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Design of Water Distribution System In WATERGEMS For KharwalVillage

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Abstract - *In tribal village of Kharwal, water scarcity has been one of the major issues for several decades. Villagers travel long distances just to obtain few litres of water from the well. The objective of our study was to understand the water scarcity problems of villagers and how we can eradicate their day-to-day complexities of travelling long miles to obtain water. For this purpose, different methods and processes were used. Forecasting water demand which will meet daily requirements of villagers is a very first aspect we started with. Then, by understanding the topography of village helped us in planning an efficient water distribution system for the village in WATERGEMS. Consequently, pump selection was done which remains crucial as it would help deliver water from source using distribution network to the overhead tank in the village. Cost estimation of the plan was also done. This paper presents the glimpses of our experience and gives analysis of different sectors.*

Key Words: Water Distribution System, WATERGEMS, Pump Selection, Cost Estimation.

1. INTRODUCTION

Kharwal is a Village in Trimbak Taluka in Nashik District of Maharashtra State, India. It is situated in the Northern Maharashtra region & belongs to Nashik Division. It is located 45 KM towards west from District headquarters Nashik. 7 KM from Trimbak. 153 KM from State capital Mumbai. Kharwal consists of 6 hamlets, Fanaspada being the largest in area. Gavatha, Harsul, Nandgaon, Thanapada, Dalpatpur are the nearby Villages to Kharwal. Kharwal is surrounded by Peth Taluka towards North, Mokhada Taluka towards South, Jawhar Taluka towards west, Kaprada Taluka towards North. The village is situated on the hill and has valley on the both sides. It has a population of around 1245 according to Population Census 2011[2] and area of 4.42 sq.km. The region receives annual rainfall of about 2585 mm during monsoon season (June – September), but faces severe water scarcity in the months of April and May. Table 1.1 shows the co-ordinates of the Kharwal.

Table -1.1 : Co-ordinates of Village

Habitation	Latitude	Longitude
Kharwal	19.0705N	73.4505E

Fig -1.1: Kharwal Village Map

1.1 POPULATION AND LITERACY RATE

People of Kharwal Village mainly speak Marathi with konkni dialect. Kharwal Village has a total population of 1245 and number of houses are 160 [2]. Female Population is 48.6% of the total population. Village literacy rate is 51.1% and the Female Literacy rate is 21.1%.

Table -1.2: Population & Literacy rate [Census 2011 Data]

Census Parameter	**Census Data**
Total Population	1245
Total No of Houses	160
Female Population %	48.6 % (605)
Working Population %	57.3 %

1.2 WATER SOURCES

The major sources of water in the village are water supply through wells. Kharwal does not have a perennial surface water source in terms of lakes or rivers. It however is transgressed by a network of streams. The major water resource for Kharwal is ground water. Water for agriculture in Kharwal is majorly obtained through rainfall. The water needs and availability in a region dictate the cropping pattern followed by the cultivators in the region. In summers water is very scarce thus people mostly prefer to fetch water from well.

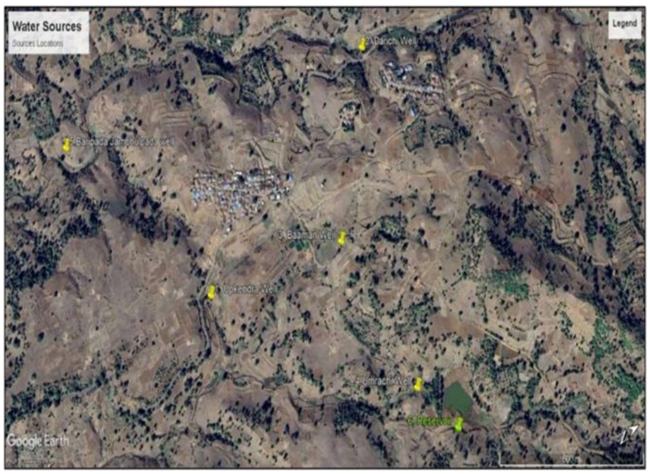

Fig -1.2: Water Sources in Kharwal

2. LITERATURE REVIEW

Vidya et al. [5] studied how a structured form survey was conducted in the Chondwade Bk tribal village, Dhadgaon Tehsil, Nandurbar district, Maharashtra. Their main aim was to study and understand the village ecosystem and the daily problems they faced. PRA Technique was used to collect Data by Household survey, Water Resources Survey, Health Survey, Livelihood Survey etc. They had closely interacted with the villagers and concern officials of Gram Panchayat and the Govt. Authorities like Gramsevak, Talathi, and Agriculture Officers to have comprehensive understand of village. Having various difficulties in village they tried to implement solutions like solar household lighting system, CSR proposal for malnutrition program & many more.

Hemant et al. [6] Investigated the single village drinking water scheme and understand the reasons for its failure from technical and social perspectives. The village receives annual rainfall of about 3500mm during monsoon season but faces severe drinking water scarcity during the summer season. Their source of water supply is a well situated 2kms south of target region which comprises of 637 people (536 of Talwadi and 101 of Morewadi). The geology and geography of the region is such that the groundwater there was not abundant despite of receiving high rainfall during the monsoon season because of the typical nature of the Deccan traps. The paper explained the faults in the ongoing piped water schemes such as the people were not willing to pay regular tariff. The paper also listed the technical issues such as the GSR (Ground service reservoir) which was supposed to distribute water by gravity to Talwadi and Morewadi but failed because it was slightly lower in elevation than the Morewadi's stand post. Irregular electric supply and irregularity of the operator were also some of the reasons responsible for failure of the implemented schemes.

Amit Kumar et al. [7] The paper we have referred to tells us about different problems faced by people of Juwi village situated in Gadchiroli District which is located in state of Maharashtra. Parched lands, seasonal availability of water, agricultural issues, educational problems. The issue which mainly pertains to our project is water scarcity problems. In, Juwi village it was solved by using GSDA's Dual Pump Scheme, the scheme is designed for existing well only. The package consists of overhead reservoir, steel frame, D.C submersible motor, Solar panel with frame, water supply pipes and taps. The disadvantages of this scheme are during rainy and winter season, sunlight is low and panel is cold then system efficiency decreases.

Pravinkumar et al. [8] Studied the hydraulic analysis of Shivaji Nagar of Panvel City. The steady state analysis has been carried out for calculation of hydraulic parameter such as head pressure and discharge flow. In their project WaterGEMS software is used for obtaining optimal design of water supply network they calculated different alternative optimal design solution considering pipe diameter and pipe material.

3. METHODOLOGY

This section discusses the various methods and tools we adopted for the collection of primary and secondary data for the village. This is important to understand about the behavior and mindsets of people.

The Village Report methodology includes,

I. Primary data collection.

II. Secondary data collection.

III. Other field work activities.

Each of these methods is described below: -

3.1 PRIMARY DATA COLLECTION

We adopted standard practices of understanding the basicgeography of the region, conducting village surveys & transect walk. During the process we understood how to extract information from people. Sometimes it is difficult to get out information, in such case we need to extract information through indirect means like through informal talks, activities, each of which is discussed in the followingsub-section.

Methods of collecting primary data -

- Basic Geography of the Region
- Village Survey
- Transect Walk

Each of these methods is described below: -

3.1.1 Basic Geography of the Region

The map of Kharwal Gram Panchayat area was studied to get more information about the land use pattern and vegetation cover near the village. Kharwal village consists of 12 small hamlets which are located on a top of a hill surrounded by forest; hence the agricultural land is very less when compared to the forest cover. Apart from this a satellite map had been used as a reference. The map helped to understand the topography of village and helped us to understand the land use pattern and vegetation cover of the village. Base map gives a picture of different land usages like forest, agricultural land, water bodies and roads.

3.1.2 Transect Walk

We with other local people helped in observation of things around and walk with consistent steps and make note of various things like slope, type of soil and trees, hills, habitations, infrastructure. Though walk in and around the village we have gather important document and observations, documented the living and non-living things that surround. Transect walk is such a tool which helps us understand above said aspects.

Transect walk is focused to cover all types of resources of the village. We started from top of the hill which is towards the south of the village. The village is located on a small valley where houses are on both the sides of the valley at upper elevations. It was about 50 m height and all the village spread round the top of valley. Around 500 m walk down the slope we got to the village community well which was the only source for drinking water for village apart from the small stream flowing by which is seasonal and feeds the well itself. This activity had given us a glance of whole village and helped us to know how much variations are there in the village in all aspects like social, economic, physical, etc.

3.2 Secondary Data Collection

To understand the administrational setup, it is very necessary to look at the secondary data related to the village. Table 3.1 describes the list of secondary data collected during the visit.

Table -3.1: Secondary Data Collection

Source of Secondary Data	Outcome
Gram Sevak's Office water	Detailed data of total population, no of households, no of bodies, Wells, Agricultural produce, etc.
Talathi Office	Detail Partition of Agricultural/ Nonagricultural lands Detail Partition of Land utilizationDetail Partition of Forest land Resource map

4. CONCEPT DESIGN

4.1 Domestic need of water per day in Kharwal

Daily water demands for per person per day is taken 20 litres per person per day, which includes water for drinking and cooking. The system is designed considering the 40 years of the service. Population estimation for next 40 years is done considering the decadal growth rate of 8.4% for rural India.

Table -4.1: Present and Forecasted Population

Year	Population
2020	1245
2060	1650

Table -4.2: Total water requirement per day

Per Capita WaterNeed (liter)	Total Population	Daily Water Req.for Village
A	B	A*B
20	1,650	29,330 liters

4.2 Storage system

Ground Service Reservoir (GSR): GSR is ground level or plinth level storage tank. The plinth level is generally not more than 3 m. Storage capacity of the service reservoirs is estimated based on pumping hours, demand and hours of supply, electricity available for pumping. Systems with higher pumping hours require less storage capacity.

Considering The water need of village for 40 years Tank ofcapacity of 30,000 liter is selected.

4.3 Proposed Well Location

After surveying the village water source which can cater the need of village for over 40 years, all existing sources were found inadequate. New potential aquifer source was found using ERT (Electrical Resistivity Test method. The Well 12m deep and 7m wide was proposed in surveyed area. Which is located in a valley South of the village.

4.4 Pump Calculation

A pump is a device which converts mechanical energy into hydraulic energy. It lifts water from a lower to a higher level and delivers it at high pressure. Proposed schematic diagram of water pumping for Kharwal village is shown in the chart 1. Pump Capacity calculation is essential for selection of pump and Energy requirement. All the required input parameters for pump selection are listed in Table 4.3

Table -4.3: Pump Calculations

Parameter		**Parameter**	
Well depth	12 m	Pipe Inner Dia (D)	50 mm
Well Surface Ground level	0 m	Total Pipe Length (L)	678 m
Village mean elevation	38 m	Pipe Material	HDPE
Water Storage tank base	1.5 m	Pipe Roughness coefficient (C)	140
Water Storage tank Height	4 m	Discharge (Q)	0.0025 m^3/sec
Net Static head (H_S)	55.5 m	Density of water (ρ)	1000 kg/m^3

Hf = 0.04339 m

Hf = **0.04339 m** @ 150 LPM

Total dynamic Head (HT) -Total dynamic head is total sum of suction head, delivery head and friction head.

HT = Hf + hf + HS

HT = 0.04339 + 9.173 + 55.5HT = 64.7163 m

HT ≈ **80 m**

(Considering unaccounted losses due to temperature change, scale formation inside pipe, working condition)

Hydraulic Power **-** Hydraulic power is the amount of work done to lift the water to a certain height and discharge. Hydraulic power is calculated using equation

Ph = (ρ x Q x HT x 9.81)/1000

Ph = (1000 x 0.0025 x 80 x 9.81)/1000Ph = 1962 W

Ph = 1.962 KW

Assuming 60% efficiency,

Total Hydraulic Power needed = (1.962)/0.6

= 3.27 KW

Hydraulic Power in HP = 3.27 * 1.34102(1KW = 1.34102 HP)

Static Head (HS) - Static head is the total vertical distancethat a pump has to raises water.

HS = 12 +38 + 1.5 + 4HS = **55.5 m**

Friction Head (Hf) - In fluid flow it is the head loss that occurs in a containment such as a pipe or duct due to the effect of the fluid's viscosity near the surface of the containment. Friction head is calculated by the Hazen–William's equation (1)

Hf = 10.67/D^4.8704 〖.(Q/C)〗^1.852* L

Hf = 10.67/60^4.8704 〖.(0.0025/140)〗^1.852* 678 Hf = 9.173 m

Hf = **9.173 m** @ 150 LPM

Loses in Fittings (hf) – Pipe fittings, valves and bends have some associated K factor or local loss coefficient. Manufacturers of pipe work fittings and valves publish a fitting's associated 'K' factor. For 900 bend K is 0.54.

Hf = (K*V^2) / 2g

Hf = (0.54*0.78841) / 9.81 (K = 0.54 for 900 bend)

= 4.385 HP

≈ **5 HP**

Therefore, 5 HP pump deliver 150 LPM at 80m head.

4.5 Selection of Pump

From Kirloskar's catalogue,

KS4G-5017 was selected which was 100mm/4" Borewell Submersible Pump

The selected pump is 220V Single Phase

Table -4.4: Pump Performance Chart

	Discharge	Head
LPM	m3/s	(m)
0	0	115
60	0.001000002	110
90	0.001500003	101
120	0.002000004	90
150	0.002500005	77
170	0.002833339	65
180	0.003000006	62
240	0.004000008	29

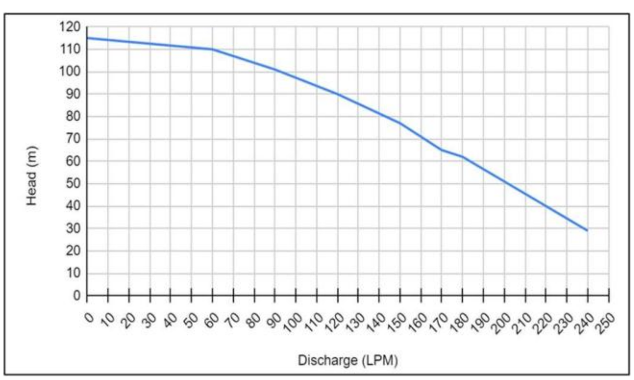

Chart- 1: Pump Curves

4.6 Selection of Pipe

Factors considered while selection of pipe: -

1. Type of Fluid
2. Flow Rate
3. Pipe Size
4. Pressure loss due to frictional drag
5. Surface roughness of pipe interior (K)
6. Length of flow path

Economical pipe size selection

From a purely economic standpoint involving pressurized flow, the optimum pipe size diameter is the factor that minimizes the life cycle cost of a piping system. The installation cost and the recurring costs associated with operation and maintenance are the components which were examined using the concept of time-value of money inthis study.

Table -4.5: Head & Discharge of Various Pipe Diameter

Discharge		**Head**			
	Pump Curve	**40mm**	**50mm**	**60mm**	**75mm**
0	115	55.5	55.5	55.5	55.5
60	110	67.545	59.599	57.199	56.078
90	101	81.023	64.186	59.100	56.725
120	90	98.983	70.299	61.634	57.587
150	77	121.23	77.873	64.774	58.656
180	62	147.63	86.859	68.499	59.924
210	45.5	178.08	97.221	72.794	61.386
240	29	212.47	108.92	77.646	63.037

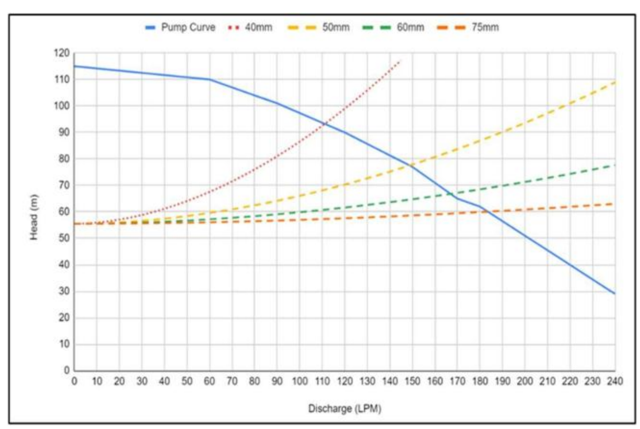

Chart-2: Head & Discharge Curves

Table -4.6: Pipe Costing

HDPE Pipe					
Pipe Dia (mm)	kWh per day	Rs/Year	Running Cost for 10 Years	Total Fixed Cost	Total Cost
40	55.446	20237	202378	38900	241278
50	35.614	12999	129993	61528	191521
60	29.623	10812	108127	96106	204233
75	26.887	9791	97915	133996	231911

PVC Pipe					
Pipe Dia (mm)	kWh per day	s/Year	Running Cost for 10 Years	Total Fixed Cost	Total Cost
40	51.897	18940	189405	72884	262289
50	34.421	12563	125639	80324	205963
60	29.144	10637	106377	115936	222313
75	26.679	9738	97380	160906	258286

GI Pipe					
Pipe Dia (mm)	kWh per day	Rs/Year	Running Cost for 10 Years	Total Fixed Cost	Total Cost
40	65.444	23887	238873	442951	472951
50	39.034	14247	142475	431981	461981
60	31.056	11335	113356	491680	521680
75	27.330	9975	99755	577067	607067

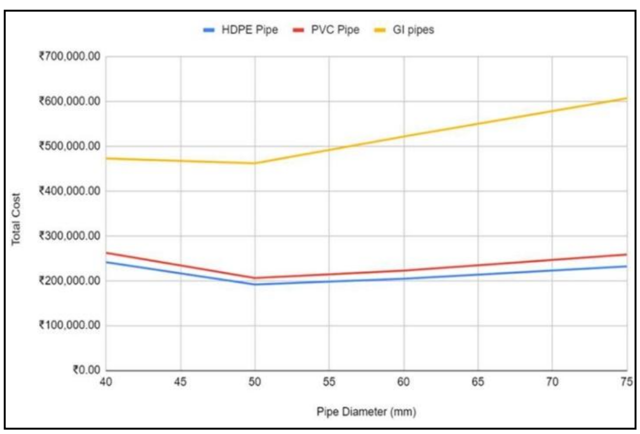

Chart -3: Cost Comparison Chart

From this study, HDPE pipe of 50mm diameter was found to be best suited for the application with most economical pipe size and material.

5. DETAILED DESIGN

5.1 System Modelling

The purpose of distribution system is to deliver water to consumer with appropriate quality, quantity and pressure. Distribution system is used to describe collectively the facilities used to supply water from its source to the point of usage. All the design & modelling is done in WaterGEMSSoftware.

Fig -5.1: Proposed Pipeline Layout

Table -5.1: Water Demand

Type of supply	Intermittent
Supply hours	2
Max demand on each tap	15 LPM
Each node on each node	30 LPM
Total node	4
Total demand	120 LPM
Total water consumption for 2 hrs	14400 Litres

Table -5.2: Branch Network Length

Type	Dia	Length	Material	Flow (L/min)	Number of Stand Post	Color Code
Main Line	50mm	674m	HDPE	181	0	
Branch 1	50mm	86m	PVC	18	1	
Branch 2	50mm	65m	PVC	36	1	
Branch 3	50mm	64m	PVC	54	1	
Branch 4	50mm	266m	PVC	72	1	

5.2 Tools & Software used

WaterGEMS software: The ever-increasing demand of Continuous water with increase in population can be fulfilled by designing efficient water distribution networks based on advance computing systems include modern hydraulic modeling. In present study water distribution network of Kharwal village, Nasik, Maharashtra, India. For the design of water distribution network, study of present population, daily water demand, flow characteristics and also survey of the village is done with help of digital GPS. Water distribution network for the villages is analyzed and designed with help of Bentleys WATERGEMS software. The schematic layout is shown in fig 5.2. This software helped in designing Water distribution network systems to deliver water from a source in the adequate quantity, quality and at satisfactory pressure to all individual consumers.

Water distribution network is designed with an objective of minimizing the overall cost while meeting the water demand requirements at adequate pressures. The system is a pipeline network consisting of one source node and several demand nodes is considered to find its optimal geometrical layout which delivers to required demands from source to destination. The software uses hydraulic model results which help in optimizing the design of complex water distribution systems and utilize built-in scenario management features to keep track of design alternatives. Water demand peak factor is taken 3 as per GOI guidelines [14]. Considering this, the demand at each node is taken as 30 Litres/min. Also, for each Junction (node) elevation value was assigned as shown in table 5.2 according to the village topography.

Water Distribution system modelling in WaterGEMS software-

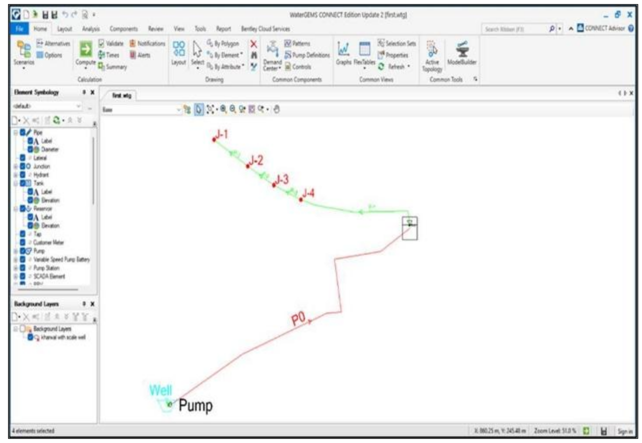

Fig -5.2: Pipeline network diagram in WaterGEMS software

5.3 Simulation Results

For each Junction the value of hydraulic Grade (Hydraulic Head) is calculated. Simulation Results are shown in the table 5.3. The data is arranged in ascending of Hydraulic grade. Such as Junction 1 has the least hydraulic grade of 4.77 m and Junction 4 has maximum grade of 6.14 m at30 L/min demand.

Table -5.3: Pipeline Junction

Label	Demand (L/min)	Hydraulic Grade (m)	Pressure (kPa)
Junction 1	30	4.77	47
Junction 2	30	4.92	48
Junction 3	30	5.31	52
Junction 4	30	6.14	60

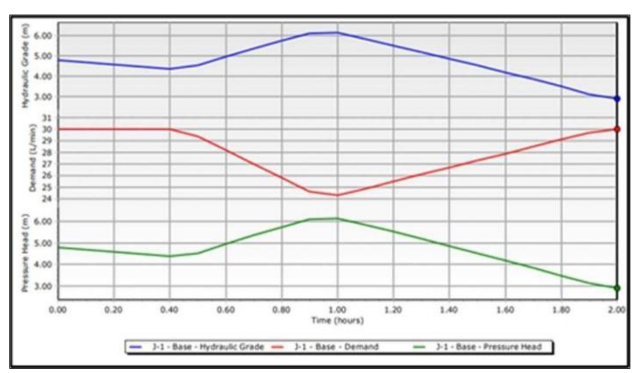

Chart 4 : Water Quality at Junction

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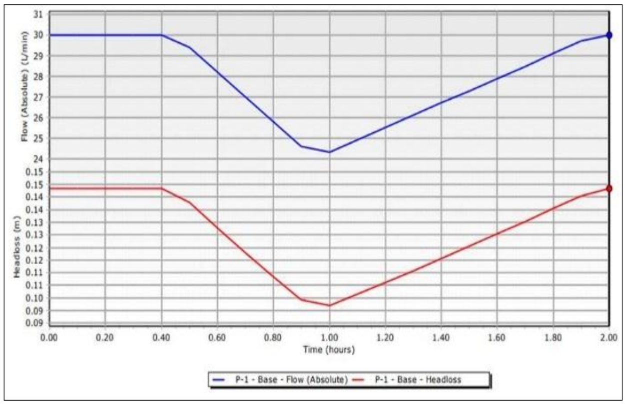

Chart- 5: Water flow and Losses

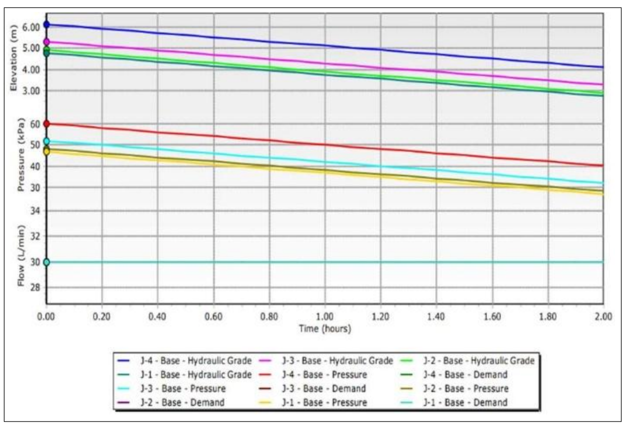

Chart- 6: Pipeline network diagram in WaterGEMS software

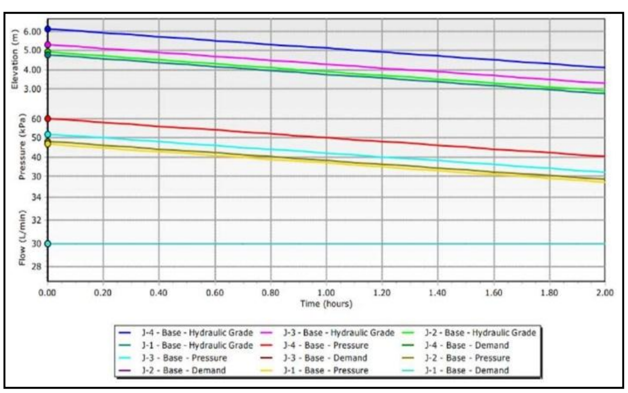

Chart- 7: Time taken to fill the tank at flow rate of 150 LPM

5.4 Cost Estimation

The purpose of cost estimation was to predict the Capital & Resources required to check the financial feasibility of project. For cost estimation we approached local contractors who have been working in the area for past few years & got the following data as shown in table 5.4.

Table -5.4: Cost Estimation

Sr No	Description of Item	Rate	Quantity	Amount in INR
1	Drilling & Construction of Well	-	1	5,52,000
2	Construction of Tank	-	1	4,80,000
3	HDPE pipe (50 mm)	70 □/m	800 m	56,000
4	PVC pipe (50 mm)	76 □/m	500 m	38,000
5	Cost of Pump	30,000	1	30,000
6	Cost of Electrical Connections	-	1	2,000

6.CONCLUSION

From several group discussions carried out with villagers of Kharwal we were able to understand water scenario of village in summer season and how it has affected the lives of the people. We carried out various surveys to understand the topography and potential aquifers which would help to fulfill the water needs of people. After finding potential water source, water distribution system was designed and cost estimation of entire project was calculated. With the effective use of water from structures like network of Wells and ponds, will improve the overall water availability of village. This will facilitate percolation and recharge the ground water table and hence contribute to the overall development of village.

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