THESIS

On

DESIGN OF SEWERAGE SYSTEM FOR RURAL HUMAN SETTLEMENT: A CASE STUDY

In the partial fulfilment for the award of

Degree

MASTER OF TECHNOLOGY

in

ENVIRONMENTAL SCIENCE & TECHNOLOGY

by

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CERTIFICATE

This is to certify that the work done in this Thesis report entitled " Design of sewerage system for rural human settlement: a case study " submitted in partial fulfilment of requirement for the award of the **Master degree in Environmental science and technology** in the Biotechnology and environmental sciences department, Thapar University, Patiala, is an authentic record of work carried out by me under the guidance of **Dr. A. S. Reddy, Associate professor, Thapar University, Patiala.**

The matter embodied in this report has not been submitted in any other university or institute for the award of any degree.

Date: 15-07-2010

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This is to certify that above declaration made by the student concerned is correct to the best of my knowledge & belief.

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ABSTRACT

In the present study for rural human settlement, a sewerage system in Kanech village near Ludhiana has been designed. Being a village with human population of 3422 and cattle population of 767, for keeping the sewer depth within limits and for having four smaller STP at the four village ponds, simplified sewerage system has been opted. Based on surface drainage patterns, village was divided into four zones. For each zone a separate simplified sewerage system and sewage treatment plant integrating the village pond was planned. For each of the village zones, sewer map was divided and sewer stretches and manholes needed were finalized. For each of sewer stretch through survey and population forecasting both present and design peak flow were worked out. Design peak flow were worked out through assuming increase of population at 1.22 percentage per year (The value affirmed by Punjab state water supply and sanitation board) and through identifying new areas of development and assessing their population densities when fully developed. A typical water consumption rate of 135 lpcd has been considered for the designing purpose. A peaking factor of 2.4 was assumed for this designing purpose. Cattle tanks were planned to handle the dung of the village. For ensuring self-cleansing velocity through the sewers from the beginning in order to have some sufficient minimum flow automatic siphoned system were planned into the sewerage system. Two size of siphon system one to serve upto 15 people and the other to serve up to 50 people have been provided. These siphons are to deliver a maximum of 8lps of sewage when running. This 8lps has been taken as the minimum peak flow for the sewerage system design.

Instead of 0.4m, as per the advice of PSWSSB, a minimum cover of 0.9m was assumed for the sewer. The design approach of Bakalian and modified by Duncan Mara was followed in the sewer design. Using the present peak flow, minimum slope was worked out on the basis of ensuring minimum tractive tension of 1.5Pascals. Diameter of the sewer was then decided on the basis of design peak flow while ensuring d/D □ 0.8. Depending on the need three types of manholes, simplified manholes, junction manholes and drop manholes were provided. Simplified manholes were used only in those stretches where sewer depth was □ 1.65m. For sewer depth □1.65m, rectangular and circular manholes of conventional sewerage system were used as per IS: 4111(part1)-1986.

For comparison and appreciation of the merits of simplified sewerage system for one of the four zones, even conventional and small bore sewerage system were designed. In case of small bore system intercepting tank were provided at household level .The automatic siphon systems have been considered even for the conventional sewerage system. All design detail of both the small bore and conventional sewerage system has been including in the detailed project.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1
INTRODUCTION

1.1. BACKGROUND

The Government of Punjab proposes to access the World Bank funds to expand the coverage of water and sanitation scheme in rural areas of Punjab. For improving the sustainability and standard of rural sanitation services, the department of water supply and sanitation (DWSS) has introduced new rural water supply and sanitation policy. According to the policy, each rural area has its own water supply and sanitation facilities. The two facilities safe water and hygienic sanitation are required for the healthy living. Hence, these two facilities are gaining importance in our country especially for small towns, communities and rural human settlement.

In most of the rural areas of Punjab, the wastewater generated by the household, including the wastewater from cattle shed, flows into open surface drains leading to stagnation in the lanes. Without adequate arrangement for treatment and disposal, the wastewater often seeps into hand pumps, open dug wells and pipelines, and water quality of the village ponds deteriorated. Due to the poor sanitation, several diseases like diarrhoea, malaria, typhoid are mostly found in the rural area.

In the present study, selected village have the same above said condition. Wastewater from the cattle shed was allowed to flow into the open surface drain and block the drains. As a result of it, water over flow on the road. This creates unhygienic condition for villagers. So an effort is needed to design an appropriate sewerage scheme for a rural area, keeping in view the typical requirements and problems related with village area that includes scattered population, lack of skilled man power and resources. Simplified sewerage is proposed to design for this village because of low maintenance and operation cost. In addition to this, an attempt has also been made to design other alternatives of simplified sewerage i.e. conventional sewerage and small bore sewerage system for one site. In conventional and simplified sewerage system, unsettled water is dispatched to the treatment site, while in small bore, settled water is discharged to the treatment site.

1.2. OBJECTIVE

To design the sewerage system (simplified, conventional, small bore sewerage system) for rural human settlement.

1.3. OVERVIEW OF THE REPORT

Contents of this thesis have been organized into the following five chapters:

Chapter-1 Introduction: This chapter introduces the topic and objective of this thesis. It further includes a brief overview of the contents of this report.

Chapter-2 Literature review: Review of literature related to thesis work has been presented in this chapter. It includes the types of sewerage system, design parameter for sewerage system, hydraulic concept, appurtenances and problems associated with sewer.

Chapter-3 Approach followed: This chapter discusses the stepwise approach followed to achieve the objective of this work. This also includes the design procedure and example of the design.

Chapter-4 Result: Result of design has been presented in this chapter. The information collected from the site, layouts of the sewer, drawing of the component and dimension of units are presented in this chapter.

Chapter-5 Conclusion: This is the last chapter that summarizes the scheme and outcomes of study.

On implementation of the scheme developed and the system designed in the present study can prove very useful for managing the wastewater of the villages. The experiences gained with this system for this village can be used in other villages for better implementation of the system. This thesis work has been limited to sewer design. Lack of time period has restricted the STP (sewage treatment plant) design.

CHAPTER -2

LITERATURE REVIEW

2.1. SEWERAGE SYSTEM

Sewerage system offers important advantages and interesting possibilities for sustainable development under the idea of sustainability; a concept of sustainable rural sewerage system is put forward in this thesis. A rural sewerage system cannot only be a basic facility for draining waste water to protect the rural environment and public water bodies but also contributes to the restoration of the water environment for maintaining the healthy social water cycle. A social water cycle is defined as a system that includes drawing water from natural bodies, utilizing it and discharging back to the water bodies **(Zhang, 2001)**. This chapter is an effort to review the literature relevant to design of different sanitary sewerage system. Being a design project, established procedures and criteria given in the handbooks, standard and manuals have been given preference over the research papers.

The sewerage system is the network or system of sewer and associated works designed for the collection of foul sewage or wastewater, conveying it via pipes, discharging it at a treatment work or other place to disposal. It consists of various sub systems and each sub system is required to be designed in detail keeping in view the objective, data and background information available.

2.2. TYPES OF SEWERAGE SYSTEM

On the basis of carrying water, three types of sewerage systems are there. These are given below.

2.2.1. COMBINED SEWERAGE SYSTEM

This single pipe system carries both domestic water and storm water. During wet weather, the combined volume of wastewater and storm water runoff entering in sewerage system often exceeds conveyance capacity. Due to this reason, combined sewerage system was designed to overflow occasionally and discharge excess water directly into nearby stream, river or water bodies. As wastewater overflows into creeks, rivers, lakes, and streams, it contaminates all bodies of water fed by the waterways and all creatures/ plants coming in contact with the polluted water. Sewer overflows also contribute to beach advisories and closures due to contamination. These are prevalent in the older communities but such system are not longer constructed **(USEPA, 2002**).

2.2.2. STORM SEWERAGE SYSTEM

This carries rainwater from roof paved areas, pavements and roads. Storm water sewers are normally much larger than sanitary sewer systems because they are designed to carry much larger amounts of water. When clear water enters sanitary sewer systems, it must be transported and treated like sanitary wastewater. For reducing the unnecessary overloading in sewage treatment plant and avoiding the variation of flow, these two systems are used separately. In this sewerage system, sediments are mainly inorganic and noncohesive.

2.2.3. SANITARY SEWERAGE SYSTEM

This system is used for the domestic sewage. This system is composed of various sewer lines terminating at the junction of a large sewer line. The large sewer line also terminates at the junction of a still larger sewer line. Finally, the main sewer line terminates at the outfall. This system carries the sediments to the treatment plants, where it can be removed. Sediments in sanitary sewer are generally having cohesive like properties due to the particles and the presence of greases and biological slimes.

These sediments when deposit in the sewer causes the problem. In sanitary sewer, these vary from (100 – 500mg/l) and particle size from (10-60µm). If water carries the 100mg/l and 10µm sediment load then it is referred to as low strength wastewater. If it carries the 350mg/l & 500mg/l then it is referred to as medium and low strength wastewater, respectively **(Butler, 2003).** Sediment when entrained into the flow, it travels in suspension or as bed load. Finer lighter material tends to travel in suspension and influenced by the turbulent fluctuations in the flow. Heavier material travels by rolling, sliding or slanting along the pipe invert as bed load. This movement is affected by the velocity and by shear stress. If flow velocity or turbulence level decrease, there will be a net reduction in the amount of sediment held in suspension. If flow velocity is reduced further, sediment transport will cease completely. Sediment particles in suspension, during both dry and wet weather flows, are typically 40µm in size **(Crabtree, 1989).** Under dry weather flow conditions, sediment particles can form a highly concentrated, mobile layer just above the bed. Solids in this region are relatively large (□0.5mm), organic (□90%) particles and concentrations up to 3500 mg/l have been measured **(Ashley *et al.*, 1992)**. According to Ashley *et al.*, typically 12% of total solids are conveyed in the material moving near the bed. Granular particles (2-10mm) are transported as pure bed load only in steeper sewer (□2%). Sediment bed will develop and cause to increase the bed resistance, causing the depth of flow to increase and the velocity to decrease. Reduction in velocity would cause reduction in the sediment transporting capacity of the flow leading to further deposition and blockage. **(May, 1993)** laboratory evidence has shown that the presence of the deposited bed actually allows the flow to acquire a greater capacity for transporting sediment as bed load. This is due to the fact that the degree of sediment transport is related to the width of the deposited bed.

1. Conventional sewerage system

Conventional sewer system is an offsite technology to carry the wastewater from house to the treatment plant. These are typically used in urban areas with consistently sloping ground and these are used in city. These are not very good for the hilly or flat areas as it results in deep excavations. These are also not good for the areas where water level is high. In conventional sewerage system, the human excreta is diluted with flushing water, mixed with other water and finally treated. **(Gardner, 1997)** pointed that the flush water counts to 20-40% of total municipal water consumption. In these system, sewer are laden in road system due to the heavier traffic. The minimum cover of 1m should be provided. In conventional design layouts, trunk pipelines should be built in the streets around the house blocks to potentially allow individual connections for all the households **(Sarmento, 2001).** In this system, manholes are provided at the upper end of all laterals, change in direction, slope and junctions **(CPHEEO, 1993).** This system can handle grit and solids in sanitary sewage.

2. Simplified sewerage system

Simplified sewerage is an off-site sanitation technology that removes all wastewater from the household environment. This system was developed for low-income areas. Where there is insufficient space problem for onsite system. Simplified sewerage system has been found to be reliable, upgradeable and extendable. It is applicable in all situations but especially suitable for areas characterized by gently sloping topography, high and low-density population with reasonably water supply, small homesteads with lack of space, high water table, impervious soil and shallow bedrock. In rural and low density area to medium density area, where space is not the problem for onsite treatment while in high population density area, there is no space for the onsite treatment these system can be used. These sewer system are cost effective at lower densities than the other **(Mara, 2008)**.

Simplified sewerage was first implemented in Brazil based on the review of the design criteria used for conventional sewerage **(Bakalian *et al*., 1994)**. It is also successfully used in rural areas for example in the north-eastern Brazilian state of ceara **(Sarmento, 2001).** This system has also been used in some other Latin American countries (Bolivia and Peru) and some asian countries (Pakistan and Sri Lanka) **(Sinnatamby *et al.,* 1986)**. While in India, there is only one place (Ramagundam in Karimnagar district of Andhra Pradesh) where this system is being tried **(Nema).**

Key features of this system are:

Capital cost is half than the conventional sewerage **(Mara, 2008)**. These are laid on shallow depth and away the traffic load simplified systems are designed in a way that the wastewater from households in the same block is collected by a shallow and small diameter pipeline and then, delivered to the trunk sewers by a single (or just a few) connection **(Sarmento, 2001)**.

Manholes are not needed instead of this junction box are provided. Major junction Manholes are provided. Plastic pipes can be used instead of concrete and asbestos pipe because sewers are laden far from the traffic loads **(Sinnatamby, 1986; Bakalian *et al*., 1994)**. Concrete and asbestos pipe are not recommended in simplified sewerage due to high probability of sulphide attack on the pipe material **(Mara, 1996).**

3. Small bore sewerage system

These systems are designed to receive only the liquid portion of the household wastewater for offsite treatment and disposal. Grit, grease and other troublesome solids which might cause obstruction in the sewer are separated from the waste flow in septic tank, reducing the potential for clogging to occur and allowing for smaller diameter piping both downstream of the septic tank in the lateral and in the sewer main. They can also be effective where the topography is to flat without deep excavation, where the soil is rocky or unstable and where ground water level is high, domestic water consumption is low, water-saving plumbing fixtures and appliances are widely used. Cleanouts are used to provide access for flushing, manholes are rarely used. Air release risers are required at or slightly downstream. Plastic pipe are typically used these are resist to erosion. Collecting only settled wastewater in this manner has advantages:

1. **Reduced water requirements**: Since the sewers are not required to carry solids, large quantities of water are not needed for solids transport.
2. **Reduced excavation cost**: With the troublesome solids removed, the sewers do not need to be designed to maintain a minimum flow velocity for self-cleansing. Therefore, rather than being installed on a straight path with a uniform gradient, they may be laid with curvilinear alignment with a variable or inflective gradient.
3. **Reduced materials cost**: The sewer and any pumping equipment can be reduced in size (and pumps handling only liquids are simpler). In addition, expensive manholes can be replaced with much less costly cleanouts or flushing points, since mechanical cleaning equipment is not necessary to maintain the sewers in a free-flowing condition.
4. **Reduced treatment requirements**: Screening, grit removal and primary sedimentation or treatments in anaerobic ponds are not needed at the treatment works, since these unit processes are performed in the interceptor tanks.

These systems cannot handle commercial waste water with high grit or settleable solids levels. Disposing of collected seepage from septic tank is the most complex aspect of small bore sewerage system. Odour is the most common problem in these systems. In united state corrosion outside the pipe has been a problem notice in these systems.

2.3. DESIGN OF SEWERAGE SYSTEM

The flow in simplified and conventional sewers is always open channel flow. There is always some free space above the flow of wastewater in the sewer. These are designed based on the properties of a circular section and Manning's equation **(Mara, 1996)**. While in case of small bore sewerage system sewer is in open channel flow and in pressure flow **(Otis, 1985).**

The hydraulic design of simplified sewers requires knowledge of the area of flow and the hydraulic radius. These two parameters vary with the depth of flow.

2.3.1. HYDRAULIC CONCEPTS

Two hydraulic design approaches can be used for the design of sewers: minimum self-cleansing velocity and minimum tractive tension.

The first approach is based on the requirement for a minimum flow velocity in order to avoid the deposition of solids into the pipes. This concept considers that the minimum self-cleansing velocity at peak flow calculated for the system will be enough to carry the solids away, even if this is achieved only once a day. This approach is also applied in the design of conventional sewerage. In conventional design, the minimum self-cleansing velocity of, at least, 0.6m/s is considered **(CPHEEO, 1993)** sometimes even 1m/s **(Mara, 1996)**, the value is equal to (e.g. ASCE standard), or smaller than (British code and polish code), table (2.1) reviewed the require value of minimum velocity(**Chiueh, 1999).** Simplified sewers are designed using 0.5m/s as the standard value for self-cleansing velocity in order to obtain the main design parameters (sewer gradient and diameter).While small bore sewers minimum self cleansing velocity are achieved is not necessary because these carry the settled waste water **(Otis, 1985; USEPA, 2000)**. Maximum velocity of flow at which pipe can erode were occurs at flow velocity in excess of 4m/sec **(Sinnatamby, 1986)**.The velocity is directly proportional to a power function of the gradient and inversely proportional to a power function of the peak flow, thus, the lower the minimum velocity; the shallower the sewer can be kept. Nevertheless, the value for peak flow, which was taken as 2.2l/s in the first trials with condominial systems in Natal, is now 1.5l/s and this is the standard value stated in the Brazilian code **(ABNT, 1988)**. This approach is currently used in condominial designs with successful examples of application especially in the Northeast of Brazil **(Mara, 1996; Sinnatamby, 1986)**.

The second approach, based on minimum tractive tension, also has the objective of ensuring the transportation of solids. However, this approach is based on tangential force exerted by the flow of sewage per unit of wetted boundary area. This force is enough to keep the solids in suspension and prevent the solid deposition which blocks the sewer **(Broome, 2009)**. (**Yao, 1974)** used this concept for designing of sewer. Therefore, the design parameters are now obtained by considering that the minimum tangential force (or minimal shear stress) of 1Pascal is satisfactory for simplified sewerage design **(Broome, 2009; Mara, 1996; Bakalian *et al.*, 1994)**. Critical shear stress value between 1Pascal to 2Pascal is sufficient for sanitary sewer system **(Yao, 1974).**

Comparing both approaches, the adoption of minimum tractive tension appears to provide a more economical design. Although, in the examples studied **(Mara, 1996; Bakalian *et al.*, 1994)**, the comparison between both approaches did not result in significant differences for the pipe diameter, the calculated minimum gradients in the second approach were lower than the first. **(Chiueh, 1999)** redesign a sewerage system based on the average shear stress 1Pascal for Taiwan. According to his study pipe size is reduced. In original condition the pipe size in Taiwan having the largest diameter 1000mm while in redesign it get only 700mm and slope is also changed its changed from 0.010 to 0.004. Moreover, the state water company of Parana in the South of Brazil, has simplified systems designed with a minimum shear stress of 1Pascal which have been operating satisfactorily for over 15 years, thus providing a reliable reference for the application of this methodology, which is also adopted in the Brazilian code **(ABNT, 1988)**.

Table: 2.1 Minimum self-cleansing criteria for different country

Source	Country	Minimum velocity	Pipe condition
ASCE	USA	0.6	Full/ half full flow
British code of practice	UK	0.75	At least once in a day
Polish code of standards	Poland	0.8	Full flow
Taiwan standard for sewer work	Taiwan	0.6	Design peak flow
CPHEEO	India	0.6	At minimum peak flow

Source: (Chiueh, 1999)

2.3.2. DESIGN PARAMETERS

There are other parameters which governs the hydraulic design

1. Design period

In conventional sewerage system sewers are designed for the period of 30 years **(CPHEEO, 1993)** such long periods capture economy and maintains of sewer in low flow conditions **(Bakalian,1994)**.While in case of simplified and small bore this period is reduced and these can be designed for 10- 30 years**(Otis, 1985).**

2. Peak flow

The estimation of peak flow is calculated by equation is based on:

Size of the population (initial/final), Percentage of water consumption that returns as sewage (usually considered a loss of 15 percent due to water usage that is not collected by housing connections - i.e. cooking, gardening, cleaning and others), and the k_1 and k_2 coefficients of maximum daily and hourly flow variation, respectively. Consideration should also be taken for the inclusion of upstream flows discharging into the sewer as well as for the possibility of groundwater infiltration into the pipes. This infiltration may occur due to imperfections in pipe joint sealing and it is typically considered as 0.2-0.3l/s/km **(Sinnatamby, 1986)**. Peak flow for small bore sewerage system is the 2 of average flow **(Otis, 1985).** While for conventional it is 3 to average flows and for simplified it is 1.5l/s this value represent the discharge from a single WC.

$$Q = \left[\frac{(C \times K_1 \times K_2 \times P \times w)}{86400}\right] + Q_C + Q_i$$

Where

Q = peak flow in a sewer section (l/s)

C = sewage return factor (usually adopted 85%)

k_1= coefficient of maximum daily flow variation

k_2= coefficient of maximum hour flow variation

P = contributing population

w = water consumption (l/person x day)

Q_c =flow from upstream flow contributions (l/s)

Q_i =infiltration flow (l/s)

3. Proportional depth of flow

This parameter is based on the properties of circular sections and expresses the ratio between the depth of flow in the pipe and the pipe diameter. It is used during the design to check if the depth of flow is high enough to ensure the transportation of solids at peak flow and if it is low enough to guarantee sufficient ventilation at the end of the design life. Therefore, the minimum and maximum values for the proportional depth of flow (d/D) are: $0.2 < d/D < 0.8$

Minimum depth of flow in pipe: 0.2 times pipe diameter

Maximum depth of flow in pipe: 0.8 time pipe diameter

4. Minimum gradient

The necessary slope is required to move the solids. Design a sanitary sewer with a slope that achieves the specified minimum self-cleaning velocity for the expected design flow. For a pipe expected to flow at depths less than full use the peak design flow rate to establish a slope to achieve this velocity. In conventional sewerage system the pipe is laden deeper for moving the solids. For a 2l/s peak flow slope should be 0.006 **(CPHEEO, 1993)** while for 30l/s the slope may reach up to the 0.001. While in simplified sewerage system the minimum sewer gradient is (1/167) recommend for getting self cleansing velocity. Minimum sewer gradient is (1/225) recommended for tractive tension. Gradient can be calculated by using the equation for any flow condition.

$$Imin = 2.33 \times 10^{-4}(\tau min)^{16/13} q^{\frac{-6}{13}}$$ **(Mara, 2008; Broome, 2009)**

$$Imin = 0.01 q^{\frac{-2}{3}}$$

Where

τmin= minimum tractive tension (N/m^2)

q = discharge (m^3/s)

(Esen, 1993) give an expression for calculating the slope by using the minimum velocity. This equation is valid for the circular sewer for which the depth of flow less than the 40% of the sewer diameter.

$$f_1\left(\frac{d}{D}\right) = \frac{q}{vD^2}$$

$$s = \left(\frac{vn}{\emptyset D^{\frac{2}{3}} f_2}\right)^2$$

$$f_2 = 0.6148 f_1^{\ 0.4256}$$

5. **Velocity**

The velocity of the waste water is an important parameter in a sewer design. A velocity must be maintained to reduce solid deposition in the sewer. Minimum velocity for the conventional sewer is 0.6m/s **(CPHEEO, 1993)** while for simplified sewerage system the velocity 0.5m/s recommended. Number of equations are put forward for getting the velocity out of which manning equation are used for open channel flow.

$$v = \frac{1}{n} r^{\frac{2}{3}} s^{\frac{1}{2}}$$

6. Pipe diameter

The minimum pipe diameter recommended by the ten standards is 200mm these ten state standards are adopted by ten specific states (Indiana, Iowa, Michigan, Minnesota, Missouri, Newyork, Ohio, Pennsylvania, Wisconsin, and Illinois) **(USEPA, 2002).** 150 mm minimum pipe diameter is recommended in India **(CPHEEO, 1993)**. 100mm is usually recommended as the minimum diameter for pipes applied in simplified sewerage designs **(Sinnatamby, 1986).** While for small bore this diameter is less than the 100mm. 75mm diameter pipe have been successfully used in Scandinavia **(Sinnatamby, 1986)**. In these system solids are not transported these are previously settle. The diameter of sewers can be calculated by the equation below

$$D = (nq)^{\frac{3}{8}} k_a^{\frac{-3}{8}} k_r^{\frac{-1}{4}}\ Imin^{\frac{-3}{16}}$$ **(Mara, 2008)**

Where

Q = peak flow (l/s)

I_{min}= minimum gradient (m/m)

k_a = coefficient of proportional area

k_r = coefficient of proportional hydraulic radius

D = pipe diameter

n = Manning's Roughness Coefficient

For d/D(0.8) k_a and k_r value 0.3042, 0.6736 respectively diameter of the sewer is designed to carry the water upto the end of design period.

6. Depth of sewers

Two parameters are mainly responsible for the shallow depth of the sewers: layout and gradient. In comparison with conventional systems, simplified sewerage layouts allow a reduction in the overall length of the sewer lines, which is especially true in backyard condominium layouts. The sewer gradient may be directly related to the flow velocity or to the shear stress. The flow velocity is also the parameter adopted in conventional designs; however, simplified sewerage applies this parameter in a less conservative way resulting in a design with a lower gradient.

With the association of these reductions in sewer extension and gradient, the pipelines can be kept shallower, and hence decrease the cost of excavation as well as the number of pumping stations required. Moreover, the in-block sewers are laid in areas without heavy traffic and, consequently, the cover layer over the crown that is required for protection (cover to soffit) of the sewer can be thinner than in conventional sewerage designs. In simplified sewerage system typical sewer depth are 0.6m below the sidewalk and 0.9 to 1.5 for the residential streets **(Bakalian, 1994)**. The minimum cover criteria adopted will depend on local factors, in particular on the pipe material used. In northeast Lahore, Pakistan 230mm diameter reinforced concrete sewers were laid successfully in lanes with minimal traffic loading at covers of only around 250 mm. In Britain, good quality clay pipes can be laid through gardens at a depth of 350mm. In Brazil a minimum cover of 200mm is used for in-block clay or PVC sewers, and 400mm for in-pavement sewers **(Sinnatamby, 1986).**

In conventional design layouts, trunk pipelines should be built in the streets around the house blocks to potentially allow individual connections for all the households. On the other hand, simplified systems are designed in a way that the wastewater from households in the same block is collected by a shallow and small diameter pipeline and then, delivered to the trunk sewers by a single (or just a few) connection as shown in figure (2.1).

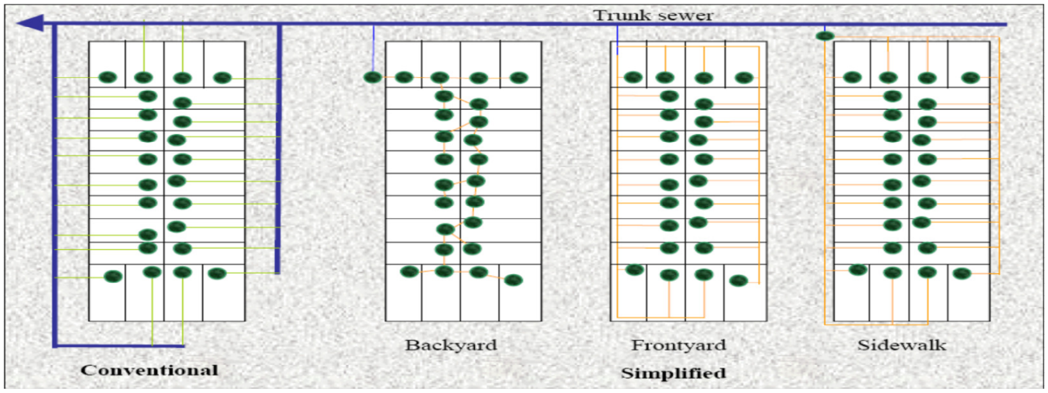


Fig: 2.1 Conventional and simplified sewerage system layout

Source: (Sarmento, 2001)

2.3.4. SEWER APPURTENANCES

The various accessories on the sewerage system those are necessary for the efficient operation of the system. They include manholes, lamp holes, clean outs.

Manholes form one of the essential ancillary structures in any sewerage system. Manholes are the openings of either circular or rectangular in shape constructed on the alignment of a sewer line to enable a person to enter the sewer for inspection, cleaning and flushing. They serve as ventilators for sewers, by the provisions of perforated manhole covers. In addition, they facilitate the laying of sewer lines in convenient length. They are generally provided at every change of alignment or gradient of sewers at every junction of two or more sewers, at head of all sewers or branches, wherever there is a change in size of sewer and at regular intervals in the sewerage system **(CPHEEO, 1993).**

IS: 4111(Part1)-1986 covered the detail related to the Arch type, rectangular and circular manholes. Guidance for design of manholes has been elaborated. Brickwork construction and plastering have been modified and given in detail. Construction details of channels and benching inside the manhole have been covered in detail. Guidance for fixing rungs and manhole covers and frames have been included. When two sewers meet at a different level the guidance for providing drop manholes has been given in detail.

In simplified sewerage manholes are replaced by the inspection chamber or by junction boxes. figure (2.2) shows a brick inspection box chamber in Brazil. In Pakistan cylindrical concrete chamber is used shown in figure (2.3) simplified manholes are similar to the conventional manholes they are reduced in size from 1.5 m to 0.6-0.9m.

Fig: 2.2 Simplified brick junction chamber

Fig: 2.3 Junction chamber in Pakistan

Source: (Mara, 2001)

1. Condomial TILs

CAESB's developed a 100% plastic system for simplified sewerage system is being tested by the company in full-scale projects.

In this system the whole network (pipes and appurtenances) is made of PVC. These units are the TILs these are used in place of the traditional inspection chambers. These are available for 100 mm diameter pipelines and have three entrances (that receive the household wastewater and the sewage from the previous plot) and an outlet for the next connection. Figure (2.4) show the system.

Fig: 2.4 PVC inspection chamber (Condomial TILs)

Source: (Melo, 2005)

2. Special Man-holes

Junction chambers

Man-hole constructed at the intersection of two large sewers.

Drop man-hole

When the difference in elevation of the invert levels of the incoming and outgoing sewers of the man-hole is more than 60cm, the interception is made by dropping the incoming sewer vertically outside and then it is jointed to the man-hole chamber.

Flushing man-holes

They are located at the head of a sewer to flush out the deposits in the sewer with water.

Lamp-holes

Lamp holes are the openings constructed on the straight sewer lines between two man-holes which are far apart and permit the insertion of a lamp into the sewer to find out obstructions if any inside the sewers from the next man-hole

Rapid TILs

These are developed in place of manholes by CAESB. These are easy to clean, reduced the access for the entrance of solids waste and objects of large dimension. Quicker and easy to install these are shown in figure (2.5) and (2.6) respectively

Fig: 2.5 Rapid TILs solid view

Source: (Sarmento, 2001)

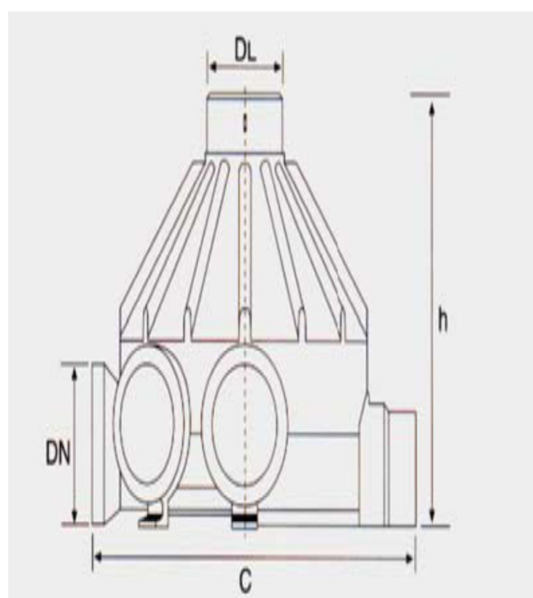


Fig: 2.6 Rapid TILs drawing

Source: (Sarmento, 2001)

3. Intercepting tank (Septic tank)

IS: 2470 (Part1)-1985, lays down the design aspects to be considered for septic tank. It recommends the maximum flow to the tank based on number of fixtures discharging simultaneously. This IS further elaborates the construction details and suggests typical sketches of septic tanks. **IS: 2470 (Part2)-1985**, provides information on treatment and disposal of septic tank effluent, the recommended methods of disposal are soil absorption system, biological filters and up flow anaerobic filters.

2.4. SEWERAGE SYSTEM PROBLEMS

Sanitary sewer problems are caused by several factors including the condition of the sanitary sewer system itself, natural phenomena such as earth movement and rain, and the incorrect usage of the system by the public. The following are typical sanitary sewer system problem.

2.4.1. CORROSION

Corrosion is the main problem of sewerage system. In waste water sulfide is present in the form of H_2S and HS^- and partly as insoluble sulfide. Sulfide in waste waters reacts with dissolved oxygen, and product of reaction is Thiosulfate. H_2S that escapes as a gas from solution in a sewer may be oxidized on exposed surfaces **(Fjerdingstad, 1969)**. If the surfaces are quite dry, free sulfur may be formed, but under moist conditions a species of bacteria named *Thiobacillius concretivorus* oxidizes it to sulphuric acid by the reaction.

$$H_2S + 2O_2 \rightarrow H2SO4$$

The acid produce by this reaction can cause the corrosion of the sewer as sown in figure (2.7).

H_2S oxidation on sewer pipe surfaces was investigated in a pilot scale experimental setup. During the experiments, hydrogen sulfide gas was injected intermittently into the headspace of partially filled concrete and plastic (PVC and HDPE) sewer pipes in concentrations of approximately 1000ppm. Between each injection, the hydrogen sulfide concentration was monitored while it decreased because of adsorption and subsequent oxidation on the pipe surfaces. The experiments showed that the rate of hydrogen sulfide oxidation was approximately two times faster on the concrete pipe surfaces than on the plastic pipe surfaces. Removal of the layer of reaction (corrosion) products from the concrete pipes was found to reduce the rate of hydrogen sulfide oxidation significantly. However, the rate of sulfide oxidation was restored to its background level within 10–20 days. A similar treatment had no observable effect on hydrogen sulfide removal in the plastic pipe reactors. The experimental results were used to model hydrogen sulfide oxidation under field conditions. This showed that the gas-phase hydrogen sulfide concentration in concrete sewers would typically amount to a few percent of the equilibrium concentration calculated from Henry's law. In the plastic pipe sewers, significantly higher concentrations were predicted because of the slower adsorption and oxidation kinetics on such surfaces **(Nielsen, 2008).** The most common species find in concrete corrode sewer after 1 year are *Thiothrix* species, *Thiobacillius plumbophilus, Thiomonas intermedia, Halothiobascillius neapolitanus, Acidiphilium acidophilum, Acidithiobascillus thiooxidans, A. Hyperacidophilic* was the most common species **(Okabe *et al.*, 2007)**.

Under the amount of sulfide that can be produced is strongly influenced by choices that are made in respect to sewer routings, slopes, pipe sizes, pumping or not pumping, and other design features.

Effects of sulfide on different material

The choice of materials of construction will determine whether or not there will be deterioration in those places where sulfide does appear. Material for sewer can directly affect the corrosion rate. For long term service the material used for sewer should be non corrosive.

1. Vitrified clay

This material is immune to attack by sulphuric acid and resistant to all chemicals found in sewage. A vitrified clay sewer properly laid and jointed will, if not disturbed by external forces, remain serviceable indefinitely.

2. Steel

If a steel pipe flows partly filled with wastewater containing sulfide, corrosion may not occur only by the formation of sulphuric acid, but also by the corrosiveness of H_2S toward iron in the presence of air or dissolved oxygen, producing bulky accumulations of iron sulfide. In a pipe completely filled with wastewater there is little or no corrosion even if sulfide is present, provided the pH is above 6.5 and the chloride content is less than 500mg/l. Even where air is injected, corrosion due to dissolved oxygen is generally at a slow rate. However, if there are any high points or pockets, air may collect there and sulphuric acid may form. Serious corrosion has occurred in such locations.

3. Cast Iron

Cast iron pipes generally last longer than steel in all services because the pipe wall is thicker. Like steel pipes, they give good service when completely filled with wastewater provided that the pH is 6.5 or higher and the chloride content is moderate. If the pipe is carrying sewage that contains sulfide and is flowing only partly filled, corrosion may be severe.

4. Asbestos-Cement

Asbestos-cement pipe is susceptible to attack by sulphuric acid, and it therefore is not safe to use for sewers except where it can be assured that sulfide concentrations will be very low because of the greater proportion of cement in the mix, it corrodes more slowly than concrete made with aggregates of an igneous type (granitic or basaltic) but this advantage is counteracted by the thinness of the wall.

5. Concrete

The corrosion of concrete sewers in the presence of H_2S has already been described. Despite its vulnerability, concrete is an important sewer pipe material. For large trunk sewers the corrosion rates are generally lower than in small pipes because the slope, which influences the rate of release of H_2S from the water, is generally smaller. Large pipes have thick walls, so that with small sulfide concentrations the pipe may serve for a long time before it is materially weakened. Concrete may be used for smaller sewers, too, provided there is assurance that there will be very little sulfide. The heaviest corrosion occurred in the area around the sewage level of the concrete sewer pipe. The corrosion rate of this area was 4.3–4.7mm/yr. The corrosion rates decreased according to the distance from the sewage level. The deterioration at the crown of the sewer pipe was lowest, 1.4mm/yr. It is concluded that water and nutrients provided by sewage are important factors for microbial corrosion. Two corroded products were mainly produced, depending on pH levels. Gypsum was formed at pH levels less than 3 on the surface of the concrete sewer pipe and mortar specimens. On the other hand, ettringite was produced when pH levels were higher than 3 inside the specimens **(Mori, 1992).**

6. Plastics

Pipes of polyvinyl chloride (PVC), acrylonitrile-butadiene-styrene (ABS), and polyethylene (PE) have been used for sewers in small sizes. The materials are all resistant to sulphuric acid attack. The plastic and plastic composite materials are usually made into pipes with relatively thin walls because of the high cost of the materials. To prevent fracture or collapse of the pipes, they must be laid carefully to avoid unacceptable deflections under the backfill load. A composite pipe is made by mixing polyester resin with sand and then providing fibreglass reinforcement. The most vulnerable part of the composite is the glass, because water has the ability to creep along the fibres. The pipe must be manufactured so that this cannot happen. Under some conditions pipes of this kind have deteriorated when sulphuric acid was present and the pipes were under load.

Prevention for corrosion

Nitrite dosing is a promising technology to prevent sulfide and methane formation in sewers, due to the known inhibitory/toxic effect of nitrite on sulfate-reducing bacteria (SRB) and methanogenic archaea (MA). The dependency of nitrite-induced inhibition on sulfide and methane producing activities of anaerobic sewer biofilm on nitrite levels and exposure time is investigated using a range of nitrite concentrations (40, 80, 120mg-N/L) and exposure time up to 24 days. The inhibition level was found to be dependent on both nitrite concentration and exposure time, with stronger inhibition observed at higher nitrite concentrations and/or longer exposure time. However, the time required for achieving 50% recovery of both sulfate-reducing and methanogenic activities after the cessation of nitrite dosage only marginally depended on nitrite concentration. Model-based analysis of the recovery data showed that the recovery was likely due to the regrowth of SRB and methanogens. The field trial confirmed that intermittent dosing of nitrite can effectively reduce/prevent the formation of both sulfide and methane **(Jiang *et al.*, 2010)**

Fig: 2.7 235 mm asbestos pipe showing the effect of 14 year of acid attack

Source: www.cpda.co.uk

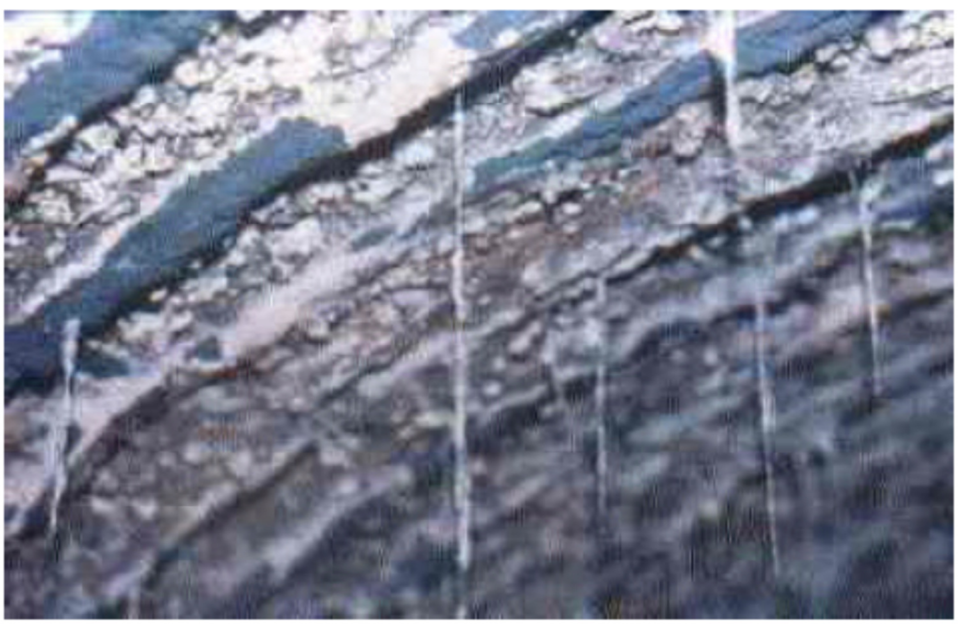


Fig: 2.8 Concrete pipe was attacked by the sulphuric acid oxidised from atmospheric hydrogen sulfide in presence of moisture

Source: www.cpda.co.uk

2.4.2. ACCUMULATION OF SOLIDS

Deposition of solids in sewer causes the problem in sewer working. Accumulation of solids directly depends upon the velocity or shear stress. Solids deposited in sewer when the sewer was not properly designed and its maintenance has been not occur regularly.

2.4.3. INFLOW

Rain water entering in the sewer can cause the overflow in sewer. During rainy season the most of countries facing overflow problem. These are occurred mostly where the combined sewerage system are install.

CHAPTER-3
APPROACH FOLLOWED

3.1. INTRODUCTION

Objective of the present study is to design sewerage system for a village near to Ludhiana. Approach followed for the design of above system is briefly described in this chapter. The work was divided into three phases. These are:

- Background information collection
- Analysis of data, development of site map and obtaining basic information needed for the design
- Design of sewerage system

Approach followed for completing each phases are given below.

3.2. BACKGROUND INFORMATION COLLECTION

For completing this work element, site was visited, surveyed and also the local villagers at the site were discussed to know the basic design requirement. The required information was collected from the site, maps and data available from different secondary data sources. The following data was collected in this phase of study.

1. Current population distribution pattern and future plans of growth

Current human and cattle population of the village were collected from the site. Site was visited to locate the future development area. These areas were located and marked on the map. For future growth, incremental rate was also collected.

2. Location details, land use patterns and drainage patterns of the area

Village is near to the grand trunk road and on one side, there is railway track. Land use pattern and drainage of water were collected from that site. Detailed plan showing buildings, population, cultivation land, future growth and roads layout of village drawn to a scale of 1:1000 has been used for showing the detail of the area.

3. Water supply and zoning details

This includes the quantity, pattern and schedule of water supplied to that village. This whole data was collected from the site. General topography of the village was studied. Required elevation detail was collected from the village.

3.3. ANALYSIS OF DATA, DEVELOPMENT OF SITE MAP AND OBTAINING THE BASIC INFORMATION FOR DESIGN

The data collected from the village was analysed for getting the basic information required for the design. Following data was identified in this phase of study:

1. Present population and population forecasting

In this village, population is scattered. The data collected from this village was according to the house number. From these house numbers, the stretch wise population was collected. Population in this village is mostly present in middle of the village and near to the main road. The household and cattle population was referred for current population. For estimation of current population, population equivalent concept was followed and population obtained is marked on the map.

Approach followed for future population estimation was based on the two concepts. First concept is new area development and second concept is population increase in already settled area. Vacant plots and undefined area is included in new area development. For undefined area, population is estimated through the concept of population density of the nearby area. For vacant plot, population is estimated through the population equivalent concept. For this, average cattle population and average person in each house is taken as one and five respectively. Population increment rate in settled area is collected. Future population is estimated using the equation:

$$P_n = \left(1 + \frac{r}{100}\right)^n$$

Where

P_n = population after n number of years

r = incremental rate

n = number of years

Projected population is the combination of current population and its increment over the next 30 years population through new housing development and vacant home filling by reestablishment. These projected populations have been marked on the map.

2. Potential sites for STP

In this site, 5 ponds are there, these have potential to use as STP plant. The potential site for STP plant was identified and located in map. These STP site was decided on the basis of village topography and also satisfies the local villagers.

3. Site map preparation

Different colour code, numbering system and symbols for different situation were used for making the map. Details such as, road network, layout of buildings, population distribution, natural drains, boundaries and land use patterns of adjoining areas have been marked on the site map.

4. Finalizing the schemes for the sewerage system

Based on the background information collected, schemes for sewerage system were decided. Decisions were taken on the basis of the gravity flow, satisfying the local villagers and discussions with the local authority.

Some of the aspects given importance in deciding the scheme for sewerage system are:

- Preventing clogging of sewers and minimizing need for frequent cleaning
- Minimizing the excavation costs and eliminating the need for intermediate pumping of sewage

3.4. DESIGN OF SEWERAGE SYSTEM

Sewerage system consists of various sub systems and each sub system is required to be designed for proper functioning of the system. These are designed keeping in view the objective, data and background information available. While designing, each and every subsystem was given importance. First step in the design of a sewerage system is to decide the scheme. Finalizing the scheme require careful review of background information and field data. General considerations of designing the sewerage system was topography of the area, availability of land and its use pattern, population density, social and cultural acceptability of the scheme.

Second step of sewerage system designing includes the layout preparation. The layout of sewer was finalized based on the distribution of population and topography. Codes for each street and main sewer are shown in Layout. Layout of sewers, junction name, current population, elevations, and flow direction are indicated in the map with different colours.

Three different type of sewerage systems were tried.

Simplified sewerage system

Small bore sewerage system

Conventional sewerage system

3.4.1. SIMPLIFIED SEWERAGE SYSTEM

The village is having scattered population and during most part of the year, self cleansing velocities cannot be ensured in the sewer. For getting the self cleansing velocity, household level siphon systems have been incorporated into the sewerage system. Both household sewage and the wastewater from the household cattle tank are carried into the siphon system located within the premises of the household. From here, the sewage is discharged into the sewer. Sewers are designed on the basis of tractive tension. Manholes provided in this system is according to **(IS: 4111 (part1)-1986).** In branch sewer, manholes are provided according to the simplified.

Different components included in designing of the present case system are:

- Cattle tanks for collecting the wastewater and cattle dung coming from the Dungar (cattle house).
- Siphon system receive both domestic sewage and wastewater from the cattle tank.
- Sewers.
- Manholes and other appurtenances.

1. Cattle tank

This tank is just similar to the septic tank. This tank is designed to hold the solids and floating material while the clear water is allowed to go into the siphon system. For ensuring this, a provision has been provided in the cattle tank as shown in figure (4.5). Dung accumulating in the tank is supposed to remove daily for 6-15 cattle. While for 1-5, cattle tank are supposed to clean once in a week. The cattle tank is supposed to hold the dung generated over the day at 8% consistency. Each cattle head is supposed to consume 75lpcd of water and produce 7kg of wet dung.

Equation used for designing of cattle tank

Quantity of waste water produced = water consumption rate × number of cattle

Volume of tank includes the volume for sludge accumulation and wastewater. In cattle tank, wastewater coming is very less in comparison to sludge (cattle dung). Volume for wastewater is taken as constant as 200liter. Volume for sludge is varying according to cattle number.

Total volume = volume for sludge accumulation + volume for waste water

$$\text{Volume required for sludge accumulation} = \frac{\text{Total Discharge in a day}}{\text{Number of times empty in a day}}$$

Shape of tank is rectangular with length to width in the ratio of 2:1. One side of the tank is sloppy that provide extra space for sludge deposition and thus preventing the sludge movement. Tank dimension is calculated by using the equation:

Volume for a rectangular tank = length × width× depth

Depth with 1: 10 slope = length/10+ depth

<u>Design example:</u>

Production of cattle dung in a day = 7kg/day

Water consumption rate for cattle house = 75lpcd (It includes whole water utilized for washing of cattle, cleaning of floor and drinking purpose)

Quantity of waste water produce = water consumption rate × number of cattle

= 75lpcd × 2

Discharge = 150lpd

Number of times tank will empty = 1 times in a day

$$\text{Volume} = \frac{\text{Total discharge in a day}}{\text{Number of times empty in a day}}$$

$$= \frac{150 \text{ lpd}}{1}$$

$$= 0.15 m^3$$

In cattle, water coming is very less in comparison to sludge (cattle dung), so varying the size of tank with respect to water is not a good idea. So we are taking this volume as constant volume as $0.2 m^3$.

Assume the consistency of cattle dung is = 8%

= 8g/100ml

Volume required for sludge accumulation = 0.01 × cattle × number of day sludge retained

$= 0.01 \times 2 \times 7$

$= 0.14$

Total volume = volume for sludge accumulation + volume for waste water

$= 0.14 + 0.2$

$= 0.34$

Volume for a rectangular tank = length × width× depth

$0.34 = 2 \text{ width} \times \text{width} \times 0.6$ (Here depth =0.6)

By solving, we get Width = 0.5m

Depth = 0.6m

Length= 1.1m

Depth with 1: 10 slope = length/10+ Depth

$= 1.1/10 + 0.6$

$= 0.7 m$

$$\text{Maximum depth of sludge} = \frac{\text{volume required for sludge accumulation}}{\text{Area of the tank}}$$

Area of the Tank = rectangular tank area + extra chamber area

= (length ×width)+ (½ length× width)

$= (1.1 \times 0.5) + (1/2 \times 1.1 \times 0.5)$

$= 0.825 m^2$

Maximum depth of sludge = $\frac{0.14}{0.825}$

$= 0.167 \approx 0.2m$

Clear space depth = $\frac{\text{Volume for waste water}}{\text{Area of the tank}}$

$= \frac{0.2}{0.825}$

$= 0.2m$

Free board provided for this tank = 0.2m

Pipe of 100mm is provided at the outlet side according to the IS: 2470(part1)-1985

2. Siphon system

Line diagram of the siphon system used is shown in figure (4.6) **(Cosgrove, 2008)**.This siphon works on the principle in a way that as sewage flow into the tank, the trap is full of water, it gradually rises above the bottom of the bell. Thus, air confines between the mouth of the bell and surface of the water in the trap. As head is increased, air is compressed in the long leg of the trap, thus gradually forcing out the water to escape the lower end. The difference in the water level in the two leg of the trap is always equal to the head of water above the level of water in the bell. When the equilibrium of two columns is destroyed, siphon starts working. The water is thus drawn out in the bottom of the bell, siphon gets broken by the admission of air and again it get started, when it is filled.

Depth of sewage that will accumulate in a tank depends on the length of the short leg of trap. The head from the level of liquid in the bell to the surface of liquid in the tank will be equal to the distance from the bend of trap to the surface of the outlet pipe. For getting the desired value of velocity, the siphon system of 0.5m depth is used. For getting the velocity, Bernoulli equation is used for the system.

$$H = \frac{V^2}{2g} + h_f + \text{minor loss in pipe}$$

Where

h_f = major loss in pipe

Darcy's formula for head loss due to friction in pipe

$$h_f = \frac{4flv^2}{2gd}$$ **(Bansal, 1998)**

Where

f = Darcy frictional coefficients

d = diameter of the pipe

v = velocity

g= acceleration due to gravity

l= length of pipe

Darcy found that the constant f depends upon roughness of the pipe surface. He recommended the following value of f.

$f = 0.005(1 + \frac{1}{40d})$ for new and smooth pipes

Minor losses are due to entrance and bending which are being referred here.

Entrance loss = $\frac{0.5v^2}{2g}$

Bending loss =$\frac{kv^2}{2g}$

$$v = \sqrt{\frac{2gh}{\left(1+\frac{4fl}{d}+0.5+K\times number\ of\ bends\right)}}$$

Where

k= bending constant (www.engineeringtoolbox.com)

f = frictional coefficient

v= velocity

d= diameter of the pipe

$$Q = \frac{\pi d^2}{4} \times v$$

Siphon chamber is based on the discharge coming from the households. These chambers are designed to carry the waste water for different household size. These are designed up to the 50 users. Square tank is used for siphon chamber having slope at the bottom. Extra chamber is provided for storage of some solids. Siphon system only allows storing water for some time and then discharging with a particular velocity. This system is designed in a way that water moves along with the solids. Equations used for designing of chamber are:

Discharge Q= quantity of water supplied× number of person× return factor

Volume V= $\frac{\text{Total discharge in a day}}{\text{Number of times empty in a day}}$

Design example:

Pipe diameter selected for the siphon system = 75mm

$$H = \frac{V^2}{2g} + h_f + \text{minor loss in pipe}$$

$$hf = \frac{4flv^2}{2gd}$$

$f = 0.005(1 + \frac{1}{40d})$ for new and smooth pipes

Now f for 0.075m pipe = 0.00667

Minor losses are due to entrance and bending which are being referred here.

$$H = \frac{v^2}{2g} + \frac{4flv^2}{2gd} + \frac{0.5v^2}{2g} + \frac{kv^2}{2g} + \frac{kv^2}{2g} + \frac{kv^2}{2g}$$

$$H = \frac{v^2}{2g}(1 + \frac{4fl}{d} + 0.5 + 3k)$$

k value is 0.3 (www.engineeringtoolbox.com)

$$0.4625 = \frac{v^2}{19.6}\left(1 + \frac{4\times0.00667\times0.9}{0.075} + 0.5 + 3 \times 0.3\right)$$

Maximum v = 1.82 m/s

$$Q = \frac{\pi d^2}{4} \times v$$

$$Q = \frac{\pi\times0.075^2}{4} \times 1.82 \times 1000$$

Q = 8.04l/sec

Through this siphon system, 8.04l/sec of water is discharged with a velocity of 1.8m/s.

Square siphon chamber is having 0.5m depth having slope at both sides of additional chamber.

Discharge = water consumption × Number of person × Return factor

= 135 × 5×0.85

= 574l/day

Volume of the tank = $\frac{\text{Discharge}}{\text{Number of times empty in a day}}$

$= \frac{574}{4}$

$= \frac{143.5}{1000}$

= 0.143m^3

Width of the tank= $\left(\frac{volume}{Depth}\right)^{\frac{1}{2}}$

Width of tank = $\left(\frac{0.143}{0.5}\right)^{\frac{1}{2}}$

= 0.536m

Length of the tank = 0.536m

3. Sewer

The design of simplified sewer is based on the concept of tractive tension. This is the tangential force exerted by the flow of wastewater per unit wetted boundary area. The tractive tension is derived from the component of the weight of wastewater in a length of sewer that is acting in the direction of flow and is balanced by tractive tension acting on it. Design of sewer can be done manually by using the excel sheet or through by the simplified sewerage software.

The program requires the sewer network, sewer may only be linked in a tree type manner i.e. the network expands from the most downstream point branching at junction to several upstream ends and there must be no loop in the network. Minimum informations required by the software are number of people connected to sewer, length of sewer, ground level at each end, junction name and drop junction. Program screen containing visual editor, data entry edit, result table, calculator is shown in figure (3.1).

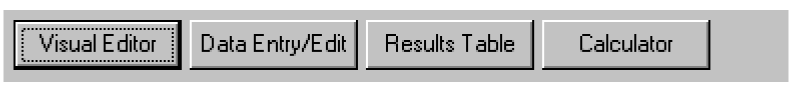


Fig: 3.1 The main tool bar

Source: http://www.efm.leeds.ac.uk/CIVE/Sewerage

By using Visual editor screen, sewer network is drawn, and parameter required for description of sewer can be edited. Data entry and edit screen is used for editing the sewer network. Result table screen gives the result for the sewer network. Calculator shows the calculation. Due to some problem with software, manually calculation is done.

Incremental rate per year for village is referred for calculating the projected population.

All the water supply is not collected as sewage from the household. Since some water is lost in evaporation, seepage into ground, leakages etc., only 80-90% of water supply may be expected to reach the sewer. A significant quantity of water is lost in lawn irrigation, water sprinkling in open areas and other household uses where water is lost in evaporation. Hence, only 85% of the supplied water has been considered as sewage generated by the households.

The minimum flow used in this sewerage system is not referred here. The flow coming from the siphon system is used as minimum peak flow. No Infiltration has been considered because of the usage of PVC pipe. For sewer design, peaking factor of 2.4, tractive tension of 1.5Pascal and 0.9m sewer cover has been considered.

Manning coefficient for PVC pipe is referred as 0.013 **(www.engineeringtoolbox.com).** The manholes according to the simplified sewerage system cannot be used due to more depth of the sewer. Conventional manholes according to **IS: 4111 (part1)-1986** were provided at major junctions and simplified manholes were provided at branch line. Manholes were provided at upstream end, at the junction and also where there is change in direction of sewer.

Sewer design includes:

Determine the initial and final peak flow by using the equation given below.

$$Q = \frac{K1 \times K2 \times P \times W}{86400}$$

Where

Q = daily peak flow

K_1= peak factor

K_2= return factor

W = average water consumption

Determine the minimum gradient for any particular wastewater flow. For minimum gradient, the minimum peak flow value is considered. Minimum gradient required for sewer is calculated by using the equation:

$$Imin = 2.33 \times 10^{-4} (\tau min)^{16/13} q^{\frac{-6}{13}}$$

Where

Imin = minimum gradient required for sewer (m/m)

τmin= minimum tractive tension (Pascal)

q= initial peak flow (m^3/s)

Find diameter of the sewer using the design peak flow and assume d/D=0.8 at full flow condition. Diameter of the sewer is calculated by using the equation given below. Here, K_a and K_r are referred for d/D=0.8.

$$D = (nq)^{\frac{3}{8}} k_a^{\frac{-3}{8}} k_r^{\frac{-1}{4}} \ Imin^{\frac{-3}{16}}$$

Where

D = pipe diameter

I_{min}= minimum gradient (m/m)

k_a = coefficient of proportional area

k_r = coefficient of proportional hydraulic radius

n = Manning's Roughness Coefficient

Check depth of the flow at initial and for final flow. Find the d/D value and it is in the range of 0.2- 0.8. For initial flow, it is not less than the 0.2 and for final flow, it is not more than the 0.8. If d/D is less than or more than the value, then pipe size and slope will change. The lower limit ensures that there is sufficient velocity of flow to prevent solids deposition in the initial part of the design period, and the upper limit provides for sufficient ventilation at the end of the design period.

$$k = \frac{nq}{D^{\frac{8}{3}} \times i^{\frac{1}{2}}}$$

Where

n= manning coefficient of friction

D= diameter of the pipes (m)

i = gradient (m/m)

k = fractional number

The value of k is determined for selected diameter, slope, n and known value of Q. From k value in table (3.1), **(Metcalf, 1981)** d/D (ratio of depth of flow to diameter of pipe) is determined.

Once slope and diameter are decided, find the invert level of the upstream and downstream ends. These are worked out with respect to surface elevations.

Invert level of sewer at downstream side ≤Invert level at upstream side - length× Gradient

Invert level at upstream side ≥ Datum level- (minimum required cover + diameter)

Depth at upstream side = Ground upstream level- invert level upstream

Table: 3.1 k value for circular channels in terms of diameter.

$Q = (K'/n)D^{8/3}S^{1/2}$

$\frac{d^a}{D}$	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	....	0.000047	0.00021	0.00050	0.00093	0.00150	0.00221	0.00306	0.00407	0.00521
0.1	0.00651	0.00795	0.00953	0.0113	0.0131	0.0152	0.0173	0.0196	0.0220	0.0246
0.2	0.0273	0.0301	0.0331	0.0362	0.0394	0.0427	0.0461	0.0497	0.0534	0.0572
0.3	0.0610	0.0650	0.0691	0.0733	0.0776	0.0820	0.0864	0.0910	0.0956	0.1003
0.4	0.1050	0.1099	0.1148	0.1197	0.1248	0.1298	0.1349	0.1401	0.1453	0.1506
0.5	0.156	0.161	0.166	0.172	0.177	0.183	0.188	0.193	0.199	0.204
0.6	0.209	0.215	0.220	0.225	0.231	0.236	0.241	0.246	0.251	0.256
0.7	0.261	0.266	0.271	0.275	0.280	0.284	0.289	0.293	0.297	0.301
0.8	0.305	0.308	0.312	0.315	0.318	0.321	0.324	0.326	0.329	0.331
0.9	0.332	0.334	0.335	0.335	0.335	0.335	0.334	0.332	0.329	0.325
1.0	0.312									

where Q = flowrate, m^3/s
n = Manning coefficient of friction
D = diameter of conduit
S = slope of energy grade line, m/m.
$^a d$ = depth of flow
Note: $m^3/s \times 35.3147 = ft^3/s$

Source: (Metcalf, 1981)

Design example:

Sewer number = 1

Direction of flow for sewer number 1 = 1 to 2

Length of sewer = 100m

Present peak flow = 5lps

Future peak flow = 15lps

Ground level at 1st junction =99.07

Ground level at 2nd junction = 99.02

Minimum cover up to pipe invert = 1m

Minimum tractive tension= 1.5Pascal

Minimum gradient required for minimum peak flow is

$$Imin = 2.33 \times 10^{-4}(\tau min)^{16/13} q^{\frac{-6}{13}}$$

$$Imin = 2.33 \times 10^{-4}(1.5)^{16/13}(5 \times 10^{-3})^{\frac{-6}{13}}$$

$$= 0.0044$$

Now, calculate the diameter of the sewer for final flow (Q_f) in sewer. Here K_a and K_r are taken for d/D =0.8.

$$D = (nq)^{\frac{3}{8}} k_a^{\frac{-3}{8}} k_r^{\frac{-1}{4}} Imin^{\frac{-3}{16}}$$

$$D = (0.013 \times 0.015)^{3/8} \times 0.6736^{-3/8} \times 0.3042^{\frac{-1}{4}} \times 0.0044^{\frac{-3}{16}}$$

$$D = 0.175\text{m}$$

Now, choose the sewer diameter 175mm and slope 0.0044.

Check depth of flow at initial flow and final flow

$$k = \frac{nq}{D^{\frac{8}{3}} \times i^{\frac{1}{2}}}$$

$$k = \frac{0.013 \times 0.005}{0.175^{\frac{8}{3}} \times 0.0044^{\frac{1}{2}}}$$

k = 0.1022

$\frac{d}{D}$ initial= 0.49

$$k = \frac{nq}{D^{\frac{8}{3}} \times i^{\frac{1}{2}}}$$

$$k = \frac{0.013 \times 0.015}{0.175^{\frac{8}{3}} \times 0.0044^{\frac{1}{2}}}$$

$$= 0.306$$

$$\frac{d}{D} = 0.8$$

From table (3.1), d/D value is calculated and it is in the range of 0.2-0.8**.** If d/D is less than or more than the value then the pipe size and slope will change.

The lower limit ensures that there is sufficient velocity of flow to prevent solids deposition in the initial part of the design period, and the upper limit provides for sufficient ventilation at the end of the design period.

For sewer number (1), 175mm diameter pipe having the slope of (1/225) is used.

Invert level at upstream side = Datum level- (minimum required cover + diameter)

= 99.07- 1

= 98.07

Invert level of sewer at downstream side = Invert level at upstream - (length× Gradient)

= 98.07-(100×0.0044)

=97.63

Depth at upstream side = Ground upstream level- invert upstream level

= 99.07- 98.07

= 1m

Depth at downstream side = Ground downstream level- invert downstream level

= 99.02- 97.63

= 1.39m

3.4.2. SMALL BORE SEWERAGE SYSTEM

Small-bore sewerage system is used to carry settled sewage from households to offsite treatment. Solids are separated from the sewage in an interceptor tank. The settled sewage from the tank is discharged into the small-bore sewer, where flow occurs by gravity utilising the head resulting from the difference in elevation of its upstream and downstream levels. The solids accumulated in the interceptor tanks are removed periodically. Minimum size prescribed for sewer is 100 mm **(CPHEEO, 1993; Otis *et al.* 1985)**. In small bore system, since clarified sewage is flowing, strict sewer gradients are not necessary to ensure minimum self cleansing velocity and hold no relevance. Still 0.3 m/s velocity at peak flow is recommended **(CPHEEO, 1993)** in these sewers.

A small-bore sewerage system is designed according to the procedure given in manual "The small bore design" **(Otis *et al.*, 1985)**.Small bore sewerage system includes:

- Interceptor tank
- Sewer
- Manholes and other appurtenances

1. Interceptor tanks

Interceptor tanks are used in household level or community wise, design for up to 20 users were considered. Interceptor tank are actually septic tanks, so these tanks are designed according to **IS: 2470 (part1)-1985**.

In designing of these tanks, the maximum flow to the tank is based on the number of plumbing fixtures discharging simultaneously. For this purpose, various sanitation facilities are equal in terms of fixture units. Fixture equivalent is given in table (3.2).

Table: 3.2 Peak discharge for 20 users

Number of Users	Number of Fixture Units	Probable Number of Fixture Units Discharging Simultaneously	Probable Peak Discharge lpm
(1)	(2)	(3)	(4)
5	1	1	9
10	2	2	18
15	3	2	18
20	4	3	27

Note 1 — Number of fixture units is based on the assumption that each house consisting of 5 persons may have one WC which will discharge into septic tank.

Note 2 — Probable number of fixture units are based on 70 percent fixture units discharging simultaneously.

Source: IS: 2470 (part1)-1985

The capacity of the tank is determined by the rational method. In this method, the capacity of the tank is determined on the basis of space required for sedimentation, sludge digestion and storage of sludge digested. According to IS: 2470 (part1)-1985, the surface area of the tank required is 0.92 m^2 for every 10liters per minutes of peak flow. Per capita suspended solids entering the tank is taken as 70g/day. The capacity required for sludge digestion is 0.033m^2 per capita. Volume of digested sludge is 0.00021m^2 per capita per day. Inlet of the tank is in such a way that the top limb is rising above the scum level and bottom limb is extending about 300mm below the top water level. Outlet of the tank shall be 50mm below the invert of the inlet pipe. 100mm pipe is recommended for less than 1200mm wide tank. Invert of the outlet of this tank must be above the hydraulic gradient of the sewer.

2. Sewer

The hydraulic analysis of sewer is simplified by assuming steady flow conditions. The available head in wastewater line is utilized to overcome the surface resistance and in attaining kinetic energy for flow. The design practice is to use Manning's equation for open channel flow and Hazen-Williams Formulae for closed conduits or pressure flow **(CPHEEO, 1993)**. Small-bore system can also be designed on full flow conditions unlike the normal sewers.

Sewer design includes the following:

Decide the sewer routes.

Identify the junction and stretches of sewer and work out the distance and ground elevation at each point. Also work out the sewage that is being added at each of the junction, and further find out the cumulative sewage flow through each of the sewer stretches.

To start with, consider minimum diameter for each section of the sewer and with the available slope, estimate capacity of the sewer, **(CPHEEO, 1993)** which is actually Q_{full} by Manning's equation. If the capacity of the sewer is greater than the design peak flow then accept the considered diameter and slope of the sewer. Otherwise, increase either diameter of the sewer to the next level or the slope or both and repeat the capacity calculation and comparison with the design peak flow for deciding about the sewer diameter and slope. Then according to **(CPHEEO, 1993)**, find flow velocity for the present peak flow and check whether it is >0.3m/sec. If yes, then the chosen diameter and slope are ok, otherwise increase the diameter or the slope or both until even this condition is satisfied. These are estimated through the hydraulic element curve using the q/Q ratio.

Manning's equation for sewer capacity estimation:

$$Q = 24 \times D^{\frac{8}{3}} \times S^{\frac{1}{2}}$$

Where

Q= Discharge in (m^3/s)

D= Depth in (m)

S= slope in (m/m)

In small bore sewer designs, the critical section are carefully analysed hydraulically to ensure that they do not become excessively surcharged during peak flow periods and back flow into any connection. The maximum elevation up to which hydraulic gradient rise is determined. To avoid the back flow possible options are:

Invert of the outlet of any interceptor tank at this section is above the hydraulic grade line.

Larger pipe diameter can be used at this section.

Individually lift station provided.

Sewer elevation at the downstream station is lowered.

Out of these four options in this study, lowered sewer elevation in downstream side is referred.

Invert level of upstream and downstream ends are worked out with respect to surface elevations.

Invert level at downstream side = Invert level at upstream side–Total fall (slope× length)

Invert level at upstream side ≥ Ground level- minimum cover

Invert level of the upstream sewer ≤ Invert level of the downstream sewer

Depth at downstream side = Ground level at downstream side- invert level at downstream

Design example:

Sewer number 1-

The direction of flow for the sewer number 1 = 1^{st} to 2^{nd}

Length of sewer = 100m

Water consumption rate =135lpcd

Peak factor for small-bore sewerage system are 2 **(Otis *et al.*1985)**

Average peak flow in sewer = Population× water consumption rate× return factor

= 100× 135×0.85

= 0.133

Designed initial peak flow = Peak factor × Average flow

= 2× 0.133

= 0.265l/s

Hydraulic gradient for this section is calculated by using the chosen pipe with respect to the designed flow. This can be calculated by using the manning equation for full flow condition.

$$Q = 24 \times D^{\frac{8}{3}} \times S^{\frac{1}{2}}$$

$$0.265 \times 10^{-3} = 24 \times 0.1^{\frac{8}{3}} \times s^{\frac{1}{2}}$$

$$s = 0.005$$

It can rise upto 0.5m, for avoiding this, invert level of interceptor tank outlet should be above this or sewer elevation at downstream side is lowered to 0.006. In this study, sewer is designed according to the gravity flow.

As flow is very less, so the pipe diameter of 100mm is considered. Slope 0.006 and 100mm diameter are considered for this stretch. Now check the slope and pipe for Q full.

$$Q = 24 \times D^{\frac{8}{3}} \times S^{\frac{1}{2}}$$

$Q = 24 \times 0.1^{\frac{8}{3}} \times 0.006^{\frac{1}{2}}$

$Q = 0.004 m^3/s$

Qfull = 4l/s

As Qfull is □ Qactual hence, provide 100mm pipe diameter and 1/166 slope for the sewer number 1.

Now check the velocity at full flow condition,

$r = 0.2500 \times D$

$$vfull\ flow = \frac{1}{n} r^{2/3} s^{1/2}$$

V full =0.509

Using the q/Q value= 0.06625, locate v/V from the hydraulic curve and it is equal to 0.58.

vactual = 0.3m/s

As velocity is also in the range, so selected diameter and slope are as it is considered.

Invert level at upstream side of sewer = ground level at upstream side- minimum cover

= 96.62 – 1

= 95.62m

Invert level at downstream side of sewer = Invert level at upstream – (slopes × length)

= 95.62- (0.006×100)

= 95.02m

Depth at upstream side sewer = Ground level at upstream side- invert level upstream side

= 96.62- 95.62

= 1m

Depth at downstream side = Ground level at downstream side – invert level down stream

= 97.10 – 95.02

= 2.08m

3. Appurtenances

Clean outs are provided for cleaning and maintaining the sewer. Cleanouts are provided at upstream termini, intersection of sewer lines, major change in direction greater than 45°, high points and at intervals of 25m (**Wentink *et al.*, 2007; CPHEEO, 1993**). And 150-200 m in long flat section (**Otis *et al.*, 1985**) for small pipe. Manholes used in this system are of conventional type and these are provided at major junction.

3.4.3. CONVENTIONAL SEWERAGE SYSTEM

Conventional sewerage system is used to carry the wastewater from household to the treatment site. In designing the conventional sewerage system, self-cleansing velocity is mainly concerned. Velocity in the sewer should reach self-cleansing velocity at least once in a day. But the maximum velocity in the sewer should not be very high to cause erosion of the sewer surface. Minimum size prescribed for sewer is 150mm and for this size sewer ensuring self-cleansing velocity demands certain minimum flow, which is difficult to achieve in rural sparely populated human settlements. In order to ensure the much needed self cleansing velocity, siphon system are introduced at the household level. The sewage generated by the household is collected into this system. Once the sewage level in the system cross a set limit, the siphon gets activated and all the sewage siphon out at much higher rate. This will ensure the self-cleansing velocity in the sewer on the downstream side.

In the present case, the conventional sewerage system is considered to include:

- Siphon systems (Household level /end)
- Sewers
- Manholes and other appurtenances.

1. Sewer

Sewer design includes the following:

Sewer routes are decided mainly on the basis of surface gradient.

Junctions and stretches are identified. Junctions are coded with a number and sewage added at each of the junction is worked out. Average cumulative sewage flow through the sewer is found out for each of the stretches. Based on the contributing population, the value prescribed in table (3.3) **(CPHEEO, 1993)** are referred for peak factor. Up to the population 20000, the peak factor is three. This peak factor is used to estimate the peak flow. Peak flow expected from the siphon system has been taken as minimum peak flow. For this peak flow, sewers are designed.

Slopes are chosen on the basis of initial peak flow and ensuring that the minimum self-cleansing velocity can reach at least once in a day. Slopes are choosen according to the recommended slope shown in table (3.4) **(CPHEEO, 1993).**

Pipe size should be decided on the basis of ultimate design peak flow and the permissible depth of flow. Sewer runs ≤ 0.8 full at ultimate peak flow. The minimum diameter prescribed for sewer is 150mm. Sewer is to be designed as running 0.8 times full at designed peak flow. For calculating the diameter of pipe, manning equation was used.

$$Q = \frac{1}{n} a r^{\frac{2}{3}} s^{\frac{1}{2}}$$

Where

Q= Maximum discharge

a = area

r= hydraulic radius

S= slope

Find Qfull and Vfull using manning equation.

$$v = \frac{1}{n} r^{\frac{2}{3}} s^{\frac{1}{2}}$$

Where

V = velocity

r = hydraulic radius

s = slope

The ratio of qinitial/Qfinal is used to find hydraulic elements (v/V, d/D). These hydraulic elements are worked out by using the hydraulic elements curve. This curve is shown in figure (3.2) **(CPHEEO, 1993)**.

The actual velocity in sewer is found out by v/V. Check the velocity whether it is acceptable or not, if not then change slope or diameter or both, and whole process will repeated.

Once slope and diameter are decided, find invert level of the upstream and downstream ends.

Invert level at downstream side = Invert level at upstream side–Total fall (slope× length)

Invert level at upstream side = Ground level- minimum cover- pipe wall thickness- pipe diameter

After finding out the slope, diameter the invert level and depth of the sewer at both upstream and downstream side were found out.

Depth at downstream side = Ground level at downstream side- invert level at downstream

Depth at upstream side = Ground level at upstream side- invert level at upstream side.

Table: 3.3 Peak factor with respect to contributing population

Contributory population	Peak Factor
Upto 20,000	3.0
20,000 to 50,000	2.5
50,000 to 7,50,000	2.25
Above 7,50,000	2.00

Source: (CPHEEO,1993)

Table: 3.4 Slopes for minimum velocity

RECOMMENDED SLOPES FOR MINIMUM VELOCITY

Present peak flow in lps	Slope per 1,000
2	6.0
3	4.0
5	3.1
10	2.0
15	1.3
20	1.2
30	1.0

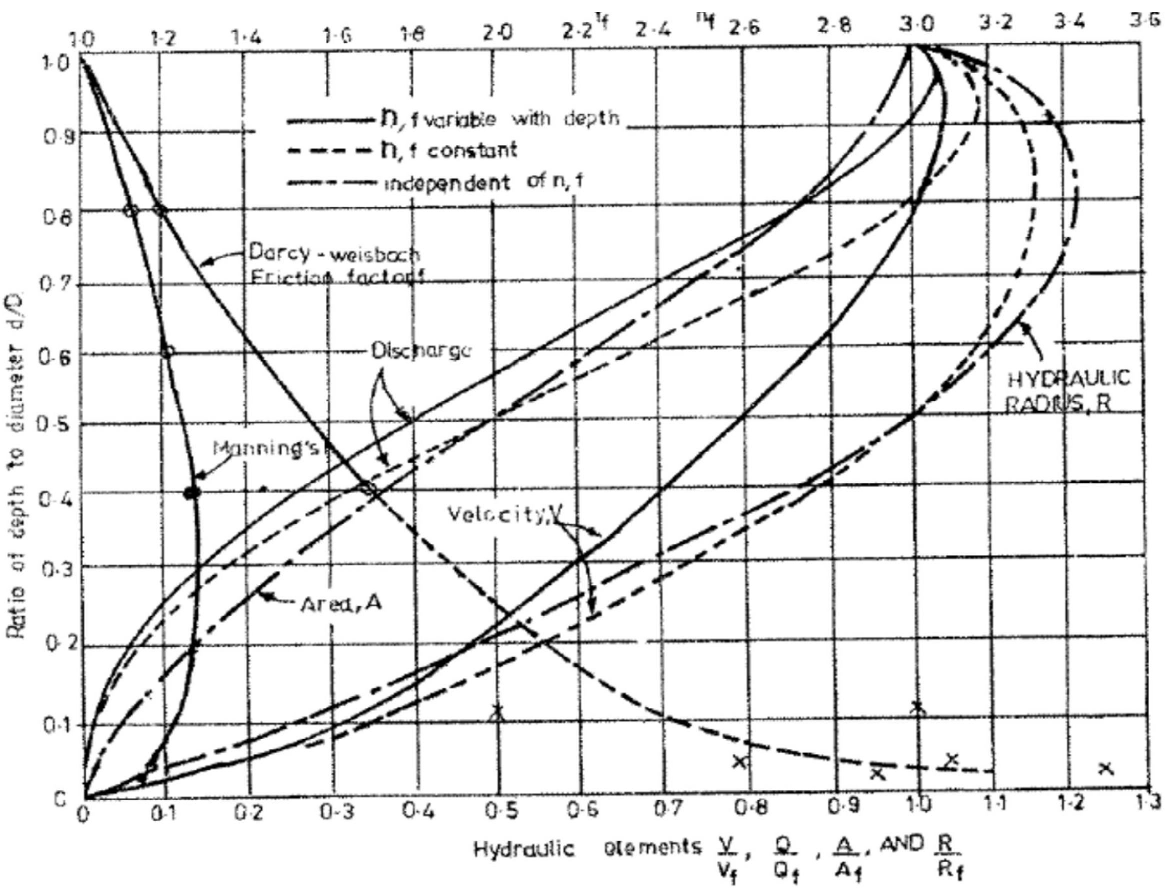


Fig: 3.2 Hydraulic element curve

Source: CPHEEO, 1993

Design Example:

Sewer number 1

The direction of flow for the sewer number 1 = 1^{st} to 2^{nd}

Length of sewer = 100m

Ground elevation at upstream side= 96.62

Ground elevation at downstream side = 96.62

Present peak flow for sewer number 1 = 4.5l/s

Designed peak flow for sewer number 1= 9l/s

For a present peak flow, 0.004 slope is chosen by using the table (3.4).

Diameter of the sewer is decided in such a way that during the designed peak flow, sewer will be flowing at 0.8 times full.

For partially full condition,

Diameter of the sewer is decided by using the manning equation for 0.8 time full flow condition.

$Q = \frac{1}{n} a r^{\frac{2}{3}} s^{\frac{1}{2}}$ for d/D= 0.8, r = 0.3042D and a= $0.6735D^2$ (annex:1)

$$9 \times 10^{-3} = \frac{1}{0.013} \times 0.6735D^2 \times (0.3042D)^{\frac{2}{3}} \times 0.004^{\frac{1}{2}}$$

$D = 0.2$m

Velocity at final flow $v = \frac{1}{n} r^{\frac{2}{3}} s^{\frac{1}{2}}$

For full flow, r= 0.2500 D

$$v = \frac{1}{0.013} (0.2500D \times 0.2)^{\frac{2}{3}} (0.004)^{\frac{1}{2}}$$

Vfinal = 0.66m/s

$$Qfull = 24 \times D^{\frac{8}{3}} \times S^{\frac{1}{2}}$$

$$Qfull = 24 \times 0.2^{\frac{8}{3}} \times 0.004^{\frac{1}{2}}$$

Qfull =20l/s

Now check the velocity at initial flow by using q/Q ratio

$$\frac{q}{Q} = \frac{4.5}{20}$$

q/Q = 0.23

v/ V value are found out by using q/Q = 0.23 through hydraulic curve.

v/V ratio = 0.81

Now, v actual = 0.81×0.66

= 0.54m/s

Now, d/D initial from the curve = 0.17

As, d/D and v/V are not in the range so, recalculate by increasing the slope or diameter. Now check with slope = 0.066, calculate the whole process and D comes out to be 0.150m.

Velocity at full flow= 0.67m/s

Q full = 11.8l/s

Now for q/Q= 0.38, check initial velocity using the q/Q ratio

As v/V = 0.93, v initial =0.62 and d/D=0.22

As d/D and v/V are in the range, for sewer no.1, pipe diameter is 150mm and slope is 0.066.

Minimum cover = 1m + pipe diameter

Invert level at upstream side of sewer = ground level at upstream side- minimum cover-pipe diameter

= 96.62 – 1-0.15

= 95.47m

Invert level at downstream side of sewer = Invert level at upstream – (slopes × length)

= 95.47- (0.005×100)

= 94.97m

Depth at upstream side sewer = Ground level at upstream side- invert level upstream side

= 96.62- 95.47

= 1.15m

Depth at downstream side = Ground level at downstream side – invert level down stream

= 96.62 – 94.97

= 1.65m

2. Manholes

Manholes are decided according to **IS: 4111 (part1)-1986**. Manholes are of such size that allows necessary cleaning and inspection. Size of the manholes is decided according to the depth of the sewer. Spacing of the manholes is also decided according to the sewer diameter. Manholes are provided at upstream side, all junctions, at all places where change in direction greater than 45°.

CHAPTER 4
RESULT AND DISCUSSION

4.1. INTRODUCTION

The results of present study on sewerage system for rural area are presented in this section:

- Site map with background information
- Treatment and disposal system planned
- Sewer paths and sewer map
- Sewerage system

4.2. SITE MAP WITH BACKGROUND INFORMATION

Village is having household population of around 3422-4000. This is an area having definite boundaries and comprised of following type of buildings:

- Residences
- Dispensary (Animal, human)
- Gurudwara
- Garage and work shop
- Small school
- Dharmshala

Village is near to the Grand Trunk Road, on one side there is railway track and the other side is covered by the cultivation land. General topography of the village shows depression at some points. There are 5 ponds in the village. Current population will be served by four ponds having 913, 1590, 1472, 285 population respectively. Most of the part of village is fully developed except the two areas where future growth is expected. These areas are near to the fourth and third pond. Population densities of 4^{th} and 3^{rd} pond nearby areas are 0.01007748 and 0.03166 respectively. The population densities of these areas are used for calculating the population in nearby unsettled area. Incremental rate per year for this village is 1.22. Future population serving by the four ponds are 1876, 3198, 2838, 660 respectively. This population includes the new area development and population in already settled area. Stretch wise current and future population are shown in map (annex: 2, 3, 4, 5) for each pond.

Village is having its own continuous water supply. Water supply for this village is 135lcd for household.

4.3. TREATMENT AND DISPOSAL SYSTEM PLANNED

All the five ponds are having the potential to be used as site for the sewage treatment plant. Out of five, four ponds will be used for treatment, as size of one pond is very less, so it cannot be used. Sewage water will reach to these ponds through sewer lines. Treated effluent from STPs will be used for irrigation. Only excess treated effluent will be drained out for disposal. Treatment site is showed in annex: 2, 3, 4, 5.

4.4. SEWER PATHS AND SEWER MAP

Scheme of the sewerage system are decided according to:

The gravity flow.

Availability of land and its land use pattern.

Social and cultural acceptability of the scheme.

Discussion with the local authority.

Preventing clogging of sewers and minimizing need for frequent cleaning.

Ease of operation and maintenance

Minimizing the excavation cost

Eliminating the need for intermediate pumping of sewage.

The path of the sewer is shown in map (annex: 2, 3, 4, 5) by arrows. In 1st pond (sewerage system 1), water is coming from 1st to 67th junction. The ground elevation is 98.40 and 96.78 at 1st and 67th junction respectively. In 2nd pond (sewerage system 2), water is coming from 152nd to 151st junction. The ground elevation is 99.07 and 96.86 at 152 and 151 junction respectively. In 3rd pond (sewerage system 3), water moves from 1st to 78th junction. The ground elevation is 96.62 and 97.67 at 1st and 78th junction respectively. In 4th pond (sewerage system 4), water moves from 9th to 24th and j_up to 24th junction. The ground elevation is 97.6, 98.35 and 97.04 at j_up, 9 and 24 respectively. Detail of the sewer coming to each of the pond is shown in table (4.1, 4.2, 4.3, 4.4). Scheme of sewer has been finalized based on the distribution of population and topography. Schematic diagram for each sewerage system is shown in figure (4.1, 4.2, 4.3, 4.4). Following notation has been used for schematic diagram.

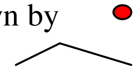
- Junction are shown by □
- Drop junction are shown by 
- Sewers are shown by 
- Junction name are shown by the numbering

Table: 4.1 Detail of sewer coming into the 1st Pond

Sewer	Length	Ground elevation u/s	Ground elevation d/s	Initial peak flow	Designed peak flow
1	76	98.21	98.21	0.000	0.019
2	108	97.40	98.21	0.000	0.229
3	64	98.78	98.78	0.019	0.083
4	14	98.78	98.78	0.000	0.000
5	9	98.78	98.78	0.047	0.178
6	11	98.78	98.78	0.028	0.068
7	37	98.78	98.78	0.055	0.267
8	20	98.78	98.78	0.043	0.062
10	149	98.21	98.63	0.026	0.267
14	76	98.73	98.73	0.004	0.005
15	36	98.73	98.73	0.000	0.000
16	75	99.07	98.75	0.267	0.912
17	35	98.75	98.75	0.318	1.013
18	48	99.24	98.75	0.000	0.028
9	23	98.78	98.63	0.133	0.379
11	15	98.63	98.73	0.163	0.651
12	29	98.73	98.73	0.163	0.706
13	10	98.73	99.07	0.163	0.706
19	53	99.24	98.51	0.064	0.119
20	36	98.96	98.51	0.006	0.037
21	44	98.51	98.54	0.136	0.250
22	17	98.54	98.54	0.064	0.119
23	37	98.54	98.54	0.268	0.469
24	35	98.54	97.67	0.330	0.612
25	24	98.54	98.54	0.043	0.089
26	72	98.56	98.03	0.170	0.300
27	51	98.03	97.87	0.378	0.759
28	50	97.87	97.89	0.061	0.087
29	7	97.89	97.89	0.812	1.594
30	24	97.89	97.92	1.045	2.013
31	13	97.92	97.92	1.159	2.255
32	23	97.92	97.67	1.210	2.356
33	18	98.56	98.56	0.026	0.115
34	24	98.56	98.03	0.057	0.161
35	9	98.72	98.56	0.022	0.032
36	41	100.37	98.03	0.069	0.099
37	32	99.35	98.03	0.000	0.055
38	46	97.87	97.87	0.035	0.179
39	22	97.87	97.87	0.094	0.291

40	20	97.87	97.87	0.058	0.084
41	46	97.89	97.89	0.140	0.229
42	23	97.89	97.89	0.047	0.068
43	61	98.51	97.92	0.131	0.244
44	39.3	97.92	97.92	0.086	0.202
45	61	97.53	97.21	0.023	0.111
46	30	97.19	97.19	0.068	0.125
47	22	97.41	97.41	0.000	0.000
48	13	97.41	97.41	0.000	0.083
49	32	97.73	97.73	0.064	0.119
51	17	97.21	97.21	0.089	0.127
52	27	97.21	97.21	0.089	0.127
53	24	97.21	97.09	0.111	0.238
54	26	97.09	96.99	0.155	0.301
55	83	96.99	97.19	0.227	0.405
56	20	97.19	97.41	0.308	0.549
57	20	97.41	97.41	0.324	0.600
58	21	97.41	97.73	0.332	0.720
59	36	97.73	97.67	0.469	0.972
50	30	97.21	97.21	0.074	0.106
69	51	97.67	97.45	2.097	4.068
70	131	97.45	97.19	2.286	4.366
71	100	97.19	97.19	0.021	0.109
72	29	97.45	97.45	0.010	0.014
60	33	97.30	97.19	2.910	5.979
61	50	97.30	97.30	0.498	1.326
62	63	97.54	97.30	0.498	1.298
63	63	98.27	97.54	0.396	1.153
64	45	98.75	98.27	0.386	1.110
65	26	97.30	97.30	0.011	0.015
66	64	97.30	97.30	0.105	0.178

Table: 4.2 Detail of sewer coming into the pond 2nd

Sewer	L (m)	Ground level u/s (m)	Ground level d/s (m)	Present peak flow	Designed peak flow
1	56	99.07	99.02	0.019	0.083
2	37	99.02	98.49	0.138	0.337
3	50	99.49	99.32	0.093	0.134
4	39	99.32	99.02	0.119	0.199
5	48.4	99.49	99.32	0.026	0.038
6	108	98.49	98.49	0.072	0.131
7	26	98.49	98.56	0.227	0.519
8	103	98.57	98.56	0.096	0.165
9	45	98.56	98.57	0.387	0.804
10	4.5	100.35	100.35	0.022	0.060
11	27	100.35	100.35	0.064	0.119
12	12	100.35	100.35	0.022	0.032
13	13	100.35	100.19	0.070	0.156
14	18	100.19	100.19	0.108	0.211
15	10	100.19	99.67	0.143	0.261
16	20	99.67	99.67	0.035	0.050
17	29	99.67	99.52	0.210	0.385
18	13	99.52	99.52	0.016	0.050
19	62	99.52	99.40	0.348	0.638
20	64	99.40	98.75	1.038	1.878
21	26	98.75	98.75	0.022	0.060
22	42	98.75	98.57	1.131	2.040
23	25.5	101.12	101.37	0.048	0.096
24	5	101.37	101.37	0.000	0.000
25	12.3	101.37	101.37	0.006	0.037
26	25	101.37	100.84	0.137	0.252
27	31	100.19	100.79	0.000	0.028
28	5	100.79	100.79	0.000	0.028
29	18	100.79	101.10	0.038	0.083
30	20	101.10	100.84	0.191	0.385
31	23	100.84	100.38	0.367	0.720
32	64	100.37	100.38	0.045	0.120
33	25.5	100.38	99.53	0.472	0.927
34	29	99.53	99.40	0.517	0.991
35	17	100.38	100.38	0.405	0.775
36	27	98.36	98.36	0.048	0.069
37	86	98.36	98.57	0.137	0.252
38	117	98.57	97.98	1.750	3.435
39	29	97.98	97.59	1.795	3.665

40	49	98.22	97.98	0.044	0.202
41	88	97.44	97.59	0.142	0.259
42	29	97.44	97.44	0.051	0.101
43	17	97.44	97.44	0.099	0.170
44	13	97.44	97.44	0.016	0.023
45	45	97.44	97.35	0.166	0.266
46	38	97.35	97.67	0.210	0.330
47	43	97.59	97.67	1.955	4.006
48	22	97.67	97.39	2.385	4.730
49	13	97.39	97.39	2.478	4.864
50	26	97.39	97.27	2.597	5.090
51	23	97.39	97.39	0.041	0.059
52	73	97.39	97.39	0.099	0.197
53	12	99.53	99.53	0.012	0.045
54	23	99.53	99.53	0.076	0.165
55	30	99.53	99.27	0.156	0.307
56	37	99.27	97.14	0.207	0.380
57	92	97.14	96.91	0.240	0.505
58	50	97.27	96.91	2.915	5.740
59	17	99.53	99.53	0.019	0.055
60	9	99.53	99.53	0.019	0.028
61	14	99.53	99.29	0.019	0.055
62	21	99.29	98.82	0.019	0.055
63	39	98.82	98.82	0.128	0.267
64	51	98.82	97.27	0.252	0.500
65	30	98.82	98.82	0.014	0.075
66	9	100.00	100.00	0.038	0.055
67	7	100.00	100.00	0.038	0.055
68	16	100.00	99.53	0.064	0.092
69	9	97.14	97.14	0.000	0.029
70	13	97.14	97.14	0.083	0.174
71	25	97.14	98.68	0.136	0.251
72	41	97.14	97.14	0.048	0.096
73	11	97.14	97.14	0.048	0.124
74	16	101.87	101.12	0.080	0.142
75	34	101.12	100.37	0.159	0.257
76	21	100.37	100.37	0.173	0.304
77	17	100.37	98.90	0.205	0.377
78	41	100.73	98.90	0.070	0.101
79	26	98.90	98.24	0.284	0.519
80	28	98.24	98.24	0.089	0.156
81	29	98.24	98.24	0.418	0.817

82	11	98.24	98.24	0.026	0.065
83	12	98.24	98.68	0.457	0.900
84	17	98.68	98.68	0.615	1.183
85	17	98.68	98.56	0.661	1.249
86	59	98.56	97.11	0.738	1.387
87	10	97.11	97.11	0.075	0.108
88	33	97.11	97.11	0.041	0.059
89	55	98.56	98.27	0.069	0.232
90	57	98.27	96.36	0.106	0.286
91	41	96.91	96.91	3.234	6.442
92	19	96.91	96.97	3.311	6.580
93	36	96.97	96.36	3.691	7.319
94	48	96.36	96.95	3.797	7.683
95	35	97.95	96.95	0.003	0.032
96	14	97.23	97.95	0.000	0.000
97	77	97.44	97.23	0.170	0.272
98	31	97.29	97.29	0.043	0.062
99	65	97.29	97.20	0.137	0.334
100	75	97.20	97.44	0.204	0.514
101	45	97.44	97.03	0.251	0.582
102	35	96.95	97.03	3.837	7.796
103	85	97.03	97.03	5.036	10.176
104	40	97.11	97.03	0.854	1.609
105	12	96.56	96.56	0.019	0.055
106	21	96.56	96.56	0.125	0.235
107	5	96.56	96.56	0.039	0.056
108	17	96.56	96.56	0.061	0.088
109	31	96.56	96.66	0.228	0.438
110	24	96.66	96.66	0.038	0.083
111	29	96.66	96.58	0.266	0.521
112	12	96.58	96.58	0.016	0.023
113	24	96.58	96.58	0.321	0.626
114	16	96.58	96.58	0.042	0.060
115	38	96.58	96.46	0.362	0.686
116	28	96.46	96.91	0.362	0.686
117	246	96.54	97.67	0.147	0.289

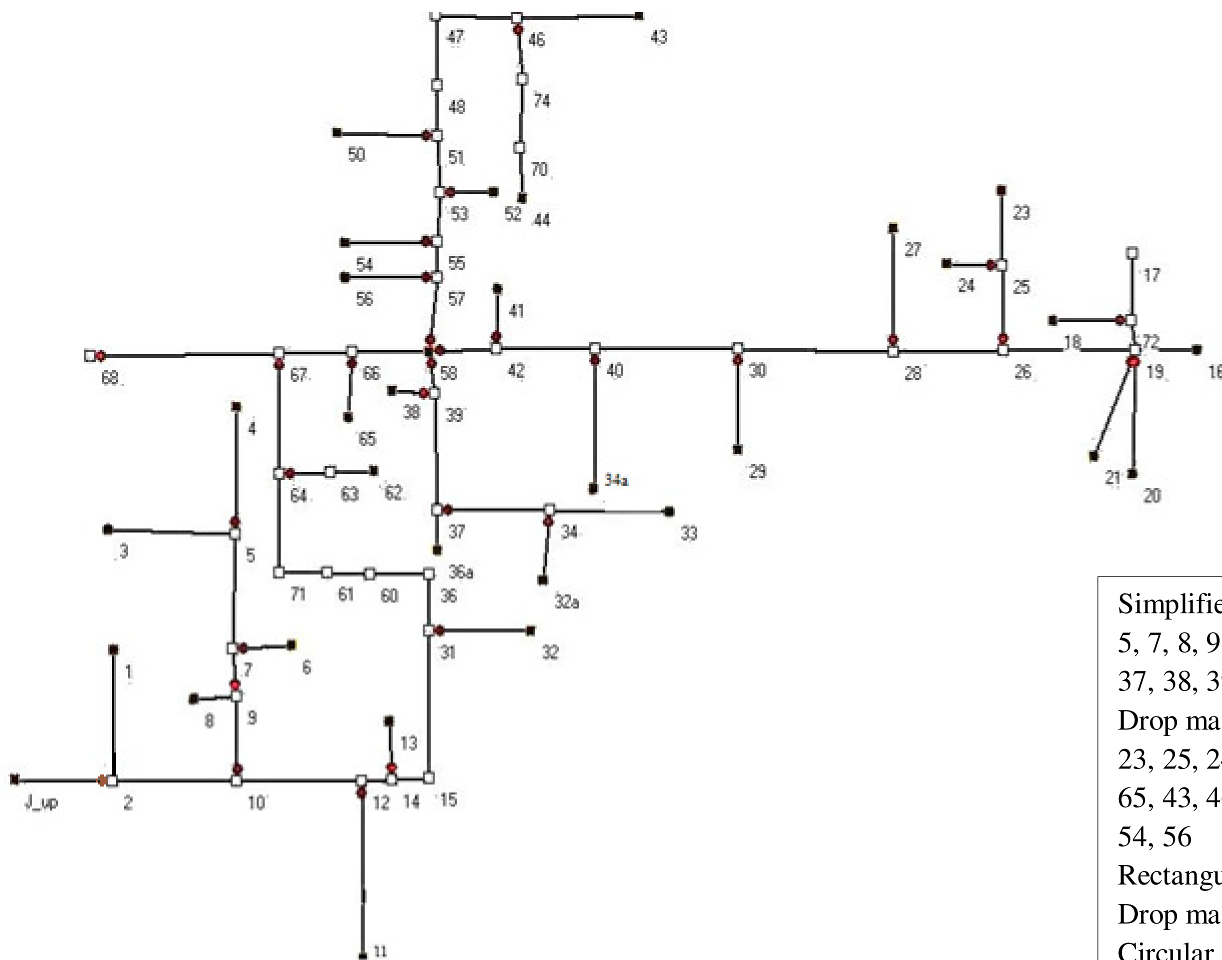
Table: 4.3 Detail of sewer coming into the 3rd pond

Sewer	Length (m)	Ground level u/s (m)	Ground level d/s (m)	Present peak flow	Design flow
1	86	96.62	97.10	0.043	0.136
2	40	97.10	97.10	0.054	0.127
3	59	97.10	97.02	0.221	0.628
4	29	97.34	97.34	0.016	0.028
5	61	97.34	97.60	0.120	0.301
6	33	97.60	97.60	0.000	0.033
7	49	97.60	97.25	0.336	0.768
8	29	97.25	97.25	0.053	0.092
9	13	97.25	97.25	0.023	0.039
10	25	97.25	97.25	0.463	0.044
12	42	97.07	97.02	0.641	1.294
13	47	97.07	97.16	0.163	0.281
14	62	97.02	97.16	0.931	2.102
15	33	96.36	97.16	0.035	0.061
16	9	97.16	97.16	0.997	2.218
17	51	97.16	97.16	0.035	0.061
19	54	97.16	97.16	0.149	0.383
20	12	97.08	97.08	0.067	0.149
21	8	97.08	97.08	0.112	0.226
23	12	97.32	97.32	0.064	0.143
24	58	96.87	96.87	0.054	0.094
26	22	97.18	97.18	0.070	0.121
28	16	97.18	97.18	0.048	0.083
30	16	97.60	97.60	0.032	0.055
31	8	97.60	97.60	0.028	0.080
32	40	97.60	97.55	0.146	0.353
33	8	97.55	97.55	0.060	0.105
34	30	97.21	96.93	0.100	0.171
35	28	97.55	97.55	0.136	0.267
36	37	97.55	96.56	0.407	0.901
37	22	96.56	96.56	0.025	0.044
39	25	96.56	96.56	0.072	0.124
40	16	96.56	96.56	0.067	0.116
41	20	96.56	96.56	0.188	0.326
42	43	96.56	96.53	0.378	0.685
43	28	96.87	96.56	0.064	0.110
44	44	96.53	96.56	0.569	1.016
45	42	96.85	96.85	0.076	0.130
46	20	96.85	96.85	0.024	0.075

47	6	96.85	96.85	0.010	0.050
48	9	96.85	96.85	0.010	0.050
49	3	96.85	96.85	0.096	0.199
50	12	96.85	96.85	0.227	0.459
51	23	96.85	97.08	0.340	0.685
52	95	97.08	96.93	0.457	1.036
53	19	97.08	96.87	0.016	0.028
54	16	96.87	96.87	0.064	0.110
55	94	96.87	96.93	0.443	0.765
56	21	97.16	97.16	1.145	2.471
57	9	97.16	97.16	1.485	3.185
58	15	97.16	97.32	1.523	3.251
59	13	97.32	97.32	1.797	3.758
60	18	97.32	97.32	1.887	3.945
61	4	97.32	97.18	2.094	4.303
62	21	97.18	97.18	2.212	4.573
63	15	97.18	96.56	2.323	4.798
64	34	96.56	96.93	3.409	6.969
65	20	96.93	96.93	4.040	8.125
66	28	96.93	97.22	4.617	9.485
67	124	97.22	97.24	4.648	10.342
68	242	97.24	97.67	4.691	10.856
11	54	97.08	97.32	0.230	0.430
69	10	97.25	97.25	0.428	0.926
70	3	97.25	97.25	0.463	0.986
71	14	97.25	97.07	0.546	1.129
72	47	96.87	97.32	0.208	0.358
73	18	97.08	97.08	0.043	0.075
74	50	97.31	97.22	0.000	0.116
75	70	97.22	97.24	0.043	0.515
76	45	97.21	96.93	0.169	0.292

Table: 4.4 Detail of sewer coming into the 4th pond

Sewer	Length	Ground elevation u/s	Ground elevation d/s	Initial peak flow	Designed peak flow
1	105	97.60	97.60	0.083	0.220
2	34	97.60	97.60	0.160	0.464
3	65.3	97.60	97.73	0.256	0.695
4	50	97.73	97.87	0.427	0.968
5	12	97.83	97.87	0.409	0.951
6	10.3	97.83	97.83	0.330	0.837
7	34	98.09	97.83	0.186	0.520
8	58	98.35	98.09	0.078	0.204
9	62.5	97.60	97.60	0.033	0.181
10	28	97.60	97.60	0.026	0.037
11	31	97.73	97.73	0.032	0.046
12	13.2	98.09	98.09	0.009	0.068
13	7.1	98.09	98.09	0.000	0.000
14	35.5	98.09	98.09	0.104	0.233
15	15.4	97.83	97.83	0.057	0.083
16	13.5	97.83	97.83	0.057	0.110
17	9	97.83	97.83	0.067	0.096
18	15.3	97.83	97.83	0.023	0.033
19	57.2	97.83	97.83	0.064	0.120
20	38	97.87	97.46	0.837	1.947
21	23	97.46	97.46	0.000	0.000
22	15	97.46	97.46	0.837	1.975
23	115	97.46	97.21	0.905	2.100



Simplified Manhole- j up, 1, 3, 4, 6, 5, 7, 8, 9, 11, 13, 36a, 68, 32, 33, 34, 37, 38, 39, 40, 16, 17, 18
Drop manhole- 72, 19, 20, 21, 26, 23, 25, 24, 27, 28, 29, 30, 40, 41, 42, 65, 43, 46, 47, 44, 70, 74, 48, 50, 52, 54, 56
Rectangular Manhole-68, 66
Drop manhole- 2, 66, 53, 57, 55, 51,
Circular Manhole-15, 36, 60, 61, 71
Drop manhole-14, 12, 10, 31, 64, 58

Fig: 4.1 Schematic diagram for 1st sewerage system

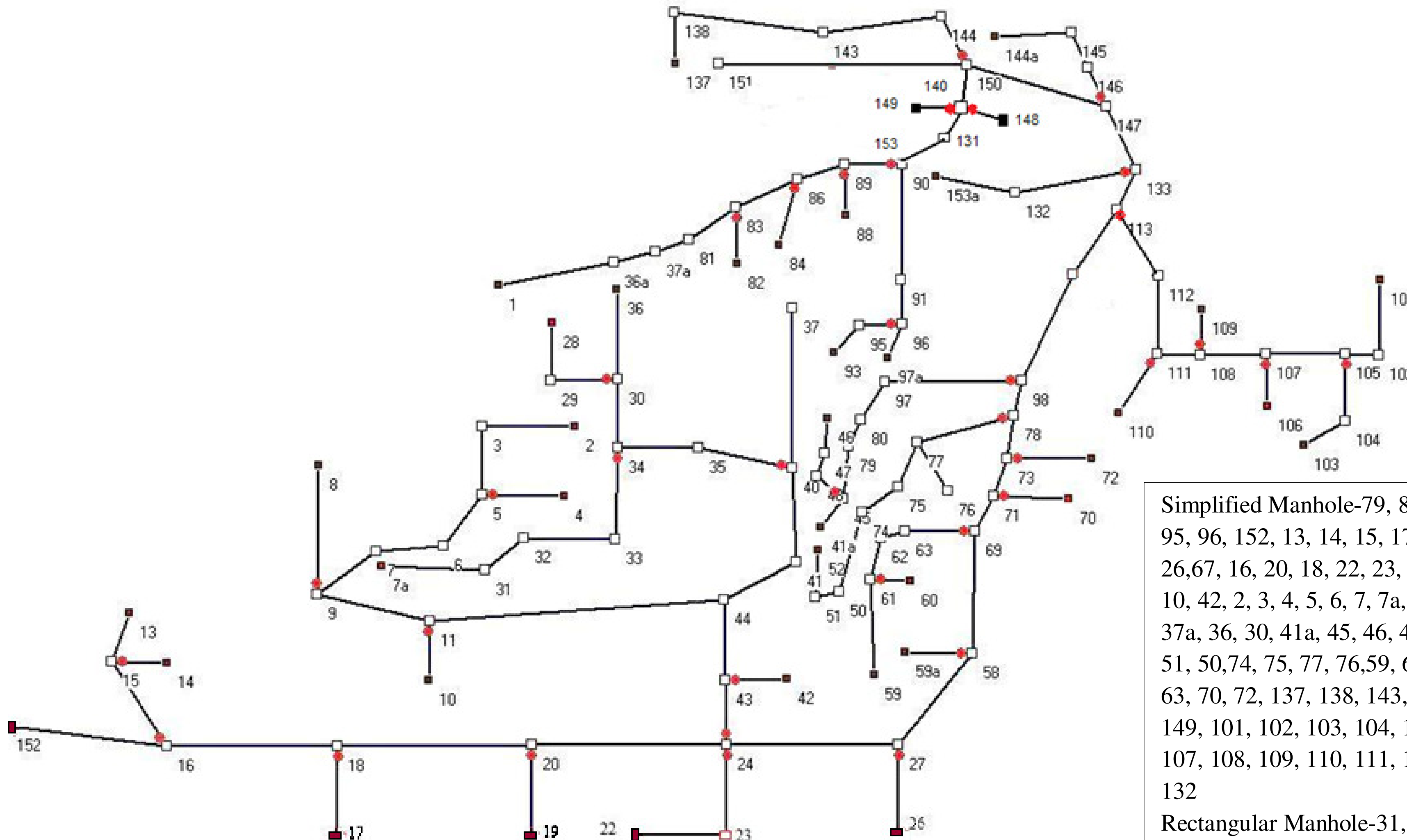


Fig: 4.2 Schematic diagram for 2nd sewerage system

Simplified Manhole-79, 80, 97, 93, 95, 96, 152, 13, 14, 15, 17, 19, 21, 26,67, 16, 20, 18, 22, 23, 8, 9, 11, 10, 42, 2, 3, 4, 5, 6, 7, 7a, 1, 36a, 37a, 36, 30, 41a, 45, 46, 47, 48, 52, 51, 50,74, 75, 77, 76,59, 60, 61, 62, 63, 70, 72, 137, 138, 143, 145, 148, 149, 101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 111, 112, 153a, 132

Rectangular Manhole-31, 32, 33, 35, 144

Drop Manhole-24, 44, 43, 34, 40, 27, 58

Circular Manhole

Drop Manhole- 78, 69, 71, 73, 98, 100, 113, 133, 90, 153, 131, 147, 150, 140

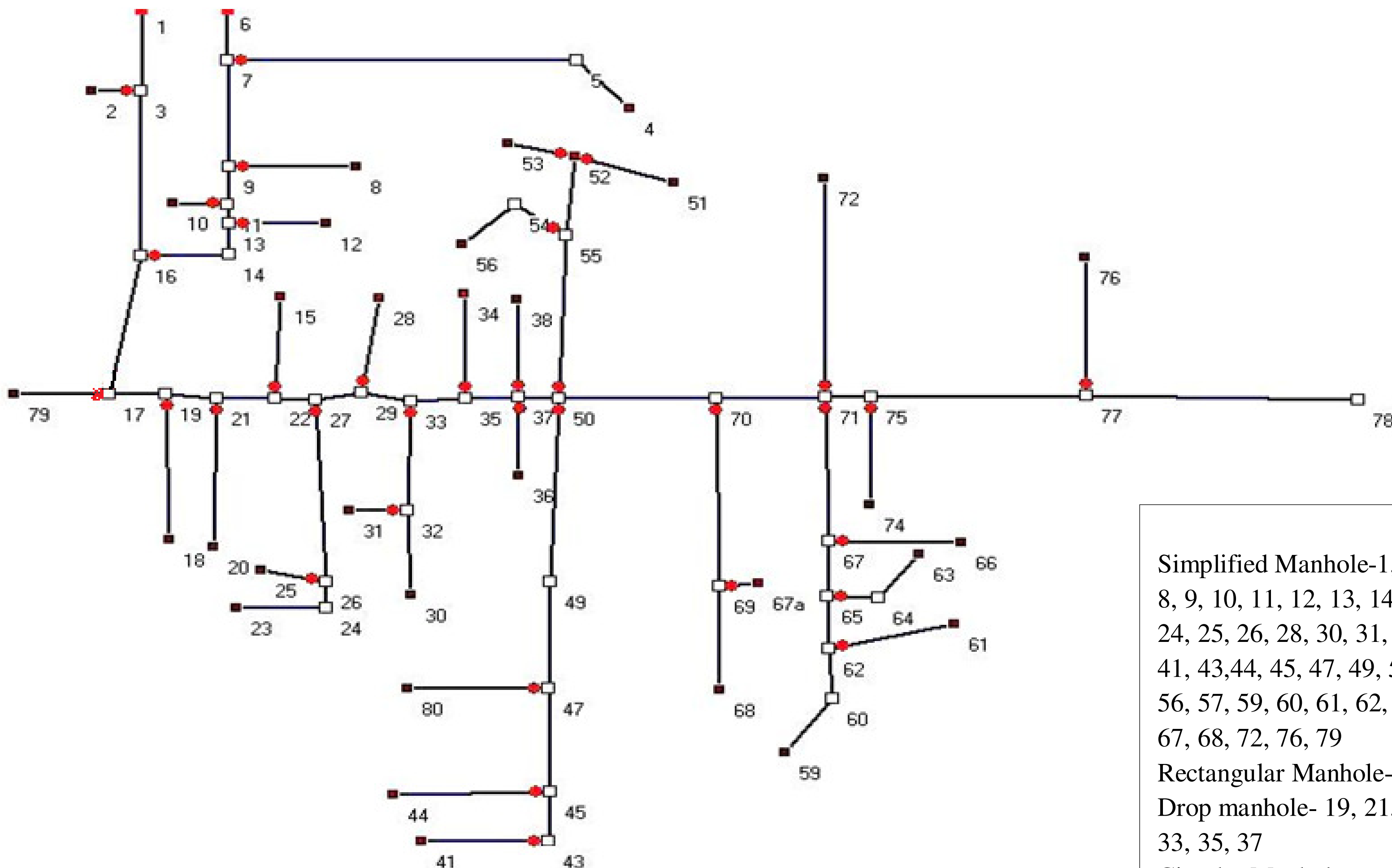
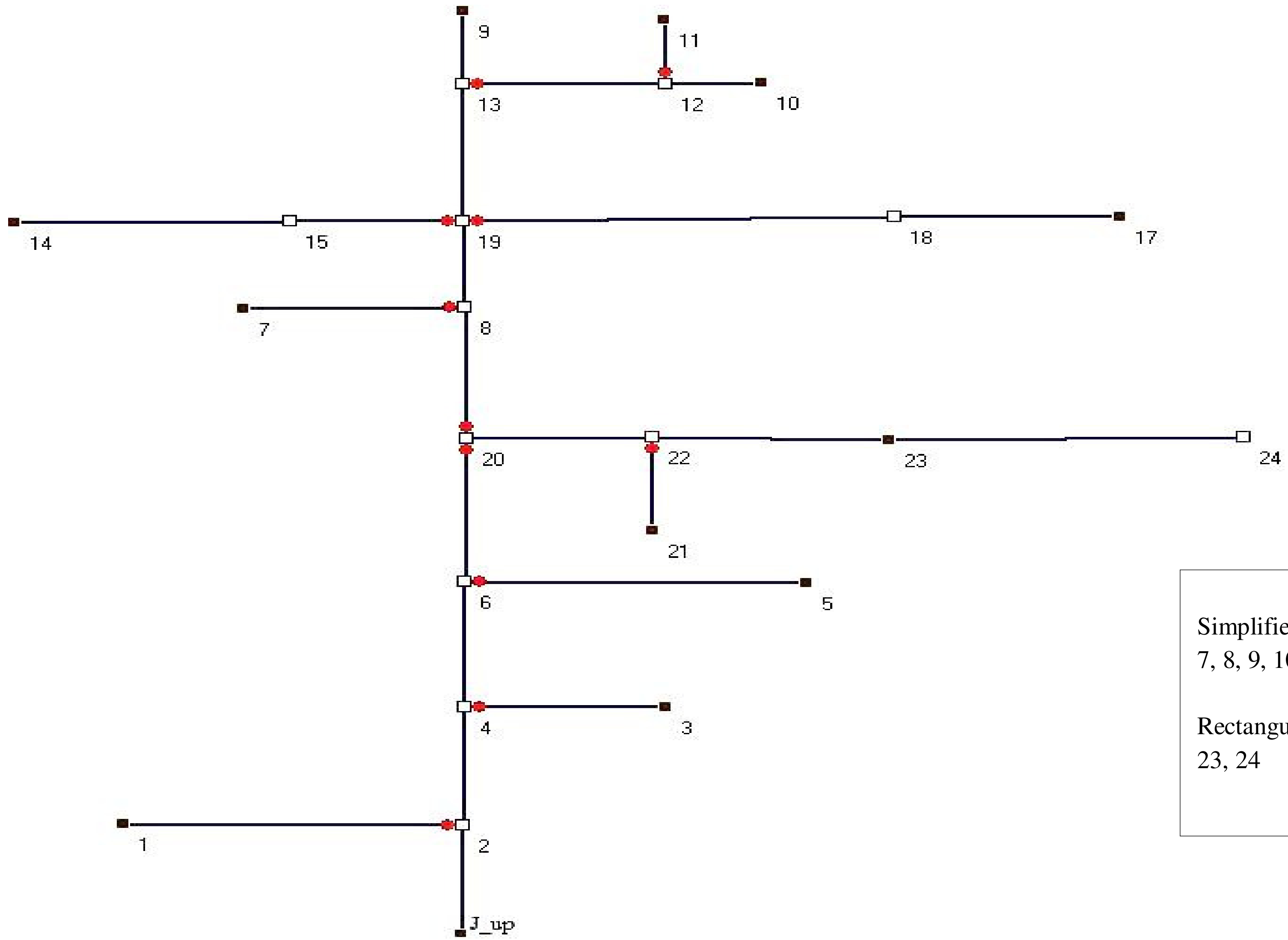


Fig: 4.3 Schematic diagram for 3rd sewerage system

Simplified Manhole-1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 18, 20, 23, 24, 25, 26, 28, 30, 31, 32, 34, 36, 38, 41, 43,44, 45, 47, 49, 51, 52, 53, 55, 56, 57, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 72, 76, 79
Rectangular Manhole- 3, 16, 17
Drop manhole- 19, 21, 22, 27, 29, 33, 35, 37
Circular Manhole
Drop Manhole- 50, 70, 71, 75, 77.



Simplified Manhole- 1, 2, jup, 3, 5, 7, 8, 9, 10, 12, 13, 14, 15, 17, 18, 19

Rectangular Manhole- 4, 6, 20, 22, 23, 24

Fig: 4.4 Schematic diagram for 4th sewerage system

4.5. SEWERAGE SYSTEM

Three types of sewerage system have been designed. These are simplified sewerage system, conventional sewerage system and small bore system. Simplified system are designed for all the four sites. While conventional and small bore are designed for only one site. Pond 3rd site is chosen for small bore and conventional system. Detail of design is shown below.

4.5.1. SIMPLIFIED SEWERAGE SYSTEM

Simplified sewerage system is used to carry the unsettled wastewater from household to the treatment side. In this system, sewer are laid away from traffic load. While for present case, these are laid down at the centre of street due to this reason, cover provided is 0.9m. Simplified sewerage includes the cattle tank, siphon system, sewers, manholes and other appurtenances.

1. Cattle tank

Cattle tank is used to hold the dung and allowed the clear water to move into the siphon. Dimension and assumptions of the tank for different number of cattle are shown below.

Quantity of water consumption = 75lpcd

Depth of the tank = 0.6m

Depth with slope = 0.7m

Slope varies from 1:10 to 1:12

Minimum spacing between the tee pipe bottom and the maximum sludge level = 0.2m

Minimum length of the pipe invert to bottom limb = 0.1m

Maximum sludge level = 0.3m

Inlet size = 0.1m

Outlet size = 0.1m

Outlet are provided below the 0.05 to inlet.

Invert level of the inlet is 0.15m below the ground level.

Invert level of the outlet is 0.2m below the ground level.

Volume of tank includes the volume for sludge accumulation and wastewater. Volume for wastewater is taken as constant as 200 liter. Volume for sludge is varying according to cattle number.

Tank empty times = 1 time in a day for larger size tank while for smaller size, tank it is 7 days.

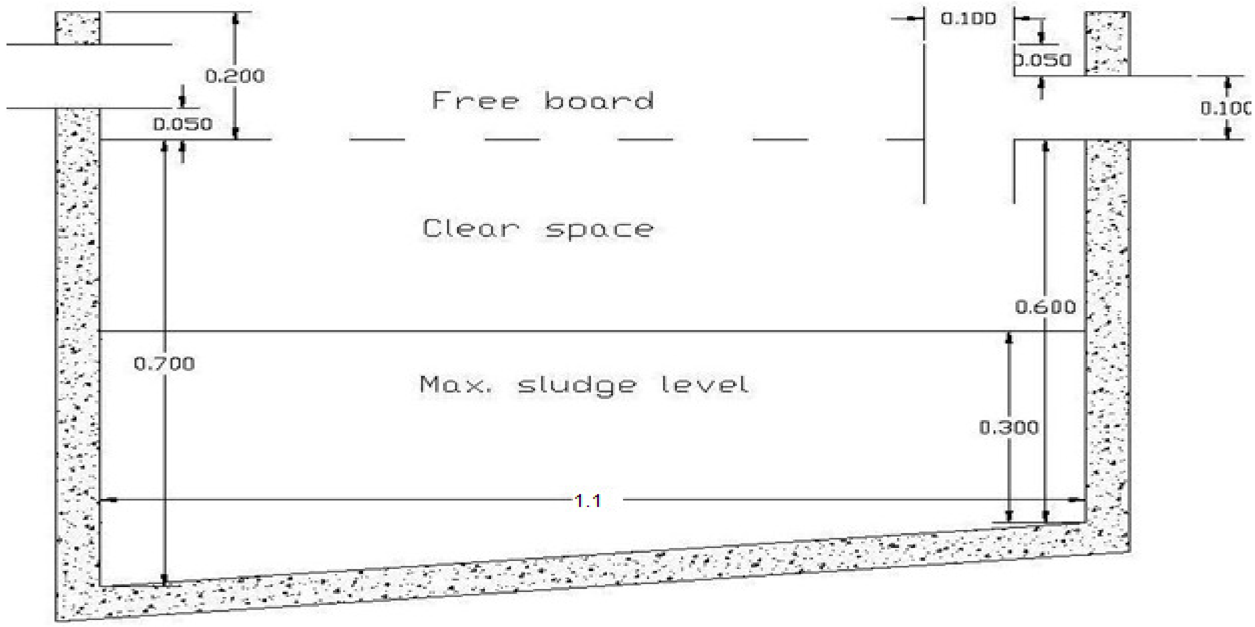


Fig: 4.5 Cattle tank for 2 cattle

Table: 4.5 Computation table for cattle tank

S.no.	No. of cattles	Discharge	Volume require for dung	Total volume	Depth	Length	Width	Depth with slope
		lpd	m3	m3	m	m	m	m
1	1	75	0.07	0.27	0.6	0.9	0.5	0.7
2	2	150	0.14	0.34	0.6	1.1	0.5	0.7
3	3	225	0.21	0.41	0.6	1.2	0.6	0.7
4	4	300	0.28	0.48	0.6	1.3	0.6	0.7
5	5	375	0.35	0.55	0.6	1.4	0.7	0.7
6	6	450	0.06	0.26	0.6	0.9	0.5	0.7
7	7	525	0.07	0.27	0.6	0.9	0.5	0.7
8	8	600	0.08	0.28	0.6	1.0	0.5	0.7
9	9	675	0.09	0.29	0.6	1.0	0.5	0.7
10	10	750	0.10	0.30	0.6	1.0	0.5	0.7
11	11	825	0.11	0.31	0.6	1.0	0.5	0.7
12	12	900	0.12	0.32	0.6	1.0	0.5	0.7
13	13	975	0.13	0.33	0.6	1.0	0.5	0.7
14	14	1050	0.14	0.34	0.6	1.1	0.5	0.7
15	15	1125	0.15	0.35	0.6	1.1	0.5	0.7

2. Siphon system

Siphon system is working for the depth of 0.5

Siphon Diameter- 0.075m

Outlet size - 0.075m

Well size - 0.235m

Width of Trap - 0.205m

Trap to Discharge- 0.300m

Height of trap above low water line- 0.12m

Space provide below the well is 0.08 (assumption for clogging safety)

The dimension details for the different number of users are shown in table (4.6). Number of flushing is dependent on the flow coming from the household. Tank is vacant four to twelve times in a day.

All internal and external dimensions detail are shown in figure (4.6) while wire frame view and solid view are shown in figure (4.7), figure (4.8) respectively. The design of Siphon chamber being repetitive can be summarized in tabular form and is shown in table (4.6) on subsequent pages.

Table: 4.6 Computation table for design of siphon chamber

S.NO.	No. of person	Volume	Depth	Width	Length	Depth with slope	Depth of extra chamber	Length of extra chamber	Remaining length
1	5- 15	0.143	0.5	0.536	0.536	0.507	0.59	0.395	0.141
2	20-50	0.574	0.5	1.071	1.071	0.534	0.61	0.395	0.676

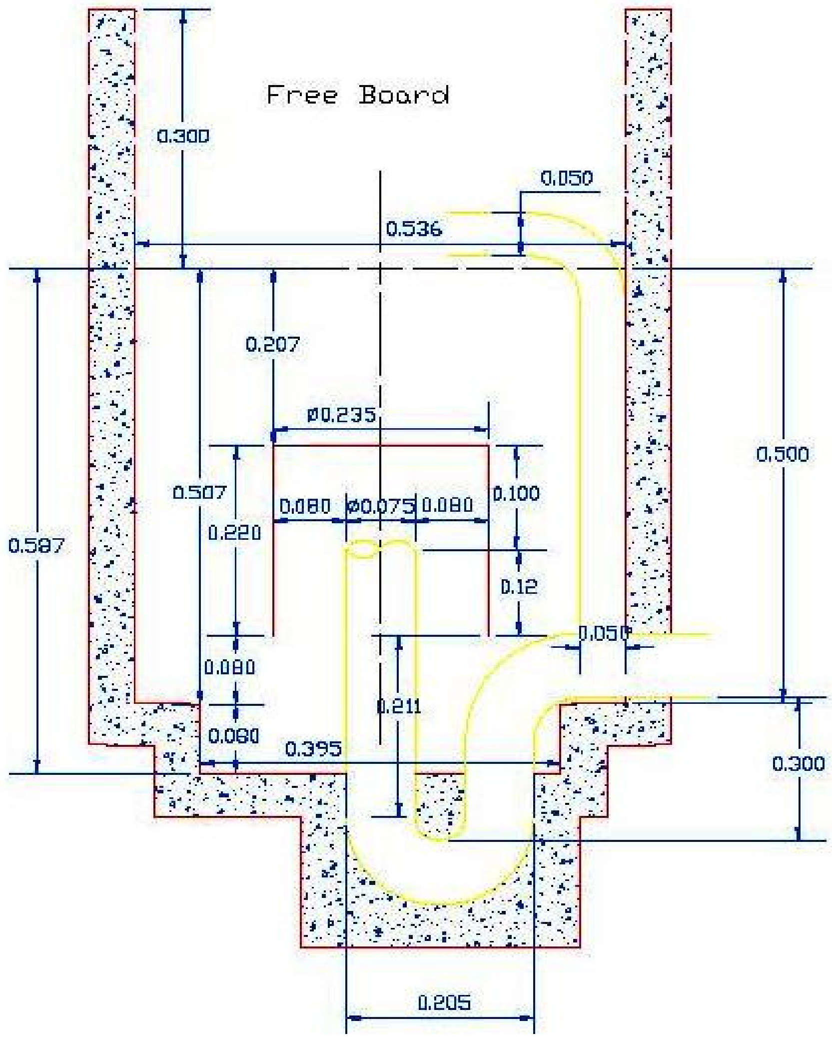
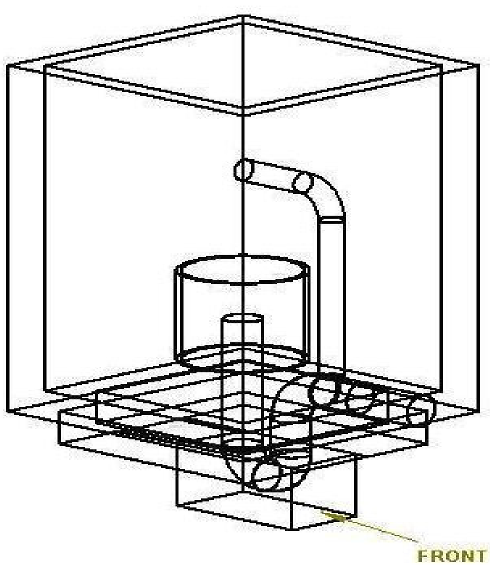


Fig: 4.6 Siphon system with internal and outer dimension for up to 15 users.



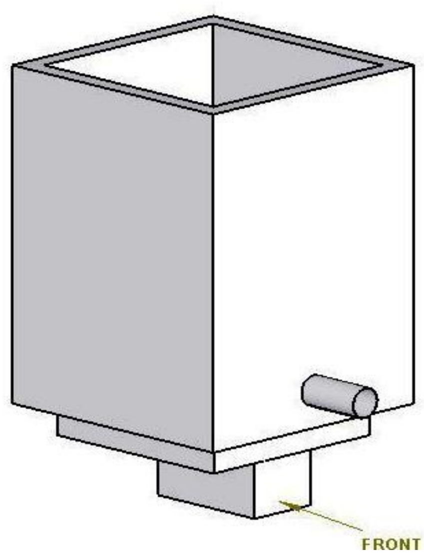


Fig: 4.7 Wire frame view of siphon system **Fig: 4.8** Solid view of siphon system

3. Sewer

Schematic diagram of sewer are shown in figure (4.1, 4.2, 4.3, 4.4).

Detailed plan showing building, population cultivated land, future growth, roads layout and elevation are shown in map (annex: 2, 3, 4, 5).

Water supply for that village is 135 liter per capita per day (Data collected from that village). All the water supply is not collected as sewage from the household. Hence, only 85% of the supplied water has been considered as sewage generated by the households. Hence, design sewage generation rate considered in the present study is 115lpcd. While in case of cattle house, it is 75lpcd.

The village is having scattered population and during part of the year, most of the sewer are not able to ensure self cleansing velocities. For getting the self cleansing velocity, a siphon system has been designed. The flow coming from the siphon system is referred to as the minimum peak flow which is 8.04l/s.

Peaking factor of 2.4 and tractive tension of 1.5Pascal has been considered for sewer design.

Incremental rate per year for village is 1.22.

No Infiltration has been considered because of using the PVC pipe. The hydraulic calculation of sewer being repetitive can be summarized in tabular form and shown in table (4.7, 4.8, 4.9, 4.10) on subsequent page.

Table: 4.7 Calculation table for sewerage system 1

Sewer	L (m)	Initial u/s flow (l/s)	Initial flow (l/s)	Total Initial flow (l/s)	Final u/s flow (l/s)	Final flow (l/s)	Total final flow (l/s)	u/s J. no.	d/s J. no.	Ground level u/s (m)	Ground level d/s (m)	Ground slope	Invert level U/s	Invert level D/s	I	Choosen D	d/D initial	d/D final	Initial v	Final v	Depth U/s	Depth d/s
1	76	0.000	0.008	8.04	0.000	0.011	8.04	J_up	2	98.21	98.21	0.000	97.16	96.91	0.003	0.15	0.755	0.755	0.562	0.562	1.1	1.3
3	64	0.000	0.010	8.04	0.000	0.041	8.04	3	5	98.78	98.78	0.000	97.73	97.52	0.003	0.15	0.755	0.755	0.562	0.562	1.1	1.3
4	14	0.000	0.000	8.04	0.000	0.000	8.04	4	5	98.78	98.78	0.000	97.73	97.68	0.003	0.15	0.755	0.755	0.562	0.562	1.1	1.1
5	9	0.000	0.000	8.04	0.074	0.013	8.04	5	7	98.78	98.78	0.000	97.52	97.49	0.003	0.15	0.755	0.755	0.562	0.562	1.3	1.3
6	11	0.000	0.014	8.04	0.000	0.033	8.04	6	7	98.78	98.78	0.000	97.73	97.69	0.003	0.15	0.755	0.755	0.562	0.562	1.1	1.1
7	37	0.023	0.003	8.04	0.087	0.043	8.04	7	9	98.78	98.78	0.000	97.49	97.37	0.003	0.15	0.755	0.755	0.562	0.562	1.3	1.4
8	20	0.000	0.021	8.04	0.000	0.030	8.04	8	9	98.78	98.78	0.000	97.73	97.66	0.003	0.15	0.755	0.755	0.562	0.562	1.1	1.1
10	149	0.000	0.013	8.04	0.113	0.018	8.04	2	10	98.21	98.63	-0.003	95.92	95.43	0.003	0.15	0.755	0.755	0.562	0.562	2.3	3.2
14	76	0.000	0.002	8.04	0.000	0.002	8.04	11	12	98.73	98.73	0.000	97.68	97.43	0.003	0.15	0.755	0.755	0.562	0.562	1.1	1.3
15	36	0.000	0.000	8.04	0.000	0.000	8.04	13	14	98.73	98.73	0.000	97.68	97.56	0.003	0.15	0.755	0.755	0.562	0.562	1.1	1.2
16	75	0.080	0.051	8.04	0.346	0.101	8.04	15	31	99.07	98.75	0.004	95.25	94.95	0.004	0.15	0.7	0.7	0.610	0.610	3.8	3.8
17	35	0.131	0.025	8.04	0.460	0.036	8.04	31	36	98.75	98.75	0.000	94.95	94.81	0.004	0.15	0.7	0.7	0.610	0.610	3.8	3.9
18	48	0.000	0.000	8.04	0.000	0.013	8.04	32	31	99.24	98.75	0.010	98.19	97.71	0.010	0.15	0.515	0.515	0.873	0.873	1.1	1.0
9	23	0.048	0.017	8.04	0.161	0.025	8.04	9	10	98.78	98.63	0.007	97.37	97.21	0.007	0.15	0.575	0.575	0.762	0.762	1.4	1.4
11	15	0.080	0.000	8.04	0.319	0.000	8.04	10	12	98.63	98.73	-0.007	95.43	95.38	0.003	0.15	0.755	0.755	0.562	0.562	3.2	3.3
12	29	0.080	0.000	8.04	0.319	0.027	8.04	12	14	98.73	98.73	0.000	95.38	95.29	0.003	0.15	0.755	0.755	0.562	0.562	3.3	3.4
13	10	0.080	0.000	8.04	0.346	0.000	8.04	14	15	98.73	99.07	-0.034	95.29	95.25	0.003	0.15	0.755	0.755	0.562	0.562	3.4	3.8
19	53	0.000	0.031	8.04	0.000	0.058	8.04	32a	34	99.24	98.51	0.014	98.19	97.45	0.014	0.15	0.565	0.565	1.071	1.071	1.1	1.1
20	36	0.000	0.003	8.04	0.000	0.018	8.04	33	34	98.96	98.51	0.012	97.91	97.44	0.013	0.15	0.475	0.475	0.961	0.961	1.1	1.1
21	44	0.034	0.032	8.04	0.076	0.046	8.04	34	37	98.51	98.54	-0.001	97.44	97.30	0.003	0.15	0.755	0.755	0.562	0.562	1.1	1.2
22	17	0.000	0.031	8.04	0.000	0.058	8.04	36a	37	98.54	98.54	0.000	97.49	97.43	0.003	0.15	0.755	0.755	0.562	0.562	1.1	1.1
23	37	0.098	0.034	8.04	0.181	0.049	8.04	37	39	98.54	98.54	0.000	97.30	97.17	0.003	0.15	0.755	0.755	0.562	0.562	1.2	1.4
24	35	0.152	0.009	8.04	0.237	0.027	8.04	39	58	98.54	97.67	0.025	97.17	96.30	0.025	0.15	0.395	0.395	1.222	1.222	1.4	1.4
25	24	0.000	0.021	8.04	0.000	0.043	8.04	38	39	98.54	98.54	0.000	97.49	97.41	0.003	0.15	0.755	0.755	0.562	0.562	1.1	1.1
26	72	0.000	0.083	8.04	0.000	0.147	8.04	16	19	98.56	98.03	0.007	97.51	97.01	0.007	0.15	0.575	0.575	0.762	0.762	1.1	1.0

27	51	0.145	0.040	8.04	0.301	0.071	8.04	19	26	98.03	97.87	0.003	96.96	96.79	0.003	0.15	0.755	0.755	0.562	0.562	1.1	1.1
28	50	0.231	0.069	8.04	0.515	0.112	8.04	26	28	97.87	97.89	0.000	96.79	96.63	0.003	0.15	0.755	0.755	0.562	0.562	1.1	1.3
29	7	0.392	0.006	8.04	0.773	0.009	8.04	28	30	97.89	97.89	0.000	96.63	96.60	0.003	0.15	0.755	0.755	0.562	0.562	1.3	1.3
30	24	0.462	0.050	8.04	0.901	0.086	8.04	30	40	97.89	97.92	-0.001	96.60	96.52	0.003	0.15	0.755	0.755	0.562	0.562	1.3	1.4
31	13	0.555	0.014	8.04	1.086	0.020	8.04	40	42	97.92	97.92	0.000	96.52	96.48	0.003	0.15	0.755	0.755	0.562	0.562	1.4	1.4
32	23	0.568	0.025	8.04	1.105	0.049	8.04	42	58	97.92	97.67	0.011	96.48	96.23	0.011	0.15	0.5	0.5	0.904	0.904	1.4	1.4
33	18	0.000	0.013	8.04	0.000	0.050	8.04	17	72	98.56	98.56	0.000	97.51	97.45	0.003	0.15	0.755	0.755	0.562	0.562	1.1	1.1
34	24	0.023	0.005	8.04	0.072	0.007	8.04	72	19	98.56	98.03	0.022	97.45	96.92	0.022	0.15	0.415	0.415	1.174	1.174	1.1	1.1
35	9	0.000	0.011	8.04	0.000	0.016	8.04	18	72	98.72	98.56	0.018	97.67	97.51	0.018	0.15	0.435	0.435	1.086	1.086	1.1	1.1
36	41	0.000	0.034	8.04	0.000	0.049	8.04	20	19	100.37	98.03	0.057	99.32	96.98	0.057	0.15	0.315	0.315	1.640	1.640	1.1	1.0
37	32	0.000	0.000	8.04	0.000	0.027	8.04	21	19	99.35	98.03	0.041	98.30	96.99	0.041	0.15	0.345	0.345	1.460	1.460	1.1	1.0
38	46	0.000	0.017	8.04	0.000	0.088	8.04	23	25	97.87	97.87	0.000	96.82	96.67	0.003	0.15	0.755	0.755	0.562	0.562	1.1	1.2
39	22	0.046	0.000	8.04	0.129	0.013	8.04	25	26	97.87	97.87	0.000	96.67	96.60	0.003	0.15	0.755	0.755	0.562	0.562	1.2	1.3
40	20	0.000	0.029	8.04	0.000	0.041	8.04	24	25	97.87	97.87	0.000	96.82	96.75	0.003	0.15	0.755	0.755	0.562	0.562	1.1	1.1
41	46	0.000	0.069	8.04	0.000	0.113	8.04	27	28	97.89	97.89	0.000	96.84	96.69	0.003	0.15	0.755	0.755	0.562	0.562	1.1	1.2
42	23	0.000	0.023	8.04	0.000	0.033	8.04	29	30	97.89	97.89	0.000	96.84	96.76	0.003	0.15	0.755	0.755	0.562	0.562	1.1	1.1
43	61	0.000	0.064	8.04	0.000	0.119	8.04	34a	40	98.51	97.92	0.010	97.46	96.85	0.010	0.15	0.515	0.515	0.873	0.873	1.1	1.1
44	39.3	0.000	0.042	8.04	0.000	0.099	8.04	41	42	97.92	97.92	0.000	96.87	96.74	0.003	0.15	0.755	0.755	0.562	0.562	1.1	1.2
45	61	0.000	0.011	8.04	0.000	0.054	8.04	43	46	97.53	97.21	0.005	96.48	96.18	0.005	0.15	0.645	0.645	0.668	0.668	1.1	1.0
46	30	0.000	0.033	8.04	0.000	0.061	8.04	50	51	97.19	97.19	0.000	96.14	96.04	0.003	0.15	0.755	0.755	0.562	0.562	1.1	1.1
47	22	0.000	0.000	8.04	0.000	0.000	8.04	52	53	97.41	97.41	0.000	96.36	96.29	0.003	0.15	0.755	0.755	0.562	0.562	1.1	1.1
48	13	0.000	0.000	8.04	0.000	0.040	8.04	54	55	97.41	97.41	0.000	96.36	96.32	0.003	0.15	0.755	0.755	0.562	0.562	1.1	1.1
49	32	0.000	0.031	8.04	0.000	0.058	8.04	56	57	97.73	97.73	0.000	96.68	96.57	0.003	0.15	0.755	0.755	0.562	0.562	1.1	1.2
2	108	0.000	0.000	8.04	0.000	0.113	8.04	1	2	97.40	98.21	-0.007	96.28	95.92	0.003	0.15	0.755	0.755	0.562	0.562	1.1	2.3
51	17	0.036	0.007	8.04	0.052	0.010	8.04	70	74	97.21	97.21	0.000	96.06	96.00	0.003	0.15	0.755	0.755	0.562	0.562	1.1	1.2
52	27	0.043	0.000	8.04	0.062	0.000	8.04	74	46	97.21	97.21	0.000	96.00	95.92	0.003	0.15	0.755	0.755	0.562	0.562	1.2	1.3
53	24	0.055	0.000	8.04	0.117	0.000	8.04	46	47	97.21	97.09	0.005	95.92	95.80	0.005	0.15	0.645	0.645	0.668	0.668	1.3	1.3
54	26	0.055	0.022	8.04	0.117	0.031	8.04	47	48	97.09	96.99	0.004	95.80	95.69	0.004	0.15	0.695	0.695	0.609	0.609	1.3	1.3
55	83	0.076	0.035	8.04	0.148	0.051	8.04	48	51	96.99	97.19	-0.002	95.69	95.42	0.003	0.15	0.755	0.755	0.562	0.562	1.3	1.8

56	20	0.145	0.006	8.04	0.260	0.009	8.04	51	53	97.19	97.41	-0.011	95.42	95.35	0.003	0.15	0.755	0.755	0.562	0.562	1.8	2.1
57	20	0.151	0.008	8.04	0.269	0.025	8.04	53	55	97.41	97.41	0.000	95.35	95.29	0.003	0.15	0.755	0.755	0.562	0.562	2.1	2.1
58	21	0.159	0.003	8.04	0.334	0.018	8.04	55	57	97.41	97.73	-0.015	95.29	95.22	0.003	0.15	0.755	0.755	0.562	0.562	2.1	2.5
59	36	0.194	0.036	8.04	0.411	0.194	8.04	57	58	97.73	97.67	0.002	95.22	95.10	0.003	0.15	0.755	0.755	0.562	0.562	2.5	2.6
50	30	0.000	0.036	8.04	0.000	0.052	8.04	44	70	97.21	97.21	0.000	96.16	96.06	0.003	0.15	0.755	0.755	0.562	0.562	1.1	1.1
69	51	0.985	0.043	8.04	1.932	0.062	8.04	58	66	97.67	97.45	0.004	95.10	95.21	0.004	0.15	0.695	0.695	0.609	0.609	2.6	2.2
70	131	1.033	0.088	8.04	2.008	0.139	8.04	66	67	97.45	97.19	0.002	95.21	94.78	0.003	0.15	0.755	0.755	0.562	0.562	2.2	2.4
71	100	0.000	0.010	8.04	0.000	0.053	8.04	68	67	97.19	97.19	0.000	94.78	94.45	0.003	0.15	0.755	0.755	0.562	0.562	2.4	2.7
72	29	0.000	0.005	8.04	0.000	0.000	8.04	65	66	97.45	97.45	0.000	96.40	96.30	0.003	0.15	0.755	0.755	0.562	0.562	1.1	1.1
60	33	1.426	0.000	8.04	2.931	0.000	8.04	64	67	97.30	97.19	0.003	93.15	93.05	0.003	0.15	0.79	0.79	0.538	0.538	4.2	4.1
61	50	0.244	0.000	8.04	0.636	0.013	8.04	71	64	97.30	97.30	0.000	93.31	93.15	0.003	0.15	0.755	0.755	0.562	0.562	4.0	4.2
62	63	0.194	0.050	8.04	0.565	0.071	8.04	61	71	97.54	97.30	0.004	93.56	93.31	0.004	0.15	0.695	0.695	0.609	0.609	4.0	4.0
63	63	0.189	0.005	8.04	0.558	0.007	8.04	60	61	98.27	97.54	0.012	94.32	93.56	0.012	0.15	0.485	0.485	0.932	0.932	4.0	4.0
64	45	0.156	0.033	8.04	0.497	0.047	8.04	36	60	98.75	98.27	0.011	94.81	94.32	0.011	0.15	0.5	0.5	0.904	0.904	3.9	4.0
65	26	0.000	0.005	8.04	0.000	0.007	8.04	62	63	97.30	97.30	0.000	96.25	96.16	0.003	0.15	0.755	0.755	0.562	0.562	1.1	1.1
66	64	0.005	0.046	8.04	0.007	0.080	8.04	63	64	97.30	97.30	0.000	96.16	95.95	0.003	0.15	0.755	0.755	0.562	0.562	1.1	1.3

Table: 4.8 Calculation table for 2nd sewerage system

Sewer	L (m)	Initial u/s flow (l/s)	Initial flow (l/s)	Total Initial flow (l/s)	Final u/s flow (l/s)	Final flow (l/s)	Total final flow (l/s)	u/s J.	d/s J.	Ground level u/s (m)	Ground level d/s (m)	Ground slope	Invert level U/s	Invert level D/s	I	Choosen D	d/D initial	d/D final	initial V	Final V	Depth U/s	Depth D/s
1	56	0.000	0.009	8.04	0.000	0.040	8.04	152	16	99.07	99.02	0.001	98.02	97.84	0.003	0.15	0.76	0.76	0.56	0.56	1.1	1.2
2	37	0.068	0.000	8.04	0.138	0.027	8.04	16	18	99.02	98.49	0.014	97.84	97.32	0.014	0.15	0.47	0.47	0.99	0.99	1.2	1.2
3	50	0.046	0.000	8.04	0.066	0.000	8.04	13	15	99.49	99.32	0.003	98.44	98.28	0.003	0.15	0.76	0.76	0.56	0.56	1.1	1.0
4	39	0.059	0.000	8.04	0.084	0.013	8.04	15	16	99.32	99.02	0.008	98.25	97.93	0.008	0.15	0.56	0.56	0.80	0.80	1.1	1.1
5	48.4	0.000	0.013	8.04	0.000	0.018	8.04	14	15	99.49	99.32	0.004	98.44	98.25	0.004	0.15	0.70	0.70	0.61	0.61	1.1	1.1
6	108	0.000	0.035	8.04	0.000	0.064	8.04	17	18	98.49	98.49	0.000	97.44	97.08	0.003	0.15	0.76	0.76	0.56	0.56	1.1	1.4
7	26	0.103	0.008	8.04	0.230	0.025	8.04	18	20	98.49	98.56	-0.003	97.08	97.00	0.003	0.15	0.76	0.76	0.56	0.56	1.4	1.6
8	103	0.000	0.047	8.04	0.000	0.081	8.04	19	20	98.57	98.56	0.000	97.52	97.18	0.003	0.15	0.76	0.76	0.56	0.56	1.1	1.4
9	45	0.158	0.032	8.04	0.335	0.059	8.04	20	24	98.56	98.57	0.000	97.00	96.85	0.003	0.15	0.76	0.76	0.56	0.56	1.6	1.7
10	4.5	0.000	0.011	8.04	0.000	0.029	8.04	2	3	100.35	100.35	0.000	99.30	99.29	0.003	0.15	0.76	0.76	0.56	0.56	1.1	1.1
11	27	0.022	0.009	8.04	0.045	0.013	8.04	3	5	100.35	100.35	0.000	99.29	99.20	0.003	0.15	0.76	0.76	0.56	0.56	1.1	1.2
12	12	0.000	0.011	8.04	0.000	0.016	8.04	4	5	100.35	100.35	0.000	99.30	99.26	0.003	0.15	0.76	0.76	0.56	0.56	1.1	1.1
13	13	0.031	0.003	8.04	0.058	0.018	8.04	5	6	100.35	100.19	0.012	99.20	99.04	0.012	0.15	0.49	0.49	0.94	0.94	1.2	1.1
14	18	0.034	0.019	8.04	0.076	0.027	8.04	6	7	100.19	100.19	0.000	99.04	98.98	0.003	0.15	0.76	0.76	0.56	0.56	1.1	1.2
15	10	0.070	0.000	8.04	0.128	0.000	8.04	7	9	100.19	99.67	0.052	99.14	98.62	0.052	0.15	0.33	0.33	1.59	1.59	1.1	1.1
16	20	0.000	0.017	8.04	0.000	0.025	8.04	8	9	99.67	99.67	0.000	98.62	98.55	0.003	0.15	0.76	0.76	0.56	0.56	1.1	1.1
17	29	0.070	0.033	8.04	0.128	0.061	8.04	9	11	99.67	99.52	0.005	98.55	98.41	0.005	0.15	0.65	0.65	0.67	0.67	1.1	1.1
18	13	0.000	0.008	8.04	0.000	0.025	8.04	10	11	99.52	99.52	0.000	98.47	98.43	0.003	0.15	0.76	0.76	0.56	0.56	1.1	1.1
19	62	0.111	0.060	8.04	0.214	0.110	8.04	11	44	99.52	99.40	0.002	98.41	98.20	0.003	0.15	0.76	0.76	0.56	0.56	1.1	1.2
20	64	0.424	0.085	8.04	0.799	0.122	8.04	44	43	99.40	98.75	0.010	97.07	96.43	0.010	0.15	0.52	0.52	0.87	0.87	2.3	2.3
21	26	0.000	0.011	8.04	0.000	0.029	8.04	42	43	98.75	98.75	0.000	97.70	97.61	0.003	0.15	0.76	0.76	0.56	0.56	1.1	1.1
22	42	0.520	0.035	8.04	0.950	0.050	8.04	43	24	98.75	98.57	0.004	96.43	96.26	0.004	0.15	0.70	0.70	0.61	0.61	2.3	2.3
23	25.5	0.000	0.023	8.04	0.000	0.047	8.04	36	30	101.12	101.37	-0.010	100.07	99.99	0.003	0.15	0.76	0.76	0.56	0.56	1.1	1.4
25	12.3	0.000	0.003	8.04	0.000	0.018	8.04	29	30	101.37	101.37	0.000	99.99	99.95	0.003	0.15	0.76	0.76	0.56	0.56	1.4	1.4
26	25	0.027	0.041	8.04	0.065	0.058	8.04	30	34	101.37	100.84	0.021	99.95	99.42	0.021	0.15	0.42	0.42	1.15	1.15	1.4	1.4

27	31	0.000	0.000	8.04	0.000	0.013	8.04	7a	31	100.19	100.79	-0.019	98.98	98.88	0.003	0.15	0.76	0.76	0.56	0.56	1.2	1.9
28	5	0.000	0.000	8.04	0.013	0.000	8.04	31	32	100.79	100.79	0.000	98.88	98.86	0.003	0.15	0.76	0.76	0.56	0.56	1.9	1.9
29	18	0.000	0.019	8.04	0.013	0.027	8.04	32	33	100.79	101.10	-0.017	98.86	98.80	0.003	0.15	0.76	0.76	0.56	0.56	1.9	2.3
30	20	0.086	0.008	8.04	0.164	0.025	8.04	33	34	101.10	100.84	0.013	98.80	98.54	0.013	0.15	0.48	0.48	0.96	0.96	2.3	2.3
31	23	0.161	0.019	8.04	0.312	0.040	8.04	34	35	100.84	100.38	0.020	98.54	98.08	0.020	0.15	0.43	0.43	1.13	1.13	2.3	2.3
32	64	0.000	0.022	8.04	0.000	0.059	8.04	37	40	100.37	100.38	0.000	99.32	99.11	0.003	0.15	0.76	0.76	0.56	0.56	1.1	1.3
33	25.5	0.220	0.011	8.04	0.439	0.016	8.04	40	41	100.38	99.53	0.033	98.03	97.18	0.033	0.15	0.37	0.37	1.35	1.35	2.4	2.3
34	29	0.231	0.022	8.04	0.454	0.031	8.04	41	44	99.53	99.40	0.004	97.18	97.07	0.004	0.15	0.70	0.70	0.61	0.61	2.3	2.3
35	17	0.180	0.019	8.04	0.353	0.027	8.04	35	40	100.38	100.38	0.000	98.08	98.03	0.003	0.15	0.76	0.76	0.56	0.56	2.3	2.4
36	27	0.000	0.023	8.04	0.000	0.034	8.04	22	23	98.36	98.36	0.000	97.31	97.22	0.003	0.15	0.76	0.76	0.56	0.56	1.1	1.1
37	86	0.023	0.044	8.04	0.034	0.090	8.04	23	24	98.36	98.57	-0.002	97.22	96.94	0.003	0.15	0.76	0.76	0.56	0.56	1.1	1.6
38	117	0.758	0.047	8.04	1.414	0.166	8.04	24	27	98.57	97.98	0.005	96.26	95.68	0.005	0.15	0.65	0.65	0.67	0.67	2.3	2.3
39	29	0.880	0.000	8.04	1.783	0.013	8.04	27	58	97.98	97.59	0.013	95.68	95.30	0.013	0.15	0.48	0.48	0.96	0.96	2.3	2.3
40	49	0.000	0.022	8.04	0.041	0.058	8.04	26	27	98.22	97.98	0.005	97.17	96.93	0.005	0.15	0.65	0.65	0.67	0.67	1.1	1.1
41	88	0.000	0.069	8.04	0.000	0.127	8.04	59a	58	97.44	97.59	-0.002	96.39	96.10	0.003	0.15	0.76	0.76	0.56	0.56	1.1	1.5
42	29	0.000	0.025	8.04	0.000	0.050	8.04	59	61	97.44	97.44	0.000	96.39	96.29	0.003	0.15	0.76	0.76	0.56	0.56	1.1	1.1
43	17	0.033	0.016	8.04	0.061	0.022	8.04	61	62	97.44	97.44	0.000	96.29	96.24	0.003	0.15	0.76	0.76	0.56	0.56	1.1	1.2
44	13	0.000	0.008	8.04	0.000	0.011	8.04	60	61	97.44	97.44	0.000	96.39	96.35	0.003	0.15	0.76	0.76	0.56	0.56	1.1	1.1
45	45	0.048	0.033	8.04	0.083	0.047	8.04	62	63	97.44	97.35	0.002	96.24	96.09	0.003	0.15	0.76	0.76	0.56	0.56	1.2	1.3
46	38	0.081	0.022	8.04	0.130	0.031	8.04	63	69	97.35	97.67	-0.008	96.09	95.96	0.003	0.15	0.76	0.76	0.56	0.56	1.3	1.7
47	43	0.949	0.009	8.04	1.923	0.040	8.04	58	69	97.59	97.67	-0.002	94.68	94.54	0.003	0.15	0.76	0.76	0.56	0.56	2.9	3.1
48	22	1.134	0.036	8.04	2.267	0.051	8.04	69	71	97.67	97.39	0.013	94.54	94.25	0.013	0.15	0.48	0.48	0.96	0.96	3.1	3.1
49	13	1.189	0.026	8.04	2.347	0.037	8.04	71	73	97.39	97.39	0.000	94.25	94.21	0.003	0.15	0.76	0.76	0.56	0.56	3.1	3.2
50	26	1.263	0.010	8.04	2.481	0.014	8.04	73	78	97.39	97.27	0.005	94.21	94.08	0.005	0.15	0.65	0.65	0.67	0.67	3.2	3.2
51	23	0.000	0.020	8.04	0.000	0.029	8.04	70	71	97.39	97.39	0.000	96.34	96.26	0.003	0.15	0.76	0.76	0.56	0.56	1.1	1.1
52	73	0.000	0.048	8.04	0.000	0.097	8.04	72	73	97.39	97.39	0.000	96.34	96.10	0.003	0.15	0.76	0.76	0.56	0.56	1.1	1.3
53	12	0.000	0.006	8.04	0.000	0.022	8.04	41a	45	99.53	99.53	0.000	98.48	98.44	0.003	0.15	0.76	0.76	0.56	0.56	1.1	1.1
54	23	0.037	0.000	8.04	0.067	0.013	8.04	45	79	99.53	99.53	0.000	98.44	98.36	0.003	0.15	0.76	0.76	0.56	0.56	1.1	1.2
55	30	0.037	0.039	8.04	0.081	0.070	8.04	79	80	99.53	99.27	0.009	98.36	98.09	0.009	0.15	0.54	0.54	0.84	0.84	1.2	1.2

56	37	0.076	0.025	8.04	0.150	0.036	8.04	80	97	99.27	97.14	0.058	98.09	95.95	0.058	0.15	0.32	0.32	1.65	1.65	1.2	1.2
57	92	0.101	0.016	8.04	0.186	0.061	8.04	97	98	97.14	96.91	0.003	95.95	95.67	0.003	0.15	0.80	0.80	0.54	0.54	1.2	1.2
58	50	1.397	0.032	8.04	2.740	0.073	8.04	78	98	97.27	96.91	0.007	94.08	93.73	0.007	0.15	0.58	0.58	0.76	0.76	3.2	3.2
59	17	0.000	0.000	8.04	0.000	0.013	8.04	52	51	99.53	99.53	0.000	98.48	98.42	0.003	0.15	0.76	0.76	0.56	0.56	1.1	1.1
60	9	0.000	0.009	8.04	0.013	0.013	8.04	51	50	99.53	99.53	0.000	98.48	98.45	0.003	0.15	0.76	0.76	0.56	0.56	1.1	1.1
61	14	0.009	0.000	8.04	0.000	0.027	8.04	50	74	99.53	99.29	0.017	98.45	98.21	0.017	0.15	0.45	0.45	1.07	1.07	1.1	1.1
62	21	0.009	0.000	8.04	0.027	0.000	8.04	74	75	99.29	98.82	0.022	98.21	97.75	0.022	0.15	0.46	0.46	0.96	0.96	1.1	1.1
63	39	0.009	0.053	8.04	0.027	0.104	8.04	75	77	98.82	98.82	0.000	97.75	97.62	0.003	0.15	0.76	0.76	0.56	0.56	1.1	1.2
64	51	0.070	0.054	8.04	0.168	0.077	8.04	77	78	98.82	97.27	0.030	97.62	96.09	0.030	0.15	0.38	0.38	1.30	1.30	1.2	1.2
65	30	0.000	0.007	8.04	0.000	0.037	8.04	76	77	98.82	98.82	0.000	97.77	97.67	0.003	0.15	0.76	0.76	0.56	0.56	1.1	1.1
66	9	0.000	0.019	8.04	0.000	0.027	8.04	46	47	100.00	100.00	0.000	98.95	98.92	0.003	0.15	0.76	0.76	0.56	0.56	1.1	1.1
67	7	0.019	0.000	8.04	0.027	0.000	8.04	47	48	100.00	100.00	0.000	98.92	98.90	0.003	0.15	0.76	0.76	0.56	0.56	1.1	1.1
68	16	0.019	0.013	8.04	0.027	0.018	8.04	48	45	100.00	99.53	0.029	98.90	98.43	0.029	0.15	0.39	0.39	1.30	1.30	1.1	1.1
69	9	0.000	0.000	8.04	0.000	0.014	8.04	97a	96	97.14	97.14	0.000	96.09	96.06	0.003	0.15	0.76	0.76	0.56	0.56	1.1	1.1
70	13	0.023	0.017	8.04	0.061	0.025	8.04	96	91	97.14	97.14	0.000	96.06	96.02	0.003	0.15	0.76	0.76	0.56	0.56	1.1	1.1
71	25	0.041	0.026	8.04	0.037	0.085	8.04	91	90	97.14	98.68	-0.062	96.02	95.93	0.003	0.15	0.76	0.76	0.56	0.56	1.1	2.7
72	41	0.000	0.023	8.04	0.000	0.047	8.04	93	95	97.14	97.14	0.000	96.09	95.95	0.003	0.15	0.76	0.76	0.56	0.56	1.1	1.2
73	11	0.023	0.000	8.04	0.047	0.013	8.04	95	96	97.14	97.14	0.000	95.95	95.92	0.003	0.15	0.76	0.76	0.56	0.56	1.2	1.2
74	16	0.000	0.039	8.04	0.000	0.070	8.04	1	36a	101.87	101.12	0.047	100.82	100.07	0.047	0.15	0.34	0.34	1.54	1.54	1.1	1.1
75	34	0.039	0.039	8.04	0.070	0.056	8.04	36a	37a	101.12	100.37	0.022	100.07	99.32	0.022	0.15	0.43	0.43	1.19	1.19	1.1	1.1
76	21	0.078	0.007	8.04	0.126	0.023	8.04	37a	81	100.37	100.37	0.000	99.32	99.25	0.003	0.15	0.76	0.76	0.56	0.56	1.1	1.1
77	17	0.085	0.016	8.04	0.149	0.036	8.04	81	83	100.37	98.90	0.086	99.25	97.79	0.086	0.15	0.29	0.29	1.91	1.91	1.1	1.1
78	41	0.000	0.034	8.04	0.000	0.050	8.04	82	83	100.73	98.90	0.045	99.68	97.84	0.045	0.15	0.35	0.35	1.53	1.53	1.1	1.1
79	26	0.135	0.005	8.04	0.234	0.020	8.04	83	86	98.90	98.24	0.025	97.79	97.14	0.025	0.15	0.40	0.40	1.22	1.22	1.1	1.1
80	28	0.000	0.044	8.04	0.000	0.076	8.04	84	86	98.24	98.24	0.000	97.19	97.10	0.003	0.15	0.76	0.76	0.56	0.56	1.1	1.1
81	29	0.183	0.022	8.04	0.331	0.070	8.04	86	89	98.24	98.24	0.000	97.14	97.04	0.003	0.15	0.76	0.76	0.56	0.56	1.1	1.2
82	11	0.000	0.013	8.04	0.000	0.032	8.04	88	89	98.24	98.24	0.000	97.19	97.15	0.003	0.15	0.76	0.76	0.56	0.56	1.1	1.1
83	12	0.218	0.006	8.04	0.432	0.009	8.04	89	90	98.24	98.68	-0.037	97.04	97.00	0.003	0.15	0.76	0.76	0.56	0.56	1.2	1.7
84	17	0.291	0.011	8.04	0.564	0.016	8.04	90	153	98.68	98.68	0.000	95.93	95.88	0.003	0.15	0.76	0.76	0.56	0.56	2.7	2.8

85	17	0.302	0.022	8.04	0.580	0.032	8.04	153	131	98.68	98.56	0.007	95.88	95.76	0.007	0.15	0.58	0.58	0.76	0.76	2.8	2.8
86	59	0.324	0.038	8.04	0.612	0.068	8.04	131	140	98.56	97.11	0.025	95.76	94.28	0.025	0.15	0.40	0.40	1.22	1.22	2.8	2.8
87	10	0.000	0.037	8.04	0.000	0.053	8.04	148	140	97.11	97.11	0.000	96.06	96.03	0.003	0.15	0.76	0.76	0.56	0.56	1.1	1.1
88	33	0.000	0.020	8.04	0.000	0.029	8.04	149	140	97.11	97.11	0.000	96.06	95.95	0.003	0.15	0.76	0.76	0.56	0.56	1.1	1.2
89	55	0.000	0.034	8.04	0.000	0.114	8.04	153a	132	98.56	98.27	0.005	97.51	97.24	0.005	0.15	0.65	0.65	0.67	0.67	1.1	1.0
90	57	0.018	0.034	8.04	0.114	0.027	8.04	132	133	98.27	96.36	0.034	97.19	95.25	0.034	0.15	0.36	0.36	1.35	1.35	1.1	1.1
91	41	1.546	0.039	8.04	3.061	0.097	8.04	98	100	96.91	96.91	0.000	93.73	93.59	0.003	0.15	0.76	0.76	0.56	0.56	3.2	3.3
92	19	1.601	0.022	8.04	3.180	0.045	8.04	100	113	96.91	96.97	-0.003	93.59	93.53	0.003	0.15	0.76	0.76	0.56	0.56	3.3	3.4
93	36	1.801	0.009	8.04	3.562	0.026	8.04	113	133	96.97	96.36	0.017	93.53	92.92	0.017	0.15	0.46	0.46	1.08	1.08	3.4	3.4
94	48	1.861	0.000	8.04	3.728	0.038	8.04	133	147	96.36	96.95	-0.012	92.92	92.76	0.003	0.15	0.76	0.76	0.56	0.56	3.4	4.2
95	35	0.000	0.002	8.04	0.027	0.016	8.04	146	147	97.95	96.95	0.029	96.09	95.07	0.029	0.15	0.39	0.39	1.30	1.30	1.9	1.9
96	14	0.000	0.000	8.04	0.000	0.000	8.04	145	146	97.23	97.95	-0.051	96.14	96.09	0.003	0.15	0.76	0.76	0.56	0.56	1.1	1.9
97	77	0.000	0.083	8.04	0.000	0.133	8.04	144a	145	97.44	97.23	0.003	96.39	96.14	0.003	0.15	0.76	0.76	0.56	0.56	1.1	1.1
98	31	0.000	0.021	8.04	0.000	0.030	8.04	137	138	97.29	97.29	0.000	96.24	96.14	0.003	0.15	0.76	0.76	0.56	0.56	1.1	1.2
99	65	0.021	0.046	8.04	0.071	0.093	8.04	138	143	97.29	97.20	0.001	96.14	95.92	0.003	0.15	0.76	0.76	0.56	0.56	1.2	1.3
100	75	0.067	0.033	8.04	0.164	0.088	8.04	143	144	97.20	97.44	-0.003	95.92	95.68	0.003	0.15	0.76	0.76	0.56	0.56	1.3	1.8
101	45	0.252	0.023	8.04	0.123	0.033	8.04	144	150	97.44	97.03	0.009	95.68	95.27	0.009	0.15	0.54	0.54	0.84	0.84	1.8	1.8
102	35	1.863	0.018	8.04	3.782	0.039	8.04	147	150	96.95	97.03	-0.002	92.76	92.64	0.003	0.15	0.76	0.76	0.56	0.56	4.2	4.4
103	85	2.423	0.046	8.04	4.895	0.093	10.2	150	151	97.03	97.03	0.000	92.59	92.31	0.003	0.2	0.46	0.53	0.58	0.61	4.4	4.7
104	40	0.418	0.000	8.04	0.762	0.027	8.04	140	150	97.11	97.03	0.002	94.28	94.15	0.003	0.15	0.76	0.76	0.56	0.56	2.8	2.9
105	12	0.000	0.009	8.04	0.000	0.027	8.04	101	102	96.56	96.56	0.000	95.51	95.47	0.003	0.15	0.76	0.76	0.56	0.56	1.1	1.1
106	21	0.009	0.052	8.04	0.027	0.088	8.04	102	105	96.56	96.56	0.000	95.47	95.40	0.003	0.15	0.76	0.76	0.56	0.56	1.1	1.2
107	5	0.000	0.019	8.04	0.000	0.027	8.04	103	104	96.56	96.56	0.000	95.51	95.49	0.003	0.15	0.76	0.76	0.56	0.56	1.1	1.1
108	17	0.019	0.011	8.04	0.027	0.016	8.04	104	105	96.56	96.56	0.000	95.49	95.44	0.003	0.15	0.76	0.76	0.56	0.56	1.1	1.1
109	31	0.091	0.020	8.04	0.158	0.056	8.04	105	107	96.56	96.66	-0.003	95.40	95.30	0.003	0.15	0.76	0.76	0.56	0.56	1.2	1.4
110	24	0.000	0.019	8.04	0.000	0.041	8.04	106	107	96.66	96.66	0.000	95.61	95.53	0.003	0.15	0.76	0.76	0.56	0.56	1.1	1.1
111	29	0.131	0.000	8.04	0.255	0.000	8.04	107	108	96.66	96.58	0.003	95.30	95.20	0.003	0.15	0.76	0.76	0.56	0.56	1.4	1.4
112	12	0.000	0.008	8.04	0.000	0.011	8.04	109	108	96.58	96.58	0.000	95.53	95.49	0.003	0.15	0.76	0.76	0.56	0.56	1.1	1.1
113	24	0.138	0.019	8.04	0.267	0.041	8.04	108	111	96.58	96.58	0.000	95.20	95.12	0.003	0.15	0.76	0.76	0.56	0.56	1.4	1.5

114	16	0.000	0.020	8.04	0.000	0.029	8.04	110	111	96.58	96.58	0.000	95.53	95.48	0.003	0.15	0.76	0.76	0.56	0.56	1.1	1.1
115	38	0.178	0.000	8.04	0.336	0.000	8.04	111	112	96.58	96.46	0.003	95.12	95.00	0.003	0.15	0.76	0.76	0.56	0.56	1.5	1.5
116	28	0.178	0.000	8.04	0.336	0.000	8.04	112	113	96.46	96.91	-0.016	95.00	94.91	0.003	0.15	0.76	0.76	0.56	0.56	1.5	2.0
117	246	0.000	0.072	8.04	0.000	0.142	8.04	67	69	96.54	97.67	-0.005	95.49	94.68	0.003	0.15	0.76	0.76	0.56	0.56	1.1	3.0

Table: 4.9 Calculation table for 3rd sewerage system

Sewer	L (m)	Initial u/s flow (l/s)	Initial flow (l/s)	Total Initial flow (l/s)	Final u/s flow (l/s)	Final flow (l/s)	Total final flow (l/s)	u/s J. no.	d/s J. No.	Ground level u/s (m)	Ground level d/s (m)	Ground slope	Invert level U/s	Invert level D/s	I	Choosen D	d/D initial	d/D final	initial V	Final V	Depth U/s	Depth D/s
1	86	0.000	0.021	8.04	0.000	0.055	8.04	1	3	96.62	97.10	-0.006	95.57	95.29	0.003	0.15	0.755	0.755	0.562	0.562	1.1	1.8
2	40	0.000	0.027	8.04	0.000	0.052	8.04	2	3	97.10	97.10	0.000	96.05	95.92	0.003	0.15	0.755	0.755	0.562	0.562	1.1	1.2
3	59	0.048	0.059	8.04	0.107	0.149	8.04	3	16	97.10	97.02	0.001	95.29	95.09	0.003	0.15	0.755	0.755	0.562	0.562	1.8	1.9
4	29	0.000	0.008	8.04	0.000	0.011	8.04	4	5	97.34	97.34	0.000	96.29	96.19	0.003	0.15	0.755	0.755	0.562	0.562	1.1	1.1
5	61	0.008	0.051	8.04	0.011	0.112	8.04	5	7	97.34	97.60	-0.004	96.19	95.99	0.003	0.15	0.755	0.755	0.562	0.562	1.1	1.6
6	33	0.000	0.000	8.04	0.000	0.013	8.04	6	7	97.60	97.60	0.000	96.55	96.44	0.003	0.15	0.755	0.755	0.562	0.562	1.1	1.2
7	49	0.059	0.106	8.04	0.137	0.177	8.04	7	9	97.60	97.25	0.007	95.99	95.65	0.007	0.15	0.575	0.575	0.762	0.762	1.6	1.6
8	29	0.000	0.026	8.04	0.000	0.038	8.04	8	9	97.25	97.25	0.000	96.20	96.10	0.003	0.15	0.755	0.755	0.562	0.562	1.1	1.1
9	13	0.000	0.011	8.04	0.000	0.016	8.04	10	11	97.25	97.25	0.000	96.20	96.16	0.003	0.15	0.755	0.755	0.562	0.562	1.1	1.1
10	25	0.000	0.013	8.04	0.000	0.018	8.04	12	13	97.25	97.25	0.000	96.20	96.12	0.003	0.15	0.755	0.755	0.562	0.562	1.1	1.1
12	42	0.268	0.047	8.04	0.461	0.067	8.04	14	16	97.07	97.02	0.001	95.43	95.29	0.003	0.15	0.755	0.755	0.562	0.562	1.6	1.7
13	47	0.000	0.073	8.04	0.000	0.157	8.04	15	22	97.07	97.16	-0.002	96.02	95.86	0.003	0.15	0.755	0.755	0.562	0.562	1.1	1.3
14	62	0.422	0.034	8.04	0.785	0.073	8.04	16	17	97.02	97.16	-0.002	95.09	94.89	0.003	0.15	0.755	0.755	0.562	0.562	1.9	2.3
15	33	0.000	0.017	8.04	0.000	0.025	8.04	79	17	96.36	97.16	-0.024	95.31	95.20	0.003	0.15	0.755	0.755	0.562	0.562	1.1	2.0
16	9	0.475	0.016	8.04	0.884	0.022	8.04	17	19	97.16	97.16	0.000	94.89	94.86	0.003	0.15	0.755	0.755	0.562	0.562	2.3	2.3
17	51	0.000	0.017	8.04	0.000	0.025	8.04	18	19	97.16	97.16	0.000	96.11	95.94	0.003	0.15	0.755	0.755	0.562	0.562	1.1	1.2
19	54	0.000	0.080	8.04	0.000	0.157	8.04	20	21	97.16	97.16	0.000	96.11	95.93	0.003	0.15	0.755	0.755	0.562	0.562	1.1	1.2
20	12	0.000	0.033	8.04	0.000	0.061	8.04	23	24	97.08	97.08	0.000	96.03	95.99	0.003	0.15	0.755	0.755	0.562	0.562	1.1	1.1
21	8	0.033	0.022	8.04	0.061	0.031	8.04	24	26	97.08	97.08	0.000	95.99	95.96	0.003	0.15	0.755	0.755	0.562	0.562	1.1	1.1
22	10	0.000	0.000	8.04	0.000	0.000	8.04	25	26	97.08	97.08	0.000	96.03	96.00	0.003	0.15	0.755	0.755	0.562	0.562	1.1	1.1
23	12	0.000	0.031	8.04	0.000	0.058	8.04	28	29	97.32	97.32	0.000	96.27	96.23	0.003	0.15	0.755	0.755	0.562	0.562	1.1	1.1
24	58	0.000	0.027	8.04	0.000	0.038	8.04	30	32	96.87	96.87	0.000	95.82	95.63	0.003	0.15	0.755	0.755	0.562	0.562	1.1	1.2
25	15	0.000	0.000	8.04	0.000	0.000	8.04	31	32	96.87	96.87	0.000	95.82	95.77	0.003	0.15	0.755	0.755	0.562	0.562	1.1	1.1
26	22	0.000	0.034	8.04	0.000	0.049	8.04	34	35	97.18	97.18	0.000	96.13	96.06	0.003	0.15	0.755	0.755	0.562	0.562	1.1	1.1
27	20	0.000	0.000	8.04	0.000	0.000	8.04	36	37	97.18	97.18	0.000	96.13	96.06	0.003	0.15	0.755	0.755	0.562	0.562	1.1	1.1

28	16	0.000	0.023	8.04	0.000	0.034	8.04	38	37	97.18	97.18	0.000	96.13	96.08	0.003	0.15	0.755	0.755	0.562	0.562	1.1	1.1
30	16	0.000	0.016	8.04	0.000	0.022	8.04	51	52	97.60	97.60	0.000	96.55	96.50	0.003	0.15	0.755	0.755	0.562	0.562	1.1	1.1
31	8	0.000	0.013	8.04	0.000	0.033	8.04	53	52	97.60	97.60	0.000	96.55	96.52	0.003	0.15	0.755	0.755	0.562	0.562	1.1	1.1
32	40	0.029	0.055	8.04	0.067	0.089	8.04	52	55	97.60	97.55	0.001	96.50	96.37	0.003	0.15	0.755	0.755	0.562	0.562	1.1	1.2
33	8	0.000	0.030	8.04	0.000	0.043	8.04	56	54	97.55	97.55	0.000	96.50	96.47	0.003	0.15	0.755	0.755	0.562	0.562	1.1	1.1
34	30	0.000	0.049	8.04	0.000	0.070	8.04	72	71	97.21	96.93	0.009	96.16	95.89	0.009	0.15	0.535	0.535	0.841	0.841	1.1	1.0
35	28	0.030	0.037	8.04	0.042	0.066	8.04	54	55	97.55	97.55	0.000	96.47	96.38	0.003	0.15	0.756	0.755	0.562	0.562	1.1	1.2
36	37	0.139	0.061	8.04	0.253	0.115	8.04	55	50	97.55	96.56	0.027	96.52	95.52	0.027	0.15	0.395	0.395	1.270	1.270	1.0	1.0
37	22	0.000	0.013	8.04	0.000	0.018	8.04	41	43	96.56	96.56	0.000	95.51	95.44	0.003	0.15	0.755	0.755	0.562	0.562	1.1	1.1
39	25	0.000	0.035	8.04	0.000	0.051	8.04	44	45	96.56	96.56	0.000	95.51	95.43	0.003	0.15	0.755	0.755	0.562	0.562	1.1	1.1
40	16	0.013	0.020	8.04	0.018	0.029	8.04	43	45	96.56	96.56	0.000	95.44	95.38	0.003	0.15	0.755	0.755	0.562	0.562	1.1	1.2
41	20	0.068	0.024	8.04	0.098	0.035	8.04	45	47	96.56	96.56	0.000	95.38	95.32	0.003	0.15	0.755	0.755	0.562	0.562	1.2	1.2
42	43	0.124	0.061	8.04	0.178	0.102	8.04	47	49	96.56	96.53	0.001	95.32	95.18	0.003	0.15	0.755	0.755	0.562	0.562	1.2	1.4
43	28	0.000	0.031	8.04	0.000	0.045	8.04	80	47	96.87	96.56	0.011	95.82	95.51	0.011	0.15	0.505	0.505	0.908	0.908	1.1	1.0
44	44	0.185	0.094	8.04	0.280	0.135	8.04	49	50	96.53	96.56	-0.001	95.18	95.03	0.003	0.15	0.755	0.755	0.562	0.562	1.4	1.5
45	42	0.000	0.037	8.04	0.000	0.053	8.04	59	60	96.85	96.85	0.000	95.80	95.66	0.003	0.15	0.755	0.755	0.562	0.562	1.1	1.2
46	20	0.000	0.012	8.04	0.000	0.030	8.04	61	62	96.85	96.85	0.000	95.80	95.73	0.003	0.15	0.755	0.755	0.562	0.562	1.1	1.1
47	6	0.000	0.005	8.04	0.000	0.020	8.04	63	64	96.85	96.85	0.000	95.80	95.78	0.003	0.15	0.755	0.755	0.562	0.562	1.1	1.1
48	9	0.005	0.000	8.04	0.020	0.000	8.04	64	65	96.85	96.85	0.000	95.80	95.77	0.003	0.15	0.755	0.755	0.562	0.562	1.1	1.1
49	3	0.589	0.053	8.04	0.112	0.076	8.04	60	62	96.85	96.85	0.000	95.66	95.65	0.003	0.15	0.755	0.755	0.562	0.562	1.2	1.2
50	12	0.059	0.052	8.04	0.112	0.059	8.04	62	65	96.85	96.85	0.000	95.65	95.61	0.003	0.15	0.755	0.755	0.562	0.562	1.2	1.2
51	23	0.116	0.050	8.04	0.208	0.072	8.04	65	67	96.85	97.08	-0.010	95.61	95.54	0.003	0.15	0.755	0.755	0.562	0.562	1.2	1.5
52	95	0.188	0.036	8.04	0.311	0.113	8.04	67	71	97.08	96.93	0.002	95.54	95.22	0.003	0.15	0.755	0.755	0.562	0.562	1.5	1.7
53	19	0.000	0.008	8.04	0.000	0.011	8.04	67a	69	97.08	96.87	0.011	96.03	95.82	0.011	0.15	0.505	0.505	0.908	0.908	1.1	1.0
54	16	0.000	0.031	8.04	0.000	0.045	8.04	68	69	96.87	96.87	0.000	95.82	95.77	0.003	0.15	0.755	0.755	0.562	0.562	1.1	1.1
55	94	0.039	0.178	8.04	0.056	0.256	8.04	69	70	96.87	96.93	-0.001	95.77	95.46	0.003	0.15	0.755	0.755	0.562	0.562	1.1	1.5
56	21	0.506	0.055	8.04	0.931	0.079	8.04	19	21	97.16	97.16	0.000	94.86	94.79	0.003	0.15	0.755	0.755	0.562	0.562	2.3	2.4
57	9	0.714	0.014	8.04	1.281	0.020	8.04	21	22	97.16	97.16	0.000	94.79	94.76	0.003	0.15	0.755	0.755	0.562	0.562	2.4	2.4
58	15	0.728	0.027	8.04	1.301	0.027	8.04	22	27	97.16	97.32	-0.011	94.76	94.71	0.003	0.15	0.755	0.755	0.562	0.562	2.4	2.6

59	13	0.859	0.022	8.04	1.504	0.031	8.04	27	29	97.32	97.32	0.000	94.71	94.67	0.003	0.15	0.755	0.755	0.562	0.562	2.6	2.7
60	18	0.912	0.013	8.04	1.595	0.018	8.04	29	33	97.32	97.32	0.000	94.67	94.61	0.003	0.15	0.755	0.755	0.562	0.562	2.7	2.7
61	4	1.026	0.000	8.04	1.758	0.000	8.04	33	35	97.32	97.18	0.035	94.61	94.47	0.035	0.15	0.365	0.365	1.389	1.389	2.7	2.7
62	21	1.061	0.023	8.04	1.807	0.061	8.04	35	37	97.18	97.18	0.000	94.47	94.40	0.003	0.15	0.755	0.755	0.562	0.562	2.7	2.8
63	15	1.108	0.031	8.04	1.902	0.058	8.04	37	50	97.18	96.56	0.041	94.40	93.78	0.041	0.15	0.345	0.345	1.460	1.460	2.8	2.8
64	34	1.617	0.053	8.04	2.743	0.104	8.04	50	70	96.56	96.93	-0.011	93.78	93.67	0.003	0.15	0.755	0.755	0.562	0.562	2.8	3.3
65	20	1.971	0.010	8.04	3.278	0.041	8.04	70	71	96.93	96.93	0.000	93.67	93.60	0.003	0.15	0.755	0.755	0.562	0.562	3.3	3.3
66	28	2.253	0.010	8.04	3.812	0.062	8.04	71	75	96.93	97.22	-0.010	93.60	93.51	0.003	0.15	0.755	0.755	0.562	0.562	3.3	3.7
67	124	2.263	0.016	8.04	3.922	0.300	8.04	75	77	97.22	97.24	0.000	93.51	93.10	0.003	0.15	0.755	0.755	0.562	0.562	3.7	4.1
68	242	2.285	0.000	8.04	4.435	0.000	9.05	77	78	97.24	97.67	-0.002	93.10	92.13	0.004	0.15	0.695	0.770	0.609	0.609	4.1	5.5
11	54	0.055	0.058	8.04	0.092	0.083	8.04	26	27	97.08	97.32	-0.004	95.96	95.79	0.003	0.15	0.755	0.755	0.562	0.562	1.1	1.5
69	10	0.191	0.019	8.04	0.352	0.027	8.04	9	11	97.25	97.25	0.000	95.65	95.62	0.003	0.15	0.755	0.755	0.562	0.562	1.6	1.6
70	3	0.221	0.006	8.04	0.394	0.009	8.04	11	13	97.25	97.25	0.000	95.62	95.61	0.003	0.15	0.755	0.755	0.562	0.562	1.6	1.6
71	14	0.239	0.028	8.04	0.421	0.040	8.04	13	14	97.25	97.07	0.013	95.61	95.43	0.013	0.15	0.475	0.475	0.961	0.961	1.6	1.6
72	47	0.027	0.075	8.04	0.038	0.108	8.04	32	33	96.87	97.32	-0.010	95.63	95.47	0.003	0.15	0.755	0.755	0.562	0.562	1.2	1.8
73	18	0.000	0.021	8.04	0.000	0.031	8.04	66	67	97.08	97.08	0.000	96.03	95.97	0.003	0.15	0.755	0.755	0.562	0.562	1.1	1.1
74	50	0.000	0.000	8.04	0.000	0.047	8.04	74	75	97.31	97.22	0.002	96.26	96.10	0.003	0.15	0.755	0.755	0.562	0.562	1.1	1.1
75	70	0.000	0.021	8.04	0.000	0.210	8.04	76	77	97.22	97.24	0.000	96.17	95.94	0.003	0.15	0.755	0.755	0.562	0.562	1.1	1.3
76	45	0.000	0.083	8.04	0.000	0.119	8.04	57	70	97.21	96.93	0.006	96.16	95.89	0.006	0.15	0.605	0.605	0.718	0.718	1.1	1.0

Table: 4.10 Calculation table for 4th sewerage system

Sewer	L (m)	Initial u/s flow (l/s)	Initial flow (l/s)	Total Initial flow (l/s)	Final u/s flow (l/s)	Final flow (l/s)	Total final flow (l/s)	u/s J. no.	d/s J. no.	Ground level u/s (m)	Ground level d/s (m)	Ground slope	Invert level U/s	Invert level D/s	I	choosen D	d/D initial	d/D final	Initial V	Final V	Depth U/s	Depth d/s
1	105	0.000	0.041	8.04	0.000	0.108	8.04	J_up	2	97.60	97.60	0.000	96.55	96.20	0.003	0.15	0.755	0.755	0.562	0.562	1.2	1.5
2	34	0.057	0.022	8.04	0.246	0.095	8.04	2	4	97.60	97.60	0.000	96.20	96.09	0.003	0.15	0.755	0.755	0.562	0.562	1.5	1.7
3	65.3	0.091	0.035	8.04	0.246	0.095	8.04	4	6	97.60	97.73	-0.002	96.09	95.88	0.003	0.15	0.755	0.755	0.562	0.562	1.7	2.0
4	50	0.141	0.068	8.04	0.363	0.117	8.04	6	20	97.73	97.87	-0.003	95.88	95.71	0.003	0.15	0.755	0.755	0.562	0.562	2.0	2.3
5	12	0.194	0.006	8.04	0.457	0.009	8.04	8	20	97.83	97.87	-0.003	95.71	95.67	0.003	0.15	0.755	0.755	0.562	0.562	2.3	2.3
6	10.3	0.151	0.011	8.04	0.367	0.043	8.04	19	8	97.83	97.83	0.000	96.78	96.75	0.003	0.15	0.755	0.755	0.562	0.562	1.2	1.2
7	34	0.090	0.002	8.04	0.214	0.040	8.04	13	19	98.09	97.83	0.008	97.04	96.78	0.008	0.15	0.755	0.755	0.852	0.852	1.2	1.2
8	58	0.000	0.038	8.04	0.000	0.100	8.04	9	13	98.35	98.09	0.004	97.30	97.04	0.005	0.15	0.755	0.755	0.656	0.656	1.2	1.2
9	62.5	0.000	0.016	8.04	0.000	0.089	8.04	1	2	97.60	97.60	0.000	96.55	96.34	0.003	0.15	0.755	0.755	0.562	0.562	1.2	1.4
10	28	0.000	0.013	8.04	0.000	0.018	8.04	3	4	97.60	97.60	0.000	96.55	96.46	0.003	0.15	0.755	0.755	0.562	0.562	1.2	1.3
11	31	0.000	0.016	8.04	0.000	0.022	8.04	5	6	97.73	97.73	0.000	96.68	96.58	0.003	0.15	0.755	0.755	0.562	0.562	1.2	1.3
12	13.2	0.000	0.004	8.04	0.000	0.033	8.04	10	12	98.09	98.09	0.000	97.04	97.00	0.003	0.15	0.755	0.755	0.562	0.562	1.2	1.2
13	7.1	0.000	0.000	8.04	0.000	0.000	8.04	11	12	98.09	98.09	0.000	97.04	97.02	0.003	0.15	0.755	0.755	0.562	0.562	1.2	1.2
14	35.5	0.004	0.047	8.04	0.033	0.081	8.04	12	13	98.09	98.09	0.000	97.02	96.90	0.003	0.15	0.755	0.755	0.562	0.562	1.2	1.3
15	15.4	0.000	0.028	8.04	0.000	0.041	8.04	14	15	97.83	97.83	0.000	96.78	96.73	0.003	0.15	0.755	0.755	0.562	0.562	1.2	1.3
16	13.5	0.028	0.000	8.04	0.041	0.013	8.04	15	19	97.83	97.83	0.000	96.73	96.68	0.003	0.15	0.755	0.755	0.562	0.562	1.3	1.3
17	9	0.000	0.033	8.04	0.000	0.047	8.04	7	8	97.83	97.83	0.000	96.78	96.75	0.003	0.15	0.755	0.755	0.562	0.562	1.2	1.2
18	15.3	0.000	0.011	8.04	0.000	0.016	8.04	17	18	97.83	97.83	0.000	96.78	96.73	0.003	0.15	0.755	0.755	0.562	0.562	1.2	1.3
19	57.2	0.011	0.020	8.04	0.016	0.043	8.04	18	19	97.83	97.83	0.000	96.73	96.54	0.003	0.15	0.755	0.755	0.562	0.562	1.3	1.4
20	38	0.410	0.000	8.04	0.941	0.013	8.04	20	22	97.87	97.46	0.011	95.67	95.26	0.011	0.15	0.755	0.755	1.016	1.016	2.3	2.3
21	23	0.000	0.000	8.04	0.000	0.000	8.04	21	22	97.46	97.46	0.000	96.41	96.33	0.003	0.15	0.755	0.755	0.562	0.562	1.2	1.3
22	15	0.410	0.000	8.04	0.954	0.135	8.04	22	23	97.46	97.46	0.000	95.26	95.21	0.003	0.15	0.755	0.755	0.562	0.562	2.3	2.4
23	115	0.410	0.034	8.04	0.968	0.062	8.04	23	24	97.46	97.21	0.002	95.21	94.83	0.003	0.15	0.755	0.755	0.562	0.562	2.4	2.5

4. Manholes

Manholes provided are of three types: Simplified manhole, conventional (rectangular, circular) manholes and drop manholes.

Simplified manholes are provided upto the depth of 1.65m. These manholes are circular having 0.9m diameter.

Rectangular manholes are provided upto the depth of 1.65 to 2.5m. For rectangular manhole, size provided is 1200×900mm according to the Indian standard 4111. Size of access shaft are 0.75×0.6m.

While circular manholes are provided upto the depth of 2.5 to 9m. Size for these manholes is 1500mm diameter. Size of access shaft 0.7m.

Upper step is provided after 450mm and distance between two steps is 300mm. While, width of the step is 15cm.

Types of manholes provided at each point are shown in figure (4.1, 4.2, 4.3, 4.4). Drop manholes are of T type.

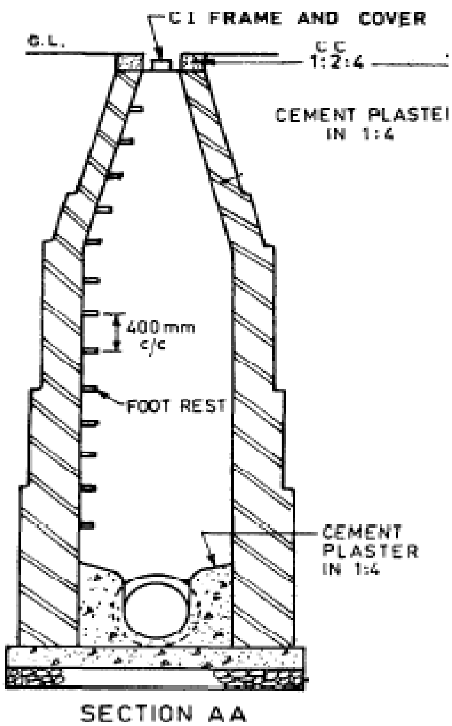


Fig: 4.9 Circular manholes
Source: IS: 4111

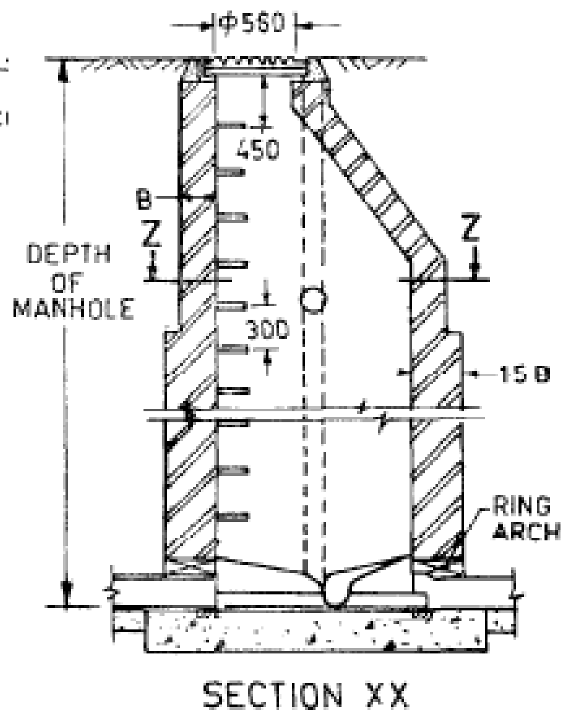
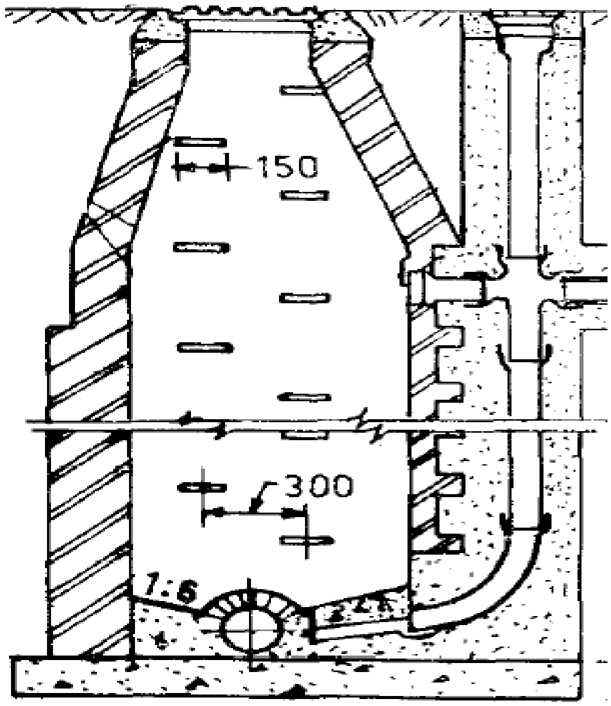


Fig: 4.10 Drop manhole
Source: IS: 4111



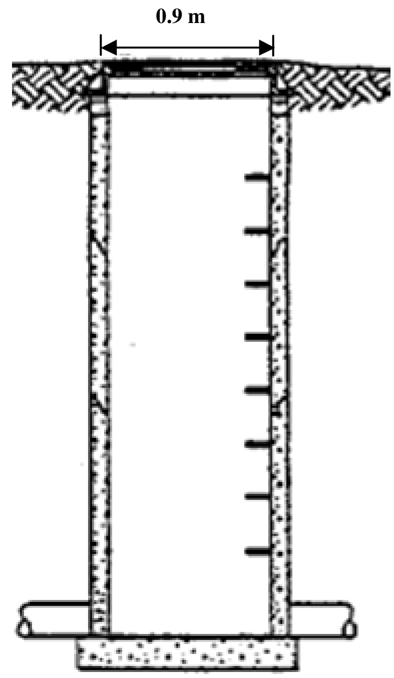


Fig: 4.11 Drop manhole (YY) section
Source: IS: 4111

Fig: 4.12 Simplified manhole
Source: Bakalian, 1994

4.5.2. CONVENTIONAL SEWERAGE SYSTEM

Conventional sewerage system for present case includes:

- Siphon systems (Household level /end)
- Sewers
- Manholes and other appurtenances

1. Sewer

Sewer is designed to handle the sewage water from household to the treatment side. The flow of 8.04 l/s coming through the siphon is referred to as the minimum peak flow. Peaking factor is taken as 3. Minimum cover provided is 1m. The hydraulic calculation of the sewer are shown in the subsequent page in table (4.11).

2. Manholes

In conventional sewer, the rectangular and circular type manholes are provided according to the Indian standard. Rectangular manholes are provided upto the depth of 2.5m. Above this, circular manholes are provided. Manholes are provided at upper terminal, at each bend and junction and maximum distance is upto 30m.

Table: 4.11 Calculation table for 3rd conventional sewerage system

Sewer	Length	Present peak flow	Design flow	Total initial peak flow	Total Final peak flow	u/s Junct. no.	d/s Junct. no.	Ground level u/s	Ground level d/s	Diameter	slope	Q full	Vfull	Vactual	Total fall	Invert level u/s	Invert level d/s	Depth u/s	Depth d/s
	m	l/s	l/s	l/s	l/s			m	m	m	m/m	l/s	m/s	m/s	m	m	m	m	m
1	86	0.05	0.14	8.04	8.04	1	3	96.62	97.10	0.15	0.005	11	0.6	0.67	0.43	95.47	95.04	1.15	2.06
2	40	0.07	0.13	8.04	8.04	2	3	97.10	97.10	0.15	0.005	11	0.6	0.67	0.2	95.95	95.75	1.15	1.35
3	59	0.28	0.65	8.04	8.04	3	16	97.10	97.02	0.15	0.005	11	0.6	0.67	0.295	95.04	94.75	2.06	2.28
4	29	0.02	0.03	8.04	8.04	4	5	97.34	97.34	0.15	0.005	11	0.6	0.67	0.145	96.19	96.05	1.15	1.30
5	61	0.15	0.31	8.04	8.04	5	7	97.34	97.60	0.15	0.005	11	0.6	0.67	0.305	96.05	95.74	1.30	1.86
6	33	0.00	0.03	8.04	8.04	6	7	97.60	97.60	0.15	0.005	11	0.6	0.67	0.165	96.45	96.29	1.15	1.32
7	49	0.42	0.80	8.04	8.04	7	9	97.60	97.25	0.15	0.007	13	0.6	0.64	0.343	95.74	95.40	1.86	1.85
8	29	0.07	0.10	8.04	8.04	8	9	97.25	97.25	0.15	0.005	11	0.6	0.67	0.145	96.10	95.96	1.15	1.30
9	13	0.03	0.04	8.04	8.04	10	11	97.25	97.25	0.15	0.005	11	0.6	0.67	0.065	96.10	96.04	1.15	1.22
10	25	0.03	0.05	8.04	8.04	12	13	97.25	97.25	0.15	0.005	11	0.6	0.67	0.125	96.10	95.98	1.15	1.28
12	42	0.80	1.35	8.04	8.04	14	16	97.07	97.02	0.15	0.005	11	0.6	0.67	0.21	95.26	95.05	1.81	1.97
13	47	0.20	0.29	8.04	8.04	15	22	97.07	97.16	0.15	0.005	11	0.6	0.67	0.235	95.92	95.69	1.15	1.47
14	62	1.16	2.19	8.04	8.04	16	17	97.02	97.16	0.15	0.005	11	0.6	0.67	0.31	94.75	94.44	2.28	2.73
15	33	0.04	0.06	8.04	8.04	79	17	96.36	97.16	0.15	0.005	11	0.6	0.67	0.165	95.21	95.05	1.15	2.12
16	9	1.25	2.31	8.04	8.04	17	19	97.16	97.16	0.15	0.005	11	0.6	0.67	0.045	94.44	94.39	2.73	2.77
17	51	0.04	0.06	8.04	8.04	18	19	97.16	97.16	0.15	0.005	11	0.6	0.67	0.255	96.01	95.76	1.15	1.40
19	54	0.19	0.40	8.04	8.04	20	21	97.16	97.16	0.15	0.005	11	0.6	0.67	0.27	96.01	95.74	1.15	1.42
20	12	0.08	0.15	8.04	8.04	23	24	97.08	97.08	0.15	0.005	11	0.6	0.67	0.06	95.93	95.87	1.15	1.21
21	8	0.14	0.24	8.04	8.04	24	26	97.08	97.08	0.15	0.005	11	0.6	0.67	0.04	95.87	95.83	1.21	1.25
23	12	0.08	0.15	8.04	8.04	28	29	97.32	97.32	0.15	0.005	11	0.6	0.67	0.06	96.17	96.11	1.15	1.21
24	58	0.07	0.10	8.04	8.04	30	32	96.87	96.87	0.15	0.005	11	0.6	0.67	0.29	95.72	95.43	1.15	1.44
26	22	0.09	0.13	8.04	8.04	34	35	97.18	97.18	0.15	0.005	11	0.6	0.67	0.11	96.03	95.92	1.15	1.26
28	16	0.06	0.09	8.04	8.04	38	37	97.18	97.18	0.15	0.005	11	0.6	0.67	0.08	96.03	95.95	1.15	1.23
30	16	0.04	0.06	8.04	8.04	51	52	97.60	97.60	0.15	0.005	11	0.6	0.67	0.08	96.45	96.37	1.15	1.23

31	8	0.03	0.08	8.04	8.04	53	52	97.60	97.60	0.15	0.005	11	0.6	0.67	0.04	96.45	96.41	1.15	1.19
32	40	0.18	0.37	8.04	8.04	52	55	97.60	97.55	0.15	0.005	11	0.6	0.67	0.2	96.37	96.17	1.23	1.38
33	8	0.08	0.11	8.04	8.04	56	54	97.55	97.55	0.15	0.005	11	0.6	0.67	0.04	96.40	96.36	1.15	1.19
34	30	0.12	0.18	8.04	8.04	72	71	97.21	96.93	0.15	0.009	15	0.75	0.64	0.27	96.06	95.79	1.15	1.14
35	28	0.17	0.28	8.04	8.04	54	55	97.55	97.55	0.15	0.005	11	0.6	0.67	0.14	96.36	96.22	1.19	1.33
36	37	0.51	0.94	8.04	8.04	55	50	97.55	96.56	0.15	0.005	11	0.6	0.67	0.185	96.17	95.99	1.38	0.58
37	22	0.03	0.05	8.04	8.04	41	43	96.56	96.56	0.15	0.005	11	0.6	0.67	0.11	95.41	95.30	1.15	1.26
39	25	0.09	0.13	8.04	8.04	44	45	96.56	96.56	0.15	0.005	11	0.6	0.67	0.125	95.41	95.29	1.15	1.28
40	16	0.08	0.12	8.04	8.04	43	45	96.56	96.56	0.15	0.005	11	0.6	0.67	0.08	95.30	95.22	1.26	1.34
41	20	0.24	0.34	8.04	8.04	45	47	96.56	96.56	0.15	0.005	11	0.6	0.67	0.1	95.22	95.12	1.34	1.44
42	43	0.47	0.71	8.04	8.04	47	49	96.56	96.53	0.15	0.005	11	0.6	0.67	0.215	95.12	94.91	1.44	1.63
43	28	0.08	0.11	8.04	8.04	80	47	96.87	96.56	0.15	0.005	11	0.6	0.67	0.14	95.72	95.58	1.15	0.98
44	44	0.71	1.06	8.04	8.04	49	50	96.53	96.56	0.15	0.005	11	0.6	0.67	0.22	94.91	94.69	1.63	1.88
45	42	0.09	0.14	8.04	8.04	59	60	96.85	96.85	0.15	0.005	11	0.6	0.67	0.21	95.70	95.49	1.15	1.36
46	20	0.03	0.08	8.04	8.04	61	62	96.85	96.85	0.15	0.005	11	0.6	0.67	0.1	95.70	95.60	1.15	1.25
47	6	0.01	0.05	8.04	8.04	63	64	96.85	96.85	0.15	0.005	11	0.6	0.67	0.03	95.70	95.67	1.15	1.18
48	9	0.01	0.05	8.04	8.04	64	65	96.85	96.85	0.15	0.005	11	0.6	0.67	0.045	95.67	95.63	1.18	1.22
49	3	0.12	0.21	8.04	8.04	60	62	96.85	96.85	0.15	0.005	11	0.6	0.67	0.015	95.49	95.48	1.36	1.37
50	12	0.57	0.48	8.04	8.04	62	65	96.85	96.85	0.15	0.005	11	0.6	0.67	0.06	95.48	95.42	1.37	1.43
51	23	0.43	0.71	8.04	8.04	65	67	96.85	97.08	0.15	0.005	11	0.6	0.67	0.115	95.42	95.30	1.43	1.78
52	95	0.57	1.08	8.04	8.04	67	71	97.08	96.93	0.15	0.005	11	0.6	0.67	0.475	95.30	94.83	1.78	2.10
53	19	0.02	0.03	8.04	8.04	67a	69	97.08	96.87	0.15	0.005	11	0.6	0.67	0.095	95.93	95.84	1.15	1.04
54	16	0.08	0.11	8.04	8.04	68	69	96.87	96.87	0.15	0.005	11	0.6	0.67	0.08	95.72	95.64	1.15	1.23
55	94	0.55	0.80	8.04	8.04	69	70	96.87	96.93	0.15	0.005	11	0.6	0.67	0.47	95.64	95.17	1.23	1.76
56	21	1.43	2.57	8.04	8.04	19	21	97.16	97.16	0.15	0.005	11	0.6	0.67	0.105	94.39	94.29	2.77	2.88
57	9	1.86	3.32	8.04	8.04	21	22	97.16	97.16	0.15	0.005	11	0.6	0.67	0.045	94.29	94.24	2.88	2.92
58	15	1.90	3.39	8.04	8.04	22	27	97.16	97.32	0.15	0.005	11	0.6	0.67	0.075	94.24	94.17	2.92	3.16
59	13	2.25	3.91	8.04	8.04	27	29	97.32	97.32	0.15	0.005	11	0.6	0.67	0.065	94.17	94.10	3.16	3.22
60	18	2.36	4.11	8.04	8.04	29	33	97.32	97.32	0.15	0.005	11	0.6	0.67	0.09	94.10	94.01	3.22	3.31

61	4	2.62	4.48	8.04	8.04	33	35	97.32	97.18	0.15	0.005	11	0.6	0.67	0.02	94.01	93.99	3.31	3.19
62	21	2.77	4.76	8.04	8.04	35	37	97.18	97.18	0.15	0.005	11	0.6	0.67	0.105	93.99	93.89	3.19	3.30
63	15	2.91	5.00	8.04	8.04	37	50	97.18	96.56	0.15	0.005	11	0.6	0.67	0.075	93.89	93.81	3.30	2.75
64	34	4.26	7.26	8.04	8.04	50	70	96.56	96.93	0.15	0.005	11	0.6	0.67	0.17	93.81	93.64	2.75	3.29
65	20	5.05	8.46	8.04	8.46	70	71	96.93	96.93	0.15	0.005	11	0.6	0.67	0.1	93.64	93.54	3.29	3.39
66	28	5.77	9.88	8.04	9.88	71	75	96.93	97.22	0.15	0.005	11	0.6	0.67	0.14	93.54	93.40	3.39	3.82
67	124	5.80	10.77	8.04	10.77	75	77	97.22	97.24	0.20	0.005	23	0.74	0.67	0.62	93.35	92.73	3.82	4.46
68	242	5.86	11.31	8.04	11.31	77	78	97.24	97.67	0.20	0.005	23	0.74	0.67	1.21	92.73	91.57	4.46	6.10
11	54	0.29	0.45	8.04	8.04	26	27	97.08	97.32	0.15	0.005	11	0.6	0.67	0.27	95.83	95.56	1.25	1.76
69	10	0.54	0.96	8.04	8.04	9	11	97.25	97.25	0.15	0.005	11	0.6	0.67	0.05	95.40	95.35	1.85	1.90
70	3	0.58	1.03	8.04	8.04	11	13	97.25	97.25	0.15	0.005	11	0.6	0.67	0.015	95.35	95.33	1.90	1.92
71	14	0.68	1.18	8.04	8.04	13	14	97.25	97.07	0.15	0.005	11	0.6	0.67	0.07	95.33	95.26	1.92	1.81
72	47	0.26	0.37	8.04	8.04	32	33	96.87	97.32	0.15	0.005	11	0.6	0.67	0.235	95.43	95.20	1.44	2.13
73	18	0.05	0.08	8.04	8.04	66	67	97.08	97.08	0.15	0.005	11	0.6	0.67	0.09	95.93	95.84	1.15	1.24
74	50	0.00	0.12	8.04	8.04	74	75	97.31	97.22	0.15	0.005	11	0.6	0.67	0.25	96.16	95.91	1.15	1.31
75	70	0.05	0.54	8.04	8.04	76	77	97.22	97.24	0.15	0.005	11	0.6	0.67	0.35	96.07	95.72	1.15	1.52
76	45	0.21	0.30	8.04	8.04	57	70	97.21	96.93	0.15	0.005	11	0.6	0.67	0.225	96.06	95.84	1.15	1.10

4.5.3. SMALL BORE SEWERAGE SYSTEM

Small bore sewerage system includes the different components:

- Intercepting tank
- Sewer
- Clean outs

1. Intercepting tank

In small bore sewer system, the sewage is required to be clarified before allowing it to enter the sewer. Options considered for primary treatment are:

- Intercepting tank for individual house/block
- Intercepting tank for cluster of houses (community tank)

Intercepting tanks in present case is a combination of sedimentation and digestion tank (septic tanks). Here, sewage is held for one to two days. During this period, suspended solids settle down to the bottom and digested anaerobically, thereby causing reasonable reduction in volume of sludge. For efficient removal of suspended solids, the septic tank should be of sufficient capacity with proper inlet and outlet. It provides only settled water to move through them. This septic tank is designed for different users according to Indian standard. The IL of outlet of septic tank should be 50mm below the IL of inlet pipe. (IS: 2470 (Part1)-1985, can be referred for design of septic tanks). Septic tanks are designed as per criteria given in this standard. Dimensions for tank upto 20 users are shown in table (4.12) and figure (4.13, 4.14).

Table: 4.12 Size of septic tank upto 20 users

No. of person	Peak discharge	Area	Vol. for sedimentation	Vol. for sludge digestion	Vol. for sludge storage	Vol. corresponding the free board	Total vol.	Depth of tank	Provide depth	Width	Length	Selected width	Selected length
	lpm	m2	m3	m3	m3	m3	m3	m	m	m	m	m	m
5	9	0.828	0.248	0.165	0.383	0.248	1.045	1.212	1.3	0.576	1.44	0.6	1.5
10	18	1.656	0.497	0.33	0.767	0.497	2.090	1.212	1.3	0.814	2.035	0.8	2
15	18	1.656	0.497	0.495	1.150	0.497	2.638	1.543	1.6	0.814	2.035	0.8	2
20	27	2.484	0.752	0.66	1.533	0.745	3.683	1.433	1.5	0.997	2.492	1	2.5

Note 1: The maximum flow to the tank is based on the number of plumbing fixture discharging simultaneously. Number of fixture units is based on the assumption that discharge from only WC will be treated in the septic tank.

Note 2: A provision of 300mm should be made for free board.

Note 3: Depth for sedimentation is 300mm.

Note 4: Desludging period of 1 year.

Note 5: Depth of the tank is (Depth + free board)

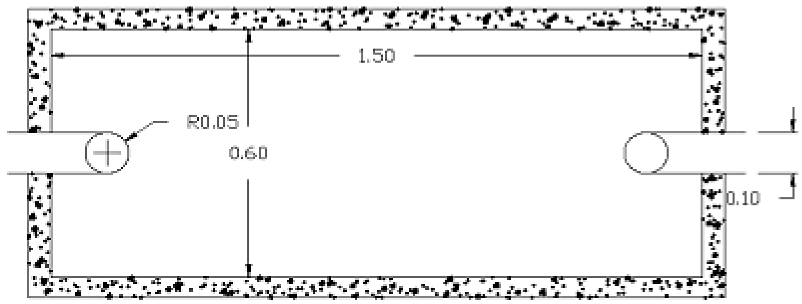


Fig: 4.13 Septic tank for 5 users (top view)

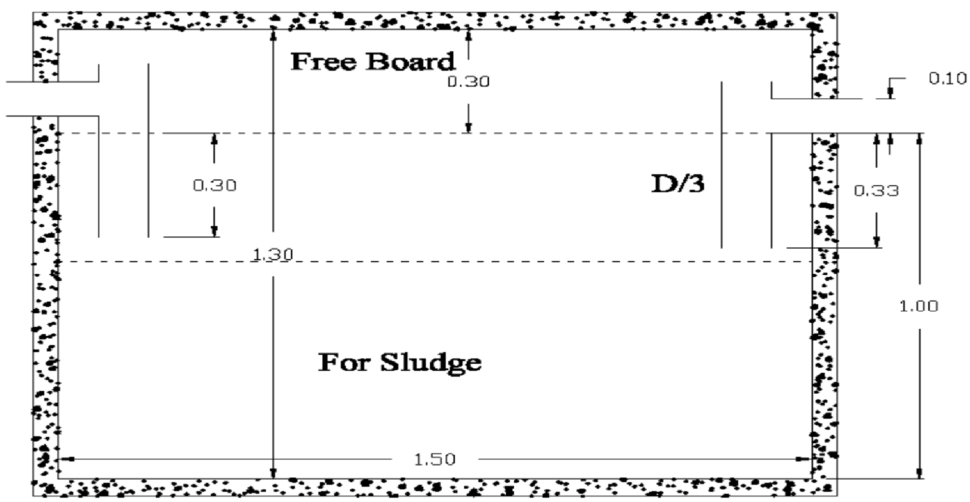


Fig: 4.14 Septic tank for 5 users (front view)

2. Sewer

Schematic diagram of the sewer is shown in figure (4.3).

Detailed plan showing building, population cultivated land, future growth, roads layout and elevation are shown in map (annex: 4).

All the water supply is not collected as sewage from the household. Only 85% of the supplied water has been considered as sewage generated by the households. Hence, design sewage generation rate is considered as 115lpcd in the present study. While in case of cattle house, it is 75lpcd.

Zero Infiltration has been considered because of using the PVC pipe. Peaking factor of 2 is referred for peak flow and minimum cover provided is 1m (cover + pipe diameter). These are designed according to the design of small bore manual by Otis. Indian manual conditions of velocity are not satisfied due to the larger pipe size and very less discharge.

The hydraulic calculations of sewer are repetitive and summarized in table (4.13) on subsequent page.

3. Manholes and other appurtenances

Manholes are provided at major junctions where two sewer meet. These are not provided at the upstream points of sewer. Clean outs are provided at upstream termini, major change in direction and are provided after 25m distance on straight sewer. Size of cleanouts should be same as the piping.

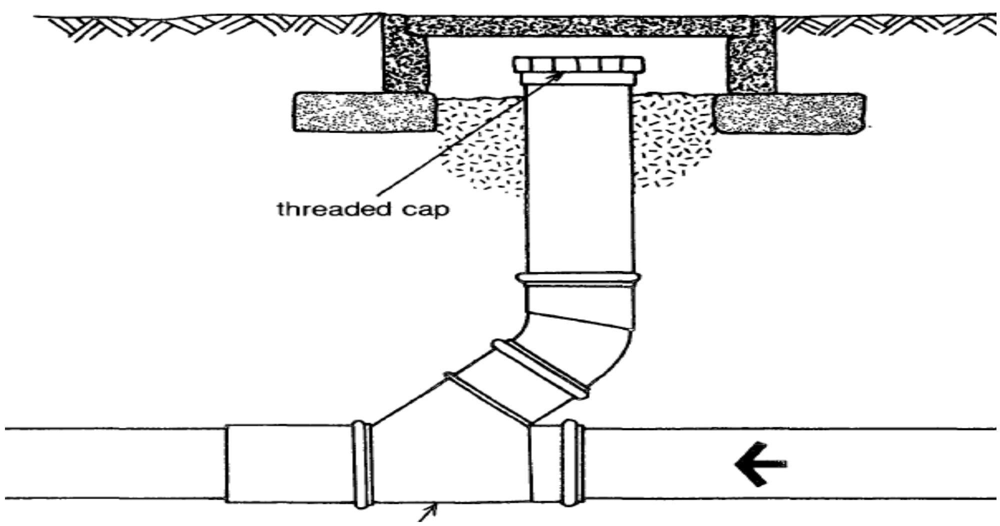


Fig: 4.15 Cleanout for small bore sewer

Table: 4.13 Calculation table for 3rd sewerage system

Sewer	Length (m)	Present peak flow	Design flow	u/s Junct. name	d/s Junct. name	Ground level u/s (m)	Ground level d/s (m)	Ground slope	Gradient	Diameter	Flow at full pipe	Invert level u/s	Invert level d/s	Depth at u/s	Depth at d/s
1	86	0.0360	0.113	1	3	96.62	97.10	-0.006	0.0025	0.1	2.54	95.62	95.41	1.00	1.69
2	40	0.0450	0.106	2	3	97.10	97.10	0.000	0.0025	0.1	2.54	96.10	96.00	1.00	1.10
3	59	0.1840	0.523	3	16	97.10	97.02	0.001	0.0010	0.1	1.64	95.41	95.35	1.69	1.67
4	29	0.0130	0.023	4	5	97.34	97.34	0.000	0.0025	0.1	2.54	96.34	96.27	1.00	1.07
5	61	0.1000	0.251	5	7	97.34	97.60	-0.004	0.0025	0.1	2.54	96.27	96.12	1.07	1.49
6	33	0.0000	0.028	6	7	97.60	97.60	0.000	0.0025	0.15	2.54	96.60	96.52	1.00	1.08
7	49	0.2800	0.640	7	9	97.60	97.25	0.007	0.0070	0.1	4.33	96.12	95.77	1.49	1.48
8	29	0.0440	0.076	8	9	97.25	97.25	0.000	0.0025	0.1	2.54	96.25	96.18	1.00	1.07
9	13	0.0190	0.032	10	11	97.25	97.25	0.000	0.0025	0.1	2.54	96.25	96.22	1.00	1.03
10	25	0.3860	0.037	12	13	97.25	97.25	0.000	0.0025	0.1	2.54	96.25	96.19	1.00	1.06
12	42	0.5340	1.079	14	16	97.07	97.02	0.001	0.0010	0.1	1.64	95.56	95.52	1.51	1.50
13	47	0.1360	0.234	15	22	97.07	97.16	-0.002	0.0025	0.1	2.54	96.07	95.95	1.00	1.21
14	62	0.7760	1.752	16	17	97.02	97.16	-0.002	0.0025	0.1	2.54	95.52	95.36	1.50	1.80
15	33	0.0290	0.050	79	17	96.36	97.16	-0.024	0.0025	0.1	2.54	95.36	95.28	1.00	1.88
16	9	0.8310	1.848	17	19	97.16	97.16	0.000	0.0025	0.1	2.54	95.28	95.26	1.88	1.90
17	51	0.0290	0.050	18	19	97.16	97.16	0.000	0.0025	0.1	2.54	96.16	96.03	1.00	1.13
19	54	0.1240	0.319	20	21	97.16	97.16	0.000	0.0025	0.1	2.54	96.16	96.03	1.00	1.14
20	12	0.0560	0.124	23	24	97.08	97.08	0.000	0.0025	0.1	2.54	96.08	96.05	1.00	1.03
21	8	0.0930	0.188	24	26	97.08	97.08	0.000	0.0025	0.1	2.54	96.05	96.03	1.03	1.05
23	12	0.0530	0.119	28	29	97.32	97.32	0.000	0.0025	0.1	2.54	96.32	96.29	1.00	1.03
24	58	0.0450	0.078	30	32	96.87	96.87	0.000	0.0025	0.1	2.54	95.87	95.73	1.00	1.15
26	22	0.0580	0.101	34	35	97.18	97.18	0.000	0.0025	0.1	2.54	96.18	96.13	1.00	1.06
28	16	0.0400	0.069	38	37	97.18	97.18	0.000	0.0025	0.1	2.54	96.18	96.14	1.00	1.04
30	16	0.0270	0.046	51	52	97.60	97.60	0.000	0.0025	0.1	2.54	96.60	96.56	1.00	1.04
31	8	0.0230	0.067	53	52	97.60	97.60	0.000	0.0025	0.1	2.54	96.60	96.58	1.00	1.02

32	40	0.1220	0.294	52	55	97.60	97.55	0.001	0.0010	0.1	1.64	96.56	96.52	1.04	1.03
33	8	0.0500	0.087	56	54	97.55	97.55	0.000	0.0025	0.1	2.54	96.55	96.53	1.00	1.02
34	30	0.0830	0.143	72	71	97.21	96.93	0.009	0.0090	0.1	4.91	96.21	95.94	1.00	0.99
35	28	0.1130	0.223	54	55	97.55	97.55	0.000	0.0025	0.1	2.54	96.53	96.46	1.02	1.09
36	37	0.3390	0.751	55	50	97.55	96.56	0.027	0.0270	0.1	8.50	96.46	95.46	1.09	1.10
37	22	0.0210	0.037	41	43	96.56	96.56	0.000	0.0025	0.1	2.54	95.56	95.51	1.00	1.06
39	25	0.0600	0.103	44	45	96.56	96.56	0.000	0.0025	0.1	2.54	95.56	95.50	1.00	1.06
40	16	0.0560	0.097	43	45	96.56	96.56	0.000	0.0025	0.1	2.54	95.51	95.47	1.06	1.10
41	20	0.1570	0.272	45	47	96.56	96.56	0.000	0.0025	0.1	2.54	95.47	95.42	1.10	1.15
42	43	0.3150	0.571	47	49	96.56	96.53	0.001	0.0010	0.1	1.64	95.42	95.37	1.15	1.16
43	28	0.0530	0.092	80	47	96.87	96.56	0.011	0.0110	0.1	5.42	95.87	95.56	1.00	1.00
44	44	0.4740	0.846	49	50	96.53	96.56	-0.001	0.0025	0.1	2.54	95.37	95.26	1.16	1.30
45	42	0.0630	0.108	59	60	96.85	96.85	0.000	0.0025	0.1	2.54	95.85	95.75	1.00	1.11
46	20	0.0200	0.062	61	62	96.85	96.85	0.000	0.0025	0.1	2.54	95.85	95.80	1.00	1.05
47	6	0.0080	0.041	63	64	96.85	96.85	0.000	0.0025	0.1	2.54	95.85	95.84	1.00	1.02
48	9	0.0080	0.041	64	65	96.85	96.85	0.000	0.0025	0.1	2.54	95.84	95.81	1.02	1.04
49	3	0.0800	0.166	60	62	96.85	96.85	0.000	0.0025	0.1	2.54	95.75	95.74	1.11	1.11
50	12	0.1890	0.382	62	65	96.85	96.85	0.000	0.0025	0.1	2.54	95.74	95.71	1.11	1.14
51	23	0.2830	0.571	65	67	96.85	97.08	-0.010	0.0025	0.1	2.54	95.71	95.65	1.14	1.43
52	95	0.3810	0.864	67	71	97.08	96.93	0.002	0.0020	0.1	2.31	95.65	95.46	1.43	1.47
53	19	0.0130	0.023	67a	69	97.08	96.87	0.011	0.0110	0.1	5.42	96.08	95.87	1.00	1.00
54	16	0.0530	0.092	68	69	96.87	96.87	0.000	0.0025	0.1	2.54	95.87	95.83	1.00	1.04
55	94	0.3690	0.637	69	70	96.87	96.93	-0.001	0.0025	0.1	2.54	95.83	95.60	1.04	1.34
56	21	0.9540	2.059	19	21	97.16	97.16	0.000	0.0025	0.1	2.54	95.26	95.20	1.90	1.96
57	9	1.237	2.654	21	22	97.16	97.16	0.000	0.0030	0.1	2.80	95.20	95.18	1.96	1.98
58	15	1.269	2.709	22	27	97.16	97.32	-0.011	0.0030	0.1	2.80	95.18	95.13	1.98	2.19
59	13	1.498	3.132	27	29	97.32	97.32	0.000	0.0040	0.1	3.47	95.13	95.08	2.19	2.24
60	18	1.572	3.288	29	33	97.32	97.32	0.000	0.0040	0.1	3.47	95.08	95.01	2.24	2.31
61	4	1.745	3.586	33	35	97.32	97.18	0.035	0.0350	0.1	9.67	95.01	94.87	2.31	2.31

62	21	1.843	3.811	35	37	97.18	97.18	0.000	0.0030	0.15	7.90	94.87	94.80	2.31	2.38
63	15	1.936	3.999	37	50	97.18	96.56	0.041	0.0410	0.1	10.47	94.80	94.19	2.38	2.37
64	34	2.840	5.807	50	70	96.56	96.93	-0.011	0.0025	0.15	7.90	94.19	94.10	2.37	2.83
65	20	3.367	6.771	70	71	96.93	96.93	0.000	0.0025	0.15	7.90	94.10	94.05	2.83	2.88
66	28	3.848	7.904	71	75	96.93	97.22	-0.010	0.0030	0.15	8.10	94.05	93.97	2.88	3.25
67	124	3.873	8.618	75	77	97.22	97.24	0.000	0.0040	0.15	9.20	93.97	93.47	3.25	3.77
68	242	3.9090	9.047	77	78	97.24	97.67	-0.002	0.0040	0.15	9.20	93.47	92.51	3.77	5.16
11	54	0.1920	0.358	26	27	97.08	97.32	-0.004	0.0025	0.1	2.54	96.03	95.90	1.05	1.43
69	10	0.3570	0.771	9	11	97.25	97.25	0.000	0.0025	0.1	2.54	95.77	95.75	1.48	1.50
70	3	0.3860	0.822	11	13	97.25	97.25	0.000	0.0025	0.1	2.54	95.75	95.74	1.50	1.51
71	14	0.4550	0.941	13	14	97.25	97.07	0.013	0.0130	0.1	5.90	95.74	95.56	1.51	1.51
72	47	0.1730	0.298	32	33	96.87	97.32	-0.010	0.0025	0.1	2.54	95.73	95.61	1.15	1.71
73	18	0.0360	0.063	66	67	97.08	97.08	0.000	0.0025	0.1	2.54	96.08	96.04	1.00	1.05
74	50	0.0000	0.096	74	75	97.31	97.22	0.002	0.0020	0.1	2.31	96.31	96.21	1.00	1.01
75	70	0.0360	0.429	76	77	97.22	97.24	0.000	0.0025	0.1	2.54	96.22	96.05	1.00	1.19
76	45	0.1410	0.243	57	70	97.21	96.93	0.006	0.0060	0.1	4.01	96.21	95.94	1.00	0.99

CHAPTER-5
CONCLUSION

Scheme of sewerage system for disposing the sewage water for rural area has been developed. In sewer, water is flowing with a certain velocity, which is difficult to achieve in rural sparely populated human settlements. For achieving this velocity, the siphon system are provided at household level. Cattle tanks are provided for holding the dung and allowing only the clear water to flow to the siphon system. Sewers are used to dispose the water to the treatment site.

Use of material and maintenance are important along with providing the sewerage network. The material chosen for sewer is directly affecting the corrosion rate. For long term service, the material should be non-corrosive.

PVC pipes are used for the sewer, using these pipes, the infiltration is reduced. In sanitary sewer, sulphuric corrosive conditions can occur. Sulphuric acid is derived through the oxidation of hydrogen sulfide by bacterial action on the exposed sewer pipe wall above the wastewater flow level. PVC is inert in presence of sulphuric acid. In PVC sewer pipes, grease deposition is easily removed by using the mechanical cleaning tools.

Maintenance is required for efficient working of the sewer. For maintaining the sewer, cleaning should be done on regular intervals.

REFERENCES

1. ABNT, (1988). “Associacao brasilerira de normas tenicas- projeto de reded coletoras de esgoto sanitaria.” ABES, Rio de Janeiro.

2. Ashley, R. M., and Crabtree, R. W., (1992). “Sediment origins, deposition, and build up in combined sewer systems.” Water Sci. Technol., 25(8), 1-12.

3. Bakalian, A., Wright, A., Otis, R., and Azevedo-Netto, J., (1994). “Simplified sewerage: Design guidelines.” World Bank, Washington, DC.

4. Bansal, R.K., (1998). “Fluid mechanics and hydraulic machines.” Laxmi Pub. New Delhi.

5. Broome, J., (2009). “Designing sewers for reduced wastewater flows.” International W062 symposium, Germany.

6. Butler, D., May, R., and Ackers, J., (2003). “Self cleansing sewer design based on sediment transport principles.” J. Hydraul. Eng., 4(129), 276-282.

7. Chiueh, P.T., Lo, S. L., and Liao, P.Y., (1999). “A study of self-cleansing velocity for sanitary sewer design” J. Inst. Env. Eng., 9(4), 285-292.

8. Cleavland, H.B., (2008). “Practical methods of sewage disposal for residence, hotels and institutions.” Lafayettest, New York.

9. Cosgrove, J.J., (2008). “Sewage purification and disposal.”

10. CPHEEO, (1993). “Manual on Sewerage and Sewage Treatment. 2nd ed.” Ministry of Urban Development, New Delhi.

11. Crabtree, R. W., (1989). “Sediment in sewers.” J. Inst. Water Environ. Managem., 3, 569-578.

12. Esen, I.I., (1993). “ Design of sewers based on minimum velocity.” J. Env. Eng., 119(3).

13. Fjerdingstad, (1969). “Bacterial corrosion of concrete in water.” Water Res., 3, 21-30.

14. Gardner, G., (1997). “Recycling organic waste: from urban pollutant to farm resource.” Worldwatch Inst., 58(135).

15. http://www.efm.leeds.ac.uk/CIVE/Sewerage

16. IS: 2470-(Part1), (1985). “Code of practice for installation of septic tanks: Part 1 Design criteria and construction (Second Revision).” Bureau of Indian Standards, New Delhi.

17. IS: 2470-(Part2), (1985). "Code of practice for installation of septic tanks: Part 2 Secondary treatment and disposal of septic tank effluent (Second Revision)." Bureau of Indian Standards.

18. IS: 4111- (Part1), (1986). "Code of practice for ancillary structures in sewerage system." Bureau of Indian Standards, New Delhi.

19. Jiang, G., Guiterrez, O., Sharma, K.R., and Yuan, Z. (2010). "Effects of nitrite concentration and exposure time on sulfide and methane production in sewer systems." Water Res., In Press.

20. Manning, R., (1891). "On the flow of water in open channels and pipes." Inst. of Civil Eng., 20, 161–207.

21. Mara, D., (1996). "Low-Cost sewerage." John Wiley & Sons Ltd., Chichester.

22. Mara, D., and Broome, J., (2008). "Sewerage: a return to basics to benefit the poor." Muncipial Eng., 161, 231-237.

23. Mara, D., Sleigh, A., and Tayler, K. (2001). "PC-Based Simplified Sewer Design." University of Leeds, Leeds.

24. May, R. W. P., (1993). "Sediment transport in pipes and sewer with deposited beds." Rep. No. SR 320, HR Wallingford.

25. Melo, J.C. (2005). "The experience in condominial water and sewerage system in Brazil: Case studies from Brasilia, Salvador, and Parauapebas."

26. Metcalf and Eddy, Inc.(1981). "Wastewater Engineering: Collection and pumping of Wastewater." Mcgraw- hill Book Co. New York.

27. Mori, T., Nonaka, T., Tazaki, K., Koga, M., Hikosaka, Y., and Noda, S. (1992). "Interaction of nutrients, moisture and pH on microbial corrosion of concrete sewer pipes." 26(1), 29-37.

28. Nema, A., "Simplified sewerage- an appropriate option for rapid sanitation coverage in urban areas." E-report at www.Green-ensys.org .

29. Nielsen, A. H., (2008). "Influence of pipe material and surfaces on sulfide related odor and corrosion in sewers." Water Res., 42(15), 4206-4214.

30. Okabe, S., Odagiri, M., Ito, T., and Satoh, H. (2007). " Succession of sulfur-oxidizing bacteria in the microbial community on corroding concrete in sewers system." Applied and Env. Microbio., 73(3), 971-980.

31. Otis, R. J., and Mara, J., (1985). "The design of small bore sewer system." United nation development program, Washington, DC.

32. Sarmento, V. B. A., (2001). "Low cost sanitation improvements in poor communities: condition for physical sustainability." PHD Thesis, University of Leeds.

33. Sinnatamby, G. S., (1986). "The design of shallow sewer systems." United Nations Centre for Human Settlements, Nairobi.

34. Sinnatamby, G., Mcgarry, M., and Mara. D. (1986). “Sewerage: Shallow systems offer hope to slums.” World Water, 9, 39-41.

35. USEPA., (2000). “Decentarlized system technology fact sheet.” Office of Water., Washington, DC.

36. USEPA., (2002). “Collection system technology fact sheet.” Municipal Tech. Branch., Washington, DC.

37. Wentink, K. G., and Jackson, R. D., (2007). “Sanitary sewerage systems.” PSD, 142.

38. www.cpda.co.uk

39. www.engineeringtoolbox.com

40. www.siphons.com

41. Yao, K. M., (1974). “Sewer line design based on critical shear stress.” J. Env. Eng., 100(EE2).

42. Zhang, J., (2001). “Modern concept of city sewerage system.” China Eng. Sci., 3(10), 33–5.

ANNEXURE

ANNEX: 1 Geometric elements of circular channel

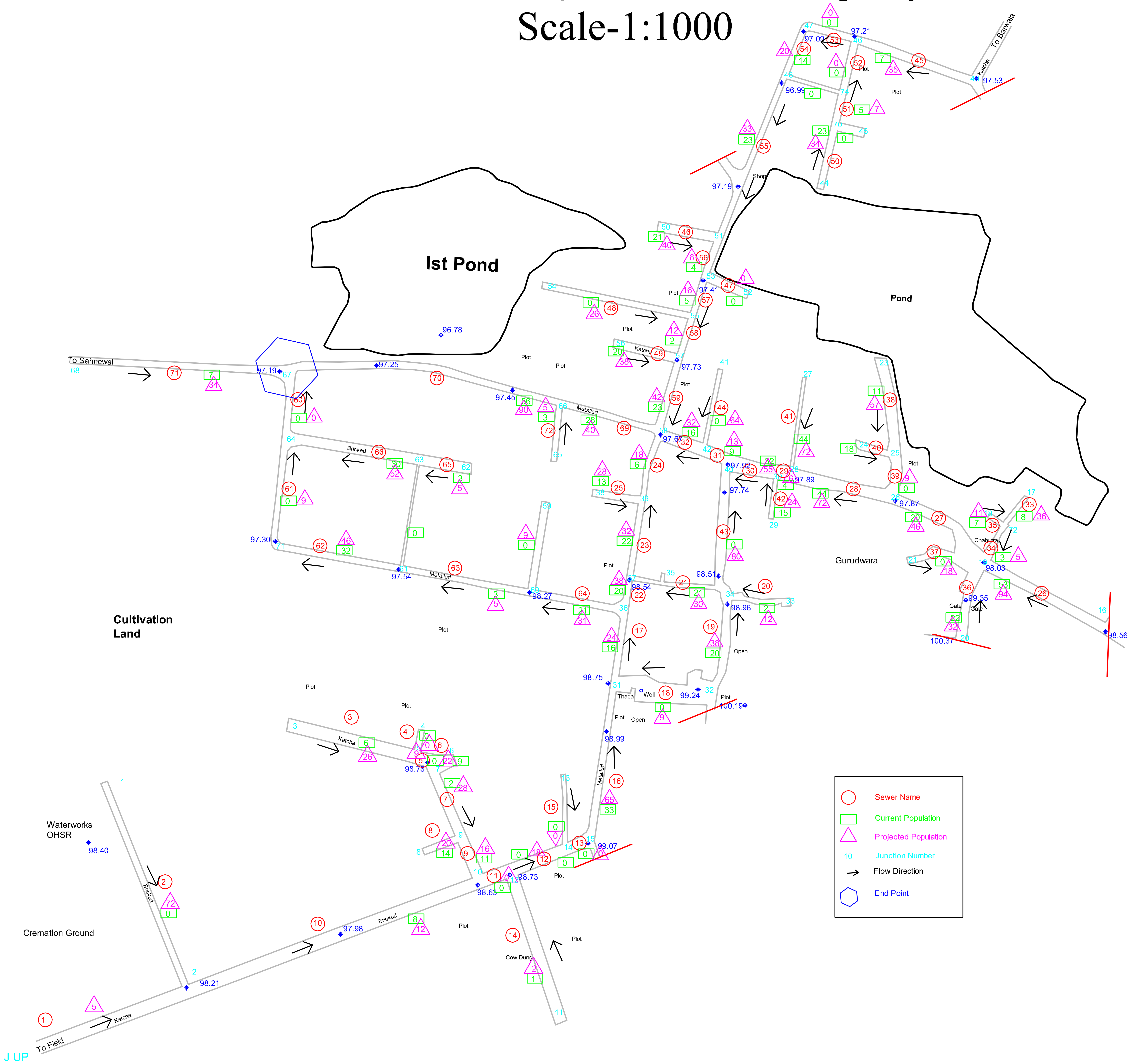
$\frac{y}{d_o}$	$\frac{a}{d_o^2}$	$\frac{p}{d_o}$	$\frac{r}{d_o}$	$\frac{ar^{2/3}}{d_o^{8/3}}$
0.01	0.0013	0.2003	0.0066	0.0000
0.02	0.0037	0.2838	0.0132	0.0002
0.03	0.0069	0.3482	0.0197	0.0005
0.04	0.0105	0.4027	0.0262	0.0009
0.05	0.0147	0.4510	0.0326	0.0015
0.06	0.0192	0.4949	0.0389	0.0022
0.07	0.0242	0.5355	0.0451	0.0031
0.08	0.0294	0.5735	0.0513	0.0040
0.09	0.0350	0.6094	0.0574	0.0052
0.10	0.0409	0.6435	0.0635	0.0065
0.11	0.0470	0.6761	0.0695	0.0079
0.12	0.0534	0.7075	0.0754	0.0095
0.13	0.0600	0.7377	0.0813	0.0113
0.14	0.0668	0.7670	0.0871	0.0131
0.15	0.0739	0.7954	0.0929	0.0152
0.16	0.0811	0.8230	0.0986	0.0173
0.17	0.0885	0.8500	0.1042	0.0196
0.18	0.0961	0.8763	0.1097	0.0220
0.19	0.1039	0.9020	0.1152	0.0247
0.20	0.1118	0.9273	0.1206	0.1273
0.21	0.1199	0.9521	0.1259	0.0301
0.22	0.1281	0.9764	0.1312	0.0333
0.23	0.1365	1.0003	0.1364	0.0359
0.24	0.1449	1.0239	0.1416	0.0394
0.25	0.1535	1.0472	0.1466	0.0427
0.26	0.1623	1.0701	0.1516	0.0464
0.27	0.1711	1.0928	0.1566	0.0497
0.28	0.1800	1.1152	0.1614	0.0536
0.29	0.1890	1.1373	0.1662	0.0571
0.30	0.1982	1.1593	0.1709	0.0610
0.31	0.2074	1.1810	0.1755	0.0650
0.32	0.2167	1.2025	0.1801	0.0690
0.33	0.2260	1.2239	0.1848	0.0736
0.34	0.2355	1.2451	0.1891	0.0776
0.35	0.2450	1.2661	0.1935	0.0820
0.36	0.2546	1.2870	0.1978	0.0864
0.37	0.2642	1.3078	0.2020	0.0909
0.38	0.2739	1.3284	0.2061	0.0955
0.39	0.2836	1.3490	0.2102	0.1020
0.40	0.2934	1.3694	0.2142	0.1050
0.41	0.3032	1.3898	0.2181	0.1100
0.42	0.3132	1.4101	0.2220	0.1147
0.43	0.3229	1.4303	0.2257	0.1196
0.44	0.3328	1.4505	0.2294	0.1245
0.45	0.3428	1.4706	0.2331	0.1298
0.46	0.3527	1.4907	0.2366	0.1348
0.47	0.3627	1.5108	0.2400	0.1401
0.48	0.3727	1.5308	0.2434	0.1452
0.49	0.3827	1.5508	0.2467	0.1505
0.50	0.3927	1.5708	0.2500	0.1558
0.51	0.4027	1.5908	0.2531	0.1610
0.52	0.4127	1.6108	0.2561	0.1664
0.53	0.4227	1.6308	0.2591	0.1715
0.54	0.4327	1.6509	0.2620	0.1772
0.55	0.4426	1.6710	0.2649	0.1825
0.56	0.4526	1.6911	0.2676	0.1878
0.57	0.4625	1.7113	0.2703	0.1933
0.58	0.4723	1.7315	0.2728	0.1987
0.59	0.4822	1.7518	0.2753	0.2041
0.60	0.4920	1.7722	0.2776	0.2092
0.61	0.5018	1.7926	0.2797	0.2146
0.62	0.5115	1.8132	0.2818	0.2199
0.63	0.5212	1.8338	0.2839	0.2252
0.64	0.5308	1.8546	0.2860	0.2302
0.65	0.5404	1.8755	0.2881	0.2358
0.66	0.5499	1.8965	0.2899	0.2407
0.67	0.5594	1.9177	0.2917	0.2460
0.68	0.5687	1.9391	0.2935	0.2510
0.69	0.5780	1.9606	0.2950	0.2560
0.70	0.5872	1.9823	0.2962	0.2608
0.71	0.5964	2.0042	0.2973	0.2653
0.72	0.6054	2.0264	0.2984	0.2702
0.73	0.6143	2.0488	0.2995	0.2751
0.74	0.6231	2.0714	0.3006	0.2794
0.75	0.6318	2.0944	0.3017	0.2840
0.76	0.6404	2.1176	0.3025	0.2888
0.77	0.6489	2.1412	0.3032	0.2930
0.78	0.6573	2.1652	0.3037	0.2969
0.79	0.6655	2.1895	0.3040	0.3008
0.80	0.6736	2.2143	0.3042	0.3045
0.81	0.6815	2.2395	0.3044	0.3082
0.82	0.6893	2.2653	0.3043	0.3118
0.83	0.6969	2.2916	0.3041	0.3151
0.84	0.7043	2.3186	0.3038	0.3182
0.85	0.7115	2.3462	0.3033	0.3212
0.86	0.7186	2.3746	0.3026	0.3240
0.87	0.7254	2.4038	0.3017	0.3264
0.88	0.7320	2.4341	0.3008	0.3286
0.89	0.7380	2.4655	0.2996	0.3307
0.90	0.7445	2.4981	0.2980	0.3324
0.91	0.7504	2.5322	0.2963	0.3336
0.92	0.7560	2.5681	0.2944	0.3345
0.93	0.7612	2.6061	0.2922	0.3350
0.94	0.7662	2.6467	0.2896	0.3353
0.95	0.7707	2.6906	0.2864	0.3349
0.96	0.7749	2.7389	0.2830	0.3340
0.97	0.7785	2.7934	0.2787	0.3322
0.98	0.7816	2.8578	0.2735	0.3291
0.99	0.7841	2.9412	0.2665	0.3248
1.00	0.7854	3.1416	0.2500	0.3117

d_o = diameter
y = depth of flow
a = water area
p = wetted perimeter
r = Hydraulic radius.

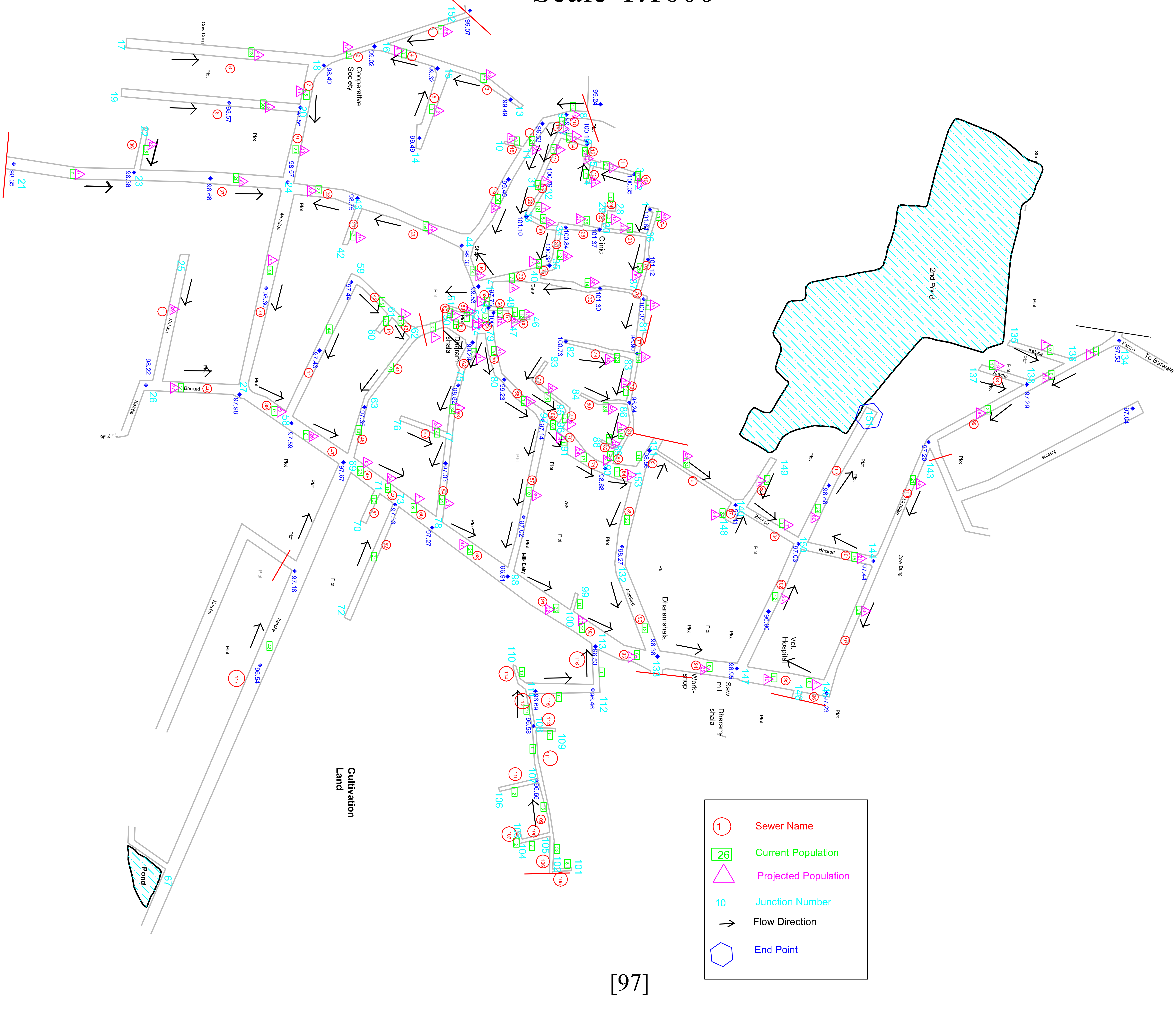
Source: CPHEEO, 1993

Annex: 2 Site map for 1st sewerage system

Scale-1:1000

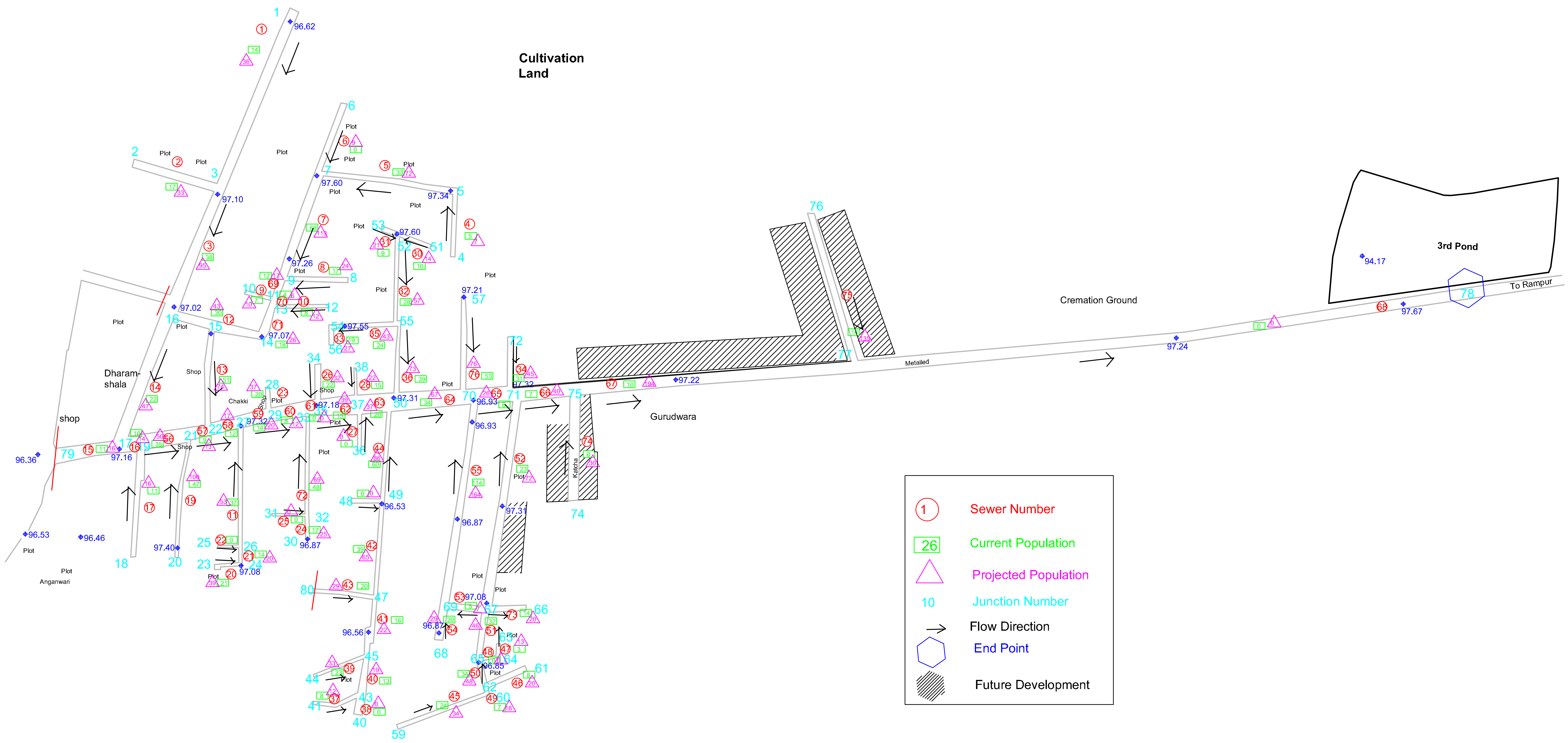


Annex: 3 Site map for sewerage system 2nd
Scale-1:1000



Annex: 4 Site map for sewerage system 3rd

Scale-1:1000



Annex: 5 Site map for sewerage system 4th Scale-1:1000