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Design of Sewerage System in Hilly Areas and Various Challenges: A Case Study on Design of Sewerage System in Baba Ghulam Shah Badshah University Rajouri, Jammu And Kashmir, India

[1]ZUHAIB ZAHOOR SHAWL, [2]YAWAR MUSHTAQ RAINA[*], [3]SHARIQ MIR
[1]Department of Civil Engineering, GIMT, Kurukshetra, Haryana, India
[2] Faculty, Department of Civil Engineering, CoET, BGSBU, Rajouri, Jammu and Kashmir, India
[3]B-Tech, Baba Ghulam Shah Badshah University, Rajouri, Jammu and Kashmir, India
Email: yawarraina35@gmail.com

Abstract: **The paper is written on the design of sewerage system for Baba Ghulam Shah Badshah University in Rajouri. The design aims at effective abatement of pollution by providing a comprehensive waste water collection, treatment and disposal system using laterals, branches and trunk mains including sewage treatment plants. There is no proper sewerage system in the university due to backwardness of the area and also due to development of university and increase in the number of students, a design of sewerage system is badly required. The details of design of sewer at different sections presented here will serve as the design itself for the university. The design done here not only covers the entire area of university and the population living within the university but also the population of neighboring areas. Total Station was used for finding the reduced levels of different sections and other data related to survey and accordingly the contour Map cross-sections and L-sections were prepared. The paper also throws some light on the population of the university calculated both analytically and graphically departmental, hostel wise and finally on the whole. Brief about the geographical and other features of the university have also been presented in the paper. Once the proper design of Sewerage system is done, friendly environment will be created for the students, water in the area will also be pollution free to some extent and hence health related issues resulting due to pollution and water will also decrease.**

Keywords: Sewerage system, Sewage, Population, Treatment, Waste, Water, Rajouri, University

I. INTRODUCTION

Sewage is generated mainly from houses schools, factories and industries. It includes waste from residential areas, liquids from toilets, bathrooms, showers, kitchens etc that are disposed through sewers. The household waste is separating and draining into blackwater and greywater. In devolped countries, these are very common. Greywater in those areas is mainly used for recycling plants and also for flushing toilets. Sewage lso include storm water runoff, the systems which are capable of handling storm water are known as combined systems. These sewer systems are usually avoided. Combined sewers require covers large area and are expensive as well. In modern sewer systems separate drain systems are provided for rainfall. Rainwater traveling from roofs and grounds contains soil particles and other organic and in organic matters before undergoing some treatment they are discharged into the rivers or oceans. Various examples of treatment process includes retention basins, wetlands etc. Septic tank, bio filters are used for the collection of sewage, sometimes it is transported by networks of pipes or by pumps and then finally to a main sewerage treatment plant wherever it is located. Treatment of sewage is done in three stages

A. PRIMARY TREATMENT

In this stage sewage is held in a basin where temporary settling of heavy solid particles takes place the particles may include grease, oil etc. In this process the floating particles and the settled particles are removed.

B. SECONDARY TREATMENT

It involves the removal of suspended biological particles. Indigenous, water-borne micro-organisms in a managed habitat are used to perform secondary treatment. Microorganisms are removed by separation process

C. TERTIARY TREATMENT

The treatment except primary and secondary is the tertiary treatment. Before being discharged into rivers or streams water is treated or disinfected both chemically and physically by lagoons and microfiltration.

II. STUDY AREA

The University is located at the slopes of Dhanidhar, which is peripheral part of the majestic Pir Panjal mountain range. The unique geographical location, far from madding crowds of cities, offers ideal ambience for teaching and learning. The campus is located 9 Kms away from Rajouri town (latitude 33˚23' N, longitude 74˚21' E) at an altitude of 975.36 meters above the mean sea level. The climate of the place varies from subtropical to temperate. Frequent rains, occasional hailstorms and snowfall account for the moderate climate and serene atmosphere of the campus and its neighborhood. Spread over a fully fenced area of 80406.90 km^2 of undulating rocky slopes, part of the University campus is covered by oak-pine forests. The physical landscape comprising hillocks of all shapes and sizes, outcrops of rocks, lush green slopes, profusion of native seasonal flowers and the commanding view of sunrise and sunset are the features that add color, beauty and serenity to the campus. Silent features of the University are shown in table I.

Table I. Silent features of university

Area	400000 m^2
Avg. Annual Rainfall	500 mm
Avg. Temperature	7.42 – 37.4˚C
Present Population	3840
Departments	6
Total built up area	45000m^2
Region	Semi-arid

A. PRESENT SCENARIO OF SEWERAGE SYSTEM IN BGSB UNIVERSITY

The BGSB University has no comprehensive sewerage system. The human excreta is disposed of using on-site sanitation methods. Open defection is also not uncommon. Spent water from kitchen and bathroom is left into surface drains which lead to local depressions. Septic effluents from septic tanks are also led into the surface drains. Contamination of drinking water sources by sewage can occur from raw sewage overflow, septic tanks, leaking sewer lines, land application of sludge and partially treated waste water. Sewage itself is a complex mixture and can contain many types of contaminants.. Seepage overflow into drinking water sources can cause diseases from then ingestion of micro organisms such as E-Coli, Cryptosporidium, Hepatitis A and Helminths. The options available for disposal of excreta are either on-site or off-site sewerage systems. The topography of the town is that of hilly area. The mean annual rainfall is 500mm mostly confined to monsoon season and with maximum temperature during summer between 37˚C and minimum temperature of 7˚C during winter season. The proposed project aims effective abatement of pollution by providing a comprehensive waste water collection, treatment and disposal system using laterals, branches and trunk mains including sewage treatment plants.

III. DATA COLLECTION & ANALYSIS

The data of both the population and design of sewer is presented in the form of tables, graphs and figures.

A. POPULATION FORECASTING OF BABA GHULAM SHAH BADSHAH UNIVERSITY

Population is forecasted both analytically and graphically

- **ANALYTICALLY**

Population **o**f the university on the whole, hostel wise and departmental wise is calculated both analytically and graphically table 2 gives the details of population analytically calculated at the end of year 2042

Table II Population of various departments and other residential areas at the end of year 2042

S.no	Departments/Hostels/Residential Buildings	Population
1	College of Engineering and Technology (CoET)	14653
2	MBA/M.ScIT/B.A./Arabic/BBA/BCA/ Mathematics/B.Sc IT	11266
3	University Polytechnic College	4250
4	Hostels	3885
5	Residential Buildings	3243
6	Baba Ghulam Shah Badshah University	53976

- **Graphically**

Figures I to VI give details of population graphically at the end of year 2042. In this method, a graph is plotted from the available data, between time and population. The curve is then smoothly extended up to the desired year.

Figure I Yearly population variation of CoET

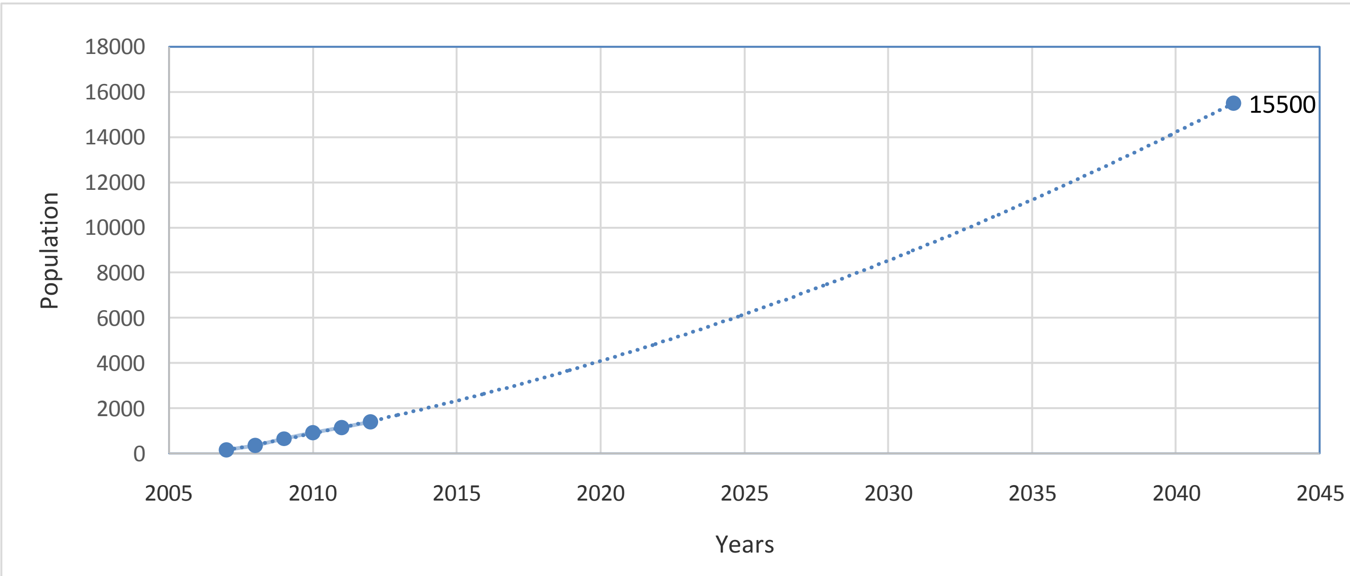


Figure II Yearly population variation of MBA and adjacent departments

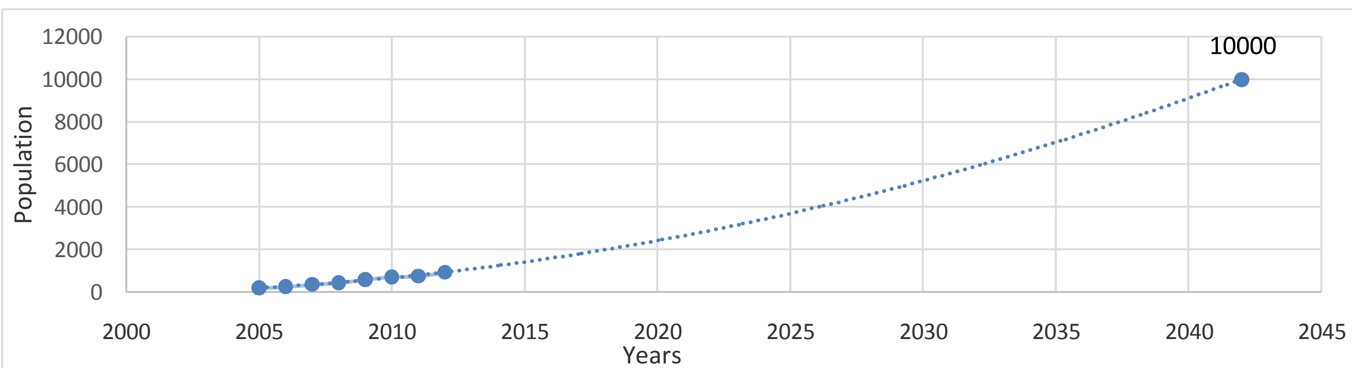


Figure III Yearly population variation of University Polytechnic College

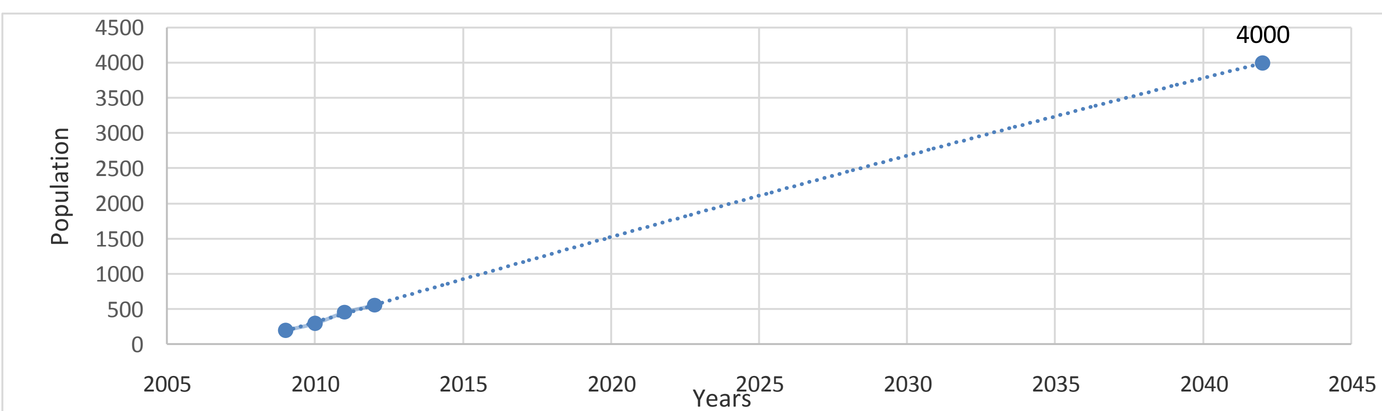


Figure IV Yearly population variation of Hostels

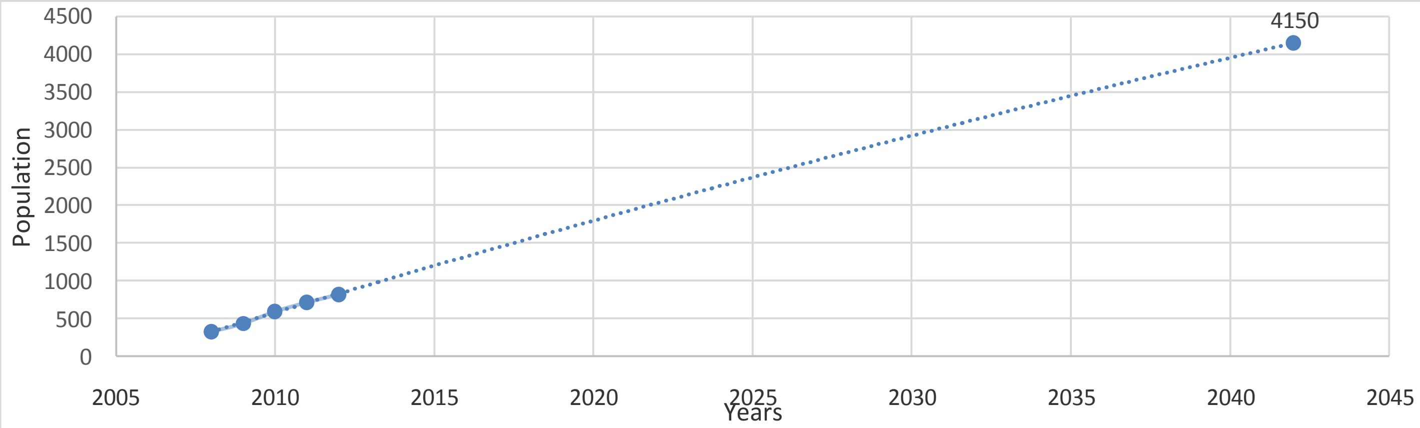


Figure V Yearly population variation of Residential Buildings

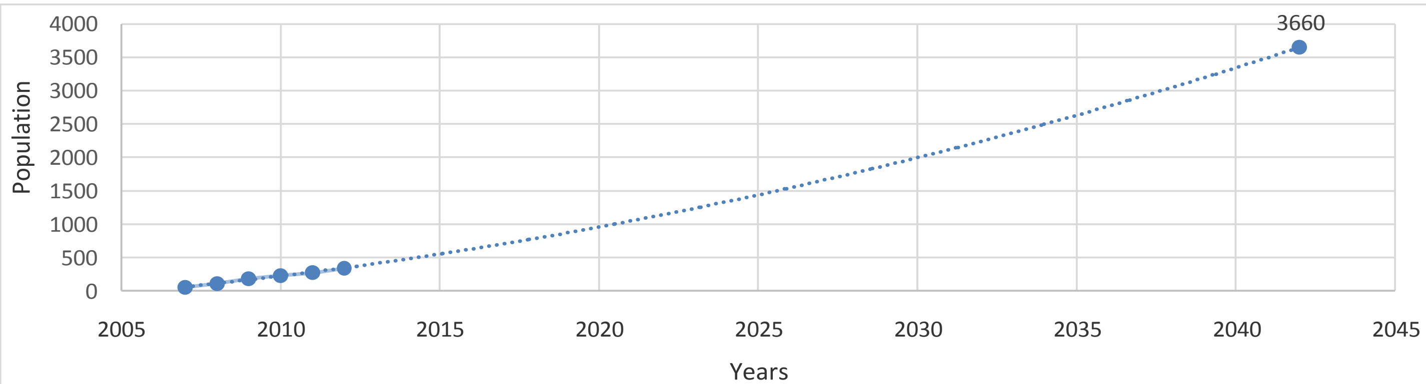
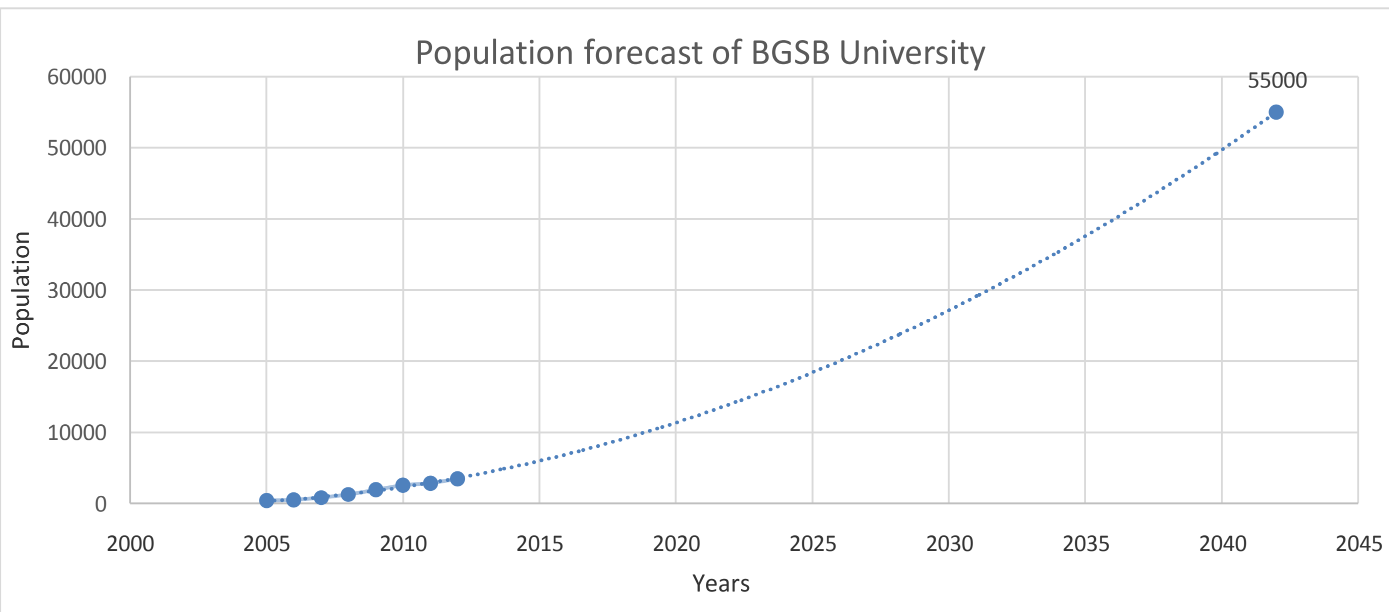


Figure VI Yearly population variation of Bgsb University



The difference can be seen in the population calculated both analytically and graphically, however graphical method is not that accurate and gives us approximate results.

B. SEWAGE PUMPING STATIONS

For a sewage pumping station, the following factors are required to be considered.

- **LOCATION OF PUMPING STATION**

For properly draining of the area pumps should be located at the proper places, for locating the pumps at proper location thorough study of the area is required. The site chosen for pumping station should be nearer to water bodies such as rivers and streams or strom water drain, so that overflow can be diverted during power failure. The pumping stations should be located in areas which can be easily accessible during all whether conditions. Also the station should be located near the water bodies in such a way that it is not affected during floods

- **BUILDING OF PUMPING STATION**

The building is designed to sustain all the forces to which it may be subjected during its life span. The sub structure of the pumping station is normally made up of R.C.C or sometimes mass structures construction is also done. Earth pressure, water pressure and uplift pressure on the bottom is taken into account in the design of sub structure of the building. For design of super structure one can make use of any material. The external walls are either solid slabs constructions supported on horizontal or vertical ribs. The internal walls and the floors are designed for the weight of machinery and live load of 5 kN/m^2.

- **NUMBER OF PUMPS**

The capacity of a pump is usually stated in terms of Dry Weather Flow (DWF), estimated for the pumping station. Normally 3 pumps for a small capacity pumping station comprising 1 pump of 1 DWF, 1 of 2 DWF and third of 3 DWF capacity. For large capacity pumping station, 5 pumps are usually provided, comprising 2 of 1/2 DWF, 2 of 1 DWF. The open impeller screw picks up and lifts the sewage on the screw and discharges at the top of the screw. The rotational speed is generally about 20 to 30 rpm. The motor is mounted at the top with a gearbox kept inclined and thus driving the impeller axially. Depending on the speed of rotation the quantity lifted varies. There is no piping or valve.

- **SELECTION OF PUMP STATIONS**

Where suction lifts are about 3 to 5 m only, the horizontal foot mounted centrifugal pump stations should be explored in view of the ease of repairs from local resources and the fact that motors and pumps can be independently taken out for repairs. Also, where space limitations are constricting, submersible pump stations could be preferred.

- **DESIGN OF PUMPS**

The details of design of pumps at various stations are given in the following tables

- **PUMP NO 1 NEAR TAJ HOSTEL**

Taj hostel is located on the hills of the university, students, hostel staff and teaching staff is residing here. The pump to be located here will also cover the areas in which some departments are located like CoET, Management studies and also the girls hostel. The details are given in table III

Table III Details of pump no 2 near Taj hostel

Total Discharge (Q) = 0.00625 m^3/s					
Rising Mains					
Diameter (m)	Velocity	Minimum permissible velocity (m/s)	Maximum permissible velocity (m/s)	Length (m)	
0.03	0.88	0.78	3.0	350	
SUMP					
Total Capacity (m^3)	Diameter (m)	Depth (m)	No. Of Sumps	Detention Period (min)	
1.372	1.5	1.0	01	30	
Pumps					
Capacity of pump (m^3/s)	Total lift (m)			Horse Power	Break Horse Power (Kw)
	Head due to difference in elevation (m)	Friction loss (m)	Bend Loss (m)		
0.007624	16.61	18.41	1.0	0.40	0.7

- **PUMP NO 2 NEAR SABRANG SQUARE**

Sabrang Square is located just after the entry gate of the university. The area is facilitated with market, canteen, faculty quarters besides the hostel. It will cover the entire area of the Sabrang Square, the polytechnic college as well as some faculty quarters. Details are given in table IV

Table IV Details of pump no 2 near Sabrang square

Total Discharge (Q) = 0.0494556 m^3/s					
Rising Mains					
Diameter (m)	Velocity	Minimum permissible velocity (m/s)	Maximum permissible velocity (m/s)	Length (m)	
0.250	1.01	0.78	3.0	150	
SUMP					
Total Capacity (m^3)	Diameter (m)	Depth (m)	No. Of Sumps	Detention Period (min)	
51.873	3.17	3.0	2	15	
Pumps					
Capacity of each pump (m^3/s)	Total lift (m)			Horse Power	Break Horse Power (Kw)
	Head due to difference in elevation (m)	Friction loss (m)	Bend Loss (m)		
0.02881	7.94	1.247	0.9	7.0	12

3.3.3 PUMP NO 3 NEAR BIO-TECHNOLOGY DEPARTMENT

The biotechnology department was the first department in the university. It is located about 5km away from the entry gate, so an additional pump is required here to cover this area, the pump here may also cover some PG- block boys hostels. The details are shown in table V

Table V details of pump no 3 near bio-technology department

Total Discharge (Q)=					
Rising Mains					
Diameter (m)	Velocity (m/s)	Minimum permissible velocity (m/s)	Maximum permissible velocity (m/s)	Length (m)	
0.03 m	0.88	0.78	3.0		
SUMP					
Total Capacity (m^3)	Diameter (m)	Depth (m)	No. of Sumps	Detention Period (min)	
51.873	3.5	3	2	15	
Pumps					
Capacity of pump (m^3/s)	Total lift (m)			Horse Power	Break Horse Power (KW)
	Head due to difference in elevation (m)	Friction loss (m)	Bend Loss (m)		
0.02881	7.94	1.247	0.9	7	12

- **Hydraulic design of sewer** The flow in sewers varies from hour to hour and also seasonally. But for the purpose of hydraulic design it is the estimated peak flow that is adopted. Also to ensure that deposition of suspended solids does not take place, self-cleansing velocities using Shield's formula is considered in the design of sewers, which states that

$$V = \frac{1}{n}\left[R^{1/6}\sqrt{K_s(S_s - 1)d_P}\right]$$

Where,

n = Manning's n

R = Hydraulic Mean Radius in m

K_s = Dimensionless constant with a value of about 0.04 to start motion granular particles and about 0.8 for adequate for self cleansing velocity

S_S = Specific gravity of particle

d_P = Particle size in mm.

The above formula indicates that velocity required to transport material in sewers is mainly dependent on the particle size and specific weight, and slightly on the conduit shape and depth of flow. The specific gravity of the grit is usually in the range of 2.4 to 2.65 Silent features of the sewer at various section are shown in table 3. Manning's formula given by Robert Manning (1889) is used for design of sewer. This formula states velocity of flow

$$V = (1/n) \times R^{2/3} S^{1/2}$$

V = velocity of the flow in m/s

R = hydraulic mean depth

S = slope of sewer

n = Manning's roughness coefficient

The details of design of the sewerage system in the university at different sections are shown in the following tables from table VI to table XI.

Table VI cross section elements, discharge and velocity of sewer From section 1 to 15

S.NO:	Discharge (M^3/s)	Slope	d/D	Length of sewers (meters)	Diameter of sewers (mm)	Velocity m/s
1	0.01875	1 in 10.36	0.3	45	250	2.11
2	0.01875	1 in 8.587	0.3	22	250	2.32
3	0.01875	1 in 10.83	0.3	75	250	2.08
4	0.01875	1 in 22.83	0.3	15	250	1.43
5	0.01875	1 in 14.16	0.3	15	250	1.81
6	0.01875	1 in 11.29	0.3	07	250	2.03
7	0.01875	1 in 8.45	0.3	30	250	2.346
8	0.01875	1 in 10.39	0.3	105	250	2.116
9	0.00287	1 in 7.57	0.3	45	150	1.763
10	0.00287	1 in 9.21	0.3	25.8	150	1.6
11	0.01875	1 in 10.277	0.3	22	250	2.12
12	0.01875	1 in 10.717	0.3	75	250	2.075
13	0.01875	1 in 12.755	0.3	105	250	1.90
14	0.0153	1 in 140	0.3	135	310	0.8
15	0.0153	1 in 12.99	0.3	30	310	1.13

Table VII: Velocity details and load on the sewer from section 1 to 15

S.NO:	Min velocity (settlement consideration)	Max velocity (scouring consideration)	Velocity at 1/5 of discharge m/s	load on sewer due to back fill kg/m	Load on sewer due to concentrated wheel load(kg/m)	Safe working strength of pipe (Kg/m)
1	1	3	0.63	218.04	206.00	4261
2	1	3	0.700	218.04	206.00	4261
3	1	3	0.628	218.04	206.00	4261
4	1	3	0.467	218.04	206.00	4261
5	1	3	0.555	218.04	206.00	4261
6	1	3	0.613	218.04	206.00	4261
7	1	3	0.708	218.04	206.00	4261
8	1	3	0.643	218.04	206.00	4261
9	1	3	1.225	218.04	139.14	3669.7
10	1	3	1.112	218.04	139.14	3669.7
11	1	3	0.642	218.04	206.00	4261
12	1	3	0.63	218.04	206.00	4261
13	1	3	0.57	218.04	206.00	4261
14	0.75	3	0.53	1962.36	147.59	4583
15	0.75	3	0.67	1962.36	147.59	4583

Table VII Cross section elements, discharge and velocity of sewer from section 16 to 33

S.NO:	Discharge (M^3/s)	Slope	d/D	Length of sewers (meters)	Diameter of sewers (mm)	Velocity m/s
Pump 1						
16	0.0397	1 in 16.67	0.3	45	150	1.184
17	0.0397	1 in 10.93	0.3	75	150	1.46
18	0.0397	1 in 72.11	0.3	15	150	1.20
19	0.0377	1 in 14.86	0.3	75	350	2.206
20	0.0377	1 in 15.81	0.3	105	350	2.13
21	0.0377	1 in 12.86	0.3	45	350	2.37
22	0.0377	1 in 11.81	0.3	30	350	2.474
23	0.0377	1 in 57.69	0.3	45	350	1.1197
24	0.0377	1 in 29.90	0.3	30	350	1.555
25	0.0377	1 in 45.80	0.3	30	350	1.26
26	0.0377	1 in 93.75	0.3	90	350	0.88
27	0.0377	1 in 75	0.3	30	350	0.98
28	0.0377	1 in 60	0.3	30	350	1.097
29	0.0377	1 in 58.44	0.3	45	350	1.11
30	0.0377	1 in 41.28	0.3	45	350	1.32
31	0.0377	1 in 44.77	0.3	30	350	1.27
32	0.032979	1 in 24.69	0.3	60	350	1.71
33	0.04404	1 in79.36	0.3	45	450	1.13

The velocity details and the load details at this section are same as that of section 1 to 15.

Table IX: Velocity details and load on the sewer from section 34 to 51

S.NO:	Min velocity (settlement consideration)	Max velocity (scouring consideration)	Velocity at 1/3 of discharge m/s	load on sewer due to back fill kg/m	Load on sewer due to concentrated wheel load(kg/m)	Safe working strength of pipe (Kg/m)
34	0.75	3	1.58	872.16	69.69	5501.2
35	0.75	3	1.83	872.16	69.69	5501.2
36	0.75	3	0.713	872.16	69.69	5501.2
37	0.75	3	1.41	872.16	69.69	5501.2
38	0.75	3	1.26	872.16	69.69	5501.2
39	0.75	3	0.60	872.16	69.69	5501.2
40	0.75	3	0.985	872.16	69.69	5501.2
41	0.75	3	0.79	872.16	69.69	5501.2
42	0.75	3	0.46	872.16	69.69	5501.2
43	0.75	3	0.98	872.16	69.69	5501.2
44	0.75	3	1.59	872.16	69.69	5501.2
45	0.75	3	1.77	872.16	69.69	5501.2
46	0.75	3	1.65	872.16	69.69	5501.2
47	0.75	3	2.05	872.16	69.69	5501.2
48	0.75	3	1.506	872.16	69.69	5501.2
49	0.75	3	0.45	872.16	69.69	5501.2
Pump 2						
50	1	3	0.93	218.04	139.14	3669.7
51	1	3	1.53	218.04	139.14	3669.7

Cross section elements, discharge and velocity of sewer from section 34 to 51 is same as that of 16 to 33.

Table X Cross section elements, discharge and velocity of sewer from section 52 to 68

S.NO:	Discharge (M^3/s)	Slope	d/D	Length of sewers (meters)	Diameter of sewers (mm)	Velocity m/s
52	0.00875	1 in 3.87	0.3	35	150	2.46
53	0.00875	1 in 12.70	0.3	15	150	1.36
54	0.00875	1 in 36	0.3	45	150	0.809
55	0.05018	1 in 166	0.3	60	550	0.89
56	0.05018	1 in 21.42	0.3	15	550	2.50
57	0.06049	1 in 141.50	0.3	75	560	0.98
58	0.06049	1 in 105.26	0.3	60	550	1.138
Pump 3						
59	0.00620	1 in 23.75	0.3	45	200	1.206
60	0.00620	1 in 16.07	0.3	45	200	1.46
61	0.00620	1 in 9.43	0.3	30	200	1.91
62	0.00620	1 in 7.35	0.3	40	200	2.16
63	0.00620	1 in 14.184	0.3	30	200	1.56
64	0.00620	1 in 5.617	0.3	12	200	2.48
Outfall						
65	0.0739	1 in 12.5	0.3	15	400	2.63
66	0.0739	1 in 11.95	0.3	75	400	2.70
67	0.0739	1 in 11.21	0.3	30	400	2.78
68	0.0739	1 in 13.95	0.3	45	400	2.497

Table XI: Velocity details and load on the sewer from section 52 to 68

S.NO:	Min velocity (settlement consideration)	Max velocity (scouring consideration)	Velocity at 1/3 of discharge m/s	load on sewer due to back fill kg/m	Load on sewer due to concentrated wheel load(kg/m)	Safe working strength of pipe (Kg/m)
52	1	3	1.85	218.04	139.14	3669.7
53	1	3	1.02	218.04	139.14	3669.7
54	1	3	0.606	218.04	139.14	3669.7
55	0.75	3	0.518	872.18	85.173	6126.8
56	0.75	3	1.45	872.18	85.173	6126.8
57	0.75	3	0.568	872.18	85.173	6126.8
58	0.75	3	0.66	872.18	85.173	6126.8
Pump 3						
59	1	3	0.814	872.16	77.18	4002.90
60	1	3	0.981	872.16	77.18	4002.90
61	1	3	1.28	872.16	77.18	4002.90
62	1	3	1.46	872.16	77.18	4002.90
63	1	3	1.049	872.16	77.18	4002.90
64	1	3	1.66	872.16	77.18	4002.90
Outfall		3				
65	0.75	3	1.84	872.16	61.994	5254.13
66	0.75	3	1.89	872.16	61.994	5254.13
67	0.75	3	1.95	872.16	61.994	5254.13
68	0.75	3	1.74	872.16	61.994	5254.13

IV. CONCLUSION

This paper gives the details about design of sewerage in hilly areas and the problems which occurs while designing the sewer in hilly area. In this paper the population at the end of year 2041 for the respective departments have also been calculated. After carrying out the study it was concluded that three pumps were required one near Taj hostel, one at sabrang square and one at bio technology department. Location of pumps at these three were found to be best because they were covering each and every part not only of the university but also some of its neighbouring parts. In the design of sewer from section 1-68 difference can clearly be seen that at discharge is varying at different sections this is clearly due to variation of population. In hilly areas where there is populated human settlement, it is difficult to make the water to flow with certain velocity in a sewer which is clear in the design presented in the paper. Syphon system needs to be provided to over come this problem. The material used in sewers should be non corrosive. To overcome the problem of infiltration PVC pipes are cosidered to be the best. It was observed that while negotiating a curve in this area a new reading altogether was required, which created lot of problems in taking out the levelling work and because of the area being hilly and having curves at every half kilometer , chances of head losses increases, which is clear in the design of sewer presented in the paper. The biggest challenge of course found in hilly area like this is that it takes lot of time in designing a sewer which ofcourse requires lot of field work. The proposal being put forward will help in effective abatement of pollution by providing a comprehensive waste water collection, treatment and disposal system using laterals, branches and trunk mains including sewage treatment plants.

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