CHAPTER FOUR

PRESENTATION OF RESULTS

Data and information were compiled in tabular form in the attached Appendix A to F. In this chapter, results were presented with some descriptions for clarity and better understanding.

4.1 Generral Description

4.1.1 Technical aspects.

4.1.1.1 Source of raw water.

Surface water is preferably collected as raw supply in urban water works practice. It was found that from the total 166 water works already constructed and operated, there were 140 water works drawing raw water from surface sources. Due to inadequacy of raw supply, 7 studied water works needed two places of surface sources and one water works needed three places of surface sources.

4.1.1.2 Type of Treatment and Process

The common method found by all studied water works are conventional physical and chemical treatment. The treatment consists of coagulation by dosing alum and lime or alum alone, flocculation, gravity sedimentation and followed by rapid sand filtration as shown in Figure 3. This only treatment was for turbidity removal and partial pH or alkalinity control. No other special treatment such as softening, fluoridation was ever found in the past practice

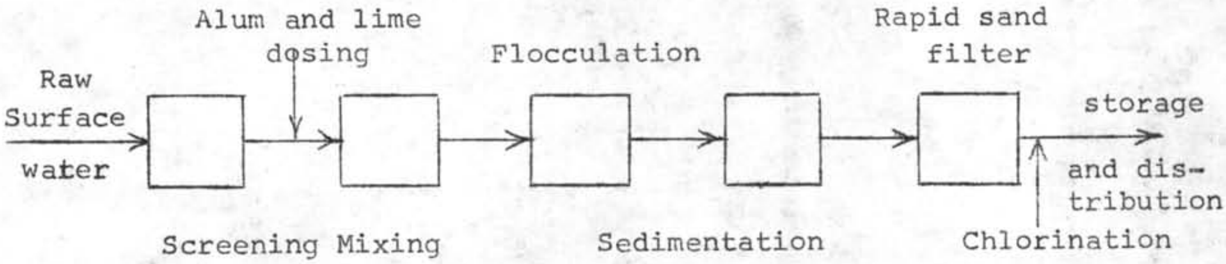

Figure 3 Process used in urban water works practices.

Post chlorination either with liquid or powder form fed at clear water tank is used for disinfection.

4.1.1.3 Plant size

Plant size denotes the capacity of water m^3/day on 20 hour operation which waterworks can produce to serve population in the particular area.

Capacities of the existing water works vary from 400 up to 34,800 m^3/day. There are 10 water works which have no treatment facilities, served as boostering station and standing for service purpose. Number of each size of the total operated water works are shown in the Table 4.

Table 4 Numbers and plant sizes in year 1975

Plant size m^3/day	Number of Water works	Plant size m^3/day	Number of Water works
400	9	5,600	1
800	41	6,000	3
1,200	6	6,400	2
1,600	24	7,200	1
2,000	16	8,200	1
2,400	19	9,000	2
2,480	1	12,400	1
3,200	7	14,400	1
3,600	2	18,000	1
4,000	7	18,200	1
4,400	4	20,000	1
4,800	2	24,400	1
5,200	1	34,800	1

4.1.1.4 Types of projects

There are two types of existing projects as follows:

a. New construction project

This type of projects is provided for communities which never have water works system before. For

Sanitary Areas, it was found that new water works systems of 800 m^3/day were provided for population about 4,000 to 8,000.

b. Improvement or expansion of existing water works.

This type of project is stage addition to existing operated water works which were constructed in big communities such as those in the municipalities. The expansion schemes are often conducted after insufficient supply is encountered.

4.1.1.5 Project facilities

Investigation of thirty water works projects showed that components of constructed works were nearly the same. Usually, each project includes the following facilities in general.

a. Intake facilities

b. Purification facilities

c. Distribution facilities

d. Electrical facilities

e. Service and miscellaneous facilities

Each facility dominates its own features. Following lists of construction items were mostly built in the same manner by sets of proper standard design drawings. Some items may be omitted due to budget constraint and only some components such as intake special structures, yard improvements, etc. may be different from place to place due to site or local conditions. Lists show also the amount of whole works,in each project and may be used as check lists.

a. Intake facilities comprise of

- Intake special structures
- Low lift pump houses
- Low lift pumps and equipments
- Intake conducts
- Transmission pipe line systems

b. Purification facilities comprise of

- Mixing, flocculation and sedimentation basins
- Rapid sand filters
- Clear water tanks
- Chemical feeding and disinfection apparatus
- Pipe arrangement inside the plants
- Sludge pond
- Laboratory instruments

c. Distribution facilities comprise of

- High lift pump houses
- Pumps and equipments
- Elevated tanks
- Distribution pipe line systems.

d. Electrical facilities comprise of

- Electric power equipments
- Illumination equipments.

e. Service and miscellaneous facilities comprise of

- Office
- Warehouses
- Lodging houses
- Yard improvement works
- Office furniture and stationary
- Connecting pipe tools.

To meet the objective of this study, construction items in all above facilities were grouped into process part, non process part, raw water transmission and distribution pipe-line systems as described in Chapter Three.

4.1.2 Operating aspects

4.1.2.1 Routine performance

As described in Chapter One that these water works are supervised by PWSD, the routine work is to maintain and operate the functions. The work can be classified into two parts i.e. production and service part.

The work in production part is

- to operate both low and high lift pumps
- to feed the chemicals in the process.
- to control the flows of sedimentation tank and rapid sand filter
- to backwash the rapid sand filter and to blow the sludge off sedimentation tank.

- to analyse the characteristic of raw and treated water in some water works.

The work in service part is

- to maintain and repair the pipeline systems.
- to provide household connections of new applicants.
- to record customer consumption.
- to collect bills and register accounts.

Other work can be classified by the position of the staff.

4.1.2.2 Personnel conditions

Since all observed water works belong to the government so that the staff in each water works are either officers or employees. The staff in each water works varies from 8 to 74 person. Their salaries range from 750 ฿ to 2100 ฿ per month per capita.

Position descriptions are as followed:

a. Executive
   - Superintendant
   - Assistant superintendent

b. Production
   - Mechanics or pump operators 2 -21 persons.
   - Laboratory analysers up to 2 persons.

c. Service

- Civil technicians 1-10 persons.
- Accountants or ledger keepers 1-12 persons
- Meter recorders up to 6 persons.
- Bill collectors up to 7 persons.

d. General

- Clerical service up to 4 persons.
- Store keepers up to 3 persons.
- Workers 1 - 9 persons.
- Drivers up to 2 persons.
- Gaurds up to 4 persons.

4.1.2.3 Chemicals consumption

Chemicals used in the process are alum and chlorine. Lime is occasionally used. Alum and Chlorine are bought by bidding at PWSD in Bangkok and conveyed to the water works.

The unit cost of alum was 1.50 ฿ per kilogram.

The unit cost of powder chlorine was 6.50 ฿ per kilogram.

The unit cost of liquid chlorine was 1,320 ฿ per tube. One tube contains 100 kilogram.

The unit cost of lime was approximately 0.6 ฿ per kilogram.

4.1.2.4 Power consumption

Electricity and gasoline are main sources of power. Three phase current and diesel gasoline using as power to drive pumps and generators were in the production part while benzene for vehicles and electric for lighting were in service part. Electric tariff of all water works was paid by PWSD in Bangkok. Unit costs of gasoline were different from one place to another.

Tariff of electric for lighting and power was 1.20 ฿ and 0.70 ฿ per unit (Kw-hr) respectively.

Diesel gasoline for pumps and generator ranges from 2.20 ฿ to 2.90 ฿ per litre.

Benzene for vehicles ranges from 3.30 ฿ to 3.95 ฿ per litre.

4.1.2.5 Maintenance and replacement

Routine maintenance and small repairing of machines, pipe apurtenance and structures were done by mechanics and civil technicians. In case of large damages, repairing and replacement were done by local sale representatives or shophouses. These items were classified by clerical service according to inventory system.

4.2 Results of Computation for Construction Cost Functions

In Appendix D, the computer output for values of constants 'k' and economies of scale factors 'α' were shown. The results were:

$$C_{ip} = 22.03 \quad Q_d^{0.67} \qquad \text{with } R = 0.967 \qquad (4.1)$$

$$C_{in} = 255.34 \quad Q_d^{0.21} \qquad \text{with } R = 0.367 \qquad (4.2)$$

$$C_{it} = 89.53 \quad Q_d^{0.62} \qquad \text{with } R = 0.9\text{[illegible]} \qquad (4.3)$$

$$C_{ic} = 78.46 \quad Q_d^{0.55} \qquad \text{with } R = 0.934 \qquad (4.4)$$

where Q_d is design capacity in m^3/day.

C_{ip} is construction costs for only items in process part in 1,000 Ø

C_{in} is construction costs for only items in non process part in 1,000 Ø

C_{it} is construction costs for items in both process and non process parts or items within treatment plants in 1,000 Ø

C_{ic} is total construction costs of intake special structures, items in process and non process parts, items in raw water transmission and distribution pipe line systems, and administrative expenditure expressed in 1,000 Ø

R is Pearson product moment coefficient of correlation.

Value of R in equation (4.2) approaching zero shows that the fit is poor since 13.5 percent (R^2= 0.135) of the variability has been explained by the equation. Values of R for other equations show that the relationship between construction costs and design capacity is acceptable.

4.3 Magnitude of Constructed Component Costs.

In table 3, 4, 5 Appendix B, costs of construction components were expressed in per-centage of each total value. The details of these construction components will be well described in their own voluminuous drawings and specifications, all of which cannot be presented in this thesis. The results presented here were average means and standard deviations of each component costs in thirty projects expressed in per-centage of each part.

4.3.1 Process part

The average means and standard deviations of construction costs for components in process part were shown in Table 5.

Table 5 Average mean and standard deviation of construction costs for each components in process part.

Items	Average mean (%)	Standard deviation (%)
Pump houses [1]	5.7	2.9
Pumps and equipments:		
Low lift	9.5	4.7
High lift	11.4	4.0
Other[2]	1.0	2.5
Chemical feeding apparatus	3.3	3.0
COAG-SED-RSF Units[3]	31.2	7.6
Clear water tank	15.9	5.8
Elevated tank	11.5	8.4
Pipe arrangement inside the plants:		
- Pipe, fittings and accessories	3.2	1.4
- Valves	1.7	0.8
- Master meter	1.9	1.2
Electric power equipment and installation.	3.8	3.3

Note 1. Pump houses included low and high lift pump houses.

2. 'Other' in item of 'pumps and equipments' denoted that

these pump were required for various purposes such as cleaning, backwashing, etc.

3. COAG-SED-RFS Units contained two tanks. One tank was for coagulation, mixing, flocculation and sedimentation. One tank was rapid sand filter. Both tanks were concrete structures.

4.3.2 Non-process part.

The average means and standard deviations of construction costs for components in non process part were shown in Table 6.

Table 6 Average mean and standard deviation of construction costs for each components in non-process part.

Items	Average mean (%)	Standard deviation (%)
Office	11.2	7.7
Warehouses	7.2	6.7
Lodging houses	30.8	10.3
Yard improvement:		
1. Fence, gate, flag pole, sign.	8.0	4.0
2. Earth embankment	9.7	11.6
3. Road in plants	9.3	8.0
4. Drainage system	8.6	12.3
Illumination equipments[2]	4.0	4.3

Table 6 (continued)

Items.	Average mean (%)	Standard deviation (%)
Connecting pipe tools[1]	3.3	4.6
Laboratory instruments[1]	1.1	1.5
Stationary[1]	5.4	7.7

Note 1. There are many sets of specifications for connecting tools, laboratory instruments and stationary depending on size of the projects.

2. Illumination equipments included those outside the houses and structures

4.3.3 Raw water transmission pipe line systems

The results were presented in Table 7.

Table 7 Average means and standard deviations of construction costs for each components in raw water transmission pipe-line systems.

Items	Average mean (%)	Standard deviation (%)
A/C - pipe[1]	40.7	33.0
G/S and other pipes	5.8	16.4
Fittings and accessories[2]	9.6	3.5

Table 7 (continued)

Items	Average mean (%)	Standard deviation (%)
Pipe Appurtenance[3]	4.0	8.5
Supporters[4]	1.5	2.8
Laying expenditures[5]	8.7	9.3

Note. 1. Sizes of A/C and G/S pipe ranged from Ø 100 mm. to Ø 400 mm. freguently laid at the average depth of 1.50 m. under surface of pavement.

2. Fittings and accessories means elbows, tees, crosses, plugs, etc.

3. Pipe appurtenance means gate valves, check valve, air valve blow-off and fire hydrants.

4. Supporters means concrete anchorages, bridges, etc.

5. Laying expenditures include repairing of pavement, labour, form works, bracings, pipe cleaning and disinfection, and testing.

4.3.4 Distribution water pipe line systems

The results of average means and standard deviation were shown in Table 8.

Table 8 Average means and standard deviations of construction costs for each components in distribution pipe-line systems.

Items	Average mean (%)	Standard deviation (%)
A/C pipe	46.4	10.8
G/S and other pipe	9.3	5.9
Fittings and accessories	9.6	3.5
Pipe apurtenance	10.4	5.3
Supporters	4.1	4.3
Laying expenditure	18.3	1.3
Spare pipes and fittings[1]	1.3	3.3

Note. 1. Spare pipes and fittings were prepared when districts growth was in unknown direction.

In Table 6 Appendix B, Ratios of costs of intake special structures, non process part, raw water transmission pipe line, distribution pipe line systems and administrative expense to process part (i.e. I/P, N/P, R/P, D/P, A/P) were calculated. The shapes of distribution of I/P and R/P were kurtosis. Others also showed high variation ranging from 0 to 1.17 therefore conclusion can not be made from this observation.

4.4 Results of OMR Cost Functions

The results of OMR Cost Functions were

$$C_{op} = 6.36 \ Q_p^{0.59} \quad \text{with } R = 0.945 \qquad (4.5)$$

$$C_{os} = 19.49 \ Q_p^{0.35} \quad \text{with } R = 0.821 \qquad (4.6)$$

$$C = 30.93 \ Q_p^{-0.42} \quad \text{with } R = 0.900 \qquad (4.7)$$

where Q_p is average daily production, m^3/day

C_{op} is OMR costs in production part in 1,000 ฿

C_{os} is OMR costs in service part in 1,000 ฿

C is unit total OMR costs of both production and service part, ฿

R is defined the same as in Article 4.2

Value of R for these derived equations show that the relationship between OMR costs and average daily production is acceptable.

It was found from Table 10 and 11 Appendix C that OMR costs in production part were 62.5% of the total OMR costs in average with standard deviation of 9.9%. The curve relating unit total OMR costs to average daily production was shown in Fig. 4

4.5 Magnitude of OMR Component Costs

In table 10, 11 Appendix C, Costs of OMR components were expressed in percentage of each total value. Average means and standard deviations of forty four water works for costs in

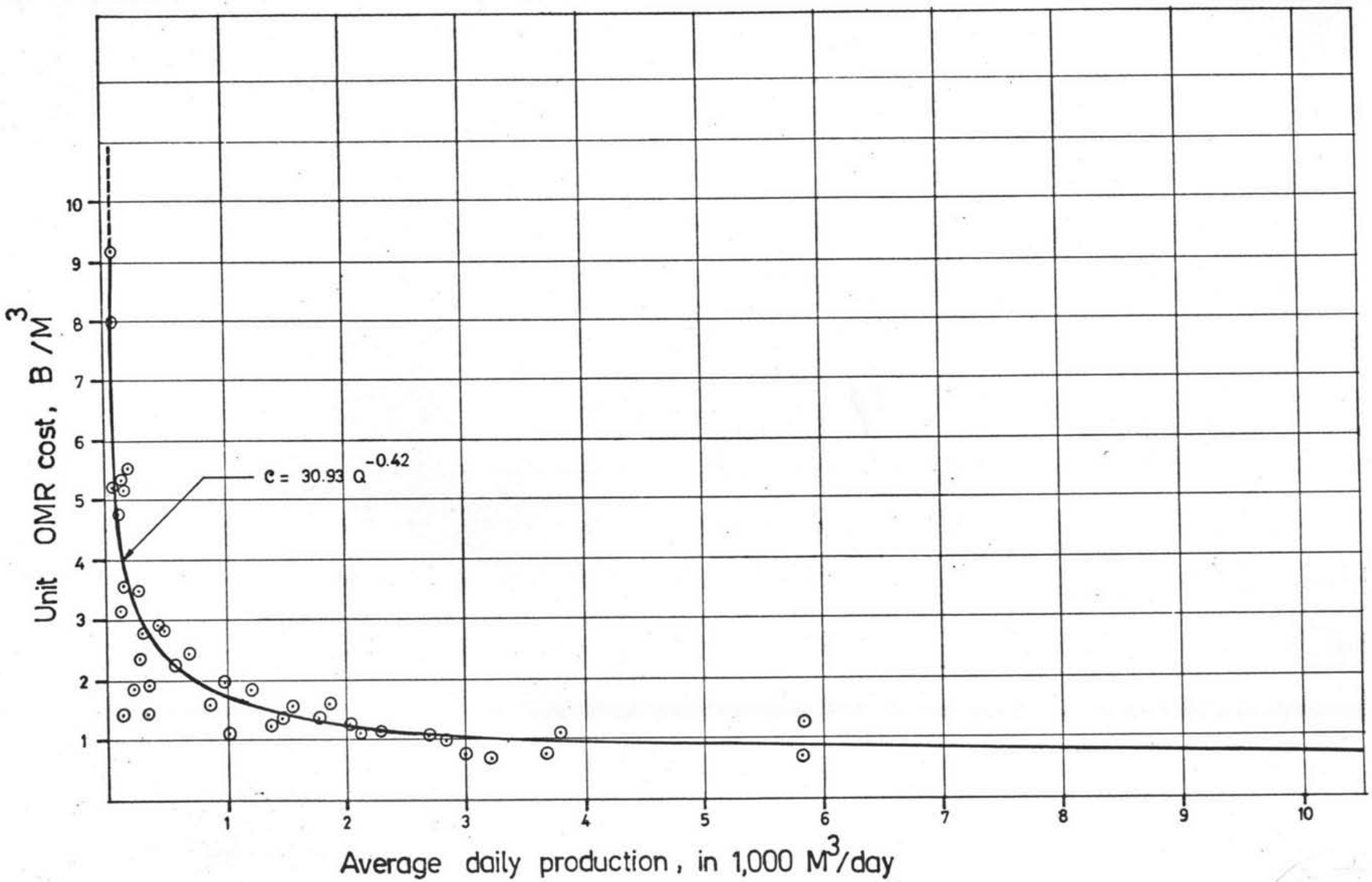

FIGURE 4 Graph represents relationship of unit OMR cost and average daily production

production and service parts were presented in Table 9.

Table 9 Average means and standard deviations of OMR costs in production and service part.

Items	Production Part		Service Part	
	Average mean (%)	Standard deviation (%)	Average mean (%)	Standard deviation (%)
Chemicals	15.9	8.3	-	-
Power	33.9	15.3	9.3	3.8
Maintenance	7.2	6.7	4.1	3.1
Salary	39.5	15.2	85.8	5.8
Miscellaneous	3.7	3.4	0.8	0.7

Only costs of chemicals and power in production part are variable. In Table 1 Apendix C, the unit chemicals cost varies from 0.04 to 0.33 with the average mean of 0.16 and standard deviation of 0.07 ฿ per m^3 of produced water. In Table 2 Appendix C, the unit power cost varies from 0.04 to 1.04 with the average mean of 0.35 and standard deviation of 0.19 ฿ per m^3 of produced water. Others are fixed costs. It should be noted also that total salary in both production and service parts can be allocated according to work descriptions.

The results of salary in each type of works were:

Salary in executive work

$\bar{X}$ = 10.8 % ; S = 5.3 %

Salary in general work

$\bar{X}$ = 25.3 % ; S = 6.4 %

Salary in production work

$\bar{X}$ = 27.3 % ; S = 4.5 %

Salary in service work

$\bar{X}$ = 37.5 % ; S = 8.2 %

4.6 Optimal Design Periods

Various optimal design periods were presented in Appendix D. These Values were presented for two assumed types of growth demand i.e. arithmetic and geometric rate. It was found that interest rate suitable for public investment should be in the range of 4 to 8 per-centage per annum. Only results which D_1 = 1,2,3,4,5 m^3/day/yr. and D_0 = 100,200,300,400,500 m^3/day were shown in Appendix D because other gave the same results. Some of these results were presented here for such interval of these interest rates. Selected geometric rates of demand growth were in correspondence with those of population growth.

For arithmetic rate of demand growth, optimal design periods with D_1 =1m^3/day/yr were shown in Table 10.

Table 10 Various optimal design periods and interest rate

Interest rate (%)	Optimal design period (year)
4	19.8
5	15.9
6	13.2
7	11.4
8	9.9

For geometric rate of demand growth, optimal design periods with D_O = 100 m^3/day were shown in Table 11.

Table 11 Various optimal design periods, geometric rate of demand growth (G) and interest rate (R).

Optimal design period (year)

R (%) \ G (%)	1.5	2.0	2.5	3.0
4	18.3	17.8	17.3	16.9
5	14.8	14.5	14.2	13.9
6	12.5	12.3	12.1	11.9
7	10.8	10.6	10.5	10.3
8	9.5	9.4	9.2	9.1

Other values of interest rate up to 20 % can be obtained from Appendix D.

4.7 Results of Demand Study

4.7.1 Demand function

The assumed demand rate - size of communities function was derived as shown in following:

$$D = 28.23 \ P^{0.16} \quad \text{with } R = 0.330 \qquad (4.8)$$

where D is water demand rate in lpcd.

P is size of communities or total population in the communities in person.

The collected data consist of 331 samples. The values for coefficient of correlation for N over 100 were given below for different confidence interval:

Confidence Limit	R
95 %	0.16
97.5 %	0.19
99.0 %	0.23
99.5 %	0.25
99.95%	0.32

It sould be confirmed that data of demand rate were derived from household sales.

4.7.2 Sales and Losses

In Table 8 Appendix A, various types of sales and losses were expressed in percentage of total sale. The average means and standard deviations were shown i. Table 12.

Table 12 Average means and standard deviation of sales and losses.

Items	Average mean (%)	Standard deviation (%)
Sales		
Household sale	98.3	5.2
Fountain sale	1.1	5.1
Amount without charge	0.6	1.4
Losses		
Backwash & blow-off	6.1	4.7
Interior usage	5.1	6.9
Pipe leakage	2.6	5.6
Unknown leakage	11.4	9.9
Total of above losses	24.8	17.5

Note 1. 'House-hold sale' means amount of sold water through all connected meters.

2. 'Fountain sale' means amount of sold water delivered either by vehicles or other means.

3. 'Amount without charge' means water for public use

4. 'Backwash and blow off' means water for backwashing rapid and filter and blowing sludge off sedimentation tank.

5. 'Interior usage' means water for mixing chemicals, cooling generators, cleaning and gardening inside water works, consuming in lodging house etc.

6. 'Pipe leakage' means water for cleaning pipe after repairing, water loss while connecting new household meters, water for testing fire hydrants. The amount was estimated by each water works.

7. 'Unknown leakage' means amount by subtracting the sum of total sales and above accounted losses from total produced water.

The data were 42 samples by excluding data from Ubon Ratchathani and Udon Thani due to too large values of losses.

4.8 Water Rates Obtained

It was found that the average marginal cost from observed water works was 0.51 ฿ per m^3 of produced water. If the water rate is set equal to this value, there will be large deficit. Even the marginal cost will satisfy the economic requirement, the rate would have to be equal to the average cost for the financial requirement to be satisfied.

Constructed rates should be set up for two types of communities as follows:

4.8.1 Sanitary Areas

It was found that most water works in Sanitary Areas have capicity less than 2,000 m^3/day. As calculated in Appendix F, the uniform rate of 3.50 ฿ per m^3 of metered water will be charged to all types of customers. The constructed rate is 1.50 ฿ higher than the existing one. It is necessary because water works with small daily production will require large revenue covering the OMR costs. The derived equation (4.7) will well explain this condition.

4.8.2 Municipality

Rate in Municipality should be constructed for two classes of customers.

For residential customers, incremental block rate was set up as follow:

Water consumption (m^3/month)	Rate (฿/m^3)
0 - 10	1.0
10 - 30	2.0
Over 30	3.0

For commercial and special customers, the uniform rate of 3.50 ฿ per m^3 of metered water will be charged. These suggested rates will result in lowering the expense of 0.33 ฿/m^3 for residential customers with average use of 30 m^3/month as shown in Appendix F. The profit will be generated from the sale for residential customers with average use over 30 m^3/month and for those of commercial and special class.

4.9 Evaluation of Existing Condition

In Table 9 Appendix A, the calculated ratios of annual production to annual household sale from year 1966 to 1975 were shown. The values should be around 1.20 to 1.25 due to leakage through pipe-line systems. The values less than unity indicate that real amount of water sold is less than assumed amount of water charged because of dead meters. The values over 1.20 to 1.25 indicate that either there is too much leakage through pipe-line systems or inefficient collection of bills may occur. Most of these values were much more than 1.25 and some rose over two.

In Table 11 Appendix A, utilization factors which were the ratios of average daily production to design capacity were shown. It was found that factors of only 7 studied water works were over unity. Others were less than unity. Several reasons could be responsible for this condition:

1) it was over design of capacity for purification system was overdesigned or;

2) storage was too small

In Table 12 Appendix A, the calculated ratios of served population to total population of the communities were shown. Most of the values were lower than fifty percent. The values showed that the level of service was low or the inhabitants using tapped water were less than fifty percent of total inhabitants in that community.