6. Cost Comparative Study

Four water supply systems for the respective water sources are shown on Figure 6.1.1. In this section, preliminary cost estimation of direct construction costs as well as operation and maintenance (O & M) costs of four alternatives are described.

6.1 Basis of Cost Estimation

Price Level: Base year for the cost estimation is 1999 and all costs are shown in Japanese Yen.

Unit Cost: Unit cost data in this cost estimation are collected from government offices, local consultants and manufacturers as shown on Table 6.1.1. These information are also checked against costs used in recent similar projects in Cambodia. It should be noted that the costs used for the estimation are only direct costs unless otherwise indicated.

Table 6.1.1 Source of Unit Cost Data

Source of Unit Cost Data	Item
Provincial Department of Industry, Mines and Energy (PDIME)	Cost for house connection, chemical costs and land acquisition, etc.
Electricity de Siem Reap	Power cost
Phnom Penh Water Supply Authority (PPWSA)	Salary of staff, chemical costs, etc.
Siam Tone Co., Ltd	Cost of well construction
JICA Project: The Study on Phnom Penh Water Supply System in the Kingdom of Cambodia, 1993	Costs of pipe and civil work, etc.

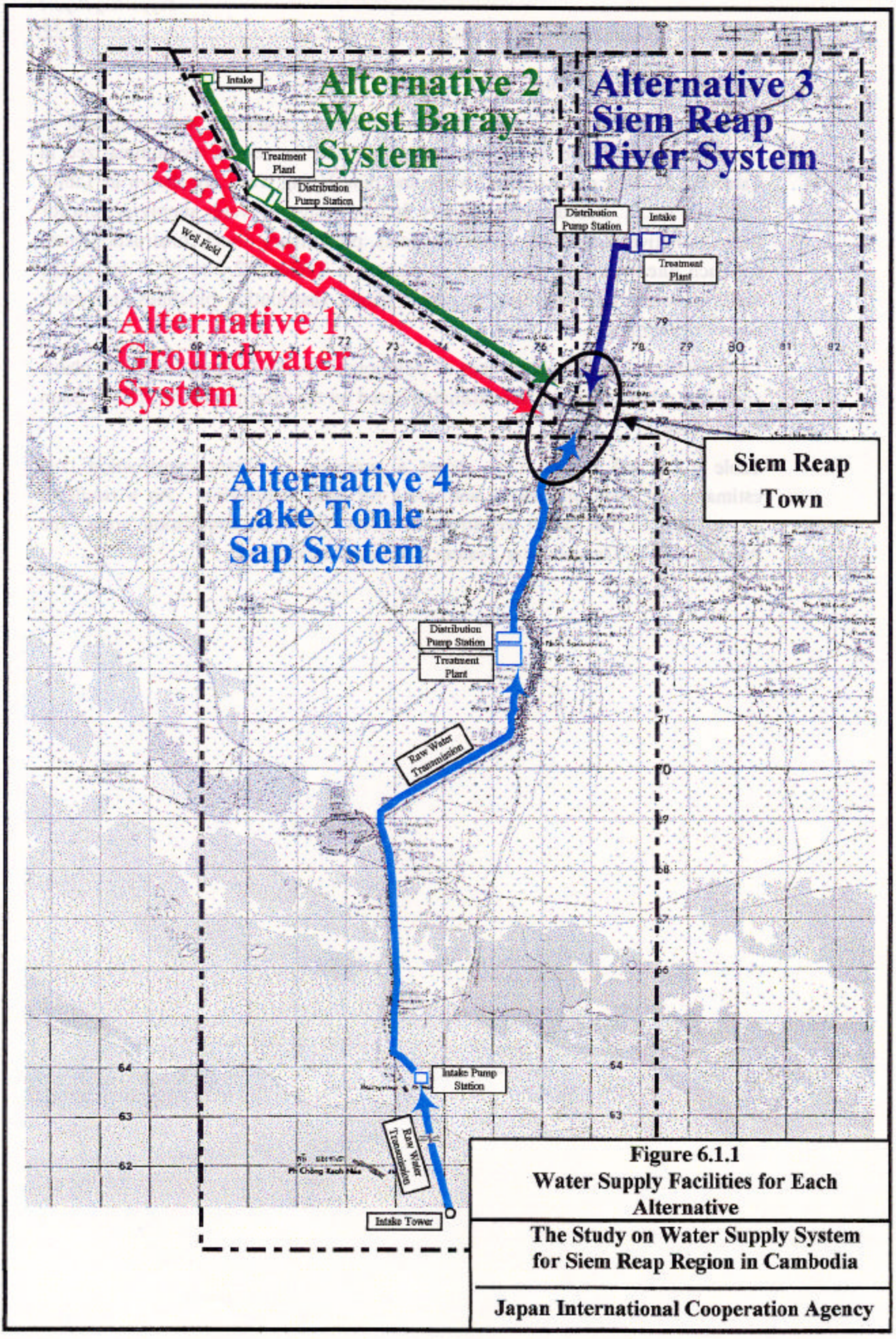

Figure 6.1.1
Water Supply Facilities for Each Alternative

The Study on Water Supply System for Siem Reap Region in Cambodia

Japan International Cooperation Agency

6.2 Direct Construction Cost

A survey concerning unit costs of labor, materials, machines and equipment in Siem Reap and Phnom Penh was carried out and the results are summarized in Table 6.2.1. Unit costs of civil work and pipe laying work are shown in Tables 6.2.2 and 6.2.3. Based on preliminary facility design of water supply system for four alternatives and unit construction costs, preliminary direct construction costs for each alternative are estimated as shown in Tables 6.2.4 to 6.2.7 for intake facilities, conveying facilities, treatment plants, distribution pipelines and water source development.

Land price of the prospective sites of well houses, pump stations, treatment plants and other related facilities are estimated based on the information of PDIME Siem Reap office.

Table 6.2.8 and Figure 6.2.1 shows a summary of direct construction cost estimates for each alternative and costs for land acquisition. As a result of comparison of the direct construction costs and land acquisition costs, the Alternative –1 : Groundwater System is the most economical.

Table 6.2.1 (1/4) Summary of Unit Price in Siem Reap and Phnom Penh

(US$)

	Item	Spec.	Unit	Rate in Siem Reap	Remarks	Rate in Phnom Penh	Remarks
1	Engineer (20 years exp.)		month			1,700	
2	Civil Engineer		month			1,130	
3	Assist. Civil Engineer		month			900	
4	Architect Engineer		month			1,130	
5	Assist. Architect Engineer		month			900	
6	Surveyor		month			900	
7	Assist. Surveyor		month			680	
8	Clerk (English/French)		month	460		680	
9	Admi. Officer (10 years exp.)		month	460		680	
10	Draftsman (First grade)		month			900	
11	Draftsman		month			570	
12	Typist (English/Khmer)		month			570	
13	Typist		month			340	
14	Driver		month	290		340	
15	Office Boy		month	170		170	
16	Office Girl		month	150		170	
17	Storekeeper		month			340	
18	Guardian		month	200		230	
19							
20	Foreman		day	20		30	
21	Mechanic		day			20	
22	Electrician		day			20	
23	Operator		day	15		20	
24	Welder		day			20	
25	Timberman		day			20	
26	Steel Worker/Steel Setter		day			20	
27	Pipe Fitter		day			20	
28	Skilled Worker		day			20	
29	Semi-skilled Worker		day			20	
30	Unskilled Worker		day	5		10	

Table 6.2.1 (2/4) Summary of Unit Price in Siem Reap and Phnom Penh

(US$)

Item		Spec.	Unit	Rate in Siem Reap	Remarks	Rate in Phnom Penh	Remarks
31	Cement		ton	90	Thai Elephant	100	Thai Elephant
32	Cement	50kg/bag	bag	6	Thai Elephant	10	Thai Elephant
33	Ready Mixed Concrete	210kg/cm^2	m^3			90	
34	Ready Mixed Concrete	180kg/cm^2	m^3			90	
35	Gravel	150×250 mm	m^3	15		20	
36	Gravel	40-100 mm	m^3	24		20	
37	Sand		m^3	6		10	
38	Laterite Soil		m^3	7		10	
39	Nail		kg	0.7		0.8	
40	Steel Wire		kg	0.7		0.7	
41	Steel Bar	D16-D19	ton	450	Quality problem	540	Thai
42	Steel Bar	D10-D13	ton	450	Quality problem	570	Thai
43	H-Steel		ton	550	Quality problem	790	
44	L-Steel		ton	460	Quality problem	810	
45	Bitumen		ton			410	
46	Plywood	12 mm thick	sheet		1200×2400mm	23	1200×2400mm
47	Plywood (900×1,800 mm)	10 mm thick	sheet		1200×2400mm	20	1200×2400mm
48	Diesel Oil		litre	0.30		0.33	
49	Petrol		litre	0.40	0.44US$/l--Total	0.55	
50	Concrete Pipe	ϕ500 mm	m	7		25	
51	Concrete Pipe	ϕ1000 mm	m	13		50	
52	Poly-chloride Pipe	ϕ50 mm	m	1.0		2.3	
53	Poly-chloride Pipe	ϕ100 mm	m	4.0		3.3	
54	Hard Wood		m^3	300		320	
55	Timber/Log		m^3	200		250	
56	Sand Bag	bag only	100 bags	10.0		50.0	
57	Brick		100 pcs	3.8		3.5	
58	Barbed Wire		kg	0.7		0.8	
59	Tie Wire		kg	0.7		0.7	

Table 6.2.1 (3/4) Summary of Unit Price in Siem Reap and Phnom Penh

(US$)

Item		Spec.	Unit	Rate in Siem Reap	Remarks	Rate in Phnom Penh	Remarks
60	Dump Truck	11 ton	day	80		100	
61	Back Hoe	0.6 m^3	day	230		240	
62	Truck Crane (Hydraulic Feed Type)	50 ton	day			900	
63	Truck Crane (Hydraulic Feed Type)	35 ton	day			680	
64	Truck Crane (Hydraulic Feed Type)	25 ton	day			450	
65	Truck Crane (Hydraulic Feed Type)	20-22 ton	day			400	
66	Truck Crane (Hydraulic Feed Type)	15-16 ton	day			230	
67	Truck Crane (Hydraulic Feed Type)	10 ton	day	160		170	
68	Vibrating Hammer	40 kW	day			110	
69	Concrete Mixer	0.3 m^3	day	50	0.1-0.2 m^3	70	
70	Concrete Mixer	0.6 m^3	day			110	
71	Agitating Truck	5 to 6 m^3	day			280	
72	Asphalt Sprayer	200 litre	day			110	
73	Vibrating Roller	500 kg	day			70	
74	Welding Machine	300 A	day			70	
75	Winch	2 ton	day			25	
76	Bulldozer	15 ton	day	230		230	
77	Bulldozer	21 ton	day			260	
78	Tractor Shovel	1.4 m^3	day			200	
79	Tractor Shovel	1.8 m^3	day			240	
80	Macadam Roller	8-10 ton	day			200	
81	Macadam Roller	10-12 ton	day			250	
82	Pneumatic Tired Roller	8-15 ton	day			250	
83	Pneumatic Tired Roller	8-20 ton	day			310	
84	Tamper	60-100 kg	day			35	
85	Concrete Bucket	0.6 m^3	day			25	
86	Soil Compactor	60-800 kg	day			70	

Table 6.2.1 (4/4) Summary of Unit Price in Siem Reap and Phnom Penh

(US$)

Item		Spec.	Unit	Rate in Siem Reap	Remarks	Rate in Phnom Penh	Remarks
87	Air Compressor	5 m^3/min	day			170	
88	Air Compressor	7 m^3/min	day			230	
89	Air Compressor	10 m^3/min	day			280	
90	Generator	100 KVA	day			70	
91	Generator	50 KVA	day			60	
92	Concrete Vibrator	1 kW	day			35	
93	Trailer	40 ton	day			340	
94	Motor Grader	3.1 m	day			280	
95	Water Cart	5.5-6.5 kl	day			100	
96	Asphalt Finisher (Wheel Type)	2.4-5m	day			160	

Table 6.2.2 Unit Cost of Civil Work

Item		Unit	Unit Cost (US$)
1	Manual Excavation Work	m^3	4.2
2	Machine Excavation Work	m^3	1.7
3	Concrete (σ =210 kg/cm^2)	m^3	210
4	Reinforcement	ton	1,190
5	Formwork	m^3	37.8

Table 6.2.3 Unit Direct Cost of Pipeline

Diameter and Material	Unit Cost		
	Supply	Laying	Total Unit Cost
	US $/m	US $/m	US $/m
700 DIP	287.5	127.9	415.4
600 DIP	237.5	115.2	352.7
500 DIP	177.8	102.9	280.7
450 DIP	150.0	97.1	247.1
400 DIP	126.1	83.8	209.9
350 DIP	102.2	78.9	181.1
300 DIP	86.7	73.0	159.7
250 DIP	69.7	68.1	137.8
200 DIP	56.0	62.7	118.7
150 DIP	42.7	49.5	92.2
150 PVC	18.0	49.5	67.5
100 PVC	9.3	44.1	53.5
75 PVC	6.3	28.9	35.2
50 PVC	3.2	24.5	27.7

Exchange Rate: 1 US$= 120 Yen

Table 6.2.4 Estimated Direct Construction Cost of Groundwater System

Description	Unit	Quantity	Amount (US $)
1. Intake Facilities			1,765,000
1.1 Deep Wells (φ450 mm × H 50 m, Q 800 m^3/d)	well	15	442,000
Submergible Pump (0.56 m^3/min × H 13 m × 4 pumps, 2.2 kw)	set	4	68,000
Submergible Pump (0.56 m^3/min × H 18 m × 11 pumps, 3.7kw)	set	11	195,000
1.2 Connecting Pipelines (including conveyance)			
DIP φ250 mm	m	3,000	414,000
DIP φ200 mm	m	2,400	285,000
DIP φ150 mm	m	1,500	139,000
1.3 Well House (25 m^2 × 15 locations)	m^2	375	222,000
2. Treatment Facilities			1,943,000
2.1 Receiving Well (H 3 m × Area 14 m^2)	m^3	42	54,000
2.2 Chlorinator House (W 7 m×L 15 m)	m^2	105	107,000
2.3 Clear Water Reservoir (W 15 m × L 25 m × H 3.5 m × 3 basins)	m^3	3,938	593,000
2.4 Generator House (50 m^2)	m^2	50	59,000
2.5 Generator (3P 350KVA) and Instrumentation System etc.	L.S.	1	904,000
2.6 Pump Station (100 m^2)	m^2	100	107,000
Distribution Pumps (5 m^3/min × H 40 m, 55 kw)	set	3	119,000
3. Distribution Main (DIP φ500mm × 8,400 m)	m	8,400	2,359,000
Total Cost			6,067,000

1US$ = 120 Yen

Table 6.2.5 Estimated Direct Construction Cost of West Baray System

Description	Unit	Quantity	Amount US $
1. Intake Facilities			582,000
1.1 Intake Weir (Top W 1.0 m × Bottom W 2.5 m × L 16 m × H 2.5 m)	m^3	70	130,000
1.2 Intake Gate and Connecting Culvert	set	1	229,000
1.3 Protection of Banks (W 13 m × L 50 m × 2 sides)	m^2	1,300	223,000
2. Conveying Facilities			884,000
2.1 Pump Well (W 2.0 m × L 6.0 m × H 2.5 m)	m^3	30	83,000
2.2 Pump Station (W 6.0 m × L 12 m × 1 station)	m^2	72	77,000
Pumps, Gate and Valves (4.6 m^3/min × H 19.5 m × 3 pumps, 22 kw)	set	3	136,000
2.3 Conveying Pipeline (DIP φ 400 mm × 2,800 m)	m	2,800	588,000
3. Treatment Plant			4,672,000
3.1 Receiving Well (W 4.0 m × L 4.0 m × D 3.0 m)	m^3	48	57,000
3.2 Flocculation Basins (W 7.0 m × L 6.0 m × D 2.0 m × 2 basins)	m^3	168	121,000
3.3 Sedimentation Basins (W 6.0 m × L 35 m × D 3.5 m × 2 basins)	m^3	1,470	402,000
3.4 Rapid Sand Filters (W 4.0 m × L 7.0 m × 4 beds)	m^2	112	1,017,000
3.5 Chemical Building (W 7.0 m × L 15 m × 2 stories)	m^2	210	129,000
Chlorinators, Lime and Alum Feeding Facilities	L.S.	1	250,000
3.6 Clear Water Reservoir (W 15 m × L 25 m × D 3.5 m × 3 basins)	m^3	3,938	698,000
3.7 Operation Building (W 10 m × L 20 m × 2 stories)	m^2	400	274,000
3.8 Connecting Pipeline etc. (DIPφ600～400mm, L1,000m)	L.S.	1	605,000
3.9 Instrumentation System etc.	L.S.	1	272,000
3.10 Pump Station and Generator etc. (72 m^2, 5.0 m^3/min, 55 kW, 3 pumps)	L.S.	1	847,000
4 Distribution Main (DIPφ500 mm × 8,400 m)	m	8,400	2,359,000
5. Rehabilitation of Dikes of West Baray			1,070,000
5.1 Tree Cutting & Clearing on Inner Surface of Dikes	m^2	600,000	300,000
5.2 Required Embankment Work	m^3	80,000	320,000
5.3 Gravel Metalling of Inspection Road	m^2	80,000	320,000
5.4 Rehabilitation of French Weir, American Weir and Takev Canal	set	1	130,000
Total Cost			9,567,000

1US$ = 120 Yen

Table 6.2.6 Estimated Direct Construction Cost of Siem Reap River System

Description	Unit	Quantity	Amount US $
1. Intake Facilities			579,000
1.1 Intake Weir (Top W 1.0 m × Bottom W 2.5 m × L 25 m × H 2.5 m)	m^3	109	202,000
1.2 Intake Tower (φ3.0 m × H 6.0 m)	m^3	42	156,000
Pumps, Gates and Screen (4.6 m^3/min × H 12 m, 3 pumps, 15 kw)	set	3	221,000
2. Treatment Facilities			4,659,000
2.1 Receiving Well (W 4.0 m × L 4.0 m × D 3.0 m)	m^3	48	57,000
2.2 Flocculation Basins (W 7.0 m × L 6.0 m × D 2.0 m × 2 basins)	m^3	168	121,000
2.3 Sedimentation Basins (W 6.0 m × L 35 m × D 3.5 m × 2 basins)	m^3	1,470	402,000
2.4 Rapid Sand Filters (W 4.0 m × L 7.0 m × 4 beds)	m^2	112	1,017,000
2.5 Chemical Building (W 7.0 m × L 15 m × 2 stories)	m^2	210	129,000
Chlorinators, Lime and Alum Feeding Facilities	L.S.	1	250,000
2.6 Clear Water Reservoir (W 15 m × L 25 m × D 3.5 m × 3 basins)	m^3	3,938	698,000
2.7 Operation Building (W 10 m × L 20 m × 2 stories)	m^2	400	274,000
2.8 Connecting Pipeline etc. (DIPφ600～400 mm, L 1,000 m)	L.S.	1	605,000
2.9 Instrumentation System	L.S.	1	272,000
2.10 Pump Station and Generator etc. (72 m^2, 5.0 m^3/min, 45 kW, 3 pumps)	L.S.	1	834,000
3. Distribution Main (DIPφ450mm × 4,500m)	m	4,500	1,112,000
4. Rehabilitation of North Baray			5,995,000
4.1 Pump Station and Pumps etc. (13.2 m^3/min, 22 kW, 2 pumps)	L.S.	1	287,000
4.2 Water Release Facilities	L.S.	1	220,000
4.3 Rehabilitation of North Baray			0
Clay Blanket (350.4 ha, 30 cm)	m^3	1,051,200	4,731,000
Land Clearing and Leveling (350 ha)	ha	350	700,000
Dikes Embankment (19,000 m^3)	m^3	19,000	57,000
Total Cost			12,345,000

1US$ = 120 Yen

Table 6.2.7 Estimated Direct Construction Cost of Lake Tonle Sap System

Description	Unit	Quantity	Amount US $
1. Intake Facilities			1,921,000
1.1 Intake Head (Steel φ2.0 m × H 1.0 m, 1set)	set	1	184,000
1.2 Intake Pipe (Steel φ500 mm × 4,000 m)	m	4,000	1,123,000
1.3 Intake Pump Station (W 6 m × L 6 m × H 12 m)	m^3	432	194,000
Pump (4.6 m3/min × H 25 m × 3 pumps, 30 kw) and Generator (250 KVA)	L.S.	1	420,000
2. Conveying Facilities			4,669,000
2.1 Conveying Pipeline (DIP φ500 mm × 10,500 m)	m	10,500	2,948,000
2.2 Equipment and Machine	L.S.	1	36,000
3. Treatment Facilities			4,633,000
3.1 Receiving Well (W 4.0 m × L 4.0 m × D 3.0 m)	m^3	48	57,000
3.2 Flocculation Basins (W 7.0 m × L 6.0 m × D 2.0 m × 2 basins)	m^3	168	121,000
3.3 Sedimentation Basins (W 6.0 m × L 35 m × D 3.5 m × 2 basins)	m^3	1,470	402,000
3.4 Rapid Sand Filters (W 4.0 m × L 7.0 m × 4 beds)	m^2	112	1,017,000
3.5 Chemical Building (W 7.0 m × L 15 m × 2 stories)	m^2	210	129,000
Chlorinators, Lime and Alum Feeding Facilities	L.S.	1	250,000
3.6 Clear Water Reservoir (W 15 m × L 25 m × D 3.5 m × 3 basins)	m^3	3,938	698,000
3.7 Operation Building (W 10 m × L 20 m × 2 stories)	m^2	400	274,000
3.8 Connecting Pipeline etc. (DIP φ600～400mm, L1,000m)	L.S.	1	605,000
3.9 Instrumentation System	L.S.	1	272,000
3.10 Pump Station and Generator etc. (72 m^2, 5.0 m^3/min, 45 kW, 3 pumps)	L.S.	1	808,000
4. Distribution Main (DIP φ500 mm × 4,500 m)	m	4,500	1,264,000
Total Cost			12,487,000

1US$ = 120 Yen

Table 6.2.8 Summary of Direct Construction Cost and Land Acquisition Cost

(× 1,000 US$)

Description		Alternative			
		1 Groundwater System	2 West Baray System	3 Siem Reap River System	4 Lake Tonle Sap System
A	Direct Construction Cost				
	Well/Intake	1,765	582	579	1,921
	Raw Water Conveying		884		4,669
	Treatment Plant	1,943	4,672	4,659	4,633
	Distribution Trunk Main	2,359	2,359	1,112	1,264
	Water Source Development		1,070	5,995	
	Subtotal A	6,067	9,567	12,345	12,487
B	Land Acquisition	250	388	750	775
Grand Total		**6,317**	**9,955**	**13,095**	**13,262**
Comparison		**100%**	**158%**	**207%**	**210%**

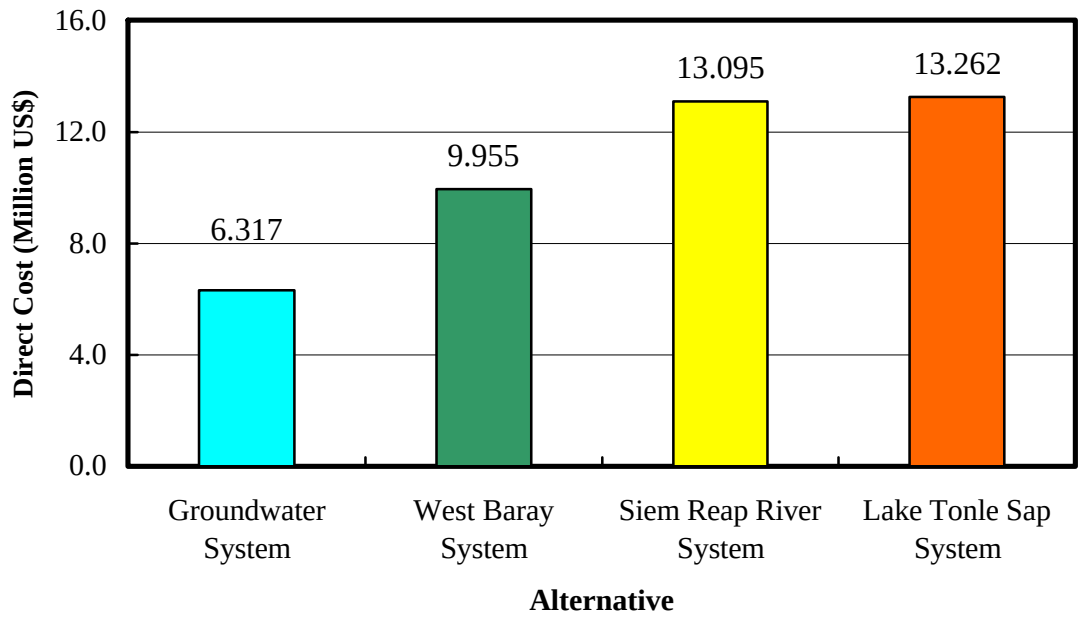

Figure 6.2.1 Comparison of Construction Cost (Direct Cost Only)

Costs shown on the table above are estimated based on capacity of 12,000 m^3/day, unit cost per m^3 is calculated as shown on Table 6.2.9.

Table 6.2.9 Unit Direct Construction Cost per m^3

Alternative		Unit Direct Construction Cost
		US$/$m^3$
1	**Groundwater System**	**526**
2	West Baray System	830
3	Siem Reap River System	1091
4	Lake Tonle Sap System	1105

Note: Above costs include land acquisition costs

6.3 Operation and Maintenance Costs

6.3.1 Electric Power Cost

Load of equipment, operating hours, power consumption per day of each alternative are summarized in Table 6.3.1. The unit cost of electricity in Siem Reap Town is 0.27 US$/kWh, which is 2 times higher than that of Phnom Penh (0.14 US$/kWh). Generally, in a water supply system the electric cost is accounted for a relatively high proportion of the operation cost. To reduce the operation cost, a generator system is proposed to supply electricity for each alternative. Least-cost analysis of investment and operation / maintenance cost for using generator or public electricity is carried out by using present value method as shown on Table 6.3.2. The results indicate that for each alternative the generator system appears to be more economical except alternative 4 - Lake Tonle Sap System.

Power cost and unit power consumption by the generator system are calculated as shown on Table 6.3.3.

Table 6.3.3 Power Cost and Unit Power Consumption

Alternative		Annual Power Cost	Unit Power Cost	Power Consumption
		US$/year	US$/$m^3$	kWh/m^3
1	Groundwater System	120,553	0.033	0.34
2	West Baray System	116,967	0.032	0.33
3	Siem Reap River System	100,609	0.028	0.28
4	Lake Tonle Sap System	119,778	0.033	0.33

Table 6.3.1 Estimation of Electric Power Cost (Alternative Comparison)

Design Maximum Daily Supply $Q_{max.}$ = 12,000 m^3/d

Load Name	Quantity		Capacity	Sub-total	Operating Hours	Operation Rate	Average Power Consumption	Annual Power Consumption	Power Factor and Efficiency	Fuel Cost per kWh	Annual Power Cost	Unit Power Cost	Unit Power Consumption
	Amount	Common Use	(kw)	(kw)		(%)	(kwh/day)	(kwh/year)	(%)	(US$/kwh)	(US$/year)	(US $/$m^{3)}$)	(kwh/$m^{3)}$)
1. Groundwater System													
Submerged Pump													
2.2 kW	4	4	2.2	8.8	24 hr/day		176	64,240			Generator		
3.7 kW	11	11	3.7	40.7	24 hr/day		814	297,110			350 KVA		
Distribution Pump	3	2	55	110	24 hr/day		2,200	803,000			2 sets		
Others (lighting etc.)			10	10	24 hr/day		200	73,000					
Total				169.5		83	3,390	1,237,350	75	0.097	120,553	0.033	0.34
2. West Baray System													
Intake Pump	3	2	22	44	24 hr/day		880	321,200			Generator		
Distribution Pump	3	2	55	110	24 hr/day		2,200	803,000			350 KVA		
Backwash Pump	2	1	11	11	1 hr/day		9	3,346			2 sets		
Others (lighting etc.)			10	10	24 hr/day		200	73,000					
Total				175		83	3,289	1,200,546	75	0.097	116,967	0.032	0.33
3. Siem Reap River System													
Intake Pump	3	2	15	30	24 hr/day		600	219,000					
Distribution Pump	3	2	45	90	24 hr/day		1,800	657,000			Generator		
Backwash Pump	2	1	11	11	1 hr/day		9	3,346			350 KVA		
North Baray Pump	2	1	22	22	12 hr/day		220	80,300			2 sets		
Others (lighting etc.)			10	10	24 hr/day		200	73,000					
Total				163		83	2,829	1,032,646	75	0.097	100,609	0.028	0.28
4. Lake Tonle Sap System													
Intake Pump	3	2	30	60	24 hr/day		1,200	438,000			Generator		
Distribution Pump	3	2	45	90	24 hr/day		1,800	657,000			150+270KVA		
Backwash Pump	2	1	11	11	1 hr/day		9	3,346			2+2 sets		
Others (lighting etc.)			15	15	24 hr/day		300	109,500					
Total				176		83	3,309	1,207,846	75	0.099	119,778	0.033	0.33

Table 6.3.2 Power Consumption and Power Costs

Year		Present Value Rate	Produc-tion	Alternative1-Ground Water System							Alternative 2-West Baray System							Alternative 3-Siem Reap River System							Alternative 4-Lake Tonle Sap System						
				Generator (350 kVA)					Public Supply		Generator (350 kVA)					Public Supply		Generator (350 kVA)					Public Supply		Generator (150 KVA+270 kVA)					Public Supply	
				Invest-ment	Fuel Cost	Mainten-ance Cost	Total Cost	Present Value	Total Cost	Present Value	Invest-ment	Fuel Cost	Mainten-ance Cost	Total Cost	Present Value	Total Cost	Present Value	Invest-ment	Fuel Cost	Mainten-ance Cost	Total Cost	Present Value	Total Cost	Present Value	Invest-ment	Fuel Cost	Mainten-ance Cost	Total Cost	Present Value	Total Cost	Present Value
			m3/d	(×1,000 US$)					(×1,000 US$)		(×1,000 US$)					(×1,000 US$)		(×1,000 US$)					(×1,000 US$)		(×1,000 US$)					(×1,000 US$)	
1	2001	1.000	0	552	0		552	552	0	0	552	0		552	552	0	0	552	0		552	552	0	0	906	0		906	906	0	0
2	2002	0.909	1,242	0	15.0	55.2	70.2	63.8	41.0	37.3	0	14.5	55.2	69.8	63.4	39.8	36.1	0	12.5	55.2	67.7	61.6	34.2	31.1	0	14.9	90.6	105.5	95.9	40.0	36.4
3	2003	0.826	2,293	0	27.6	55.2	82.9	68.5	75.7	62.5	0	26.8	55.2	82.1	67.8	73.4	60.7	0	23.1	55.2	78.3	64.7	63.1	52.2	0	27.5	90.6	118.1	97.6	73.9	61.0
4	2004	0.751	3,522	0	42.5	55.2	97.7	73.4	116.2	87.3	0	41.2	55.2	96.4	72.5	112.8	84.7	0	35.4	55.2	90.7	68.1	97.0	72.9	0	42.2	90.6	132.8	99.8	113.4	85.2
5	2005	0.683	4,598	0	55.4	55.2	110.7	75.6	151.7	103.6	0	53.8	55.2	109.0	74.5	147.2	100.5	0	46.3	55.2	101.5	69.3	126.6	86.5	0	55.1	90.6	145.7	99.5	148.1	101.2
6	2006	0.621	5,408	0	65.2	55.2	120.4	74.8	178.4	110.8	0	63.3	55.2	118.5	73.6	173.1	107.5	0	54.4	55.2	109.6	68.1	148.9	92.5	0	64.8	90.6	155.4	96.5	174.2	108.2
7	2007	0.564	7,253	0	87.4	55.2	142.7	80.5	239.3	135.1	0	84.8	55.2	140.1	79.1	232.2	131.1	0	73.0	55.2	128.2	72.4	199.7	112.7	0	86.9	90.6	177.5	100.2	233.6	131.9
8	2008	0.513	8,091	0	97.5	55.2	152.8	78.4	267.0	137.0	0	94.6	55.2	149.9	76.9	259.0	132.9	0	81.4	55.2	136.6	70.1	222.8	114.3	0	96.9	90.6	187.5	96.2	260.6	133.7
9	2009	0.467	8,592	0	103.6	55.2	158.8	74.1	283.5	132.3	0	100.5	55.2	155.7	72.7	275.1	128.3	0	86.4	55.2	141.7	66.1	236.6	110.4	0	102.9	90.6	193.5	90.3	276.7	129.1
10	2010	0.424	9,096	0	109.7	55.2	164.9	69.9	300.1	127.3	0	106.4	55.2	161.6	68.5	291.2	123.5	0	91.5	55.2	146.7	62.2	250.5	106.2	0	109.0	90.6	199.6	84.6	293.0	124.3
11	2011	0.386	9,531	552	114.9	55.2	722.5	278.5	314.5	121.2	552	111.5	55.2	719.1	277.2	305.1	117.6	552	95.9	55.2	703.5	271.2	262.5	101.2	906	114.2	90.6	1,110.8	428.3	307.0	118.4
12	2012	0.350	9,909	0	119.5	55.2	174.7	61.2	327.0	114.6	0	115.9	55.2	171.1	60.0	317.2	111.2	0	99.7	55.2	154.9	54.3	272.9	95.6	0	118.7	90.6	209.3	73.4	319.2	111.9
13	2013	0.319	10,374	0	125.1	55.2	180.3	57.4	342.3	109.1	0	121.3	55.2	176.6	56.3	332.1	105.8	0	104.4	55.2	159.6	50.9	285.7	91.0	0	124.3	90.6	214.9	68.5	334.1	106.5
14	2014	0.290	12,000	0	144.7	55.2	199.9	57.9	396.0	114.7	0	140.4	55.2	195.6	56.7	384.2	111.3	0	120.7	55.2	176.0	51.0	330.4	95.7	0	143.7	90.6	234.3	67.9	386.5	112.0
15	2015	0.263	12,000	0	144.7	55.2	199.9	52.6	396.0	104.3	0	140.4	55.2	195.6	51.5	384.2	101.2	0	120.7	55.2	176.0	46.3	330.4	87.0	0	143.7	90.6	234.3	61.7	386.5	101.8
16	2016	0.239	12,000	0	144.7	55.2	199.9	47.9	396.0	94.8	0	140.4	55.2	195.6	46.8	384.2	92.0	0	120.7	55.2	176.0	42.1	330.4	79.1	0	143.7	90.6	234.3	56.1	386.5	92.5
17	2017	0.218	12,000	0	144.7	55.2	199.9	43.5	396.0	86.2	0	140.4	55.2	195.6	42.6	384.2	83.6	0	120.7	55.2	176.0	38.3	330.4	71.9	0	143.7	90.6	234.3	51.0	386.5	84.1
18	2018	0.198	12,000	0	144.7	55.2	199.9	39.5	396.0	78.3	0	140.4	55.2	195.6	38.7	384.2	76.0	0	120.7	55.2	176.0	34.8	330.4	65.4	0	143.7	90.6	234.3	46.4	386.5	76.5
19	2019	0.180	12,000	0	144.7	55.2	199.9	36.0	396.0	71.2	0	140.4	55.2	195.6	35.2	384.2	69.1	0	120.7	55.2	176.0	31.6	330.4	59.4	0	143.7	90.6	234.3	42.1	386.5	69.5
20	2020	0.164	12,000	0	144.7	55.2	199.9	32.7	396.0	64.7	0	140.4	55.2	195.6	32.0	384.2	62.8	0	120.7	55.2	176.0	28.8	330.4	54.0	0	143.7	90.6	234.3	38.3	386.5	63.2
21	2021	0.149	12,000	552	144.7	55.2	752.3	111.8	396.0	58.9	552	140.4	55.2	747.9	111.2	384.2	57.1	552	120.7	55.2	728.3	108.3	330.4	49.1	906	143.7	90.6	1,140.4	169.5	386.5	57.5
22	2022	0.135	12,000	0	144.7	55.2	199.9	27.0	396.0	53.5	0	140.4	55.2	195.6	26.4	384.2	51.9	0	120.7	55.2	176.0	23.8	330.4	44.7	0	143.7	90.6	234.3	31.7	386.5	52.2
23	2023	0.123	12,000	0	144.7	55.2	199.9	24.6	396.0	48.6	0	140.4	55.2	195.6	24.0	384.2	47.2	0	120.7	55.2	176.0	21.6	330.4	40.6	0	143.7	90.6	234.3	28.8	386.5	47.5
24	2024	0.112	12,000	0	144.7	55.2	199.9	22.3	396.0	44.2	0	140.4	55.2	195.6	21.8	384.2	42.9	0	120.7	55.2	176.0	19.7	330.4	36.9	0	143.7	90.6	234.3	26.2	386.5	43.2
25	2025	0.102	12,000	0	144.7	55.2	199.9	20.3	396.0	40.2	0	140.4	55.2	195.6	19.9	384.2	39.0	0	120.7	55.2	176.0	17.9	330.4	33.5	0	143.7	90.6	234.3	23.8	386.5	39.2
26	2026	0.092	12,000	0	144.7	55.2	199.9	18.4	396.0	36.5	0	140.4	55.2	195.6	18.1	384.2	35.5	0	120.7	55.2	176.0	16.2	330.4	30.5	0	143.7	90.6	234.3	21.6	386.5	35.7
27	2027	0.084	12,000	0	144.7	55.2	199.9	16.8	396.0	33.2	0	140.4	55.2	195.6	16.4	384.2	32.2	0	120.7	55.2	176.0	14.8	330.4	27.7	0	143.7	90.6	234.3	19.7	386.5	32.4
28	2028	0.076	12,000	0	144.7	55.2	199.9	15.2	396.0	30.2	0	140.4	55.2	195.6	14.9	384.2	29.3	0	120.7	55.2	176.0	13.4	330.4	25.2	0	143.7	90.6	234.3	17.9	386.5	29.5
29	2029	0.069	12,000	0	144.7	55.2	199.9	13.9	396.0	27.5	0	140.4	55.2	195.6	13.6	384.2	26.6	0	120.7	55.2	176.0	12.2	330.4	22.9	0	143.7	90.6	234.3	16.2	386.5	26.8
30	2030	0.063	12,000	0	144.7	55.2	199.9	12.6	396.0	25.0	0	140.4	55.2	195.6	12.3	384.2	24.2	0	120.7	55.2	176.0	11.1	330.4	20.8	0	143.7	90.6	234.3	14.8	386.5	24.4
Total								2,202		2,290					2,177		2,222					2,063		1,911					3,070		2,235

The Results of Comparison

Item	Ground Water System	West Baray System	Siem Reap River System	Lake Tonle Sap System	Condition of Comparison
Total Present Value (×1000Yen) Generator	2,202	2,177	2,063	3,070	Discount Rate = 10.0% Fuel Cost = 0.3 US$/l Fuel Consumption = 30.1l/h (150kVA), 53.2 l/h (270kVA), 68.2 l/h (350kVA) Maintenance Cost = Generator Initial Investment × 10% Generator Life = 10 Years
Total Present Value (×1000Yen) Public Electricity	2,290	2,222	1,911	2,235	Discount Rate = 10% , 1 US$= 120 Yen Unit Public Electricity Cost = 0.2 US$/kWh, Maintenance = 0
Unit Public Electricity Cost (US$/kwh) (Total PVGenerator= Total PVPublic Electricity)	0.192	0.196	0.216	0.275	

6.3.2 Chemicals Cost

The dosage of coagulant (aluminum sulphate), pH control chemical (lime) and disinfectant (chlorine gas) in each alternative, and the unit costs of each chemical are summarized in Table 6.3.4. The unit costs of aluminum sulphate, lime and chlorine are proposed to be 235 US$/ton, 150 US$/ton and 1,000 US$/ton taking into account the unit cost of chemicals in Phnom Penh and Siem Reap.

Table 6.3.4 Estimation of Chemicals Costs

Item	Unit	Groundwater System	West Baray System	Siem Reap River System	Lake Tonle Sap System
Design Maximum Daily Supply	m^3/d	12,000	12,000	12,000	12,000
Operation Rate (Peak Factor=1.2)	%	83	83	83	83
Design Average Daily Supply	m^3/d	10,000	10,000	10,000	10,000
Annual Average Supply	m^3/year	3,650,000	3,650,000	3,650,000	3,650,000
Dosage of Aluminum Sulfate	mg/l	0	20.0	30.0	40.0
Annual Consumption of Alum	ton/year	0	73	110	146
Unit Cost of Alum (Phnom Penh)	US $/ton	235	235	235	235
Annual Alum Cost	US $/year	0	17,155	25,733	34,310
Dosage of Chlorine	mg/l	4.0	2.0	2.0	2.0
Annual Consumption of Chlorine	ton/year	15	7	7	7
Unit Cost of Chlorine	US $/ton	1,000	1,000	1,000	1,000
Annual Chlorine Cost	US $/year	14,600	7,300	7,300	7,300
Dosage of Lime	mg/l	20.0	10.0	15.0	20.0
Annual Consumption of Lime	ton/year	73	37	55	73
Unit Cost of Lime	US $/ton	150	150	150	150
Annual Lime Cost	US $/year	10,950	5,475	8,213	10,950
Average Annual Chemical Cost (83% operation rate)	US $/year	25,550	29,930	41,245	52,560
Unit Cost of Chemicals	US $/$m^3$	0.0070	0.0082	0.0113	0.0144

Based on the unit cost of chemical and estimated dosage rate, calculated chemical cost of each alternative is shown on Table 6.3.5.

Table 6.3.5 Chemicals Cost

Alternative		Chemicals Cost	
		US$/year	US$/$m^3$
1	**Groundwater System**	**25,550**	**0.007**
2	West Baray System	29,930	0.008
3	Siem Reap River System	41,245	0.011
4	Lake Tonle Sap System	52,560	0.014

6.3.3 Personnel Cost

According to the results of organizational study, the total number of employees in Groundwater System, West Baray System, Siem Reap River System and Lake Tonle Sap System are 25, 25, 25 and 29, respectively, and those employees are divided into the following categories:

Qualified Administrator
Engineer
Clerk
Skilled Worker
Technician, and
Worker

Considering the monthly salary (50 US$ to 600 US$) of employees working in Phnom Penh Water Supply Authority (PPWSA), the monthly salary of employees for each category is proposed as followings:

Director	:	450 US$
Deputy Director	:	350 US$
Engineer	:	350 US$
Clerk	:	200 US$
Technician	:	200 US$
Assistant Technician	:	100 US$

Based on the number of staff and monthly salary shown above, Unit Personnel Cost is calculated as shown on Table 6.3.6 and summarized as shown on Table 6.3.7.

Table 6.3.6 Estimation of Personnel Costs

Item	Unit	Groundwater System	West Baray System	Siem Reap River System	Lake Tonle Sap System
		Q=12,000m^3/d	Q=12,000m^3/d	Q=12,000m^3/d	Q=12,000m^3/d
Director	Person	1	1	1	1
Monthly Salary	US$/man･month	450	450	450	450
Dep. Director	Person	2	2	2	2
Monthly Salary	US$/man･month	350	350	350	350
Engineer	Person	2	2	2	2
Monthly Salary	US$/man･month	350	350	350	350
Clerk	Person	2	2	2	2
Monthly Salary	US$/man･month	200	200	200	200
Technician	Person	7	7	7	7
Monthly Salary	US$/man･month	200	200	200	200
Assist. Technician	Person	11	11	11	15
Monthly Salary	US$/man･month	100	100	100	100
Total Number of Staff	Person	25	25	25	29
Annual Personnel Costs	US$/year	57,000	57,000	57,000	61,800
Unit Personnel Cost	US $/m^3	0.016	0.016	0.016	0.017

Table 6.3.7 Unit Personnel Cost

Alternative		Personnel Cost	
		US$/year	US$/m^3
1	Groundwater System	57,000	0.016
2	West Baray System	57,000	0.016
3	Siem Reap River System	57,000	0.016
4	Lake Tonle Sap System	61,800	0.017

6.3.4 Maintenance Cost

The maintenance costs for each alternative has been estimated as a percentage (1%) of accumulated direct construction costs as shown on Table 6.3.8.

Table 6.3.8 Maintenance Cost

Alternative		Maintenance Cost	
		US$/year	US$/m^3
1	**Groundwater System**	**60,670**	**0.017**
2	West Baray System	95,670	0.026
3	Siem Reap River System	123,450	0.034
4	Lake Tonle Sap System	124,870	0.034

6.3.5 Summary of Operation and Maintenance Cost

From the unit cost of electric power cost, chemical cost, personnel cost and maintenance cost described above, total unit operation and maintenance cost was calculated as shown on Table 6.3.9 and Figure 6.3.1.

The Alternative – 1 : Groundwater System has the lowest operation and maintenance costs.

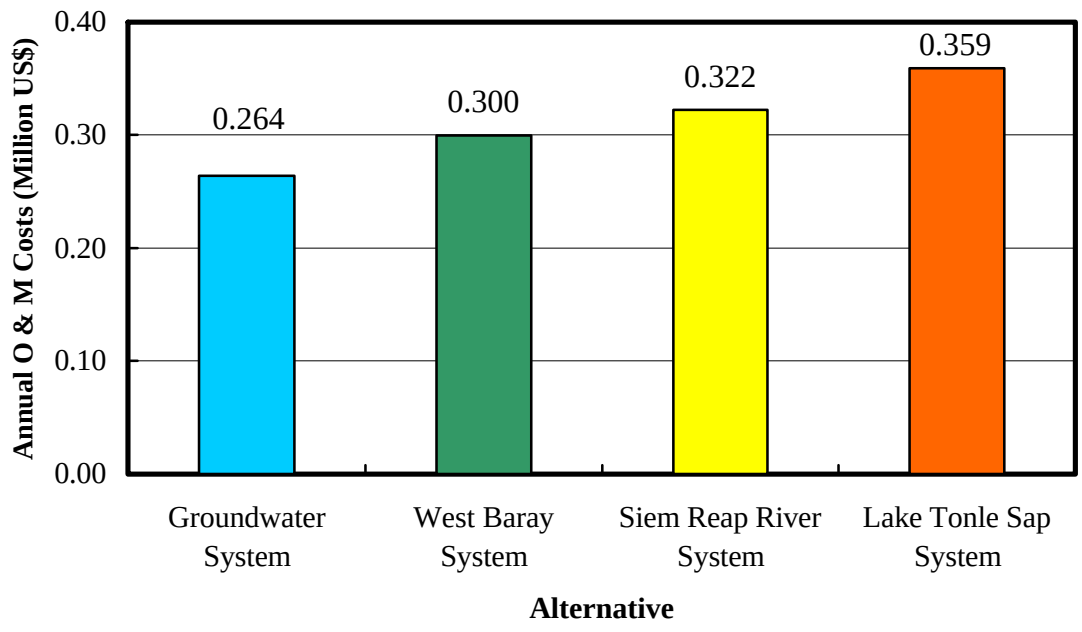

Figure 6.3.1 Comparison of Annual Operation and Maintenance Costs

Table 6.3.9 Operation and Maintenance Costs

Item	1.Groundwater System			2.West Baray System			3.Siem Reap River System			4.Lake Tonle Sap System		
	US$/$m^3$	US$/year	%	US$/$m^3$	US$/year	%	US$/$m^3$	US$/year	%	US$/$m^3$	US$/year	%
Electric Power Cost	0.033	120,553	59	0.032	116,967	57	0.028	100,609	51	0.033	119,778	51
Chemical Cost	0.007	25,550	13	0.008	29,930	15	0.011	41,245	21	0.014	52,560	22
Personnel Cost	0.016	57,000	28	0.016	57,000	28	0.016	57,000	29	0.017	61,800	26
Total Operation Cost	0.057	207,157	100	0.056	203,897	100	0.054	198,854	100	0.064	234,138	100
Maintenance Cost	0.017	60,670		0.026	95,670		0.034	123,450		0.034	124,870	
Annual O & M Cost	263,773			299,567			322,304			359,008		
Unit O & M Cost (US$/$m^3$)	0.072			0.082			0.088			0.098		
Comparison	100 %			114 %			122 %			136 %		

6.4 Results of Cost Comparison

The direct construction costs, which includes construction cost of water source development and water supply facilities, and operation and maintenance cost of respective alternatives are combined and compared by net preset value.

Conditions of calculation of the net present value are as follows;

- Construction cost will be disbursed in year 2001 (70%) and year 2002 (30%).
- Operation and maintenance cost will be spent in every year conforming to the production of each year.
- Mechanical and electrical equipment will be replaced after 15 years and cost for the replacement will be disbursed.
- Duration of the net present value calculation is 30 years.
- Discount rate is 10% per annum.

Results of net present value calculation are shown on Tables 6.4.1 to 6.4.4 and summarized on Table 6.4.5 and Figure 6.4.1. The Alternative – 1 : Groundwater System shows the lowest present value.

Table 6.4.5 Comparison of Net Present Value

Alternative		Net Present Value (US$)	Comparison
1	**Groundwater System**	**7,508,438**	**100 %**
2	West Baray System	11,246,262	150 %
3	Siem Reap River System	14,260,995	190 %
4	Lake Tonle Sap System	14,626,343	195 %

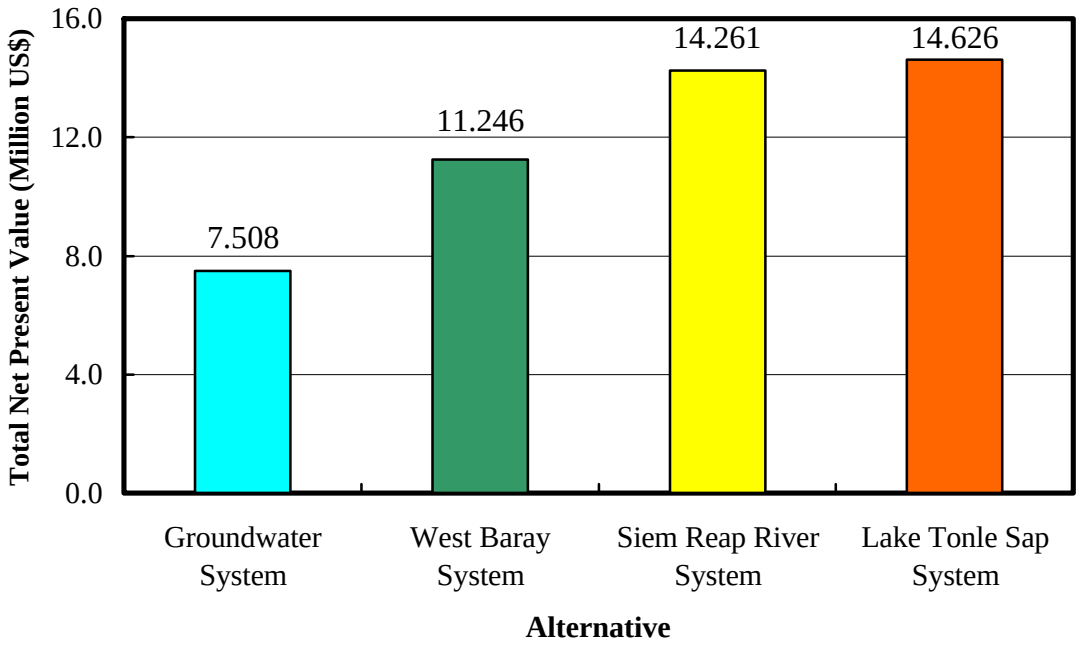

Figure 6.4.1 Comparison of Total Net Present Value
(Discount Rate=10%, 30 Years)

Table 6.4.1 Present Value of Alternative 1 - Groundwater System

Year		Production	Direct Cost	O&M Cost	Total Cost	Present Value Rate	Net Present Value
		m^3/d	US$	US$	US$		US$
1	2001	0	4,421,900	0	4,421,900	0.9091	4,019,909
2	2002	1,242	1,895,100	130,271	2,025,371	0.8264	1,673,861
3	2003	2,293		140,935	140,935	0.7513	105,886
4	2004	3,522		153,404	153,404	0.6830	104,777
5	2005	4,598		164,322	164,322	0.6209	102,031
6	2006	5,408		172,540	172,540	0.5645	97,394
7	2007	7,253		191,259	191,259	0.5132	98,146
8	2008	8,091		199,762	199,762	0.4665	93,190
9	2009	8,592		204,845	204,845	0.4241	86,874
10	2010	9,096		209,959	209,959	0.3855	80,948
11	2011	9,531		214,372	214,372	0.3505	75,136
12	2012	9,909		218,207	218,207	0.3186	69,528
13	2013	10,374		222,925	222,925	0.2897	64,573
14	2014	12,000		239,423	239,423	0.2633	63,047
15	2015	12,000		239,423	239,423	0.2394	57,316
16	2016	12,000	1,286,000	239,423	1,525,423	0.2176	331,976
17	2017	12,000		239,423	239,423	0.1978	47,369
18	2018	12,000		239,423	239,423	0.1799	43,062
19	2019	12,000		239,423	239,423	0.1635	39,148
20	2020	12,000		239,423	239,423	0.1486	35,589
21	2021	12,000		239,423	239,423	0.1351	32,353
22	2022	12,000		239,423	239,423	0.1228	29,412
23	2023	12,000		239,423	239,423	0.1117	26,738
24	2024	12,000		239,423	239,423	0.1015	24,308
25	2025	12,000		239,423	239,423	0.0923	22,098
26	2026	12,000		239,423	239,423	0.0839	20,089
27	2027	12,000		239,423	239,423	0.0763	18,263
28	2028	12,000		239,423	239,423	0.0693	16,602
29	2029	12,000		239,423	239,423	0.0630	15,093
30	2030	12,000		239,423	239,423	0.0573	13,721
Total							7,508,438

Condition

1) Construction Cost disbursed 70% in year 2001, 30% in year 2002.
2) Discount Rate = 10%
3) Equipment Life = 15 Years
4) Treatment Facilities Life = 30 Years
5) Operation and maintenance costs in each year varied with the water production

Table 6.4.2 Present Value of Alternative 2 - West Baray System

Year		Production	Direct Cost	O&M Cost	Total Cost	Present Value Rate	Net Present Value
		m^3/d	US$	US$	US$		US$
1	2001	0	6,968,150	0	6,968,150	0.9091	6,334,682
2	2002	1,242	2,986,350	165,340	3,151,690	0.8264	2,604,702
3	2003	2,293		176,061	176,061	0.7513	132,278
4	2004	3,522		188,599	188,599	0.6830	128,815
5	2005	4,598		199,575	199,575	0.6209	123,920
6	2006	5,408		207,838	207,838	0.5645	117,319
7	2007	7,253		226,659	226,659	0.5132	116,312
8	2008	8,091		235,208	235,208	0.4665	109,726
9	2009	8,592		240,319	240,319	0.4241	101,919
10	2010	9,096		245,460	245,460	0.3855	94,636
11	2011	9,531		249,898	249,898	0.3505	87,588
12	2012	9,909		253,754	253,754	0.3186	80,854
13	2013	10,374		258,497	258,497	0.2897	74,877
14	2014	12,000		275,085	275,085	0.2633	72,438
15	2015	12,000		275,085	275,085	0.2394	65,853
16	2016	12,000	2,295,000	275,085	2,570,085	0.2176	559,325
17	2017	12,000		275,085	275,085	0.1978	54,424
18	2018	12,000		275,085	275,085	0.1799	49,476
19	2019	12,000		275,085	275,085	0.1635	44,979
20	2020	12,000		275,085	275,085	0.1486	40,890
21	2021	12,000		275,085	275,085	0.1351	37,172
22	2022	12,000		275,085	275,085	0.1228	33,793
23	2023	12,000		275,085	275,085	0.1117	30,721
24	2024	12,000		275,085	275,085	0.1015	27,928
25	2025	12,000		275,085	275,085	0.0923	25,389
26	2026	12,000		275,085	275,085	0.0839	23,081
27	2027	12,000		275,085	275,085	0.0763	20,983
28	2028	12,000		275,085	275,085	0.0693	19,075
29	2029	12,000		275,085	275,085	0.0630	17,341
30	2030	12,000		275,085	275,085	0.0573	15,765
Total							11,246,262

Condition

1) Construction Cost disbursed 70% in year 2001, 30% in year 2002.
2) Discount Rate = 10%
3) Equipment Life = 15 Years
4) Treatment Facilities Life = 30 Years
5) Operation and maintenance costs in each year varied with the water production

Table 6.4.3 Present Value of Alternative 3 - Siem Reap River System

Year		Production	Direct Cost	O&M Cost	Total Cost	Present Value Rate	Net Present Value
		m^3/d	US$	US$	US$		US$
1	2001	0	9,166,500	0	9,166,500	0.9091	8,333,182
2	2002	1,242	3,928,500	192,685	4,121,185	0.8264	3,405,938
3	2003	2,293		203,038	203,038	0.7513	152,546
4	2004	3,522		215,145	215,145	0.6830	146,947
5	2005	4,598		225,745	225,745	0.6209	140,170
6	2006	5,408		233,724	233,724	0.5645	131,931
7	2007	7,253		251,899	251,899	0.5132	129,264
8	2008	8,091		260,154	260,154	0.4665	121,364
9	2009	8,592		265,090	265,090	0.4241	112,424
10	2010	9,096		270,055	270,055	0.3855	104,118
11	2011	9,531		274,340	274,340	0.3505	96,154
12	2012	9,909		278,063	278,063	0.3186	88,600
13	2013	10,374		282,644	282,644	0.2897	81,872
14	2014	12,000		298,662	298,662	0.2633	78,647
15	2015	12,000		298,662	298,662	0.2394	71,497
16	2016	12,000	2,401,000	298,662	2,699,662	0.2176	587,525
17	2017	12,000		298,662	298,662	0.1978	59,089
18	2018	12,000		298,662	298,662	0.1799	53,717
19	2019	12,000		298,662	298,662	0.1635	48,834
20	2020	12,000		298,662	298,662	0.1486	44,394
21	2021	12,000		298,662	298,662	0.1351	40,358
22	2022	12,000		298,662	298,662	0.1228	36,689
23	2023	12,000		298,662	298,662	0.1117	33,354
24	2024	12,000		298,662	298,662	0.1015	30,322
25	2025	12,000		298,662	298,662	0.0923	27,565
26	2026	12,000		298,662	298,662	0.0839	25,059
27	2027	12,000		298,662	298,662	0.0763	22,781
28	2028	12,000		298,662	298,662	0.0693	20,710
29	2029	12,000		298,662	298,662	0.0630	18,827
30	2030	12,000		298,662	298,662	0.0573	17,116
Total							14,260,995

Condition

1) Construction Cost disbursed 70% in year 2001, 30% in year 2002.
2) Discount Rate = 10%
3) Equipment Life = 15 Years
4) Treatment Facilities Life = 30 Years
5) Operation and maintenance costs in each year varied with the water production

Table 6.4.4 Present Value of Alternative 4 - Lake Tonle Sap System

Year		Production	Direct Cost	O&M Cost	Total Cost	Present Value Rate	Net Present Value
		m^3/d	US$	US$	US$		US$
1	2001	0	9,283,400	0	9,283,400	0.9091	8,439,455
2	2002	1,242	3,978,600	201,534	4,180,134	0.8264	3,454,656
3	2003	2,293		214,112	214,112	0.7513	160,866
4	2004	3,522		228,821	228,821	0.6830	156,288
5	2005	4,598		241,698	241,698	0.6209	150,076
6	2006	5,408		251,393	251,393	0.5645	141,905
7	2007	7,253		273,473	273,473	0.5132	140,335
8	2008	8,091		283,502	283,502	0.4665	132,256
9	2009	8,592		289,498	289,498	0.4241	122,776
10	2010	9,096		295,530	295,530	0.3855	113,940
11	2011	9,531		300,736	300,736	0.3505	105,406
12	2012	9,909		305,260	305,260	0.3186	97,265
13	2013	10,374		310,825	310,825	0.2897	90,035
14	2014	12,000		330,285	330,285	0.2633	86,974
15	2015	12,000		330,285	330,285	0.2394	79,068
16	2016	12,000	2,544,000	330,285	2,874,285	0.2176	625,528
17	2017	12,000		330,285	330,285	0.1978	65,345
18	2018	12,000		330,285	330,285	0.1799	59,405
19	2019	12,000		330,285	330,285	0.1635	54,004
20	2020	12,000		330,285	330,285	0.1486	49,095
21	2021	12,000		330,285	330,285	0.1351	44,632
22	2022	12,000		330,285	330,285	0.1228	40,574
23	2023	12,000		330,285	330,285	0.1117	36,886
24	2024	12,000		330,285	330,285	0.1015	33,532
25	2025	12,000		330,285	330,285	0.0923	30,484
26	2026	12,000		330,285	330,285	0.0839	27,713
27	2027	12,000		330,285	330,285	0.0763	25,193
28	2028	12,000		330,285	330,285	0.0693	22,903
29	2029	12,000		330,285	330,285	0.0630	20,821
30	2030	12,000		330,285	330,285	0.0573	18,928
Total							14,626,343

Condition

1) Construction Cost disbursed 70% in year 2001, 30% in year 2002.
2) Discount Rate = 10%
3) Equipment Life = 15 Years
4) Treatment Facilities Life = 30 Years
5) Operation and maintenance costs in each year varied with the water production

7. Comprehensive Comparison and Selection of the Best Alternative

In the previous section, direct construction cost and operation/maintenance costs were estimated and compared. As a results of comparison, the Alternative – 1 : Groundwater System is found to be the most economical option.

Cost is one of the most important criteria for the comparative study. However for the selection of the most suitable water source, the following criteria are also considered.

1) Costs
2) Easy Operation and Maintenance
3) Less Impact to Angkor Heritage
4) Reliability
5) Stable and Suitable Water Quality
6) Flexibility of the System
7) Less Impact to Environment

Each alternative is evaluated by this criteria and the results of the evaluation are shown on Table 7.1.

Table 7.1 Results of Evaluation

Criteria	Alternatives			
	Alternative – 1 Groundwater System	Alternative - 2 West Baray System	Alternative - 3 Siem Reap River System	Alternative - 4 Lake Tonle Sap System
Costs	◎	○	△	×
Easy Operation and Maintenance	◎	○	△	×
Less Impact to Angkor Heritage	○	○	○	◎
Reliability	◎	○	○	◎
Stable and Suitable Water Quality	◎	◎	○	○
Flexibility of the System	◎	○	○	○
Less Impact to Environment	◎	○	○	×

Note : Good ◎ <- ○ -- △-> × Bad

From the results of evaluation shown above, Alternative – 1 : Groundwater System is the most suitable alternative and recommendable as a water source for the Siem Reap Water Supply System.

However, for future water supply system after the Year 2010, West Baray System, Siem Reap River System, and Lake Tonle Sap System including further development of groundwater should be considered as an option.