ANNEX 4.4.1

EXISTING WATER SUPPLY SYSTEM

THE STUDY ON WATER SUPPLY SYSTEM
FOR SIEM REAP REGION IN CAMBODIA

FINAL REPORT
Vol. III SUPPORTING REPORT

ANNEX 4.4.1 EXISTING WATER SUPPLY SYSTEM

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ANNEX 4.4.1 EXISTING WATER SUPPLY SYSTEM

1. Introduction

Public piped water supply system in Siem Reap Town is under responsibility of the Siem Reap Waterworks, which is one of the waterworks controlled by the Ministry of Industry, Mines, and Energy (MIME). It should be noted that the Siem Reap Waterworks does not have direct organizational relation with the Provincial Government of Siem Reap.

The first public piped water supply system was established in the 1930's by French aid. The system so called "Old French System" was consisted of treatment plant taking its raw water from the Siem Reap River and small-scale distribution system. The treatment plant was constructed on the corner of crossing National Road No. 6 and Siem Reap River.

The second system was constructed in 1960's by American aid and the Old French System was abandoned at this time. This Old American System also took its raw water from the Siem Reap River. The treatment plant was constructed in the premises of the Old French System treatment plant. Distribution system was expanded to cover the central part of the Siem Reap Town. This system had been operated until March 1995; water treatment was terminated and the Waterworks stopped its public water supply services because of deterioration of raw water quality of the Siem Reap River and deterioration of the facilities.

MIME commenced construction of a new water supply system using groundwater in 1995 financed by French aid. Two deep wells were dug in the existing treatment plant. However, groundwater from these two deep wells contains high iron and it was not suitable for drinking. To remove the high iron contents, aeration facility and pressure filters were additionally installed. This New French System was completed in September 1998.

Although the New French System was completed in September 1998, MIME did not approve its inauguration because MIME considered that the Waterworks could not afford to the electrical cost for operation.

In 1999, PDIME Siem Reap received a grant of US$ 299,000 from UNDP to finish the remaining work of the New French System, rehabilitation of distribution network, and administrative development. Disbursement period was completed in the end of May 1999. Finishing work of the plant was completed at that time; however, rehabilitation work on distribution network had not been completed.

After that, Waterworks continues its effort to rehabilitate the distribution networks. Waterworks operates its treatment plant to check distribution system by feeding treated water to existing distribution network and the Waterworks tried to find pipe break or leakage. Once pipe break or leak point is found, Waterworks repairs the pipe. This pipe rehabilitation work has been conducted from June 1999 to date, and finally Waterworks started its water supply services from the end of July 1999 even though distribution network rehabilitation work had not been completed and there still many problems on distribution network.

During this pipe rehabilitation work, PDIME has been negotiated with public electric supply about concession electric rate and PDIME finally received special rate, discounted from US$ 0.23/kWh to US$ 0.195/kWh.

2. Old French System

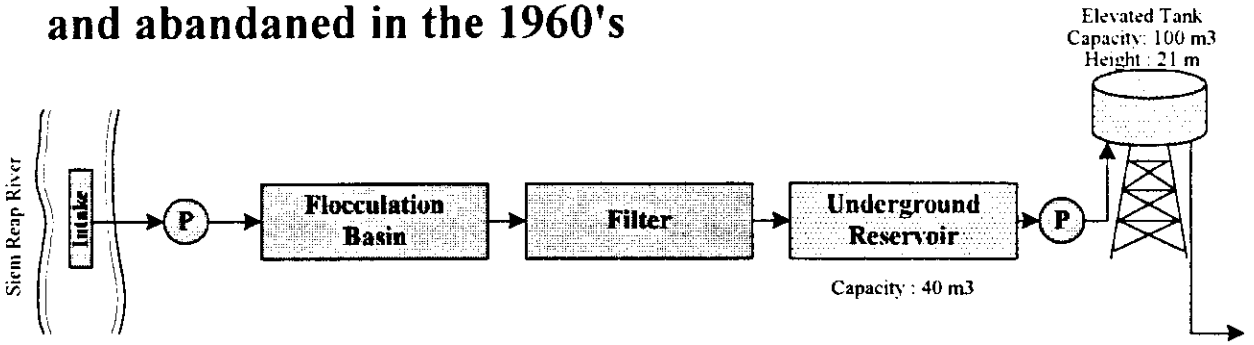
Details of the Old French System, which was constructed in the 1930's, are not known now but its treatment system seems to be as shown on Figure 2.1 according to interview from the staff of the Waterworks.

Raw water was taken from the Siem Reap River. Intake structure was constructed about 50 m upstream from the bridge on the National Road No. 6. Raw water was pumped up to flocculation basin and coagulated by dozing alum. After flocculation basin, water was conveyed to filtration basin and filtered water was stored in underground reservoir. Treated water was distributed by distribution pumps through elevated tank of which height is 21 m. Production capacity of the plant is unknown.

All structures except the underground reservoir and the elevated tank were demolished when the Old American System was constructed, therefore details of each facility can not be investigated. The reservoir and the elevated tank still exist but they are not used now.

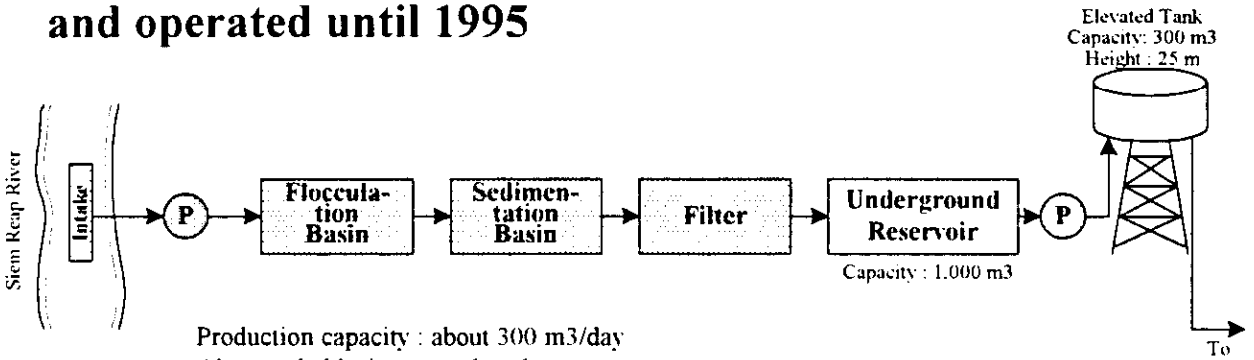
Treated water was distributed to Grand Hotel and houses in very limited area near from the Plant. Drawings of the distribution network do not exist anymore.

Old French System constructed in the 1930's and abandaned in the 1960's



Production capacity of this system is unknown. Alum and chlorine seem to be dozed.

Old American System constructed in the 1960's and operated until 1995



Production capacity : about 300 m3/day
Alum and chlorine were dozed.
Operation was terminated in 1995 because of deteriorated water quality of the Siem Reap River.

Structure is demolished

Structure exists but not used operated

Structure which is used operated as a part of a New French System

The Study on Water Supply System for Siem Reap Region in Cambodia	**Figure 2.1** Schematic Flow of Treatment System (Old French System and Old American System)
Japan International Cooperation Agency	

3. Old American System

The Old American System was constructed by demolishing the Old French System in 1960's financed by American aid. Treatment system was as shown also on Figure 2.1. The plant capacity was about 300 m^3/day. However, actual treatment capacity was less than 150 m^3/day according to the information from the Waterworks. Raw water was taken from the Siem Reap River as same as the Old French System through a new intake facility constructed about 100 m upstream from the former intake. Raw water was transmitted by intake pumps to up down flow type flocculation basin. Alum, which was transported from Phnom Penh, was dozed as a coagulant. Although the alum from Vietnam was available but the quality was not acceptable. Sedimentation basin had 4 separated basins and then water was transmitted to filters. Filter was rapid sand filtration system and there were two filter beds. Filtered water was conveyed to underground reservoir of which capacity was 1,000 m^3. Treated water was pumped up to the new-elevated tank and sent to distribution network.

This Old American System had been operated until March 1995. Operation of the Plant was terminated in 1995 because of deterioration of raw water quality of the Siem Reap River and because facilities became too old to operate. Deterioration of river water quality was resulted from domestic wastewater inflow, throwing garbage to the river and open defecation along the river. They are because lacking of appropriate wastewater treatment, solid waste control and sanitation facilities.

According to the information from the Waterworks, this Old American System had been operated in good condition in aspect of treated water quality only for one year after its inauguration. This System employed rapid sand filtration and washed-out sand was never refilled. After one year from its inauguration, sand in the filter bed was completely washed-out and the Waterworks could not find sand for refill in Siem Reap. Filtration, the most important process of water treatment, had not been functioned almost entire life period of the Old American System.

Concrete structures of flocculation, sedimentation and filtration basins still exist but surface of concrete has been eroded and they can not be used anymore.

Distribution network was constructed at the same time of the construction of the treatment plant. This distribution network covers rather larger area than the Old French System but still limited in the central part of the Siem Reap Town. When the distribution pipelines were installed, pipelines installed under the Old French

System were completely abandoned.

Range of diameter was 100 mm to 250 mm and the material of the distribution pipeline was ACP. Alignment of the distribution network is shown on Figure 3.1.

Number of connection supplied by the Old American System was 207 in total in 1995 and breakdown of the connections by category is shown in Table 3.1. These all connection were not equipped with water meter.

Table 3.1 Number of Connections in 1995

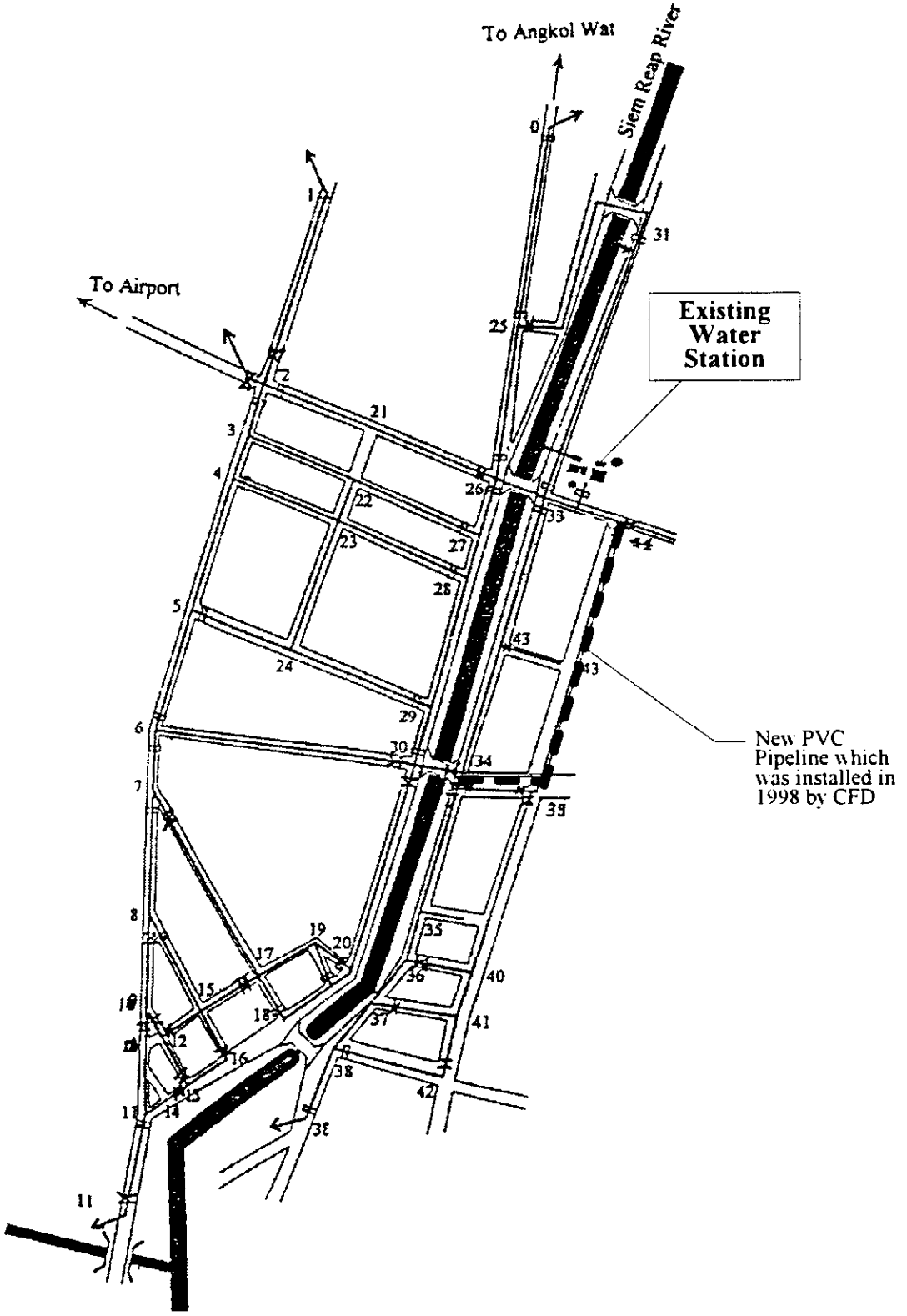
Category	Nos. of Connection
House Connection	172
Hotel	6
Hospital	3
Government Office	23
School	3
Total	207

The Water Supply Station in Siem Reap

4. New French System

After termination of the Old American System, MIME constructed the new groundwater system using French aid (CFD) fund in the existing treatment plant premises. Construction was completed in September 1998 and was ready for operation. Schematic system flow is shown on Figure 4.1.

MIME finally quit using surface water from the Siem Reap River as a source of water supply and it changes water source to deep wells. This New French System consists of two deep wells, aeration basin, two pressure filters, distribution pumps, Lime feeding facilities and Chlorine gas disinfection facilities. Clear water reservoir and elevated tank, which were constructed under the Old American System, are used in this New System.



The Study on Water Supply System for Siem Reap Region in Cambodia	Figure 3.1 Existing Distribution Network
Japan International Cooperation Agency	

4.1 Deep Wells

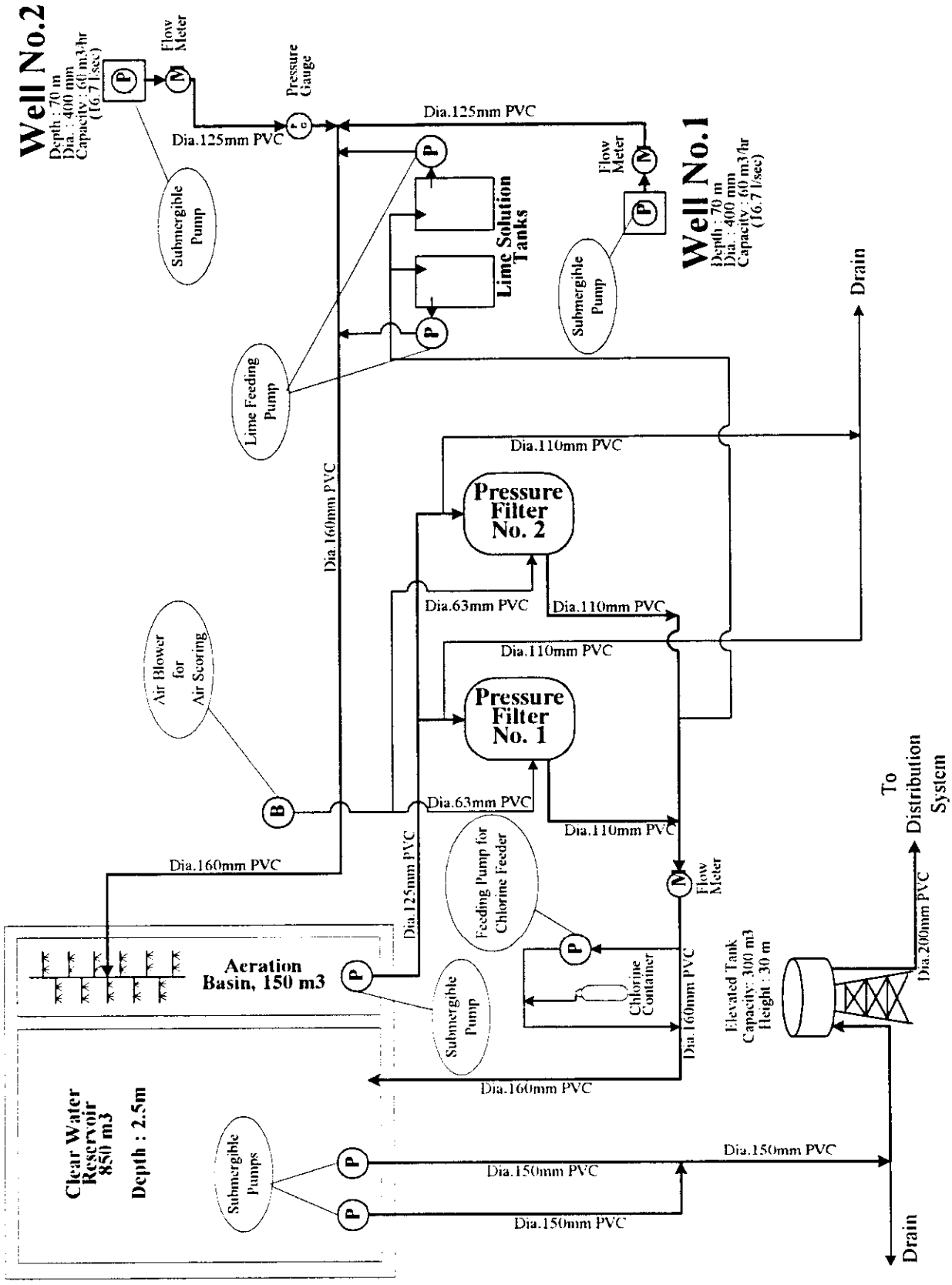
UNICEF drilled two deep wells in the treatment plant in 1992. However these two wells had capacity of only 15 m^3/h each and the quality of groundwater was not suitable for drinking because of high iron contents. These UNICEF wells have never been used for water supply. After termination of the Old American System, CFD drilled two additional deeper wells in the treatment plant in August 1997 and these two deep wells became new water source. These two wells have same specifications. Depth of the well is about 60 m and diameter of casing is 400 mm. Capacity of groundwater abstraction from each deep well is 60 m^3/h (1,440 m^3/day or 16.7 l/sec). These two wells are operated alternately, not operated simultaneously. Specifications of two submergible pumps in the deep wells are as shown in Table 4.1.1.

Table 4.1.1 Specifications of Deep Well Submergible Pumps

Flow Rate	60 m^3/h
Height	57 m
Power	15KW, 380/660 V, 50Hz
Type	SP 77.4 - GRUNDFOS

Notice D'Exploitation et D'Entretien, Station de Potabilisation, by SATTE

Quality of groundwater is shown in Table 4.1.2. As shown in the table below, concentration of iron is high and pH is low. To remove the iron contents, this System employed aeration system and pressure filter. Lime feeding facilities were installed for pH control before the aeration system.



The Study on Water Supply System for Siem Reap Region in Cambodia	Figure 4.1 Schematic System Flow of New French System
Japan International Cooperation Agency	

Table 4.1.2 Quality of Groundwater

Parameter	Unit	Concentration
pH	-	5.2 to 5.61
Conductivity	μS/cm	48 to 63
Turbidity	NTU	0
Hardness	mg/l $CaCO_3$	4.8 to 5.0
TDS	mg/l	24 to 31.6
SS	mg/l	0
Fe	mg/l	1.42 to 1.89
Manganese	mg/l	0
NH_4+	mg/l	0 to 0.08
COD($KMnO_4$)	mg/l	1.34 to 1.89

Notice D'Exploitation et D'Entretien, Station de Potabilisation, by SATTE

4.2 Lime Feeding Facilities

There are two batch type lime solution tanks. The tanks are polyethylene made and capacity of each tank is 1,500 l. Each tank is equipped with mechanical motor driven mixer and Lime feeding pump. During one tank is used for lime solution feeding, lime solution is prepared in the another tank. One pack of lime (25 kg) is usually dissolved in one tank (1,500 l).

Water for lime solution is transmitted from filtered water pipe and lime solution feeding point is before the aeration. This connecting pipe is vinyl flexible pipe and lifetime of this material seems rather short.

The Waterworks keeps some chemicals in their storage, but the Waterworks does not know how and from where they can procure these chemicals when they run out their stock.

4.3 Aeration Basin

Aeration basin is constructed using the part of the existing underground clear water reservoir by construction of separation wall inside the reservoir. Capacity of the aeration basin is 150 m^3 and spray type aerators are installed in half portion of the basin. Remaining portion is reserved for future expansion. Raw groundwater, pH regulated by dozing lime solution, will be sprayed from 102 nozzles installed on 34 branch pipes and contacted with air. Piping from deep

wells and piping of aerator is all PVC made and they are exposed to sunshine without any sunshade. These pipes are already whitened by strong Siem Reap sunshine.

Aerated water in the aeration basin is pumped to the following pressure filter tanks by submergible pump in the basin. Specifications of the submergible pump are as shown in Table 4.3.1. There is only one pump and no standby pump is available.

Table 4.3.1 Specifications of Submergible Pump for Pressure Filtration

Flow Rate	60 m^3/h
Height	15 m
Power	5.5 KW, 380 V, 50 Hz
Type	FDL 65.22 - LOWARA

Notice D'Exploitation et D'Entretien, Station de Potabilisation, by SATTE

4.4 Pressure Filter

There are two pressure filter tanks. Specifications of the filter tank are as shown in Table 4.4.1.

Table 4.4.1 Specifications of Pressure Filter Tank

Material	Steel Made Tank
Diameter	1,800 mm
Height	1,400 mm
Operating Pressure	4 bar
Filter Media	Dual media, sand and ansurasite
Sand	2 ton, diameter range 0.8 to 1.2 mm
Anthracite	1.3 m^3, diameter range 0.8 to 1.6 mm
Backwash	Air + Water
Air Blower	130 m^3/h, 0.3 bar, 4 KW, 220/380V/50 Hz

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To operate these filters and to start backwashing, rather complicated valve operation is required. Filter media, sand and Anthracite, are stored in the Plant storage, but their quantity is only for one time media change. Once they are

changed, there is no more filter media. Procurement of supplemental filter media will be required.

4.5 Underground Clear Water Reservoir

The underground clear water reservoir was constructed and used under the Old American System. Original capacity was 1,000 m^3. Part of the reservoir is used as the aeration tank and current capacity is reduced to 850 m^3 and depth is 2.5 m.

Filtered clear water is stored in this reservoir and pumped up to the elevated tank for distribution by two submergible pumps in the reservoir. One pump is for operation and the another is stand-by. Specifications of these submergible pumps are shown in Table 4.5.1.

Table 4.5.1 Specifications of Submergible Distribution Pump

Flow Rate	60 m^3/h
Height	72 m
Power	18.5 KW, 380/660 V, 50Hz
Type	SP 77.5 - GRUNDFOS

Notice D'Exploitation et D'Entretien, Station de Potabilisation, by SATTE

4.6 Elevated Tank

The elevated tank, which was constructed under the Old American System, is used in the new system. The tank was checked by CFD on its water tightness and small leaking points were found but they were all repaired. Capacity of the tank is 300 m^3 and height is 25 m.

4.7 Distribution System

When the New French System was constructed, CFD checked all distribution network pipeline, and in the case they found broken pipe, they repaired the pipe. There was no expansion works except one pipe additionally installed which is shown on Figure 3.1.

CFD repaired pipeline, but the condition of distribution network is still not good according to the staff of Waterworks. When the CFD checked the pipeline, water pressure in the pipeline was not enough, 10 m at the end of the distribution, therefore they could not find all leak points. After the CFD's repairing works,

many construction activities have been taken place such as electric cable installation along the distribution pipelines. These construction works must damage water pipeline according to the staff of the Waterworks.

4.8 Connections

At the same time of pipeline repairing works mentioned above, installation of new connections and rehabilitation on existing 207 connections were implemented. As rehabilitation works, local steel made saddles, which were heavily corroded, were replaced with new cast iron made saddles. Total number of connection became 409. Breakdown of 409 connections by category is shown in Table 4.8.1.

Table 4.8.1 Number of Connections under New French System in 1998

Category	Nos. of Connection	Diameter (mm) of Connection
House Connection	385	15
Hotel	5	25
Hospital	2	15
Government Office	15	15
School	2	15
Total	409	-

The Water Supply Station in Siem Reap

4.9 Water Tariff in 1995

During the Old American System operation, until 1995, no connection had water meter. Therefore, water tariff was collected by flat rate basis. Flat rate was decided by pressure range in distribution system as shown in Table 4.9.1, and each connection was categorized in one of the pressure range by investigation of the Waterworks staff.

Table 4.9.1 Water Tariff Structure in 1995 (for Old American System)

Category	Pressure Range	Water Tariff (Riel/month)
Domestic	High	3,700
	Medium	2,500
	Low	1,500
Government Office	High	3,700
	Medium	2,500
	Low	1,500
School	High	3,700
	Medium	2,500
	Low	1,500
Grand Hotel	NA	18,000
Villa Apsara (Palace)	NA	8,000
Hospital	NA	5,500

Water Supply Station in Siem Reap

5. Recent Inauguration of the New French System

5.1 Inauguration of the New French System

Although the New French System was completed in September 1998, MIME did not approve its inauguration because MIME considered that the Waterworks in Siem Reap Town could not afford to the electrical cost for operation.

In 1999, PDIME Siem Reap received a grant of US$ 299,000 from UNDP to finish the remaining work of the New French System, rehabilitation of distribution network, and administrative development. Disbursement period was completed in the end of May 1999. Finishing work of the plant was completed at that time; however, rehabilitation work of distribution network had not been completed.

After that, Waterworks continues its effort to rehabilitate the distribution networks. Waterworks operates its treatment plant to check distribution system by feeding treated water to existing distribution network and the Waterworks tried to find pipe break or leakage. Once pipe break or leak point is found, Waterworks repairs the pipe. This pipe rehabilitation work has been conducted from June 1999 to date, and finally Waterworks started its water supply services from the end of July 1999 even though distribution network rehabilitation work had not been completed and there still many problems on distribution network..

During this pipe rehabilitation work, PDIME has been negotiated with public electric supply about concession electric rate and PDIME finally received special rate, discounted from US$ 0.23/kWh to US$ 0.195/kWh.

5.2 Modification of Treatment Flow

The Waterworks started operation of the New French System from the end of July. Unfortunately, the Waterworks could not continue its operation with original set-up.

There were several reasons of the modification and the most significant reason was high iron concentration of the groundwater. Concentrations of iron in groundwater from the Well No. 1 and 2 sometimes reached 11 mg/l and 3 mg/l, respectively.

Because of the high iron contents, original spray type aeration system could not oxidize iron contents effectively. Filtered water contained a lot of dissolved iron since aeration was not enough and the Waterworks had received many complains from its customers about the smell of iron from the distributed water.

Although the aeration was not enough in the aeration basin, sediments of oxidized iron had been accumulated in the basin. Since no drain is equipped in the basin and base slab of the basin is flat, manual removal of the sediments was practiced. This was very difficult and consumed long time.

Furthermore, spray nozzles were clogged by sand contained in the pumped up groundwater. Staff of the Waterworks had to clean the nozzles every day.

Finally the Waterworks decided not to use the original aeration basin and the Waterworks modified its treatment flow. In August 1999, the Waterworks installed fountain type aerator on the previous sedimentation basin, which was constructed in 1960s and had not been used from 1995. Location of lime solution feeding for pH control before the aeration was shifted to the previous sedimentation basin accordingly.

Groundwater from the Well No. 1 and 2, they are operated alternately, is introduced in the new fountain aeration on the previous sedimentation basin and aerated water is conveyed to pressure filters through the original aeration basin (as proposed in New French System) in which spray type aerator was removed.

This modified treatment flow is shown on Figure 5.2.1. As shown on this Figure, in addition to the modification of aeration system, the Waterworks installed two distribution pumps to save energy costs. Original two submergible pumps have

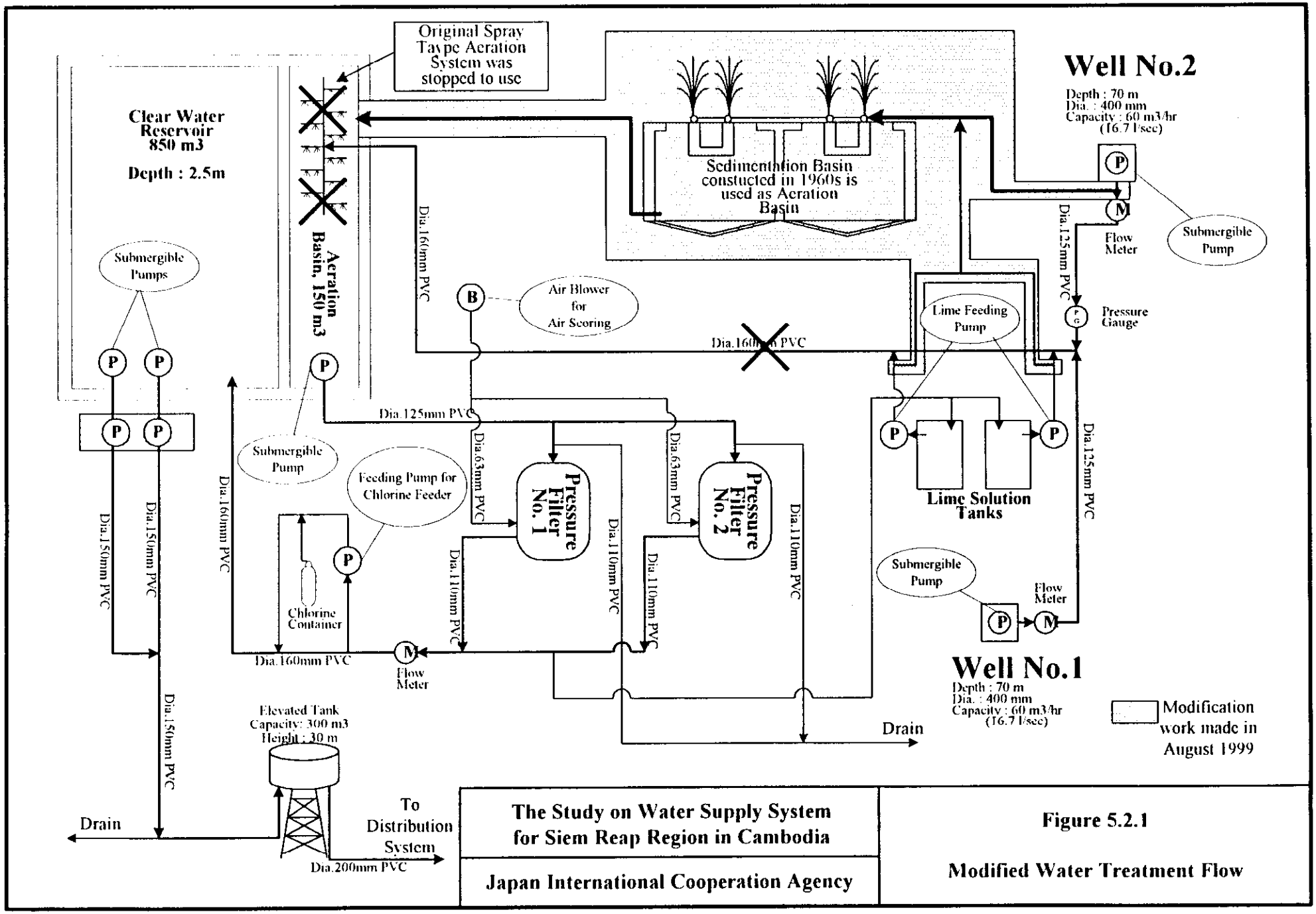
capacity of 18.5 kWh/pump with 70 m pumping head. New two pumps have capacity of 10 kWh with 30 m pumping head, which is enough to pump water up to the elevated tank.

During these new pump installations, the Waterworks modified pipe arrangement within the Water Station in order to distribute water by direct pumping without using the elevated tank in case it is required. This modification was made to achieve continuous water supply even during the maintenance of the elevated tank. Current pipe arrangement in the Water Station is shown on Figure 5.2.2.

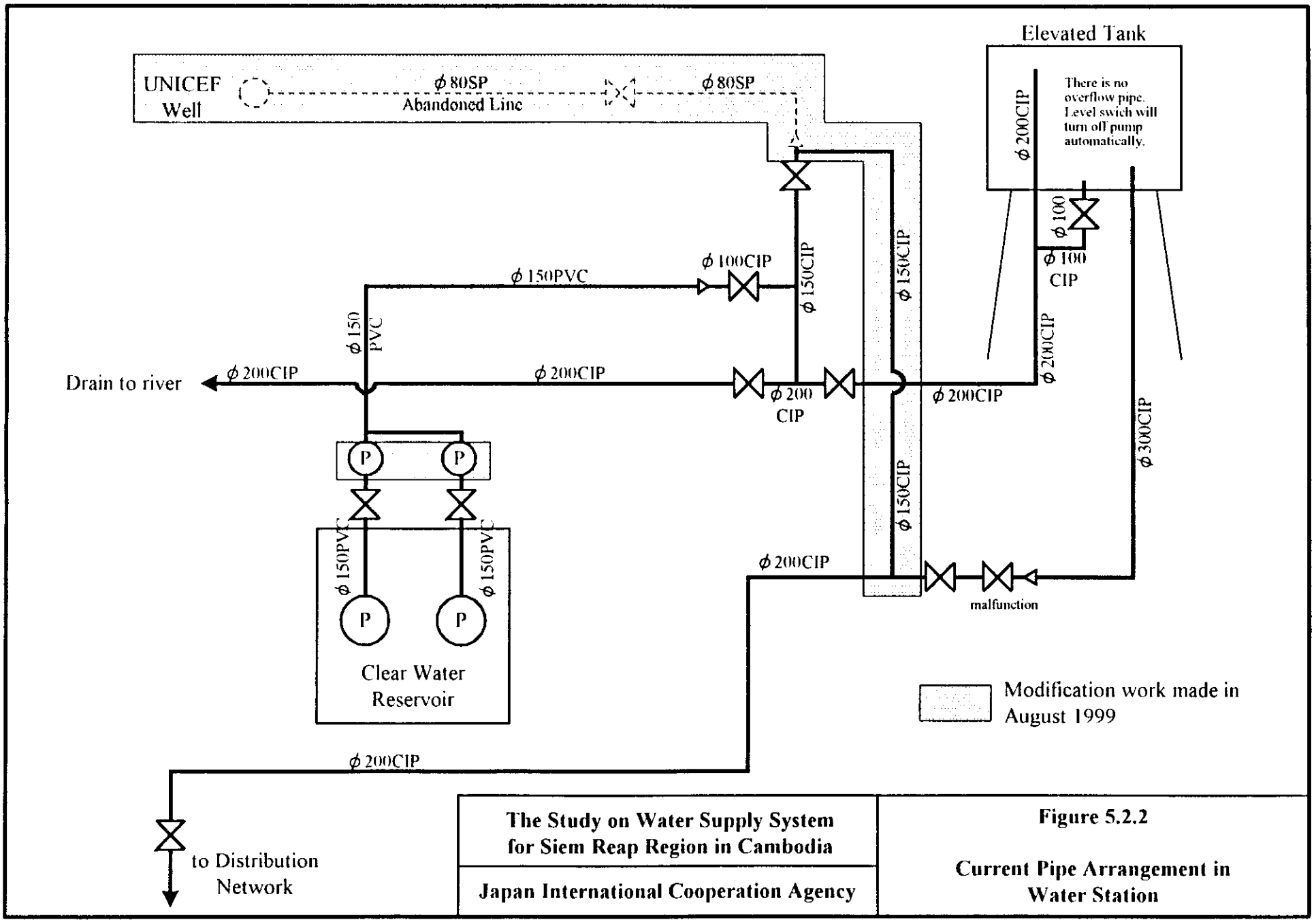
Figure 5.2.3 shows the new aeration system that is installed on the previous sedimentation basin. It should be noted that operation of the new aeration system is not continuous and operated in batch system. The new aeration system is consisted of two units and these two units are operated alternately. Groundwater is sprayed upward like fountain to have contact with air. When the half section of the previous sedimentation basin becomes full, aeration in the unit is stopped and aeration in the another unit starts. Aerated water in the sedimentation basin is kept for about 3 hours for sedimentation of oxidized iron. After sedimentation, water is transferred to the pressure filters through the original aeration basin.

Concentration of iron in treated water after these process modifications is 0.1 to 0.3 mg/l and the quality is acceptable for the customers. Although the quality of treated water is much improved by this modification; plant capacity becomes low to 500 m^3/day against design capacity of 1,440 m^3/day because of the batch operation.

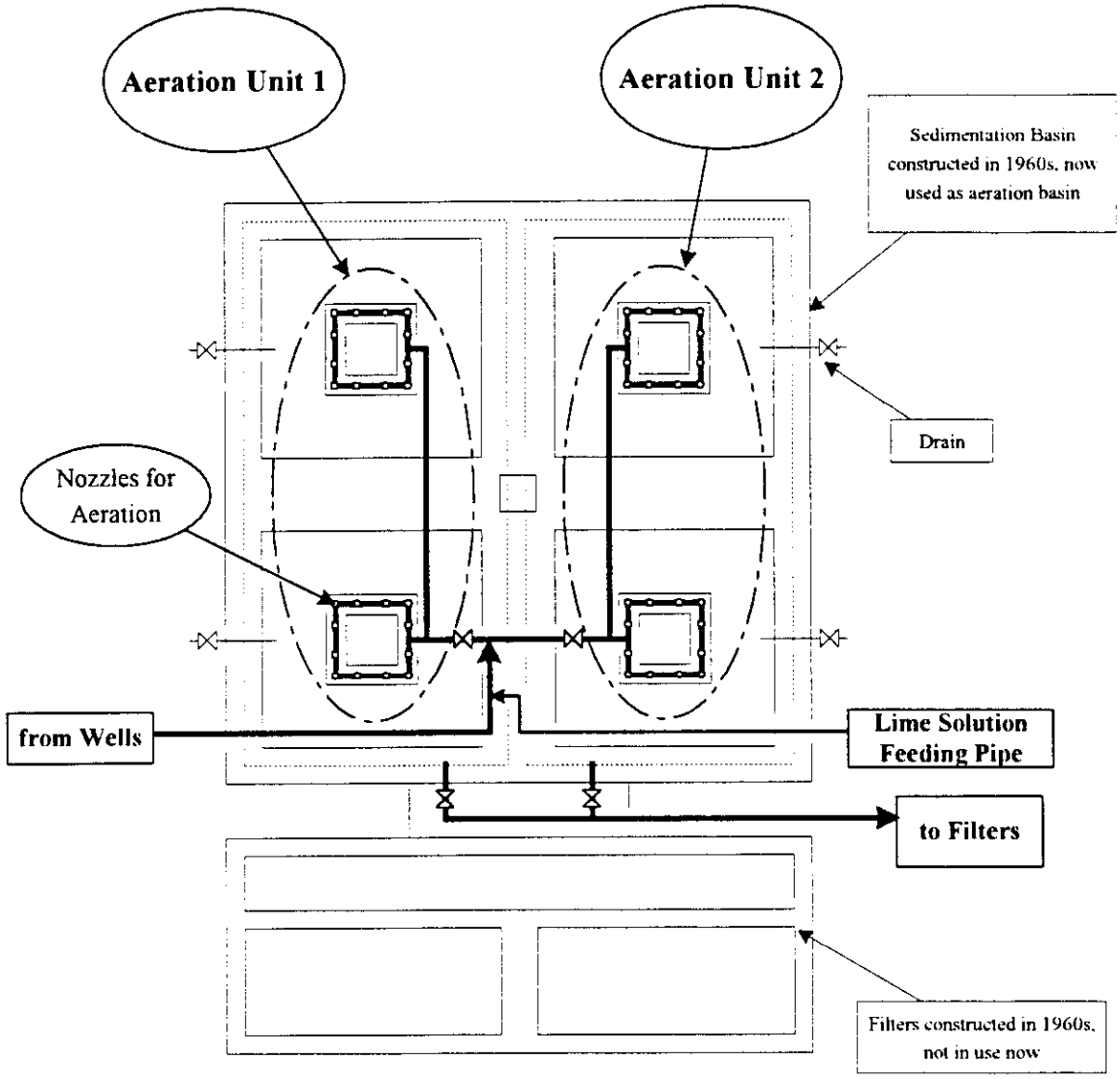
To increase treatment capacity, the Waterworks has a plan to expand its aeration system occupying previous filter basin. According to the estimation of the Waterworks, capacity will be increased up to 800 m^3/day by the expansion.



The Study on Water Supply System for Siem Reap Region in Cambodia	Figure 5.2.1
Japan International Cooperation Agency	Modified Water Treatment Flow



The Study on Water Supply System for Siem Reap Region in Cambodia	Figure 5.2.2
Japan International Cooperation Agency	Current Pipe Arrangement in Water Station



Batch Operation System

Time	9:00	19:00/20:00
Aeration Unit 1	Aeration Sedimentation Filtration	
Aeration Unit 2	Aeration Sedimentation Filtration	

Each work duration is 2 to 3 hours

The Study on Water Supply System for Siem Reap Region in Cambodia	Figure 5.2.3 Current Aeration System
Japan International Cooperation Agency	

5.3 Increasing House Connection

In 1996, after construction of the New French System, new house connections were installed and total number of house connection in 1996 was 382, total 409 – 27 missing connection, including old house connection which had been installed from 1960's to 1995.

Customers of these 382 house connections were requested to resister again by official announcement from the Waterworks on July 19,1999 just before the inauguration of the New French System on July 28, 1999 to resume public water supply service.

Total number of registered connection has been increased as shown on Table 5.3.1.

Table 5.3.1 Number of Registered Connections

Month, 1999	No. of Resisted Connection
July	28
August	113
September	189
October (as of October 12)	259

Source: Siem Reap Waterworks as of October 1999

Number of connections shown on table above includes not only registered from old connections but also newly applied connections. When old customers registered again, he should pay 12,000 Riel as deposit which equivalent to water charge of 10 m^3 and US$ 20 for cost of re-open connection including some minor repair work. Newly applied customers should also pay 12,000 Riel as deposit and US$ 137.73 for material and installation cost of the new connection. This US$ 137.73 is a standard price for typical 25 mm connection and also includes pavement restoration cost. In the case that the Waterworks excavates road pavement, it should pay restoration cost, US$ 15 per 1 m^2 to the provincial department of the Public Works.

ANNEX 4.4.2

REHABILITATION OF

EXISTING DISTRIBUTION NETWORK

THE STUDY ON WATER SUPPLY SYSTEM
FOR SIEM REAP REGION IN CAMBODIA

FINAL REPORT
Vol. III SUPPORTING REPORT

ANNEX 4.4.2 REHABILITATION OF EXISTING DISTRIBUTION NETWORK

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ANNEX 4.4.2 REHABILITATION OF EXISTING DISTRIBUTION NETWORK

1. Condition of Existing Distribution Network

Existing distribution network was constructed in 1960's when the treatment plant of the old American System was constructed. This distribution network covers rather larger area than the Old French System which was constructed in 1930's but still limited in the central part of the Siem Reap Town. When the distribution pipelines were installed, pipelines installed under the Old French System were completely abandoned.

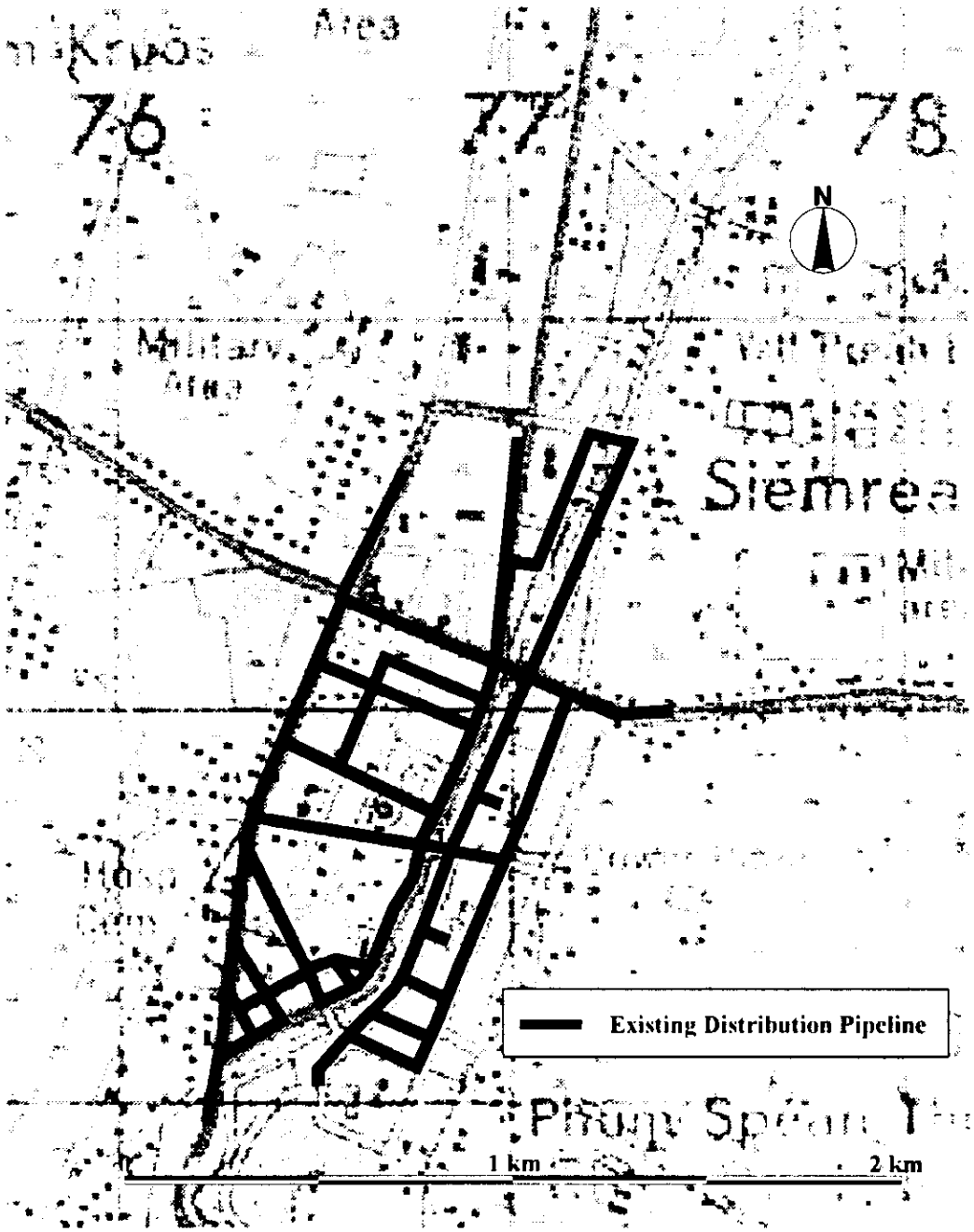
Range of diameter of the existing distribution network, which was constructed in 1960's, is 100 mm to 250 mm and the dominant material of the distribution pipeline is ACP. PVC material was used in very limited pipeline which was recently installed by AFD in 1995. Breakdown of the network by its diameter and material is shown on Table 1.1. Alignment of the existing distribution network is shown on Figure 1.1 and diameter and length of each pipeline is shown on network diagram, Figure 1.2.

Table 1.1 Length of Existing Distribution Network

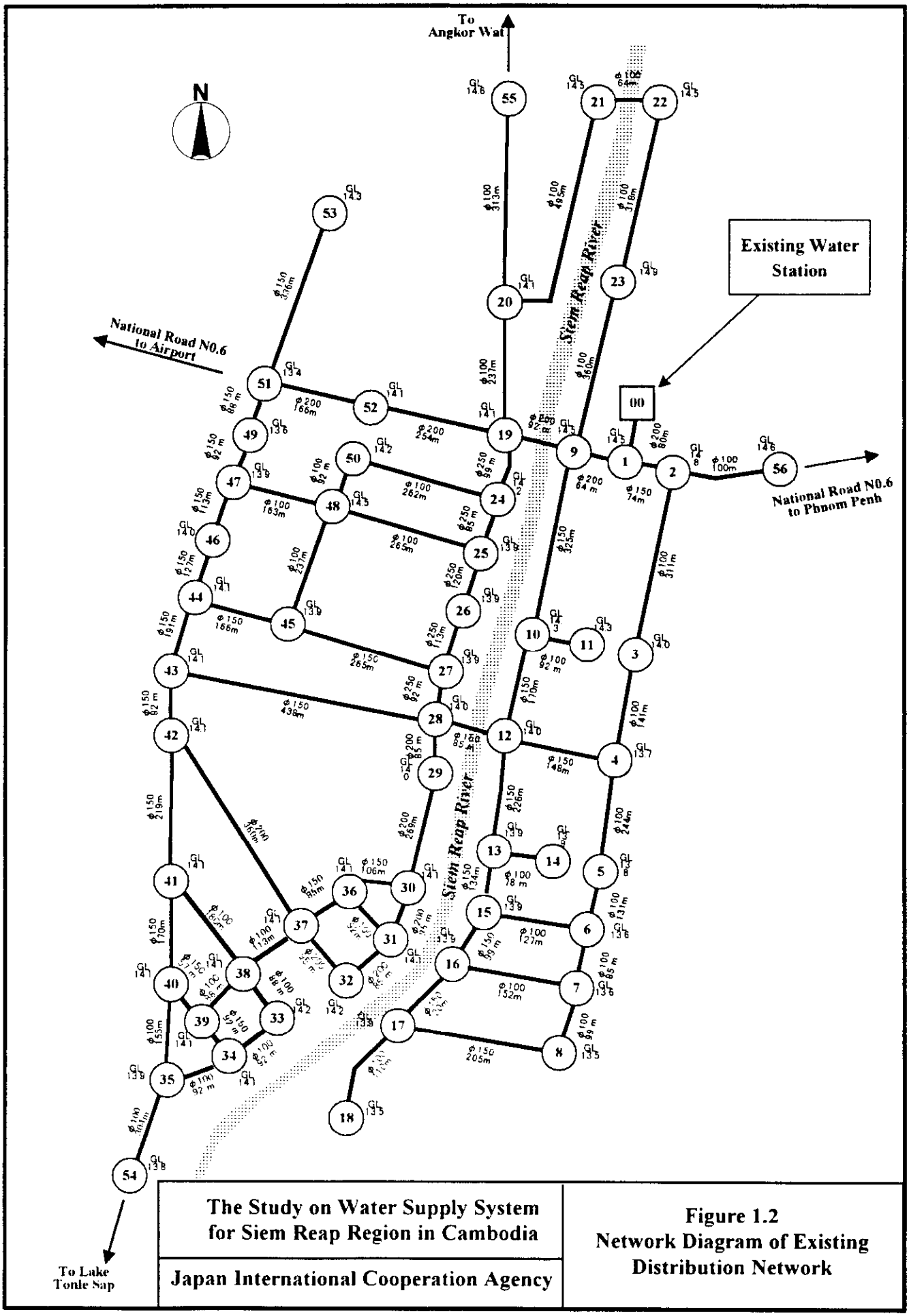
Diameter (mm)	Length (m)
250 ACP	509
200 ACP	1,646
150 ACP	4,075
150 PVC	148
100 ACP	5,227
100 PVC	452
Total	**12,057**

Using the pipe network diagram shown on Figure 1.2, hydraulic analysis of the existing distribution network was conducted. According to the results of the analysis, capacity of the exiting network is enough to distribute water which is produced by the New French System. Detail results of the analysis are shown in Table 1.2. Capacity of the network is enough, however, condition of the existing distribution pipelines is quite questionable.

When the New French System was constructed, AFD checked all distribution network pipeline, and in case they found broken pipe, they repaired the pipe. Although AFD repaired some pipelines, but the condition of distribution net work is still not good according to the staff of Waterworks. After the AFD's repairing work, many construction activities have been taken place such as electric cable installation along the distribution pipelines. These construction works must damage water pipeline according to the staff of the Waterworks.



The Study on Water Supply System for Siem Reap Region in Cambodia	Figure 1.1
Japan International Cooperation Agency	Existing Distribution Network



The Study on Water Supply System for Siem Reap Region in Cambodia	Figure 1.2 Network Diagram of Existing Distribution Network
Japan International Cooperation Agency	

Table 1.2 Results of Hydraulic Analysis on Existing Distribution Network (1/2)

Nos of nodes 57
Nos of pipes 74

NODE

NO	Type	Q l/sec	WL m	GL m	EH m
0	1	-19.992	37.00	14.00	23.00
1	0	0.357	36.74	14.50	22.24
2	0	0.357	36.72	14.80	21.92
3	0	0.357	36.45	14.00	22.45
4	0	0.357	36.37	13.70	22.67
5	0	0.357	36.29	13.80	22.49
6	0	0.357	36.28	13.70	22.58
7	0	0.357	36.27	13.60	22.67
8	0	0.357	36.27	13.50	22.77
9	0	0.357	36.58	14.50	22.08
10	0	0.357	36.43	14.30	22.13
11	0	0.357	36.42	14.30	22.12
12	0	0.357	36.37	14.00	22.37
13	0	0.357	36.30	13.90	22.40
14	0	0.357	36.30	13.90	22.40
15	0	0.357	36.28	13.90	22.38
16	0	0.357	36.27	13.90	22.37
17	0	0.357	36.27	13.90	22.37
18	0	0.357	36.26	13.50	22.76
19	0	0.357	36.45	14.10	22.35
20	0	0.357	36.39	14.10	22.29
21	0	0.357	36.39	14.50	21.89
22	0	0.357	36.40	14.50	21.90
23	0	0.357	36.45	14.90	21.55
24	0	0.357	36.43	14.20	22.23
25	0	0.357	36.41	13.90	22.51
26	0	0.357	36.40	13.90	22.50
27	0	0.357	36.38	13.90	22.48
28	0	0.357	36.37	14.00	22.37
29	0	0.357	36.36	14.00	22.36
30	0	0.357	36.34	14.10	22.24
31	0	0.357	36.34	14.10	22.24
32	0	0.357	36.33	14.20	22.13
33	0	0.357	36.28	14.20	22.08
34	0	0.357	36.28	14.10	22.18
35	0	0.357	36.28	13.90	22.38
36	0	0.357	36.34	14.10	22.24
37	0	0.357	36.33	14.10	22.23
38	0	0.357	36.29	14.10	22.19
39	0	0.357	36.28	14.10	22.18
40	0	0.357	36.28	14.10	22.18
41	0	0.357	36.30	14.10	22.20
42	0	0.357	36.33	14.10	22.23
43	0	0.357	36.35	14.10	22.25
44	0	0.357	36.37	14.10	22.27
45	0	0.357	36.37	13.90	22.47
46	0	0.357	36.38	14.00	22.38
47	0	0.357	36.39	13.90	22.49
48	0	0.357	36.39	14.50	21.89
49	0	0.357	36.40	13.60	22.80
50	0	0.357	36.39	14.20	22.19
51	0	0.357	36.41	13.40	23.01
52	0	0.357	36.43	14.10	22.33
53	0	0.357	36.41	14.30	22.11
54	0	0.357	36.26	13.80	22.46
55	0	0.357	36.38	14.60	21.78
56	0	0.357	36.72	14.60	22.12

Table 1.2 Results of Hydraulic Analysis on Existing Distribution Network (2/2)

PIPE

NO(u)	NO(d)	Dia mm	Length m	C	dH m	Q l/sec	V m/sec	I o/oo
0	1	200	80	110		19.99	0.64	3.25
1	2	150	74.21457	110		2.30	0.13	0.24
2	56	100	100	110		0.36	0.05	0.06
2	3	100	310.9944	110		1.58	0.20	0.87
3	4	100	141.3611	110		1.23	0.16	0.54
4	12	150	148.4291	110		-0.06	0.00	0.00
12	10	150	169.6333	110		-2.61	-0.15	-0.30
10	11	100	91.8847	110		0.36	0.05	0.06
10	9	150	325.1305	110		-3.32	-0.19	-0.48
9	1	200	63.61249	110		-17.34	-0.55	-2.50
9	19	200	91.8847	110		12.66	0.40	1.40
19	20	100	236.7798	110		0.79	0.10	0.24
20	55	100	313	110		0.36	0.05	0.06
20	21	100	494.7638	110		0.08	0.01	0.00
21	22	100	63.61249	110		-0.28	-0.04	-0.04
22	23	100	318.0624	110		-0.64	-0.08	-0.16
23	9	100	360.4707	110		-1.00	-0.13	-0.37
19	24	250	98.95275	110		8.47	0.17	0.22
24	25	250	84.81665	110		7.49	0.15	0.18
25	26	250	120.1569	110		6.63	0.14	0.14
26	27	250	113.0889	110		6.27	0.13	0.13
27	45	150	265.052	110		0.78	0.04	0.03
45	44	150	166.0993	110		0.76	0.04	0.03
44	46	150	127.225	110		-0.98	-0.06	-0.05
46	47	150	113.0889	110		-1.34	-0.08	-0.09
47	49	150	91.8847	110		-1.62	-0.09	-0.13
49	51	150	88.35067	110		-1.97	-0.11	-0.18
51	53	150	335.7326	110		0.36	0.02	0.01
51	52	200	166.0993	110		-2.69	-0.09	-0.08
52	19	200	254.4499	110		-3.05	-0.10	-0.10
24	50	100	261.518	110		0.62	0.08	0.15
25	48	100	265.052	110		0.51	0.06	0.11
48	47	100	162.5652	110		0.08	0.01	0.00
50	48	100	91.8847	110		0.26	0.03	0.03
48	45	100	236.7798	110		0.34	0.04	0.05
27	28	250	91.8847	110		5.14	0.10	0.09
28	43	150	438.2193	110		1.02	0.06	0.05
43	44	150	190.8375	110		-1.38	-0.08	-0.09
12	28	150	84.81665	110		-0.45	-0.03	-0.01
28	29	200	84.81665	110		3.31	0.11	0.12
29	30	200	268.586	110		2.95	0.09	0.09
30	31	200	95.41873	110		1.74	0.06	0.04
31	36	100	91.8847	110		0.13	0.02	0.01
30	36	150	106.0208	110		0.86	0.05	0.04
31	32	200	84.81665	110		1.25	0.04	0.02
36	37	150	84.81665	110		0.63	0.04	0.02
32	37	200	95.41873	110		0.89	0.03	0.01
37	42	200	360.4707	110		0.17	0.01	0.00
37	38	100	113.0889	110		1.00	0.13	0.37
33	38	100	88.35067	110		-0.48	-0.06	-0.10
38	41	100	180.2354	110		-0.28	-0.04	-0.04
33	34	100	91.8847	110		0.12	0.02	0.01
38	39	100	88.35067	110		0.44	0.06	0.08
34	39	150	91.8847	110		-0.60	-0.03	-0.02
39	40	150	56.54443	110		-0.52	-0.03	-0.02
34	35	100	91.8847	110		0.37	0.05	0.06
35	40	100	155.4972	110		-0.35	-0.04	-0.05
40	41	150	169.6333	110		-1.22	-0.07	-0.07
41	42	150	219.1097	110		-1.86	-0.11	-0.16
42	43	150	91.8847	110		-2.05	-0.12	-0.19
35	54	100	303.9263	110		0.36	0.05	0.06
4	5	100	243.8479	110		0.93	0.12	0.33
5	6	100	130.759	110		0.57	0.07	0.13
6	7	100	84.81665	110		0.45	0.06	0.09
7	8	100	98.95275	110		0.25	0.03	0.03
12	13	150	226.1777	110		2.64	0.15	0.31
13	14	100	77.74859	110		0.36	0.05	0.06
13	15	150	134.293	110		1.93	0.11	0.17
6	15	100	127.225	110		-0.23	-0.03	-0.03
15	16	150	98.95275	110		1.33	0.08	0.09
16	7	100	151.9632	110		0.15	0.02	0.01
16	17	150	120.1569	110		0.82	0.05	0.04
17	8	150	204.9736	110		0.11	0.01	0.00
17	18	100	110	110		0.36	0.05	0.06

End

Under such situation, Waterworks has continued its effort to rehabilitate existing distribution pipeline, and, Waterworks is still having a very busy time to repair pipelines every day.

2. Selection of Pipelines To Be Replaced

It is apparent that rehabilitation of the existing distribution network is indispensable considering current situation. For the rehabilitation of the existing network, two options will be considered. One is pipe replacement and the other is pipe repairment. Pipe repairing work has been conducted by the Waterworks every day, however, because of the age of the pipeline installed in 1960s, another leak point may be found on the next day on the same pipeline which was repaired on the previous day. Therefore, pipe replacement will be recommended for the pipeline, which seems to be very deteriorated, even though the replacement will be more costly than pipe repair.

For the selection of the pipelines to be replaced, following data and information were considered.

1. Results of leakage survey conducted by AFD
2. Record of location of leak repaired by the Waterworks
3. Record of location of house connection repaired by the Waterworks
4. Density of house connection
5. Pipelines where Waterworks experienced difficult maintenance

2.1 Results of Leakage Survey Conducted by AFD

Results of leakage survey conducted by AFD are included in its report "RESEAU D'EAU POTABLE DE SIEM REAP, ETUDE DIAGNOSTIC", September 1999. AFD's consultants conducted diagnostic survey on existing water supply system including distribution network. AFD conducted the leakage survey because it felt great concern about the condition of existing distribution network.

For the leakage survey, AFD divided the distribution network into 27 sections. Water from the elevated tank in the water station was introduced to the section by section by operating related valves. After water introduced to a certain section, valves on section boundary were closed and section was isolated from the distribution network. Upon completion of the isolation, water level fall of the elevated tank was measured and leak amount in the section was calculated from the sectional area of the elevated tank and the level down.

This leakage survey was conducted from August 9 to August 17, 1999. Methodology of the survey is quite reasonable and adequate. But the results of the leakage survey may include some errors because of the following reason.

Section isolation could not be confirmed

Valves on the section boundary were closed. However, these valves were installed in 1960s and it was not sure that valves could be closed completely or not. If valves on the section boundary were not closed completely, it would allow water flow through the boundary valves and the amount of water effluent would increase leak amount and water influent would decrease leak amount in the section.

Water consumption by customers

During the leakage survey, stop valves on house connections in the target section were not closed. Therefore, water consumption by the customers in the measuring section was count as leakage.

Time variation of measuring

Leak amount measurement had been conducted during 6 days and at different time. To estimate the leak amount in a certain section, the leak amount in upstream section, which was measured in previous day, was deducted from total amount of water discharge from the elevated tank. If the measurement of upstream section was conducted during the consumption peak hours, which accounts more leakage in upstream section, leak amount in all downstream section would become low. On the other hand, if the measurement of upstream section was conducted during low consumption period, leak amount in all down stream section would become high.

Even though there were some factors which would increase error in measured leak amount, the results of this survey is very valuable and tendency of the leakage condition can be obtained.

Table 2.1.1 shows the results of the AFD leakage survey. The lower table is sorted by the unit leak amount, m3/hour/100m pipe length. These results are also shown on Figure 2.1.1. This figure shows the pipelines which has high unit leakage in three different level such as pipeline of which unit leakage is more than 10 m3/hr/100m, 5 to 10 m3/hr/100m and 1 to 5 m3/hr/100m.

According to the figure, high leak pipelines exist in southern part of town and along the major roads, National Road No. 6 and trunk road along the Siem Reap River.

2.2 Record of Location of Leak Repaired by the Waterworks

After completion of the treatment plant under the New French System, the Waterworks concentrated their effort to improve the condition of the distribution network. Before the official inauguration of the System, the Waterworks conducted test operation of the treatment plant and at that time water was introduced in the existing distribution network. When the Waterworks found a leak point, they repaired the leak using repair materials, which were supplied by AFD Project. These efforts to improve distribution network were started from June 1999.

Number of location of leak repair on the distribution pipelines, excluding leakage on house connections, reached 21 as of October 20, 1999. Locations of these leak repairs are shown on Figure 2.2.1.

As shown on the figure, many leakage points are found on pipe Node No. 19 to 55, No. 10 to 13, and No. 4 to 8.

Table 2.1.1 Leak Amount in Each Section measured by AFD

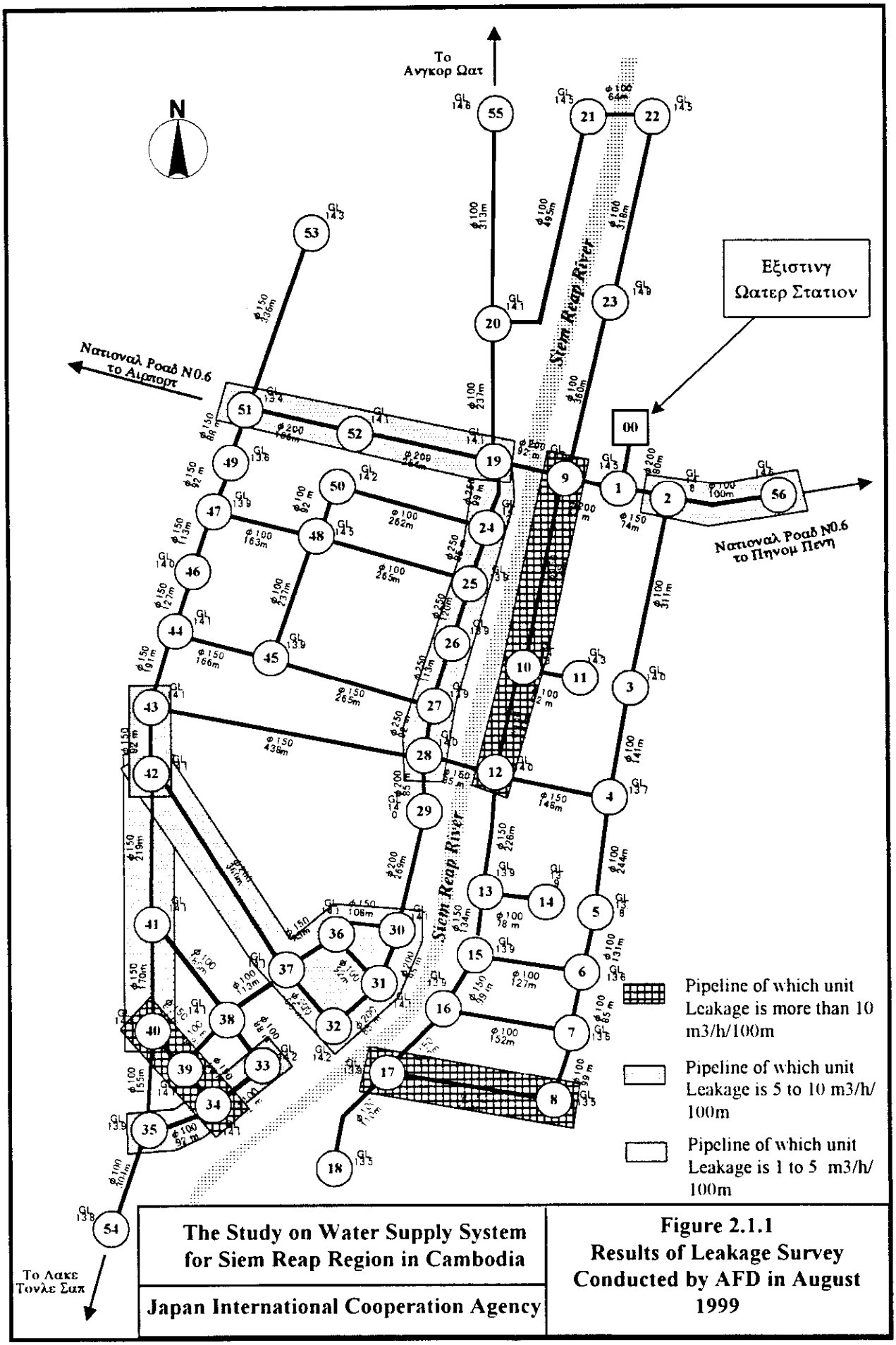
AFD Section Number	JICA Nodes Included in Each Section	Pipe Length (m)	Measured Leak Amount (m3/h)	Unit Leak Amount (m3/h/100m)
T.00	Water Station		0.5	
T.01	19,9,1,2	230	0.5	0.22
T.02	9,23,22	678	2.5	0.37
T.03	19,20,21,22	798	0.1	0.01
T.04	20,55	313	DNA	DNA
T.05	19,52,51	420	19.2	4.57
T.06	51,53	336	DNA	DNA
T.07	2,56	100	3.4	3.40
T.08	51,49,47,46,44,43	611	0.0	0.00
T.09	19,24,25,26,27,28	509	10.3	2.02
T.10	9,10,12	495	53.1	10.73
T.11	2,3,4,10,11	452	2.8	0.62
T.12	12,4	148	DNA	DNA
T.13	50,48,45,47,44,25,27	1,193	8.4	0.70
T.13-2	50,24	262	DNA	DNA
T.14	43,28	438	0.0	0.00
T.15	43,42	92	7.1	7.72
T.16	42,37,32,36,31,30	738	26.5	3.59
T.17	42,41,40	389	4.9	1.26
T.18	41,38,33,39,37	469	0.0	0.00
T.19	40,39,34	149	24.7	16.58
T.20	40,35	150	0.0	0.00
T.21	33,34,35	139	9.3	6.69
T.22	35,54	304	0.0	0.00
T.23	28,29,30,31,32	534	0.7	0.13
T.24	12,13,14,15,16,17,18	767	0.0	0.00
T.25	4,5,6,7,8,15,16	838	1.7	0.20
T.26	17,8	205	32.4	15.80

Source : RESEAUDEAU POTABLE DE SIEM REAP, AFD, Sep. 1999
DNA : Data not available

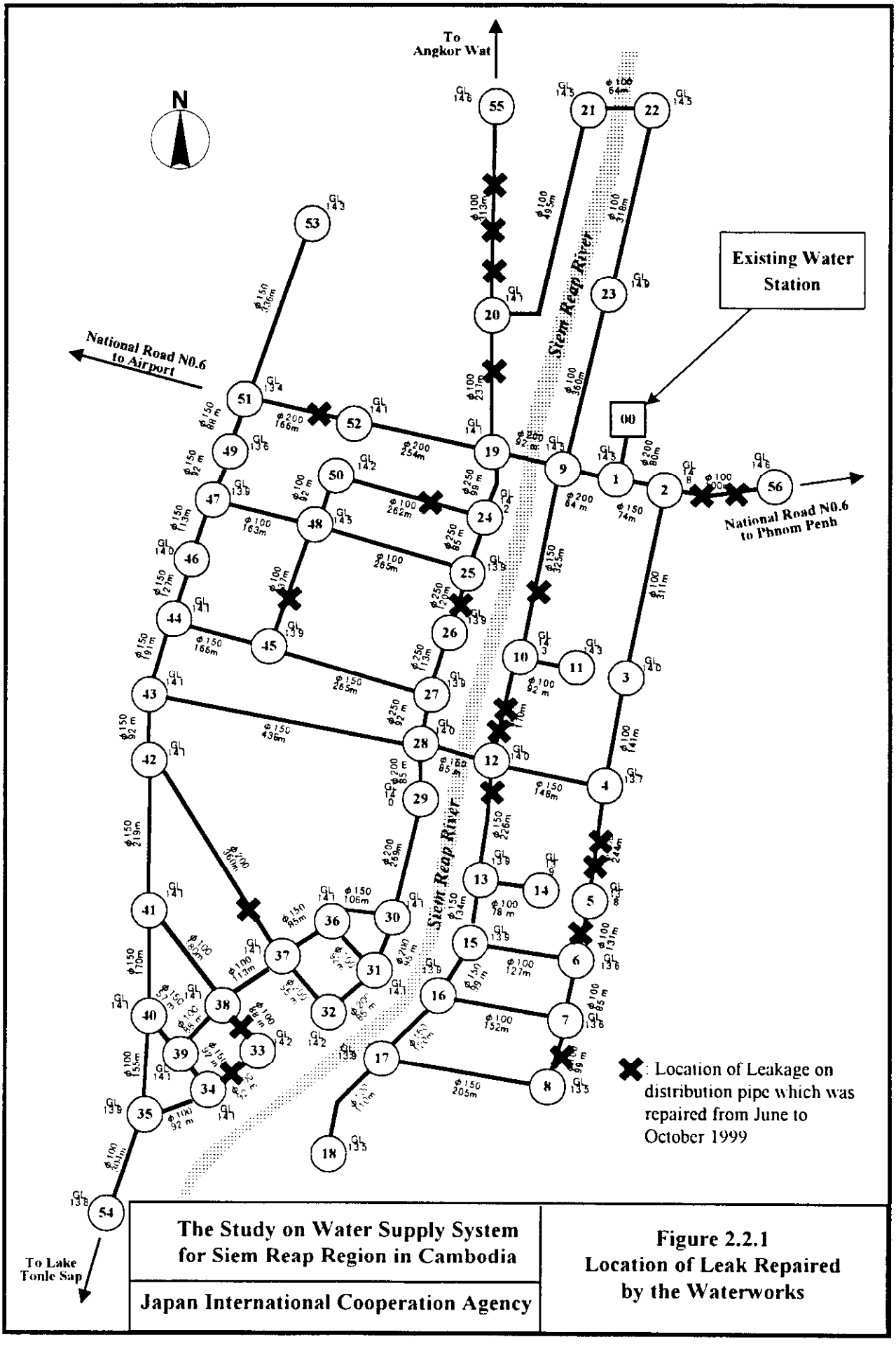
Sorted by "Unit Leak Amount"

AFD Section Number	JICA Nodes Included in Section	Pipe Length (m)	Measured Leak Amount (m3/h)	Unit Leak Amount (m3/h/100m)
T.19	40,39,34	149	24.7	16.58
T.26	17,8	205	32.4	15.80
T.10	9,10,12	495	53.1	10.73
T.15	43,42	92	7.1	7.72
T.21	33,34,35	139	9.3	6.69
T.05	19,52,51	420	19.2	4.57
T.16	42,37,32,36,31,30	738	26.5	3.59
T.07	2,56	100	3.4	3.40
T.09	19,24,25,26,27,28	509	10.3	2.02
T.17	42,41,40	389	4.9	1.26
T.13	50,48,45,47,44,25,27	1,193	8.4	0.70
T.11	2,3,4,10,11	452	2.8	0.62
T.02	9,23,22	678	2.5	0.37
T.01	19,9,1,2	230	0.5	0.22
T.25	4,5,6,7,8,15,16	838	1.7	0.20
T.23	28,29,30,31,32	534	0.7	0.13
T.03	19,20,21,22	798	0.1	0.01
T.08	51,49,47,46,44,43	611	0.0	0.00
T.14	43,28	438	0.0	0.00
T.18	41,38,33,39,37	469	0.0	0.00
T.20	40,35	150	0.0	0.00
T.22	35,54	304	0.0	0.00
T.24	12,13,14,15,16,17,18	767	0.0	0.00
T.04	20,55	313	DNA	
T.06	51,53	336	DNA	
T.12	12,4	148	DNA	
T.13-2	50,24	262	DNA	
T.00	Water Station		0.5	

Source : RESEAUDEAU POTABLE DE SIEM REAP, AFD, Sep. 1999
DNA : Data not available



The Study on Water Supply System for Siem Reap Region in Cambodia	**Figure 2.1.1 Results of Leakage Survey Conducted by AFD in August 1999**
Japan International Cooperation Agency	



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

Japan International Cooperation Agency

Figure 2.2.1
Location of Leak Repaired by the Waterworks

2.3 Record of Location of House Connection Repaired by the Waterworks

From June 1999 to October 1999, the Waterworks repaired leakage found on house connections and total number of repair reached about 100 locations. Locations of repaired house connections are shown on Figure 2.3.1. Although the leakage on house connection will not represent the grade of deterioration of a distribution pipeline, repair works of house connection will sometime cause future leakage. For instance, the Waterworks should replace old saddle of the house connection because of leakage and make new drilling on the distribution pipe for a new saddle; old drilled hole will be plugged by bolt. Old drilled hole had been used for long time and the shape of the hole is not accurately circular anymore, therefore, plugging the old hole to complete watertight is very difficult.

Such old house connections are found in southern area of the town as shown on Figure 2.3.1.

2.4 Density of House Connection

Density of house connection should be taken into account for the selection of the pipeline to be replaced. Pipeline, which has a lot of house connections, has high risk of leakage because of many drilling holes.

On the other hand, effectiveness of leakage reduction is higher in high-density area comparing with pipeline, which was installed in very low-density area.

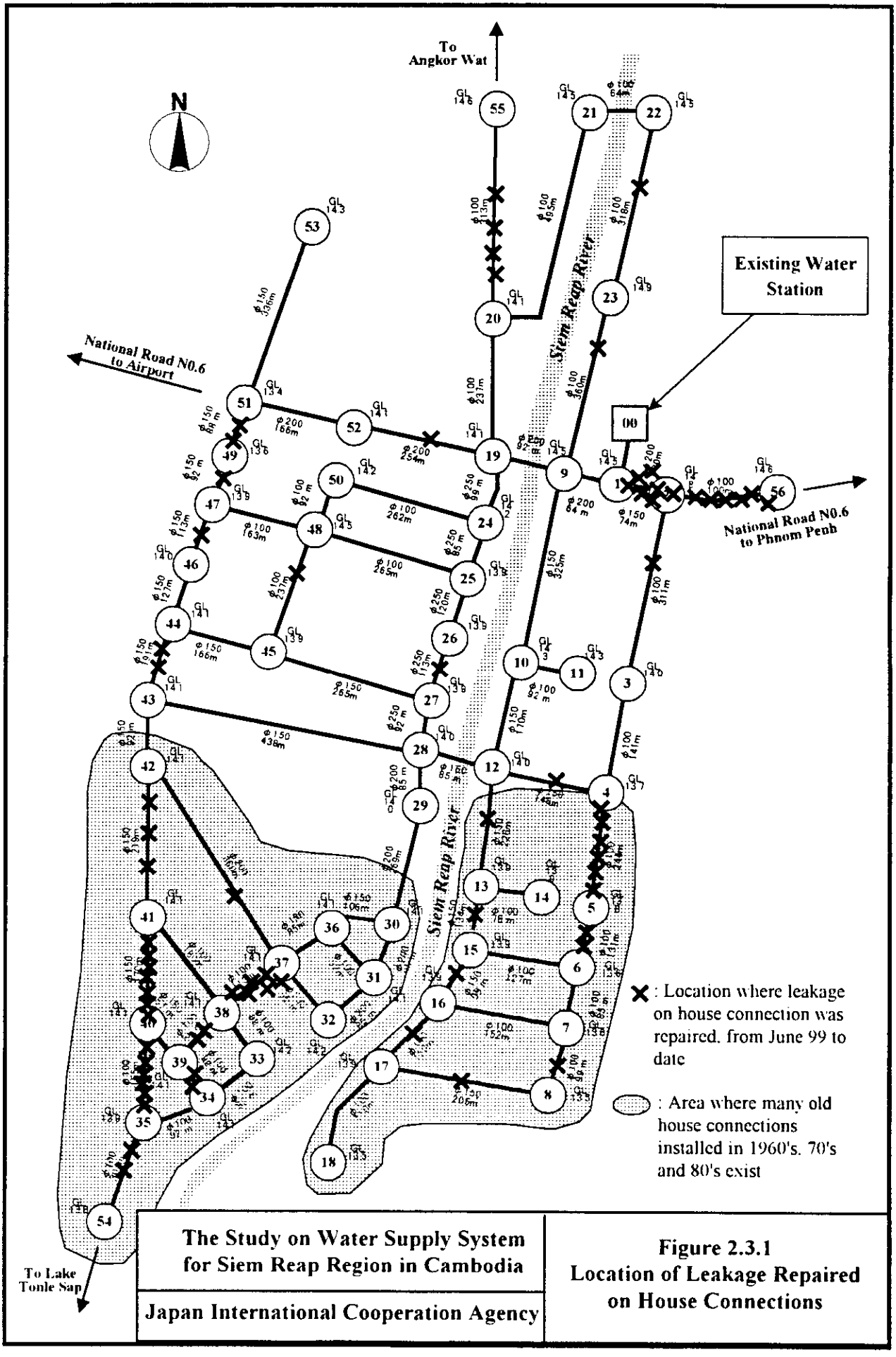
Density of house connection is shown on Figure 2.4.1 as of October 19, 1999 and total number of the registered connection was 259.

2.5 Pipelines Where Waterworks Experienced Difficult Maintenance

One of the most important factor is, on which pipeline the Waterworks experienced difficult maintenance during their routine maintenance work. Pipelines were installed in 1960s and town situation has been changed drastically. Buildings were constructed above the distribution pipeline and the Waterworks can not access to the pipeline.

Staffs of the Waterworks know that which pipeline is the most deteriorated and in which pipeline they had many difficulties to repair leakage with their limited repairing parts.

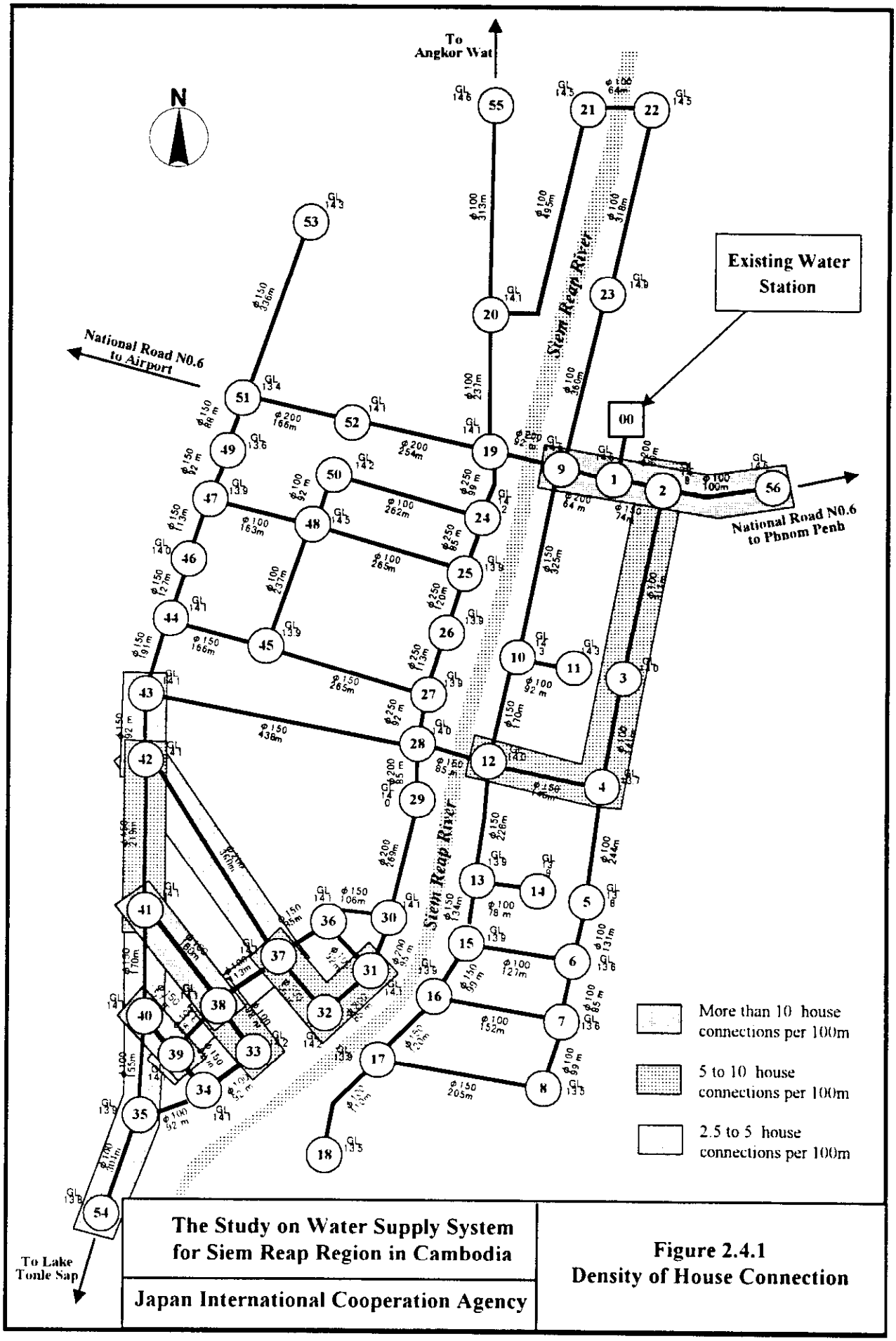
Figure 2.5.1 shows the location of pipelines where the Waterworks experienced such difficulties.



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

Japan International Cooperation Agency

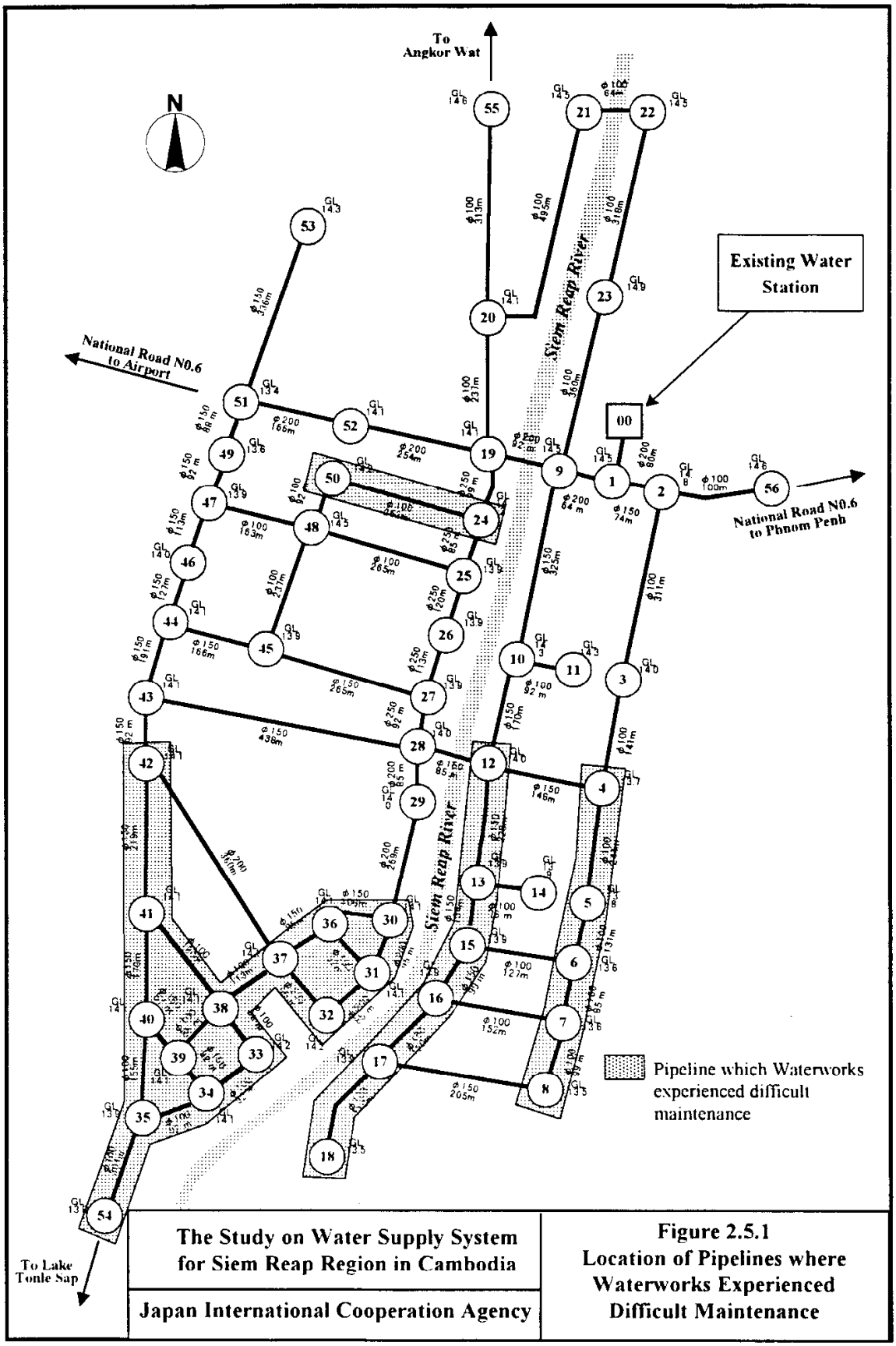
Figure 2.3.1
Location of Leakage Repaired on House Connections



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

Japan International Cooperation Agency

Figure 2.4.1
Density of House Connection



The Study on Water Supply System for Siem Reap Region in Cambodia	Figure 2.5.1 Location of Pipelines where Waterworks Experienced Difficult Maintenance
Japan International Cooperation Agency	

2.6 Selection of Pipelines To Be Replaced

Based of the factors for the selection of pipelines to be replaced as explained in the previous sections, numeric values are assigned to pipelines for different states under each selection criteria. Scores are shown below.

Results of leakage survey conducted by AFD

Category	Score
Unit leakage (m3/hr/100m) is more than 10	3
Unit leakage (m3/hr/100m) is 5 to 10	2
Unit leakage (m3/hr/100m) is 1 to 5	1
Unit leakage (m3/hr/100m) is less than 1	0

Record of location of leak repaired by the Waterworks

Score
Number of location of leak repair becomes score

Record of location of house connection repaired by the Waterworks

Category	Score
Number of repaired location in old house connection area is more than 5	3
Number of repaired location in old house connection area is less than 5	2
Number of repaired location outside of old house connection area is more than 1	1
No repaired location	0

Density of house connection

Category	Score
Number of House Connection is more than 10 per 100m	3
Number of House Connection is 5 to 10 per 100m	2
Number of House Connection is 2.5 to 5 per 100m	1

Pipelines where Waterworks experienced difficult maintenance

Category	Score
Pipeline for which difficult maintenance is experienced by the Waterworks	2
Pipeline which is not difficult for maintenance	0

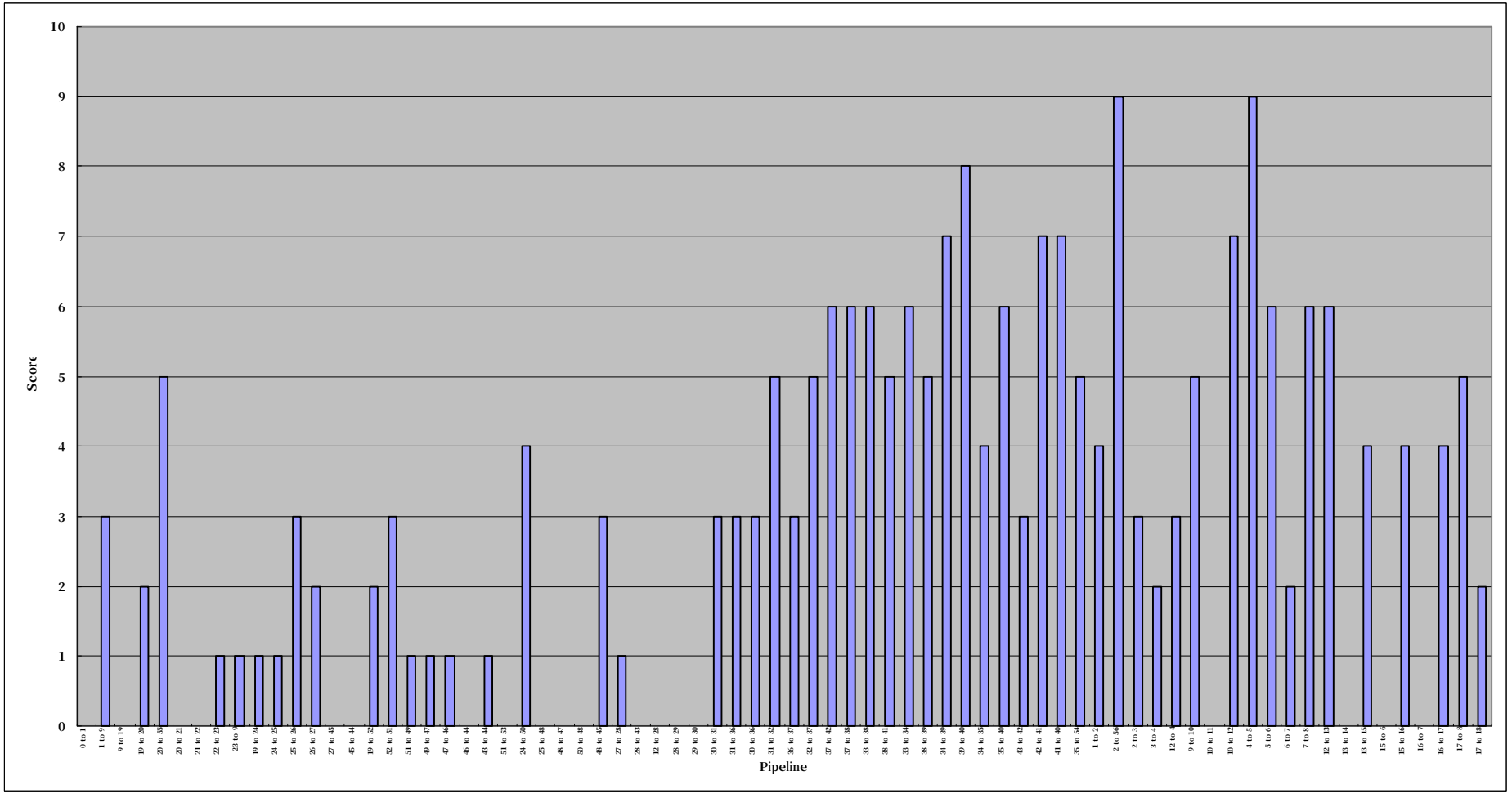
Table 2.6.1 is the scoring sheet of each pipeline scored by the scoring method mentioned above and results are shown on Figure 2.6.1. High-risk pipelines scored more than 4, which are highly recommended to be replaced, obtained from the scoring are shown on Figure 2.6.2.

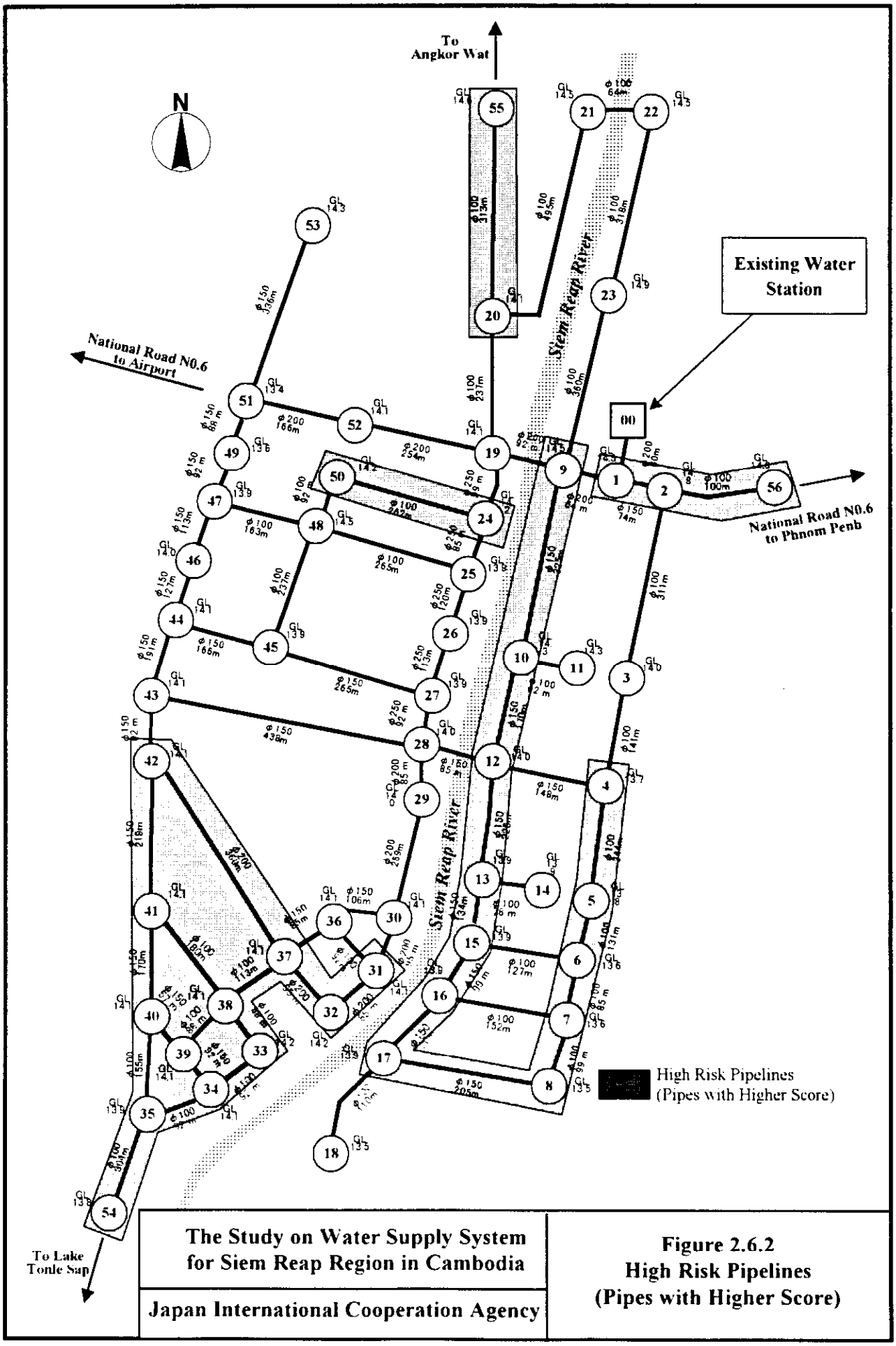
Table 2.6.1 Scoring Sheet

Serial No.	Pipeline	AFD Results	Leak Repair	Connection Repair	Difficult Maintenance	Density of Connection	Total Score
1	0 to 1						0
2	1 to 9					3	3
3	9 to 19						0
4	19 to 20		2				2
5	20 to 55		4	1			5
6	20 to 21						0
7	21 to 22						0
8	22 to 23			1			1
9	23 to 9			1			1
10	19 to 24	1					1
11	24 to 25	1					1
12	25 to 26	1	2				3
13	26 to 27	1		1			2
14	27 to 45						0
15	45 to 44						0
16	19 to 52	1		1			2
17	52 to 51	1	2				3
18	51 to 49			1			1
19	49 to 47			1			1
20	47 to 46			1			1
21	46 to 44						0
22	43 to 44			1			1
23	51 to 53						0
24	24 to 50		2		2		4
25	25 to 48						0
26	48 to 47						0
27	50 to 48						0
28	48 to 45		2	1			3
29	27 to 28	1					1
30	28 to 43						0
31	12 to 28						0
32	28 to 29						0
33	29 to 30						0
34	30 to 31	1			2		3
35	31 to 36	1			2		3
36	30 to 36	1			2		3
37	31 to 32	1			2	2	5
38	36 to 37	1			2		3
39	32 to 37	1			2	2	5
40	37 to 42	1	2	2		1	6
41	37 to 38			3	2	1	6
42	33 to 38		2		2	2	6
43	38 to 41				2	3	5
44	33 to 34	2	2		2		6
45	38 to 39			2	2	1	5
46	34 to 39	3		2	2		7
47	39 to 40	3			2	3	8

48	34 to 35	2			2		4
49	35 to 40			3	2	1	6
50	43 to 42	2				1	3
51	42 to 41	1		2	2	2	7
52	41 to 40	1		3	2	1	7
53	35 to 54			2	2	1	5
54	1 to 2			1		3	4
55	2 to 56	1	4	1		3	9
56	2 to 3			1		2	3
57	3 to 4					2	2
58	12 to 4			1		2	3
59	9 to 10	3	2				5
60	10 to 11						0
61	10 to 12	3	4				7
62	4 to 5		4	3	2		9
63	5 to 6		2	2	2		6
64	6 to 7				2		2
65	7 to 8		2	2	2		6
66	12 to 13		2	2	2		6
67	13 to 14						0
68	13 to 15			2	2		4
69	15 to 6						0
70	15 to 16			2	2		4
71	16 to 7						0
72	16 to 17			2	2		4
73	17 to 8	3		2			5
74	17 to 18				2		2

Figure 2.6.1 Results of Scoring





The Study on Water Supply System for Siem Reap Region in Cambodia	Figure 2.6.2 High Risk Pipelines (Pipes with Higher Score)
Japan International Cooperation Agency	

High-risk pipelines are selected and these pipelines are recommended to be replaced. It should be noted that this does not mean the remaining pipelines are in good condition. Remaining pipelines were also installed from 1960s and they should also be replaced gradually after the replacement of the high-risk pipeline by the Siem Reap Waterworks using own funds or donor's assistance.