IMPACT OF STAGING HEIGHT OF SERVICE RESERVOIR ON THE INSTALLATION COST OF WATER SUPPLY SCHEME - A CASE STUDY

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ABSTRACT

The total cost of water supply scheme includes cost of source, pumping main, service reservoir and distribution network system. Conventionally, optimization of pumping and distribution system is done separately sans considering variation of the staging height of service reservoir. An attempt has been made, as an integrated approach, to optimise the total cost of the scheme taking into account of the various staging height of service reservoir. Planning and design of water supply scheme to Kamayakoundanpatty, a town panchayat, in Theni district, has been done with the above concept as a case study. Cost of service reservoir increases with height due to lifting charge and cantering. Cost of distribution network remains almost unchanged after certain height of service reservoir. Economical choice of pumping main component increases with the staging height of service reservoir in lieu of increasing duty of pump set and electrical energy consumption with the same. The staging height is found to affect the optimum cost of pumping system and the distribution system. It is found that 12 metres staging height gives the least cost option for the project studied.

KEY WORDS: Cost of water supply scheme, integrated approach, staging height of SR, ECP, Loop Ver.4

INTRODUCTION

Provision of safe and protected water supply ensures public health as a preventive measure. Great importance is paid to install protected water supply systems to public, by mostly governments, in developing countries. Huge investments are allocated every year for the drinking water sector. Holistic method of planning and design may yield cost effective schemes. A typical layout of water
supply system, from the source to the distribution system, is shown in figure 1 for a groundwater based–pumping scheme. More than 80% of rural water scheme in India are groundwater dependent. Generally, a water supply scheme accommodates a source, transmission main, may be pumping or gravity, treatment plant if warranted, service reservoir (storage) and distribution network with house service connections and public fountains.

![Figure 1. Schematic diagram of a typical Water Supply Scheme with a bore well as source](image)

The cost of any water supply system (WSS) generally includes the cost of source, pumping system, conveying system. Water Treatment Plant (WTP) (if necessary), service reservoir and distribution system. The source accounts for nearly 10% to 15% of scheme while the conveying main coupled with pumping system shares the cost of fairly 30% to 35%. The rest 60% to 65% of cost of the water supply scheme is shared by the service reservoir and distribution system. In practice, economical size selection of pumping main (including pumping plant), which compromises between the pumping unit cost and cost of pipe, is done. The optimization of distribution system is performed for cost effectiveness.

The impact of variation of staging height of service reservoir is seldom taken into consideration in the process of optimization of pumping main (conveying main) and distribution system. Instead, a fixed height is considered. Increasing the staging height may increase the cost of pumping main by warranting high head of pump and a higher size of pipe and decrease the cost of distribution system permitting to go for lower pipe size. The vice versa is also possible. Hence, an integrated approach was made by taking into consideration of various staging height of service reservoir on the cost of a water supply system.

In order to optimize the pumping main, various application software, like LPP88, ECP are commonly used. LPP88 is based on the principle of linear programming and ECP is a tailor made software developed following the guidelines contained in the CPHEEO (1999) manual being used in Tamil Nadu Water Supply and Drainage Board, India. Economical pipe size had also been chosen using maximum and minimum technique (Mariappan, 1994). Pannirselvam (2004) has reported
that transporting certain quantity of water by pumping through several sizes of pipes within the velocity ranges of 0.6 to 1.5 m/s are suitable. The smaller diameter of pipes increases the velocity and high frictional losses. When the diameter of pipe is larger, the cost of pump and annual cost of pipes can be reduced. The diameter of the pipeline, which provides such optimum condition, is known as the economic diameter of the pumping main. Further, an optimum velocity range in the water conveying system for selecting the size of pipe has been reported as 0.8 to 1.2 m/s (Raja Jayachandra Bose, Neelakantan and Mariappan, 2013).

Numerous research works have been done on the optimization of distribution system with fixed staging height (Quindry et al., 1984; Bhave, 1983; Chiplunkar et al, 1986; Waiski, 1987; Perez et al., 1993; Brian, 1994; Gupta and Bhave, 1994; Walski, 1995; and Savic and Walters, 1997) and none of them studied the impact of staging height on the total cost.

DESCRIPTION OF STUDY AREA

Kamaya Koundan Patty is a special panchayat located in Theni district of Tamil Nadu situated at 3.5km west of Kambam town. It covers an area of 13 square kilometre. As per the 2001 census, population is 9220. Population growth increases to a minimum extend of 10% growth for 15 years and 20% growth for 30 years. The entire town of Kamayakoundanpatty has been divided into 3 zones for design convenience. The design and analysis of water supply distribution network has been performed for each zone separately. It requires a potable and protected water supply scheme. The source for the Kamayakoundanpatty water supply scheme is river Mullai Periyar. Since the Kamayakoundanpatty town panchayat is located at the foothills of Western Ghats, a remote area, the chance for polluting the source is very less.

METHODOLOGY

In order to assess the contours of KamayaKoundanpatty, topographical survey was done and other details: population, length from source to SR and street length were also collected. Population forecast was done adopting the methods: Arithmetic increase method, Incremental increase method, Geometric increase method, Graphical method and Method of density. Demand estimation, street wise requirement, is determined according to the norms of Central Public Health and Environmental Engineering Organisation (CPHEEO), 1999, and Tamil Nadu Water Supply and Drainage Board (TWAD Board), Government of Tamil Nadu. Standard schedule of rates of Public Works Department (PWD) and TWAD Board were used for cost estimates. Economical size of pumping main was determined by using ECP (Economic cost of pumping main) software for the staging height of Service Reservoir (SR) from 10 m to 20 m. The cost of SRs for the various staging height was also reckoned. The optimization of distribution system considering the effect of staging of service reservoir was performed using the application software, LOOP 4 Loop version 4.0 is entirely a new version of the earlier program LOOP version 3.0, developed and distributed under the joint efforts of UNDP/WORLD BANK. LOOP program can be used for the design and simulation of new, partially or fully existing, gravity as well as pumped water distribution system. It is capable of designing networks upto 1000 pipes and 750 nodes.

The economical total installation cost is given by

$$\text{Optimum total cost (TC)} = C_{ECP} + C_{SR} + C_{\text{dist}} \quad \text{(1)}$$

Where $TC$ - Optimum total cost, $C_{ECP}$ - Economical cost of pumping main, $C_{SR}$ - cost of service reservoir, and $C_{\text{dist}}$ - optimum cost of distribution system.
RESULTS AND DISCUSSION

The results of topographical survey, population forecast and cost details of pumping main, service reservoir and distribution system are presented below.

Topography

Ground level (GL) in the distribution area of study area varies from a maximum of 395.86 m to a minimum of 382.95 m above MSL. The contour map is shown in figure 2. It infers that town is undulating with a .13 m difference in GL.

![Contour map of Kamaya Koundan Patty](image)

Figure 2. Contour of distribution system in Kamaya Koundanpatty

Design Population

The population projection made from decadal population of 1961. 1971, 1981,1991, and 2001 to the year 2031 by various methods is depicted in figure 3. Considering the scope of expansion and growth rate, the design population obtained by the method of population growth rate was taken, i.e., 12500.
Economical size of pumping main with staging height of SR

The staging height of SR decides the static head in a system. The duty of pumpset, in turn, increases with the staging height. The results of economical cost analysis for the staging height 10 metre to 20 metre of SR are plotted for easy visualisation (Figure 4). It is observed from the figure 4 that the economical cost of pumping main increases with the staging height due to increasing duty of pumpset and corresponding the electrical energy cost. The following relationship governs the relationship between staging height and economical cost of pumping main.

\[ C_{ECP} = -915.6x^2 + 12362x + 6E+06 \] \[ \text{correlation coefficient } R^2 = 0.969 \]

Where \( x \) – staging height of SR in metre.
Cost of SR with staging height

The cost variation of Service Reservoir with the staging height from 10 metre to 20 metre is shown in figure 5. The cost of SR varies exponentially with staging height due to centering and lift charges.

\[ C_{SR} = 4.723e^{0.068x} \]  
---(3)

Figure 5. Cost of SR with the Staging height

Correlation coefficient, \( R^2 = 0.981 \)

Cost of Distribution system with staging height of SR

The results of optimal design of distribution system for the staging height of 10 to 20 m of SR are depicted in figure 6. The correlation coefficient for relationship between the optimum cost of distribution system and staging height of SR is nearly 1. It shows very good relationship.

\[ C_{dist} = -0.004x^5 + 0.337x^4 - 10.51x^3 + 162.2x^2 - 1239x + 3748 \]  
---(4)

Correlation coefficient, \( R^2 = 0.977 \)

Where x is the staging height of SR
Figure 5. Optimum Cost of Distribution system with staging height of SR

It is noticed from the figure five that a staging height beyond certain value does not influence the optimum size of distribution system. It may be due to the reason that a minimum pipe size, 100 mm, has been stipulated in the CPHEEO manual for the distribution system. Hence, static head available shall be used to go for lower pipe size. But the staging height 10 and 11, with the pressure head, warrant higher pipe size to ensure minimum residual pressure, 7 metre for singly storey building area and 12 metre for double storey house are, in the distribution system. The frictional loss which can be permitted is the main concern in the cases of lower staging height.

Total Cost

The optimum cost of pumping main, distribution system and cost of SR for the various staging height of SR are presented in table 1 and figure 6. Figure 7 gives the summary of the cost of the components with the grand total.
Table 1. Cost of various components with staging height of SR

<table>
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<tr>
<th>SL No</th>
<th>Staging Height in metre</th>
<th>Service Reservoir cost in Rs</th>
<th>Optimum cost of distribution system in Rs</th>
<th>Optimum cost of pumping main in Rs</th>
<th>Total cost in Rs</th>
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The table 1 infers that an integrated approach is necessary to arrive at the lowest cost of a water supply scheme with pumping system. Staging height is the main cost controlling factor. The method of analysing the optimum cost of pumping main and distribution system separately without taking into consideration of staging height may not yield true least cost option. The total Cost for 12 m staging height of SR is found to be the least for the Kamayagoundanpatty water supply scheme. The relationship between the staging height of SR and the total cost is shown in the equation 5.

\[ TC = 0.016x^4 - 1.087x^3 + 26.28x^2 - 276.8x + 1151 \]

Correlation coefficient, \( R^2 = 0.991 \)
CONCLUSION

The present study suggests an integrated approach to get the least cost system. The staging height of SR is an important factor which has influence the cost of pumping unit, size of pumping main and distribution network. An integrated approach helps to optimise the overall scheme installation cost. A compromising staging height, which results in economical pumping cost and least cost distribution network, may be decided. In the case of Kamayagoundanpatty water supply scheme, the least cost occurs at the staging height of 12 metre. Depending upon the topography and scheme capacity, the optimum staging height may vary. The present study suggests the planners, design and field to follow the above concept for economical system.

REFERENCES