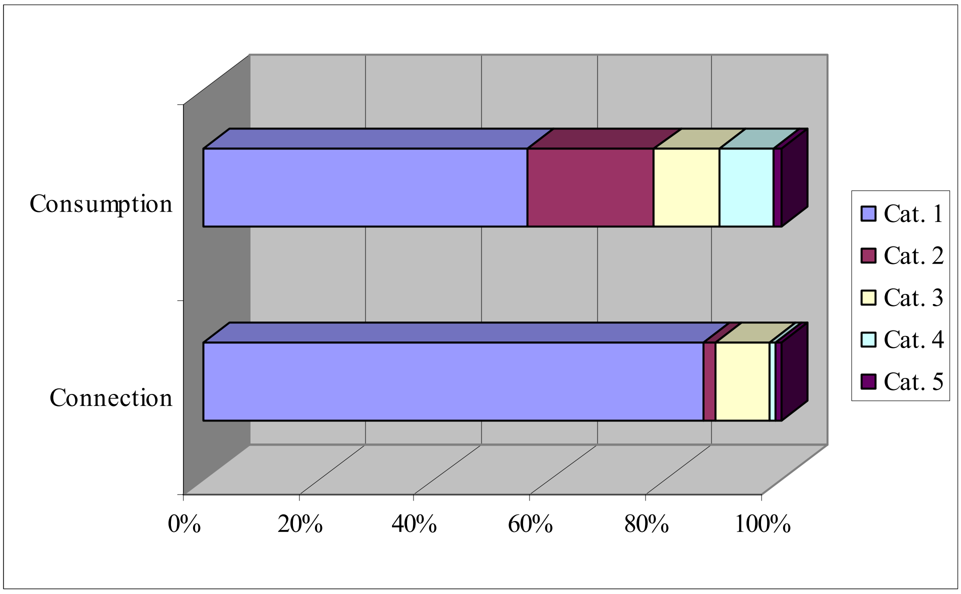
Some sub-zones are duplicated and included in two zones since sub-zone boundaries do not always conform to the zone boundary. However, each connection carries a three digit number, the first digit signifies the zone number and the 2nd and 3rd numbers signify the sub-zone number a system designed to avoid confusion due to the sub-zone duplication.

3.2.2 Number of Connections and Water Consumption

Data on the number houses that are connected to the water supply and water consumption is provided from the NPVC computing system for billing. Table 32-3 shows the number of connections and relevant water consumption in March 2003 by sub-zone basis. The total number of connections is 43,444 and total metered water consumption is 2,416,152 m3/month (77,940 m3/day). Connection and water consumption statistics are broken down by category, as shown on Figures 32-2.

Figure 32-2 Water Consumption and Connection by Category



Note
Source : NPVC
Cat. 1 : Domestic
Cat. 2 : Administration offices
Cat. 3 : Enterprises, factories, businesses class 1 to class 6
Cat. 4 : Businesses using water as the raw materials for production, hotels, guest houses, restaurants, and swimming pools
Cat. 5 : Diplomatic missions, international organizations, foreigners and expatriates

Table 32-3 Number of House Connections and Water Consumption in March 2003 by NPVC Sub-Zone

NPVC	NPVC			Number of Connection						Water Consumption (m3/month)					
Zone	S-Zone	NVP Branch	District	Cat. 1	Cat. 2	Cat. 3	Cat. 4	Cat. 5	Total	Cat. 1	Cat. 2	Cat. 3	Cat. 4	Cat. 5	Total
1	1	Sikhottabong	02Sikhottabong	4,155	9	433	11		4,608	138,549	581	28,823	1,880		169,833
1	2	Sikhottabong	02Sikhottabong	641	2	81	7	2	733	21,538	249	4,617	1,135	20	27,559
1	3	Sikhottabong	02Sikhottabong	1,595	3	113	22	7	1,740	59,997	259	8,377	5,494	229	74,356
1	4	Sikhottabong	02Sikhottabong	444	3	92	5	13	557	14,483	259	4,034	315	305	19,396
1	5	Sikhottabong	02Sikhottabong	130		38	2	1	171	6,502		2,973	1,926	40	11,441
2	5	Chanthabuli	01Chanthabuli	29		25	1		55	1,295		1,212	169		2,676
2	6	Chanthabuli	01Chanthabuli	78	1	67		1	147	3,140	40	5,263		60	8,503
1	7	Sikhottabong	02Sikhottabong	1,141	7	223	11	3	1,385	41,957	388	10,434	815	42	53,636
2	7	Chanthabuli	01Chanthabuli	1,367	3	349	20		1,739	50,644	175	14,633	2,651		68,103
2	8	Chanthabuli	01Chanthabuli	263		194	5	4	466	9,919		10,756	411	28	21,114
2	9	Chanthabuli	01Chanthabuli	178		56	28	1	263	7,865		3,115	2,382	36	13,398
2	10	Chanthabuli	01Chanthabuli	165	1	54	7	1	228	6,293	89	2,453	1,275	5	10,115
2	11	Chanthabuli	01Chanthabuli	146		18	6		170	5,743		851	219		6,813
2	12	Chanthabuli	01Chanthabuli	148	1	80	5		234	5,427	42	3,849	157		9,475
2	13	Chanthabuli	01Chanthabuli	41		36	7		84	3,307		1,864	769		5,940
2	14	Chanthabuli	01Chanthabuli						0						0
4	14	Sisattanak	04Sisattanak	235	2	38	2	2	279	8,007	1,300	2,269	508	31	12,115
4	15	Sisattanak	04Sisattanak	171	3	17			191	7,306	153	334			7,793
3	16	Sayse/Xayth	03Saysettha	152		31			183	5,060		1,131			6,191
4	16	Sisattanak	04Sisattanak	1,302	7	234	2	10	1,555	45,458	201	12,388	229	423	58,699
4	17	Sisattanak	04Sisattanak	335	2	29	4	2	372	14,970	217	1,412	307	45	16,951
4	18	Sisattanak	04Sisattanak	2,544	12	124	27	114	2,821	106,095	782	9,625	2,862	4,274	123,638
3	19	Sayse/Xayth	03Saysettha	117		42	5	3	167	4,173		1,508	817	125	6,623
2	19	Chanthabuli	01Chanthabuli	16		1			17	1,002		199			1,201
2	20	Chanthabuli	01Chanthabuli	1,352	3	182	5		1,542	46,207	112	7,118	501		53,938
3	21	Sayse/Xayth	03Saysettha	590	4	70		15	679	19,679	459	7,787		886	28,811
2	21	Chanthabuli	01Chanthabuli	106		22			128	4,814		972			5,786

3	22	Sayse/Xayth	03Saysettha	313	2	63	1	9	388	14,095	306	4,059	63	511	19,034
3	23	Sayse/Xayth	03Saysettha	1,608	11	200	4	45	1,868	65,993	650	9,806	330	1,337	78,116
3	24	Sayse/Xayth	03Saysettha	962	1	36	3	1	1,003	33,830	10	1,364	183	123	35,510
2	25	Chanthabuli	01Chanthabuli	4,075	14	238	17	5	4,349	137,785	629	15,916	1,357	120	155,807
3	26	Sayse/Xayth	03Saysettha	787	5	88	2	29	911	30,435	638	5,235	172	1,107	37,587
4	26	Sisattanak	04Sisattanak	1,062	4	57	5	19	1,147	43,499	409	5,887	388	716	50,899
4	27	Sisattanak	04Sisattanak	783		89	3	15	890	33,096		4,714	91	359	38,260
3	28	Sayse/Xayth	03Saysettha	3,578	17	178	9	1	3,783	114,559	1,123	12,797	1,191	94	129,764
2	28	Chanthabuli	01Chanthabuli	305	1	4	1		311	9,423	21	272	0		9,716
3	29	Sayse/Xayth	06Xaythany	632	1	111	5	5	754	21,477	101	7,329	660	85	29,652
4	30	Sisattanak	04Sisattanak	2,116	12	98	12	5	2,243	85,840	1,266	8,770	1,532	284	97,692
4	31	Sisattanak	04Sisattanak	1,217	8	51	15		1,291	31,712	95	2,683	1,424		35,914
3	32	Sayse/Xayth	06Xaythany	630	5	32	3		670	20,040	195	2,179	399		22,813
3	33	Sayse/Xayth	06Xaythany	1,347	9	66	2		1,424	43,186	442	9,893	1,288		54,809
3	34	Sayse/Xayth	06Xaythany	588	6	44			638	21,446	245	5,056			26,747
3	35	Sayse/Xayth	06Xaythany	13		1			14	628		64			692
4	36	Sisattanak	04Sisattanak	121		21	2		144	6,412		1,534	1,375		9,321
5	L	Large Consumer	-		719	114	161	107	1,102		521,345	26,975	192,806	18,589	759,715
			Total	37,578	878	4,140	427	420	43,444	1,352,886	532,781	272,530	228,081	29,874	2,416,152

Note
Source : NPVC
Cat. 1 : Domestic
Cat. 2 : Administration offices
Cat. 3 : Enterprises, factories, businesses class 1 to class 6
Cat. 4 : Businesses using water as the raw materials for production, hotels, guest houses, restaurants, and swimming pools
Cat. 5 : Diplomatic missions, international organizations, foreigners and expatriates

3.2.3 Served Population and Service Ratio

The served population can be calculated from the number of connections and number of persons per connection, and the household size. In the previous section, household size was obtained as follows.

- Data from National Statistical Centre, total capital city population in 2000 = 568,779, total capital city households = 105,075, household size = 5.41
- Data from NPVC meter readers, household size = 5.786
- Data from questionnaire survey conducted by the JICA Study Team = 6.84

Data from the NPVC meter reader and data from the questionnaire survey represent the number of people who use water from one connection. These two results 5.786 and 6.84, are then averaged out to 6.3 persons per connection, and is the figure used in this study to calculate the served population.

The served population is calculated as follows;

Number of domestic connections in 2003 = 37,578 connections
Number of people per connection = 6.3 people
Served population in 2003 = 37,578 x 6.3 = 236,741 people

Based on the served population, the service ratio is calculated as follows.

Served population in 2003 = 236,741 people
Population in service area in 2000 = 282,562 (refer to Annex 6)
Population in service area in 2003 = 304,288 (if growth rate is 2.5 % per annum)
Service ratio in service area in 2003 = 236,741/304,288 = <u>77.8 %</u>

Served population in 2003 = 236,741 people
Population in whole capital city in 2000 = 568,779
Population in whole capital city in 2003 = 612,513 (if growth rate is 2.5 % per annum)
Service ratio in whole capital city in 2003 = 236,741/612,513 = <u>38.65 %</u>

3.2.4 Per Capita Water Consumption

The per capita water consumption is derived from the served population and the total domestic water consumption, as shown on Table 52-3.

Served population in 2003 = 236,741 people
Total domestic water consumption in March 2003 = 1,352,886 m3/month
Per capita water consumption = 1,352,886/236,741/31x1,000 = 184 l/day

The per capita water consumption, 184 lpcd (liters per capita day), seems to be rather high compared with statistics from other South East Asian countries. The following causes, obtained from the results of the questionnaire survey are thought to be possible reasons for high per capita water consumption.

1) 20 % of households which do not have piped water supply obtain their water supply from a neighbouring household which has a piped water supply.

2) 22.7% of households which have piped water supply have leakage points within their houses which are not repaired

3) It has been observed that some taps are kept open when the water supply is not available and wastage occurs when the water supply service is resumed.

The quantity of water supplied to neighbouring households can be calculated, and the per capita water consumption is modified as follows:

Population in service area in 2003 = 304,288 people
Served population in 2003 = 236,741 people
Unserved population in 2003 = 67,547 people
20% of the unserved population = 13,509 people (indirectly served through the neighbour's house connection)
Served population including the indirectly served population = 236,741 + 13,509 = 250,251
Total domestic water consumption in March 2003 = 1,352,886 m3/month
Per capita water consumption = 1,352,886/250,251/31x1,000 = 174 l/day

3.3 Water Sources

3.3.1 Mekong River

(1) Water Level

The water source for the two existing major treatment plants, Chinaimo and Kaolieo, is the Mekong River. The Mekong River originates in the Tibet Plateau, traverses the Indo-China Mountains, runs between the Annam Cordillera and the Korat Plateau, then runs through the Cambodian Plain and Mekong Delta, and drains into the South-China Sea. The catchment area size of the river at Km 4, Vientiane at Muang Sisatanak is 299,000 km2.

The water level of the Mekong River fluctuates by season and fluctuates during flood and drought years. Past records of annual water level and discharge of the river since 1960 are tabulated in Annex 7. The highest and the lowest water levels over the past 43 years are a maximum height of 170.75 m in 1966, dropping to a minimum of 157.76 m in 1960. However, water level lower than 158.0 m was recorded once in 1960 and others were equal or higher than 158.0 m in other years.

Over the last 12 years, 1995 was a drought year and 2002, the last year, was a flood year. The minimum water level of the river in 1995, a drought year, was 158.11 m, and the maximum level was recorded at 170.64 m in a flood year, 2002. The maximum difference of the water level in the last 12 years reached 13 m and this big difference should be considered as the most significant factor in the case of construction of the new intake facilities. Although the high water level of 2002, at 170.64 m was higher than the designed high water level of Chinaimo Intake facilities, at 170.45, there was no damage to the pumping facilities since there was some clearance between the high water level and the floor level of the pump installation. Detailed records of water level fluctuation are shown in Annex 7.

(2) Discharge

The recorded discharges of the Mekong River over the past 43 years are 22,900 m^3/sec., maximum, and 598 m^3/sec., minimum. The average flow of the river in the dry season was 1,010 m^3/sec. Past records of annual water discharge of the river since 1960 are tabulated in Annex 7.

(3) Raw Water Quality

Surface water from the Mekong River is treated at the two water treatment plants (WTPs), Kaolieo and Chinaimo. Raw water quality is examined daily for operational purposes. The water treatment processes applied to the existing WTPs are, sedimentation with coagulant, rapid sand filtration, and disinfection with chlorination. These processes meet the potable water quality standards. Among the parameters for water quality, the principal parameter is turbidity from the viewpoint of the treatment process. The maximum and the minimum turbidity recorded in Chinaimo WTP since 1984 are 6,840 NTU and 2 NTU respectively. Concerning the monthly average turbidity in 2002, the highest was 1,370 NTU in August and the lowest was 13 NTU in April in Chinaimo. Meanwhile in Kaolieo, the highest was 1,407 NTU in August and the lowest was 59 NTU in April. Detailed turbidity data, together with WTP operation data are shown in Annex 9. Polymer has been used as a coagulant aid since 1994 to deal with high turbidity.

3.3.2 Nam Ngum River

(1) Water Level

The Nam Ngum River is a water source for the existing Thangone Treatment Plant and will be a source for the proposed Thangone Treatment Plant which is the one of the alternative plans in this study. The Nam Ngum River is one of the larger tributaries of the Mekong River. The catchment area of the river at the Veunekham water level monitoring station 2 km upstream from the Thanogne area, is 15,230 km2.

The water level of the Nam Ngum River fluctuates by season and and fluctuates in flood and drought years. Yearly fluctuation of the water level of the Nam Ngum River is shown in Annex 7. From records of the water level fluctuations over the past 13 years, it can be observed that the lowest water level was measured in 1993 and the highest water level was in 1995. Since the huge Nam Ngum Dam exists upstream of the Nam Ngum River, water level fluctuation is different from that of the Mekong River. The data shown in Annex 7 was measured at the water level monitoring station in Veunekham which is 2 km upstream from the Thanogne area and monitoring started from July 1990. The highest water level over the past 13 years was 169.00 m in 1995 and is higher than the designed high water level of 167.00 m of the existing Intake Pumping Station for irrigation.

The lowest water level of the river was 154.48 m in 1994 and the maximum level was measured as 169.00 m in 1995. The maximum difference of the water level in the last 13 years was 14.5 m and this big difference should be considered as the most significant factor in the case of construction of the new intake facilities if new construction plans are adopted. Fluctuation of the water level of the Nam Ngum River is larger than that of the Mekong River which is about 13 m.

(2) Discharge

Monthly mean discharge of the Nam Ngum River measured from 1973 to 1989, ranged from 215 m^3/sec in April to 1,790 m^3/sec in September. The frequency analysis result presented said that a discharge of 60 m^3/sec will occur once in 20 years.
(source: Basic Design Study Report, Agricultural and Rural Development Project in the Suburbs of Vientiane)

(3) Water Quality

The water quality of the Nam Ngum River, and the Nam Ngum Dam (which will be the water source for the new treatment plant which is one of the alternatives for the future) was examined in order to test the water quality as a source of drinking water. The water sampled in the dry and the rainy seasons were examined separately.

The samplings for water quality analysis were conducted on the dates as below:

	Dry Season	Rainy Season
Nam Ngum Dam	2^{nd} and 8^{th} April 2003	11^{th} and 18^{th} September 2003
Nam Ngum River	2^{nd} and 8^{th} April 2003	11^{th} and 18^{th} September 2003

1) Parameters of water quality analysis

The following parameters were examined in consideration of practicable analysis of local and water quality standard for raw water and drinking water.

Parameters: Temperature, pH, Turbidity, Color, Odor, Taste, Dissolved Oxygen, Suspended Solid(SS), Biochemical oxygen demand(BOD),Chemical oxygen demand(COD), Ammonia-Nitrogen(NH4-N),Nitrite-Nitrogen (NO2-N), Nitrate-Nitrogen(NO3-N), Chloride, Postassium Permanganate Consumed, Total Colony, Total Coliform, Cyanide, Mercury, Ethyl para nitrophenyl(ENP), Copper, Iron, Manganese, Zinc, Lead, Chromium, Cadmium, Arsenic, Fluoride, Hardness, Phenol, Alkalinity

2) Result

The result of the analysis is summarized in Table 33-1.

The water was sampled at the following places:

- Nam Ngum Dam: 50 m down stream from the spillway
- Nam Ngum River (Thangone): at the irrigation pumping station

Nam Ngum Dam was constructed for purpose of power generation and irrigation. The water quality will vary according to the sampled location and depth because the dam reservoir is large. Thus, the discharged water from the dam is assumed as representing that of the dam reservoir water. In addition, the degree of water pollution will be confirmed by comparing samples of the dam water with sampled water from Thangone. Results of water quality were evaluated based on both dry and rainy seasons' results and they are shown in Annex 8.

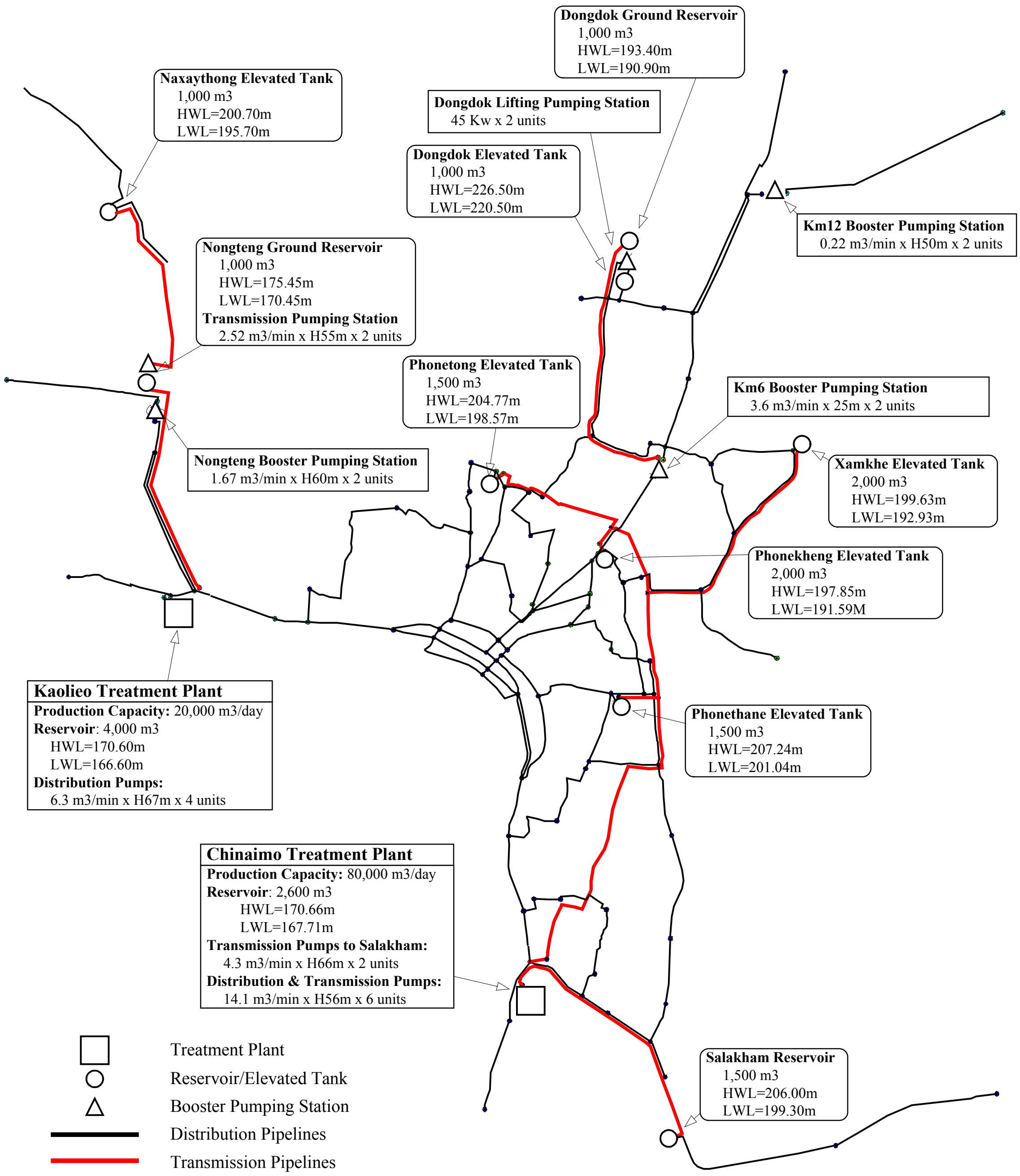
Table 33-1 Results of Water Quality Analysis

Item of Analysis	Unit	Water Standard	Nam Ngum Dam				Nam Ngum River (Thangone)				
			2003.04.02	2003.04.08	2003.09.11	2003.09018	1999.10.14	2003.04.02	2003.04.08	2003.09.11	2003.09018
Water Temperature	℃		25.0		24.0	28.1	28	25.1		26.1	24.3
PH	—	6.5～8.5	7.1	7.0	7.5	7.3	7.4	7.3	7.2	7.6	7.3
Odour	—	No offensive	NONE	NONE	NONE	NONE	-	NONE	NONE	NONE	NONE
Taste		No offensive	Normal	Normal	Normal	Normal	-	Normal	Normal	Normal	Normal
Colour	°	5	0.4	0.5	2.5	3.0	-	0.5	0.5	6.0	4.0
Turbidity	NTU	5	1.0	0.3	7.0	12.0	25	6.0	3.9	50.0	35.0
Dissolved Oxygen	mg/L		14.0	8.1	8.9	7.6	4.9	11.0	7.6	10.2	7.3
Suspended Solid (SS)	mg/L	1000	7.0	0.5	<1	<1	35	6.0	4.0	4.9	8.0
Biochemical oxygen demand (BOD)	mg/L		25.0	10.0	10.0	10.0		15.0	5.0	5.0	15.0
Chemical oxygen demand (COD)	mg/L		1.2	0.6	1.0	2.2		1.6	1.2	4.0	4.3
Ammonia Nitrogen (NH_4-N)	mg/L		N.D<0.01	N.D<0.01	0.05	0.04		N.D<0.01	N.D<0.01	0.2	0.06
Nitrite-Nitrogen (NO_2-N)	mg/L	0.1 or less	N.D<0.01	N.D<0.01	N.D<0.01	0.02	0.12	N.D<0.01	N.D<0.01	N.D<0.01	0.03
Nitrate-Nitrogen (NO_3-N)	mg/L	10 or less	N.D<0.01	N.D<0.01	0.04	0.04		N.D<0.01	N.D<0.01	N.D<0.01	0.1
Chloride ion (Cl^-)	mg/L	250 or less	14.0	4.8	3.4	3.9	10.3	10.0	6.7	4.1	3.4
Total Bacteria	cell/mL	less than 100/1mL	168	84	28	140	84	136	86	219	660
Total Coliform group	MPN	0/100mL	3/5	3/5	0/5	3/5	230	1/5	1/5	5/5	5/5
Cyanide (CN)	mg/L	0.07 or less	N.D<0.01	N.D<0.01	N.D<0.01	N.D<0.01	N.D.	N.D<0.01	N.D<0.01	N.D<0.01	N.D<0.01
Mercury (Hg)	mg/L	0.005 or less	N.D<0.0005	N.D<0.0005	N.D<0.0005	N.D<0.0005	N.D.	N.D<0.0005	N.D<0.0005	N.D<0.0005	N.D<0.0005
Copper (Cu)	mg/L	1.0 or less	N.D<0.02	N.D<0.02	N.D<0.01	N.D<0.01	-	N.D<0.02	N.D<0.02	N.D<0.01	N.D<0.01
Iron (Fe)	mg/L	0.3 or less	0.47	0.34	0.11	0.37	0.4	0.63	0.42	0.28	1.34
Manganese (Mn)	mg/L	0.1 or less	0.09	0.04	N.D<0.01	0.05	-	0.03	0.02	N.D<0.01	0.16
Zinc (Zn)	mg/L	3.0 or less	0.10	0.17	0.16	0.15	-	0.14	0.18	0.18	0.17
Lead (Pb)	mg/L	0.02 or less	N.D<0.01	N.D<0.01	N.D<0.01	N.D<0.01	N.D.	N.D<0.01	N.D<0.01	N.D<0.01	N.D<0.01
Chromium (Cr^{+6})	mg/L	0.05 or less	N.D<0.01	N.D<0.01	N.D<0.01	N.D<0.01	N.D.	N.D<0.01	N.D<0.01	N.D<0.01	N.D<0.01
Cadmium (Cd)	mg/L	0.01 or less	N.D<0.005	N.D<0.005	N.D<0.001	N.D<0.001	0.003	N.D<0.005	N.D<0.005	N.D<0.001	N.D<0.001
Arsenic (As)	mg/L	0.05 or less	N.D<0.01	N.D<0.01	N.D<0.01	N.D<0.01	N.D.	N.D<0.01	N.D<0.01	N.D<0.01	N.D<0.01
Fluoride (F^-)	mg/L	1.0 or less	N.D<0.01	N.D<0.01	N.D<0.01	N.D<0.01	0.41	N.D<0.01	N.D<0.01	N.D<0.01	N.D<0.01
Total Hardness ($CaCO_3$)	mg/L	300 or less	42	44	60	122	52	54	52	52	72
Phenol	mg/L	0.005 or less	N.D<0.01	N.D<0.01	N.D<0.001	N.D<0.001	-	N.D<0.01	N.D<0.01	0.002	N.D<0.001
Electric Conductivity	mS/cm		0.106	0.110	0.107	0.110		0.102	0.83	0.09	0.082
Alkalinity	mg/L						-		48		

3.4 Treatment Plants

The two treatment plants, Kaolieo and Chinaimo, supply potable water of an amount of 100,000 m3/day to population in Vientiane via 2 ground reservoirs, 7 elevated tanks, 5 pumping stations and transmission and distribution pipelines, as shown in Figure 34-1. Details of each facility are explained in the followings.

Figure 34-1 Existing Vientiane Water Supply System



3.4.1 Kaolieo Treatment Plant

(1) General

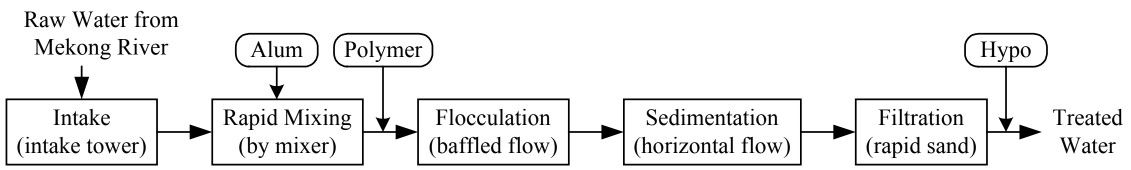
The Kaolieo Treatment Plant is locate in the western side of central part of the capital city along the Mekong River. The Kaolieo Treatment Plant, with a production capacity of 20,000 m3/day was constructed in 1964 as a Japan's Grant Aid Project and is the oldest treatment plant in Vientiane. In 1983, rehabilitation works was implemented also by Japan's Grant Aid. The outline of the plant is shown on the Table 34-1. The design capacity shown in the table is the capacity of the intake facilities. In 2002, since the efficiency of the existing intake pumps in the intake tower became low, additional intake pumps were installed on a floating dock which is moored just upstream of the existing intake tower.

Table 34-1 Outline of Treatment Plant

Type of Water Source	Name of Source	Water Level	Type of Intake Structure	Year of Construction	Design Capacity (m^3/d)
Surface Water	Mekong River	HWL:+171.500 m LWL:+159.500 m	Intake Tower	1964	20,000
			Pontoon(Floating Dock)	2002	6,480
Total	---	---	---	---	26,480
Method of Water Purification (Start from year 1964)			Flocculation and Sedimentation W/Pre-filtration / Rapid Sand Filtration		

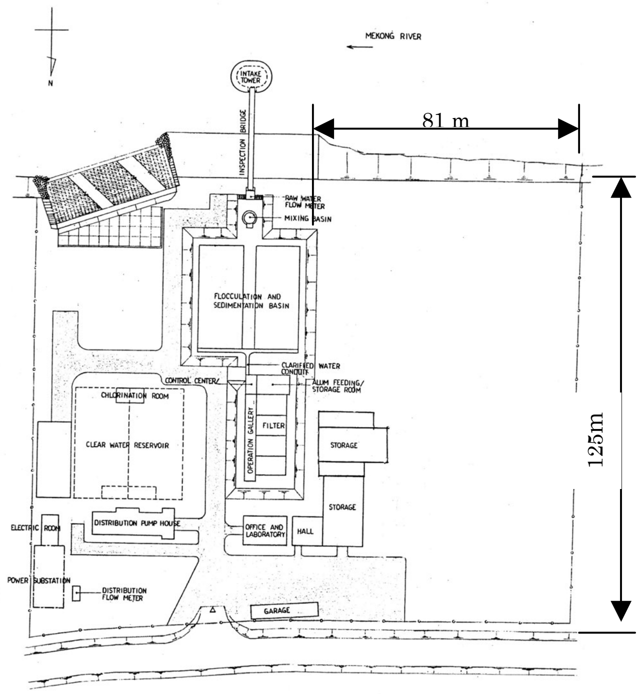
The existing Kaolieo Treatment Plant utilises the rapid sand filtration system which is the most popular treatment system in the world. The raw water from the Mekong River is treated through the treatment process as shown in Figure 34-2 with a help of three kinds of chemicals, i.e. aluminium sulphate (alum), anionic polymer (polymer), and calcium hypochlorite (hypo). The existing sedimentation basins has a gravel filter at the end of the basin, however, the gravel filter does not function well.

Figure 34-2 Flow of Treatment Process of Kaolieo Treatment Plant



The polymer is dosed for the coagulation in addition to the alum but only in case that the raw water turbidity is very high, more than 400 NTU. Therefore, the Kaolieo Treatment Plant does not conduct the pH control by adding lime, because the amount of the alum can be reduced by dosing with polymer.

Figure 34-3 General Plan of Kaolieo Treatment Plant



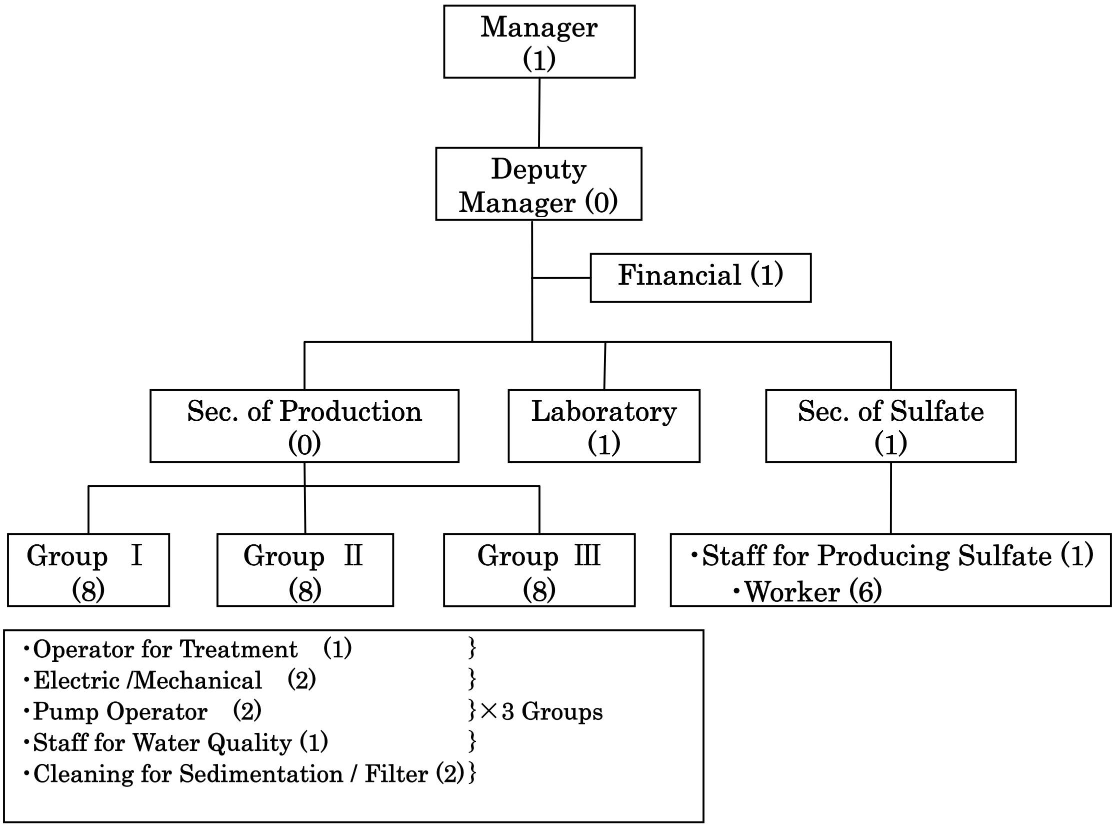
The general plan of the Kaolieo Treatment Plant is as shown on Figure 34-3.

As is shown in the figure, there is a vacant area for future expansion on the western side, or the upstream side of the Mekong River.

(2) Organization Chart and Staff

The total number of staff at the Kaolieo Treatment Plant is 35 persons, including 8 persons for a plant to produce Aluminium Sulphate, used in the water treatment process as a coagulant. The Aluminium Sulphate produced is used in the Kaolieo Treatment Plant and the Chinaimo Treatment Plant and is also delivered to other Nam Papa in Lao PDR. The organization chart of the Plant is shown on Figure 34-4.

Figure 34-4 Organization Chart of Kaolieo Treatment Plant



As shown in the organization chart, the positions of Deputy Manager and Section Chief of Production Section are vacant. Routine operations of the plant are conducted by the three groups from the production sections. Since the Chief of the Production Section position has been vacant, the Manager of the Plant is taking care directly of these three operation groups.

(3) Operation of the Treatment Plant

In 2002, both the intake amount and treated water amount increased from July 2002 because of the installation of additional intake pumps. Before the installation 19,200 m^3/day was the maximum raw water intake, but after the installation of extra pumps in October 2002, the intake increased to 33,539 m^3/day. After July 2002, the quantity of treated water, was 26,000 to 30, 000 m^3/day and it is apparent that the plant has been operating under overloaded conditions since the design capacity of the plant is 20,000 m^3/day. Detailed operation records of the plant are shown in Annex 9. The quantity of raw water intake, treated water and water loss in the Plant in year 2002 are also shown in Annex 9.

The flow meter for the existing intake tower is out of order and a flow meter is not available for the additional intake pumps, therefore, quantity of raw water introduced to the plant is an estimate based on pump capacity and pump operating hours.

Although data of raw water quantity is not so reliable, water loss rate in the plant fluctuates from 25 % to less than 5 %. It can be concluded that the plant operation or flow control in the plant is not adequately controlled.

At the Kaolieo Treatment Plant, polymer and aluminium sulphate (Alum) are dosed as coagulants. The correlation between raw water turbidity and polymer usage in quantity and rate are shown in Annex 9. The correlation between raw water turbidity and Alum usage in quantity and in rate calculated from water quantity are also shown in Annex 9. Alum consumption and the dosing rate, based on the data obtained from the plant are shown in Annex 9.

As shown in Annex 9, the consumption of chemicals, or the chemical dosage rate has not always conformed to the fluctuation of raw water turbidity. This might be caused by problems in communications between the laboratory which decides chemical dosage rate, and the plant operation groups.

It has been found that there is a significant difference in the Alum dosage rate calculated from the raw water quantity, and the Alum consumption shown in Annex 9, and the dosage rate which was actually recorded at the plant. This may be because there is a possibility of misunderstandings of chemical dosage rates at the plant.

(4) Physical and Operating Condition of the Treatment Plant

Table 34-2 shows the operating conditions of the plant in 2002, details of which are shown in Annex 9. Frequency of facility cleaning and the maintenance/repair of mechanical/electrical equipment is extremely high as shown on the table in Annex 9.

The Kaolieo Treatment Plant is the oldest plant in Vientiane, therefore deterioration of facilities and equipment has become a significant problem for the stable operation of the plant. Intake pumps, distribution pumps, flash mixer, surface wash system and backwash pumps for filters, facilities for chemical dosage and maintenance valves for clear water reservoir were rehabilitated in 1984. However, that was nearly 20 years ago, and some other equipment and facilities in the plant are more than 40 years old. Operators are struggling against such deterioration without sufficient spare parts under overloaded conditions to meet an increasing water demand.

Table 34-2 Operation Conditions of Treatment Plant in Year 2002

a. Daily Water Production	Maximum		33,539 m^3/day		
	Average		23,424 m^3/day		
	Minimum		13,840 m^3/day		
b. Number of Staff for Operation of Treatment Plant	Operator for Treatment Plant		1 Person	8:00----20:00 : All Member 20:00----8:00 : 3 Shift 8 Persons / Group (24 hours) : including Treatment Plant	
	Operator for Pump		2 Persons		
	Electrical		1 Person		
	Mechanical		1 Person		
	Staff for Laboratory		1 Person		
	Staff for Cleaning of Sed. / Filter		2 Persons		
c. Operation of Chemical Feeding	Names of Chemicals		Dosage Rate (Calculation)		
			Average (mg/l)	Maximum(mg/l)	Minimum(mg/l)
	Aluminium Sulphate		36.9	156.7	0
	Polymer		0.017	0.105	0
	Hypochlorite		1.5	2.8	0.9
	Name of Chemicals	Unit Price (kip/kg)	Consumption of Chemicals (kg/Month)		
			Average	Maximum	Minimum
	Alum	2,222	923	4,250	200
	Polymer	81,320	0.44	2.40	0
	Hypo	15,447	30	30	30
d. Consumption of Electricity	Unit Price (kip/kWH)		Consumption of Electricity (kWH/Month)		
			Average	Maximum	Minimum
	400		3,535	3,900	2,100
e. Maintenance of Treatment Facilities	Frequency of Cleaning Facilities		Sedimentation	1 Time/Month	
			Filter	4-7 Time/Month	
			Gravel Filter	2-4 Time/Month	
	Frequency of Maintenance / Repairing for Equipment		Mechanical Equipment	1 – 12 Time/Month	
			Electrical Equipment	4 – 6 Time/Month	

Detail conditions of facilities/equipment as well as pictures are shown in Annex 9 and the following are major problems found during a field investigation.

- Significant leakage, spurting water, from a gate valve at the intake was observed even though the valve was completely open. This valve may not be able to close completely.
- Although it is not confirmed whether the intake tower causes erosion to the river bank or not, serious damage to the river bank in the vicinity of the existing intake tower has been observed.
- Cracks and leakage from cracks, were observed at a wall of concrete structures of the flocculation and sedimentation basins.
- The washing system of gravel filters installed at the end of the sedimentation basin does not work well. Therefore, the operator has to remove the gravel from the basin and wash the gravel outside of the basin. When the operator returns the gravel after washing, it will not be easy for the operator to restore the gravel layer due to the complicated work involved in replacing the gravel by grain size.
- Facilities and equipment concerning the filtration basin which is 40 years old, and the head-loss meter is broken down.
- All the chemical dosage pumps and flow controllers malfunction and the chemicals are dosed by

gravity. This makes it difficult to achieve accurate chemical dosage control.

- Control of the back wash rate and the surface wash rate for the filtration basin is almost impossible because the butterfly valves on these lines are malfunction.

(5) Condition of Pumps

To evaluate the pump condition, the JICA Study Team measured discharge from the intake pump and the distribution pump by using an ultrasonic flow meter. The results of the measurements on the raw water line are shown in Annex 9.

As is shown on the figure in Annex 9, the pump capacity is calculated at about 6 m^3/min. However, the rated capacity of these pumps is 7.65 m^3/min. Therefore the efficiency of the intake pumps is reduced by about 22 %. The discharge of additional intake pump was also measured and the results showed that capacity of pump was 3.85 m^3/min against a rated capacity of 4.5 m^3/min.

The results of flow measurements of the distribution pump discharge are shown in Annex 9. Discharge of the distribution pumps was measured at 5.3 m^3/min/unit. Considering that the design capacity of the distribution pumps is rated at 6.3 m3/min/unit, the distribution pumps are also working at a reduced capacity.

(6) Power Failure

The power sub-station in Kaolieo WTP was constructed in 1964, and a lot of the equipment and facilities are now 40 years old. The power sub-station receives power through a single electric power supply line from the Lao Electric Company. Kaolieo WTP sustains great losses every year due to many power failures, as shown in Annex 9.

(7) Laboratory

It was explained by the NPVC that the daily water quality analysis in the Kaolieo WTP is conducted in the same manner as in the Chinaimo WTP. However, on a visit by the study team, laboratory equipment in Kaolieo looked as if it had not been in operation for long time i.e., covered with dust and cobwebs. Only one staff member is assigned to work in the laboratory of the Kaolieo WTP, however, he has been absent due to illness.

The equipment installed in the laboratory are, Turbidity meter, Jar Tester, Incubator, Conductivity Meter, Electric Balance, pH Meter, Oven, and Absorption meter. Most of the equipment is broken or the sensors of the equipment do not function.

(8) Rehabilitation Works Required

In the initial stage of this study, investigation of the existing water supply facilities was conducted and the result is summarized in above section (5). Among the works to be improved or restored in Kaolieo plant, the following works should be integrated into the Master Plan and immediate work should begin on rehabilitation of the plant.

Table 34-3 Rehabilitation Works Required in Kaolieo Plant

Facility	Item	Description
1. Intake		
	- Intake Pumps & Valves	Replacement with 7.65 m3/min x 37 kw x 3 units
	- Maintenance Bridge	Repair & Repainting
	- Protection against erosion	Revetment in the vicinity of the intake tower,
2. Raw Water Transmission Pipe		
	- Civil Works	Flow meter chamber construction
	- Electric & Mechanical Works	Installation of flow meter and accessories
3. Flocculation & Sedimentation Basins		Repair crack in the wall
4. Filtration		Replacement of valve and gates with accelerator, Backwash pumps 14.5 m^3/min x 60 kw x 3 units
5. Clear Water Reservoir		Repair structure
6. Distribution Pumping Facilities		
	- Distribution Pumps	Replacement of pumps 6.3 m3/min x 67 m x 110 kw x 4 units
7. Chemical Feeding Facilities		
	- Chemical Feeding Equipment	Installation of equipment and solution tank
8. Electrical Equipment Facility		
	- Emergency Generator	Installation of a new generator having one third of power supply to the plant
	- Instrumentation Equipment	Flow meter appurtenances
9. Chlorination		Dissolving Tank and Feeding pumps
10. Laboratory Equipment		Necessary equipment and tools for daily monitoring of required parameters

3.4.2 Chinaimo Treatment Plant

(1) General

The Chinaimo Treatment Plant is located in the south central part of the capital city along the Mekong River. The Chinaimo Treatment Plant with a rated capacity of 40,000 m^3/day was constructed in 1980 with finance provided by the ADB. During 1992 - 1996, rehabilitation and expansion works were implemented by Japan's Grant Aid and the total capacity was expanded to 80,000 m^3/day. An outline of the plant is as shown on the Table 34-4. The design capacity shown on the table is the capacity of the intake facilities.

Table 34-4 Outline of Treatment Plant

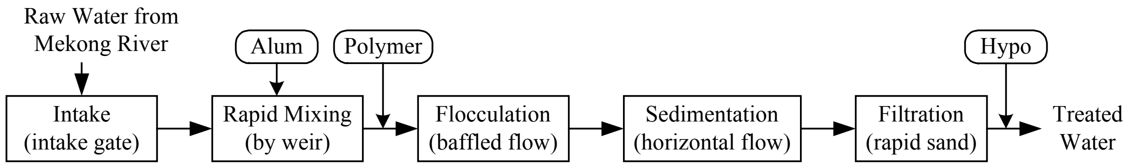
Type of Water Source	Name of Source	Water Level	Type of Intake Structure	Year of Construction	Design Capacity (m^3/d)
Surface Water	Mekong River	HWL:+170.450 m LWL:+157.010 m	Intake	1980 (Establishment)	40,000
				1996(Expansion)	40,000
Total	---	---	---	---	80,000
Method of Water Purification (Start from year 1980)			Flocculation and Sedimentation / Rapid Sand Filtration		

The general plan of the Chinaimo Treatment Plant is as shown on Figure 34-6. As shown in the figure, the northern part of the existing plant, upstream of the Mekong River is reserved for future expansion of the plant. Also on the eastern side of the plant, there is a space for expansion of the plant, however, the width of the space is almost same as the width of the existing sedimentation basin. If the expansion of the plant takes place in this space, the existing wall on the boundary of plant premises on the eastern side should be removed temporarily for construction works.

On the northern side, the NPVC has a plan to construct a training centre with assistance of the AFD. However, detailed information about the training centre has not been made available.

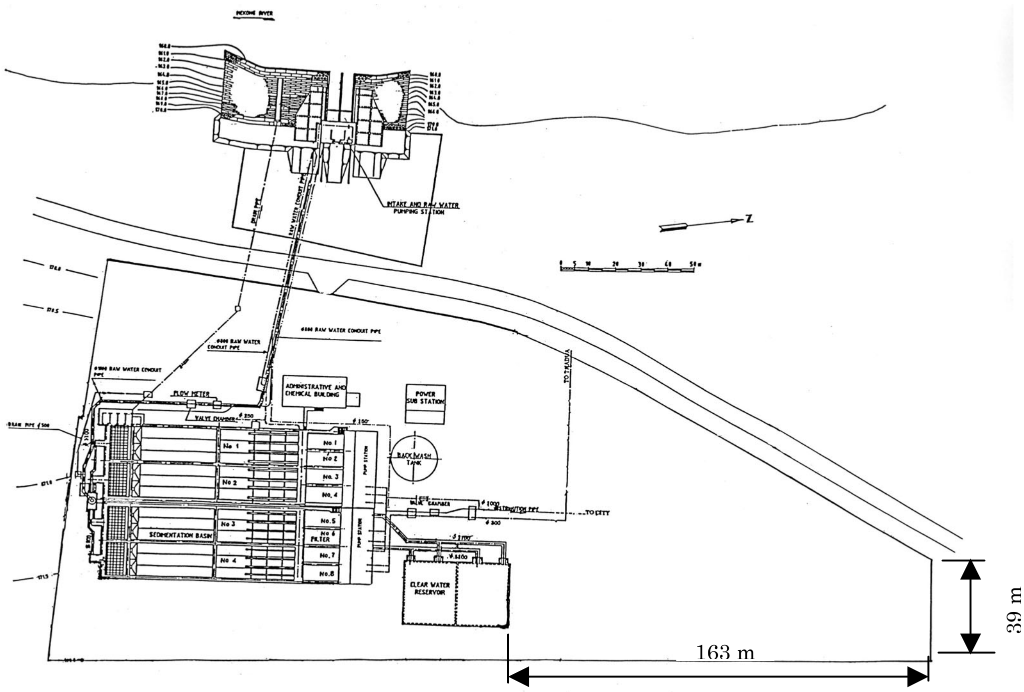
The Chinaimo Treatment Plant also utilises the rapid sand filtration system, the same system used at the Kaolieo Treatment. The raw water from the Mekong River is treated through the treatment process as shown in Figure 34-5 with a help of three kinds of chemicals, aluminium sulphate (alum), anionic polymer (polymer), and calcium hypochlorite (hypo).

Figure 34-5 Flow of Treatment Process of Chinaimo Treatment Plant



The Chinaimo Treatment Plant has a lime feeding facility for controlling the pH level. The plant uses polymer for coagulation in addition to using alum in the case of high turbidity levels of the raw water, as does the Kaolieo Treatment Plant, however, the lime feeding facility is not used at present.

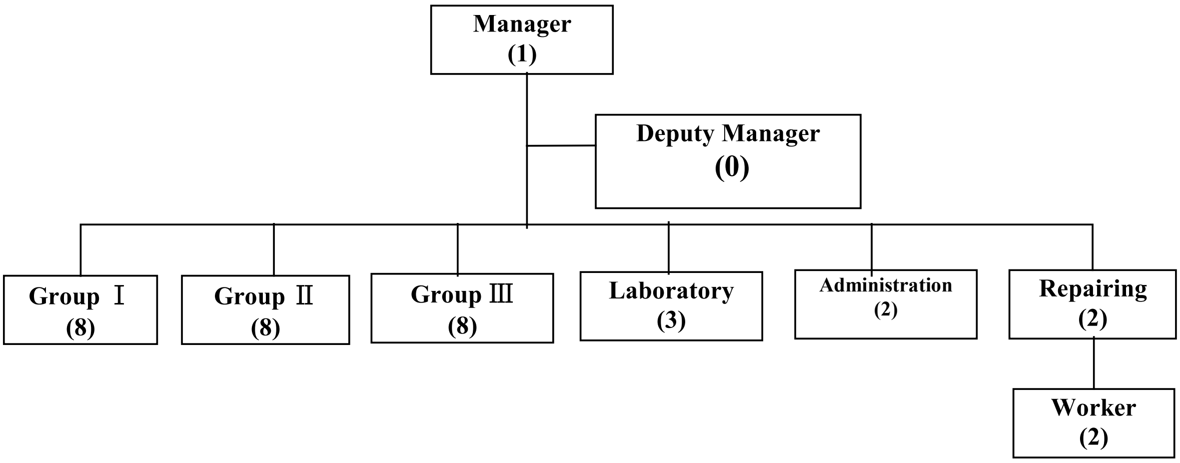
Figure 34-6 General Plan of Chinaimo Treatment Plant



(2) Organization Chart and Staff

The total number of staff in the plant is 35 persons, including two workers for repairs. The organization chart is shown in Figure 34-7.

Figure 34-7 Organization Chart of Kaolieo Treatment Plant



The position of Deputy Manager is vacant, as is the same at the Kaolieo Treatment Plant mentioned previously. The organization structure is similar to the Kaolieo Treatment Plant.

(3) Operation Record of the Treatment Plant

The average quantity of the intake water in 2002 was 96,790 m^3/day. The quantity of raw water intake, treated water and water loss in the plant in 2002 are shown in Annex 9. The average quantity of treated water in 2002, distributed water is 93,234 m^3/day, and it is apparent that the plant has been operating under overloaded conditions because the design capacity of the plant is 80,000 m^3/day. Details of the operation record of the plant are shown in Annex 9.

As shown in Annex 9, the water loss rate in the plant has fluctuated from 1 %, to less than 7 %. From this, it can be interpreted that the plant operation or flow control in the plant is not adequately conducted.

The quantity of total water distributed to the city and to the Thadeua area, together with the quantity of filtered water are schematically shown in Annex 9. As the flow meter on the distribution pipe to Thadeua has been out of order since October 2002, the statistics of the quantity of water to Thadeua is based on an estimation from the pump capacity and its operational hours. Therefore, the data of distribution water quantity to Thadeua is not reliable.

At the Chinaimo Treatment Plant, polymer and aluminium sulphate (alum) are used as coagulants. The correlation between raw water turbidity and polymer dosage in both quantity and rate, are shown in Annex 9.

The correlation between raw water turbidity and alum dosage in both quantity and rate are shown in Annex 9. The rate calculated between water quantity and alum consumption are shown in Annex 9. The alum dosing rate is based on data obtained from the plant and is also shown in Annex 9.

As shown in Annex 9, the chemical consumption or the chemical dosage rate does not always conform to the fluctuations of raw water turbidity. This might be caused by problems in communication between the laboratory who decides the chemical dosage rate, and the plant operation groups.

There is a significant difference in the alum dosage rate, calculated from raw water quantity and chemical consumption data shown in Annex 9, and the actual dosage rate which was recorded at the plant.

Tables 34-5 to 34-7 show the comparison of raw water turbidity, dosage rate of alum and polymer between the Kaolieo and Chinaimo Treatment Plants. There is a tendency for the data between the two plants to be similar because the two plants raw water use the same water source. However, there is a difference in the dosage rate of chemicals between the two plants.

Table 34-5 Correlation of Raw Water Turbidity between Chinaimo and Kaolieo

Month	Chinaimo Water Treatment Plant			Kaolieo Water Treatment Plant		
	Maximum (mg/l)	Minimum (mg/l)	Average (mg/l)	Maximum (mg/l)	Minimum (mg/l)	Average (mg/l)
Jan	106	28	57	188	121	140
Feb	77	21	39	138	70	99
Mar	53	12	30	100	74	82
Apr	90	2	13	85	41	59
May	544	21	182	550	30	204
Jun	1,910	229	487	1,835	224	444
Jul	4,645	237	1,164	3,521	335	1,107
Aug	4,460	645	1,370	2,415	610	1,407
Sep	1,653	334	782	1,324	275	649
Oct	1,165	270	553	778	204	384
Nov	757	136	494	282	190	230
Dec	875	23	209	365	141	215

Table 34-6 Correlation of Alum Dosing Rate between Chinaimo and Kaolieo

Month	Chinaimo Water Treatment Plant			Kaolieo Water Treatment Plant		
	Maximum (mg/l)	Minimum (mg/l)	Average (mg/l)	Maximum (mg/l)	Minimum (mg/l)	Average (mg/l)
Jan	14.7	7.2	9.6	29.3	22.8	24.7
Feb	14.8	6.1	9.8	24.2	22.2	23.1
Mar	13.1	6.0	8.2	23.2	17.1	17.7
Apr	9.4	5.1	7.3	18.1	14.3	17.0
May	21.8	6.0	13.0	83.3	11.4	28.1
Jun	34.7	14.7	19.8	109.9	17.4	47.6
Jul	53.2	13.6	29.0	140.4	24.0	62
Aug	90.1	20.8	36.4	156.7	36	87.4
Sep	37.5	15.9	22.9	98.6	31.0	55.5
Oct	28.8	11.4	17.7	80.2	0	32.8
Nov	21.8	10.5	17.6	38.2	15.9	22.6
Dec	21.7	8.4	16.2	37.9	17.3	22.6

Table 34-7 Correlation of Polymer Dosing Rate between Chinaimo and Kaolieo

Month	Chinaimo Water Treatment Plant			Kaolieo Water Treatment Plant		
	Maximum (mg/l)	Minimum (mg/l)	Average (mg/l)	Maximum (mg/l)	Minimum (mg/l)	Average (mg/l)
Jan	0	0	0	0.015	0	0.007
Feb	0	0	0	0.014	0	0.001
Mar	0	0	0	0	0	0
Apr	0	0	0	0	0	0
May	0.036	0	0.005	0.059	0	0.014
Jun	0.049	0.010	0.027	0.059	0.024	0.051
Jul	0.059	0.011	0.037	0.051	0.023	0.031
Aug	0.135	0.031	0.063	0.105	0.025	0.053
Sep	0.063	0.016	0.039	0.026	0	0.012
Oct	0.042	0	0.027	0.021	0	0.017
Nov	0.031	0	0.017	0.023	0.009	0.020
Dec	0.023	0	0.004	0	0	0

(4) Physical and Operating Conditions of the Treatment Plant

Table 34-8 shows the operating condition of the plant in 2002, details of the operating conditions are shown in Annex 9.

Table 34-8 Operation Conditions of Treatment Plant in Year 2002

<table>
<tr><td colspan="3" rowspan="3">a. Daily Water Production</td><td>Maximum</td><td colspan="2">98,213 m^3/day</td></tr>
<tr><td>Average</td><td colspan="2">96,539 m^3/day</td></tr>
<tr><td>Minimum</td><td colspan="2">76,694 m^3/day</td></tr>
<tr><td colspan="3">b. Number of Staff for Operation of Treatment Plant</td><td colspan="3">8:00----20:00 : All Member,
20:00----8:00 : 3 Shift
8 Persons/Group (24 hours) : including Treatment Plant</td></tr>
<tr><td rowspan="10">c. Operation of Chemical Feeding</td><td colspan="2" rowspan="2">Names of Chemicals</td><td colspan="3">Dosage Rate (Calculation)</td></tr>
<tr><td>Average (mg/l)</td><td>Maximum(mg/l)</td><td>Minimum(mg/l)</td></tr>
<tr><td colspan="2">Aluminium Sulfate</td><td>17.4</td><td>90.1</td><td>5.1</td></tr>
<tr><td colspan="2">Polymer</td><td>0.018</td><td>0.135</td><td>0</td></tr>
<tr><td colspan="2">Hypochlorite</td><td>1.5</td><td>1.5</td><td>1.3</td></tr>
<tr><td rowspan="2">Name of Chemicals</td><td rowspan="2">Unit Price (kip/kg)</td><td colspan="3">Consumption of Chemicals (kg/Month)</td></tr>
<tr><td>Average</td><td>Maximum</td><td>Minimum</td></tr>
<tr><td>Alum</td><td>2,222</td><td>1,675</td><td>8,000</td><td>400</td></tr>
<tr><td>Polymer</td><td>81,320</td><td>1.80</td><td>12.00</td><td>0</td></tr>
<tr><td>Hypo</td><td>15,447</td><td>125</td><td>125</td><td>125</td></tr>
<tr><td rowspan="3">d. Consumption of Electricity</td><td colspan="2" rowspan="2">Unit Price
(kip/kWH)</td><td colspan="3">Consumption of Electricity (kWH/Month)</td></tr>
<tr><td>Average</td><td>Maximum</td><td>Minimum</td></tr>
<tr><td colspan="2">400</td><td>25,753</td><td>28,500</td><td>15,600</td></tr>
<tr><td rowspan="4">e. Maintenance of Treatment Facilities</td><td colspan="2" rowspan="4">Frequency of Cleaning Facilities</td><td rowspan="2">Sedimentation</td><td>Dry Season</td><td>1 Time/Month</td></tr>
<tr><td>Wet Season</td><td>3 Time/Month</td></tr>
<tr><td rowspan="2">Filter</td><td>Dry Season</td><td>2.4-3.4 me/Month</td></tr>
<tr><td>Wet Season</td><td>3 Time/Month</td></tr>
</table>

Compared with the Kaolieo Treatment Plant, the condition of facilities and equipment at the Chinaimo plant are better. However, the operators at the plant have a problem with a shortage of spare parts for routine repair works. The frequency of cleaning the sedimentation basin is high, 3 times a month during the rainy season, compared with once a month at the Kaolieo Treatment Plant.

(5) Condition of Pumps

Since the flow meter on the pipeline to Thadeua area was not functioning, the JICA Study Team measured the discharge of the distribution pump to Thadeua area with an ultrasonic flow meter for 24 hours. The results of the measurement are shown in Annex 9. The pumps were operated for15 hours a day, and the average discharge rate was about 5.7 m^3/min.

(6) Power Failures

The record of power failures is included in Annex 9. According to the records, the duration of power failures per year at Kaolieo Treatment Plant was, in hours, 17:55 hrs in 2000, 13:52 hrs in 2001 and 6:03 hrs in 2002. On the other hand, Chinaimo Treatment Plant had power failures for, 5:35 hrs in 2001 and 7:16 hrs in 2002. Both plants, had power failures which, on average, affected production for 5 to 15 hours per year.

(7) Laboratory

1) Water Quality Analysis

Equipment at the laboratory in Chinaimo WTP is summarized in following table.

Table 34-9 List of Equipment for water quality analysis at Chinaimo WTP

Equipment	Condition	Frequency of Use
Water bath	Good	
Jar test	Good	Everyday
Turbidity Meter	Good	Everyday
pH/ORP Meter	Good	Everyday
Absorptiometer	Good	
Electric Balance	Good	
Automatic Oven	Good	
Incubator	Good	
Distiller	Good	
Draft	Good	
Oven	Good	
Analytical Balance	Good	
Conductivity Meter	Good	
Atomic Absorption Spectrophotometer	Good	

Water quality is examined daily, weekly, monthly, and every 6 months for designated parameters. All of the equipment used for water quality analysis is kept in an acceptable condition for use. However, portable equipment brought by a JICA senior volunteer was not available for use due to unavailability of a particular type of dry cell battery in Laos. The testing parameters and frequency of water quality analysis are shown in Table 34-10.

The results of the water quality analysis are kept as a printed form after input into a computer; however, those results could be accumulated and statistically examined. Accumulation of this data would improve the accuracy of the analysis, and annual tendency of Mekong River water quality and would be a practical reference for future water treatment plant operation.

2) Determination of Chemical Dosage

The dosage of alum and polymer are determined by the turbidity levels are obtained by the Jar Test for raw water, while the required chemical dosage is an estimate based on the production rate as fixed at 80,000 m^3/day in Chinaimo WTP. If the alum dosage ratio is fixed, the volume of chemicals should be adjusted to the flow rate of raw water which will likely change as a consequence of changing pumping operations. However, the actual alum dosage ratio may be smaller than the ratio determined by the Jar Test because no adjustment of the alum volume to the raw water flow is conducted and the production rate is often more than 80,000 m^3/day.

According to the water quality analysis, no residual chlorine was detected in treated water in testing several days a month at the plant.

Table 34-10 Parameters of Water Quality Analysis

Daily Analysis

Parameter	Raw Water	Settled Water	Filtered Water	Clear Water	Clear Water in Town	Test method	Spectro-Photometer
Temperature	O	O	O	O	−		
pH	O	O	O	O	−	Electrometric	
Turbidity	O	O	O	O	−	Turbidity Meter(NTU)	
Alkalinity	O	O	O	O	−	Acid Titration	
Residual Chlorine	−			O	−	Orthotoridine	
Temp.Atomos							
Jar Test	O						

Weekly Analysis (plus Daily Analysis parameters)

Color	O	−	O	O	O	Photometric	O
Odor and Taste	O	−	O	O	O	Sensual Test	
Ammonia Nitrogen	O	−	O	O	O	Phenate Method	O
Nitrate Nitrogen	O	−	O	O	O	Sodium Salicylate	O
Nitrite Nitrogen	O	−	O	O	O	G.R Method	
Chloride Ion	O	−	O	O	O	AgCl Titration	
KMnO4 Consumed	O	−	O	O	O	Titration	
Total Hardness	O	−	O	O	O	EDTA Titration	
Total Coliform	O	−	O	O	O	Multiple Fermentation	
Total Colony	O	−	O	O	O	Plate Count Agar	

Monthly Analysis (plus Weekly Analysis parameters)

Coliform Group(MPN)	O in every 2months	−	O in every 2months	−	−	MPN Method	
Iron (Fe)	O	−	O	O	O	O-phenanthroline	O
Manganese (Mn)	O	−	O	O	O	Form Aldoxime	O
Aluminium (Al)	−	−	−	O	O	Oxine-Chloroform	O
Total Dissolved Solids	−	−	−	O	O	Evaporation	

Yearly Analysis (plus Monthly Analysis) (in April and October)

Parameter	Colorimetric	Analysis Method	Atomic Absorption S.
Cadmiun (Cd)	O	Dithizone Photometric Method	O
Chromium (Cr6+)	O	Diphenyl Carbazide	O
Mercuy (Hg)	O	Dithizone Colorimetric	O
Lead (Pb)	O	Dithizone Photometric Method	O
Arsenic (As)	O	DDTC-Pyridine Photometric	
Selenium (Se)	O	Diaminobenzidine Colorimetric	
Zinc (Zn)	O	Zinecon Method	
Copper (Cu)	O	Dithizone Photometric Method	O
Anionic Surface active Agents (ASAA)	O	Ethylviolet-Toluene Method	O
Phenol	O	Aminoantipyrine-Chloroform	
Cyanide (CN-)	O	Pyridine-Barbituric Acid	
Fluoride (F-)	O	Alizarin Complexon Method	
Sulphate Ion (SO4-)	O	BaCl Gravimetric Method	
DO (Dissolved Oxygen)	O	Lodomeric Method	

3) Laboratory Staff

The three staff members in the laboratory have been trained by a JICA senior volunteer and are judged to be qualified in the understanding of analytical methods, and the handling and operation of the equipment. Furthermore they know testing procedures for sampling water i.e. parameters to be examined on site, and methods of sampling.

(8) Rehabilitation works

In initial stage of this study, an investigation of the existing water supply facilities was conducted and the result is summarized in above section. No work except those on the distribution facilities should be integrated into the Master Plan and immediate works for rehabilitation of the plant.

3.4.3 Thangone Treatment Plant

The Thangone Treatment Plant was constructed in 1993 with a production capacity of 550 m^3/day, replacing the old water supply which used groundwater. Raw water for the existing plant is taken from the Nam Ngum River.

The total number of the staff members at the plant is 5 persons, consisting of two engineers and three administrators, who also work as branch office staff.

A flow diagram is shown on Figure 34-8 and the outline of the treatment plant is shown on Table

34-11.

Figure 34-8 Flow Diagram

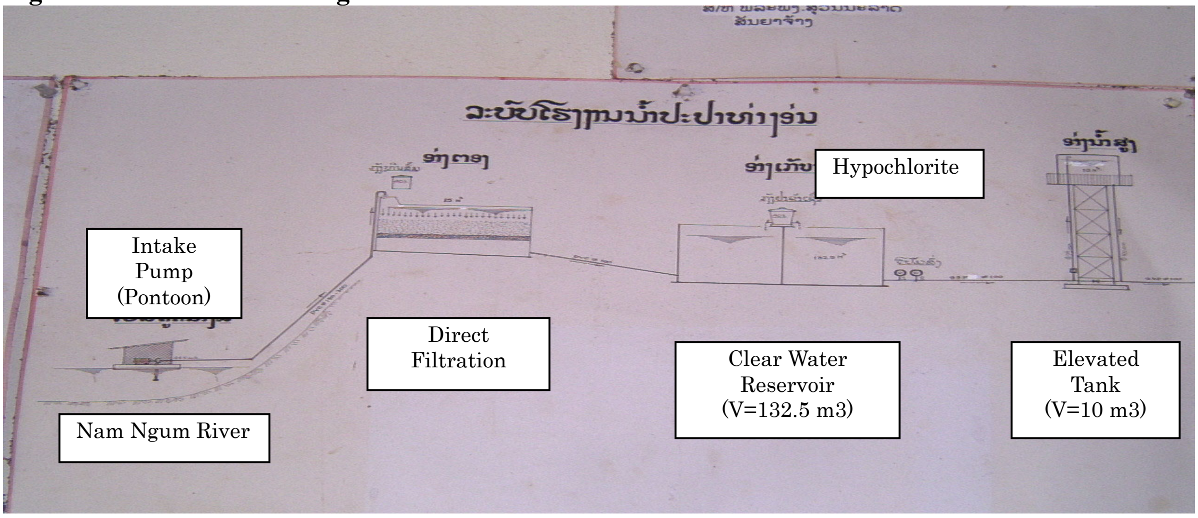


Table 34-11 Outline of Treatment Plant

Type of Water Source	Name of Source	Type of Intake Structure	Year of Construction	Current Capacity (m^3/day)
Surface Water	Nam Ngum River	Pontoon (Floating Dock)	1993	550 - 600
Method of Water Purification		Direct Filtration		

Although a direct filtration unit is installed in the receiving well, filtration effects are observed as very limited. Specifications of the plant are shown on Table 34-12.

Table 34-12 Specifications of Treatment Facilities

a. Intake Pump	48 m^3/h × 22 kW × 1 Unit	Pontoon (Floating Dock)
	22 m^3/h × 1 Unit	
b. Sand Filter	Volume : 15.0 m^3	
c. Reservoir	Volume : 132.5 m^3	
d. Elevated Tank	Volume : 10.0 m^3	
e. Distribution Pump	D65 mm × D80 mm × 1.0 m^3/min × 5.5 kW × 2,860 rpm × 2 Units	
f. Hypochlorite	Solution Tank : 40 l on the Reservoir feeding by gravity flow	
f. Piping	D25 mm – D100 mm	

3.4.4 Thadeua Treatment Plant

Water supply facilities in Thadua were constructed in 1994 with aid granted by the French Government. Raw water for treatment plant of Thadua is obtained from groundwater from 30m below ground level and is extracted by using a well pump (capacity of 50m^3/h). The treatment plant has an estimated capacity of 600 m^3/day and uses a pressurised filtration system.

The total number of staff is 14 persons, and the break down of the staff roles is as follows.

Total staff: 14 persons

Engineer:	1 person
Technician:	2 persons
Operator:	2 Persons
Worker:	3 Persons
Accounting:	2 Persons
Repair/Connection:	4 persons

Table 34-13 shows the outline of the plant, and Table 34-14 shows the specifications of the plant.

Table 34-13 Outline of Treatment Plant

Type of Water Source	Type of Intake Structure	Year of Construction	Current Capacity (m^3/day)
Underground Water	Well	1994	1,200
Method of Water Purification	Direct Pressurized Sand Filtration		

Table 34-14 Specifications of Treatment Facilities

a. Intake Pump (Well)	22 - 56 m^3/h × 32 m × 1 Unit
b. Pressurized Sand Filter	300 m^3/d/Unit × 4 Units
c. Elevated Tank	Gravity Flow from Elevated Tank
d. Sodium Carbonate	Dosing by Feeding Pump
e. Piping	D100 mm

Raw water quality is acceptable as a source of water supply, except the pH value, which is slightly lower than the minimum water quality standards. To adjust the pH, sodium carbonate is added to the filtered water. The existing facilities are maintained in good condition.

3.5 Clear Water Transmission and Distribution System

3.5.1 Organization

The existing clear water transmission and distribution system including pipelines, reservoirs and booster pumping stations within the study area are operated and maintained mainly by the Phonekeng Head Office (Vientiane Water Supply), Thangone Branch Office and The Thadeua Branch Office of the NPVC. These two branches, Thangone and Thadeua, have their own water supply system which consists of intake facilities, water treatment plants and distribution systems. The operation and maintenance of water supply facilities in Thangone and Thadeua areas are controlled by each branch office. The following is an explanation of the organization and organizational workflow of the NPVC, relating to the transmission and distribution system.

(1) Organization Related to Transmission and Distribution System

The NPVC has three organizations which control the water supply system, Phonekeng Head Office, Thangone Branch Office and Thadeua Branch Office. The following are the outline of these organizations for the transmission and distribution systems that they manage.

1) Phonekeng Head Office

In Phonekeng Head Office, there are three sections related to the transmission and distribution system, these are, Engineering Section, Leak Detection & Control Section and Construction & Extension Section. In addition, the four branch offices Chanthabuli, Sikhottabong, Saysettha and Sisattanak, are also in charge of transmission and distribution system especially for small diameter pipelines and house connections. The overall organization of the NPVC is explained in Section 3.1 Organization, and is shown in Figure 31-1. Work responsibilities and outlines of each section related to transmission and distribution systems, as of the beginning of April 2003, are as follows.

a) Engineering Section

The Engineering Section covers mainly the following services of the NPVC and has 13 staff members.

- Planning and design for water supply facilities and buildings
- Construction supervision of the NPVC's own projects

In case where large projects are financed by other donors, the planning, design and construction works are generally tendered out and new sections are established for each project at Phonekeng Head Office.

b) Leak Detection & Control Section

The Leak Detection & Control Section is responsible for;

- task 1: maintenance of facilities related to the pipeline network such as pipes, valves, booster pumps, reservoirs etc, with 2 staff members.
- task 2: leak detection of pipelines and house connections, including water meters and their associated pipes with 4 staff members
- task 3: meter maintenance such as testing of water meter at a meter test bench, or in situ, 6 staff members
- task 4: final inspection/checking after construction and installation.

At present, there is no staff available for task 4, but the NPVC plan to increase staff to 25 in total to improve this section.

c) Construction & Extension Section

The Construction & Extension Section covers the following services of the NPVC with 51 staff members.

- Construction and extension of pipelines
- Repair of pipelines and restoration
- Mechanical section and equipment
- Administration of the section

2) Thangone Branch Office

The Thangone Treatment Plant was constructed in 1993 with a production capacity of 550 m3/day, replacing the old water supply plant which relied on groundwater for its source. Raw water for the existing plant is taken from the Nam Ngum River. The Thangone branch office is located on the premises of the plant, and has 5 staff, including 2 technical staff and 3 administrative staff. The office services and covers 576 house connections and the operation and maintenance of the plant as well as about 10 km of pipeline as shown in Table 35-1.

The maintenance and repair works for leakages for small diameter pipelines less than 40 mm, and installation of new connections which branch from the main pipeline and associated service pipelines are conducted by the branch office.

Table 35-1 Pipeline Length at Thangone Water Supply System

Pipe dia. (mm)	Length (m)
DN200	208
DN150	340
DN100	950
DN75	3,916
DN50	1,888
DN40	1,719
DN30	660
Total	9,681

3) Thadeua Branch Office

Water supply facilities in Thadua were constructed in 1994 with aid granted by the French Government. Raw water for the treatment plant at Thadua is obtained from groundwater 30m below ground level and is extracted by a well pump (capacity of 50m3/h). The treatment plant has an estimated capacity of 600 m3/day and uses a pressurised filtration system. There are 1,712 house connections in the Thadeua service area.

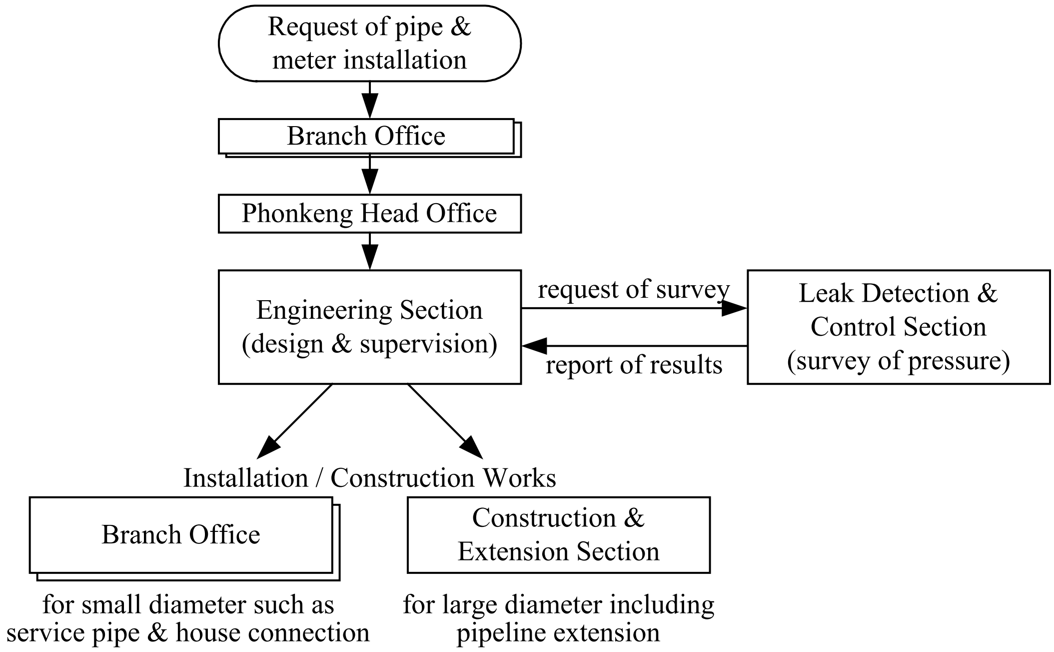
The water supply system at Thadua is connected to a distribution pipeline from the Salakham Reservoir, but the operation and maintenance of the water supply facilities at Thadeua is separate from the Vientiane Water Supply System. Therefore, the maintenance and repair in case of leakage for small diameter pipelines and the installation of new connections with branches from the main pipeline and associated service pipelines, are conducted by the branch office.

(2) Work Flow Related to Transmission and Distribution System

1) New installation of pipes and house connections

When the NPVC install new pipes or house connections, the Engineering Section conducts design work based on the survey results of pressure testing carried out by the Leak Detection & Control Section, in accordance with a request from the Engineering Section. After completion of the design and planning, the Engineering Section requests either the Construction & Extension Section to install large diameter pipelines or the Branch Office to install small diameter pipelines, and house connections. Figure 35-1 shows an organizational work flow for the new installation of pipes and house connections.

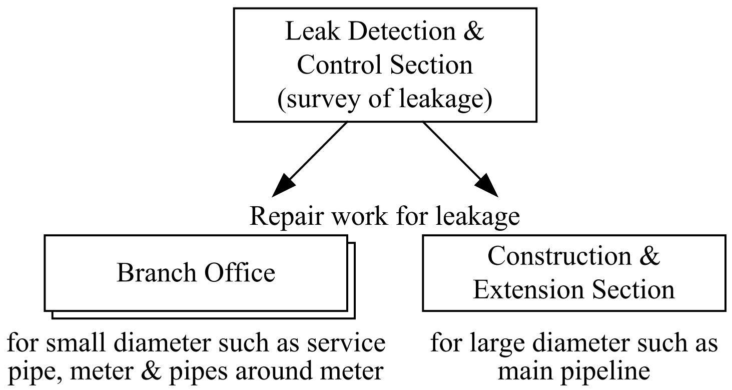
Figure 35-1 Work Flow of New Installation



2) Leak Detection and Repair Work

Three organizations are concerned with leakage control as shown in Figure 35-2. Surveys of leakage are carried out by the Leak Detection & Control Section daily and/or periodically. If they find a leakage, they inform the Construction & Extension Section who maintain large diameter pipes, or the Branch Office for maintain small diameter pipes and request that repairs be done.

Figure 35-2 Work Flow of Leakage Control



3.5.2 Pipe Network

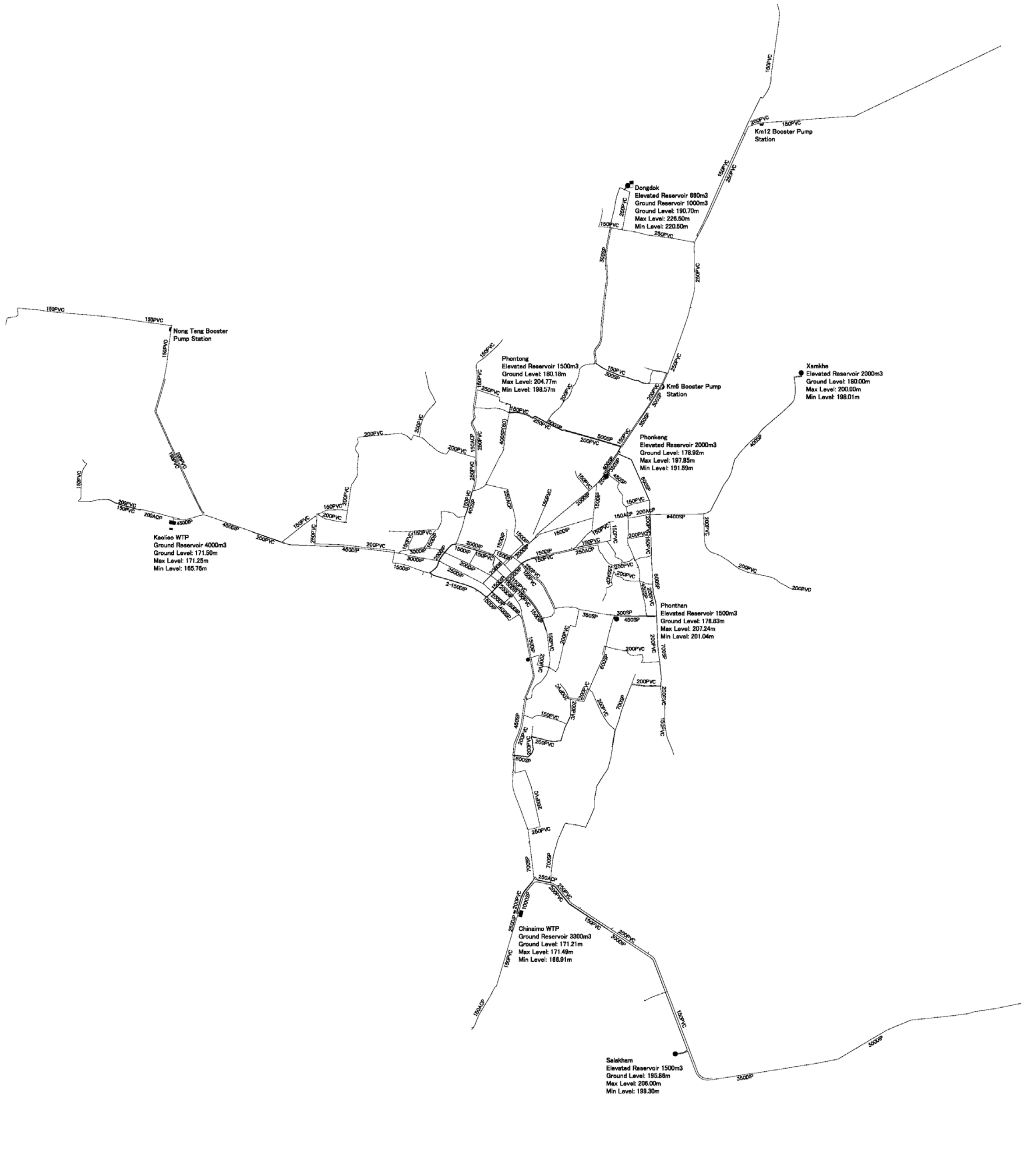
Figure 35-3 shows an outline of pipeline network system for Vientiane Water Supply System together with the locations of treatment plants, reservoirs and pump stations. The total length of pipelines in the capital city of more than 40 mm is estimated at about 460 km, as shown in Table 35-2. Pipelines more than 300 mm in diameter are Ductile Iron Pipe (DIP), or Steel Pipe (SP). Pipelines less than 300 mm in diameter are mainly PVC Pipe. Pipelines in the downtown area of Vientiane Capital City were installed in the 1960s and 1980s, at the time of construction of the Kaolieo and Chinaimo Water Treatment Plants respectively. Although the NPVC installed the small diameter pipelines by itself, pipelines of large diameters for DIP and SP were mainly installed in the 1990s with aid granted for a project by the GOJ and financed by the ADB.

Table 35-2 Existing Pipeline Length by Material (Kilometres)

Material	DIP	GSP	PVC	SP	ACP	PE	PB	Total	%
DN 1000				486				486	0.1%
DN 700				9,685				9,685	2.1%
DN 600				7,774				7,774	1.7%
DN 500				2,919				2,919	0.6%
DN 450	4,590			7,044				11,634	2.5%
DN 400	1,440			10,875				12,315	2.7%
DN 350	4,040			4,264				8,304	1.8%
DN 300	12,850			6,607				19,457	4.2%
DN 250	1,385		14,775		2,480			18,640	4.1%
DN 200	10,337	88	39,754	60	1,485			51,724	11.2%
DN 150	14,958	1	28,991	36	4,010			47,996	10.4%
DN 100	5,986	3,559	34,557		5,545			49,647	10.8%
DN 80					9,045			9,045	2.0%
DN 75	8,395	8,312	77,165					93,872	20.4%
DN 65		1,637				1,061		2,698	0.6%
DN 50		7,394	41,702			18,689	1,248	69,033	15.0%
DN 40		2,243	39,015			2,595	821	44,674	9.7%
Total	63,981	23,234	275,959	49,750	22,565	22,345	2,069	459,903	100.0%
%	13.9%	5.1%	60.0%	10.8%	4.9%	4.9%	0.4%	100.0%	

DIP: Ductile Iron Pipe
GSP: Galvanized Steel Pipe
PVC: Polyvinyl Chloride Pipe
SP: Steel Pipe
ACP: Asbestos Cement Pipe
PE: Polyethylene Pipe
PB: Polybutylene Pipe

Figure 35-3 Existing Pipeline Network System in Vientiane Water Supply



There is no routine replacement plan for old pipes and asbestos cement pipes. The NPVC maintains and repairs the pipeline only in cases where leakage is detected.

At present, the project for the extension of the distribution network in 5 areas is being implemented, and financed by the AFD. The construction work for the extension of the distribution network in those 5 areas commenced in March 2003 and the pipe materials are currently being delivered. The leakage reduction project, the Project for Leak Detection Campaign and Reduction of Unaccounted-for Water, was completed in May 2002, as explained in Section 3.5.5, Unaccounted-for Water.

3.5.3 Reservoirs

The Vientiane water supply system has 9 reservoirs with a total capacity of 17,460 m3 including 3 ground reservoirs and 6 elevated reservoirs. The total capacity of the reservoirs is calculated as 4.2 hours of the total production capacity of the Chinaimo and Kaolieo Treatment Plants.

Table 35-3 Details of Reservoirs

Name	Capacity (m3)	HWL (m)	LWL (m)	Depth (m)	GL (m)
Chinaimo WTP	3,300	171.49	166.91	4.58	171.21
Kaolieo WTP	4,000	171.25	165.75	5.50	171.50
Phonekheng	2,000	197.85	191.59	6.26	178.92
Phonetong	1,500	204.77	198.57	6.20	180.18
Phonethane	1,500	207.24	201.04	6.20	176.83
Salakham	1,500	206.00	199.30	6.70	170.00
Xamkhe	2,000	200.00	198.01	1.99	180.00
Dongdok G.R.	1,000	193.40	190.90	2.50	190.70
Dongdok E.R.	660	226.50	220.50	6.00	190.70
Total	17,460				

There are no serious problems with the structure of the reservoirs, such as leakage from concrete wall, and pipelines around the reservoirs. However, almost all the reservoirs can not be filled to the maximum capacity even during the night, because there is not enough water for the Vientiane water supply system, and the transmission and distribution pipelines are not separated clearly.

In order to maintain a stable water supply, the following measures are necessary to consider for the master plan of the Vientiane water supply system.