	13	44	24	2.071	2.628	D-5
7			7.00m								
				3	7	7	66	14			D-6
8											
				0	1	1	100	2	1.726	2.449	D-7
9											
			Soft to very stiff, light-brown	0	1	1	100	2			D-8
10			CLAY.								
			A-7-6, A-6	2	2	4	100	6			D-9
11			Dmin<0.08mm=93.8%								
				3	3	4	97	7	1.944	2.491	D-10
12											
				6	9	11	22	20			D-11
13			13.00m								
				3	8	9	33	17			D-12
14			Very stiff, greenish-gray								
			CLAYEY SAND. A-2-6	8	11	12	44	23			D-13
15			Dmin<0.08mm=19%								
				10	11	15	44	26			D-14
			END OF SPT-15.45m								

Elevation of borehole : EL. 7.0m

The Study on Drainage Improvement and Flood Control in the Municipality of Phnom Penh JICA - CTIE International Co., Ltd. - Nippon Koei Co., Ltd.	Figure C5-2 Boring Logs (2/11) - No. BH-2 -

Type of boring: mecanical drilling Apafor 22
Depth of water level : 0.70 m

KOP SROV DIKE
18M FROM DIKE CENTER
EAST TO WEST
LEFT SIDE

Depth, m	Water level, m	Legend	Description of soil	SPT N, Blows N0	N1	N2	% recovery	AASHTO T206-81 N values	Unit weight, g/cm	Spe.gravity, g/cm	Type of sampl
0											
1											
2	0.70			3	3	4	66	7	2.095	2.655	D-1
3											
4			Firm to stiff, brownish CLAY.	4	5	6	100	11			D-2
5			A-7-6, A-6	3	4	4	100	8			D-3
6			Dmin<0.08mm= 75 %	4	5	6	100	11			D-4
7				5	7	9	66	16			D-5
8				2	3	4	100	7	1.995	2.640	D-6
9				3	4	5	100	9			D-7
10			10.00m	2	4	5	100	9			D-8
11				4	9	11	66	20	1.963	2.621	D-9
12				4	9	10	66	19			D-10
13			Very stiff to hard, brownish	5	8	10	66	18			D-11
14			and grayish CLAY.	7	12	14	66	26			D-12
15			A-7-6, A-6	5	7	11	100	18			D-13
16			Dmin<0.08mm=56 %	4	8	10	100	18			D-14
17				7	10	11	88	21			D-15
18				7	14	19	77	33	2.108	2.567	D-16
19				13	11	38	77	49	2.150	2.606	D-17
			END OF SPT-18.45m								

Elevation of borehole : EL.6.1m

The Study on Drainage Improvement and Flood Control in the Municipality of Phnom Penh JICA - CTIE International Co., Ltd. - Nippon Koei Co., Ltd.	Figure C5-2 Boring Logs (3/11) - No. BH-3 -

Type of boring: mecanical drilling Apafor 22
Depth of water level : 2.30 m

KOP SROV DIKE
17M FROM DIKE CENTER LINE
EAST TO WEST
LEFT SIDE

Depth, m	Water level, m	Legend	Description of soil	SPT N Blows N0	N1	N2	% recovery	AASHTO T206-81 N values	Unit weight, g/cm	Spe.gravity, g/cm	Type of sampl
0											
1				2	7	21	66	28			D-1
2				5	8	13	66	21	2.044	2.490	D-2
3	2.30			5	5	7	44	12			D-3
4			Stiff to hard , brownish and	2	5	6	100	11			D-4
5			yellowish of medium plasticity								
			CLAY .	3	4	6	100	10	2.077	2.526	D-5
6			(A-7-6 , A-6)								
			Dmin<0.08mm= 41.8 %	2	4	6	0	10			D-6
7				6	11	9	88	20			D-7
8				8	12	17	33	29	2.211	2.524	D-8
9				13	17	25	6	42			D-9
10				21	26	24	22	50	2.261	2.541	D-10
11			END OF SPT-10.45m								

Elevation of borehole : EL. 6.5m

The Study on Drainage Improvement and Flood Control in the Municipality of Phnom Penh JICA - CTIE International Co., Ltd. - Nippon Koei Co., Ltd.	Figure C5-2 Boring Logs (4/11) - No. BH-4 -

Type of boring: mecanical drilling Apafor 22
Depth of water level : 1.00 m

KOP SROV DIKE
14M FROM DIKE CENTER
EAST TO WEST
RIGHT SIDE

Depth, m	Water level, m	Legend	Description of soil	SPT N values N0	N1	N2	% recovery	AASHTO T206-81 N values	Unit weight, g/cm	Spe.gravity, g/cm	Typo of sampl
0											
1											
	1.00		Stiff to hard of medium	1	2	5	44	7			D-1
2			plasticity , reddish brown and								
			light gray CLAY .	8	11	13	44	24	2.170	2.517	D-2
3			Dmin<0.08mm= 82 %								
			A-7-6	4	7	7	66	14			D-3
4			4.00m								
				18	29	45	66	74	2.245	2.635	D-4
5											
			Hard medium plasticity of	11	17	29	77	46			D-5
6			yellowish red SANDY CLAYS .								
			A - 6	11	16	22	66	38	1.918	2.494	D-6
7			Dmin<0.08mm=42 %								
				42				>50			D-7
8											
			END OF SPT-7.45m								

Elevation of borehole : EL.8.5m

The Study on Drainage Improvement and Flood Control in the Municipality of Phnom Penh
JICA - CTIE International Co., Ltd. - Nippon Koei Co., Ltd.

Figure C5-2
Boring Logs (5/11)
- No. BH-5 -

Type of boring: mecanical drilling Apafor 22
Depth of water level : 5.20 m

MEANCHEY CHANNEL
14M FROM DIKE CENTER
CORNER OF BLD.MONIRETH AND ROAD N°271

Depth, m	Water level, m	Legend	Description of soil	SPT N values N0	N1	N2	% recovery	AASHTO T206-81 N values 0 10 20 30 40 50	Unit weight, g/cm	Spe.gravity, g/cm	Type of sampl
0											
1											
	1.00										
2				1	1	2	22	3			D-1
3											
				3	5	6	44	11			D-2
4											
				5	5	7	66	12	2.080	2.536	D-3
5											
				4	5	5	66	10			D-4
6	5.20										
				3	4	4	66	8	2.061	2.566	D-5
7			Firm to stiff, dark brown,								
			dark gray CLAY of medium to	2	4	6	44	10			D-6
8			high plasticity.								
			A-7-6	2	3	7	55	10			D-7
9			Dmin<0.08mm=93 %								
				6	9	12	66	21			D-8
10											
				6	5	8	55	13	2.066	2.606	D-9
11											
				5	8	10	55	18			D-10
12											
				12	16	15	66	31			D-11
13											
				5	7	8	77	15			D-12
14											
				10	30	35	77	>50	2.235	2.597	D-13
15											
			END OF SPT-14.45m								

Elevation of borehole : EL. 10.2m

The Study on Drainage Improvement and Flood Control in the Municipality of Phnom Penh JICA - CTIE International Co., Ltd. - Nippon Koei Co., Ltd.	Figure C5-2 Boring Logs (6/11) - No. BH-6 -

Type of boring: mecanical drilling Apafor 22
Depth of water level : 2.20 m

TOMPUN DIKE
22M FROM DIKE CENTER LINE
EAST TO WEST
LEFT SIDE

Depth, m	Water level, m	Legend	Description of soil	SPT N Blows N0	N1	N2	% recovery	AASHTO T206-81 N values	Unit weight, g/cm	Spe.gravity, g/cm	Type of sampl
0											
1											
				2	4	5	22	9			D-1
2			Stiff grayish and yellowish								
	▼		gray of medium plasticity CLAY	3	4	7	33	11	1.969	2.500	D-2
3	2.20		A-6								
			Dmin<0.08mm=28 - 83 %	4	5	7	66	12			D-3
4											
				4	6	6	66	12	2.271	2.540	D-4
5			5.00m								
				6	9	9	44	18			D-5
6											
				13	15	17	44	32			D-6
7			Firm to very stif, grayish of								
			low plasticity CLAYEY SANDS	3	5	7	6	12	2.094	2.425	D-7
8			A-6								
			Dmin<0.08mm=56.2 %	3	2	4	66	6			D-8
9											
				4	5	7	55	12			D-9
10			10.00m								
				4	6	9	17	15	2.232	2.524	D-10
11											
				5	7	9	17	16			D-11
12											
			Stiff to hard of medium	8	14	15	22	29	2.138	2.400	D-12
13			plasticity, grayish CLAY,								
			A-2-6	7	9	11	22	20			D-13
14			Dmin<0.08mm=59%								
				7	10	11	33	21			D-14
15											
				15	24	35	33	>50	2.137	2.450	D-15
			END OF SPT-15.45m								

Elevation of borehole : EL. 4. 7m

The Study on Drainage Improvement and Flood Control in the Municipality of Phnom Penh JICA - CTIE International Co., Ltd. - Nippon Koei Co., Ltd.	Figure C5-2 Boring Logs (7/11) - No. BH-7 -

Type of boring: mecanical drilling Apator 22
Depth of water level : 1.80 m

TOMPUN DIKE
180M FROM DIKE CENTER LINE
EAST TO WEST
RIGHT SIDE

Depth, m	Water level, m	Legend	Description of soil	SPT N values N0	N1	N2	% recovery	AASHTO T206-81 N values	Unit weight, g/cm	Spe.gravity, g/cm	Type of sampl
0											
1											
	▼		Stiff to very stiff of low	5	7	11	33	18			D-1
2			plasticity , grayish and reddish								
	1.80		brown SILTY CLAY .	3	6	7	33	13			D-2
3			A-4								
				3	4	5	55	9	2.170	2.384	D-3
4			4.00m								
				3	4	4	77	8			D-4
5			Firm of low plasticity,yellowish								
			CLAY . (A-6)	2	2	6	77	8	2.172	2.543	D-5
6			6.00m								
				6	7	9	77	16			D-6
7											
			Very stiff to hard of light gray	7	10	11	66	21			D-7
8			SILTY SANDS .								
			A-2-4	8	15	21	55	36			D-8
9			%<0.08mm = 35%								
				8	7	7	55	14	2.065	2.456	D-9
10			10.00m								
				11	14	22	55	36			D-10
11											
			Very stiff to hard of low -	10	17	25	55	42	2.241	2.54	D-11
12			medium plasticity , grayish and								
			brownish CLAY .	7	10	14	7	24			D-12
13			A-6 , A-7-6								
			Dmin<0.08mm=37%	14	14	12	7	26			D-13
14											
				13	22	21	33	43	2.110	2.502	D-14
15											
			End of S P T - 14.45 m								

Elevation of borehole : EL.5.0m

The Study on Drainage Improvement and Flood Control in the Municipality of Phnom Penh JICA - CTIE International Co., Ltd. - Nippon Koei Co., Ltd.	Figure C5-2 Boring Logs (8/11) - No. BH-8 -

Type of boring: mecanical drilling Apafor 22
Depth of water level : 4.00 m

TOMPUN DIKE
NEAR THE WATER TANK OLYMPIC
PHNOM PENH

Depth, m	Water level, m	Legend	Description of soil	SPT N values N0	N1	N2	% recovery	AASHTO T206-81 N values	Unit weight, g/cm	Spe.gravity, g/cm	Type of sampl
0											
1			Firm to stiff of medium	2	1	3	44	4			D-1
2			plasticity , brownish CLAY .								
			A - 6	2	3	3	55	6	2.089	2.585	D-2
3			%<0.08mm = 78.2%								
				1	4	6	55	10			D-3
4			4.00m								
	4.00			1	5	7	77	12			D-4
5											
				3	4	5	55	9			D-5
6											
				2	4	6	55	10	1.947	2.589	D-6
7											
				6	11	13	66	24			D-7
8											
			Stiff to hard of low plasticity	11	13	18	55	31			D-8
9			brownish and brownish gray								
			SANDY SILTS .	19	20	24	55	44	1.967	2.615	D-9
10			(A-4)								
			Dmin<0.08mm = 46 %	5	8	10	44	18			D-10
11											
				7	10	18	44	28			D-11
12											
				13	15	15	44	30			D-12
13											
				9	36	21	0	>50		2.628	D-13
14											
			End of S P T - 13.45 m								

Elevation of borehole : EL.8.8m

The Study on Drainage Improvement and Flood Control in the Municipality of Phnom Penh JICA - CTIE International Co., Ltd. - Nippon Koei Co., Ltd.	Figure C5-2 Boring Logs (9/11) - No. BH-9 -

Type of boring: mecanical drilling Apafor 22
Depth of water level : 2.20 m

TOMPUN DIKE
NEAR THE SMALL WOOD BRIDGE
LEFT SIDE

Depth , m	Water level , m	Legend	Description of soil	SPT N Blows N0	N1	N2	% recovery	AASHTO T206-81 N values	Unit weight, g/cm	Spe.gravity, g/cm	Type of sampl
0											
1											
2			Stiff , medium plasticity of	1	3	4	55	7			D-1
3			brownish gray CLAYEY SAND	3	4	5	44	9			D-2
4	2.20		Dmin<0.08mm=22.1%	6	5	5	77	10	2.165	2.567	D-3
5			5.00m	3	4	5	77	9			D-4
6			Stiff to very stiff of low	3	7	6	77	13	2.163	2.544	D-5
7			plasticity reddish gray , yellow	7	10	16	66	26			D-6
8			SANDY CLAYS .	2	6	8	22	14			D-7
9			Dmin<0.08mm=68.2%	10	13	16	33	29			D-8
10			10.00m	11	10	11	77	21			D-9
11				5	7	8	44	15			D-10
12				6	6	8	44	14	2.141	2.535	D-11
13			Stiff to very stiff of low	7	8	11	88	19			D-12
14			low plasticity , grayish and	6	5	7	66	12			D-13
15			yellowish gray CLAYEY SAN	7	8	9	88	17			D-14
16			Dmin<0.08mm= 34.2%	5	8	12	77	20			D-15
17			17.00m	6	8	10	11	18			D-16
18				11	8	9	0	17			D-17
19				8	13	19	55	32			D-18
20				10	9	10	0	19			D-19
21			Very stiff of medium	6	8	8	0	16			D-20
22			plasticity, grayish CLAY .	8	8	9	22	17			D-21
23			Dmin<0.08mm=94.1%	9	7	9	0	16			D-22
24				8	8	8	0	16			D-23
25				7	9	14	0	23			D-24
26				3	8	10	0	18			D-25
27				4	9	11	0	20			D-26
			END OF SPT-26.45m								

Elevation of borehole : EL.5.5m

The Study on Drainage Improvement and Flood Control in the Municipality of Phnom Penh JICA - CTIE International Co., Ltd. - Nippon Koei Co., Ltd.	Figure C5-2 Boring Logs (10/11) - No. BH-10 -

Type of boring: mecanical drilling Apator 22
Depth of water level : 1.50 m

BOENG SALANG CHANNEL
NEAR THE SMALL WOOD BRIDGE
EAST TO WEST
RIGHT SIDE (ABOUT 3M FROM ROAD C.L)

Depth, m	Water level, m	Legend	Description of soil	SPT N, Blows N0	N1	N2	% recovery	AASHTO T206-81 N values	Unit weight, g/cm	Spe.gravity, g/cm	Type of sampl
0											
1											
2	1.50		Very soft of black and dark	0	0	0	0	H.W	1.683	2.338	D-1
3			gray organic CLAYS with some break at surface (BACK FILL)								
			Dmin<0.08mm=79.8%	0	0	0	33	H.W			D-2
4											
			4.50m	0	0	0	44	H.W			D-3
5											
				2	4	6	44	10			D-4
6											
				17	27	16	66	43	1.988	2.605	D-5
7											
			firm to hard of medium to low	3	4	8	88	12			D-6
8			plasticity , brownish , light gray								
			CLAY .	6	13	16	88	29			D-7
9			(A-7-6 ,A-6)								
			Dmin<0.08mm = 70.1%	10	7	10	88	17	1.839	2.579	D-8
10											
				4	11	11	88	22			D-9
11											
				6	9	9	88	18			D-10
12											
				23	52		66	>50	1.996	2.568	D-11
13											
			End of S P T - 12.30 m								

Elevation of borehole : EL. 7. 1m

The Study on Drainage Improvement and Flood Control in the Municipality of Phnom Penh JICA - CTIE International Co., Ltd. - Nippon Koei Co., Ltd.	Figure C5-2 Boring Logs (11/11) - No. BH-11 -

Site : Kop Srov dike Type of excavation : excavator Ground level : Depth of water : wet	**TEST PIT N°KT 1** **UD : 1.80 – 2.00M**

Gr level m	Depth m	Trial pit log	Description of soil	Moisture content W %	Unit weight g/cm	Specific gravity g/cm	Observation
	0.00						
	0.50 1.00 1.50 2.00		Low plasticity of brownish CLAY	24.1	2.034	2.665	%<74μ=92 % WL = 55 IP = 16 A-7-5 type
			Depth of pit – 2.00m				

- Location of pit : 60m from dike C.L (East to West – left side)

The Study on Drainage Improvement and Flood Control in the Municipality of Phnom Penh JICA - CTIE International Co., Ltd. - Nippon Koei Co., Ltd.	Figure C5-3 Test Pit Logs (1/17) - No. KT-1-

Site : Kop Srov dike Type of excavation : excavator Ground level : Depth of water : dry	**TEST PIT Nº KT 2** **UD : 1.80 – 2.00M**

Gr level m	Depth m	Trial pit log	Description of soil	Moisture content W %	Unit weight g/cm	Specific gravity g/cm	Observation
	0.00						
	0.50		Medium plasticity of brownish and light-brown CLAY .	26.3	1.962	2.540	%<74μ=94.3% WL = 45 IP = 27 A-7-6 type
	1.00						
	1.50						
	2.00						
			Depth of pit – 2.00m				

- Location of pit : 79m from dike CL (East to West – left side)

Site : Kop Srov dike Type of excavation : excavator Ground level : Depth of water : wet	**TEST PIT Nº KT 3** **UD : 1.80 – 2.00M**

Gr.level m	Depth m	Trial pit log	Description of soil	Moisture content W %	Unit weight g/cm	Specific gravity g/cm	Observation
	0.00						
	0.50 1.00 1.50 2.00		Low plasticity of dark yellow and light-brown CLAY .	17.0	1.982	2.436	%<74μ=91.8 % WL = 35 IP = 20 A-6 type
			Depth of pit – 2.00m				

- Location of pit : 35m from dike CL (East to West – left side)

The Study on Drainage Improvement and Flood Control in the Municipality of Phnom Penh JICA - CTIE International Co., Ltd. - Nippon Koei Co., Ltd.	Figure C5-3 Test Pit Logs (3/17) - No. KT-3-

Site : Kop Srov dike Type of excavation : excavator Ground level : Depth of water : dry	**TEST PIT Nº KT 4** **UD : 0.80 – 1.00M**

Gr.level m	Depth m	Trial pit log	Description of soil	Moisture content W %	Unit weight g/cm	Specific gravity g/cm	Observation
	0.00						
	0.50		Low plasticity , very stiff, dark yellow and grayish CLAY , with some gravel.	11.0	2.098	2.589	%<74μ=98.4 % WL = 36 IP = 20 A-6 type
	1.00						
	1.50						
	2.00						
			Depth of pit – 2.00m				

- Location of pit : 29m from dike center line (East to West – left side)

The Study on Drainage Improvement and Flood Control in the Municipality of Phnom Penh JICA - CTIE International Co., Ltd. - Nippon Koei Co., Ltd.	Figure C5-3 Test Pit Logs (4/17) - No. KT-4-

Site : Kop Srov dike Type of excavation : excavator Ground level : Depth of water : dry	**TEST PIT N° KT 5** **UD : 1.80 – 2.00M**

Gr.level m	Depth m	Trial pit log	Description of soil	Moisture content W %	Unit weight g/cm	Specific gravity g/cm	Observation
	0.00						
			Dark brown , very stiff Clay,with some laterite 0.50m	-	-	-	
	0.50						
	1.00		Medium plasticity , dark yellow and reddish CLAY .	17.9	1.995	2.581	%<74μ=94.2 % WL = 40 IP = 25 A-6 type
	1.50						
	2.00						
			Depth of pit – 2.00m				

- Location of pit : 44m from dike C.L (Bast to West – left side)

The Study on Drainage Improvement and Flood Control in the Municipality of Phnom Penh JICA - CTIE International Co., Ltd. - Nippon Koei Co., Ltd.	Figure C5-3 Test Pit Logs (5/17) - No. KT-5-

Site : Kop Srov dike Type of excavation : by hand Ground level : Depth of water : dry	**TEST PIT Nº KT 6** **UD : 1.80 – 2.00M**

Gr.level m	Depth m	Trial pit log	Description of soil	Moisture content W %	Unit weight g/cm	Specific gravity g/cm	Observation
	0.00						
	0.50		Medium plasticity of grayish and brownish CLAY .	21.5	1.919	2.624	%<74μ=99% WL = 48 IP = 30 A-7-6 type
	1.00						
	1.50						
	2.00						
			Depth of pit – 2.00m				

- Location of pit : 154m from dike CL and 22m from channel (East to West – left side)

Site : Kop Srov dike Type of excavation : by hand Ground level : Depth of water : dry	TEST PIT N° KT 7 UD : 1.20 – 1.40M

Gr level m	Depth m	Trial pit log	Description of soil	Moisture content W %	Unit weight g/cm	Specific gravity g/cm	Observation
	0.00		Light brown, clean fine Sands 0.25m	-	-	-	
	0.50 1.00 1.50 2.00		Medium plasticity of very stiff dark - yellow CLAY .	7.0	1.933	2.508	%<74μ=99.5 % WL = 35 IP = 23 A-6 type
			Depth of pit – 2.00m				

- Location of pit : 22m from dike CL (East to West – left side)

The Study on Drainage Improvement and Flood Control in the Municipality of Phnom Penh JICA - CTIE International Co., Ltd. - Nippon Koei Co., Ltd.	Figure C5-3 Test Pit Logs (7/17) - No. KT-7-

Site : Kop Srov dike Type of excavation : by hand Ground level : Depth of water : dry	**TEST PIT Nº KT 8** **UD : 1.40 – 1.60M**

Gr.level m	Depth m	Trial pit log	Description of soil	Moisture content W %	Unit weight g/cm	Specific gravity g/cm	Observation
	0.00		Poorly light gray and light brown Fine Sands . 0.70m	-	-	-	
	0.50						
	1.00		Medium plasticity of reddish , yellowish CLAYEY SANDS .	11.3	2.207	2.557	%<74μ=33 % WL = 47 IP = 32 A-2-7 type
	1.50						
	2.00						
			Depth of pit – 2.00m				

- Location of pit : 17m from dike center line (East to West – right side)

Site : Kop Srov dike Type of excavation : by hand Ground level : Depth of water : 1.40m	**TEST PIT Nº KT 9** **UD : 1.50 – 1.70M**

Gr level m	Depth m	Trial pit log	Description of soil	Moisture content W %	Unit weight g/cm	Specific gravity g/cm	Observation
	0.00 0.50 1.00 1.50 2.00		Light brown , very Fine clean Sands	10.5	-	2.577	%<74μ=88.2% ES = vis-21.4 pis-15.3 A-3 type
			Depth of pit – 2.00m				

- Location of pit : 18.50m from dike center line (East to West – left side)

The Study on Drainage Improvement and Flood Control in the Municipality of Phnom Penh JICA - CTIE International Co., Ltd. - Nippon Koei Co., Ltd.	Figure C5-3 Test Pit Logs (9/17) - No. KT-9-

Site : Meanchey Channel Type of excavation : excavator Ground level : Depth of water : dry	**TEST PIT Nº MT 1** **UD : 0.60 – 0.80M** **1.60 –1.80M**

Gr.level m	Depth m	Trial pit log	Description of soil	Moisture content W %	Unit weight g/cm	Specific gravity g/cm	Observation
	0.00						
	0.50		Back fill – low plasticity of brownish and yellowish brown CLAY . 1.00m	14.1	2.117	2.441	%<74μ= 98.2% WL = 25 IP = 12 A-6 type
	1.00						
	1.50		Low plasticity of yellowish CLAYEY SILTS	9.9			%<74μ=89.2% WL = 20 IP = 9 A-4 type
	2.00						
			Depth of pit – 2.00m				

- Location of pit : 74.50m from road C.L to Maeda office .

Site : Meanchey Channel Type of excavation : excavator Ground level : Depth of water : dry	**TEST PIT Nº MT 2** **UD : 1.00 – 1.20M**

Gr level m	Depth m	Trial pit log	Description of soil	Moisture content W %	Unit weight g/cm	Specific gravity g/cm	Observation
	0.00		Medium plasticity of very stiff brownish and yellowish CLAY	4.8	1.837	2.481	%<74μ=98 % WL = 42 IP = 24 A-7-6
	0.50						
	1.00						
	1.50						
	2.00						
			Depth of pit – 2.00m				

- Location of pit : 9m from the fence .

Site : Meanchey Channel Type of excavation : excavator Ground level : Depth of water : wet	**TEST PIT Nº MT 3** **UD : 1.80 – 2.00M**

Gr level m	Depth m	Trial pit log	Description of soil	Moisture content W %	Unit weight g/cm	Specific gravity g/cm	Observation
	0.00		Soft to very soft of dark gray and black organic SILTS . (highly organic)	-	-	-	
	0.50						
			1.00m				
	1.00		Medium plasticity of brownish and grayish CLAY .	20.7	1.895	2.544	%<74μ=83.8 % WL = 39 IP = 25 A-6 type
	1.50						
	2.00						
			Depth of pit – 2.00m				

- Location of pit : 13m from the fence's house .

Site : Tompun Dike Type of excavation : excavator Ground level : Depth of water : dry	**TEST PIT Nº MT 4** **UD : 1.80 – 2.00M**

Gr.level m	Depth m	Trial pit log	Description of soil	Moisture content W %	Unit weight g/cm	Specific gravity g/cm	Observation
	0.00						
		#	Back fill – soft, grayish CLAYEY SILTS 0.50m	-	-	-	
	0.50	#	Medium plasticity of dark brown and brownish CLAY	25.2	1.842	2.551	%<74μ=93 % WL = 43 IP = 25 A-7-6 type
	1.00						
	1.50						
	2.00						
			Depth of pit – 2.00m				

- Location of pit : 45m from dike center line (East to West – right side)

The Study on Drainage Improvement and Flood Control in the Municipality of Phnom Penh JICA - CTIE International Co., Ltd. - Nippon Koei Co., Ltd.	Figure C5-3 Test Pit Logs (13/17) - No. MT-4-

Site : Tompun Dike Type of excavation : excavator Ground level : Depth of water : dry	**TEST PIT Nº MT 5** **UD : 0.40 – 0.60M** **1.30 – 1.50M**

Gr.level m	Depth m	Trial pit log	Description of soil	Moisture content W %	Unit weight g/cm	Specific gravity g/cm	Observation
	0.00		Back fill – medium plasticity of yellowish and yellowish brown CLAY 1.00m	20.6	-	-	%<74μ= 67.2% WL = 34 IP = 23 A-6 type
	1.00 1.50 2.00		Medium plasticity of yellowish and yellowish brown CLAY	15.8	1.978	2.515	%<74μ=56 % WL = 33 IP = 21 A-6 type
			Depth of pit – 2.00m				

- Location of pit : 35m from dike center line (East to West – right side)

Site : Tompun Dike Type of excavation : excavator Ground level : Depth of water : dry	**TEST PIT Nº MT 6** **UD : 1.30 – 1.50M**

Gr level m	Depth m	Trial pit log	Description of soil	Moisture content W %	Unit weight g/cm	Specific gravity g/cm	Observation
	0.00		Medium plasticity of yellowish and dark yellow CLAY	15.4	2.080	2.481	%<74μ=84.1 % WL = 33 IP = 23 A-6 type
	0.50						
	1.00						
	1.50						
	2.00						
			Depth of pit – 2.00m				

* Location of pit : 19.50m from road (right hand)

Site : Tompun Dike Type of excavation : excavator Ground level : Depth of water : dry	**TEST PIT N°MT 7** **UD : 0.30 – 0.50M** **0.80 – 1.00M**

Gr.level m	Depth m	Trial pit log	Description of soil	Moisture content W %	Unit weight g/cm	Specific gravity g/cm	Observation
	0.00 0.25		Medium plasticity of yellowish brown CLAY 0.50m	17.0	1.929	2.491	%<74μ= 94 % WL = 48 IP = 31 A-7-6 type
	0.50 0.75 1.00		Medium plasticity of very stiff, dark yellow and yellowish CLAY	13.6			%<74μ=94.2% WL = 39 IP = 26 A-6 type
			Depth of pit – 1.00m				

* Location of pit : (East to West – turn right , about 500m from dike C.L) 16m from road .

Site : Boeng Salang Type of excavation : excavator Ground level : Depth of water : dry	**TEST PIT Nº MT 8** **UD : 0.50 – 0.70M** **1.20 – 1.40M**

Gr.level m	Depth m	Trial pit log	Description of soil	Moisture content W %	Unit weight g/cm	Specific gravity g/cm	Observation
	0.00						
	0.50		Back fill – medium plasticity of grayish CLAY 1.00m	19.6	1.885	2.568	%<74μ=98% WL = 35 IP = 20 A-6 type
	1.00						
	1.50		Medium plasticity of reddish brown CLAY	22.7	1.893	2.540	%<74μ= 98% WL = 56 IP = 39 A-7-6 type
	2.00						
			Depth of pit – 2.00m				

* Location of pit : in the middle of pick kill center (Boeng Salang) .

The Study on Drainage Improvement and Flood Control in the Municipality of Phnom Penh JICA - CTIE International Co., Ltd. - Nippon Koei Co., Ltd.	Figure C5-3 Test Pit Logs (17/17) - No. MT-8-

Sector D

Plan and Design

THE STUDY ON
DRAINAGE IMPROVEMENT AND FLOOD CONTROL
IN THE MUNICIPALITY OF PHNOM PENH

SECTOR D: PLAN AND DESIGN

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

D1. Introduction

This Supporting Report, Sector D "Plan and Design" is the main text of the Supporting Report, dealing with the results of plan and design for the Study on Drainage Improvement and Flood Control in the Municipality of Phnom Penh. The Study was conducted in two stages, specifically:

- Master Plan Study for the whole Study Area with a total area of 195.71 km^2; and
- Feasibility Studies on two projects identified as priority projects through the Master Plan: Reinforcement of Kop Srov and Tompun Dikes, and Tompun Watershed Drainage Improvement.

This Sector D describes on the premises, conditions, alternative studies, preliminary designs, project formulations, and relevant matters for both Master Plan Study and Feasibility Studies, which comprises the following chapters:

(a) D1. Introduction: this chapter;

(b) D2. Present Conditions: displays the present conditions of the Study Area and watersheds, flood protection and drainage facilities, and design standards and basic data for construction;

(c) D3. Master Plan Study: presents the premises and conditions for studying the Master Plan, alternative studies on flood protection and drainage improvement as well as environmental enhancement, formulation of the Master Plan, and finally selection of priority projects which are subject to the succeeding feasibility studies;

(d) D4. Feasibility Study on Reinforcement of Kop Srov and Tompun Dikes: compiles the results of the preliminary design and project formulation with respect to the Reinforcement of Kop Srov and Tompun Dikes;

(e) D5. Feasibility Study on Tompun Watershed Drainage Improvement: compiles the results of the same for the Tompun Watershed Drainage Improvement; and

(f) D6: Possible Urgent Projects: suggests, for the next step, several sub-components that should need more urgent implementation among the sub-components in the above two projects.

D2. Present Conditions

2.1 Study Area and Watersheds

The Study Area (195.71 km^2) is clearly limited by the Tonle Sap and Bassac rivers on the east, by the Prek Phnov floodplain to the north, by the Prek Thnot floodplain to the south, and by a hilly area to the west. In light of the topography, hydraulic characteristics and land use, the Study Area is shared with the following five major watersheds anti-clockwise from the City Core. These five further divides into basins as mentioned below (refer to Figure D2-1):

- City Core : C1 to C10 Basins (25.29 km^2)
- Northeast Area : E1 to E4 Basins (40.23 km^2)
- Northwest Area : No subdivision (50.79 km^2)
- Middle Area : M1 to M4 Basins (38.80 km^2)
- South Area : S1 and S2 basins (40.60 km^2)

The land use, topography and hydraulic characteristics of each basin, along with its catchment area, are enumerated in Table D2-1.

2.2 Flood Protection and Drainage Facilities

2.2.1 Ring Dikes, Roads and Crossings

Ring Dikes

There are two ring dikes called "Outer Ring Dike" and "Inner Ring Dike". The Outer Ring Dike is located on the perimeter of the Study Area and is composed of Tompun Dike, South Section (NR 303, Prey Sar Rd. and NR 3), West Section (Prey Pring Dike and the hilly portion of Kop Srov Rd.), Kop Srov Dike, Sap Upstream Section (NR 5), Sap Downstream Section, and Bassac Section (refer to Figure D2-2 together with Figure D3-1). The Inner Ring Dike is situated along the perimeter of the City Core and its crest is used as roads such as St. 271, St. 598, St. 355, St. 273 and St. 70.

(1) Outer Ring Dike

(a) Tompun Dike and South Section

Tompun Dike starts from the junction with St. 271 (a part of the Inner Ring Dike) ending at NR 303 to protect the inland from the flooding of the Thnot river basin. The total length is 4.4 km. Its crest elevation ranges from 10.0 to 10.7 m in most parts, whilst the lowest elevation is 9.7 m near the junction with NR 303. The height ranges from 4.0 to 6.5 m with a side slope of about 1:2 and the crest width is from 15 to 20 m, of which 5.0 to 7.5 m is utilized as a carriageway. The road surface is not paved and undulated. On both sides of the road are occupied mostly by squatters.

NR 303 starts from the City Core extending to the south. The road length within the Study Area is 4.8 km. The stretch forming the south section is between the junctions with the Tompun Dike and Prey Sar Rd., having a length of 1.8 km. Its crest is about 15 m wide, about 5 m of which is shared by

a carriageway surfaced with asphalt. The crest elevation ranges from 9.5 to 9.7 m and the height from 0.5 to 1.3 m.

Prey Sar Rd. runs between NR 303 and NR 3 forming the southern boundary of the Study Area. The length of the road is 11 km. The crest elevation ranges between 9.7 m and 14.2 m ascending from the junction with NR 303 to that with NR 3. Its width is about 3 to 5 m and the height varies from 1.4 to 2.8 m. The road surface is unpaved and uneven.

NR 3 is one of the principle national highways in the country extending from Phnom Penh City to Veal Rinh near Sihanoukville. The total length is 202 km, of which 16.5 km stretch passes in the Study Area. Out of the stretch, 6.6 km forms a part of the South Section. The width ranges from 8 to 10 m, of which about 5 m is utilized as a carriageway with asphalt pavement. The crest elevation ranges between 14.2 m and 12.4 m descending from south to north, and its height ranges from 0.3 to 2.3 m.

(b) West Section and Kop Srov Dike

Prey Pring Dike constructed between NR 3 and NR 4 has a function of protecting Prey Pring Town (a triangle-shaped small town) from flooding in the Thnot river basin. Its length is about 1.2 km. The crest elevation is around 10.6 m and the height ranges from 0.9 to 2.5 m.

Kop Srov Rd., both hilly and dike portions, was constructed in the Lonnol era connecting NR 4 to NR 5 to protect the invasion of Khmer Rouge from the north as well as the flooding in the Phnov river basin. The crest width ranges between 10 m and 12 m. The crest elevation varies from 14.4 to 10.2 m descending from south to north. The height ranges from 1 to 4 m (much higher at the northern part dike section). The side slopes of the road embankment vary from 1:1 to 1:3 depending on its height. The surface is unpaved and uneven, and the carriageway width is about 8 m. The total length of the road is 11 km. At a quarter point from NR 4, a railway crosses perpendicularly to the road.

(c) Sap Upstream Section (NR 5)

NR 5 runs on the right bank of the Tonle Sap River, with a length of 11 km, to prevent floods from entering the land side areas. Its crest elevation is 10.2 to 11.1 m in most parts, while the lowest is 9.9 m. The crest width is about 10 m and the carriageway is about 5 m wide. The road surface is paved with asphalt.

(d) Sap Downstream and Bassac Sections

Since the capital was transferred to Phnom Penh in the 15th century, the city has suffered from flooding caused by the Mekong river system. The riverfront has accordingly been heightened by filling earth and maintained to secure the city. The present land elevation along the riverfront is around 10.0 to 11.5 m. The area facing the Tonle Sap River is a little higher than Bassac Section.

(2) Inner Ring Dike

The Inner Ring Dike separates the City Core from suburbs. Along the dike, there are 7 drainage pumping stations constructed to discharge storm water inside to the outer area. The crest of the Inner Ring Dike is 10 to 12 m wide and its elevation varies between 9.5 m and 11.0 m. The southern part of the dike (St. 271) has relatively higher crest elevations ranging from 10.0 to 10.5 m, which lowers at the western part of the dike (St. 271) around the Salang area at 9.2 to 9.8 m and again rises in the Tuol Kork area (St. 598) at 11.0 m. The northern part's crest elevations are between 9.5 m and 10.7 m.

Roads

The present road network in the City Core had been developed during the French protectorate era, and is formed as a grid system centering the Grand Market. The roads in the City Core are basically numbered using uneven numbers for the roads running in the east-west direction and even numbers for those running in the north-south direction. The main north-south roads are Norodom Blvd., Monivong Blvd., Sivutha Blvd. and Issarak St. Major roads running in the east-west direction are Pochentong St., Kampuchea Krom St., Sivutha Blvd. and Issarak St. These roads are paved with asphalt and maintained in good condition. However, other minor roads are unpaved, or paved but damaged in places (although some are repaired by overlaying).

Other than the above-mentioned main roads in the City Core, the following three roads play an important role in the Study Area:

(a) BOT Road: located in the southern part of Pochentong Airport, passing east to west and connecting NR 303 with the junction of NR 3 and NR 4. The total length is 6.2 km. The road surface is paved with asphalt having a carriageway of 7.5 m.

(b) Khmuonb Road: branches off from NR 3 near the airport toward the north reaching Kop Srov Rd. with a length of 10.2 km. The surface is unpaved and undulated with a carriageway of 5 to 6 m.

(c) NR 4: starts from NR 3 near Pochentong Airport heading for Sihanoukville having a total length of 230 km, of which 1.8 km is included in the Study Area. The road surface is paved with asphalt, and the carriageway is about 5 m wide.

These roads in the Study Area are delineated in Figure D2-2.

Crossings

Most of roads and railways in the Study Area are constructed by filling earth and their formation levels are usually some meters higher than the surroundings. Drainage basins are thus defined. The site reconnaissance in this study identified such drainage culverts, flood gates and bridges crossing under roads and railways as below:

Major Crossings

Road/Railway/Area	Number of Crossings							
	Pipe Culvert			Box Culvert			Flood Gate	Bridge
	with gate	with gate slot	without gate/gate slot	with gate	with gate slot	without gate/gate slot		
(a) National Road No. 303	-	-	1	-	-	-	1	1
(b) Prey Sar Rd.	-	1	1	-	1	1	-	1
(c) National Road No. 3	-	-	8	-	-	-	-	1
(d) Kop Srov Rd.	-	-	6	3	-	-	-	-
(e) National Road No. 5	2	-	-	-	-	-	-	-
(f) BOT Rd.	1	-	2	-	-	-	-	-
(g) Railway	-	-	3	-	-	3	-	-
(h) Khmuonb Rd.	-	-	7	1	-	-	1	-
(i) Northeast Area	-	-	9	-	2	-	-	1
(j) Pochentong West Area	-	-	1	-	-	-	-	-
(k) Pochentong East Area	1	-	-	-	-	-	-	-
(l) Northwest Area	-	-	1	-	-	-	-	-

Note: For the detail refer to Table D2-2, and for the locations Figure D2-2.

2.2.2 Pumping Stations

There are 10 pumping stations in the Study Area. Out of these, 7 stations (Trabek, Tum Nup Toek, Salang, Toek Laak, Tuol Kork I, Tuol Kork II and Tuol Kork III) were constructed aiming at discharging storm water from the City Core to the outside of the Inner Ring Dike. The water pumped up from Tum Nup Toek, Salang and Toek Laak pumping stations is once discharged into Meanchey Channel, and then led to Tompun Pumping Station.

Tompun Pumping Station functions to drain water which is collected in Meanchey Channel to the outside of the Study Area. Olympic Stadium Pumping Station was utilized to pump up storm water in and around the stadium to Toul Sen Channel. Poungpeay Pumping Station discharges inundated water in Poungpeay East Basin to Boeng Poungpeay. Other than the above drainage pumping stations, an irrigation pumping station is located in the Study Area.

The locations and major features of the 10 pumping stations are shown in Figure D2-3 and Table D2-3, which can be categorized as follows:

(a) **Principal Pumping Stations**: consist of Trabek and Tompun pumping stations. Trabek Pumping Station has a function of discharging storm water in an area of around 40% of the City Core collected through sewer networks, Trabek Channel and Toul Sen Channel. Runoff led to Tompun Pumping Station are storm water pumped by Tum Nup Toek, Salang and Toek Laak pumping stations as well as that from its own catchment.

(b) **Intermediate Pumping Stations**: consist of Tum Nup Toek, Salang, Toek Laak and Olympic Stadium pumping stations. Tum Nup Toek, Salang and Toek Laak pumping stations have a role of intermediate pumping for Tompun Pumping Station. Olympic Stadium Pumping Station has a function of pumping excess water over the capacity of the existing culvert crossing under Sivutha Blvd. to Toul Sen Channel.

(c) **Local Pumping Stations**: have a function of discharging runoff on small areas adjacent to the respective stations. Tuol Kork I, II and II pumping stations is located in the Tuol Kork area. Poungpeay Pumping Station plays a role of discharging inundation water in the subject area to Boeng Poungpeay.

(d) **Irrigation Pumping Station**: An irrigation pumping station is located beside Khmuonb Road. The pumped water is supplied to the northwestern part of the Study Area through irrigation channels.

Principal Pumping Stations

(1) Trabek Pumping Station

Trabek Pumping Station covers a catchment area of 10.63 km^2 equivalent to 40% of the City Core area. The storm water through the sewer network, Trabek Channel and Toul Sen Channel are conveyed to the pumping station. The storm water are stored in Boeng Trabek before discharged by pumps over the Outer Ring Dike, where there is the function of retention as well as purification. It is reported that the original storage volume of the lake is about 520,000m^3. Many squatters have settled on lands around the lake and roads across the lake. These facts suggest that the lake surface has reduced and accordingly the storage function has decreased. Also, sedimentation aggravates the storage function.

The pumping station was constructed in 1960. Eight (8) units of pump equipment are housed in the station. All pumps are of the horizontal-shaft centrifugal motor-driven type. The capacity of each pump was originally 2,350 m^3/hr, but has decreased to 1,900 m^3/hr, totaling 15,200 m^3/hr (specific pump capacity: 0.40 $m^3/sec/km^2$ = 15,200 m^3/hr/10.63 km^2).

At present, the improvement/rehabilitation of the pumping station, together with Trabek and Toul Sen channels, is being undertaken by ADB, called "Phnom Penh Water Supply and Drainage Project, Part B: Drainage, ADB Loan No. 1468 (ADB Trabek Project)" , and will be completed by 2002.

(2) Tompun Pumping Station

Runoff led to Tompun Pumping Station are of the storm water from Tompun's own catchment (11.16 km^2) and water pumped by Tum Nup Toek, Salang and Toek Laak pumping stations (3 pumping station's catchment area is 6.31 km^2 in total). All runoff is collected through Meanchey Channel to the pumping station, the total catchment area being 17.47 km^2 at the station site.

The water collected through Meanchey Channel is once stored in Boeng Tompun before discharged by the pumping station to the outside of the Study Area. The

lake's figure is not precisely defined and its storage capacity is gradually decreasing due to land reclamation and sedimentation.

Firstly, a pumping station had been constructed in 1969-70 but it had collapsed. In 1972, the existing pumping station was built and several units of pump equipment (numbers unknown), having a capacity of 2,500 m^3/hr each of the vertical-shaft axial-flow motor-driven type, were installed. Among them, 4 units are still operated, however their capacity has decreased to 2,300 m^3/hr.

Then, 2 units of the vertical-shaft centrifugal motor-driven pump equipment, which were donated from the city of Paris, were installed in 1995. The equipment has a capacity of 720 m^3/hr each. Other than the above, 5 units of diesel-engine-driven pump equipment were additionally installed in 1998. The equipment has a capacity of 2,100 m^3/hr each and is of the vertical-shaft axial-flow type. As a result, Tompun Pumping Station, presently, has a capacity of 21,140 m^3/hr in total (the specific pumping capacity: 0.34 m^3/sec/km^2).

Moreover, the installation of 2 units of pump equipment, having a capacity of 2,100m^3/hr each, is planned. The contract of the supply and installation of the equipment has already been made.

Intermediate Pumping Stations

(1) Tum Nup Toek Pumping Station

Tum Nup Toek Pumping Station drains the runoff from an area of only 0.68 km^2 around Khmero-Russian Hospital. The runoff is collected through side ditches and pipe culverts, most of which are however choked and filled up with earth. The collected runoff is stored in a small pond adjacent to the pumping station and is pumped out to Meanchey Channel.

Formerly, Khmero Russian Hospital Pumping Station was constructed to discharge storm water in this area. However, this pumping station was abandoned. Instead, the existing Tum Nup Toek Pumping Station was newly constructed in 1995 by the grant aid of the city of Paris. Two (2) units of pump equipment, with a capacity of 900 m^3/hr each, are housed in the station. The equipment is secondhand and of the horizontal-shaft centrifugal motor-driven type.

(2) Salang Pumping Station

The runoff from Salang Basin (5.53 km^2) is collected through the sewer network and open channels. Before being pumped out, the collected water is stored in Boeng Salang and then discharged into Meanchey Channel. Boeng Salang is of a long and narrow shape and the width is quite reduced like a channel in some locations. It is reported that the pond surface has an area of 1.42 ha. The perimeter of the lake has been occupied by squatters.

This pumping station was constructed in 1970 and 3 units of the vertical-shaft axial-flow pumps are installed. Each pump is driven by a diesel engine and have a capacity of 2,100 m^3/hr. Two (2) units of the vertical-shaft centrifugal pump

equipment, which were donated from the city of Paris, were additionally installed. These pumps have a capacity of 720 m^3/hr each. The pumps are normally driven by motors, while in power failure case they are operated by diesel engines.

Since the water level in the discharge side (Meanchey Channel side) is normally lower than the lake water level, the storm water collected in Boeng Salang can be discharged by gravity. For this purpose, one culvert of Ø 600 mm pipe is located just beside the pumping station, however this pipe is clogged with sediment/debris. The other culvert is located 100m south of the station along St. 271. This culvert is of 2-lane Ø1,000 mm pipes with gates (now out of order) at the downstream side and with gate slots at the upstream side.

(3) Toek Laak Pumping Station

The pumping station was constructed and 2 units of pump were installed in 1962. The pumping capacity was formerly 150 m^3/hr each. At present, the pumps are replaced by 2 units of the vertical-shaft axial-flow diesel engine-driven pump having a capacity of 300 m^3/hr each.

The pumping station covers a small catchment area of 10 ha. The water is collected through side ditches. The existing side ditches are choked up with wastes and sludge due to the lack of maintenance, which results in inundation over the catchment. The inundation water flows into the adjacent Salang Basin.

(4) Olympic Stadium Pumping Station

The pumping station is located in the Olympic Stadium compound. The compound had been furnished with a sanitation complex consisting of a wastewater treatment plant, retention ponds and the pumping station. However, the whole complex is now under no operation.

The pumping station was constructed in 1965 and 3 units of pump equipment are installed. The original pumping capacity is 1,700 m^3/hr each of the vertical-shaft axial-flow motor-driven type. However, the pumps are at present out of order due to the lack of spare parts such as electric cables and transformers.

The runoff from the catchment is stored in small ponds and used to be pumped up to Toul Sen Channel. Presently, the water collected in the ponds is drained through the existing pipe culvert (Ø800 mm x 5 lanes) crossing under Sivutha Blvd. to Toul Sen Channel by gravity.

Local Pumping Stations

(1) Tuol Kork I Pumping Station

The pumping station was constructed in 1970 and a unit of the vertical-shaft axial-flow pump is installed. The capacity is originally 2,500 m^3/hr, but has decreased to 2,100 m^3/hr at present. Two Ø 600 mm pipes are installed just beside the station to allow gravity flow.

The runoff from the catchment is collected in a pond located just upstream of the pumping station (beside Phnom Penh University near the railway). The pond used to function as a retarding basin, however the entire surface of the pond is now covered with aquatic plants (water hyacinth) .

(2) Tuol Kork II Pumping Station

This pumping station was constructed in 1970, at the same time as Tuol Kork I, with a unit of the vertical-shaft axial-flow pump. The capacity has also decreased to 2,100 m^3/hr. One Ø 600 mm pipe is installed to secure gravity flow. It is planned to install 2 units of pumps to supplement the existing pump capacity. The contract therefor has already been made, however the date of supply and installation has not yet fixed.

(3) Tuol Kork III Pumping Station

This pumping station was also constructed at the same time as Tuol Kork I and II. However, the pump equipment installed was completely destroyed and no pump equipment is housed in the station. In the dry season, wastewater from the catchment is drained through Ø1,000 mm pipe installed through the Inner Ring Dike, while the runoff during storm flows into nearby Tuol Kork I Basin.

(4) Poungpeay Pumping Station

The pumping station is located in the northeastern part of the Study Area. The purpose of the pumping station is supposed to drain inundation water around the station to Boeng Poungpeay. However, it appears that the pumping station has been abandoned (although detailed information is unavailable).

Irrigation Pumping Stations

One irrigation pumping station exists in the Study Area and is located beside Khmuonb Road. There exist 2 pump houses in the station. Two (2) units of pumps are installed in the main house and a unit of pump in the sub-house. The pumped water is utilized for irrigating a paddy field area in the northwestern part of the Study Area. Data on the features such as pump type and capacity are not available.

2.2.3 Drainage Channels and Sewer Network

Drainage Channels

Major drainage open channels in the City Core are Trabek, Toul Sen and Salang channels. These channels are in many parts clogged with debris and sediments. As a result, the flow capacities are remarkably restricted. The channels have been, from time to time, cleaned up by DPWT using their own equipment and by subcontracting with local firms, however the problems have not greatly been solved. It is reported that the clogging ratio is 70 to 80 % of the original flow areas. In addition, there are several drainage open channel systems in the Tuol Kork, Tompun and Pochentong East areas. Major existing drainage channels are delineated in Figure D2-3.

(1) Trabek and Toul Sen Channels

Trabek Channel is located along St. 105, the secondary road in parallel with Monivong Blvd., and is about 1.7 km long with widths of 3 to 5 m. Some portions are occupied by squatters with the surface covered by slabs. The channel crosses small streets running in the east-west direction, where 2-lane Ø 1,500 mm pipe culverts are installed. The flow capacity of the channel is limited by such pipe culverts.

Toul Sen Channel consists of Toul Sen East and West. Toul Sen East Channel connects to Trabek Channel from the right and the length is about 520 m. The Toul Sen West Channel was formerly of an open channel over the whole stretch, however a major part of the open channel was replaced by 2 lanes of sewer pipes with a diameter of Ø1,000 mm each. At present, the middle part only remains as an open channel with a length of 470 m.

(2) Salang Channel

Salang Channel consists of two channels running in parallel, which are the west channel along St. 261 and the east channel along St. 257. Both channels connect into Boeng Salang. The west channel is about 300 m long and the east about 430 m. The widths of both channels are 2 to 3 m and they are choked up due to the lack of cleaning and maintenance works. Another open channel is between the two lakes of Boeng Salang, however the channel was recently replaced by pipes at some locations.

(3) Tuol Kork Channels

In the Toul Kork area, there were main drainage channels on both sides of St. 315 and 289. The channels are gradually buried and replaced with Ø1,000 mm concrete pipes and several parts only remain as open channels with widths of 2 to 3 m.

(4) Meanchey Channel

Outside the City Core, Meanchey Channel has a great role to drain storm water in the Tompun catchment. The channel is aligned along the southwest perimeter of the Inner Ring Dike, collecting the outflow from Salang, Toek Laak and Tum Nup Toek pumping stations and Tompun Basin, then finally connects to Boeng Tompun. In the upstream stretch of the catchment (just south of NR 3), the channel was replaced with pipes. The channel width gradually increases to the downstream direction, ranging from about 2 to 30 m.

(5) Pochentong East Area

In the eastern part of Pochentong Airport, which is under developing as factory lots, residential and school zones, etc., open ditches are constructed on both sides of inner roads running lengthwise and crosswise. At the intersections of the inner roads, several pipe culverts, having diameters of 600 to 800 mm, are provided.

A drainage channel has just been constructed to drain storm water from Pochentong Airport. The channel is of a trapezoidal section, 2.5 m wide and 2.5 m deep. For

several road crossings, Ø600 mm and Ø800 mm pipes are installed. No revetment or protection works are applied to the channel slopes at present due to budgetary constraint.

Other than such drainage open channels, there are two irrigation open channel in the Study Area, the Khmuonb and Samraong irrigation channel. The Khmuonb irrigation channel extends to west to convey the pumped water by Khmuonb Pumping Station. Both irrigation channels form a grid system.

Sewer Network

Sewers had been constructed until the end of 1960s with city development. During this period, numerous channels and ditches were filled up and converted to sewer pipes. This formed mostly the existing sewer network of the combined system over the City Core, except the Tuol Kork area and Bassac riverfront, having a total length of nearly 200 km. The sewer network is now managed by DPWT, while the need of increasing the drainage capacity to cope with the latest rapid urbanization has not been fulfilled.

Data exactly showing the present sewer pipe's features, such as the invert levels, longitudinal gradients, manhole locations, etc., are not well documented or registered. The sewers are mainly circle-shaped concrete pipes ranging 300 to 1,500 mm in diameter and the longitudinal gradients range from 1/500 to 1/2,000. The pipes are buried, with coverings of 0.5 to 3 m, on one side in narrow to medium streets and on both sides in wide streets. The present sewerage network system in the City Core identified by diameter is tabulated below (see Figure D2-4):

Existing Sewers

Diameter (mm)	Length (m)
Ø1,500	6,765
Ø1,000	27,585
Ø 800	17,595
Ø 600	130,493
Ø 500	1,298
Ø 300	10,838
Total	194,573

A greater part of sewer pipes are choked with sediment and solid waste generated mainly by inhabitants neighboring. The choke rate is reported as 50 to 90 % of their original flow capacities and especially sewers in the Daun Penh North area (around Wat Phnom) are totally choked up. DPWT is making effort to clean up such pipes, however it is not effectively conducted due to lack of equipment and budget.

Along the riverfront of the Sap and Bassac rivers, sewer outfalls are found at 17 locations. Some are completely broken and the other are clogged with sediment and wastes. It is planned to install pump facility at 3 outfalls. A pump pit has been constructed at each location, however pump equipment itself not yet being installed.

2.2.4 Bank Protection along Riverfront

The Riverfront refers to the following 5 sections facing the Tonle Sap and Bassac rivers, some parts of which sections are provided with bank protection works (see Figure D3-1).

Sap Upstream Section

This section is between Chruoy Changvar Bridge and the junction of NR-5 and Kop Srov Road. The riverfront is shared by factories and housing with quite large areas of open spaces. The river banks, mostly without any protection works, are well maintained and seems to be stable.

Sap Downstream North Section

This section is defined as the riverside from St. 108 north to Chruoy Changvar Bridge. There are many port facilities such as loading/unloading and floating jetties. Most important among these are Phnom Penh Port and Municipal Port. An intake tower is situated to abstract raw water for the Phum Prek waterworks. No bank slope protection works are encountered along the stretch, however the river bank has not collapsed or been damaged. Some riversides are occupied by squatters.

Sap Downstream Middle Section

The section is located between the front of Royal Palace and St. 108, and the whole parts are developed as riverside promenade. Slope protection is made with concrete blocks or stone masonry. The slope surfaces are damaged and even collapse at some locations. Such damage and collapse may be caused by filling with unsuitable material behind the slope (filter material such as sand or gravel is not found), and probably by the lack of periodical proper maintenance. It may be required to repair or rebuild the revetment works.

Sap Downstream South Section

This section is defined as the Sap riverside between the fronts of Sofitel Hotel and Royal Palace. Along the riverside, hotels, the city conference hall, etc. are built with quite nice riverside promenade. As for the bank protection work, concrete facing and wet masonry are used as revetments. The works are well maintained and kept in good condition.

Bassac Section

In this section between Monivong Bridge and Hun Sen Park, river bank protection works have not been done, except for the loading facility of a flower mill factory which is located just upstream of Monivong Bridge. The facility is made of concrete facing revetment wall. On the middle part of the section, a new intake tower for the Chamcar Morn waterworks is under construction. The northern part of the section up to Hun Sen Park has recently been reclaimed, where many squatters occupy its riverside. (The opposite river bank is also occupied by many squatters.) The river flow direction has been changed recently maybe resulting from the reclamation.

2.2.5 Operation and Maintenance of Facilities

Flood Protection Facilities

Flood protection facilities include dikes and revetments. No operation and maintenance manuals for those flood protection facilities have been prepared. Organization in charge of the maintenance of the dike is Road and Bridge Division of DPWT.

Periodical maintenance work has not been conducted though rainfall and seepage have heavily damaged dikes, especially Kop Srov dike. Along the Tonle Sap River, soil carried and deposited by the river water in front of revetments has been removed from time to time. However, it is said that this work is to borrow soil for land reclamation.

Sewer System

Drainage and Sewage Division of DPWT is in charge of operation and maintenance of sewer system in the Municipality of Phnom Penh. Organizational structure, staffing, budget, etc. are discussed in the previous chapter.

Operation and maintenance manual for the sewer system does not exist. Periodical dredging is conducted in the rainy season at seven points of canals of Salang, Toul Sen West, Toul Sen East and Trabek. Excavators and trucks of DPWT are used for the work.

Cleaning of sewer pipe is also conducted. It is not periodical and according to the availability of budget for purchasing fuel.

Weekly Report and Monthly Report are submitted from the Director of DSD to the DPWT and MPP. They include the work quantity for concrete works, cleaning of pipe by manpower, cleaning of pipes by vacuum truck, dredging, and maintenance work for pumping stations.

Drainage Pumping Stations

Drainage and Sewage Division of DPWT is in charge of operation and maintenance of drainage pumping stations in the Municipality of Phnom Penh. Organizational structure, staffing, budget, etc. are discussed in the previous chapter.

Major repair of the electromechanical equipment is conducted mainly in the dry season. Daily operation record includes: number of installed pumps, water level at pumping stations, operation start time and end time, number of pumps working, number of pumps broken, and electricity stop hours in each day. A form sheet for daily record of a week is filed.

Constraints for hard operation and maintenance work include: lack of fund for fuel and material, high average age of DSD personnel and operation workers.

Equipment owned by DPWT

DPWT has been making effort, using equipment for cleaning and maintenance, to secure the existing sewer networks and drainage open channels. These cleaning and maintenance

equipment owned by DPWT is listed in Table D2-4. (Due to the lack of spare parts, however, the equipment are not kept so well.)

2.3 Design Standards and Basic Data for Construction

This Section discusses on the design standards (criteria) and basic data for the construction (regarding construction equipment, construction materials and labor force).

Design Standards

No design standards (criteria) have not been furnished for the drainage and sewerage facilities, or bridge/road facilities, although MPWT intends to have an opportunity to establish the design standards for roads and bridges.

Basic Data for Construction

(1) Construction Equipment

Major construction works for the present works may comprise excavation/dredging of channels, lakes and foundation for structures, embankments, piling/concrete placing for the foundation, concrete/steel works for pumping stations, sluiceways, bridges, culverts, etc., and sewer construction. These do not require high-technical construction and the works will be achieved by applying ordinary mechanized methods.

All heavy equipment required for the works will be provided by contractors. Although the availability of reliable equipment in Phnom Penh is relatively low, all can be procured from lease companies in neighboring countries such as Thailand, Malaysia and Singapore.

(2) Construction Materials and Labor Force

Major construction materials for the works are assumed to be earth, sand, gravel, stone, lumber, cement, reinforcing bars, precast RC piles, precast RC sewer pipes, structural steel, steel pipes, steel sheet piles, etc. These are available in Phnom Penh or surrounding areas, excepting cement, reinforcing bars, structural steel and steel pipes and steel sheet piles, which are however obtainable by importing them from neighboring countries.

Moreover, skilled and common laborers for the construction works can be recruited from Phnom Penh and its surrounding areas.

D3. Master Plan Study

3.1 Premises for Study

3.1.1 Target Year

In accordance with the Scope of Work, the target year for the Master Plan is defined as year 2010. Noteworthy here is that the year 2010 is only 12 years ahead of the present, and the Master Plan must therefore be formulated in strictly realistic considerations especially on:

- Land use conditions at present and in year 2010;
- Present status and expected growth of the socioeconomic frame in the Study Area;
- Possible investments (national/local budgets and foreign aid amounts) in coming 12 years for the drainage improvement and flood control sector;
- Availability of land acquisition, house evacuation and preparation of adequate relocation sites for the actual implementation; and so on.

This understanding is a baseline for the formulation of the Master Plan.

Land Use Conditions in 1998 and 2010

The land use conditions in the Study Area at present (year 1998) and in future (year 2010) have been delineated in Sector A: Land Use and City Planning. The results are summarized in the following table:

Land Use Conditions in 1998 and 2010

Category	In 1998		In 2010		Variation
	Area (km^2)	Share (%)	Area (km^2)	Share (%)	(%)
A. Dense Urban Center	6.03	3.1	6.63	3.4	+ 10
B. Dense Residential Area	11.24	5.7	13.49	6.9	+ 20
C. Loose Residential Area	30.12	15.4	55.72	28.5	+ 85
D. Large-scale Developments	(10.80)	(5.6)	(20.17)	(10.3)	(+ 87)
D-1. Dense Activities	2.87	1.5	4.31	2.2	+ 50
D-2. Loose Activities	7.93	4.1	15.86	8.1	+ 100
E. Agricultural Land	119.19	60.9	81.30	41.5	- 32
F. Fishponds	0.70	0.4	0.77	0.4	+ 10
G. Green Space	2.09	1.1	2.09	1.1	0
H. Lakes and Ponds	15.54	7.9	15.54	7.9	0
Total	195.71	100.1	195.71	100.0	-

Note: For the detail, refer to Sector A: Land Use and City Planning.

Socioeconomic Frames in 1998 and 2010

In addition, the socioeconomic frames in years 1998 and 2010 within the Study Area are estimated in Sector F: Socioeconomy as follows:

Socioeconomic Frames in 1998 and 2010

Item		In 1998			In 2010			Growth Rate (% per annum)
		City Core	Suburbs	Total/ Average	City Core	Suburbs	Total/ Average	
Population (1,000 person)		545	272	817	795	397	1,192	3.2
GRDP	Per Capita (US $)	-	-	335 *	-	-	570	3.9
	Gross (US$ mill)	-	-	257 **	-	-	680	7.2

* Derived from the GRDP (US$ 263 million) and population (817,000/1.032^2) in year 1996.
** Record in year 1996.

3.1.2 Protection Levels

Usually, determination of the protection level (design scale of facilities) depends on preceding practices in the similar projects. Table D3-1 shows such protection levels applied to the flood protection (flood control) and drainage improvement projects in capitals of Southeast Asian countries. In due consideration of these practices, we decided the protection level for each group of flood protection facilities, major drainage facilities (whose catchments are principally more than 1 km^2), and minor drainage facilities (whose catchments less than 1 km^2) as follows:

(a) Flood protection facilities such as dikes, river walls, road heightening, etc. : 30-year return period of water level (EL. 10 m) a little higher than the maximum water level since 1960 at Chaktomuk Station (EL. 9.96 m in 1961)

(b) Major drainage facilities such as pumping stations, floodgates/sluiceways, regulation ponds, drainage mains (catchment area > approx. 1 km^2) : 5-year return period of rainfall

(c) Minor drainage facilities, meaning sewer systems (catchment area < approx. 1 km^2) : 2-year return period of rainfall

3.2 Planning and Design Conditions

3.2.1 Planning Conditions

Prior to the study for the Master Plan, the planning conditions therefor have been established as stipulated below:

(1) To save the initial investments as well as operation and maintenance cost for structures/facilities, the non-physical measures will be incorporated as a major factor of the Master Plan. Among the non-physical measures, most essential are (a) flood defense activity for flood protection; and (b) land use control, comprising zoning

control and development/building control, for assisting drainage improvement. (This is discussed in detail in Subsection 3.6.2.)

(2) Land acquisition and house evacuation must cause social conflicts in this area, so that the Master Plan should refrain from these as much as possible. For instance, when the existing sewer systems in the City Core are short in flow capacity, the installation of box culverts underneath main streets will be examined, in place of open channel construction in the house-congested area.

(3) Taking into account deteriorated environmental condition in the city of Phnom Penh, alternatives in this study will include not only those for flood protection and drainage improvement but for the environmental enhancement, like riverfront conservation, lake conservation, flush water introduction, "green" channel plan, etc. (This is examined in Section 3.5.)

(4) Most area of the City Core has been furnished with sewer networks of the combined system to collect both storm water and wastewater. The present Master Plan includes improvement of drainage situation in the Study Area, but excludes sewerage problem from its scope of work. In the Master Plan, the existing sewer networks will therefore be graded up to safely drain the storm water over the area; however it basically doesn't matter whether the improved networks would receive wastewater as they do, or a new separate system would be provided to take off the wastewater. (This is because the size of a sewer pipe is determined by the design discharge of storm water, not by that of wastewater.) As a matter of course, examination on the construction of sewage treatment plants or so is also out of scope. For such sewerage issues, another study should be formulated in the near future.

However, the Master Plan should incorporate a certain prediction on the possibility of the construction of sewage treatment plants and the like by its target year of 2010. The result affects the environment, especially water quality, along open drainage mains, in regulation ponds and at pumping stations all located downstream of the sewer networks. In this context, it is assumed in this Master Plan that:

(a) Sewage treatment plants and the like will not be provided by year 2010 since they incur huge costs for the construction and operation/maintenance, and hence the existing combined sewer system will remain in the City Core, and even develop outwards on newly urbanized areas; and

(b) As a result, the downstream facilities as listed above shall be planned and designed to cope not merely with storm water but with wastewater discharging from the combined sewer system.

(5) As for the future sewer network extension, on the other hand, the following two assumptions are applied to the Master Plan:

(a) Sewer networks be furnished publicly over A and B zones, with more than about 2 km^2 of catchment, on the 2010 land use condition. On practice, such areas are limited in the City Core.

(b) D zone in the 2010 land use "Large Scale Developments" may have similar sewer facilities, but they will be provided by the private sector under owner's responsibility and expense. Such plans and costs are ruled out from the Master Plan.

(6) There are nine pumping stations (one is not working) built mostly by the Inner Ring Dike for local drainage. However, an integrated pumping station are generally constructed at the final discharge point of the total catchment, not merely to save construction cost but to secure easy maintenance and low operation cost. This philosophy of planning in terms of the location of pumping stations is valid also for the present Master Plan, hence:

(a) Existing intermediate pumping stations, such as Tum Nup Toek, Salang, Toek Laak, Olympic and Toul Kork I, II & III provided mostly along the Inner Dike, are ignored from the Master Plan and kept as they are just in case. The drainage for the relevant basin of each station above relies on gravity flow through a sluiceway to be installed under the Inner Dike. This has been proved to be hydraulically possible by the initial investigation of the topography and water stage balances inside and outside the dike during past floods.

(b) On the contrary, the Master Plan will examine enhancement or new construction of the Trabek, Tompun and Svay Pak pumping stations to locate at the downstream ends of respective catchments.

3.2.2 Design Conditions

The design conditions enumerated in Table D3-2 will be applied to the preliminary design of facilities proposed in the Master Plan. The freeboards of dikes shown in the table are derived from an estimation presented in Table D3-3 which shows the basis of the determination of the high water level and freeboard of each section of dikes based on the water level records and considering the wave setup expected in the section of dike.

3.2.3 Conditions for Cost Estimates

The project cost of each component, to be defined latter in the wake of the Master Plan formulation, is composed of the following cost items:

(a)	Construction cost	: Including 20 % of miscellaneous cost
(b)	Compensation cost	: Cost for land acquisition, house evacuation and other compensation
(c)	Administration cost	: 3 % of the construction cost
(d)	Engineering services cost	: 15 % of the construction cost
(e)	Physical contingency	: 10 % of the construction cost
(f)	Price contingency	: Ignored in the Master Plan study

Unit prices of major construction items, as of July 1, 1998, are presented in Table D3-4 which was filled up based on the data collected through the Study period.

3.3 Alternative Studies on Flood Protection

3.3.1 Alternatives Suggested

The most essential issues on the flood protection in the Study Area are:

- The protection line, meaning on which line the Study Area should be protected from floods brought about by the Mekong river system; and
- Basic measures for the flood protection.

Primary discussions on the above issues are made in Table D3-5, and the alternatives on the protection line are depicted in Figure D3-1. These are looked into stretch by stretch hereinafter.

Riverfront

The Riverfront refers to the sections facing on the Tonle Sap and Tonle Bassac rivers, comprising the Sap Upstream (approx. 11.0 km), Sap Downstream (approx. 3.8 km) and Bassac (approx. 3.5 km) sections. Sap Downstream Section is further divided into the North (Chruoy Changvar Bridge to Street 108, approx. 1.7 km), Middle (Street 108 to Street 184, approx. 1.0 km) and South (Street 108 to Hotel Sofitel, approx. 1.1 km) sections.

(1) Sap Upstream and Bassac Sections

The Sap Upstream and Bassac sections are similar in nature. Trunk roads pass near both riverbanks: NR-5 in Sap Upstream Section and Samdach/Norodom blvds. in Bassac Section. The road surfaces are approximately 10 to 11 m in elevation, not lower than the high water level of the rivers (EL. 10 m) except several portions. However, between the roads and rivers are narrow strips with areas of 1.27 km^2 and 1.58 km^2 in the Sap Upstream and Bassac sections, respectively. The land of the strips is occupied by large-scale developments (factories, hotels, schools, embassies, etc.), housings and open spaces. The large-scale developments are in many cases established on the ground higher than the high water level, whilst most of the housings are built on lower elevations submergible during high water periods of floods. These conditions may suggest the following two alternatives on the flood protection along the Tonle Sap and Bassac sections:

- Alternative 1: Construction of dikes on the riverbank shoulders in necessary stretches in order to protect not solely inland areas behind the roads but housings in the narrow strips between the roads and rivers from being flooded.
- Alternative 2: Promotion of flood defense activity in lower portions of the trunk roads to protect the inland areas behind the roads only, and thus the riverine strips will be left as they are.

(2) Sap Downstream Section

The bank shoulder along Sap Downstream Section is as high as 10.5 m in elevation at lowest, with clearances of more than 0.5 m above the high water level, so that there is no possibility of spilling of floodwater due to the Mekong river system. In the Middle Section, however, the existing revetments have collapsed in places

(whereas revetments or natural banks in the North and South sections are yet sound). This collapse not only jeopardizes the bank safety itself, but also damages aesthetics of the riverfront used as a park zone at present, further which is anticipated to be bettered in future. To solve the problem, the existing revetments should be reconstructed with a proper structure to be selected among the following two types of alternatives:

- Alternative 1: Stone pitching type of revetment
- Alternative 2: Concrete facing type of revetment

The alternatives suggested for the above two sections of the Riverfront are examined in the succeeding Subsections 3.3.2 and 3.3.3, respectively.

Existing Dike Sections

Along the perimeter of the Study Area, there exist two dike sections with considerably large heights, say more than 3 m: i. e. Kop Srov Dike and Tompun Dike (refer to Figure D3-1). The two dikes function as a part of the protection line of the Study Area against floods caused by the Mekong river system. In addition, the dike crests are increasingly used for traffic, especially transportation of heavy equipment and materials for industrial zones. (Such has been banned to cross the center of Phnom Penh City.) The features and dimensions of the dikes are as tabulated below:

Features of Kop Srov and Tompun Dikes

Description	Kop Srov Dike	Tompun Dike
(1) Length	9.0 km	4.4 km
(2) Existing Conditions		
(a) Crest Elevation	EL. 10.1 to 10.7 m	EL. 10.0 to 10.4 m
(b) Height above Land *	4 m	5 m
(c) Crest Width *	10 m	20 m
(d) Formation Width *	26 m	40 m
(e) Side Slopes	Approx. 1:2	Approx. 1:2
(f) Structural Conditions	- No pavement on the crest, undulated, and marshy in the rainy season. - Many holes found on the dike crest and even on the slopes that should be the traces of piping in the dike body. - Slopes eroded in places.	- No pavement on the crest, undulated, and marshy in the rainy season. - No holes found on the dike crest, however some piping reported in past flood times. - Slopes eroded in several places.
(g) Social Conditions	- Squatters live on both slopes in the east end portion.	- Squatters occupy on both slopes along the entire stretch.
(3) Design Conditions		
(a) High Water Level **	EL. 10.4 m	EL. 9.0 m
(b) Freeboard **	0.8 m	1.1 m
(c) Hydraulic Gradient of Seepage Water ***	1/8 (1/5)	1/8 (1/8)

* At a higher portion of the dike.
** Refer to Table D3-3.
*** Determined in consideration of practices in major foreign rivers, and the value in the bracket shows the existing condition.

(1) Kop Srov Dike

As can be seen in the table above, Kop Srov Dike is short in height by 1.1 m at maximum and is judged to be quite week against seepage phenomenon. Hence, heightening and widening the existing dike should be a component of the Master Plan. In view of the present conditions, the following two structural alternatives are suggested:

- Alternative 1: Triple Section (A dike on the riverside not only to prevent overtopping but also to reduce seepage with non-permeable material, and a berm on the land side to avoid piping with permeable material)
- Alternative 2: Single Section (Raising of the existing dike road up to the design dike height)

(2) Tompun Dike

With respect to Tompun Dike, on the other hand, the height is sufficient to confine the high water level (EL. 9.0 m). However, the dike body is supposed to be weak against seepage judging from the fact that piping was reported in past flood events (although the formation width of the dike is relatively large even compared to other practices). Some countermeasure should be taken to cope with such piping. Most effective, economical and practical may be the provision of a land side berm.

Alternative studies and detailed discussions on the reinforcement of the Kop Srov and Tompun dikes are made in Subsection 3.3.4.

On the other hand, in consideration of the importance of these dikes, the non-physical measure, especially flood defense activity, must carefully be prepared through the high water period of the Mekong river system even after the reinforcement of the dikes has been completed. Should there be some unordinary phenomena such as seepage through dike body, erosion on the dike slopes and deformation of the dike surface, immediate countermeasures shall be taken.

South Section

The land use condition in the South Area is mainly agriculture use with few developments and less urbanization at present and even in future. Moreover, the floods of the Prek Thnot River freely come into this area via existing three openings. This condition is rather beneficial for agricultural activity than hazardous to the assets in the area. In this case, the following two alternatives can be considered for the protection line along the South Area (see Figure D3-1):

- Alternative 1: On Prey Sar Road with the heightening of the road and the provision of a pumping station, a regulation pond, 3 floodgates and drainage mains to protect the South Area itself from flooding from the Prek Thnot River.
- Alternative 2: On the planned Tompun Extension Road in future to protect areas except S2 of the South Area (for the time being, on the BOT Road, with surface elevations of higher than 9.5 m, to protect areas except the whole South Area).

The alternative study results are presented in Subsection 3.3.5.

West Section

The West Section, totaling 9.2 km, corresponds to the southern portion of Kop Srov Road and Prey Pring Dike (a small dike connecting NR-3 to NR-4 on the border of the Study Area). Both are around 0.5 m high on the adjacent land with few crossing structures. The west of this section (outside the Study Area) is slightly hilly, and less water comes down to the section. Refer to Figure D3-1. On this condition, flood protection measures along the section will not be necessary.

3.3.2 Protection Line along Sap Upstream and Bassac Sections

Two alternatives suggested in Subsection 3.3.1 on the protection line along both Sap Upstream and Bassac sections are looked into herein: i. e. Alternative 1: Construction of dikes on the riverbank shoulders; and Alternative 2: Promotion of flood defense activity in lower portions of the trunk roads.

Shown in Table D3-6 is the costs and benefits when Alternative 1 is applied to the Sap Upstream and Bassac sections. The ratios of required cost per protected household, in the bottom row of the table, are as high as US$ 11,100/household and US$ 4,000/household for the Sap Upstream and Bassac sections, respectively, compared to US$ 900/household in Tompun Watershed. This indicates that the construction of dikes along the shoulders of the riverbanks of Sap and Bassac, only to protect shanties (large-scale factories/buildings are mostly located above the high water level), can be a quite costly and ineffective exercise.

In conclusion, most economical and reasonable measures for the flood protection in the sections is to promote flood defense activity along NR-5 for the Sap Upstream Section and along Samdach Sothearos/Norodom blvds. for the Bassac Section to protect the inland areas behind the roads. In addition, the flood defense activity is only limited to several portions and short time, because the road elevations are, basically, slightly higher than the high water level (EL. 10 m) of the rivers.

The riverside strips are thus left intact in front of the roads, so that the following basins are excluded from the succeeding drainage improvement study:

- C6: Bassac Riverside Basin (1.58 km^2); and
- E4: Sap Riverside Basin (1.27 km^2).

3.3.3 Riverfront Protection in Sap Downstream Middle Section

This work refers to the reconstruction of the existing revetments from Street 108 to Street 184 with a length of approximately 1.0 km to stabilize the riverbank and better the riverfront environment. The high water level along the section is EL. 10.0 m, and adding a freeboard of 0.9 m to cope with wave setup, the design bank height becomes 10.9 m (refer to Table D3-3). This elevation is generally correspondent to the present bank heights although in some places the design bank shoulder of the new revetment may be a little higher than the adjoining land formation (say, 20 to 30 cm at highest).

To protect the riverbank securely, the revetment should comprise slope protection and foot protection. Stone filling is suitable and economical for the foot protection, while as for the slope protection the following two structural alternatives are suggested: Alternative 1: Stone Pitching ; and Alternative 2: Concrete Facing. For the structure, see Figure D3-2. The construction costs of both alternatives are estimated in Table D3-7. As a result, taking into account the following points, it is recommended that Alternative 1 be applied to the slope protection for this section:

- The cost of Alternative 1 is a little lower than that of Alternative 2;
- Alternative 1 is, environmentally, superior to Alternative 2; and
- Maintenance of stone pitching is in wide meaning easier than the concrete facing.

The work shall incorporate reconstruction of three existing outlets all provided with pump facilities in 1998. Moreover, noted herewith is the prohibition of sand mining now carried out along the shoreline of the section that must jeopardize the stability of revetments existing and even newly reconstructed.

3.3.4 Reinforcement of Kop Srov and Tompun Dikes

The Master Plan, as determined in Subsection 3.3.1, includes the reinforcement of Kop Srov Dike located in the northern part of the Study Area with a length of 9.0 km and Tompun Dike in the southern part of 4.4 km. The height of the existing Kop Srov Dike is insufficient, by 1.1 m at maximum, safely to confine the design high water level (EL. 10.4 m) plus a wave setup (0.8 m). Moreover, the dike itself is judged to be structurally week to prevent piping through the dike body or its foundation. The Tompun Dike, on the other hand, has crest elevations enough to be free from overtopping, while the dike body, likewise in Kop Srov Dike, is in problem. The design requirements for both dikes are as follows:

Design Requirements of Kop Srov and Tompun Dikes

Item	Kop Srov Dike	Tompun Dike
Design High Water Level	EL. 10.4 m	EL. 9.0 m
Design Freeboard	0.8 m	1.1 m
Design Dike Height	EL. 11.2 m	EL. 10.1 m
Design Hydraulic Gradient of Seepage Water through Dike Body	1/8	

(1) Kop Srov Dike

Two alternatives are worked out with reference to the reinforcement of Kop Srov Dike: i. e. Alternative 1: Triple Section, and Alternative 2: Single Section. The detailed structure and the construction costs are presented in Figure D3-3 and Table D3-8. Alternative 2 is the idea of simply raising the existing dike, by 1.1 m at largest, across the full width, while Alternative 1 aims at cost saving and easy construction in the following manner:

(a) Constructing a dike, with a minimal crest width of 3 m and an elevation of 11.2 m, on the riverside of the existing dike to prevent overtopping and to reduce seepage with non-permeable material; and

(b) Providing a berm, with a width of 5.0 m and an elevation of 9.0 m, on the land side to avoid piping phenomenon at the toe of the dike by using permeable material.

The cost comparison made in Table D3-8 clarifies that Alternative 1 can achieve an about 10 % cost reduction compared to Alternative 2. Taking into account the relative easiness of construction as well, Alternative 1 is selected as the optimal reinforcement method for Kop Srov Dike.

(2) Tompun Dike

As for Tompun Dike, the application of the land side berm method is recommended, similar to Kop Srov Dike, in view of economy and precedents in other countries. This method cannot stop seepage through the dike body or its foundation itself, but effective to avoid piping at the land side toe that might result in crucial failure of the dike. Completely to remove any seepage, concrete covering, sheet pile driving, etc. on the riverside of the dike are conceived, but these could be costly and unfeasible under the present condition of the Cambodian economy.

3.3.5 Protection of South Area

With respect to the flood protection line, in other words whether the South Area will be protected or not, two alternatives are suggested in Subsection 3.3.1: i. e. Alternative 1: On Prey Sar Road (to protect the whole South Area); and Alternative 2: On the planned Tompun Extension Road in future and on BOT Road for the time being (principally not to protect the South Area).

Naturally, Alternative 1 entails heightening of Prey Sar Road, and provision of a pumping station at the Prey Sar Bridge site, a regulation pond near the pumping station and three floodgates across the existing three outlets. This construction costs about US$ 24.3 million as estimated in Table D3-9. The economic efficiency of this flood protection work can be assessed using the cost per number of beneficiary. It is as high as around US$ 4,900/household as shown in the table. Comparing with US$ 900/household in Tompun Watershed for instance, this project is very costly and can be said unfeasible. The selection of Alternative 2 should be reasonable.

As a result, concerning the flood protection and drainage improvement in the South Area, it is concluded that:

(a) For the time being, the greater portion of the Study Area, except the South Area, is protected by the existing BOT Road, whose surface elevations are above 9.5 m so that it can prevent overtopping of floods due to the Prek Thnot River;

(b) In the future, the Study Area, inclusive of S1: BOT Road South Basin while still exclusive of S2: Prey Sar Basin both in the South Area, will be ensured form the floods by the planned Tompun Extension Road; and

(c) The Master Plan, in principle, does not apply physical measures to the South Area as mentioned above, but instead considers non-physical measures such as land use control and agricultural land conservation over the area.

3.4 Alternative Studies on Drainage Improvement

3.4.1 Alternatives Suggested

The alternative studies on drainage improvement, in turn, are made herein. The study principally covers the whole Study Area, however excepting the following three areas (43.45 km^2 in total) that are located outside the flood protection line as discussed in Section 3.3 above:

- C6: Bassac Riverside Basin in the City Core (1.58 km^2);
- E4: Sap Riverside Basin in the Northeast Area (1.27 km^2); and
- South Area comprising S1 and S2 (40.60 km^2).

The remaining area of 152.26 km^2 (Study Area, 195.71 km^2, minus the above excepted areas, 43.45 km^2) is hence subject to the drainage improvement study.

Study Items Identified

The most important matters on the drainage improvement study are:

- Drainage direction of each basin; and
- Basic measures for drainage in each basin.

Based on the above understanding, drainage direction and basic measures in each basin are examined as presented in Table D3-10 (refer to Figure D3-4). Most of the directions are naturally determined by the topography, land use and layout of the existing drainage facilities. As for the basic measures, on the other hand, several points still remain under further considerations. Moreover, Table D3-10 shows that E3 of the Northeast Area (1.25 km^2) and M4 in the Middle Area (0.70 km^2) can be omitted from the drainage improvement study for the reasons mentioned in the table. The study can thus focus on the area of 150.31 km^2 (152.26 km^2 above minus 1.25 km^2 and 0.70 km^2).

Summarizing the preliminary results in Table D3-10, main points in the drainage improvement study may be:

(a) Drainage direction of Pochentong East Basin;

(b) Economic optimization between the pump capacity and regulation pond volume at each site of Tompun, Trabek, Pochentong East pumping stations, etc.;

(c) Detailed comparison on the route, type, structure, etc. of drainage mains and other major facilities; and

(d) Possibility of the construction of Svay Pak Pumping Station.

Most fundamental among the above is Item (a) that dominates the boundaries of drainage areas. This will firstly be studied hereunder.

Drainage Direction of Pochentong East Basin

As for the drainage direction of Pochentong East Basin, which is expected to be developed as a commercial, industrial, educational and housing area, the following three alternatives have been suggested:

- Alternative 1: To the south over BOT Road;
- Alternative 2: To Tompun Basin through Meanchey Channel; and
- Alternative 3: To the north up to Boeng Poungpeay.

Mainly from the standpoint of difficulty of land acquisition for construction of a drainage channel connecting the basin to the outlet, Alternative 1, i.e. to the south over BOT Road, is judged to be advantageous over the others. Detailed discussions follow:

(a) Alternative 3 might require no pumping station at the outlet, however it entails an about 2.5 km drainage channel, with a width of 5 m or more, to connect the basin to Boeng Poungpeay through a house-congested area, even across NR-3 in between. Land acquisition for such construction could result in a serious social problem. This alternative is thus unfeasible.

(b) Alternative 2 could necessitate increase of pump capacity at Tompun Pumping Station and enlargement of the existing Meanchey Channel by a few meters over a stretch of about 4 km, which would also be unwelcome by the residents nearby.

(c) Compared to the above two, Alternative 1 has less problem, requiring no additional land for channel construction although a pumping station should be provided independently at the outlet.

Drainage Areas Subject to Study

As a result, the boundaries of drainage areas can be delineated dividing the objective area (150.31 km^2) into the following five:

- Tompun Watershed : 17.47 km^2
- Trabek Basin Downstream Reaches : 10.83 km^2
- City Core North Area : 6.57 km^2
- Pochentong East Basin : 15.35 km^2
- Northeast and Northwest Areas : 100.09 km^2

The studies on drainage improvement are conducted hereinafter area by area, in other word independently for the five areas, focussing mainly on Items (b) and (c) as well as Item (d) listed in Clause "Study Items Identified" in this Section.

3.4.2 Tompun Watershed

The drainage improvement in Tompun Watershed will comprise construction of a pumping station and regulation pond, improvement of Meanchey Channel (named Meanchey Drainage Main hereinafter), provision of underground drainage mains, and rehabilitation of existing sewers. The total catchment area is 17.47 km^2 consisting of:

- C8 : Salang Basin : 5.53 km^2
- C9 : Tum Nup Toek Basin : 0.68 km^2
- C10 : Toek Laak Basin : 0.10 km^2
- M1 : Tompun Basin : 11.16 km^2

Pumping Station and Regulation Pond

(1) Construction of New Pumping Station

There is an existing pumping station at the downmost of the watershed on the immediate land side of Tompun Dike, called Tompun Pumping Station built in 1972. Its present capacity has been rated at 5.9 m^3/sec on official base. In view of pump engineering, however, the pump capacity can be assessed nearly nil considering large volume of water leakage from the outlet pipes and deterioration of efficiency of pumps and motors/engines (maybe fabricated in 1950's and 1960's mostly). Moreover, the control panel in the station is now under quite dangerous condition, probably causing a short-circuit anytime during operation. On the other hand, it is technically difficult, and even economically unreasonable, not merely to repair such mechanical and electrical facilities but to rehabilitate the civil and architectural structure so aged and damaged in places. In this case, a new pumping station, with an adequate pump capacity, shall be constructed for sure and entire drainage of the watershed.

The new station is recommended to be provided on the west side of the existing station where less compensation is expected. The existing station will then be left intact just for emergency, and its capacity is not involved in the Master Plan.

(2) Construction of Regulation Pond

The pumping station is the key element of drainage in the watershed, however it is uneconomical to cope with all the peak discharge solely by pumps. Assistance of a regulation pond is essential. Fortunately, a large lake called Boeng Tompun is located just upstream of the pumping station (whose water surface area is 47.5 ha). Now, the lake is used only for aquiculture. This can function as a regulation pond, with a certain excavation of the lake bottom, to lighten the load of pump facilities, realizing an economical drainage plan for this watershed.

(3) Combination of Pump Capacity and Regulation Pond Volume

The following table shows the study results to seek the economically optimal combination of pump capacity and regulation pond volume based on the design hydrograph of Tompun Watershed, with a return period of 5 years, given in Figure B4-6 of Sector B. Although there are no significant differences among Alternatives 1, 2 and 3 in construction cost, Alternative 2 is the most economical, and hence selected as the optimal combination. The pump capacity is 15 m^3/sec and the necessary regulation pond volume is 560,000 m^3.

Dimensions and Construction Costs of Alternatives on the Combination of Pump Capacity and Regulation Pond Volume

Alternative	Pump Capacity (m^3/sec)	Regulation Pond (47.5 ha) *			Construction Cost** (US$ million)
		Necessary Volume (m^3)	Regulation Water Depth (m)	Low Water Level (EL. m)	
1	9	750,000	1.6	2.9	12.6
2	15	560,000	1.2	3.3	12.3
3	21	450,000	1.0	3.5	13.0
4	27	370,000	0.8	3.7	14.3
5	33	290,000	0.7	3.8	14.5

* The design surcharge water level is set at EL. 4.5 m on account of ground elevations around the lake.

** The breakdown is shown in Table D3-11.

Meanchey Drainage Main

Meanchey Drainage Main is an open channel running along outside of the Inner Ring Dike, and conveys all storm water from Tompun Watershed finally to discharge it to the Tompun Pumping Station site. The drainage main is divided into up- and downstream sections by Meanchey Bridge where the runoff from the western part of the City Core will join. Major points of the channel improvement are as follows:

Features of Meanchey Drainage Main

Description	Downstream Section	Upstream Section
Improvement Length (km)	Approx. 2.8	Approx. 2.1
Design Discharge (m^3/sec)	75	15 & 11
Longitudinal Profile	To be dug as deep as possible to ease drainage in the City Core area. 1/2,500.	To keep the existing profile not to affect riverine houses. 1/2,000 & 1/1,000.
Cross-section	Earth channel	Earth and revetted channels

Underground Drainage Mains

In the City Core portion of Tompun Watershed with a catchment area of 6.31 km^2, there is no open drains. This is very exceptional compared to other cases, e.g. in Hanoi City are open drains with densities of 1 km or more per km^2. Such lack of open drains is the main reason why the area suffers from repeated inundation even in small rains when the total rainfall becomes over approximately 50 mm. However, this area is completely congested with buildings, apartments and ordinary housing. No space is found for newly excavating open drains at all. Only the solution to be conceived, in this case, is the construction of underground drainage mains beneath major roads.

In the present area, on the other hand, a broad avenue, called Samdach Monireth Street, runs along the centerline of the area from the northeast to the southwest, joining several considerably wide streets. This structure of road network is favorable to provide underground drainage mains underneath. The drainage mains should be of the box culvert type in order to cope with the comparatively large design discharges (44, 20 and 8 m^3/sec).

The profiles of such drainage mains established after preliminary examinations are enumerated in Section 3.6.1. Noted herein are the following:

(a) Samdach Monireth Drainage Main connects directly to Meanchey Drainage Main near Meanchey Bridge without pump facilities, but with a gated structure (stop logs) under the Inner Ring Dike just for emergency purpose (Jawaharlal Nehru Drainage Main is a branch of this main);

(b) Salang Drainage Main will be provided digging the existing Boeng Salang south lake, connecting to Meanchey Drainage Main in the same manner as above (Boeng Salang north lake will be left intact); and

(c) As for Tum Nup Toek Basin, a sluiceway across the Inner Ring Dike, furnished with stop logs, is designed to lead storm water in the basin to Meanchey Drainage Main.

Sewer Rehabilitation

The existing sewer network, of the combined system, will be rehabilitated by means of furnishing new pipeline networks because most existing pipes are largely short in capacity. The coverage area is 631 ha including Tum Nup Toek Basin. The size of each sewer pipe is determined by Manning Formula as below:

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

where,

Q : Design discharge (m^3/sec)
n : Roughness coefficient (0.015)
I : Water surface gradient
R : Hydraulic radius (m)
A : Flow area (m^2)

Note: This Manning Formula is applied not only to the sewer systems but also to the drainage mains.

3.4.3 Trabek Basin

The drainage improvement in Trabek Basin comprises construction of a pumping station and regulation pond, provision of underground drainage mains along the existing Trabek and Toul Sen channels' alignments and so on, and rehabilitation of existing sewers. The total catchment area is 10.83 km^2.

Pumping Station and Regulation Pond

On the same considerations as applied to Tompun Watershed, a new pumping station will be provided on the west side of the existing one, and Boeng Trabek will be dug for regulation. The capacity of the new station has been set at 8 m^3/sec according to the ADB project, and the official capacity (4.2 m^3/sec) of the existing station is ignored. The regulation pond should hence store a volume remaining after subtracting the new pump capacity of 8 m^3/sec constantly from the hydrograph at the downmost of Trabek Basin, i.e.

350,000 m^3 (refer to Figure B4-6 in Sector B). The major dimensions of the pumping station and regulation pond are as follows:

Major Dimensions of Trabek Pumping Station and Regulation Pond

Description	Dimensions	Remarks
(1) Pumping Station		
(a) Existing Station	4.2 m^3/sec (official)	Ignored in the Master Plan
(b) New Station (w/ Inlet Channel)	8.0 m^3/sec	According to the ADB project
(2) Regulation Pond		
(a) Area		
- Upper Pond	10.3 ha	
- Lower Pond	18.4 ha	
- Total	28.7 ha	
(b) Surcharge Water Level (SWL)	EL. 4.0 m	1.3 m of regulation depth
(c) High Water Level (HWL)	EL. 3.7 m	
(d) Low Water Level (LWL)	EL. 2.7 m	
(e) Bottom Height	EL. 2.4 m	
(f) Regulation Volume		
- Upper Pond	130,000 m^3	
- Lower Pond	220,000 m^3	
- Total	350,000 m^3	See Figure B4-6, Sector B

The structure and detailed dimensions of the pumping station and regulation pond are tabulated in Subsection 3.6.1.

Drainage Mains

The following three drainage mains are conceived in Trabek Basin on the basis of the same strategy as in Tompun Watershed:

(a) Trabek Drainage Main, of the box culvert type, along the existing Trabek channel;

(b) Toul Sen Drainage Main along the existing Toul Sen channel, of the box culvert type in the downstream stretch while of the open channel type in the upstream stretch; and

(c) Norodom Drainage Main, of the box culvert type, on a new route along Street 360 and Norodom Blvd.

Sewer Rehabilitation

The existing sewer network, of the combined system, will be rehabilitated in the same way as in Tompun Watershed. The coverage area is 1,083 ha.

3.4.4 City Core North Area

The City Core North Area (6.57 km^2) is formed by the following five independent basins:

- C1: Wat Phnom Basin (0.89 km^2);
- C2: Kak Lakeshore Basin (0.51 km^2);
- C3: Boeng Kak Basin (1.14 km^2);

- C4: Tuol Kork Basin (3.32 km^2), which is further divided into separate three sub-basins such as: Tuol Kork I (2.64 km^2), Toul Kork II (0.43 km^2), and Toul Kork III (0.25 km^2); and
- C5: University Basin (0.71 km^2).

Major works in the City Core North Area are rehabilitation of existing sewers in C1, C2 and C4, incorporated with construction of drainage mains in C4 and provision of sluiceways in C3, C4 and C5.

Drainage Mains

Toul Kork Basin has a comparatively large catchment, hence requiring construction of drainage mains. In the same consideration in Tompun Watershed, two underground drainage mains are proposed along Streets 289 and 315. The features are summarized in Subsection 3.6.1. Both drainage mains discharge to the Northeast Area by gravity since the outlet water level is predicted to be EL. 7.0 m at maximum that is still lower than the ground elevation of 8.0 m on depressed lands in Toul Kork Basin.

Sluiceways

One sluiceway, with a single gate, will be installed at the discharge point of Boeng Kak to ensure drainage and to control water stage of the lake. In addition, similar sluiceway structures will be constructed in Toul Kork Basin (3 locations) and University Basin (2 locations).

Sewer Rehabilitation

In the same line as in Tompun Watershed, the existing sewers will be rehabilitated. The coverage areas are 89 ha in C1: Wat Phnom Basin, 51 ha in C2: Kak Lakeshore Basin, and 332 ha in Tuol Kork Basin, totaling 472 ha.

3.4.5 Pochentong East Basin

The Master Plan suggests for Pochentong East Basin, with a catchment area of 15.35 km^2, construction of a pumping station, regulation pond and drainage mains, open channel type, together with a closing gate to Tompun Watershed.

Pumping Station and Regulation Pond

One pumping station will be constructed near the existing pipe culvert across BOT Road. On the east side of the station site, there were two of slender lakes: north and south lakes. However, the south lake has been reclaimed so that the north lake, approximately 2 km away from the station site, can only be used as the regulation pond to assist the pump operation.

The water surface area of the north lake is 6.0 ha. The design low water level is set at EL. 6.0 m, equaling the bottom elevation of the drainage main (an existing channel) connecting the lake with the pumping station, while the surcharge water level at EL. 7.0 m considering adjacent land's elevations. As a result, 60,000 m^3 of regulation volume can be assured by the pond. Based on the hydrograph delineated in Figure B4-6 of Sector B, this

volume will achieve a peak cut of 5 m^3/sec, hence giving the pumping station a design capacity of 5 m^3/sec.

Features of the pumping station and regulation pond are presented in Subsection 3.6.1.

Drainage Mains and Closing Gate

Major part of Pochentong East Basin has been prepared for future developments furnished with a canal network. This network can be used as drainage mains in the Master Plan with only providing some revetment works. The design discharges are as small as 5 to 10 m^3/sec, so that no additional land acquisition might be necessary for construction of the drainage mains.

Moreover, there exists a gated structure at the outlet of the north lake (regulation pond) towards Tompun Watershed in order to control the discharge and water level of the lake. This gate is an important structure to protect Tompun Watershed from excess water generated in Pochentong East Basin and so on. The structure will be rehabilitated in the scope of the Master Plan.

3.4.6 Northeast and Northwest Areas

The Northeast Area is a huge swampy area with Boeng Poungpeay in its center, while the Northwest Area a large agricultural land. The total area is 100.09 km^2, sharing the northern half of the Study Area. The Master Plan incorporates some drainage measures for this area as well.

Svay Pak Drainage Sluiceway and Pumping Station

(1) Drainage Sluiceway

In the Northeast and Northwest areas, storm water from the catchment, 105.77 km^2 including a part of the City Core, is presently drained through a sluiceway (very old and damaged in places) provided under NR-5 to the Tonle Sap River when the river water stage is low, while in the reverse case it is just stored in the swampy area. The sluiceway is a crucial structure for flood protection and drainage improvement over the Study Area. Once that were broken down, the northern half of the Study Area should go under water. Taking into account its importance and present status, the drainage sluiceway will be rehabilitated under the Master Plan.

(2) Pumping Station

In the rainy season, as mentioned above, storm water simply accumulates, causing certain inundation over the area, then in the dry season stored water is drained through the sluiceway. This hydraulic annual cycle is roughly analyzed hereunder:

(a) Total runoff during the rainy season (7 months from May to November) is estimated at approx. 130 x 10^6 m^3 by multiplying the average rainfall amount, 1,230 mm, in the rainy season by the catchment area, 105.77 km^2;

(b) Total evaporation during the rainy season is approx. 85 x 10^6 m^3 taking the average annual evaporation height at 800 mm;

(c) The balance between the above two (approx. 45 x 10^6 m^3) is stored in E1 and E2 basins (37.71 km^2), the final inundation depth being approx. 1.2 m; and

(d) Assuming the water stage before the rainy season at EL. 5.8 m based on the field survey results, the final inundation water level may be EL. 7.0 m, which is well corresponding to the heights of flood marks in the area.

The water level of EL. 7.0 m less affects houses, fishponds, etc. in the area, resulting in minimal damage. However, there is an idea of providing pump facilities beside the said sluiceway to prevent such inundation. The operation cost of the pump facilities is calculated as follows:

(a) To maintain water level at EL. 5.8 m throughout the year, the pump capacity should be 2.5 m3/sec = 45 x 10^6 m^3 / 210 days / 86,400 sec;

(b) Necessary power is approx. 190 KW = 15 x 2.5 m3/sec x Head (5 m on average), annual energy to be consumed being 960,000 KWH = 190 KW x 210 days x 24 hr; and

(c) Taking the electric charge at US$ 0.1 per KWH, the annual operation cost becomes US$ 96,000.

The operation cost of US$ 96,000 per annum is quite expensive, and the economic effect is not high as mentioned above. In conclusion, the Master Plan excludes the construction of a pumping station at the Svay Pak site.

Poungpeay Drainage Main

This is only a drainage main in the Northeast and Northwest Areas. The major purpose is to convey to Boeng Poungpeay storm water in M3: Pochentong West Basin presently intruding into Pochentong Airport and even inflicting damage over Pochentong East Basin. Features of the drainage main are presented in Subsection 3.6.1.

Drainage Sluiceways in Poungpeay East Basin

Poungpeay East Basin is partitioned by several embankments for roads and railways. Some of the embankments are furnished with pipe culverts, whose sizes are however insufficient to drain storm water. This condition causes not merely inundation in the rainy season but deterioration of water quality in the dry season over the area of Poungpeay East Basin. To solve this, twelve (12) locations of sluiceway construction beneath said embankments are proposed in the Master Plan.

3.5 Studies on Environmental Enhancement

The Master Plan examines on environmental enhancement over the Study Area although it is, as a matter of course, limited within the scope of flood protection and drainage improvement. Shown in Figure D3-5 are such ideas, which are discussed item by item hereinafter.

(1) Riverfront Conservation: There is a series of existing revetments on the west bank of the Tonle Sap River in the approximately 1.5 km stretch from Chaktomuk (in front of

the Royal Palace). A part of the revetments have been recommended to be rehabilitated under the present Master Plan. In this case, the works should incorporate some environmental considerations such as flower planting in-between the grids of the slope protection, and provision of promenades on the riverbank and/or berm with planting, installing benches, lighting, etc. These works are inclusive in the Riverfront Protection in Sap Downstream Middle Section described in Subsection 3.3.3.

(2) Lake Conservation: In the Study Area, there exist several lakes such as Boeng Poungpeay, Boeng Kak, Boeng Trabek, Boeng Tompun, Boeng Salang. Commonly, these lakes have been encroached on by housing and other developments, and the water has been contaminated with wastewater. This item is a measure to control such environmentally deteriorated condition by dredging sediments settling on the lake bottoms, by providing interceptors and/or environmental canals, by introducing flushing water, and by taking legislative action such as land use control. Following are works taken as the physical measures in the Master Plan:

(a) Lake dredging in Boeng Tompun, Boeng Trabek, Boeng Salang (the north lake) and the north lake in Pochentong East Basin mainly for drainage improvement;

(b) Provision of an interceptor, with a diameter of 600 mm, along the shoreline of Boeng Kak to prevent wastewater from flowing into the lake and to keep its water quality;

(c) Rehabilitation of Svay Pak Sluiceway not only for flood protection but easy introduction of flushing water from the Tonle Sap River to the Poungpeay area when the river water stage is around EL. 6 to 7 m; and

(d) Construction of an environmental canal, 1 m by 1m box culvert, between Meanchey and Poungpeay drainage mains to lead the flushing water introduced as above and excess water, if any, in the Poungpeay area towards the Tompun area in order to better water quality in channels/lakes therein.

As for the non-physical measures pertaining to lake conservation, refer to Subsection 3.6.2.

(3) "Green" Channel Plan: There are very few open channels left in the Study Area, so that these remaining channels will play an important role in the city environment in the near future. The Master Plan may preserve two open channels, Meanchey and Poungpeay drainage mains, with sufficient widths of right of way, within which several environmental measures as described in 'Riverfront Conservation' above will be worked out.

3.6 Formulation of Master Plan

3.6.1 Features of Physical Measures

In accordance with the alternative studies on flood control, drainage improvement and environmental enhancement described in respective Sections 3.3, 3.4 and 3.5, preliminary

designs for necessary facilities have been made, whose results are summarized hereunder packaging the facilities into the following nine components:

- Component 1: Riverfront Protection in Sap Downstream Middle Section
- Component 2: Reinforcement of Kop Srov and Tompun Dikes
- Component 3: Tompun Watershed Drainage Improvement
- Component 4: Trabek Basin Drainage Improvement
- Component 5: City Core North Area Drainage Improvement
- Component 6: Pochentong East Basin Drainage Improvement
- Component 7: Northeast and Northwest Areas Drainage Improvement
- Component 8: Environmental Enhancement

For the location of the above components and major facilities therein, refer to Figure D3-6.

Component 1: Riverfront Protection in Sap Downstream Middle Section

(See Figure D3-16)

(1)	Stretch	:	Street 108 to Street 184 with a length of 1.0 km
(2)	Design High Water Level	:	EL. 10.0 m
(3)	Design Bank Height	:	EL. 10.9 m (adding 0.9 m of freeboard)
(4)	Type of Revetment	:	Stone Pitching Type (see Figure D3-2)
(5)	Type of Foot Protection	:	Stone filling
(6)	Environmental Measures	:	Planting, Provision of promenade, etc.

Component 2: Reinforcement of Kop Srov and Tompun Dikes

(See Figure D3-7)

(1) Reinforcement of Kop Srov Dike

(a)	Stretch	:	9.0 km section southwestwards from the junction with NR-5
(b)	Design High Water Level	:	EL. 10.4 m (30-year return period)
(c)	Design Dike Height	:	EL. 11.2 m (adding 0.8 m of freeboard)
(d)	Dike Structure	:	Earthfill of triple section with a 10 m wide asphalt-paved road (see Figure D3-3)

(2) Reinforcement of Tompun Dike

(a)	Stretch	:	4.4 km section between the junctions with the Inner Ring Dike and NR-303
(b)	Design High Water Level	:	EL. 9.0 m (30-year return period)
(c)	Design Dike Height	:	EL. 10.1 m (adding 1.1 m of freeboard)
(d)	Dike Structure	:	Provision of toe drain with coarse material (see Figure D3-3)

Component 3: Tompun Watershed Drainage Improvement, 17.47 km^2

(See Figure D3-8)

(1) Tompun Pumping Station and Regulation Pond

(a) Pumping Station

- Location	:	On the Tompun Dike, adjoining the existing pumping station to the east (see Figure D3-9)
- Pump capacity	:	15 m^3/sec (3 m^3/sec x 5 units)
- Type of Pumps	:	Submergible pump
- Structure	:	Pumping station of RC structure with foundation piles, two outlet sluiceways (one for natural drainage, the other for pump drainage), an inlet channel, an outlet channel outside the dike, and a control house.

(b) Regulation Pond

- Location	:	Existing Boeng Tompun (see Figure D3-9)
- Area	:	47.5 ha (total of East and West ponds)
- Design Surcharge Water Level	:	EL. 4.5 m (at the maximum storage)
- Design High Water Level	:	EL. 3.7 m (at the peak discharge of Meanchey Drainage Main)
- Design Low Water Level	:	EL. 3.3 m (to be maintained through the year)
- Design Bottom Height	:	EL. 3.0 m
- Regulation Volume	:	560,000 m^3 by which 60 m^3/sec of the peak discharge can be regulated.

(2) Meanchey Drainage Main, Downstream Stretch

(a)	Stretch	:	From the regulation pond to Meanchey Bridge with a length of 2.76 km
(b)	Design Discharge	:	75 m^3/sec
(c)	Channel Bed Gradient	:	1/2,500 (see Figure D3-10)
(d)	Structure	:	Earth channel with a side slope of 1:2 and some environmental measures such as planting inclusive (see Figure D3-11)

(3) Meanchey Drainage Main, Upstream Stretch

(a)	Stretch	:	From Meanchey Bridge to a road passing from the Salang area to Pochentong Airport with a length of 2.135 km

(b) Design Discharge : 15 & 11 m^3/sec

(c) Channel Bed Gradient : 1/2,000 & 1/1,000 (see Figure D3-10)

(d) Structure : Earth and masonry-riveted channels with a side slope of 1: 2 & 1: 0.3 and some environmental measures such as planting inclusive (see Figure D3-11)

(4) Tum Nup Toek Drainage Sluiceway

(a) Location : On the Inner Ring Dike near the existing Tum Nup Toul Pumping Station

(b) Structure : 2 m by 2 m box culvert with a steel-made slide gate

(5) Samdach Monireth Drainage Main

(a) Stretch : Under Samdach Monireth Street from Meanchey Bridge to a road junction behind Olympic Stadium with a length of 2.36 km, at the outlet of which a sluiceway will be provided.

(b) Design Discharge : 44 & 20 m^3/sec

(c) Channel Bed Gradient : 1/2,000 (see Figure D3-12)

(d) Structure (see Figure D3-14)

- Samdach Monireth 1 & 2 : Box culvert (4.25 m wide, 3.6 m high, 2 lanes)

- Samdach Monireth 3 : Box culvert (2.85 m wide, 3.6 m high, 2 lanes)

(6) Jawaharlal Nehru Drainage Main

(a) Stretch : Under Jawaharlal Nehru Street with a length of 1.16 km

(b) Design Discharge : 8 m^3/sec

(c) Channel Bed Gradient : 1/2,000 (see Figure D3-13)

(d) Structure (see Figure D3-14) : Box culvert (2.25 m wide, 3.1 m high)

(7) Salang Drainage Main

(a) Stretch : Along the existing Boeng Salang south lake with a length of 1.4 km, at the outlet of which a sluiceway will be constructed.

(b) Design Discharge : 21 m^3/sec

(c) Channel Bed Gradient : 1/3,000

(d) Structure : Earth channel along the alignment of the Boeng Salang south lake with 1:2 of side slopes

(8) Sewer Rehabilitation (excluding Tum Nup Toek Basin)

(a) Area : 563 ha (see Figure D3-15)

(b) Total Pipe Length : 79,900 m

(9) Sewer Rehabilitation (Tum Nup Toek Basin)

(a) Area : 68 ha (see Figure D3-15)

(b) Total Pipe Length : 5,200 m

Component 4: Trabek Basin Drainage Improvement, 10.83 km^2

(See Figure D3-16)

(1) Trabek Pumping Station and Regulation Pond

(a) Pumping Station

- Location : On the Tompun Dike, adjoining the existing pumping station to the east (see Figure D3-17)
- Pump capacity : 8 m^3/sec (3 m^3/sec x 2 units plus 2 m^3/sec x 1 unit)
- Type of Pumps : Submergible pump
- Structure : Pumping station of RC structure with foundation piles, two outlet sluiceways (one for natural drainage, the other for pump drainage), an inlet channel, an outlet channel outside the dike, and a control house.

(b) Regulation Pond

- Location : Existing Boeng Trabek (see Figure D3-17)
- Area : 28.7 ha (Upper Pond 10.3 ha plus Lower Pond 18.4 ha)
- Design Surcharge Water Level : EL. 4.0 m (at the maximum storage)
- Design High Water Level : EL. 3.7 m (at the peak discharge of Trabek Drainage Main)
- Design Low Water Level : EL. 2.7 m (to be maintained through the year)
- Design Bottom Height : EL. 2.4 m
- Regulation Volume : 350,000 m^3 by which 62 m^3/sec of the peak discharge can be regulated.

(2) Trabek Drainage Main

(a) Stretch : Along the existing Trabek Channel with a length of 1.604 km

(b) Design Discharge : 70, 38 & 27 m^3/sec

(c) Channel Bed Gradient : 1/2,000 (see Figure D3-18)

(d) Structure (see Figure D3-19)

- Trabek 1 : Box culvert (6.0 m wide, 3.6 m high, 2 lanes)
- Trabek 2 : Box culvert (4.0 m wide, 3.6 m high, 2 lanes)
- Trabek 3 : Box culvert (5.0 m wide, 3.6 m high)

(3) Toul Sen Drainage Main

(a) Stretch : Along the existing Toul Sen Channel with a length of 2.05 km

(b) Design Discharge : 8 & 5 m^3/sec

(c) Channel Bed Gradient : 1/2,000 & 1/1,500 (see Figure D3-20)

(d) Structure (see Figure D3-21)

- Toul Sen 1 & 2 : Box culvert (2.5 m wide, 2.8 m high)
- Toul Sen 3 & 4 : Earth channel with retaining walls

(4) Norodom Drainage Main

(a) Stretch : Under Street 360 and Norodom Blvd. with a length of 1.768 km

(b) Design Discharge : 18 & 10 m^3/sec

(c) Channel Bed Gradient : 1/1,500 & 1/1,000 (see Figure D3-22)

(d) Structure (see Figure D3-23)

- Norodom 1 : Box culvert (3.4 m wide, 3.6 m high)
- Norodom 2 : Box culvert (2.75 m wide, 2.6 m high)

(5) Sewer Rehabilitation

(a) Area : 1,083 ha

(b) Total Pipe Length : 128,600 m

<u>Component 5: City Core North Area Drainage Improvement, 6.57 km^2</u>

(See Figure D3-24)

(1) C1: Wat Phnom Basin, Sewer Rehabilitation

(a) Area : 89 ha (Figure D3-25)

(b) Total Pipe Length : 9,100 m

(2) C2: Kak Lakeshore Basin, Sewer Rehabilitation

(a) Area : 51 ha (Figure D3-25)

(b) Total Pipe Length : 1,800 m

(3) C3: Boeng Kak Basin, Kak Drainage Sluiceway

(a) Location : Outlet of Boeng Kak under the Inner Ring Dike

(b) Structure : 2 m by 2 m one lane box culvert with steel-made slide gates

(4) C4: Tuol Kork Basin, Major Drainage Facilities

(a) Tuol Kork Drainage Main-I

- Stretch : Under Street 315 with a length of 1.887 km
- Design Discharge : 6, 4 & 3 m^3/sec

- Channel Bed Gradient : 1/2,000 (see Figure D3-26)
- Structure (see Figure D3-28)
  + Tuol Kork-I 1 and 2 : Box culvert (3.75 m wide, 1.9 m high)
  + Tuol Kork-I 3 : Box culvert (2.75 m wide, 1.9 m high)
  + Tuol Kork-I 4 : Box culvert (2.2 m wide, 1.9 m high)

(b) Tuol Kork Drainage Main-II
- Stretch : Under Street 289 with a length of 0.577 km
- Design Discharge : 5 m^3/sec
- Channel Bed Gradient : 1/1,000 (see Figure D3-27)
- Structure (see Figure D3-28) : Box culvert (2.5 m wide, 1.9 m high)

(c) Tuol Kork Drainage Sluiceway-I
- Location : Near the existing pumping station I
- Structure : 2m by 2 m one lane box culvert with a steel-made slide gate

(d) Tuol Kork Drainage Sluiceway-II
- Location : Near the existing pumping station II
- Structure : 2m by 2 m one lane box culvert with a steel-made slide gate

(e) Tuol Kork Drainage Sluiceway-III
- Location : Near the existing pumping station III
- Structure : 2m by 2 m one lane box culvert with a steel-made slide gate

(5) C4: Toul Kork Basin, Sewer Rehabilitation
(a) Area : 332 ha (see Figure D3-29)
(b) Total Pipe Length : 38,700 m

(6) C5: University Basin, Drainage Sluiceway
(a) Location : 2 locations under the Inner Dike and railway
(b) Structure : 2m by 2 m one lane box culvert with a steel-made slide gate

<u>Component 6: Pochentong East Basin Drainage Improvement, 15.35 km^2</u>

(See Figure D3-30)

(1) Pochentong Pumping Station and Regulation Pond
(a) Pumping Station
- Location : On BOT Road, adjoining the existing culvert to the west

- Pump capacity : 5 m^3/sec in total (3 m^3/sec x 1 unit plus 2 m^3/sec x 1 unit)
- Type of Pumps : Submergible pump
- Structure : Pumping station of RC structure with foundation piles, two outlet sluiceways (one for natural drainage, the other for pump drainage), and a control house

(b) Regulation Pond

- Location : An existing lake (North Lake) in front of the Salang area
- Area : 6.0 ha
- Design Surcharge Water Level : EL. 7.0 m (at the maximum storage)
- Design Low Water Level : EL. 6.0 m (to be maintained through the year)
- Regulation Volume : 60,000 m^3 by which 5 m^3/sec of the peak discharge can be regulated.

(2) Closing Gate Structure (Sluiceway)

(a) Location : Near the regulation pond

(b) Structure : 2 m by 2 m one lane box culvert with a steel-made slide gate

(3) Drainage Mains

(a) Stretch : 9.0 km

(b) Design Discharge : 5 & 10 m^3/sec

<u>Component 7: Northeast and Northwest Areas Drainage Improvement, 100.09 km^2</u>

(See Figure D3-31)

(1) Poungpeay Drainage Main

(a) Stretch : Along the northwest side of NR-3 and then the north side of the railway with a total length of 11.92 km

(b) Design Discharge : 20, 12 & 8 m^3/sec

(c) Channel Bed Gradient : 1/10,000, 1/2,000 & 1/1,000 (see Figure D3-32)

(d) Structure (see Figure D3-33)

- Poungpeay 1 : Earth channel with 1:2 side slopes (7 m wide at the bottom, 3 m of water depth)
- Poungpeay 2 : Reveted channel with 1:0.3 side slopes (2.4 m wide at the bottom, 3 m of water depth)
- Poungpeay 3 : Earth channel with 1:2 side slopes (1.5 m wide at the bottom, 2 m of water depth)

- Poungpeay 4 : Earth channel with 1:2 side slopes (1.5 m wide at the bottom, 1.7 m of water depth)

(2) Svay Pak Drainage Sluiceway

(a) Location : Existing Svay Pak Drainage Sluiceway (PK #9) site

(b) Structure : 2-lane box culvert (each 2 m by 2 m with a steel-made slide gate)

(3) Drainage Sluiceways in Poungpeay East Basin

(a) Location : 12 locations under existing embankments in Poungpeay East Basin

(b) Structure : One-lane box culvert (2 m by 2 m with a steel-made slide gate)

Component 8: Environmental Enhancement

(See Figures D3-8 and D3-24)

(1) Environmental Canal

(a) Stretch : Along the Inner Dike between the origin of Meanchey Drainage Main and the vicinity of the outlet of Tuol Kork Drainage Sluiceway I with a length of 1.75 km

(b) Structure : One-lane box culvert (1 m by 1 m)

(2) Kak Interceptor

(a) Stretch : Along the eastern lakeshore of Boeng Kak with a length of 0.85 km

(b) Structure : 375 mm diameter of pipe

3.6.2 Features of Non-physical Measures

The Master Plan proposes construction of the facilities enumerated in Subsection 3.6.1 above. However, comprehensive flood protection and drainage improvement cannot be realized solely by such physical measures, but should incorporate the non-physical measures such as:

- Land use control (zoning control and development/building control);
- Flood defense activity with flood forecasting and warning;
- On-site storage;
- Public information and education; and
- Flood insurance.

Following are discussions on the land use control and flood defense activity that should be most applicable and effective among them as the non-physical measures in the flood protection and drainage improvement for the Study Area.

Land Use Control

The land use control is an essential component in the non-physical measures, comprising the following two aspects:

- Overall aspect : Zoning control; and
- Individual aspect: Development and building control.

The following discusses not just on the present constraints and improvement strategy but also on the concrete measures maybe applied to the Study Area.

(1) Present Constraints and Improvement Strategy

Zoning Control

Municipality of Phnom Penh has not yet established an authorized city development plan (zoning control) for its territory. This causes uncontrolled developments in many locations, not only destroying environments of the city but jeopardizing the function of flood protection and drainage facilities. Early establishment of a city development plan is strongly anticipated to better such condition. From the viewpoint of flood protection and drainage improvement, the following considerations should be made in the plan.

(a) Water Zone Conservation in the Northeast Area

The area is a large water zone with Boeng Poungpeay in its center. In addition, a lot of fishponds spread along the eastern perimeter of the lake. These lake and ponds play an important role in regulating runoff from the northern half of the Study Area, limiting inundation of the area within permissible range, and discharging the stored water safely through Svay Pak Sluiceway to the Tonle Sap River at the end of the rainy season.

However, presently, numbers of new developments for factories, housing, etc. are invading the water zone, making its area gradually narrower. This will result in decrease of its runoff control effect, causing serious inundation over the northern half of the Study Area. This trend must be controlled by the city development plan in which it is clearly stated that the water zone be preserved as it is, not merely for flood protection and drainage purpose but also for environmental conservation.

(b) Agricultural Land Conservation in the Northwest and South Areas

The areas are mostly shared by agricultural lands as of now, which function not only for runoff retention but better environment of the city. However, new developments are in progress in several places without authorized control. Such tendency may accelerate with city expansion.

Uncontrolled developments on the agricultural lands should produce increase of runoff, making severer inundation in the downstream reaches, moreover undermining the developments themselves by repeated flooding. In this

context, the city development plan should incorporate a consideration for the conservation of agricultural lands in the Northwest and South areas.

Development and Building Control

The development and building control, likely, has not functioned well up to date. Indeed, land reclamation for developments and buildings is going on at many locations in the Study Area without any control of the municipal government. To avoid this situation, the following two should be considered:

(a) There is an old announcement by the MPP regarding the right-of-way of public facilities, however at present it is a dead letter in reality, resulting even in the encroachment of squatters on the governmental lands. To cope with this, the announcement should be effective legislatively.

(b) Establishment of a future land use plan or zoning as mentioned above; otherwise, the municipal government can hardly control such disordered developments.

(2) Concrete Measures

Concrete measures proposed for materializing appropriate land use control over the Study Area are as follows.

Zoning Control

The following activities are needed to remove the present constraints.

(a) Establish CATUC of the Municipality of Phnom Penh (or appoint responsible organization for land use planning) in accordance with the CNATUC Law. We considered CNATUC Law is still active even after the creation of Ministry of Construction.

(b) CATUC (or appointed organization) of the Municipality of Phnom Penh should establish "Land Use Master Plan" as soon as possible.

(c) In the "Land Use Master Plan", the following should be considered from the view point of flood protection and drainage improvement in the MPP.

(i) Agricultural Land Conservation Area

Large-scale development should be prohibited. Settlement of polluting activities should be prohibited in the following areas:

- Southern area from BOT Road; and
- Northern area from the railway and City Core.

(ii) Water Zone Conservation Area

Development that decreases water area should be prohibited especially in the following lakes:

- Boeng Poungpeay;
- Boeng Kak;
- Boeng Salang;
- Boeng Tompun;
- Boeng Trabek; and
- North Lake in the Pochentong East Basin.

Development and Building Control

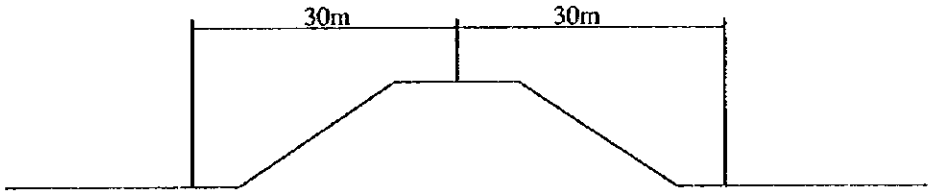
As for the development and building control that will be applied to individual developments and buildings, the following are suggested from the flood control and drainage point of view:

(a) Strict enforcement of "Sub-decree on Construction Permit" along with the reinforcement of land observations by Sangkat officials;

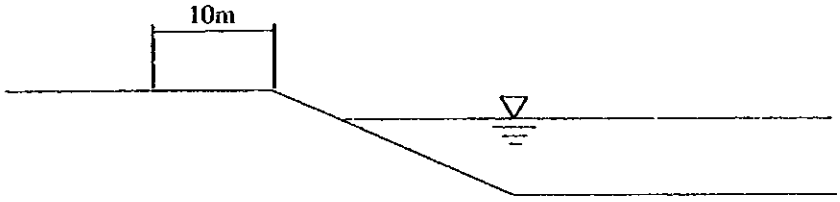
(b) Direction of reclamation heights and floor levels for new developments and buildings; and

(c) Re-setup of right-of-way (though there is an old announcement by the MPP regarding right-of-way, but presently is not functioning in reality) to prevent any people from encroaching on:

- Lake;
- River and waterway; and
- Structure (dike, sluiceway, pumping station, etc.).



Dikes and Roads



Lakes and Waterways