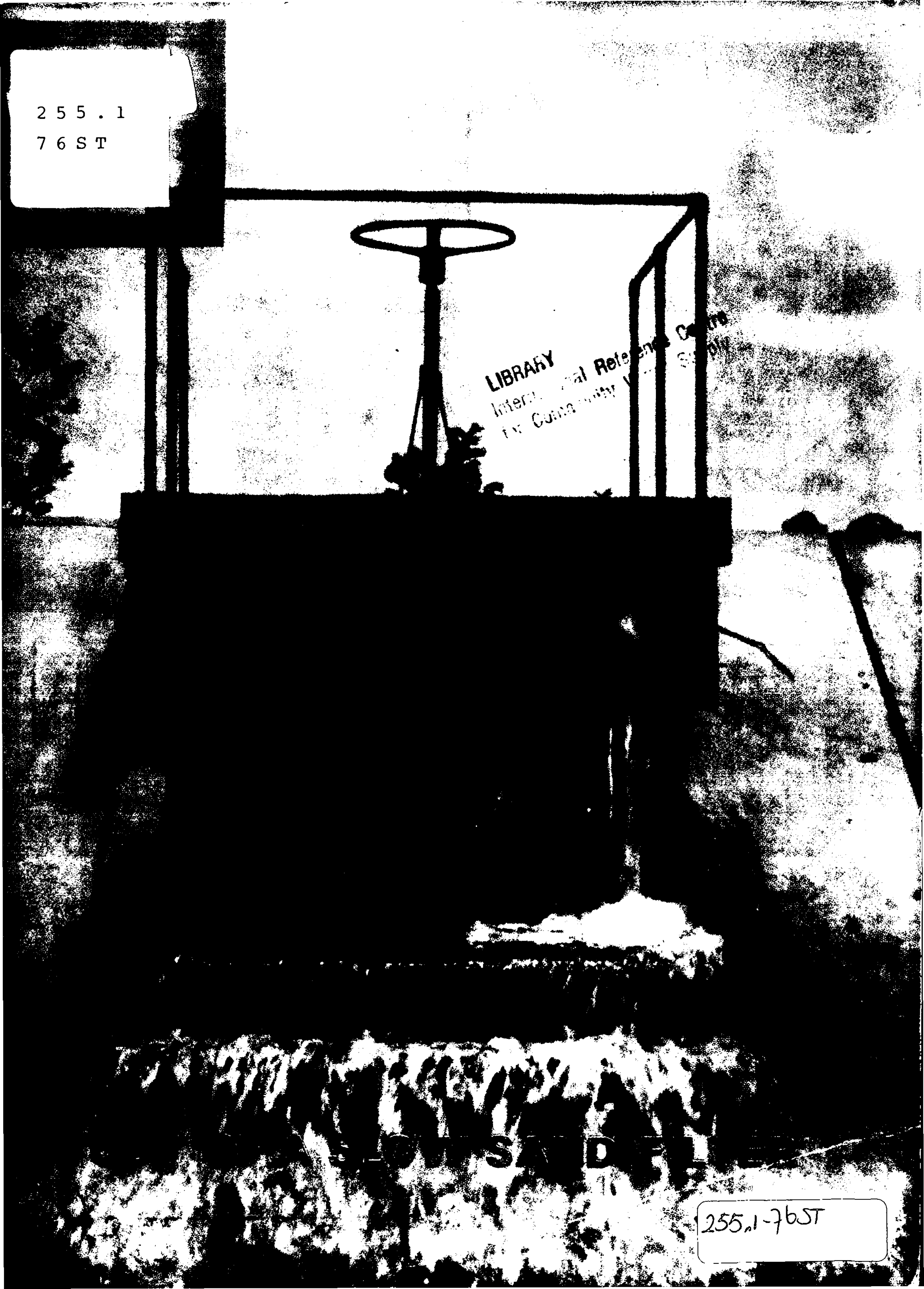

Study of an Existing Water Treatment Plant of Simple Design and Operating System for Supplying Drinking Water to Rural Communities in the Lower Mekong Basin Countries

RURAL WATER SUPPLY DIVISION
DEPARTMENT OF HEALTH
MINISTRY OF PUBLIC HEALTH

BANGKOK, THAILAND
August, 1976

TABLE OF CONTENTS

FIGURES

TABLES

INTRODUCTION

Sand filtration remains as the main concern in water treatment in Thailand. In the rural area, where modern technique and qualified operators are insufficient, simple constructing and operating systems like slow sand filter are reccommended.

The purpose of this research is to study problems associated with the design and operation of an already installed slow sand filter. The data and information to be gathered includes loading, operational difficulties, operation cost and income, process efficiency, population and society of the village served.

The slow sand filter at Kranuan was constructed in 1971 under the responsibility of the Rural Water Supply Division, Department of Health. The plant is located in the North-East part of Thailand about 500 kms. from Bangkok. The construction cost including the treatment system and main distribution pipe is about 1,100,000 baht. (1 $ = 20 baht) with government contribution equals 500,000 baht and local contribution equals 680,000 baht. It is designed to serve 9,563 population with the capacity of 100 cm/hr.

This study has been carried out from June 1975. All the data and information collections were finished in April 1976. Analysis and report were completed in July 1976.

The persons concerned in this study are the officers of the Division of Rural Water Supply both in the central office and Regional Center 4, Khon-Kaen.

The project was supported from the assistance of the Agency for International Development AID with the co-ordination of the university of Oklahoma under the main project entitled "Lower Cost Methods of Water and Waste Treatment in the Less Developed Countries".

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ACKNOWLEDGEMENT

This study of slowsand filter has been carried out for more than a year with the help from many persons and agencies that made this project possible.

The expenditure of this research is supported by the Agency for International Development (AID). Special acknowledgement is given to Professor George W. Reid of the University of Oklahoma who co-ordinates the financial supporting agency & RWS division, and also to Dr. Silas Law, his assistant, who contacted and followed up while the project was preceeding.

The division wishes to thank Mr. Visut Rugthaidee, the Regional Director of the RWS Region 4, Khon-kaen, who provided the recommendation in selecting the water treatment plant for research and his comments about the study techniques throughout the project.

Appreciations are also given to Mr. Udorn Charuratana, the chief engineer of the programme and Planning Section, who planned the project study and controlled the step of work. To Mrs.Amarat Lohwongwatana his assistant, who co-ordinated the study and the University. To Mr. Chumpol Nilaiyaka, technician, who worked fulltime in the plant as the data and information collector.

The Division gratefully acknowledges the assistance of the Research and Analysis section staff. Miss Sunanta Buasimuang, the chief scientist, who carried the water quality control and interpreted the laboratory result. Miss Chitra Chevapruk, Mrs. Devarugsa Kruerclai and Mr. Panuvat Perm-chira-panich, her assistants, who collected and analysed the water samples throughout the study.

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BACKGROUND

The slow sand filter plant at Kranuan was constructed in 1971 under the responsibility of Rural Water Supply Project. The water source of this plant is a reservoir, 8 kilometers away from the plant. It is designed to serve 9,563 population with the capacity of 100 m^3 per hour. It is composed of 2 units of slow sand filter, with capacity of 50 m^3/hr per each unit and there is also a space reserved for future expansion.

Raw water is pumped from reservoir into sedimentation pond (existing pond) and flow by gravity into filter, pass filter rate control chamber and flow into clear well. In the clear well, chlorine solution will be feeded by gravity to mix with filtered water before pumped to Elavated Tank. After that, water will be distributed to the consumer through main pipe 8", 6", 4" and 2"

The cost of the plant is about 1,180,000 baht (1 $ = 20 baht) with government contribution equals 500,000 baht and local contribution equals 680,000 baht.

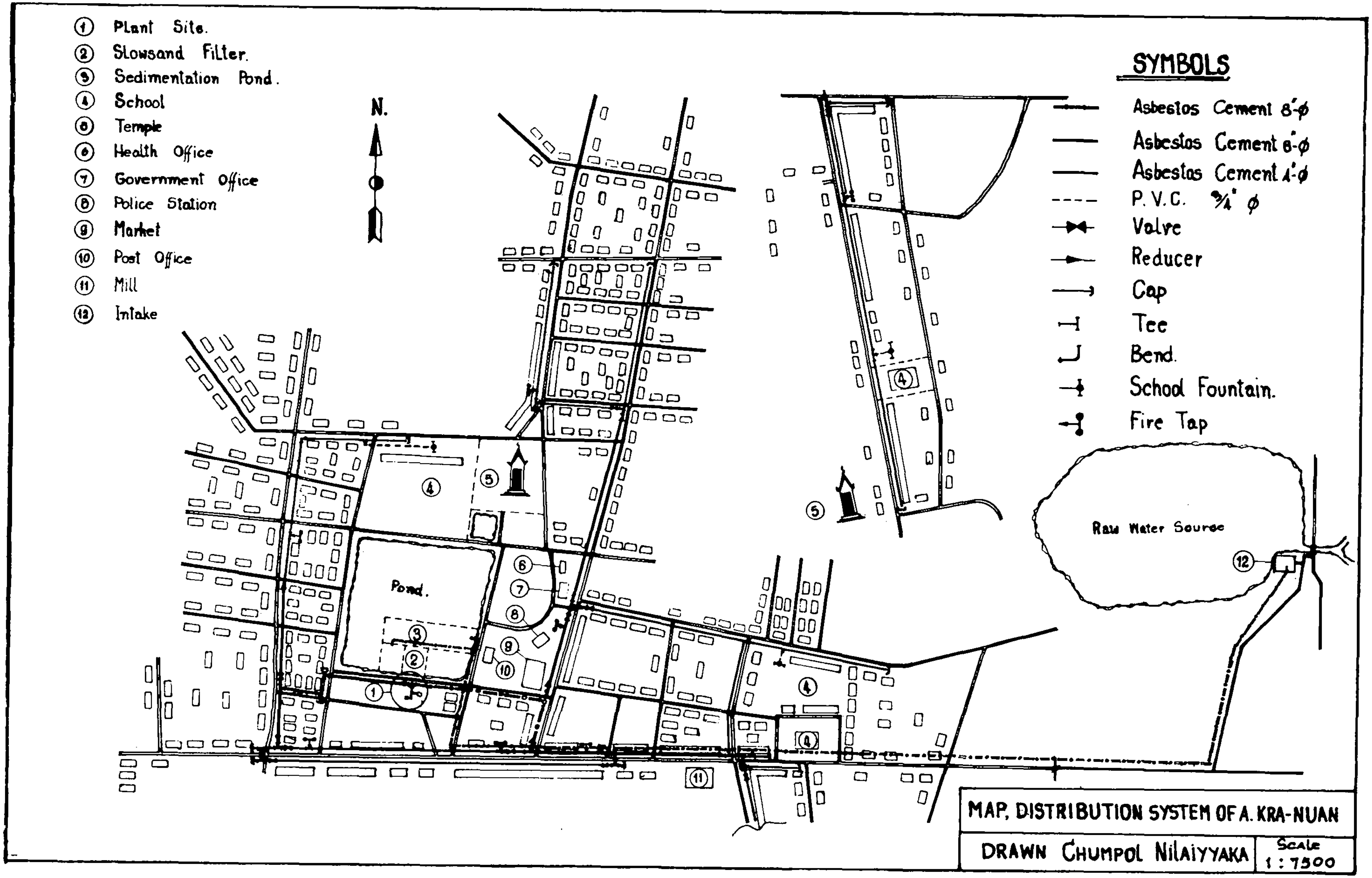
The Study of Slow and Rapid Sand Filter has devided into 4 steps:

1. Society and Population.
2. Water Consumption and expenditure.
3. Characteristics of the Filter.
4. Quality Control and Efficiency of the filter.

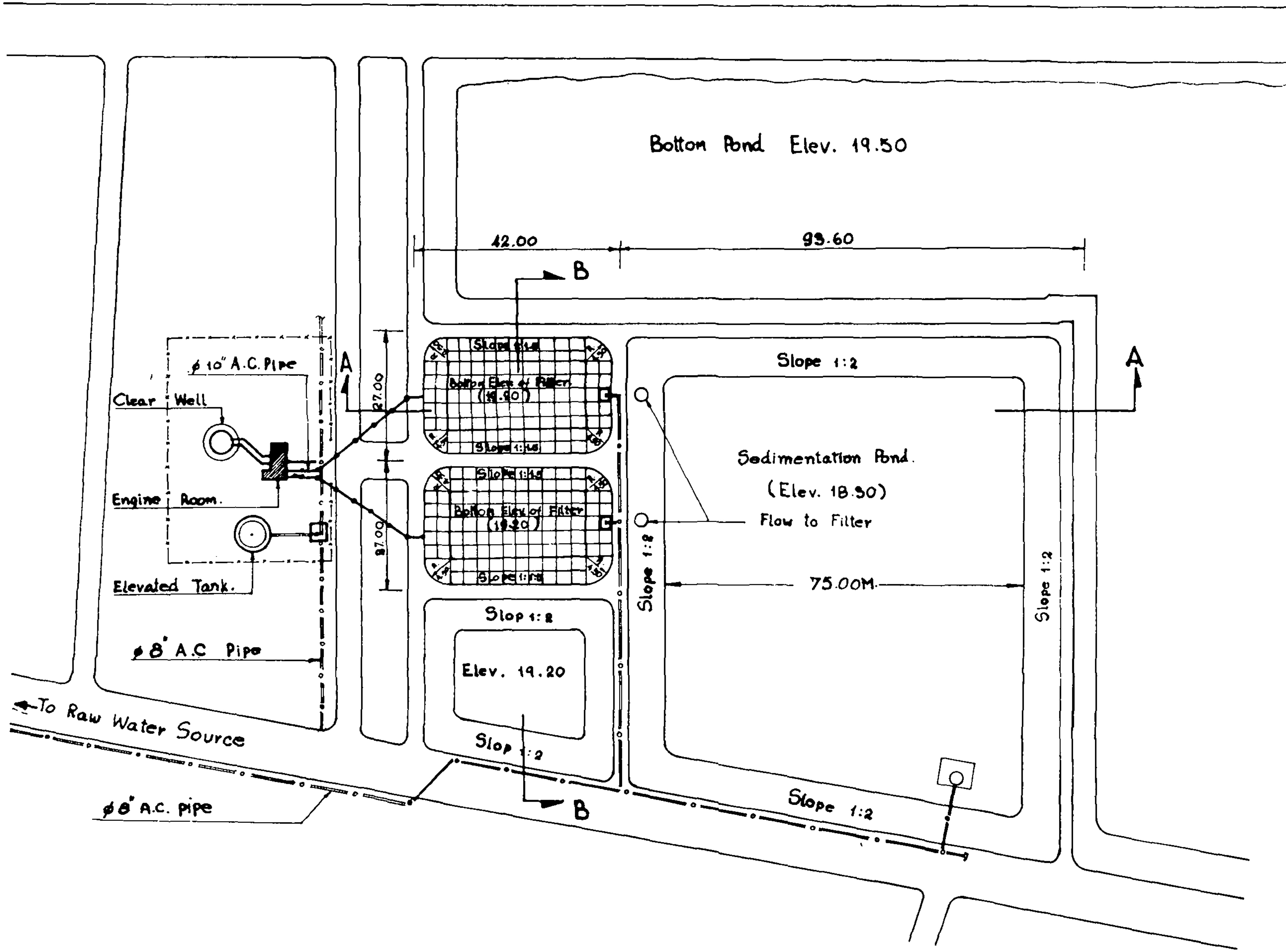
Personnels who carry out the Study :

1. Head of Program and Planning Section.
2. Head of Research and Analysis Section.
3. Head of Design and Estimation Section.
4. Head of Rural Water Supply Regional center 4^{th}.

All people above are officers of Rural Water Supply Division. They started the study in June 1975. It is expected that data and information collection will be completed before April 1976.

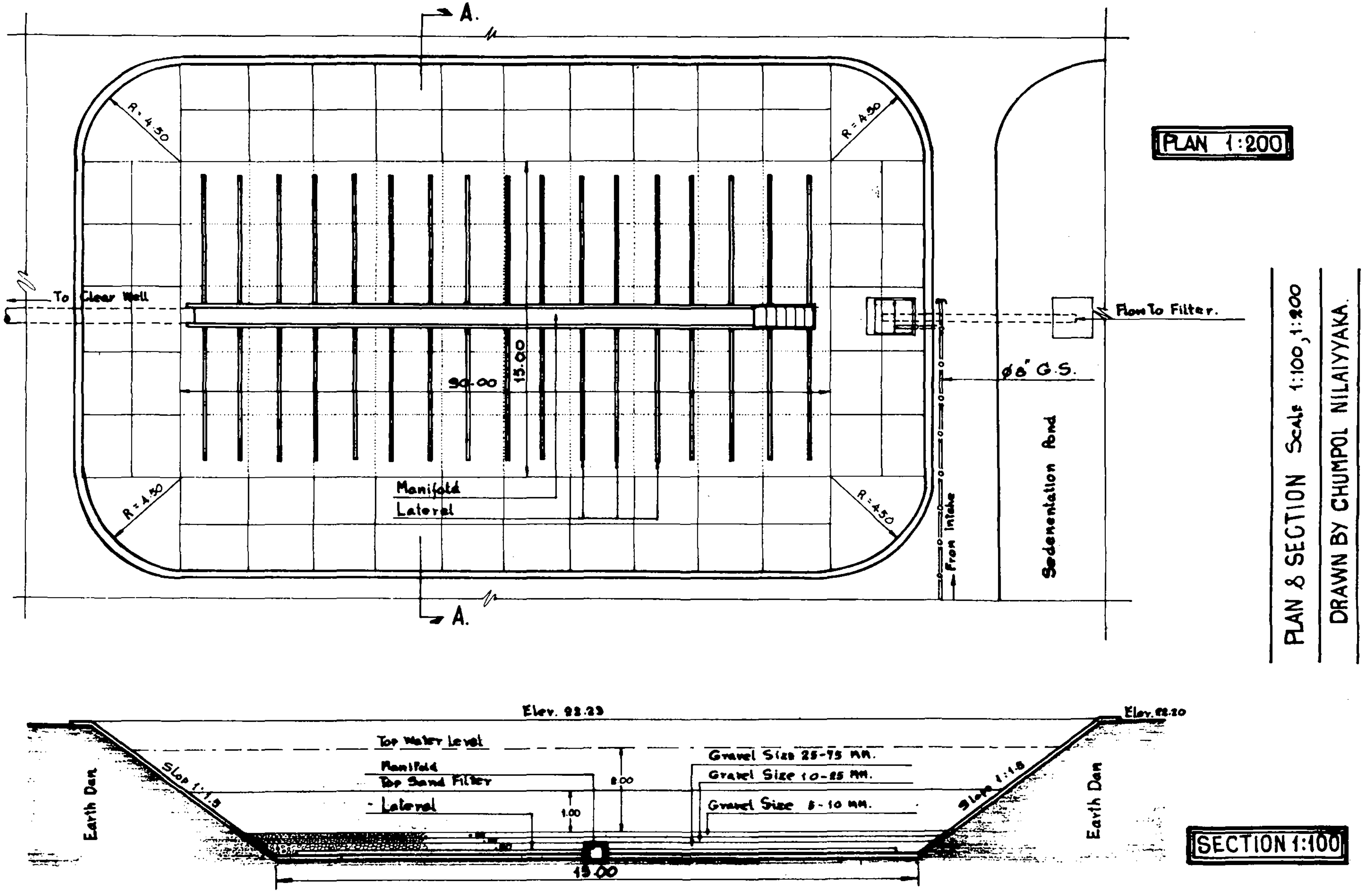


① Plant Site.
② Slowsand Filter.
③ Sedimentation Pond.
④ School
⑤ Temple
⑥ Health Office
⑦ Government Office
⑧ Police Station
⑨ Market
⑩ Post Office
⑪ Mill
⑫ Intake
N.
SYMBOLS
Asbestos Cement 8"φ
Asbestos Cement 6"φ
Asbestos Cement 4"φ
P.V.C. 3/4" φ
Valve
Reducer
Cap
Tee
Bend.
School Fountain.
Fire Tap
Pond.
Raw Water Source
MAP, DISTRIBUTION SYSTEM OF A. KRA-NUAN
DRAWN CHUMPOL NILAIYYAKA
Scale 1 : 7500

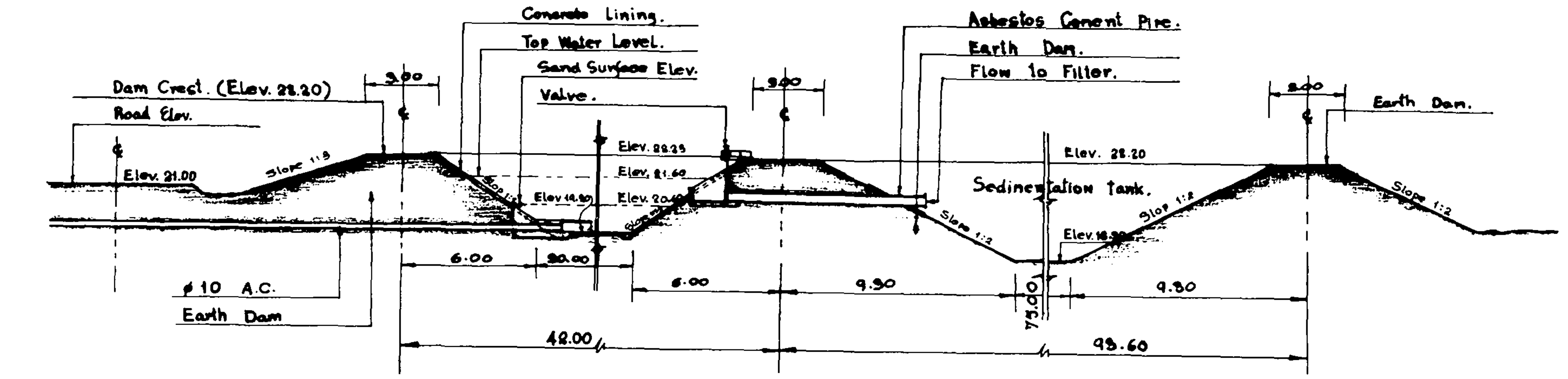


LAYOUT PLANT 1:1000

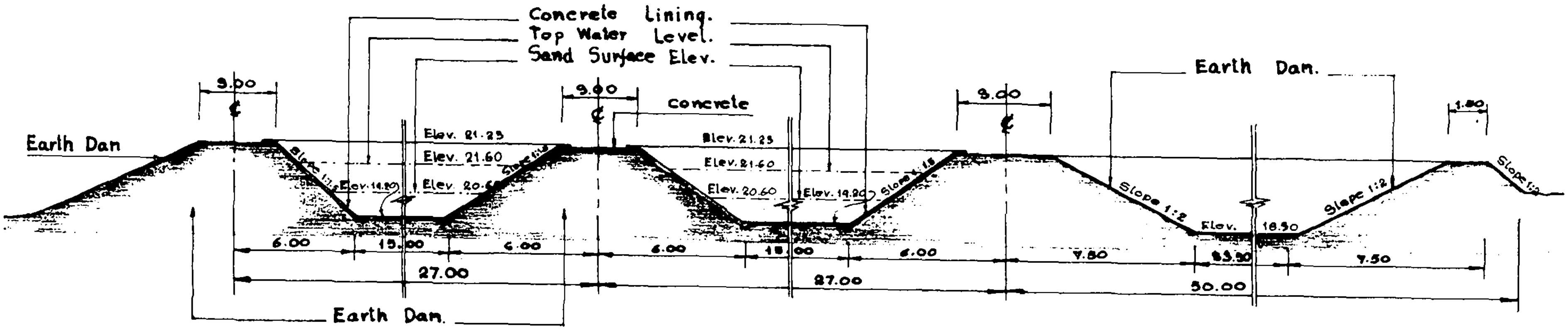
DRAWN BY CHUMPOL NILAIYYAKA.



PLAN 1:200
A.
A.
R = 4.50
R = 4.50
R = 4.50
R = 4.50
To Clear Well
Flow To Filter.
90.00
15.00
ø8" G.S.
Manifold
Lateral
From Intake
Sedenentation Pond
PLAN & SECTION Scale 1:100, 1:200
DRAWN BY CHUMPOL NILAIYYAKA.
Elev. 22.23
Elev. 22.20
Top Water Level
Manifold
Top Sand Filter
- Lateral
Gravel Size 25-75 MM.
Gravel Size 10-25 MM.
Gravel Size 5-10 MM.
2.00
1.00
Slop 1:1.5
Slop 1:1.5
Earth Dam
Earth Dam
15.00
SECTION 1:100



Section A-A 1:200



Section B-B 1:200

Section 1:200

DRAWN BY CHUMPOL NILAIYYAKA.

POPULATION AND SOCIETY

Sanitary District of Nong Ko. Amphoe Kranuan. Changwad Khonkaen

1. Present population.
   2,000 Houses 9,817 people

   Present population served by the water system.
   247 Houses 1,572 people

2. Average birth rate. in the last 5 years 1.50%
   in the last 2 years 0.52%

TABLE 1. POPULATION GROWTH

Items	1970	1971	1972	1973	1974
Population	9997	10,204	10,204	10,627	9817
Birth Number	186	249	210	39	67
Mortality Number	30	42	41	7	8
Dead Infant	-	-	-	-	-
Immigrants	57	94	-	-	-
Emigrants	-	-	47	842	-

3. Level of education obtained for the community.
   From 563 majorities

TABLE 2. EDUCATION LEVEL

Regular basis 1-12+	Number	%
Less than 4	15	2.66
4	321	57.02
7	43	7.64
10	79	14.03
12	10	1.78
12+	95	18.87

4. Highest level of school in community : 10

5. Distance to the nearest highschool offering 12th grade : 66 Km.

6. Population income

TABLE 3. POPULATION INCOME

Professions	Houses	Annual Average ฿
Rice Growing	47	2,560
Farming	7	49,500
Trading	109	93,500
Civil Service	82	24,800
General Labor	38	14,000
Chicken Farm	2	25,000
Pigs Farm	5	11,000
Unemployed	-	-

Average income per capita per year 10,030.77 Baht.

7. Building & Public Welfare

TABLE 4. BUILDING & PUBLIC WELFARE

Items	Number	Built in	Size
Water supply	1	1973	100 M^3/hr
Electricity	1	1962	From dam
School	4	1974	(2)7^{th},(2)10^{th}
Health center	1	1955	2^{nd} grade
Shop	279	-	-
Mill	6	1952	-
Hotel	1	1967	9 rooms
Theater	2	1970	500 seats
Public libraly	1	1971	5 desks

8. House Facilities

TABLE 5. HOUSE FACILITIES

Items	Houses	%
Electricity	200	95.69
Radio	191	91.39
Television	125	59.81
Newspaper	70	33.49
Cars	59	28.23
Bicycle	155	74.16
Mortorcycle	30	14.35

From the total of 209 houses.

9. Rate of sickness from intestinal diseases. (attained health center)

TABLE 6. RATE OF SICKNESS FROM INTESTINAL DISEASES

Year	Population	Number of		%	
		sick	dead	sick	dead
1970	9,997				
1971	10,204				
1972	10,505				
1973	10,627	50	-	0.47	-
1974	9,817	33	-	0.34	-

10. System of government

Local. Sanitary district.

Chairman of the sanitary district committee : Cheriff.

Number of the committee : 14

1 Chief of the police
1 Account
1 Sanitarian
1 Chief of subdistrict (Tambon)
5 Chief of the village
4 Elected member
1 Cheriff

Responsibility

1. Cleaning service
2. Public disaster service
3. Commodities price control

11. Water supply operation

Committee in - charge : yes

Chairman : Cheriff

Finance : District account

Water fare collector : 2 operators

Water fare collection system : meter

Public tap : no

Water fare rate : 3 Baht/M^3

Average revenue per month : 9,200 Baht

Expense per month : 2,940 Baht

Criteria of water use control : yes

Continuity of operation : stop once a year to wash the storage tank

Technical Problems :

a. self repaired for minor problem

b. ask Community Water Supply Center for major problem

12. Operators

Number of operators : 2

Age : 28, 42

Education : 7th, 4th grade

Experience : 3 years

Trained from the Division of Community Water Supply : yes

Started salary : 500 Baht

Present salary : 720 Baht

Responsibility of operators :

a. operate engine

b. water fare collection

c. pipe connection

d. maintenance the system

13. Consumer

Before the construction of water system, people used water from :

a. shallow well 84.69%

b. rain 57.42%

c. deep well 1.44%

Before the construction of water system, the time waste to get water per day

a.	less than 1/2 hr.	54.09%
b.	i hrs.	22.64%
c.	2 hrs.	14.66%
d.	more than 2 hrs.	8.61%

Present usage of potable water :

a.	drink	91.39%
b.	wash	100.00%
c.	bath	100.00%
d.	farm	-

Remark : still drink rain or water from shallow well 8.61%

Rate of intestinal ill after water system construction :

a.	less	36.88%
b.	same	63.12%

Expression to the water fare :

a.	Expensive	34.45%
b.	Fair	65.55%

Preferable of money collection

a.	meter	81.09%
b.	flat rate	18.91%

- - - - - - - - - -

II. WATER CONSUMPTION & EXPENDITURE

DESIGN CRITERIA

For the construction of water systems, the Rural Water Supply Division has the following design criteria :

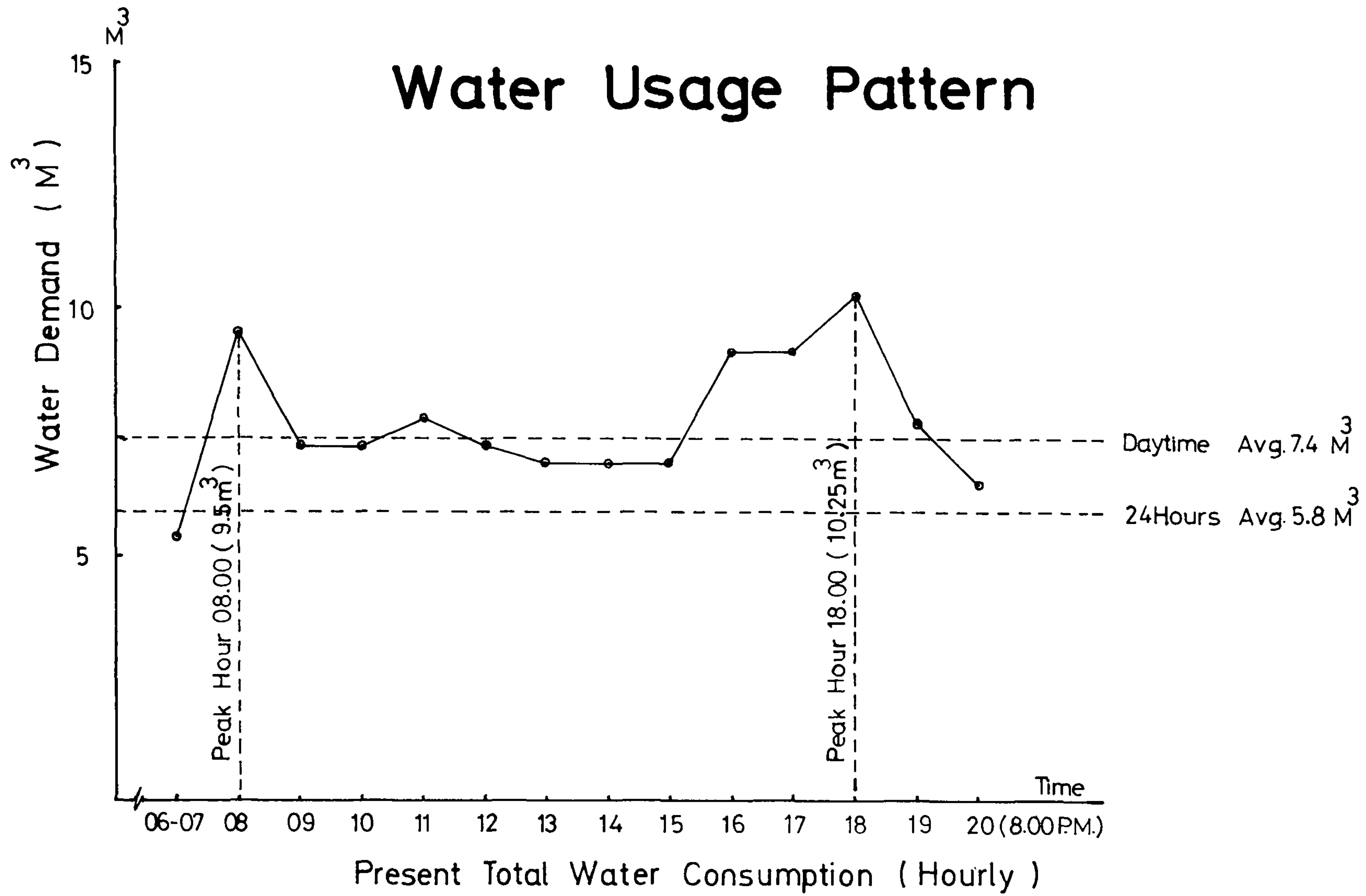
Plant life	-	10 years
Maximum day demand	-	1.5 x Average day demand
Peak hour demand	-	$\frac{4.0 \text{ x Average day demand}}{24}$
Maximum pumping day	-	15 hours
Population growth	-	3%
Total storage	-	70% Average day supply
Elevated storage	-	20% Average day supply
Per Capita Consumption		
Sanitary District	-	80 lpcd.
common village	-	50 lpcd.
Pipe Material	-	Asbestos cement, PVC, Galvanized steel
Distribution system life	-	15 years
Minimum pressure	-	10 psi at the curb

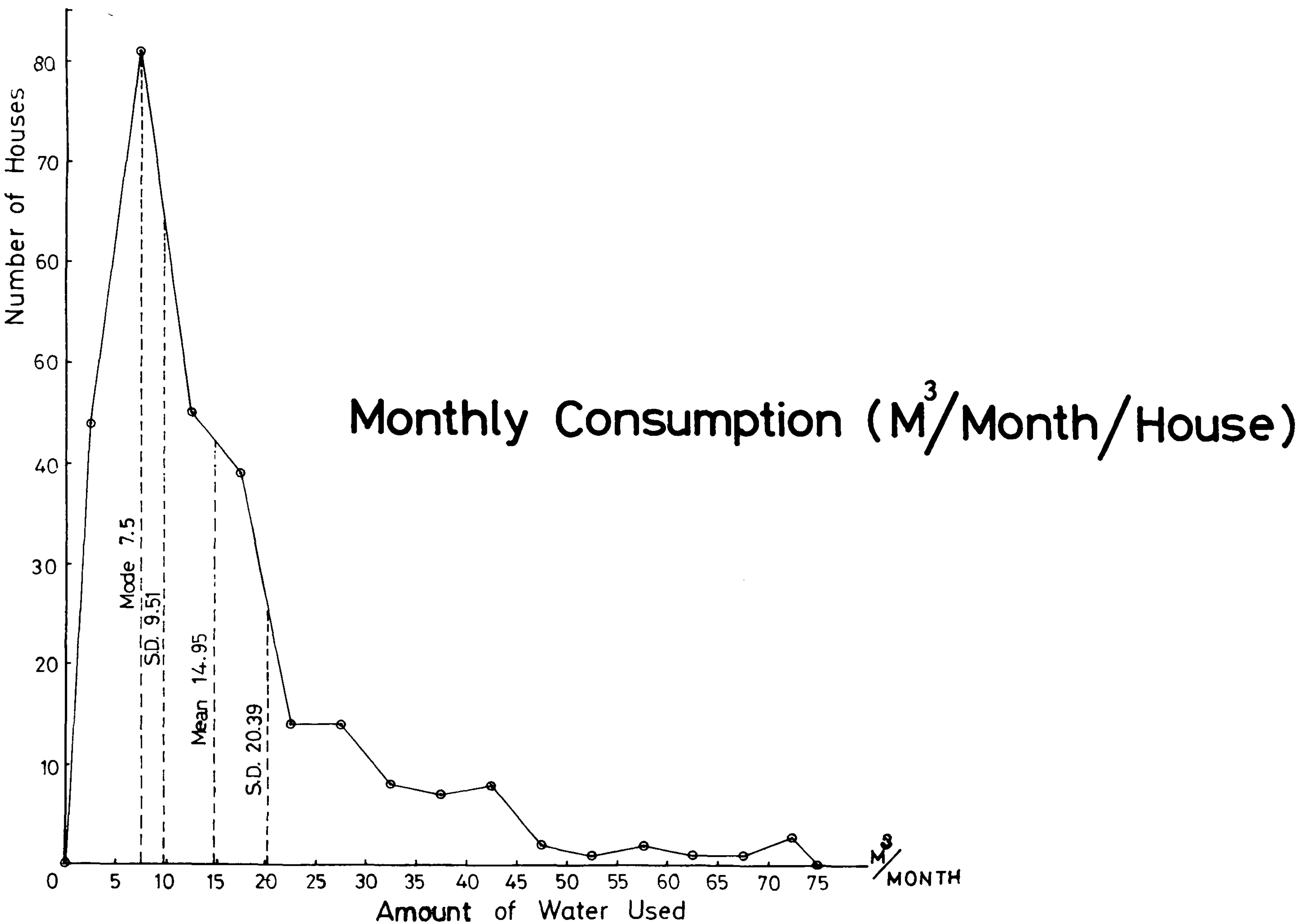
KRANUAN PLANT

Population design	-	2,000 Houses	9,817 People
Present population served	-	271 Houses	1,725 People
	-	17.6%	
(present) Maximum day demand	-	144 CM	
(present) Average day demand	-	135 CM	
(present) Peak hour demand	-	10.25 CM	
(present) Average pumping day	-	3.43 hours	
(present) Maximum pumping day	-	5.50 hours	

Per Capita Consumption (refered to the Monthly Consumption Curved)

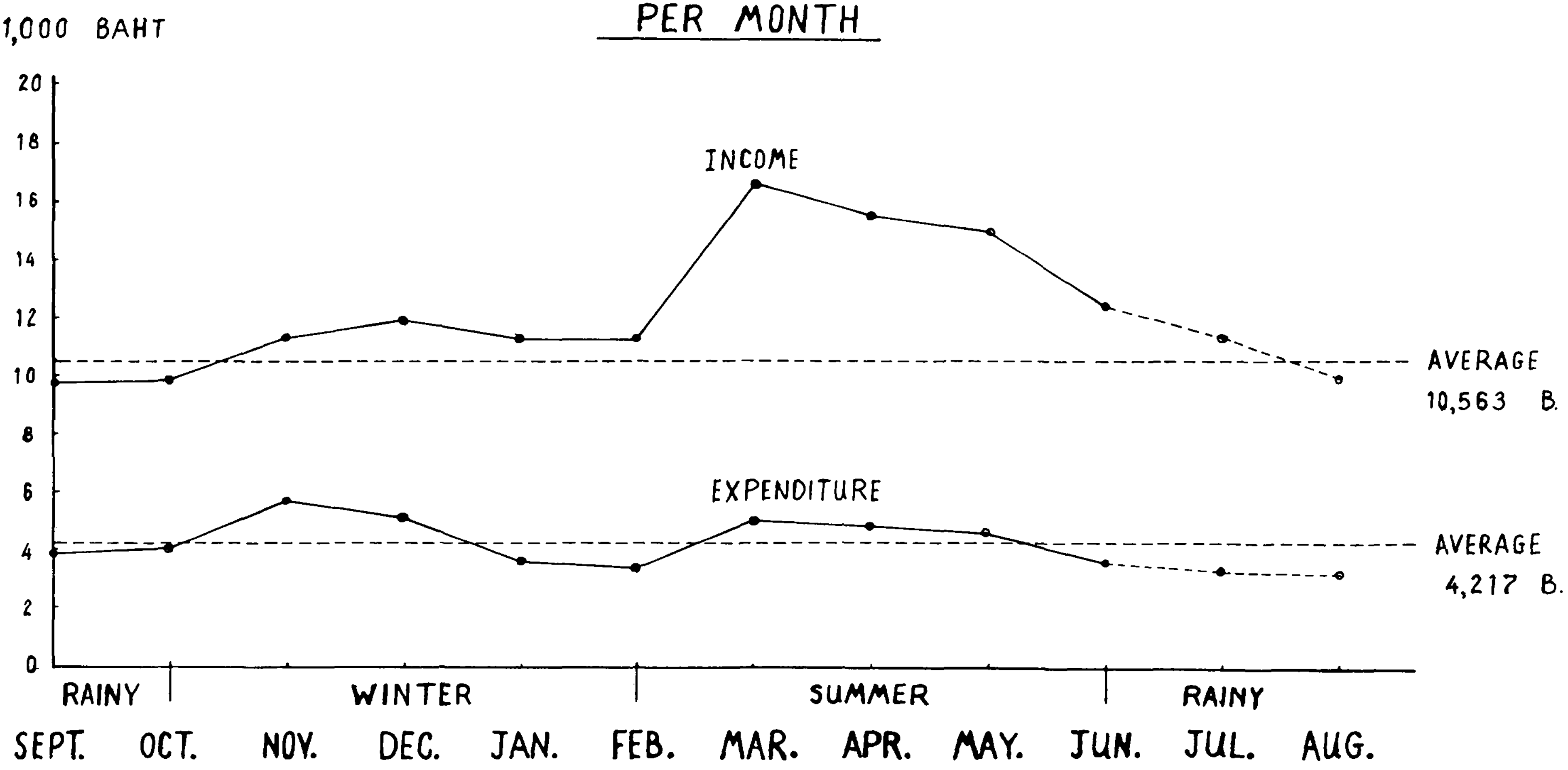
(mean) Average day demand	-	78.5 lpcd
(mode) The most consumer demand		39.2 lpcd
Standard deviation	-	28.3 lpcd


Water Usage Pattern
M^3
15
10
5
Water Demand (M^3)
Peak Hour 08.00 (9.5 m^3)
Peak Hour 18.00 (10.25 m^3)
Daytime Avg. 7.4 M^3
24Hours Avg. 5.8 M^3
Time
06-07
08
09
10
11
12
13
14
15
16
17
18
19
20 (8.00 P.M.)
Present Total Water Consumption (Hourly)



Monthly Consumption (M^3/Month/House)
Number of Houses
80
70
60
60
40
30
20
10
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
M^3/MONTH
Amount of Water Used
Mode 7.5
S.D. 9.51
Mean 14.95
S.D. 20.39

INCOME AND EXPENDITURE PER MONTH



The average per capita consumption of 78.5 lpcd is very close to the criteria set of 80 lpcd for sanitary district. But the interesting point is that the mode shows most of the houses (30%) has per capita consumption of 39.2 lpcd which is less than the criteria set of 50 lpcd for common rural area. The standard daviation is ± 28.3 lpcd or the value lying between 50 - 107 lpcd.

This daily consumption per capita analysis is no included the consumption from a saw mill which draws the water about 23 CM/day, and also for the three schools using about 5 CM/day each.

The maximum day demand is only 1.07 of the average day demand also the peak hour demand which is only equal to

$$\frac{1.82 \times \text{Average day demand}}{24}.$$

HOURLY CONSUMPTION

Daytime consumption graph shows 2 peak hour periods of 9.5 CM/hr at 08.00 in the morning and 10.25 CM/hr at 18.00 in the evening with the 24 hours average of 5.8 CM/hr and daytime (06.00 - 20.00) average of 7.4 CM/hr. The data were collected from January 15 - February 15, 1976.

EXPENDITURE

The monthly expense can be divided into 4 parts :

1.	Fuel for raw water pump	27%
2.	Electric for filtered water pump	14%
3.	Salary for 2 operators	42%
4.	Maintenance, chemical & other	17%

COST PER UNIT OF WATER

Monthly consumption	4,050	CM
Expenditure	4,033	฿
Cost per CM of water	1.00	฿

TABLE 7 INCOME AND EXPENDITURE PER MONTH

Month	Income (฿)	Expenditure (			
		Salary	Fuel	Oil	Electricity
Sept. 75	9,775	1,700	1,020	75	552
Oct. 75	9,878	1,700	1,020	75	580
Nov. 75	11,263	1,700	1,020	75	569
Dec. 75	11,985	1,700	1,020	91	582
Jan. 76	11,338	1,700	1,020	298	567
Feb. 76	11,320	1,700	1,020	105	580
Mar. 76	16,637	1,700	1,510	75	769
Apr. 76	15,598	1,700	1,020	75	682
May 76	15,021	1,700	1,550	156	628
June 76	12,468	1,700	1,020	75	589

TABLE 8 DEMAND AND PAYMENT

Demand per month (CM)	Consumer		Total amount		Payment/month ฿	
	houses	%	CM	%	per house	Total
0 - 5	44	16	110	3	7.5	330
5 - 10	81	30	608	15	22.5	1,824
10 - 15	45	16	562	14	37.5	1,686
15 - 20	39	14	683	17	52.5	2,049
20 - 25	14	5	375	9	67.5	1,125
25 - 30	14	5	385	10	82.5	1,155
30 - 35	8	3	260	7	97.5	780
35 - 40	7	2	262	7	112.5	786
40 - 45	8	3	340	8	127.5	1,020
45 - 50	2	1	95	2	142.5	285
50 - 55	1	1	53	1	157.5	159
55 - 60	2	1	115	3	172.5	345
60 - 65	1	1	62	1	187.5	186
65 - 70	1	1	68	1	202.5	204
70 - 75	3	1	72	2	217.5	216
Total	271	100	4,050	100	-	12,150

III. CHARACTERISTICS OF THE FILTER

FILTER DESIGN

The essential parts of slow sand filter at Kranuan consists of a sedimentation pond, the filter bed and underdrain system, the filter control system.

Raw water is pumped from a reservoir 8 Km. apart by a diesel engine pump to the earth sedimentation pond of about 22,000 CM capacity. But by the time of this research the sedimentation pond was not used since the raw water quality is good in the absent of turbidity. Raw water was then pumped to the filter unit directly.

At the present time, the filter was used only one unit at a time because the water demand is not fullfill the capacity design yet. One unit was closed and cleaned, preparing for the time to replace the being used one.

The bottom area of each filter unit is 15 x 30 m^2 that made the total of 900 m^2 for two filter area. The dept of the filter bed are :

Free board	0.60	m
Supernatant water	1.00	m
Sand bed (initially)	1.00	m
Gravel size 5-10 mm	0.10	m
Gravel size 10-25 mm	0.10	m
Gravel size 25-75 mm	0.20	m
Total dept	3.00	m

The underdrain system consists of concrete block as main lateral size 0.30 x 0.36 m placed 1.5 cm. apart with Ø 100 mm asbestos cement pipe 30 cm. long at 1.5 cm. apart as side lateral. The filtered water then flow to the clear well in the Ø 250 mm AC pipe.

The rate of filtration is controlled by a gate valve and a V shape weir before the clear well. The wier is served as the flow measurement and also a U tube to prevent sand surface drying.

SIEVE ANALYSIS

It is suggested in "Slow Sand Filtration" by L. Huisman & W.E. Wood that the degree of uniformity of less than 3 and effective diameter in the range of 0.15 to 0.35 mm are desirable for sand media of slow sand filter.

In this experiment, sieve analysis were made 5 times from samples of various position in the filter. The uniformity of 2.75 and effective diameter of 0.24 mm are the average results obtained. The two values are satisfactory within the ranges suggested above.

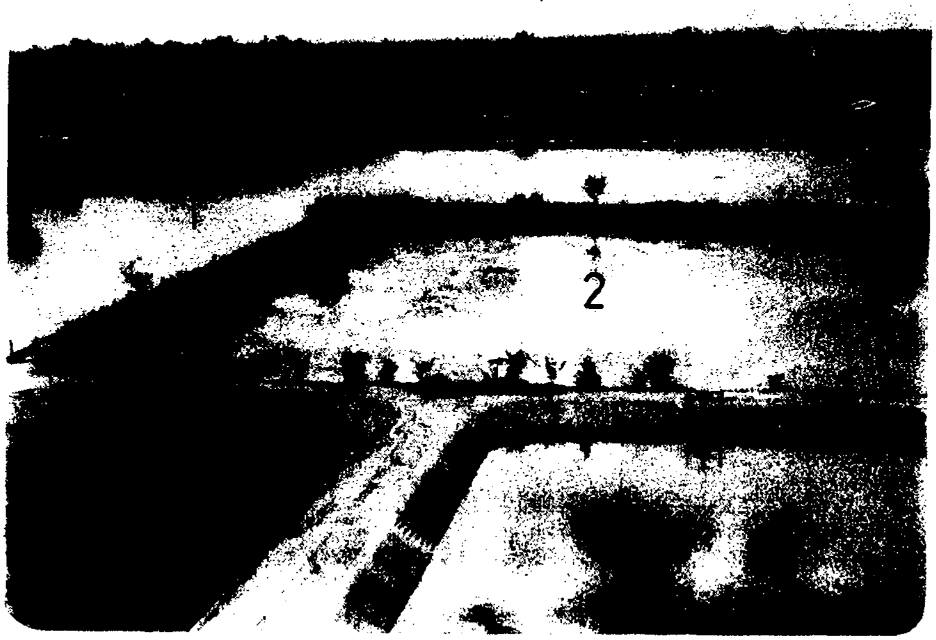
RATE OF FILTRATION

The optimum rate of 100 CM/hr are designed to be the capacity of this plant. Since it has two units, each one should run at 50 CM/hr rate or at about 0.11 CM/hr/m^2 related to the filter bottom area. Actually, the rate of filtration of this filter is adjustable by the control of the valve between filter and clearwell.

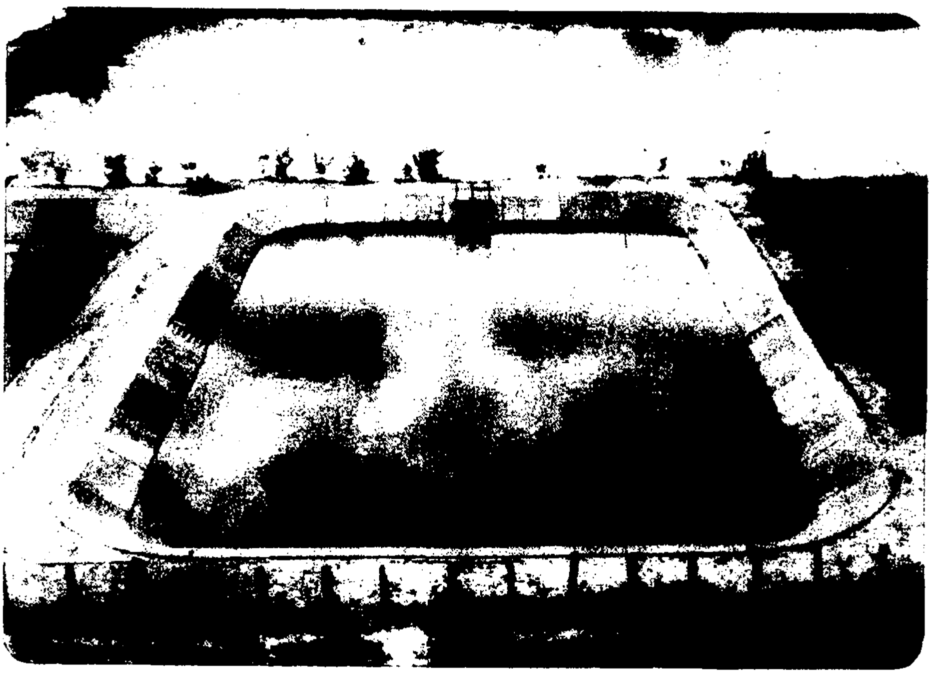
In this analysis, after cleaning the surface of the sand (the unit to be analysed) the valve was opened fully that made the filtration rate slightly higher than the design rate or at 60 CM/hr (0.133 CM/hr/m^2) with the water level at 0.90 m. above the sand surface. The raw water pump was shut down at this level allowed raw water to pass the filter bed and the rate of filtration were checked again at 0.80 and 0.70 m of water level above the sand surface. The filter stopped running at the level of 0.50 m automatically by the weir. On the next day the raw water pump started and the same procedure was run, the data were collected for the total of 120 hours of filter run.

FIGURE 5. RAW WATER INTAKE PIPE AND CASING IN RESERVOIR 8KMS. FROM PLANT.

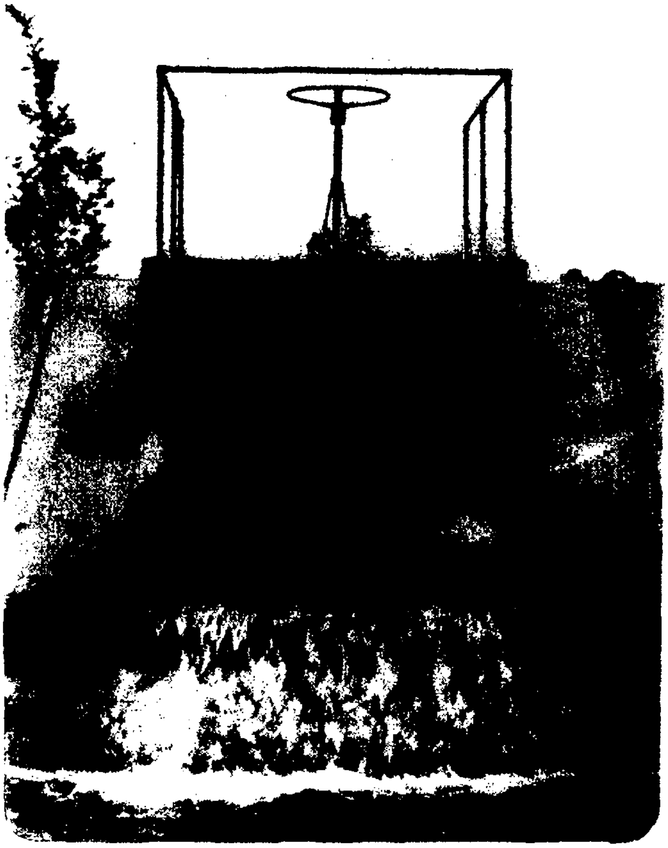
CENTRIFUGAL PUMP DRIVEN BY DIESEL ENGINE FOR RAW WATER.



1. EXISTING POND (NOT USE)
2. PRESEDIMENTATION POND
3. SLOW SAND FILTER DURING CLEANING
4. SLOW SAND FILTER DURING OPERATING

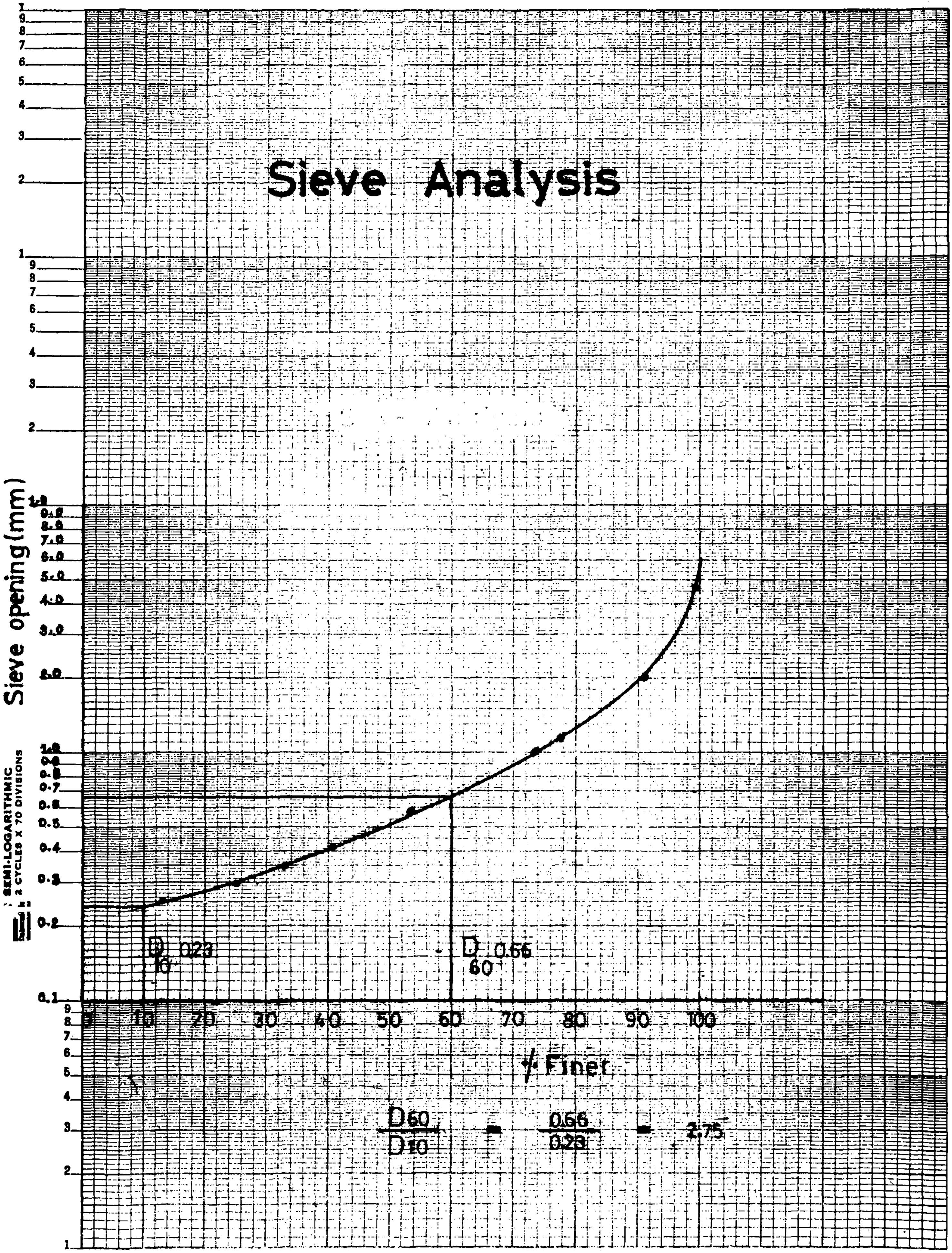


THE SLOW SAND FILTER



INLET TO THE FILTER

CONTROL WEIR AFTER FILTRATION



Sieve Analysis
Sieve opening (mm)
% Finer
D10 0.23
D60 0.66
D60 / D10 = 0.66 / 0.23 = 2.75
SEMI-LOGARITHMIC
2 CYCLES X 70 DIVISIONS

The rate of filtration corresponded to the length of filter run were plotted. The curve did not show clearly any sign of clogging since there were fluctuations along the line. After 40 hours of filter run the rate of filtration increased up to the started rate. This may be due to any crack on the surface of the sand. But this phenomenon should not happen since we never let the sand drying they were always covered with water all the time and the technician checked the filter everday.

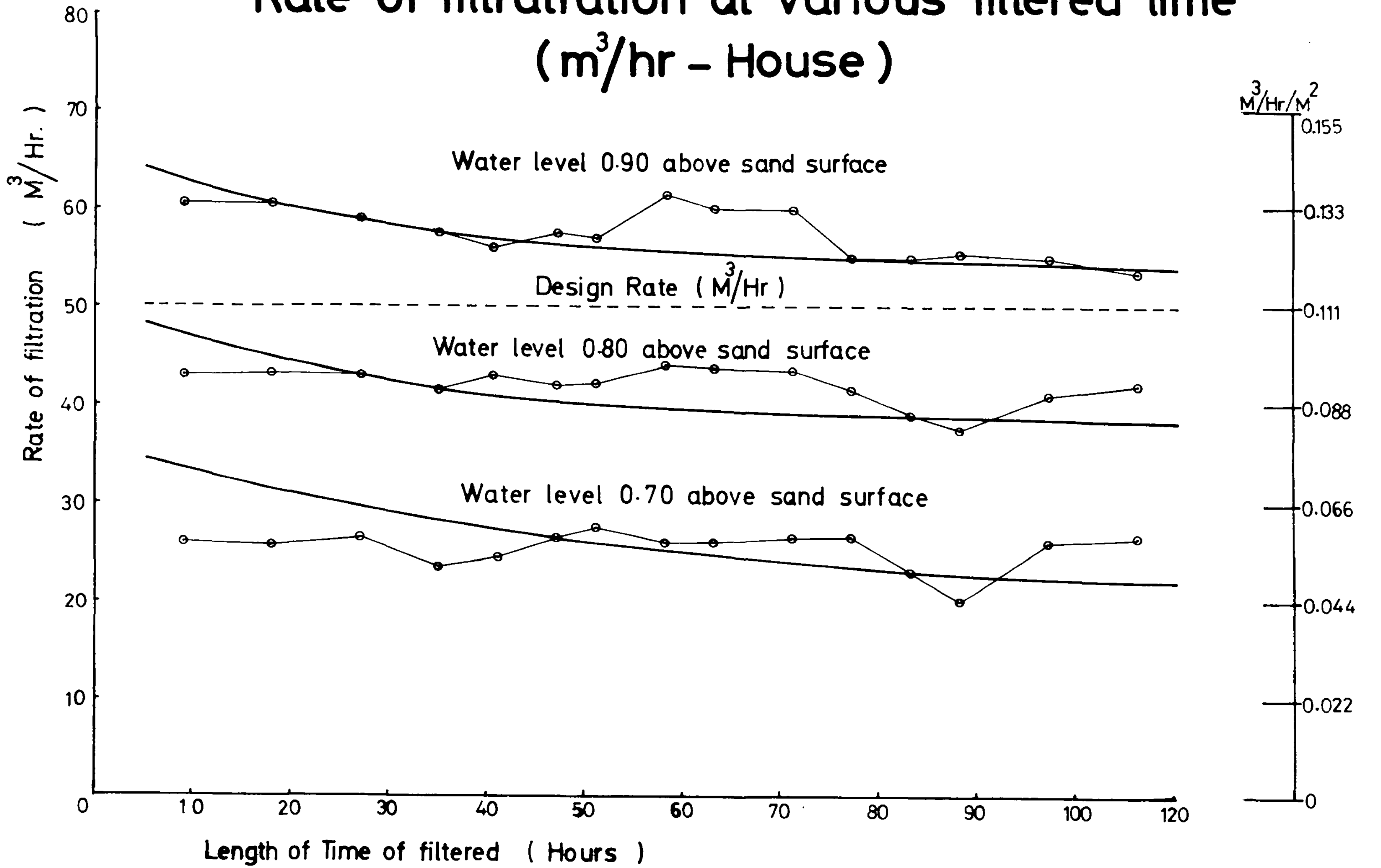
The rate of filtration curves were plotted related to 3 different water elevation above sand surface, at 0.90, 0.80 and 0.70 m. At 0.90 m water level, the rate of filtration was dropped about 7 CM/hr or 11.6 % decrease. But the other two curves at 0.80 and 0.70 m the line were up and down along 120 hours filter run, the daviation were not much.

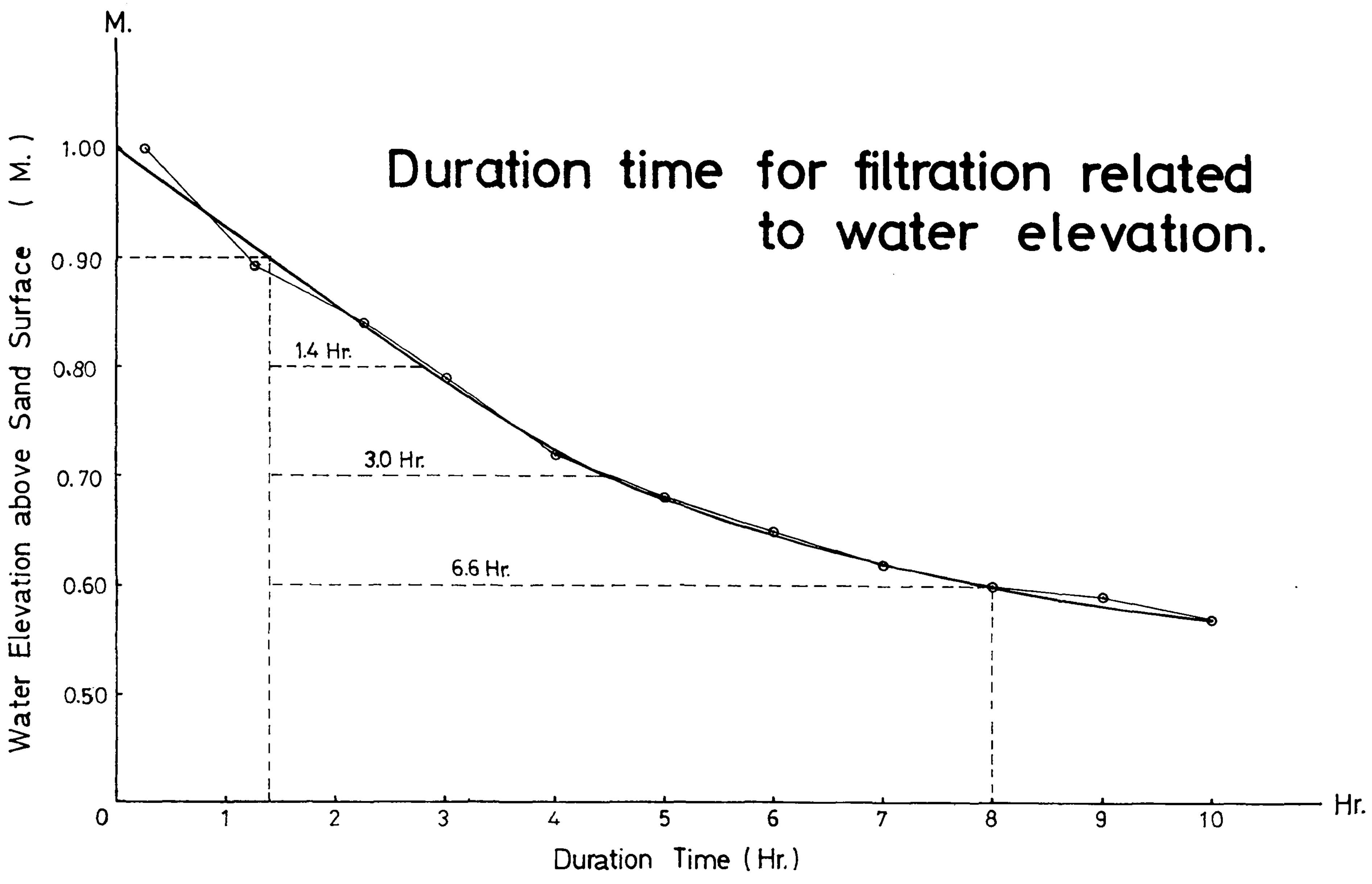
It can be seen from the curves that the different in elevation of water lever will make the rate of filtration vary a great deal. The different of 0.10 m will change the filter rate about 15 CM/hr or 0.033 CM/hr per square meter. So to run the filter at the design rate, the water elevation should be controlled around 0.80 - 0.85 m above sand surface that should make the rate about 0.10 CM/hr/m^2.

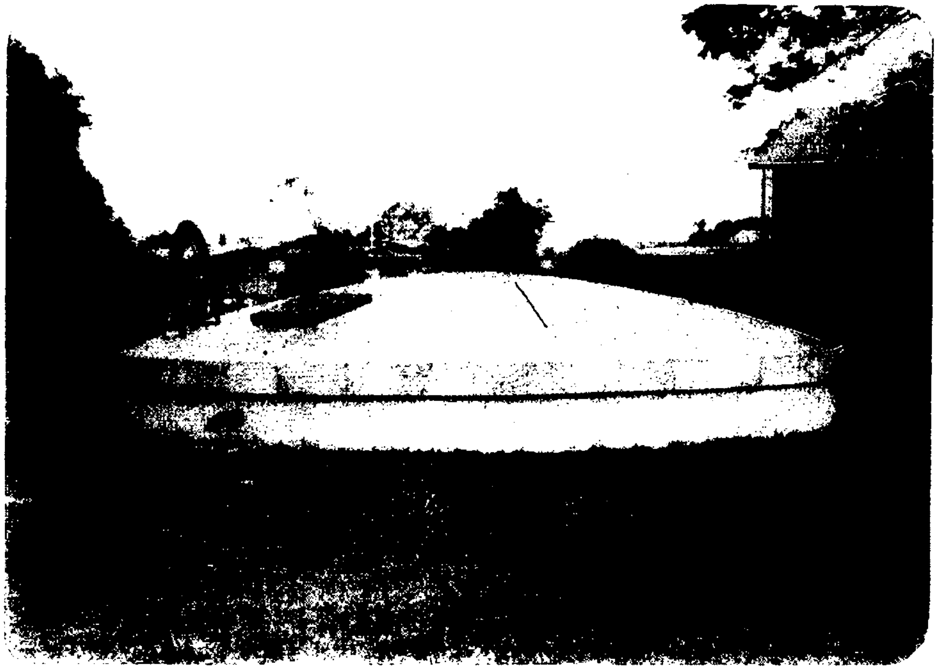
Furthermore, after the raw water was stopped and the water on the filter was allowed to fall freely, the time required for the water level to drop from the point started 0.90 m to 0.60 m was 6.6 hours.

At the water level higher than 0.70 m above sand surface the rate of filtration was high at about 0.07 m/hr and decreased to 0.03 m/hr when the level was lower than 0.70 m.

Rate of filtratration at various filtered time (m^3/hr – House)



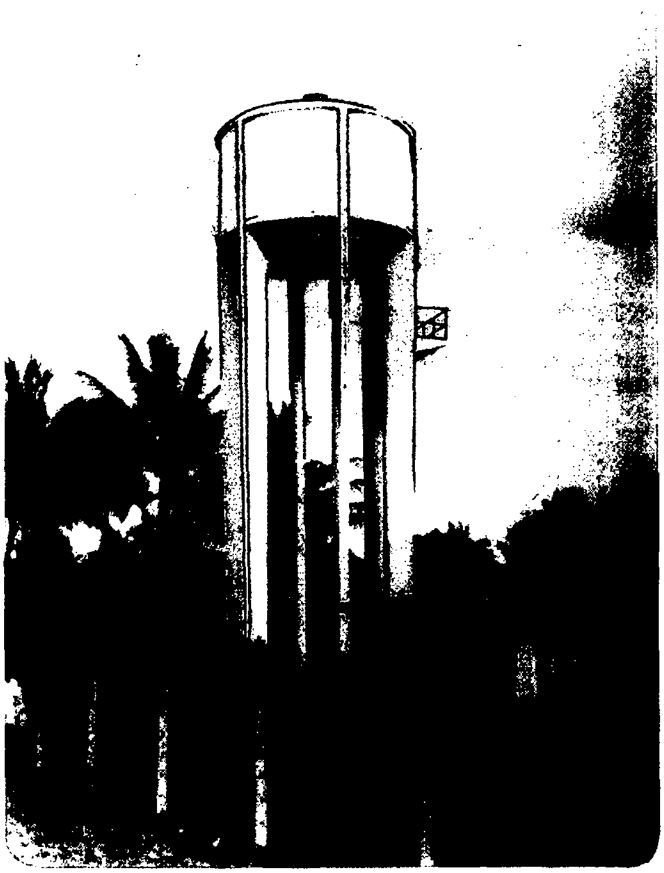

Duration time for filtration related to water elevation.
M.
Water Elevation above Sand Surface (M.)
1.00
0.90
0.80
0.70
0.60
0.50
1.4 Hr.
3.0 Hr.
6.6 Hr.
0
1
2
3
4
5
6
7
8
9
10
Hr.
Duration Time (Hr.)



200 CU.M. CLEAR WELL

CHLORINATOR

FILTERED WATER PUMP (HIGH SERVICE)
DRIVEN BY ELECTRICAL MOTORS



100 cu.m ELEVATED TANK

IV. QUALITY CONTROL & EFFICIENCY OF THE FILTER

INTRODUCTION

The purified water processes involve physical, chemical and biological treatment which transform raw water into potable water. The treatment processes used, depends upon the quality and nature of the raw water. Slow sand filtration system is used for the water source that believed to be good quality throughout the year. The system was chosen and applied at Kranuan, Khon-kaen province. The filtration plant is now operated and potable water is distributed to consumers in the village. Chemical and bacteriological of the characteristics of water at the filtration plant would give the idea of the capability and the efficiency of the filter.

Characteristics of water

A true picture of water would revealed by the analysis under the following items:-

1. temperature
2. colour
3. turbidity
4. total solids
5. pH
6. alkalinity
7. hardness
8. dissolved oxygen
9. residual chlorine
10. MPN

Sampling

Water is sampled from the inlet and outlet of the filter. The samples are subjected to physical, chemical and bacteriological determinations. Certain examinations (eg. dissolved oxygen, bacteria) are performed on seperated bottles. The bacteriological sample is taken under aseptic technique in a sterile glass bottle.

SCHOOL TAPS

SIEVE ANALYSIS FOR FILTERED SAND

Results of analysis

The results of analysis are tabulated in table 1.

Physical test

The physical analysis is carried out in the laboratory at Khon-kaen except temperature which is measured at the filter plant.

1. Temperature

The measurement of temperature is done at the water treatment plant. The temperature of water is usually varied accordingly to the seasons and the weather condition. The time of being analysis is between January and February. These two months are in the late winter of Thailand. It ranges from 22.8°C to 25.8°C. The average value of raw water is 24.5°C and for the filtrate is 24.0°C.

2. Colour

The determination of colour is reported in term of apparent colour which is due to suspended matter. The average result is 5 unit for both raw and filtered waters.

3. Turbidity

The analysis of turnidity is performed by using Turbidimeter Hach Model 2100 A. The turnidity value of raw water is between 5.6 - 7.2 which give the average of 6.5. And the turbidity of treated water ranges from 2.6 - 5.6 which provide the average of 4:2.

Chemical test

1. pH

The pH value is measured by using pH meter Orion Model 407A, ranging from 7.85 - 8.9 for the raw water and 7.98 - 8.15 for the filtered water. The average pH value of the former is 8.13 and 8.05 for the latter.

2. Alkalinity

The alkalinity of water is due to the presence of bicarbonate, carbonate and hydroxide. All forms of matter provide buffering to resist changes in pH. It can be divided into caustic alkalinity above pH 8.3 and total alkalinity above pH 4.5. The caustic or phenolphthalein alkalinity is undetectable. The total or methyl orange alkalinity of water is analysed by titration method. The average values for raw and filtered water are 123.4 and 127.2 ppm. $CaCO_3$ respectively.

3. Hardness

The hardness of water is due to the presence of metallic ions eg. calcium, magnesium, iron, associated with bicarbonate, sulphate, chloride and nitrate. It is no health hazard, but prevents lather formation and produces scale. The determination of hardness is run by titration method. It shows that the hardness value of raw water is 53.5 ppm. and of the filtrate is appeared more or less the same as the raw water.

4. Totl solids

The solids are determined as total dissolved solids. This can be done by evaporating a volume of sample to dryness and drying in an oven at 100 - 105°C. The increasing weight is the weight of solids. The solids of raw and filtered waters are 69.2 and 77.9 mg/l respectively.

5. Dissolved oxygen

The Winkler method is applied to determine the dissolved oxygen. The oxygen dissolved in raw water kept in reservoir is 8.1 mg/l. After filtration the oxygen is dropped to 5.6 mg/l.

6. Coliform

An estimation of coliform number is determined by the MPN method. Coliform bacteria have the property that they will

BACTERIA AND CHEMICAL TESTS

ferment lactose with the production of acid and gas. The appearance of acid and gas after incubation for 24 hours at $37^{o}C$, is taken as positive for the presence of coliform bacteria. The number of positive tubes are statistically interpretted as most probable number index (MPN/100 ml). The average value of raw water is 122 and after filtration the figure is dropped to 72.

7. Residual chlorine

Chlorine is used for disinfection of the filtered water. It is very toxic to most micro-organisms, stopping metabolic activities. Then it leaves a residual chlorine in water which can be detected. The residual chlorine left is ensure that the water is safe for consumption. The determination of residual chlorine is done by using comparison technique. The average result is 0.12 ppm. The amount of high test hypochlorite (60%) used is about 15 kilogrammes per month or per 4,050 cubicmetres.

Discussions

The results of analyses reveal the characteristics of raw and filtered waters. The nature of raw water is most suitable in selecting slow sand filtration system. The properties of the filtered water would specified the efficiency of the filter. From the analysis point of view, the filter system at Kranuan can produce clear, odourless and colourless water with 41% reduction of coliform organisms. Only one sample examined for coliform shows less than 2 MPN/100 ml. The slow sand filtration, theoretically, can remove bacteria efficiently 99% reduction. Water treatment does not usually produce coliform-free water. Furthermore, no distribution system will be free from coliform organisms unless residual chlorine is always present. The bacteriological test data reflects the capability of the filter. The analysis result shows that the efficiency of the filtration is not satisfactory yet. Not only the filtration itself, but some other factors are also involved in evaluating the efficiency of the filter.

The pH, colour, odour and alkalinity are analysed for data interpretation supplementary. The degree of hardness from the analysis is classified as soft water which has economic advantage of soap consumption. The dissolved oxygen of the influent is 8.1 mg/l and the effluent is above 5.6 mg/l. As the oxygen content of the effluent is above 3 mg/l, it is believed that anaerobic conditions rarely develop in the filter bed (WHO 1974 recommendation).

The physical and chemical analyses show that they are not over the limits of WHO standards for drinking water 1971. If the disinfection is strictly controlled, the water is safe for drinking.

TABLE 9 RESULTS OF ANALYSIS OF WATER

Date of Collection	Temperature		pH		Colour unit		Turbidity FTU		Total Solids mg/1		Hardness mg/1-$CaCO_3$		Alkalinity mg/1 - $CaCO_3$ PP	
	R	P	R	P	R	P	R	P	R	P	R	P	R	P
12 Jan 76	24.4	23.2	8.65	8.15	5	5	5.6	2.6	79	103	52	72	4	[illegible]
13 Jan 76	22.8	20.8	8.6	7.99	5	5	5.6	2.6	73	88	56	72	8	[illegible]
17 Jan 76	-	-	8.82	8.05	5	5	5.6	2.6	89	91	56	56	10	[illegible]
20 Jan 76	23.5	24.1	8.74	8.04	5	5	5.6	2.6	58	71	56	52	12	[illegible]
22 Jan 76	25.0	24.5	8.7	7.96	5	5	5.6	2.6	45	70	56	52	14	[illegible]
26 Jan 76	25.8	25.3	8.68	8.03	5	5	5.6	2.6	60	72	56	52	10	[illegible]
28 Jan 76	25.4	25.6	8.65	8.01	5	5	5.6	2.6	58	52	52	52	6	[illegible]
30 Jan 76	24.6	24.2	8.4	8.08	5	5	5.6	2.6	37	55	56	48	10	[illegible]
2 Feb 76	-	-	8.65	8.09	5	5	7.2	5.6	18	38	52	52	11	[illegible]

R = Raw Water

P = Potable Water

TABLE 9 RESULTS OF ANALYSIS OF WATER (Cont.)

Date of Collection	Temperature		pH		Colour unit		Turbidity FTU		Total Solids mg/1		Hardness mg/1-$CaCO_3$		Alkalinity mg/1 - CaC
													PP
	R	P	R	P	R	P	R	P	R	P	R	P	R
4 Feb 76	-	-	8.58	8.11	5	5	7.2	5.6	12	21	56	52	9
6 Feb 76	-	-	8.65	8.1	5	5	7.2	5.6	93	89	56	52	12
9 Feb 76	-	-	8.45	8.01	5	5	7.2	5.6	101	115	56	52	3
11 Feb 76	-	-	8.85	8.12	5	5	7.2	5.6	82	86	52	52	13
13 Feb 76	-	-	8.9	8.15	5	5	7.2	5.6	83	90	64	52	10
16 Feb 76	-	-	7.85	7.98	5	5	7.2	5.6	88	82	18	28	8
18 Feb 76	-	-	8.65	8.08	5	5	7.2	5.6	96	95	56	52	4
20 Feb 76	-	-	8.21	7.93	5	5	7.2	5.6	105	106	60	60	4
Average	24.5	24	8.6	8.05	5	5	6.5	4.2	69.2	77.9	53.5	53.4	8.

R = Raw Water

P = Potable Water

TABLE 10 REPORT OF SIEVE ANALYSIS

Experiment 1

Opening m.m.	U.S. No.	Wt. in gms.		Wt. of soil.		Cum % retained	% finer
		Sieve	Sieve & Soil	gms.	%		
4.689	4	590.15	593.45	3.8	1.15	1.15	98.85
2.00	10	527.05	555.75	28.7	10.0	11.15	88.85
1.168	16	497.7	520.45	22.75	7.93	19.08	80.92
1.00	18	506	518.9	12.9	4.50	23.58	76.42
0.589	30	468.15	520.55	52.4	18.26	41.84	58.16
0.420	40	394.6	442.6	48.0	16.75	58.59	41.41
0.350	45	445.2	482.05	36.85	12.84	71.43	28.57
0.295	50	440.05	462.9	22.85	7.96	79.39	20.61
0.250	60	369.55	395.9	26.35	9.18	88.57	11.43
	PAN	367.0	399.8	32.8	11.43	100.	0

D10 = .23 mm.

$$\frac{D60}{D10} = \frac{.63}{.23} = 2.74$$

Average

U.S. No.	4	% finer	99.19
"	10	"	90.63
"	16	"	77.76
"	18	"	73.3
"	30	"	53.49
"	40	"	40.61
"	45	"	33.32
"	50	"	25.03
"	60	"	13.23

D10 = .24 mm.

$$\frac{D60}{D10} = \frac{.66}{.24} = 2.75$$

Conclusion

This study of slowsand filtration is done on only one water treatment plant. All the data and results obtained are not represented or the average value of other slowsand filters in Thailand. Further studies should be performed at the slowsand filters which are scattered in other three different parts of the country, so that the data collected would show some characteristies of the filters. The information would be averaged and used as a basic of design for the new ones. However, the local situation at Kranuan, population and society, raw water quality and treatment plant unit, of this plant are not different so far from any other villages or plants and it is believed that these informations can be applied to improve some criteria of design for the Rural Water Supply Division.

The Results obtained in water consumption part are very interesting since the criteria design for capita consumption, daily demand, peak demand etc. were set up in 1966 by assuming. Some design are very close to the actual but some are different by far.

The filter bed and rate of filtration are checked to be within the range suggested from most water treatment textbooks. Because of the limits of time and budget provided some interesting informations are absent from this study such as length of filter run to the time of clogging.

The efficiency of the filter is done on laboratory experiments, comparing the quality of raw water and filtered water. The experiment were run for just one month due to the limit constraint as explained above. Actually, it should be done through out the year with different characteristics of raw water vary with the seasons. Anyhow, the results of analysis show that the water quality is within the range of WHO recommended standard for drinking water. Unless the water is disinfected before distribution, it is not safe for drinking.