EVALUATION OF WATER DISTRIBUTION NETWORK SYSTEM AND DESIGN OF WATER TREATMENT PLANT FOR PHUENTSHOLING CITY

Choki Dorji[2], Karma Dorji[3], Karma Jamtsho[4],KinleyZam[5],Leki DorjiI[1] ,

College of Science and Technology, Royal University of Bhutan
[1]leki_d@cst.edu.bt, [2]2009010@cst.edu.bt, [3]2009032@cst.edu.bt, [4]2009034@cst.edu.bt, [5]2009043@cst.edu.bt

ABSTRACT

This Project primarily focuses on two main contexts: evaluation of water distribution network system of Phuntsholing City & design of water a treatment plant. Presently, the city has been supplied with five water sources; three surface sources and two subsurface sources. Due to unusual increase in population the water crises in the city has become an issue and the major concern for the government. Construction of water treatment plants and installation of bore-holes pumping systemwere undertaken in order to eradicate water shortage especially in core town area but still the issue is beyond the control. Therefore, this Project would entirely describe the necessity of another water treatment plant which will be located at Damdara, 1.45 KM away from main town. Moreover, several defects in existing water distribution systems and corresponding remedial measures required to overcome are proposed. The Project also focuses on the total discharge available from the city source and the actual requirement based on the population residing in campus. Evaluation is also carried out in EPANET software.

Key words: *Treatment, population, distribution, network, evaluation, site, maps*

1. INTRODUCTION

Clean drinking water is a basic human need. Unfortunately, more than one in six people still lack reliable access to this precious resource in developing world.

Water distribution networks serve many purposes in addition to the provision of water for human consumption, which often accounts for less than 2% of the total volume supplied. Piped water is used for washing, sanitation, irrigation and firefighting. Networks are designed to meet peak demands; in parts of the network this creates low-flow conditions that can contribute to the deterioration of microbial and chemical water quality. To maintain microbial quality, the network should be designed and operated to prevent ingress of contaminants, to maintain disinfectant residual concentrations within a locally predetermined range and to minimize the transit time. (Kay Chambers, 2004)

1.1 BACKGROUND

Clean drinking water is a fundamental human need and it has always played a prominent role in human civilization. The rapid growth of population has exerted the portable water demand, which requires exploration of raw water sources, developing treatment and distribution systems. Therefore, the purpose of a water treatment plant is to provide a consistent supply of high quality of water to meet the needs of our growing population.

The Amochhu infiltration gallery and the Om chhu intake which were used to guarantee continuous water supply to Phuentsholing was destroyed by the august 2000 flood. Ground water extraction was then initiated including rehabilitation of the surface water intakes to stabilize the water supply. The water supply system developed after the flood is provisional and as such, long term solutions for improving the system have to be taken.

1.2 OBJECTIVES OF THE STUDY

The main aim of the project is to "Evaluate the water distribution network system of Phuentsholing City and design a water treatment plant".

And following are some of the associated objectives for this project:

- To study the associated problems in the existing water network system and come up with appropriate counteractive measures.
- To study and analyze the existing water distribution network system of the city (i.e., the main town areas)
- To study and cross check whether the supplied quantity of water is adequate to meet the minimum requirements of the individuals.
- To make provision for future demands due to increase in population, increase in standard of living, storage and conveyance, etc. for the town.
- To design a water treatment plant that is economical and reliable.
- To produce distribution map of the study area.

1.3 SCOPE OF THE STUDY

This venture largely covers on the evaluation of existing water supply system and design of a new water treatment plant as a key activity carried out for which this project may have considerable boons to water supply developer in Phuntsholing Municipality. The city which comprises of two division of areas based on extend of settlement; settlements under core area and others under extended area. The core areas are those places vicinity to the centre of the town and extended areas includes the places like Cabreytar, Damdara, Kharbandi, Pasakha, etc. which are marginally away from main town (Shown in Fig.). However, the scope of this project is limited to those core areas, mainly because the core area requires timely evaluation and maintenance, for which the impact of any water crises in the main area is highly significant.

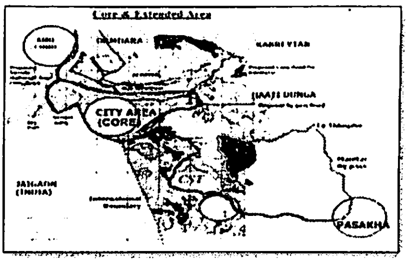


Fig.1 Map showing core and extended area under PCC

2. METHODOLOGY OF RESEARCH

The following series of work activities illustrates the flow of how the project was carried out.

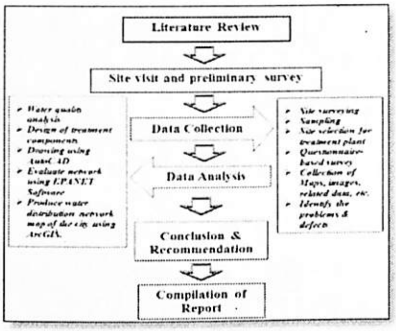


Fig.2 Methodology Chart

3. LITERATURE REVIEW

While designing the water supply scheme for a town or city, it is necessary to determine the total quantity of water required for various purposes in the city. [S. K. Garg, Text Book]

The amount and type of treatment process will depend on the quality of raw water and the standards of quality of raw water. [Sri P. Venkateswara Rao.]

Continuous monitoring and analyzing of distribution network is essential for better understanding of defects and operating difficulties. [Sarika M. Mankar]

4. GENERAL CONSIDERATIONS

4.1 WATER DEMAND

Provision of safe and adequate water is a basic necessity for the healthy living of a community. Therefore, demand of potable water in Phuentsholing City area has been calculated. Per Capita Water Supply per day is arrived normally including the following categories of consumption (in %) by different institute as represented below:

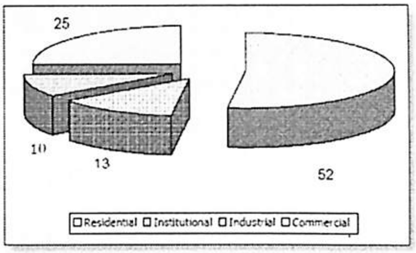


Fig. 3 Percentage of water consumption

4.2 DESIGN PERIOD

The design period should neither be too long nor too short. However, in our case the design period is taken as 30 years for the designing purposes.It cannot exceed the useful life of the component structures and is usually guided by the following considerations:

- Useful life of the component structures.
- Difficulty faced in expansions at future dates.
- Availability of additional investments.

4.3 POPULATION FORECAST

The population to be served during such period will have to be estimated with due regard to all the factors governing the future growth and development of the city.

The table below shows the estimated population of Phuntsholing city after 30 years, taking growth rate of 1.7% into account as per the population census records.

Table 1 Forecasted population using different methods

S.N	Methods	Population
1	Arithmetic increase method	45,511
2	Geometric increase method	51,354
3	Incremental increase method	49,292
4	Decreasing rate of growth method	33,791

Therefore, the forecasted population for the design period of 30 years is estimated to be 50,000.

5. EVALUATION OF WATER PROBLEM IN THE CITY

Unplanned or unprecedented growth of the city activities dwells population thereby some areas of the city experience water scarcity. However, primarily the following four reasons can be attributed to this water scarcity:

- Population increase and consequent increase in water demand.
- All nearby water sources have been tapped or being tapped.
- Increase in developmental activities.
- High water losses due to system defective.

5.1 INSTALLED & OPERATING CAPACITIES OF WATER SOURCES

Table 2: Installed and operating capacities of plants and pumping wells

Sl. No	Plant/well field	Installed capacity (m^3 per day)	Operating capacity (m^3 per day)
1	North Treatment Plant(NTP)	2000	1500-1800
2	South Treatment Plant(STP)	2000	1500-1800
3	Rinchending Treatment Plant(RTP)	250	250
4	CHPC/Revenue & Customs well field	4000	3150

5.2 POPULATION SERVED BY THE PRESENT SOURCES

Table 3 Populations served by STP and CHPC

Source	Population Served at present	Population to be served within 30years	Hours of supply
STP	7640	12248	3 hours
CHPC and R&C	20865	33791	3 hours

5.3 AUXILIARYSOURCECAPACITY REQUIRED

In order to check the availability of water, the current discharge capacity record of the sources and the required discharge with respect to the demand of population is compared so as to see whether the provided amount of discharge meets the required demand or not. The table below shows the required capacity of the source with respect to the demand:

Table 4 Provided and required discharges from surface and subsurface sources

SN	Sources	Provided (m^3/d)	Required (m^3/d)	Remark (addition)
1	Surface (STP)	1500-1800 =1650	2062.8	412.8 m^3/d
2	Sub-surface (CHPC and R&C)	3150	5633.55	2483.55 m^3/d
3	Total	4800	7696.35	2896.35 m^3/d

From the above table, it can be concluded that an additional source is required for the City. Therefore, a feasibility and treatability study is being conducted on basis of the quantity and quality of the potential surface new water source i.e. Amo Chhu which will ensure reliable source to the public supply principally for those residing in and around the Phuentsholing city.

6. WATER QUALITY ASSESSMENT

6.1 SELECTIONS OF TREATMENT UNITS

Three basic purposes for the analysis of water can be attributed to following importance.

- To produce water that is safe for human consumption.
- To produce water that is appealing to the consumer.
- To produce sufficient water - using facilities which can be constructed and operated at a reasonable cost.

Based on the quality of water, treatment approach is carried out by multi-barrier treatment involving the subsequent unit processes and treatment steps:

i. Reservoir and intake structure
ii. Sedimentation tank
iii. Sedimentation added with coagulation
iv. Filtration- rapid sand filter
v. Disinfection- chlorination treatment
vi. Distribution reservoir

6.2 WATER TREATMENT PLANT

For the proper treatment of water, it is necessary to have all the required treatment components. The main problem in the south treatment plant is high turbidity of water during the monsoon seasons. The present treatment plant does not have flocculation cum sedimentation unit which necessarily required in these places where the hydrology condition is very stiff particularly during summer.

6.3 SITE SELECTION FOR TREATMENT PLANT

The site for the treatment plant has been selected based on following criteria.

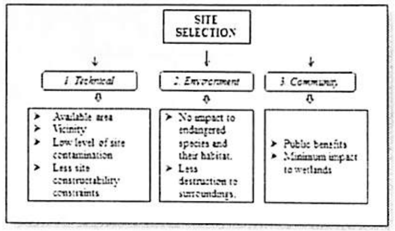


Fig. 4 Basis for the Site Selection

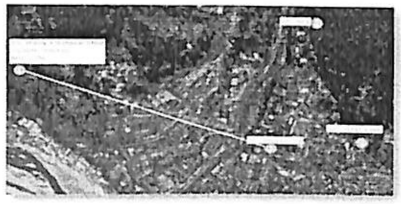


Fig. 5 Site Location at Damdara (1.45 KM from Main Town)

6.4 DESIGN OF TREATMENT PLANT

A. INFILTRATION GALLERY

Discharge = 0.1042 m^3/sec

Dimension of intake well

Length= width = 4m
Height = 6m

Coarse screen

Length=1.48m
Height=0.8m
Provide vertical iron bars of 20mmØ @ 30mm c/c

Bell mouth entry

Use 0.7m Ø bell mouth with perforations for fine screens.

Intake

Use a 300mm Ø steel conduit as conveyance pipe throughout intake well till treatment plant.

B. SEDIMENTATION TANK

Length= 30m
Width=10m
Height=5m

For long wall-20mm Ø @ 100mm c/c is being provided and for short wall, 12mm Ø @ 100mm c/c is provided. For the cantilever portion, provide 12mm Ø bar @ 150mmc/c.

C. COMBINED COAGULATION CUM SEDIMENTATION TANK

Design of settling tank

Length=45m
Width=12m
Height=4.5m
We have adopted a freeboard of 0.5m.

Design of floc chamber

Depth of tank=2.5m
Capacity of chamber=281.25m^3/sec
Plan area=112.5m^2

D. DESIGN OF RAPID SAND FILTER

Dimension=7mX4.5mX3m

Design of under drainage system

Diameter of laterals=4.1cm @ 15cm c/c with 5-1.3cm Ø perforations with 0.6m Ø manifold is being adopted.

Design of wash water trough

4 number of wash water troughs of size $40cm \times 20cm$ is used

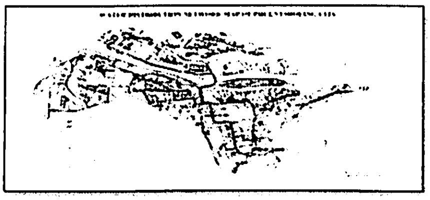
E. DISTRIBUTION RESERVOIR

Length= 20m
Width=10m
Height = 4.5m
For long wall-20mm Ø @ 100mm c/c is being provided and for short wall, 12mm Ø @ 100mm c/c is provided. For the cantilever portion, provide 12mm Ø bar @ 150mmc/c.

7. WATER DISTRIBUTION NETWORK SYSTEM

The existing layout of distribution system for Phuentsholing is dead end system or tree system and most of the existing water supply network was constructed in 1990's. The intermittent system of supply is adopted due to an inadequate amount of water available at the source. Therefore, most of the areas get water supply for about three hours a day. The intermittent system should not be continued as a long term policy, and be replaced by continuous system at the earliest possibility, due to the inherent limitation of the system.

Fig. 6 Water Distribution Network Map of Core Area, Phuentsholing



8. ANALYSIS IN EPANET

EPANET is a computer program that performs extended period simulation of hydraulic and water quality behavior within pressurized pipe networks. A network consists of pipes, nodes (pipe junctions), pumps, valves and storage tanks or reservoirs. EPANET tracks the flow of water in each pipe, the pressure at each node, the height of water in each tank, and the concentration of a chemical species throughout the network during a simulation period comprised of multiple time steps. In addition to chemical species, water age and source tracing can also be simulated.

EPANET is designed to be a research tool for improving our understanding of the movement and fate of drinking water constituents within distribution system.

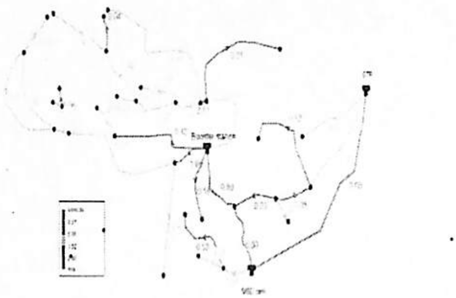


Fig.7Distribution network in EPANET showing velocity

After having drawn the water distribution network in EPANET software, the required data like diameter of pipes, elevation at junctions, length of pipes between nodes or junctions and demand required to serve population by the pipes at different zones are entered. The results obtained after running the program are as follows:

Table 5 Values obtained for node values

Node ID	Elevation (m)	Demand (LPS)	Head (m)	Pressure (m)
Junc 11	236	4.14	255.31	19.31
Junc 12	240	1.73	256.27	16.27
Junc 13	238	2.59	252.75	14.75
Junc 14	218	4.89	242.01	24.01
Junc 15	223	0.86	249.54	26.54
Junc 16	218	0.56	235.08	17.08
Junc 17	212	7.33	229.21	17.21
Junc 18	206	6.30	225.20	19.20
Junc 20	228	0.52	235.34	7.34
Junc 21	233	3.90	236.08	3.08
Junc 22	218	2.46	223.28	5.28
Junc 23	226	2.46	234.14	8.14
Junc 24	225	3.31	250.53	25.53
Junc 25	230	6.77	252.51	22.51
Junc 27	206	6.00	229.05	23.05
Junc 28	211	5.00	233.59	22.59
Junc 29	212	7.90	239.65	27.65
Junc 30	214	2.68	242.95	28.95
Junc 31	218	1.69	245.38	27.38
Junc 32	222	4.83	247.16	25.16
Junc 33	214	2.19	239.86	25.86
Junc 34	200	0.30	233.59	33.59
Junc 35	208	6.75	240.83	32.83
Junc 36	222	4.83	247.85	25.85
Junc 37	220	4.31	245.30	25.30
Junc 45	239	5.18	252.84	13.84
Junc 46	230	4.93	284.26	54.26
Junc 47	257	2.34	279.51	22.51
Junc 49	243	9.19	278.45	35.45
Junc 51	250	0.81	279.24	29.24
Junc 53	252	4.95	278.49	26.49
Junc 4	243	0.47	279.24	36.24
Tank 1	276	-22.69	286.00	10.00
Tank 2	243	-91.02	253.00	10.00
Tank 6	248	-8.46	258.00	10.00

The pressure at the joints should not be negative.

Table6 Values obtained for links (pipes)

Link ID	Length (m)	Dia (m)	Velocity (m/s)	Unit Head loss(m/km)	Friction Factor
Pipe 21	225.25	75	1.11	33.44	0.040
Pipe24	73.72	100	0.69	10.03	0.041
Pipe25	127.34	75	0.56	9.37	0.044
Pipe26	178.63	50	1.25	67.51	0.042
Pipe35	377.6	100	0.76	12.03	0.040
Pipe15	392	100	0.55	6.52	0.042
Pipe19	642.14	150	1.33	20.97	0.035
Pipe20	110.1	150	1.66	31.43	0.034
Pipe39	274.5	100	1.04	21.37	0.039
Pipe49	458.7	200	0.32	1.07	0.041
Pipe50	305	100	0.80	13.16	0.040
Pipe51	121.5	150	0.80	8.22	0.038
Pipe52	159.4	100	0.53	6.05	0.043
Pipe53	76	100	1.08	22.73	0.038
Pipe54	47.5	50	1.32	74.26	0.042
Pipe58	521.9	200	0.16	0.31	0.045
Pipe59	902.33	100	0.00	0.00	0.00
Pipe60	282.42	200	1.48	18.22	0.033
Pipe61	72.1	150	1.46	24.79	0.034
Pipe62	101.34	50	1.12	54.43	0.043
Pipe63	132.68	150	1.24	18.33	0.035
Pipe64	164.48	100	1.01	20.02	0.039
Pipe66	26.88	100	0.04	0.05	0.063
Pipe67	423.4	100	0.86	14.96	0.040
Pipe68	14	150	2.11	49.31	0.033
Pipe69	240.72	100	1.44	38.84	0.037
Pipe70	207.73	100	0.63	8.36	0.042
Pipe71	521.04	150	1.01	12.45	0.036
Pipe74	149.21	150	0.35	1.79	0.042
Pipe76	188.82	100	0.63	3.97	0.020
Pipe1	609.25	150	0.52	1.73	0.019
Pipe2	583.4	100	0.69	10.05	0.041
Pipe3	293.72	100	0.00	0.00	0.000
Pipe4	355	150	0.00	0.00	0.000
Pipe5	144	150	0.03	0.01	0.030
Pipe6	121.55	75	0.75	16.23	0.043

The velocity obtained from analysis in EPANET should be in the range of 0.6m/s to 1.5m/s. if the velocity is greater than 1.5m/s we can increase the size of the pipe to lower the velocity. And decrease the pipe size if velocity is lesser than 0.6m/s.

9. DISCUSSIONS & RECOMMENDATIONS

With the increase in population the water demand will also subsequently increase. It has been estimated that after 30 years the water demand will be 16.2 MLD. Therefore, following are some of the steps that could be taken in order to overcome the problems faced at present:

- Improvement of storage tank, i.e., reservoir capacities need to be increased.
- During rainy seasons turbidity of water is pretty high that interrupt the normal supply of water. Hence, there is a need for coagulation-cum-sedimentation tank in the treatment plant so that consumers get appealing water throughout the year.
- Chlorination system and installation of bulk meters at the plants & pumping stations.
- Additional conveyance / mains and replacement of pipes in various zones.
- Surface water intakes and design for gravity method of supply.
- Laboratory equipment for monitoring water quality.
- Requirement of additional booster station in order to help increasing the reservoir capacities.
- Using of new appurtenances and tools.

10. CONCLUSIONS

- Water supply from the sources has to be closed several times during the day in order to refill the reservoirs as the water demand in the present system is larger than what can be supplied from treatment units.
- The inability of the current system to meet the present overall water demand of Phuentsholing city.
- Most of the service area is under intermittent water supply and it causes several health related and technical concerns. It is noticed that as long as intermittent water supply is used, it is impossible to evaluate system losses reliably.
- The unaccounted for water in the present system is very high.
- Intermittent water supply has forced consumers use underground tanks and in-house tanks. These tanks, even though they are not in the responsibility of PCC, create serious health related risks. Tanks are also problematic from the hydraulic point of view, as when water is being supplied, all the tanks within the service area are filled at the same time. Thus the momentary water demand is very large and current booster pumps don't have enough capacity to fulfill this high "demand". The combination of intermittent water supply and use of underground tanks is particularly problematic when supplying water by pumping, as the pump head decreases rapidly as flow increases. As a consequence, the operation mode of the system is very complicated.
- Lack of network monitoring systems.
- Low network pressure particularly in few zones.
- People in the city face have been facing serious water crisis almost over the year during summers. With the increase in population every year, the crisis would worsen.

Therefore, following are some of the measures to solve the above associated problems:

- Due to the raw water shortage, the whole city of Phuentsholing is currently under intermittent water supply and all the house connections are equipped with underground or in-house tanks. It is recommended that as soon as the well field and transmission capacity increased, intermittent water supply is to be changed into continuous water supply of 24 hours per day. The transition phase from intermittent to continuous must be planned and implemented very thoroughly.
- The reliability and accuracy of metering is essential as network operation actions based mainly on metered information. An improvement program for metering and for water quality control is required. Continuous monitoringof the system flows within the pressure zones is the most reliable way to detect system losses. All the discharge pipes from the reservoirs and booster station has to be equipped with a new flow meter and flows have to be recorded and analyzed on a regular basis.
  - Master meters for metering flows in all outlets are needed to help avoid lack of network monitoring system.

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