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Hydraulic Design of Water Treatment Facilities: An Inode Approach

Dr. Shrikant B. Randhavane[1], Charudatta Thosar[2], Deepak Baghel[3], Dr. Basweshwar Jirwankar[4], Darshankumar Patel[5], Dr. Pramod K. Kolase[6]
[1]Head, Department of Civil Engineering, SVKM's Institute of Technology, Maharashtra, India.
[2,3,4]Assistant Professor, Department of Civil Engineering, SVKM's Institute of Technology, Maharashtra, India
[5,6]Head, Department of Civil Engineering, Pravara Rural Engineering College, Loni, Maharashtra, India

Abstract:
Water is regarded as the primary prerequisite for the development of both humankind and industry. The need for freshwater has grown over the past few decades as a result of population growth and urbanization. Fresh water sources are being taxed by the rising demand, which is ongoing. The pollution that people and industry have released into the environment has lowered the quality of the water, which has an effect on both human and marine life. According to the World Health Organization (WHO), Central Pollution Control Board (CPCB), Bureau of Indian Standards (BIS), and Indian Council of Medical Research (ICMR), over 70% of river water has inadequate water quality. India's rivers are contaminated, and some of the water cannot be consumed. Access to clean, usable water should be simple and quick. Hence, one of India's fastest-moving initiatives is the Jal Jivan Mission. It intends to connect all Indian houses to the public water system. Works overarching goal is to benefit the community by offering the village of Kusumba a hydraulic design for a WTP that will allow all residents to efficiently utilise the water while also meeting the needs of expanding industry in the future. The paper focuses on the hydraulic design of proposed water treatment plant and parameters assessment of the existing treatment facility available in village Kusumba, Tal Dhule, Maharashtra, India. This study can serve to be basic for optimum design of water treatment facilities throughout the globe.
Keywords- WHO, WaterGEMS, CPHEEO, INODE.

INTRODUCTION

Lorem One of the prerequisites for life is water. All living things require water to survive. Water is thought to be the primary prerequisite for the development of both humankind and industry. In recent decades, as the population and industrialization have grown, so has the demand for freshwater.This need is met by the rivers, which provide water for both agriculture and human life. Due to pollution released by human and industrial activity, river water quality has diminished, which has an effect on both aquatic and terrestrial life. In India, the WHO estimates that over 70% of river water is polluted by contaminants, and some river water is unfit for human consumption. (Jindal and Sharma, 2010).

IS 10500-2012 establishes water quality parameter limitations for human consumption, and water treatment is necessary to maintain those limits and prevent disease. To ensure the public's health, a water quality examination was performed on the sample of water that was taken directly from the source. According to the findings of the water quality testing, only MPN in the water sample produced positive results; all other test results fell below the acceptable range. (Jindal and Sharma, 2010). (Aparna S Pillai et al., 2019) Sample taken for the testing should be according to Indian Standard to get correct results. And to avoid mistakes in design of WTP components (IS 3025-2004 Part 1)

A water treatment plant's design takes geography, population, potential demand changes, and several other aspects into account. As a result, highly precise data is needed to assure proper water treatment plant design. Population forecasting is possible because government agencies have access to data from the prior decade. Based on the anticipated population, the amount of water needed is determined. The level difference is measured after conducting a survey from the intake well to the treatment facility. The pipe's length is also determined. The water requirement, level differential, and pipe length all factor into hydraulic design. Each component is designed utilising the water supply manual.(Aparna S Pillai et al., 2019)

For hydraulic design of the components in the water treatment plant the design criteria, Planning, Preparation of DPR, treatment process details are given as by the Central Public Health and Environment Engineering Organization (CPHEEO Manual 1999)

Now a day's different software like INODE WTP Software, Water GEMS etc. are used for theDesign, Detail Hydraulic Design Reports generation, Generate Hydraulic Process GA Drawings, Management & Power Allocation

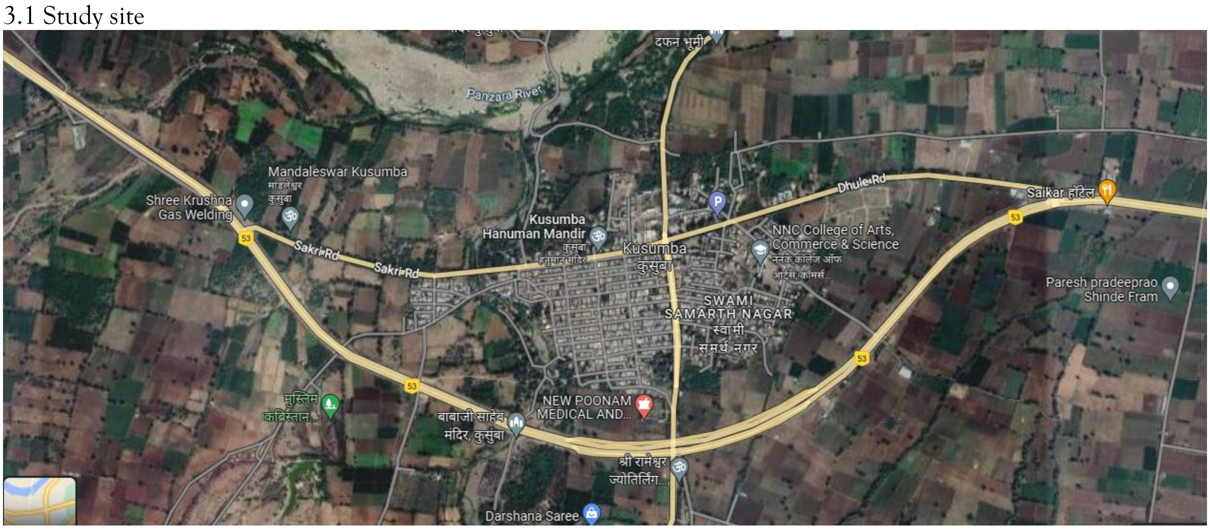
and structural design. INODE WTP - A Technology Recommended by Government of India Ministry of Jal Shakti. INODE WTP is product for Hydraulic Design of Drinking Water Treatment Plants. The design is done as per CPHEEO and relevant IS Manuals. This product is powered by Artificial Intelligence and gives Detail Design Reports, Hydraulic Drawings and Tender Validation Reports as output. It features one of its kind Design Management Portal, Design & Drawing Portal, Proof Checking Portal and Educational Portal.
This software has been designed specifically keeping in mind Government's Mission to provide Drinking Water for all by 2024. It will help standardize designs, bring uniformity and ultimately save design and review time. As far as time is concerned we have brought the Hydraulic Design and Drawing preparation time from 15 days (Average time required in industry) to 45 minutes. Further review time in Departments and Third Party Reviewers can be brought down to 3 days from 30 days (Considering 15 days at each Office). INODE WTP proudly supports Jal Jeevan Mission and all other initiatives towards drinking tap water connections in each household of India
A hydraulic model must be implemented into the simulator in order to precisely determine the division of flows across the plant's lanes and, as a result, the flow through each treatment unit, depending on valve placements and pump speeds. (G.I.M.Worm et al., 2008)
Google Earth may be used to simulate and visualize the full water supply network cycle, from the source to the home. The performance of the network system must be analyzed, simulated, and evaluated in relation to a variety of physical and hydraulic conditions. The technique is referred to as "Simulation," and the programme WaterGEMS models the behavior of hydraulic systems and water quality over lengthy time periods in pressurized pipe networks. WaterGEMS continuously tracks water flow via every pipe, junction pressure, water level in every tank, and network concentration over a simulation period. (Pravinkumar Shinde et al., 2018)
The current population, the population during the previous three decades, the daily water consumption, the features of the flow, as well as a survey of the village using digital GPS, are all taken into consideration while designing the water distribution network. The water distribution system for the settlements is researched and developed using Bentley WATERGEMS software. (Ms. Mohini M et al., 2018)
The Central Public Health and Environmental Engineering Organization (CPHEEO), a division of the Ministry of Urban Development (MoUD), created this manual as a standard reference for public health engineering by offering a code of conduct for public health engineers on a daily basis.

1. Objectives

1) To estimate the water demand for future.
2) To determine existing water quality parameters to propose the design of treatment facilities.
3) Design different units and processes as required by INODE.

2. Methods

3.1 Study site



Location: The village of Kusumba is situated along the Panzra River's riverside. Kusumba Village is located along National Highway Number 6, which runs from West End Hajira in Gujarat to East End Kolkata in West Bengal. About 18 kilometres separate Kusumba village from Dhule city.
History: The flood that occurred to the Panzra river during the years 1864-65 caused the loss of the old Kusumba settlement, which was situated on the river bank. The community was then moved away from the river bank, and the new location became the modern Kusumba Village. Like Sir Mokshagundam Visvesvaraya's Haddppa Sanskriti, the architectural plan of Kusumba village features a cross line road (each road intersects every other road at 90 degrees). By the Panzra River lies a very old and stunning Kalambeshwar (God Shiva) hemadpanthi shrine.

Source of Drinking Water: There is a chaugoan dam which has adequate water quantity. The source we selected it is around 7.8km far away from the site of water treatment plant

2.2. Sample collection

Grab Sampling was done from site in bottles. After collection samples were labelled and transported to the laboratory of the Civil Department environmental engineering lab for physiochemical parameters were analyzed according to standard methods. Parameters like PH, Turbidity Hardness, Chloride content, Alkalinity, Total solids.

3. RESULTS

Water quality parameters

A basic approach to managing surface water quality should keep pollution levels below set criteria and ensure that there is enough dissolved oxygen for aquatic life. Water temperature, pH, dissolved and suspended particles, turbidity, hardness, alkalinity, chlorides, and total solids are the main variables that must be taken into consideration for the management of surface water quality in general.

Parameters	Result	Limits as per 10500-2012
PH	7.5 +/- 0.5	6-8.5
Turbidity	1 +/- 0.5 NTU	1NTU
Hardness	300 +/- 25 as mg/lit Caco3	200 mg/lit as Caco3
Chloride	100 +/- 10 mg/ lit	250 mg/lit
Alkalinity	400 +/- 50 mg/lit	200 mg/lit
Total Solids	1000 +/- 250 mg/lit	500 mg/lit
MPN	0	NIL

IV. Population Forecasting

First we visited the village and collected the data regarding water Requirement of peoples and observe the daily activities of local peoples. To understand the Daily water requirement of Peoples.

Based on the Data collected from the Government Website and discussion with Grampanchayat. We have calculated future growth of Population for next 30years design period

Year	Population
1981	7451
1991	8334
2001	8774
2011	11079
2021	26250

2.4.1 Methods of Population Projection

2.4.1.1. Arithmetical Increase Method

It is anticipated that the rate of population change over time would remain constant. Suitable for huge, historical cities that have achieved their peak or saturation point of development without seeing any industrial expansion.

This method yields lower result for rapidly growing cities.

$P_n = (P_o + n.x)$

Where

p_o = Latest known population;

P_n = prospective population after 'n'decades.

X = Average increases in population per decade.

$$\mathbf{P2051} = 26250+3\times4700$$

$$\mathbf{P2051} = 40350$$

2.4.1.2. Geometrical Increase Method

It is believed that the population will continue to grow by the same percentage every decade. It produces positive results for cities that are developing quickly

$P_n = P_o\, [1 + (r/100)]^n$,

r = Geometrical mean percentage increase.

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Geometric mean $= \sqrt[4]{11.85 \times 5.28 \times 26.27 \times 136.93}$

$= 21.78\%$ per decade

P2051=47408.60

2.4.1.3. Incremental Increase Method

The average population growth is calculated using the arithmetic increase approach, and the average net incremental growth is then added.

$P_n = P_o + n.x + n\,(n+1)/2 \times Y$

$\boldsymbol{pn}$=$\boldsymbol{Po}$+nx+n× y

Geometric increase method gives more realistic results in this case so we adopting.

Population in 2051 =47500 ≅ 48000

Per capita demand = 70 LPCD…………..as per CPHEEO Page no 11

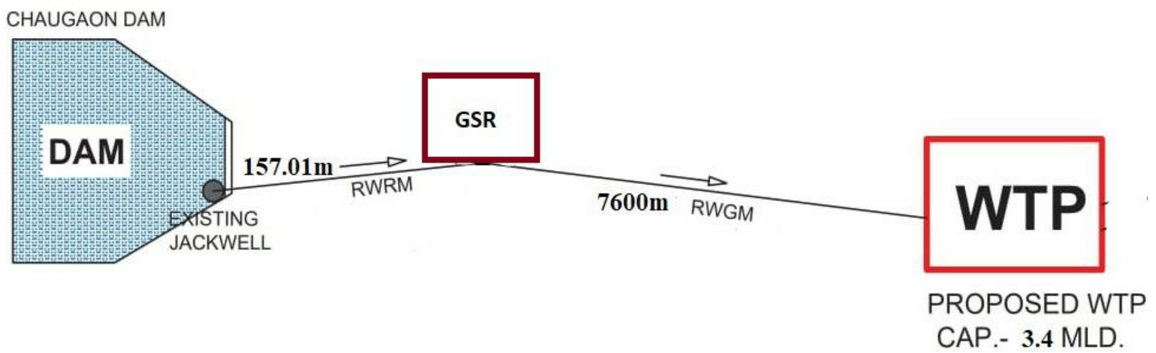
Total requirement = 48000 x70
= 3.4 MLD
= 3400 m3/day

2.4.2 Design of Rising Main

After some surveys and by Analyzing the data collected we came to know that the source that we have chosen is not reliable. The chosen source i.e. infiltration wells are not source of adequate water. And hence, so as to fulfil the needs and requirements of the community we have decided to change the Source of water.

So now we have taken the source as a chaugoan dam which has adequate quality water. But, the source that we have selected it is around 7.8km far away from the site of water Treatment plant. Hence, we have to make some extra provisions and design of various works required to deliver water in the form of rising main and Gravity main from source (i.e. dam) to the water Treatment plant

In between this 7.8 km of path, there is a great R.L or Head difference observed. Hence we have also decided to design storage facility in the form of the Ground service reservoir and Storage Tank.



2.4.3 Rising Main

The pipeline used to pump water from a source or reservoir to an elevated service reservoir or balancing reservoir is known as a rising main.

Population = 48000

Providing daily demand =70 Lpcd (CPHEEO page no 11)

Average daily demand =48000 x 70 = 3.4 MLD

Here, we have taken 20% overloading for ESR design.

Therefore, Q = 3.4 x 1.2
Q = 4.08 MLD

Now, Discharge required per second = = 0.048 m3/sec.

Therefore, Discharge = 0.048 m3/sec

RL difference = 398 380 = 18m

Length of rising main =157.01m

Providing d = 150 mm DI pipe (standard size available in the Market)

2.4.4 Pump Design

Suction Head =10m

Delivery Head =18m

Total length of pipe =170.31m

Diameter of pipe = 0.15m

Head loss = 7.16m
Power = 31.70 HP
Hence, we are providing 3 pumps of 12HP in a series of pumps + 2 stand by

2.4.5 Ground Service Reservoir Design

Considering,
Detention time = 20min = 1200 sec
Assuming 0.3m free board D = 3.3m
Therefore, Dimensions of GSR = 5m 4m 3.3m

2.4.6 Design of Gravity Main:

The pipeline that carries water by gravity from its source to its treatment facility is known as a rising main.
It is provided when the water treatment plant is at lower level and the reservoir is located at lower level.
Discharge = 0.048 m3/sec
Length of Gravity main = 7600 m
We are using HDPE pipe,
Diameter of pipe = 0.3m
And, Velocity = 0.75 m/sec
HL = 12.30m
So, therefore frictional head loss from the ground service reservoir to storage tank in a length of 12.30m.

2.4.7 Storage Tank Design: -

In gravity main we getting velocity much greater than 0.75 m/sec which is required in cascade aerator. If we directly allow that velocity in cascade aerator so water will flow outside the cascade, so we are providing one storage tank to destroy that velocity.
Considering,
Detention Time =30 min = 1800 sec
Assuming 0.3 m Free Board D = 3.3 m.
Dimension of Storage Tank 5m x 6m x 3.3m.

2.5 Hydraulic Design of Water Treatment Plant Kusumba.

The units to be designed

1. Cascade Aerators
2. Parshall flumes
3. Flash mixer
4. Clariflocculator
5. Rapid sand filter
6. Pure water sump
7. Wash water sump
8. Clarifier sludge storage lagoon
9. Sludge drying beds
10. Pure Water Tank
11. Chlorination unit
12. Alum solution tank.
13. Alum & chlorination (TLC) storage space/room

V. Design Calculations

2.5.1. Cascade Aerator: - Aeration's function is to remove unwanted dissolved gases from water and to introduce oxygen to transform unwanted compounds into more controllable forms.
Diameter of aerator = 2.8 m
Number of steps = 5
Tread = 0.25 m
Rise = 0.3 m
Total height = 1.5 m
Width of launder = 0.3m
Depth of launder = 0.4 m

2.5.2. Parshall flume:-

The Parshall flume's job is to transport water from the aerator to the flash mixer while measuring the flow. A common sort of standing wave fume is called Parshall fume.
It can measure discharge vary from 0.001 $m3/sec$ to 100 $m3/sec$.
U/S channel summary -
Length of U/S channel =1.5 m
Width of U/S channel = 225 mm

SWD = 0.646 m
Free board = 0.3 m
Summary of D/S channel –
Length of D/S channel =1.5 m
Width = 255 mm
SWD = 2.6 m
Free board = 0.3

2.5.3. Flash Mixer:-

The purpose of the flash mixer is to quickly and uniformly distribute the coagulant throughout the bulk of water to produce a homogenous system. This aids in the knowledge of micro flocs and leads to optimum coagulant utilization while avoiding premature hydroxide production, which results in less effective coagulant utilization

Assuming detention time = 60 sec……….. [20-60 sec] Assuming 20% overloading.
Diameter = 1.1m
Height = 3.5 m
Power = 1Hp

2.5.4. Clariflocculator

Flocculator – The flocculator job is to assemble the tiny flocs produced by the flash mixer. The aggregation contributes to the formation of huge, dense flocs that are efficiently eliminated in the clarifier.

Clarifier – the role of clarifier is very similar of that of sedimentation tank.
Diameter of inlet shaft 250 mm
Size of port = 100 mm × 160 mm
Spacing of port = 96 mm
Diameter of flocculator = 6.1 mm
Diameter of clarifier = 14.8 m
Size of peripheral launder = 0.5× 0.45 m.
V notch @ 50 cm c/c
Providing bottom slope of 1:12 and mechanical scrapper.

2.5.5. Rapid sand filter

In order to eliminate any particle matter that remains after flocculation and settling, a quick sand filter is one type of filter used in water purification.

Assuming water for backwashing = 3 % …… [2-5%]
Time for backwashing = 30 min
Rate of filtration = 5 $m3/m2/\ hr$…….. [4.8-6$\boldsymbol{m3/m2/\ hr}$]
Length to width ratio = 1.25 ……………… [1.11-1.66]
Providing having 2 filler units each. 1 sections of
L: 4.35m B-3.5m D- 3.1 m
Depth of Depth of Sand = 60 cm
Depth of gravel:
2mm …….9.2cm
5mm………12.1cm
10mm………9.2cm
20mm………9.2cm
40mm……..9.1cm
Diameter of Manifold = 500mm
Diameter of lateral 100mm
Length-625 mm
No of laterals 17 on each side of 200 mm c/c
No of perforation 15 on lateral of 12mm of 40mm c/c
Back washing of filter-
Rate of back washing = 600
Rate of Air wash = 750 lit/m^2 min ……. (600-900 lit/m^2.min) Pressure of Air wash =0.35 kg/cm^3
Design of wash water trough -
Width of Trough = 0.2 m
Depth of Trough = 0.5 m
Height of bottom from filler = 0.4m
Design of gullet
Width of gullet = 0.4m …. (0.4m-0.8m)
Free board = 0.3 m … [Minimum = 0.3]

Back wash required per Death bed = 0.152 m^3/sec
Depth of gullet = 0.725m
Design of wash water tank
Back wash required per bed = 0.152 $m3$/sec
Provide tank of 15$\boldsymbol{m}$ × $\mathbf{10}\ \boldsymbol{m}$ × $\mathbf{2}\boldsymbol{m}$
Design of filter Inlet:
Assumed velocity = 0.8 m/sec …… (0.6-1.2 m/sec)
Depth = 200mm
Design of wash water Inlet:
Assuming velocity = 1.6 …….. (1.5 m - 3 m /sec)
Depth = 0.347m
Check –
Provided area max of
A = 0.0962 ……… ok
Providing 350 mm pipe
Design of Air blower:
Rate of air supply = 750 lit / $m2$/min
Duration of air wash = 5min
Providing 4 air blowers of 10$\boldsymbol{m3}/\ \boldsymbol{min}$ @ 35 kg /$\boldsymbol{cm}\ \mathbf{2}$ pressure+ 2 stand by
Design of water pump:
Providing 1HP motor + 1 stand by
Design of filter back wash water storage lagoon
Provide detention time of 3 days
Provide 2 lagoons = 100m × $\mathbf{100}\boldsymbol{m}$ × $\mathbf{4}\boldsymbol{m}$ each

2.5.8. Clarifier sludge storage lagoons:

Provide a lagoon of 5 × $\mathbf{7}\ \boldsymbol{m}$
Provide 2 pumps vertical non clog open impeller type (1+ stand by) for lagoon to pump the settled sludge to the drying beds and the supernatant could be discharge into channel before flash mixer

2.5.9. Design of sludge drying beds

Assuming 20 % volume of inflow to lagoon
Provide 2 bed of 12 m 17m each

2.5.10. Design of pure water sump

Assume detention time = 60 sec = 1hr
Area = 15m x 10m

2.5.11. Design of chlorination unit

Total flow to be disinfected = 3.4 MLD
Assume dose chorine =2 ppm
Chlorine required = 7.2 kg / day
Providing 10 kg / day
Emergency chlorine
It is done by TCL (tetra phthaloyl chloride)
Bleaching powder required 300 kg / day
Provide tank: (5$\boldsymbol{m}$ × $\boldsymbol{O}.\ \mathbf{5}\boldsymbol{m}$ × $\mathbf{0}.\ \mathbf{5}\boldsymbol{m}$)
Chlorine room
Chlorine required for 7 days = 70kg
Provide 1 tonner
Providing one pipe from chlorination unit to pure water sump
Length = 5m
d = 285 mm
D = 300mm
Alum requirement
Assuming alum dose of 70 mg /lit for monsoon season
Assuming 75% purity of alum
Alum requirement = = 317.33 kg / day
Alum requirement for 90 days = = 28.56 ton

2.5.12. Alum solution tank

Assuming no of tank = 3 (2 working + 1 stand by)
Duration of tank = 8 hr.

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Assuming 75% strength /purity 8% strength of solution
Alum 86.7 gm/lit (As per operational and control of water treatment process)
Assuming
Length= 1 m
SWD = 1 m
Total depth of tank = 1.3m
7 days alum requirement = = 809.41 kg

2.5.13. Storage space for – Alum and TCL

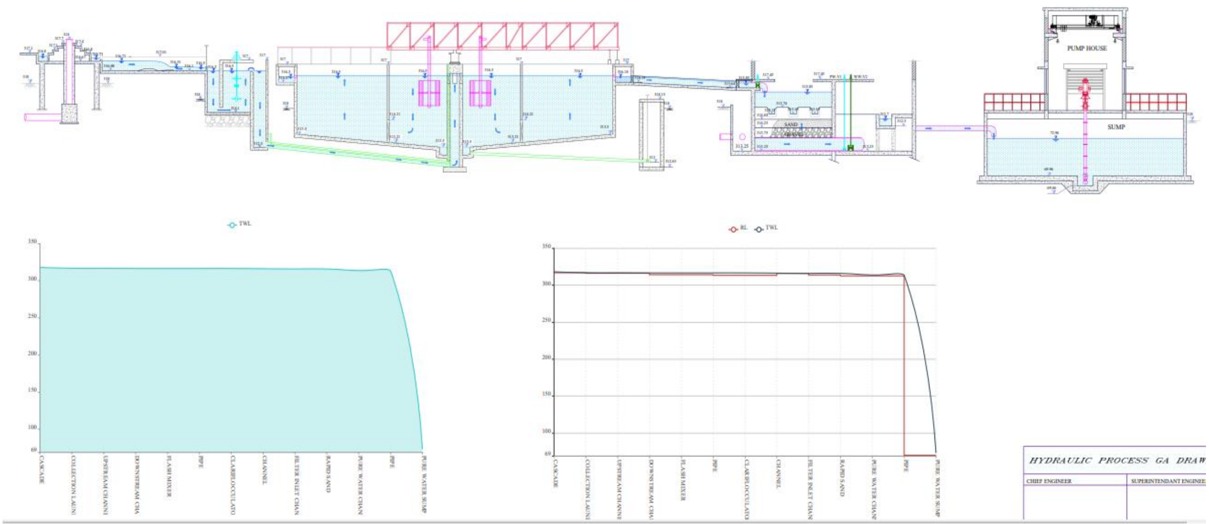
Space for alum = alum required for 90 days + 7 days temporary storage = 29369.41 kg
Assuming density of alum = 1700 kg/$m3$
Volume = = 17.27 $m3$
Space for TCL
TCL storage 7 days = 2100 kg
Assume density of TCL = 1400 kg/$m3$
Total volume of chemicals = 22.52 $m3$
Assuming,
Height of building 4m
Height of stack 3.5 m
Area = 6.43 $m2$
Provide room of 3m x 2.15mx 4m

4. DISCUSSION

VI. RL Calculations

Average GL or RL At Start						
Element	Per Unit Head Loss	Cumulative Head Loss	Total water Level		Reduced Level	
			Start	End	Start	End
Cascade Aerator	0.13	0.13	321.3	321.29	321.18	321.17
Parshall Flume	0.60 0.002	0.73 0.732	321.24 320.382	320.23 320.639	320.65 320.382	320.64 320.38
Flash Mixer	3.511	4.243	320.65	320.339	320.38	317.139
Pipe	2.58	6.823	-	-	319.773	317.193
Clariflocculator	3	9.823	320.193	-	-	317.193
Launder Channel	0.146	9.969	319.893	319.867	319.773	319.747
Filter Inlet Channel	0.172	10.141	319.467	319.415	319.307	319.295

Layout



CONCLUSION

According to the report, a water treatment facility is definitely needed for the community of Kusumba. The hamlet has grown significantly since 1981 and will continue to do so in the years to come. The research mentioned above shows how the 3.4 MLD water treatment plant was designed while taking important elements like the availability of a water supply, population projections, water consumption, etc. into account. The water quality has first been examined using water analysis. Following that, we'll construct the WTP using the Inode programme and the suggested distribution system using the WaterGEMS software.

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