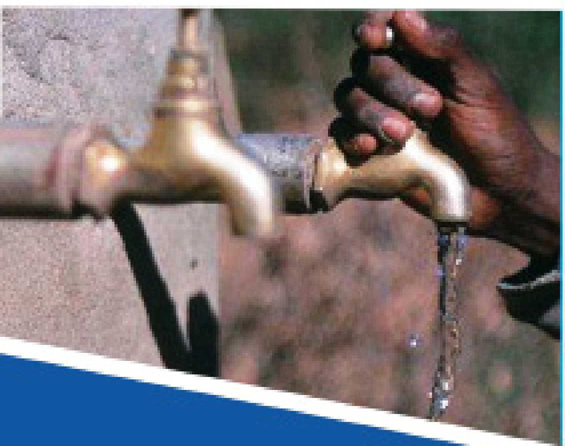
DESIGN AND CONSTRUCTION MANUAL FOR WATER SUPPLY AND SANITARY FACILITIES IN HEALTH INSTITUTIONS



MINISTRY OF HEALTH, AND WATER & ENERGY

IN COLLABORATION WITH UNICEF

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The Federal Ministries of Health and Water & Energy are pleased to publish this Design and Construction Manual for WASH Facilities in Health Institutions - the first document of its kind for Ethiopia. This manual is the product of the hard work of many people. In addition to all those who provided technical feedback in the development of this manual, we would like to acknowledge especially the contribution of the following individuals; Ato Abiy Girma from MoW&E, and Ato Getachew Wolde, Ato Getachew Belaineh, Ato Yared Tadessie from MoH for their invaluable support and technical contribution.

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PREFACE

This health institutions, Water, Sanitation and Hygiene (WASH) facilities design and construction manual has been prepared to give guidance to those involved in the construction of water supply and latrine facilities in health institutions on how to construct and maintain water supply, sanitation and hygiene facilities in health centres and health posts and provide guidelines to implement hygiene and environmental sanitation.

This manual is advantageous because it provides important information needed for the construction of safe, reliable and adequate WASH facilities in health institutions. The provision of WASH in Health Centres is critical, as these are already being used for safe delivery – a concept that is likely to be extended, over time, to a much greater number of health posts at Kebele level. In terms of maternal health, safe delivery is difficult, if not impossible, to achieve without reliable access to safe water. Health Centres may also be associated with Inpatient Therapeutic Centres treating children for Severe Acute Malnutrition – again, access to safe water and sanitation (with hand-washing facilities) is critically important.

The manual describes the possible water sources for health institutions such as rain water harvesting which can be used to augment other water supply sources in health centres and health posts and gives illustrations and designs. Also included in the manual are designs for other water sources such as spring development, hand dug wells, deep borehole, and water lifting devices. Power systems that could be used as good sources of sustainable power for accessing water sources such as solar power system, wind power, and internal combustion engine are also described with use of helpful graphs and maps. In addition, sanitation and hygiene options and waste management designs for solid waste in health facilities including Ventilated Pit Latrines (VIPL), double vault compost latrines, placenta pits, sharp pits and incinerators are described in detail with numbers, designs, and dimensions in the manual.

The need for a comprehensive guideline for the construction of WASH facilities in health institutions has been considered for a long time. This manual, which is the first of its kind, has been developed with the Ministries of Health and Water & Energy and numerous other stakeholders. It will be very helpful in solving the budget waste problem that has been seen in the construction of WASH facilities in health institutions due to a lack of knowledge and a standard design manual to use as a guide.

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Acronyms

AC	Alternate Current
D	Distance
DC	Direct Current
DW	Deep Well
FMOH	Federal Ministry of Health
HAWT	Horizontal Axis Wind Turbine
HC	Health Centre
HCF	Health Care Facility
HDW	Hand Dug Well
HP	Health Post
HSDP IV	Health Sector Development Program
I	Current
Io	Solar Constant
MDG 4	Millennium Development Goals of reducing child mortality
MDG 5	Millennium Development Goals of reducing maternal mortality
PV	Photovoltaic
RWH	Rain Water Harvesting
SD	Standard Deviation
SPD	Spring Development
SSF	Surface Solar Energy
SW	Shallow Well
VAWT	Vertical Axis Wind Turbine
VIP	Ventilated Improved Pit Latrine
WHO	World Health Organization

1. INTRODUCTION

1.1 Background

Health Center and Health Post refers to those institutions in charge of helping the community on health and sanitation issues to improve the health status. It also provides education and consultation on hygiene practices and support on the methods of improving the sanitation condition of the community. This brings the community to realize the importance of health through the use of sanitation facilities and appropriate hygiene practices so that they can practice themselves.

Health Centers and Health Posts should serve as public images and sanitation is one of those facilities that should create that image as a clean environment, creating a good image for visiting patients and as demonstration centers to communities. The aim of providing sanitation facilities to the Health Center and Health Post is to improve existing sanitation conditions at the Health Center and Health Post.

In order to effectively perform the activities, it is recommended to integrate the promotion of environmental health education along with the construction and/or maintenance of sanitary facilities.

The 4th Health Sector Development Plan aims at improving health infrastructure in the country through expanding, equipping and managing of health institutions and different facilities required at health institutions. Coupled with the ongoing health extension program, improving health infrastructure is anticipated to meet the Millennium Development Goals of reducing child mortality (MDG 4) and reducing maternal mortality (MDG 5). Towards this end, FMOH is rapidly increasing the number of health institutions (especially health centers and health posts) all over the country. It had targeted to have 3,200 health centers and 11,440 health posts by the end of 2010, and reached over 2,689 health centers and 14,416 health posts

According to the health service delivery arrangement indicated in HSDP IV, primary health care unit comprises of a health center and five satellite health posts, which altogether provide services to 25,000 people. Health posts are the frontline health care providers and health centers are the next higher level health care providers, which serves as a referral center for health posts.

1.2 Objectives

Health Center and Health Post Water Supply ,Sanitation and hygiene facilities design and implementation manual as the name implies is planned to give a working guideline for the construction or maintenance of water supply ,sanitation and hygiene facilities in health centers and health posts. This will assist to increase the service coverage of water supply, sanitation and hygiene in the Health institutions through construction of water schemes, construction of pit latrines and disseminating information on hygiene and environmental sanitation.

The major objective of the manual mainly emphasized:-

a) In designing safe, affordable, maintainable (robust) and reliable water supply and sanitation facilities to the Health institutions, and

b) To provide guidelines to implement and maintain the facilities.

1.3 Purpose of the Manual

The provision of improved sanitation facilities will benefit mainly Health Centers and Health Posts that do not have any facilities or require maintenance and rehabilitation.

The neighboring communities will also benefit from the technical assistance that will be given in the design and construction of latrines, and in hygiene and environmental sanitation education.

1.4 Existing Water Supply, Sanitation and Hygiene facility Technology Options

Access to water supply and latrine facilities for the Health facilities in all Regional States were assessed by the Federal Ministry of Health and the result is shown in Table 1.1.

Table 1.1 Health facility water and sanitation coverage rates by region

Region	Access to water Coverage rate %	Access to latrine facilities Coverage rate %
Afar	23.23	88.83
Amhara	23.58	69.09
BenishangulGumuz	29.19	69.73
Gambella	23.44	64.84
Oromiya	25.37	79.15
SNNPR	28.53	85.45
Tigray	36.77	89.20
Dire Dawa	73.68	
Harari	71.43	71.43
Addis Ababa	96.31	99.36

The above assessment report clearly reveals that the water supply in Health Institutions needs further attention in all Regional States. The latrine coverage seems relatively satisfactory. However, the assessment is not covering the sanitation aspect of the Health institutions including handling of Solid waste, which is very crucial.

Health Institutions WaSH assessment was also done by WaterAid Ethiopia and the report was submitted in February, 2012. According to the report, most of the water supply facilities to the HCs assessed is connected to the community water supply system with the exception of one HC which has its own water source. Deep well, shallow well and developed springs are the sources of water supply for the health centers assessed.

According to the summary of the report, shown in Table 1.2, 8 HC are consuming les1 m3 per day, 1 HC is consuming 1.6 m3 per day and 3 HC are consuming on an average 2.3 m3 per day. The average water consumption of HC is about 1.02 m3 per day.

Table 1.2 Water supply coverage as per WaSH Assessment by WaterAid

Region	Woredas	Health centers	Monthly water consumption (m3)	Daily water consumption(m3)	Water storage capacity
Tigray	Atsbi Wonberta	HaikMessal	41.5	1.60	2 M^3
	Raya Alamata	Gerjelle	60	2.31	10 M^3
Afar	Chifra	Chifra	58	2.23	3 M^3
	Milie	Milie	14.5	0.56	5 M^3
Amhara	Tarmaber	DebreSina	60	2.31	1.5 M^3
	Machakel	Girakidamin	10.8	0.42	2 M^3
Oromiya	EluGelan	Ejaji	6.75	0.26	No water reservoir
	DugidaDawa	Finchwa	4.26	0.16	5 M^3
Benishangul Gumuz	Assossa	Abrehamo	18	0.69	2 M^3
	Sherkole	Sherkole	20	0.77	2 M^3
SNNPR	East Badwacho	Shone	13.86	0.53	2 M^3
	Gedeb	Gedeb	10.8	0.42	10 M^3
		Average	26.54	1.02	

The study also reveals that HDW, SPD, SW and DW are the sources of water supply for Health Posts (HPs) assessed as well as for community water supply systems that share water to the HPs.

Assessment of the existing situation of latrines/toilet at the HCs assessed indicated that all of them have at least 4 rooms latrine/ cubicle. In addition to the number of rooms HCs have pour flash toilets with pedestal in maternity/delivery rooms. The latrines/toilets are cleaned by cleaners assigned for the purpose. Assessment of practical experiences of health centers indicated that they use either soak away pits or septic tanks to dispose wastewater. In rural health centers hand washing facilities in the rooms are constructed with an onsite drainage system that is connected to a soak away pit. Whereas in the health centers with pour flash toilets, wastewater from hand washing facilities, showers and pour flash toilets are connected to waste disposal Septic tanks.

Assessment of the existing situation of latrines at the HPs assessed indicated that all of them have at least 2 rooms latrine. The toilets have doors and separate rooms for male and female. But no clear signs to differentiate rooms for males and females. Latrines in all the HPs visited are not accessible to pregnant women, children, the old and persons with disabilities. Those toilets do not consider local cultural practices like anal cleansing with water. Functional hand washing facility is not available at all latrines of the HPs visited.

The findings of the field assessment indicated that, incinerator, placenta pit and solid waste disposal pit were provided to handle the solid waste generated at the HPs. Non-of the HPs have liquid waste disposal pits.

1.5 The Manual

In this manual the appropriate technology options for the construction of water supply, sanitation and hygiene facilities that can be used by the Health Institutions are described. The description for each appropriate technology option includes the type and purpose of the option, method of construction, operation and maintenance and its implementation under different conditions.

Technical Drawing and Bill of Quantities for Construction is also prepared The drawing will show in detail the size or dimensions of the structures, type of construction materials and bill of quantities of the technology option under consideration.

2. Minimum Standard for Water Supply and Sanitation in Health Institutions

The minimum WaSH facility required at Health Posts and Health Centers water supply and sanitation is not established. The program for architectural design of the Health institutions did not establish minimum patient flow at each Health Institution and the designed WaSH facility is also not complete and/or adequate for satisfactory health service. Hence, emphasis was given in establishing minimum standard

2.1 Water Demand

Water demand for the Health Institutions depends on the level of service to be provided and the amount of water required in satisfying the demand of the different facilities of the Health institutions.

According to Health Institutions WaSH Assessment report, February, 2012, the actual quantities of water required will depend on several factors such as climate, availability and type of water-use facilities (including type of toilets), level of care and local water-use practices. WHO roughly estimates the minimum amount of water that a health center requires for every patient, for purposes of: hand washing, cleaning, laundry and drinking (Table2-1).

2.1 Minimum water requirement at health centres

S/N	Purpose	Amount in liters
1	Outpatients	5 liters/consultation
2	Inpatients	40-60 liters/patient/day
3	Operating theatre/maternity	100 liters /intervention
4	Dry supplementary feeding centre (depending on waiting time)	0.5–5 liters/consultation
5	Wet supplementary feeding centre	15 liters/consultation
6	Inpatient therapeutic feeding centre	30 liters/patient/day

Source: Operation manual for staffs at primary health level, WHO, 2007

The Sphere Project: - Humanitarian Charter and Minimum Standards in Humanitarian Response, 2011 edition; established Minimum water quantity for institutions and other users. The standard is identical to WHO standard with additional parameters for Cholera centers. According to the established standard, the water supply for Cholera centers should be 60 liters per patient per day and 15 liters per carrier per day. Furthermore, it recommends additional quantity for laundry equipment, flashing toilets to be estimated by the designer.

2.2 Design Criteria for Solid and Liquid Waste Disposal

The Health Posts or Health Centre is a place where there are people in the fore-front in terms of disseminating and controlling the health and hygiene improvement in the community. Of course there are also patients and caregivers who are the largest number using the health centre sanitation facilities that on the other hand may not have the awareness in the benefits of hygiene and sanitation. As a result health centre sanitation facilities must be clean, and exemplary to the community about clean and safe environment. In this way it will provide a variety of experiences to the visiting patients for the purpose of improving attitudes, knowledge and practices to health. Together with hygiene promotion at the health centers, it will bring the patients to gradually realize the importance of health and to act intelligently in community with this awareness.

2.2.1 Solid Waste

According to national Health Care Waste management Strategy and Implementation Plan, January, 2012; the amount of solid waste production depends on the size and its level of activity of the Health Institution. These parameters can be estimated knowing the number of beds, the average daily occupancy rate and number of out-patients treated in the Health Care Facility. Literatures indicate that infectious Health Care Wastes constitute 15% to 25% of total health-care wastes (solid waste) generated among which 1% are sharps, 1 % body part waste, 3% chemical or pharmaceutical waste, and1% radioactive and cytotoxic wastes or broken thermometers(less than 1%).

A study done in Hawassa city in nine HCFs including hospitals (four), health centers(two) and higher clinics (three) shows that the median quantity of waste generated at the facilities was 3.46 kg/bed/day (range: 1.48-8.19kg/bed/day) and the generated waste per day at a HCF increased as occupancy increased ($p< 0.001$). The proportion of hazardous waste generated ranges between 20–63.1% at the different HCFs assessed.

The study done in West Gojjam Zone of Amhara Region was a cross-sectional study employed to estimate waste generation rate and evaluate its management system in ten public health centers from March 2007 to April 2007. This study revealed that general wastes, Sharps, Infectious pathological wastes and Pharmaceutical wastes were among all categories of HC waste produced in the surveyed Health Centers. The daily mean health care waste-generation rate at Health Center was 1.79 (± 0.54 S.D) kg and waste generation per outpatient was equivalent to 0.035(± 0.05 S.D) kg but the mean healthcare waste generation rate among health centers did not significantly vary. The general waste of the health centers was 52% which is equivalent to 0.93 ± 0.3 kg/day whereas 0.86 ± 0.33 kg/day (48.0%) was hazardous waste.

2.2.2 Pit latrine and Liquid Waste

2.2.2.1 Pit Latrine

According to The Sphere Project, Humanitarian Charter and Minimum Standards in Humanitarian Response, published in 2011; Minimum number of toilets at public and institutions is designated and is shown in Table 2.3.

Table 2.2 Minimum number of toilets at public places and institutions in disaster situations

Institution	Short Term	Long Term
Market areas	1 toilet for 50 stalls	1 toilet for 20 stalls
Hospitals/medical centers	1 toilet to 20 beds or 50 outpatients	1 toilet to 20 beds or 20 outpatients
Feeding centers	1 toilet to 50 adults 1 toilet to 20 children	1 toilet to 20 adults 1 toilet to 10 children

The required volume of the pit is calculated by identifying the following parameters;

- Sludge accumulation rate (R)- the estimated sludge accumulation rate for a single person (m3 / person/ year)
- Number of people (P) – average number of users of the pit each day
- Filling time or the effective life of the pit (N) in years

Then
Volume of the pit (V) = P x R x N

The basic parameters to be used for design of latrines are:

- Production of excreta volume per person per year is estimated to be 0.04 - 0.06 m3 / person/ year,
- The location of toilets shall be located at accessible and visible locations
- To some extent their external elevation made to be aesthetically attractive
- The inside of the toilets will be designed in such a way that there is sufficient space for turning, good air ventilation and naturally well lighted
- Provision of separate entrances and seats for men and women at each block of the latrine
- Provision of water seals at openings of toilets
- Provision of hand wash facilities
- Provision of hand washing soaps and mirrors optional
- The floor and wall made of non-weary and easily cleanable material
- Doors raised up from floors for easy cleaning and protecting the door
- For the flush toilets use sewer connection or compartmental, and de-sludge-able septic tanks with their secondary treatment options

If urine is let to leach in to the surrounding soils through dry /un-mortared / joints of the pit wall of the latrine then if at all there is this property of the surrounding soil, only the volume of solids will remain in the pit maximizing the filling rate or minimizing the frequency of dislodging rate. This is site specific design to be determined during the implementation period based on the soil type.

2.2.2.2 Septic tank and Soak away pits

A septic tank is an underground watertight settling chamber into which raw sewage, both grey and black water, is delivered through a pipe from plumbing fixtures inside the Health Institution and other WaSH facilities, like water point, close washing facility and hand washing, etc. in the compound. The sewage is partially treated in the tank by separation of solids form sludge and scum.

Effluent from the tank infiltrates into the ground through drains or a soak pit. The system works well where the soil is permeable and not liable to flooding or water logging, provided the sludge is removed at appropriate intervals to ensure that it does not occupy too great a proportion of the tank capacity.

For design of septic tank the following parameters are used:

- Septic tanks can be constructed from stone masonry, brick, concrete blocks, concrete and synthetic materials
- Septic tanks should be water tight both sides
- Septic tank should have provision of solid settlement and partial biological treatment of sewage
- The sizing of the tank is based on the number of users, daily per capita water consumption, sludge production rate of the users, hydraulic retention time and frequency of desludging
- The following formula is used to determine the volume of the tank
- $V = (p \times q \times Td) / 103 + (p \times v \times Nd) / 103$

Where

V = Effective volume of the tank in m3 (minimum 1 m3)
P = Users population
q = per capita daily water consumption in liters
Td = Hydraulic retention time in days (1-3 days)
v = sludge production per capita per year in liters (60-lit)
Nd= desludging period (min 365 days)

Soak away pits and infiltration trenchesare constructed for disposal of the supernatant seepage from septic tanks and the sullage from fixtures and disposing to underground strata

For design of soak pits the following parameters will be used:

- The pits are designed for specific quantity of septage and sullage
- Before determining their number and location standard infiltration test of the soil should be conducted.
- All solids, grease, scum etc must be trapped prior to the soak pits
- The following formula can be used for determining the number of circular soak pits

$$Atot = PQ / I$$
$$Nosap = Atot / \pi DH$$

Where

Atot	= Total effective area of required infiltration in m2
P	= Users population
I	= Infiltration Rate (liter/m2/day)
Q	= wastewater discharge (liter/person/day)
Nosap	= required number of soak pits (No)
D	= assumed diameter of the pit (m)
H	= effective depth of the soak pit (m)

3. Design of Water Supply System for Health Institutions

3.1 Population served in Health Centers

Information regarding recorded cases in 122 Public hospitals, 2660 health centers and 15,095 health posts were found from the Federal Democratic Republic of Ethiopia Ministry of Health in unpublished booklet on Health and Health related indicators 2003/2011G.C.

Health Institutions WaSH Assessment in Tigray, Afar, Amhara, Oromia, Benishangul and SNNP Regions of Ethiopia conducted by Water Aid Ethiopia, February, 2012. According to the report, the high patient flow in Health Centers and Health Posts in a year varies from region to region with a minimum of 2 months in Tigray and maximum of 6 months in Benishangul and SNNP. On an average Health centers and Health Posts will be overloaded 4 months in a year.

Number of cases and number of months with maximum patient flow is used to estimate the patient flow per day in Hospitals and Health centers. The estimate is basically for design purpose to be modified when accurate data is available from FMoH. The estimate disregards Health Posts as their primary purpose is health education and their number of HPs is also not matching with the reported cases. The result is shown in Table 3.1.

Table 3.1 Estimated average patient flow in 122 public hospitals and 2660 health centres

	Average per day	Maximum per day
Maternity	2	3
Inpatient	7	10
Outpatient	90	133
Total	99	146

According to Healthcare waste generation and its management system: the case of health centers in West Gojjam Zone, Amhara Region, by Muluken Azage, Abera Kumie, published in Ethiopian Journal of Health Development, the mean ± SD (standard deviation) patient flow per day in all sections and outpatients in each health center was 185.8 ± 30.3 and 51.7 ± 11.6 patients, respectively. The above data is used to estimate the water requirement of a Health Centre.

3.2 Water Demand for Health Institutions

3.2.1 Water Demand for Health Centers

Table 3.2 Estimation of average water demand of a Health Centre

S/N	Purpose	Consumption in liters	Based on the case study		Based on Health & Health indicators	
			No. of users per day	Water demand per day	No. of users per day	Water d emand per day
1	Staff	20liters per capita	20	400.00	20	400.00
2	Patient in all section	5 liters per capita	129	645.00		
3	Outpatients consultation	5 liters/consultation	52	260.00	90	450.00
4	Outpatients for drinking & washing	2 liters per capita	52	104.00	90	180.00
5	Inpatients 5 beds	40–60 liters/patient/day	4	240.00	7	420.00
6	maternity	100 liters /intervention	1	100.00	2	200.00
7	Caregivers	2 liters per capita	186	372.00	90	198.00
Total water required per day				2121.00		1848.00
Allowance for laundry, equipment flashing and toilet				2121.00		184.80
Allowance for cholera outbreak				466.62		406.56
Total				2799.72		2439.36

Table 3.3 Maximum water demand at Health centres

S/N	Purpose	Consumption in liters	Based on the case study		Based on Health & Health indicators	
			No. of users per day	Water demand per day	No. of users per day	Water d emand per day
1	Staff	20liters per capita	20	400	20	400
2	Patient in all section	5 liters per capita	147	735		
3	Outpatients consultation	5 liters/consultation	64	320	133	665
4	Outpatients for drinking & washing	2 liters per capita	64	128	64	128
5	Inpatients 5 beds	40-60 liters/patient/day	5	300	10	600
6	maternity	100 liters /intervention	2	200	3	300
7	Caregivers	2 liters per capita	218	436	146	292
Total water required per day				2519		2385
Allowance for laundry, equipment flashing and toilet				251.9		238.5
Allowance for cholera outbreak				554.18		524.70
Total				3325.08		3148.2

Based on the above table, the average water requirement of 3m3 per day is recommended for the water supply source identification and related design in HC.

If the health center is operating as a supplementary feeding centre or inpatient therapeutic feeding centre, additional water is required depending on the number of beneficiaries. On another hand, the water requirement of the neighboring community cannot be under estimated if adequate water supply is not available for the community.

3.2.2 Storage Requirement

The optimization of required storage reservoir can be analyzed based on the operation of the health center taking into consideration that storage will be required to continue the service of the health center during power interruption. The required capacity of the service reservoir, taking into account economical design approach, is 30% (8 hours) of the average day demand. The operation of a health center is mainly during the working hours. Due to this, the storage requirement should meet this demand. Therefore, the minimum storage requirement should be 3 m3.

According to Public Health Engineering practice by L.B.Escritt, 1978, water storage capacity, besides being estimated on water demand, is sometimes estimated on the number of fixtures provided. The unit storage requirement of each fixture is estimated in the book. Based on the above reference, the following storage requirement is estimated for the daily operation of the health Centre.

Table 3.4 Storage requirement at Health Centres

Fixture	Storage requirement per fixtures (litters)	No of fixtures provided	Required storage (litters)
Water-closet	151.4	1	151.4
Lavatory	227.1	9	2043.9
Sink	151.4	4	605.6
Laundry	378.5	3	1135.5
		Total	3936.4

3.2.3 Water Demand for Health Posts

Health posts are designed to be operated by health extension workers. According to Health institutions WaSH Assessment report February, 2012, the assigned health extension workers are expected to spend less than 20% of their time in health posts, and more than 80% of their time is spent on community outreach program visitation to households, especially mothers and children. Due to this, the water requirement is very limited. However, the standard design of a health post incorporates one lavatory, one sink and four taps for hand washing at the toilets. The running water from elevated tanker will feed these fixtures.

3.2.4 Storage requirement

The storage requirement for the health post is estimated as shown in Table 3-4

Table 3.5 Storage requirement at health post

Fixture	Storage requirement per fixtures (litters)	No of fixtures provided	Required storage (litters)
Lavatory	227.1	1	227.1
Sink	151.4	1	151.4
Tap for hand washing	152.4	4	605.6
		Total	984.1

According to the above estimate, a minimum of 1000 litter of water storage is required for the daily operation at a health centre.

4. Water Sources

The location, topography, geology, and climate determine the water resources characteristics and water availability. There are several types of water sources such as wells, springs, rainwater, streams or rivers, lakes etc used for different purposes. Among these sources some are available throughout the year while some are seasonal; some are convenient or provide water that tastes better while some do not.

After assessing a number of factors among the available water supply technology options the selected options are discussed in this chapter.

4.1 Rainwater Harvesting

4.1.1 Introduction

Rain Water Harvesting (RWH) is an option which can be adopted to augment the water demand of the Health institutions during the dry season. Rain water harvesting is mainly used for the provision of drinking water, and when local water supply sources dry up for a part of the year or it is can be also used as the sole water source in an area where there is uniform and adequate rainfall pattern is observed.

Every rain water system consists of three basic components:

- Catchment surface,
- Storage reservoir and
- Delivery system

Where there are two rainy seasons, rain water harvesting can be possible twice in a year and the storage, which is directly dependent on the demand and the available roof area, will be recharged during both wet seasons. However, in a single wet season the rain water harvesting can occur only once in a year and this will require a large storage capacity. The water demand and the required storage capacity may require a considerable capital cost. With such system a strict water management strategy is required to ensure that the water is used carefully and will last until next season or identify another source for sustainable supply.

4.1.2 Rainfall Distribution in the Country

The country can be divided into two according to the rainfall seasons (Daniel Gamachu 1977): (a) the western half of the country which receives one seasonal rainfall and (b) the eastern half the country which receives two seasonal rainfalls.

The most humid region is in the southwest where the mean annual rainfall exceeds 2,000 mm in several places; the highest around Gore is about 2,400mm. The highland regions in the west and south receive high rainfall, but in general, the rainfall distribution in the country is not always altitude dependent. For example, the lowlands in the southwest in the Baro-Akobo Basin receive as much rainfall as the highlands in the north (more than 1,000mm/year) though their difference in altitude is quite high, more than 1,000 meters. What accounts for this is the direction of the moisture laden winds and the fact that the mountains in the southwest meet these winds first; and as a result not only the southwest mountainous areas, but also the associated lowlands, receive high rainfall.

The arid regions are in the Ogaden, the Afar, and parts of the northwestern lowlands where the mean annual rainfall is less than 500 mm/year. These low rainfall regions have a higher intensity of rainfall than those areas which have a higher amount of mean annual rainfall (an intensity of more than 100mm/day in the lowlands and less than 50mm/day in the highlands). Generalized Isohytal map of the country is shown in Figure 4.1.

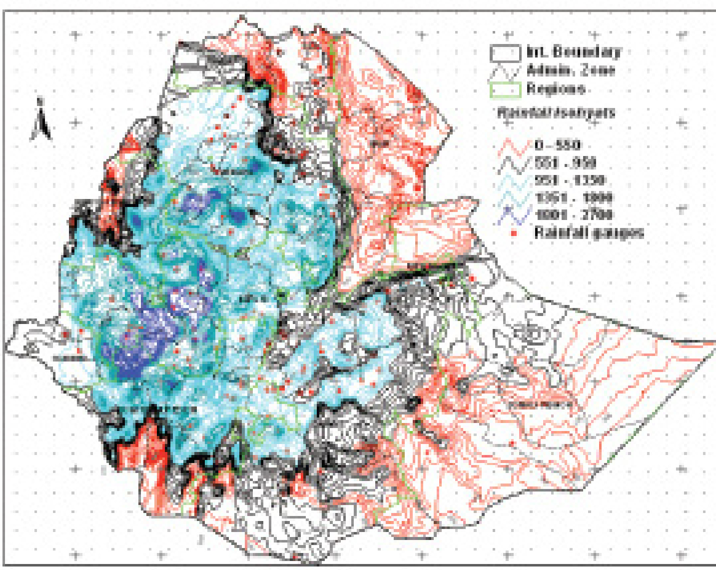


Figure 4.1 Rainfall Distribution of Ethiopia
Source: produced from digital data on rainfall database of MoWR

4.1.3 Quantity of Roof top Catchment

Roof top rain water harvesting system gathers rainwater caught on the roof using gutters and down pipes and lead to one or more storage containers ranging from simple pots to large storage tanks.

The water collected from roofs is reasonably pure if the roofs are made of galvanized sheets or tiles. It may be helpful to arrange the down pipe by fitting a foul flush device or detachable down pipe so that the first water from each shower, which is mostly contaminated with dust, leafs, insects and bird droppings, can be diverted from clear water container and allowed to run to waste.

For effective delivery of the rain water from roof catchments into storage tanks proper construction of gutter with respect to size, slope etc. is essential. The rainwater can be stored in tanks made of Ferro cement, bricks/blocks, reinforced concrete, metal, plastic and fiberglass and can be constructed over ground or underground. The storage tank has to be water tight with solid and secure cover to avoid risks from pollution sources or damage by erosion and to avoid breeding ground for mosquitoes. Furthermore, the tank has to be provided with proper inlet, overflow, and outlet and ventilation system.

The quantity of rainwater that can be collected from roof catchment largely depends on the size of the roof, the intensity of rainfall, and the storage capacity. This system can be effectively used by the health institutions in the longest season which may pass without rainfall.

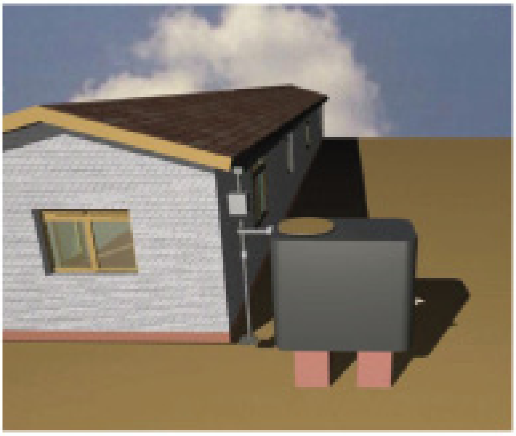
The amount of rainwater that can be harvested from roof top for different rainfall amount and roof area is shown in Table 4-1, which is a product of the surface area, amount of rainfall and run off coefficient i.e. 0.8.

$$V = K*I*A$$

Where:-

V = Volume of rain water harvested in M3
K = Runoff coefficient which is usually 0.8 for corrugated iron roofs
I = Recorded daily, monthly or annual rainfall in meters
A = Surface area of the roof in M2

Figure 4 2: Rooftop Water Harvesting



4.1.3.1 Volume of Roof Catchment in Health Centers

The quantity of water available from a rainwater harvesting system depends mainly on the amount and intensity of rain. Furthermore, the size of the roof catchment surface, the percentage catchment surface area that is guttered, the efficiency of the gutters in transporting the water, and the size of the storage tank also contribute on the amount of rainwater abstraction.

In standard Health Center, the available roof catchment surface area of all blocks, calculated from the roofing plan, is about 659.2m2. This surface area and annual average rainfall is used to calculate the possible annual rainwater abstraction volume at different places in the country. The data is plotted and shown in Figure 4.3.

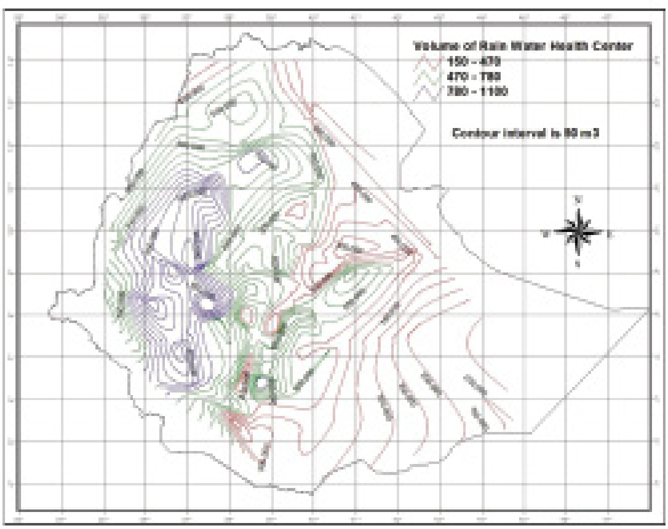


Figure 4.3 Volume of rainwater which can be abstracted from HC roof catchment in m3 in a year

The above information can be used to plan and decide the level of utilization of rainwater as a supplementary source for Health Center. The location of HC can be found using GPS and the maximum rainwater abstraction can be interpolated from the map as shown below.

- Abi-Adi; is at 39.01o Longitude and 13.53o Latitude and maximum volume is 400 m3.
- Adola; is at 39.08o Longitude and 5.91o Latitude and maximum volume is 480 m3.
- Yabelo; is at 38.10o Longitude and 4.88o Latitude and maximum volume is 500 m3.
- Gode; is at 44.56o Longitude and 5.10o Latitude and maximum volume is 140 m3.
- Bati (Kursa); is at 40.00o Longitude and 11.20o Latitude and maximum volume is 500 m3.
- Ogolcho; is at 39.03o Longitude and 8.06o Latitude and maximum volume is 450 m3.
- Debre-Birhan; is at 39.50o Longitude and 9.633o Latitude and maximum volume is 500 m3.

4.1.3.2 Volume of Roof Catchment in Health Post

In standard Health Post, the available roof catchment surface area of all blocks, calculated from the roofing plan, is about 73 m2. This surface area is used to calculate the possible annual rainwater abstraction volume at different places in the country based on annual average rainfall. The data is plotted and shown in Figure 4.4.

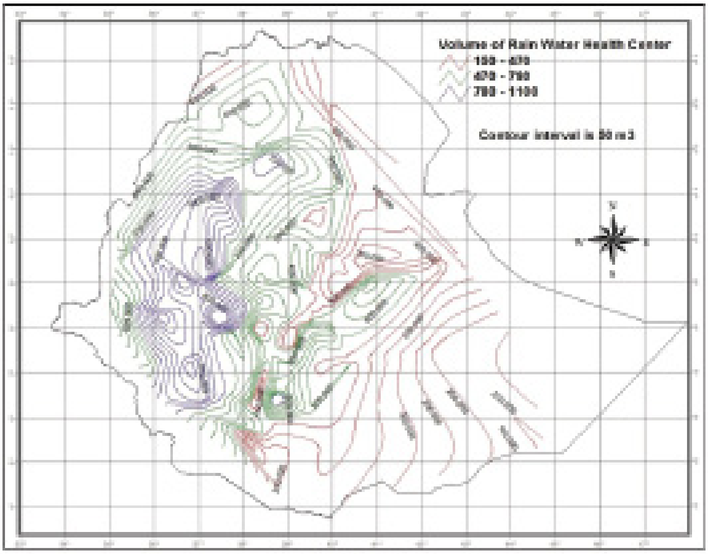


Figure 4.4Volume of rainwater which can be abstracted from HC roof catchment in m3 in a year

The above information can be used to plan and decide the level of utilization of rainwater as a supplementary source for Health Center. The location of HC can be found using GPS and the maximum rainwater abstraction can be interpolated from the map as shown below.

- Abi-Adi; is at 39.01o Longitude and 13.53o Latitude and maximum volume is 400 m3.
- Adola; is at 39.08o Longitude and 5.91o Latitude and maximum volume is 480 m3.
- Yabelo; is at 38.10o Longitude and 4.88o Latitude and maximum volume is 500 m3.
- Gode; is at 44.56o Longitude and 5.10o Latitude and maximum volume is 140 m3.
- Bati (Kursa); is at 40.00o Longitude and 11.20o Latitude and maximum volume is 500 m3.
- Ogolcho; is at 39.03o Longitude and 8.06o Latitude and maximum volume is 450 m3.
- Debre-Birhan; is at 39.50o Longitude and 9.633o Latitude and maximum volume is 500 m3.

4.1.4 Construction of Roof Catchment

4.1.4.1 Roofing Requirements

Materials commonly used in the construction of the roofs used for rainwater harvesting are corrugated galvanized iron, concrete, or tiles. The effective roof area and the material used in constructing the roof influence the collection efficiency and water quality.

4.1.4.2 Conveyance Requirements

Conveyance systems usually consist of gutters and drain pipes that deliver rainwater from the catchment area into the storage tanks. The conveyance systems should be of inert material to avoid adverse effects on water quality.

The roof guttering should slope evenly towards the down pipe, because if it sags, pools will form that can provide breeding place for mosquitoes.

Dust, dead leafs and bird droppings will accumulate on the roof during dry periods. These will be washed off by the first new rains. It may be helpful to arrange the down pipe so that the first water from each shower (the "foul flush") can be diverted from the clear water container and allowed to run to the waste.

4.1.4.3 Storage Requirements

The rainwater ultimately is stored in a storage tank, which should also be constructed of inert material. Reinforced concrete, ferro-cement, fibreglass, polyethylene, or stainless steel have been found to be suitable.

Storage tanks can be above-ground or below ground. Whichever type of storage is selected, adequate enclosure should be provided to prevent any contamination from human or animals, leafs, dust or other pollutants entering the storage tank. A cover should ensure dark storage conditions so as to prevent algal growth and the breeding of mosquito larvae. Open containers or storage ponds are generally unsuitable as sources of drinking water.

Water is taken from the storage tank by tapping, pumping, or using bucket and rope. For reasons of hygiene, the first two methods are preferred. Just before the start of the rainy season, complete system has to be checked for holes and broken parts and repaired if necessary.

Important factors to incorporate into the design of a storage tank include

- adequate capacity;
- provision of a sloped bottom and provision for collection of settled grit and sediment;
- overflow protection;
- inclusion of a manhole for easy access for cleaning;
- provision of a vent for air circulation (often the overflow pipe); and,
- Protection against insects and rodents.

The basic requirements are:

- The tank should not have excessive lose through seepage or evaporation;
- The tank should be covered to prevent entry of light, and sealed against intrusion by mosquitoes and small creatures;
- The tank should be ventilated to prevent anaerobic decomposition of any washed matter
- To reduce guttering costs and complications, the tank should be sited as close to the house as possible without undermining the foundation of the dwelling. If an underground design is used it should be more than 15 m away from any pit latrine.

4.1.4.4 Selection of Tank size

The selection of tank size is governed by several factors. In areas where the annual rainfall is above 1000 mm, the critical factor is the monthly average rainfall and number of months in which augmentation of supply is required. According to the estimate, the monthly water demand is about 78 m3 for HC and 26 m3 for HP. Hence, the storage volume will be a multiple of this quantity depending on the number of months with critical water shortage.

In areas where the monthly rainfall is below 1000mm, under sizing or over sizing of tank can be minimized by critically analyzing the daily rainfall record of the rainy season from the nearby station and correlate it with the site selected. The tank should be sized to collect the available rain in the short rainy period.

4.1.5 Cost Implications

The cost of this technology varies considerably depending on location, type of materials used, and level of implementation. The components that need cost estimate include roofing materials, gutters, conveyance pipes and storage tanks.

Thus, the main components of rooftop rainwater harvesting system which have initial investment costs are the following:

- Galvanized iron gutter
- Galvanized iron/ concrete/ ferrocement, etc. tank
- Down pipe
- Tap and filters
- Where the roof is not suitable for water harvesting, the cost of improving the roof and the gutters will have to be added to the cost of the tank

4.1.6 Operation and Maintenance

Rooftop rainwater harvesting systems require minimal attention with respect to their operation. The major concern is to prevent the entry of contaminants into the tank while it is being replenished during a rainstorm.

The main causes of bacterial pollution are from debris, bird and animal droppings, and insects that enter the tank.

The following maintenance guidelines should be considered in the operation of rooftop rainwater harvesting systems:

- Flush the rainwater to waste and away from the tank to avoid the entry of debris from the catchment area into the tank.

- Check and clean the storage tank periodically.

- Cover and ventilate the tank to avoid mosquito breeding, prevent insects and rodents from entering the tank, and minimize the growth of algae.

- Chlorinate the storage tanks as necessary if the stored water becomes contami nated. (Most times the rainwater is used without treatment.)

- Maintain gutters and down pipes. A good time to inspect gutters and down pipes is while it is raining, so that leaks can easily be detected. Regular cleaning is necessary to avoid contamination.

- If filter is provided, it should be cleaned every few months, filter sand should be washed at least every six months.

- Leaks have to be repaired throughout the year, especially leaking tanks and taps, as they present health risks.

- In some cases, where the water is pumped, periodic, preventive maintenance is required on the small pumps that lift water to selected areas of a house or building, or provide public supply from underground storage tanks;

Maintenance requirement and frequency of maintenance is summarized in Table

Table 4.1Main activities involved and frequency of maintenance for a RWH system

Activity	Frequency	Materials and spare parts	Tools & equipment
Clean the system	1-3 times per year	Chlorine	Broom, brush, bucket.1
Divert foul flush	Every storm	-	-
Clean the filters	Twice a year	Sand, charcal, plastic mesh	-
Disinfect the reservoir	Occasionally	Chlorine	Bucket
Repair roof, gutters and piping	Occasionally	Tiles, metal sheet, asbestos, cement sheet etc., bamboo or PVC pipes, nails, wire	Hammer, saw, pliers, tin cutter
Repair tap or pump	Occasionally	Washers, cup seals etc.	Spanner, Screw driver
Repair reservoir	Occasionally	Cement, sand, gravel, and bricks	Trowel, spade, bucket,

4.2 Spring Water Development

4.2.1 Introduction

A spring may be defined as a place where a natural outflow of groundwater occurs. Spring water is usually fed from a sand or gravel water-bearing ground formation (aquifer), or water flow through fissured rock. Where there are solid layers of block the underground flow of water is forced upward and can come to the surface. The water may emerge either in the open as spring, invisibly as an outflow into a river, stream, lake or the sea. Where the water emerges in the form of a spring, it can easily be tapped. If the collection point is protected with suitable structure, this will prevent contamination at the point of collection and provide the hydraulic conditions for distributing the water to points of use.

Springs are found mainly in mountainous or hilly terrains. Thus, the best places to look for springs are the slopes of hill sides and river valleys. Green vegetation at certain point in dry area may also indicate availability of spring water, or one may be found by following a stream up to its source. However, the local people are the best guides, as they usually know most springs in the area.

Spring water is safe and usually can be used without treatment, provided it is properly protected with a construction that prevents contamination of water from outside.

Springs can be exploited by developing at the spot or by a gravity-fed or pumped delivery system. Springs developed for a gravity-fed water supply should be at an elevation above the supply area.

4.2.2 Tapping of Spring

Though, the type of construction to be adopted differs from each other due to spring type, size and location, a tapping structure for a gravity type delivery system emerging down the hillside is considered for further discussion.

Springs can be tapped with drains consisting of graded gravel pack with open joints placed over an impervious layer. The drain must be placed so deep that the saturated ground above them will act as storage reservoir compensating for fluctuation of the ground water table. The water collected by a drain discharges into a storage chamber which is mostly referred as the “spring box”.

The drain system and the storage chamber should be so constructed that the contamination of the collected water is prevented. Before the back of the chamber is built, graded stones should be piled up. These serve to make a wall, and will prevent the washing away of soil. The chamber should be fitted with sealed and removable manhole cover for cleaning and access for maintenance work. Air vent, overflow pipe score drains must have screened openings. A diversion ditch should prevent surface runoff running down the hillside from entering the chamber to prevent contamination of the spring water.

4.2.3 Components of Spring Tapping Structure

The spring chosen for a water supply is to be enclosed in a structure from which a pipe leads down conveying the water to point of delivery. The structure can be constructed from concrete or masonry or brick. The spring box serves as storage and distribution for the spring water.

The spring box is usually built into hill side and deep enough to collect or access the spring – water source. This device allows water to enter from the bottom and fill up to a level established by an overflow or vent pipe. Hydraulic pressure then maintains the level in the spring box. The outflow pipe near the base of the device may be connected via pipe to a larger storage system (such as a tank) closer to the point of use or tapped directly at the location of the box.

Thus, the main parts of a spring water collection system are:

- a drain under the lowest natural water level,
- an outlet to tank or collection point
- an overflow pipe just below the roof
- a protective structure providing stability and
- a seal to prevent surface water from leaking back into the stored water.

The drain is usually placed at the lowest point and is provided with scour valve, while the outlet pipe is usually placed above the drain pipe preferably with a screen.

The protective structure may be made of concrete or masonry and the seal is usually made of puddle clay. A screened overflow pipe guarantees that the water can flow freely out of the spring at all times. To prevent contamination infiltrating from the surface, a ditch (known as interceptor drain) diverts surface water away from the spring box and a fence keeps animals out of the spring area. Usually spring water is of good quality, but this should be checked.

For low yield springs it would be advantageous to consider construction of a collection tank for night flow storage. Furthermore, when the terrain doesn't allow construction, off spot supply withdrawal can be possible by constructing underground or over ground collection tank downstream at proper location.

4.2.4 Yield of Spring

The Maximum daily demand of a health center is 0.1liters/second for eight hours. Due to this, a spring having a minimum discharge capacity of 0.1 liters per second can be selected as a source for health center if it is available within a reasonable distance from the health centre. The collection chamber will be additional storage to conserve the night discharge.

4.2.5 Cost Implications

There are different types of spring tapping structures, ranging from a simple weir structure (open) to more complex constructed (closed) systems. There is also a range of sizes depending on the flow and aerial extent of a given spring.

The main components of spring collection system which have initial investment costs implications are the following:

- Excavation and backfill
- Headwall or tapping box
- Pipe work
- Concrete work
- Masonry work.

4.2.6 Operation and Maintenance Requirements

The type of spring capping would generally require minimal intervention for operation and maintenance. Periodically, however, the chamber should be inspected and cleaned.

Thus, the main O&M activities are:

- Water should be permitted to flow out freely from the chamber at all the time so that it will not find another way out through the aquifer in different direction.
- Operation may include activities such as opening or closing of valves to divert the water to a reservoir, a conduit or a drain.
- The spring and surroundings must be kept clean.

Contamination should be prevented, both where the spring water infiltrates the ground (catchment area), if possible, and in area immediately surrounding the spring. Contamination can come from many sources, including from open defecation, latrines, cattle, pesticide and chemicals.

To avoid the contamination and deterioration of the source, the following points are anticipated to be checked at intervals and on regular basis:

- Check surface drains,
- Check and repair animal-proof fence and gate
- Check and protect the vegetative cover growth both in the area where the spring water infiltrates into the ground (if possible) and in the immediate surroundings of the spring (prevent clogging of the aquifer by growth of roots).
- Check the water flow from the spring box. If there is an increase in turbidity or flow after a rainstorm, surface run-off has to be identified and the protection of the spring improved. If the water flow decreases, it has to be suspected that the collec tion system is clogged. It may then be necessary to take out the gravel and replace with new gravel
- Regular water samples must be taken and analyzed to check for evidence of faecal contamination;
- the washout should be opened annually and the accumulate silt removed;
- screens should be checked and if they are damaged or blocked they should be cleaned (if dirty) or replaced with non-rusting materials (e.g. copper or plastic screening);
- After cleaning, the washout valve should be fully closed and the manhole covers to be sealed.
- The spring box should be disinfected each time a person enters to clean or repair it, or when there is a bacteriological contamination.
- Leaks in the protective seal, undermining of the headwall, and damaged caused by erosion or settlement of soil must be repaired.

Table 4.2 Main activities involved and frequency of maintenance

Activity	Frequency	Materials and spare parts	Tools & equipment
Clean the surroundings	Weekly	-	Broom, bucket, hoe, machete
Check the water quantity	Occasionally	-	Bucket, watch
Repair fence and clean surface drains	Occasionally	Wood, rope, wire	Machete, axe, knife, hoe, spade, pickaxe
Check the water quality	Regularly	Laboratory reagents	Labomtory equipment
Wash and disinfect the spring	Annually	Chlorine	Bucket, wrench, brush
Repair piping and valves	Occasionally	Spare pipes and valves, cement, sand, gravel	Bucket, trowel, wrench, flat spanners
Repair cracks	Annually	Cement, sand, gravel, clay	Bucket, trowel, hoe, spade, wheelbarrow
Check Turbidity	After every flood		

4.3 Hand Dug Wells

Hand dug wells may be defined as water points that tap water from shallow water tables. As the name suggests, these water points are constructed manually using hoes, picks and shovels. Usually, hand dug wells have a diameter of not less than 1.5 meters and a minimum water column of 3 meters. The wells are lined using bricks or concrete rings; and fitted with a pump.

4.3.1 Some Principles of Dug-Well Design

In principle, the hand dug well supplies water from storage. Where continuous pumping is planned, the rate of inflow to the well should be more than the rate at which the water is being pumped out. This will safeguard the pump from pumping the well dry.

The well storage acts as a "buffer" in providing water at peak pumping periods (such as early morning and late afternoon) when pump discharge can be higher than the rate of inflow to the well. For that reason a dug well is best suited in aquifers of very low permeability.

4.3.2 Well Yields

The storage requirement of the fixtures installed in health center is estimated to be 3.94m3 per day. Therefore well storage of about this volume would be required and a total 24 hour inflow of this same volume would also be necessary.

Storage of the full daily requirement is not necessary but, the minimum storage should be more than half the daily pumping requirement. As a safety margin, an arbitrary figure of two-thirds of the full daily requirement should be allowed for. It is important to remember that rate of inflow is a function of "head" or drawdown and not dug-well diameter, unless the formation is fractured.

The dug-well diameter does not greatly affect the rate of inflow, but it does directly affect its storage. A dug-well of internal diameter of 1.0m after lining, has storage of about 786 liters for each meter dug.

The capacity of pump is also a critical factor to determine the yield of a shallow well. For hand pumps with piston diameters of 7.5-10 centimeters (3-4 inches) capacities of 1200 to 2000 l/h were found, based on one full stroke per second and an effective pumping time of 75%.

Therefore, the desired well depth can be calculated after determining the full daily required yield of 3940 litter per day. Applying the safety margin the health center would need a well that will store at least two thirds of this full daily requirement which is about 2626liters. One meter depth of a 1.0 meter diameter well has storage of about 860 liters. To store 2626liters, a water column of 3.0m is required in a 1.0m diameter well. The desired well depth will be 1.0m below the static water level.

With 1m high concrete rings, at least three porous concrete rings should be installed if possible, with the top of the highest one at least 1m below the static water level. The inflow into the drained hole over 12 hours should be adequate to fill at least to the top of the third ring (i.e. a height of 3m of water). If the pump suction is to be significantly above the bottom of the well, additional depth must be added accordingly.

4.3.3 Well Water Level

A fall in static water level could result in a major drop in both storage capacity and rates of inflow. In order to maintain acceptable water levels, the following should be observed:

- Construct wells in the dry season when water levels are at their lowest.
- Be aware of longer-term water-level fluctuations, if data is available, and dig to appropriate depths.

- Be able to deepen the well fairly easily after completion should there be drastic drops in water levels.

4.3.4 Design of Well Depth

The designed well depth should take into account both the average seasonal water level fluctuation and the desired storage as discussed in the last two sub sections. The time (season) of construction should also be taken into account:

- Dry Season: It is usually adequate to allow for the desired depth of water column (storage)
- Other Seasons: After allowing for the desired storage, add depth to allow for the seasonal water level fluctuation.

4.4 Deep Borehole Construction

A deep borehole is defined as a borehole that is greater than 25 meters in depth and minimum diameter of 110mm. These are normally constructed using mechanical methods.
Construction steps for boreholes

- Site selection,
- The actual drilling operation,
- Installation of casing , screen and gravel pack, to ensure sand-free operation at maximum yield,
- Well development and
- Construction of sanitary seal

Two more of these operations may be performed simultaneously, depending upon the borehole construction technique used.

4.4.1 Drilling Methods

Drilled wells can be constructed using the rotary method or cable tool percussion method. The method selected will depend primarily on nature of the aquifer, type of terrain and economic implications. Anticipated size and depth of well and the geologic formations to be penetrated may also dictate which method is preferable.

4.4.2 Selection of Drilling Methods

The location of the Health Institution and the geologic formations to be drilled dictate the drilling method best suited to the operation. In granular formations, such as in alluvial plains, the rotary method is usually preferred to cable tool because penetration is more rapid, a better well seal is obtained and maintaining a straight hole is easier. Hard sedimentary rock, such as limestone and dolomite, is more resistant to rotary drilling; the

small rotary drill with a rock bit makes slow progress at the top of the hole where the weight of the drill pipe is not enough to force the rotating bit against the rock. Air rotary drilling is frequently used for drilling through metamorphic formations.
The cable tool method is preferred when drilling through cavernous rock or other highly permeable material, since all or most of the fluid used in the rotary method may disappear in this type formation, resulting in loss o the return flow or loss of circulation.

4.4.3 Well Completion

Well completion and development must follow the actual drilling to prepare a well for use. Elements of this process include:

- Installation of casing and screen
- Installation of gravel pack
- Development
- Test pumping
- Water sampling
- Cementing and grouting
- Sterilization

4.5 Water-lifting Devices

Water-lifting devices are used to lift water to a height that allows users easy access to water. Lifting devices can be used to raise groundwater, rainwater stored in an underground reservoir, and river water. Communities should be able to choose from a range of water-lifting devices, and each option should be presented with its advantages, disadvantages and implications. For example, water lifting involves additional O&M activities and potential problems, compared to gravity systems, and the latter are often preferred if they are available and applicable to the situation.

The following water-lifting devices are described in this manual:

- Rope and bucket (loose through a pulley, or on a windlass);
- Bucket pump;
- Rope pump;
- Electrical submersible pump; etc.

4.5.1 Rope and Bucket

This device is mainly used with hand-dug wells. A bucket on a rope is lowered into the water. When the bucket hits the water it dips and fills, and is pulled up with the rope. The rope may be held by hand, run through a pulley, or wound on a windlass. Sometimes, animal traction is used in combination with a pulley. Improved systems use a rope through a pulley, and two buckets – one on each end of the rope.

For water less than 10 m deep, a windlass with a hose running from the bottom of the bucket to a spout at the side of the well can be used. However, the hygiene of this system is poorer, even if the well is protected.

4.5.2 Bucket Pump

The bucket pump is mainly used in drilled wells. It consists of a windlass over a 125 mm PVC tube, down which a narrow bucket with a valve in the base is lowered into the water on a chain. When the bucket hits the water, the valve open sand the water flows in. When the bucket is raised, the valve closes and the water is retained in the bucket. To release the water, the pump operator rests the bucket on a water discharger, which opens the valve in the base. The windlass bearings are made of wood.

4.5.3 Rope Pump

The basic parts of a rope pump are a pulley wheel above the well, a riser pipe from under the water level to an outlet just under the wheel, and a rope with rubber or plastic washers. The rope comes up through the pipe, over the wheel; back down into the well and into the bottom of the pipe, completing the loop. When the wheel is turned, the washers move upwards and lift water into the pipe towards the outflow. Other important parts are an underwater rope guide that directs the rope and washers back into the pipe, and a frame that holds the pulley wheel. The rope pump can be made at village level using wood, rope and PVC tubing (or bamboo canes with the centers bored out).

4.5.4 Deep-well Piston Hand Pump

With a deep-well piston hand pump, the piston is placed in a cylinder below the water level, which is usually 15–45 m below the ground. The pumping motion by the user at the pump stand is transferred to the piston by a series of connected pumping rods inside the rising main. On the up-stroke, the plunger lifts water into the rising main, and replacement water is drawn into the cylinder through a foot valve. On the down-stroke, the foot valve closes, and water passes the plunger and is lifted on the next up-stroke. The pumping height is limited only by the effort needed to lift the water to the surface. Nowadays, most pump cylinders have an open top. This allows the piston and foot valve to be removed through the rising main for servicing and repairs, while the rising main and cylinder stay in place. The pump rods have special connectors that allow them to be assembled or dismantled without tools, or with only very simple ones. The connecting joints incorporate pump rod centralizers that prevent wear of the rising main. To a large extent, improved models can be maintained at village level.

4.5.5 Submersible Pump

For deep-well applications, centrifugal pumps are housed with the electric engine in a single unit that is designed to be submerged. Usually, a multiple-stage pump is used. The multiple-stage pump is placed above a motor and under a check valve that leads to the rising main. Submersible pumps are self-priming, if they do not run dry. To prevent the pump from running dry, the water level in the well must be monitored, and pumping must be stopped if the water level drops to the intake of the pump. Power is delivered through a heavily insulated electricity cable connected to a switch panel at the side of the well. The power may come from an AC mains connection, a generator, or a solar power system.

4.6 Power Systems

4.6.1 General

As per the water demand estimate in this report, the system demand is assumed to be between 3 to 10 m3 per day depending on the duration of pumping. A shallow or deep well drilled water source, with a submersible pump installed in the well and with a reservoir installed near the well is assumed as the most common method of supply when pumping is involved.

For pumped supplies from a spring the pump unit can be a surface centrifugal pump or a submersible pump installed horizontally in the spring box or wet well.

For supplies from a hand dug well with a pump installed, submersible pump can be installed except that the total head will generally be smaller.

A maximum total system head of 50-60 meter, including pipe system losses, is assumed for all demand ranges. For shallow or deep well options, the static head is calculated from the well DWL to the elevated tank. For the spring option, the static head is calculated from the surface pump inlet to the elevated tank.

A GI or PVC riser and transmission pipe of 1 ¼" is assumed for the estimation of head losses. The required pump discharge capacity and thus the required pump power is dependent on the demand and the pump running hours per day. The tables and charts below show the relationship between the demand, the pump working hours and the required pump capacity.

Table 4.3 Demand versus pump discharge capacity

Demand vs pump discharge capacity in liters per second for various working hours												
	m3/day											
	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00
2 hr	0.1389	0.2778	0.4167	0.5556	0.6944	0.8333	0.9722	0.1111	1.8333	1.3889	1.5278	1.6667
3 hr	0.0926	0.1852	0.2778	0.3704	0.4630	0.5556	0.6481	0.7407	0.5556	0.9259	1.0185	1.1111
4 hr	0.0894	0.1389	0.2083	0.2778	0.3472	0.4167	0.4861	0.5556	0.4167	0.6944	0.7639	0.8333
5 hr	0.0556	0.1111	0.1667	0.2222	0.2778	0.3333	0.3889	0.4444	0.3333	0.5556	0.6111	0.6667
6 hr	0.0463	0.0926	0.1389	0.1852	0.2315	0.2778	0.3241	0.3704	0.2778	0.4630	0.5093	0.5556
8 hr	0.0347	0.0694	0.1042	0.1389	0.1736	0.2083	0.2441	0.2778	0.2083	0.3472	0.3919	0.4167
10 hr	0.0278	0.0556	0.0833	0.1111	0.1389	0.1667	0.1944	0.2222	0.1667	0.2778	0.3056	0.3333
12 hr	0.0231	0.0463	0.0694	0.0926	0.1157	0.1389	0.1620	0.1852	0.1389	0.2315	0.2546	0.2778
14 hr	0.0198	0.0397	0.0595	0.0794	0.0992	0.1190	0.1389	0.1587	0.1190	0.1984	0.2183	0.2381
16 hr	0.0174	0.0347	0.0521	0.0894	0.0869	0.1042	0.1215	0.1389	0.1042	0.1736	0.1910	0.2083
18 hr	0.0154	0.0309	0.0463	0.0617	0.0772	0.0926	0.1080	0.1235	0.0926	0.1543	0.1698	0.1852
20 hr	0.0139	0.0278	0.0417	0.0556	0.0694	0.0833	0.0972	0.1111	0.0833	0.1389	0.1529	0.1667
22 hr	0.0126	0.0253	0.0379	0.0505	0.0631	0.0759	0.0984	0.1010	0.0759	0.1263	0.1389	0.1515
24 hr	0.0116	0.0231	0.0343	0.0463	0.0579	0.0694	0.0810	0.0926	0.0694	0.1157	0.1273	0.1389

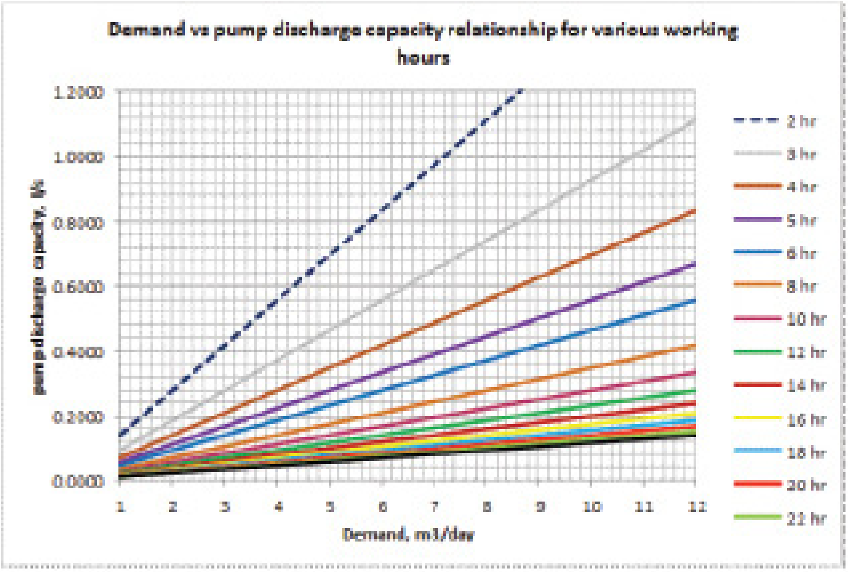


Figure 4.5 Demand Verses pump discharge

The pump power requirement is a multiple of the total system head and the discharge from the pump as well as the pumping system efficiency. It is expected that the discharge and head combination will vary from location to location depending on the water level in the well, the location of the tank and the distance from the well to the tank. Therefore, a range of system heads was calculated over a range of discharges as shown below.

The head verses discharge relationship at constant pump power and the log(head) verses log(discharge) /base exp/ relationship at constant power are shown in the following charts The log chart of the discharge and head gives a better view of the relationships between these parameters.

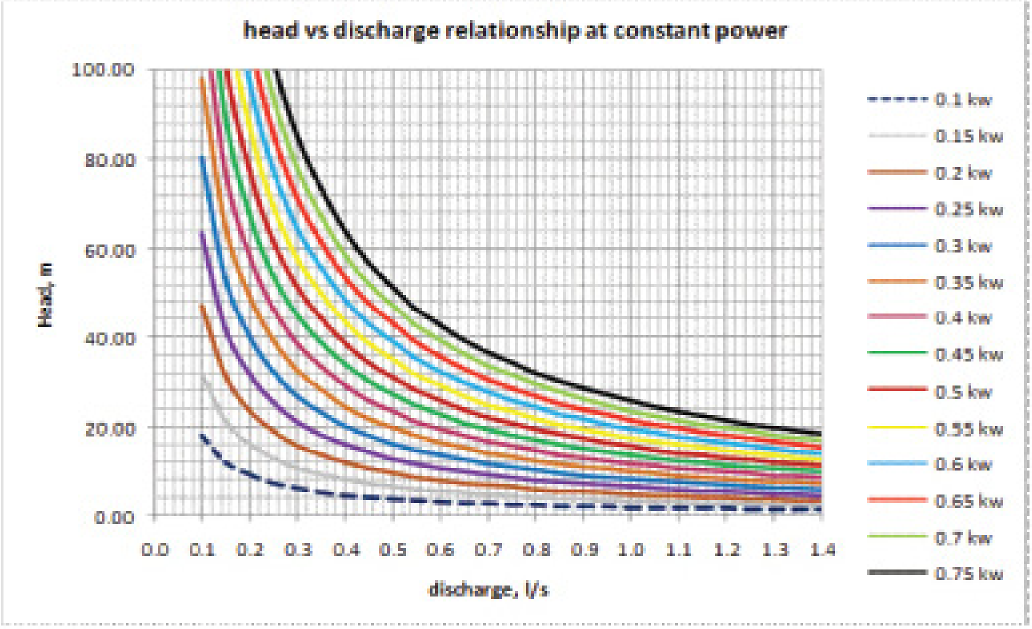


Figure 4.6 Head versus Discharge relationship

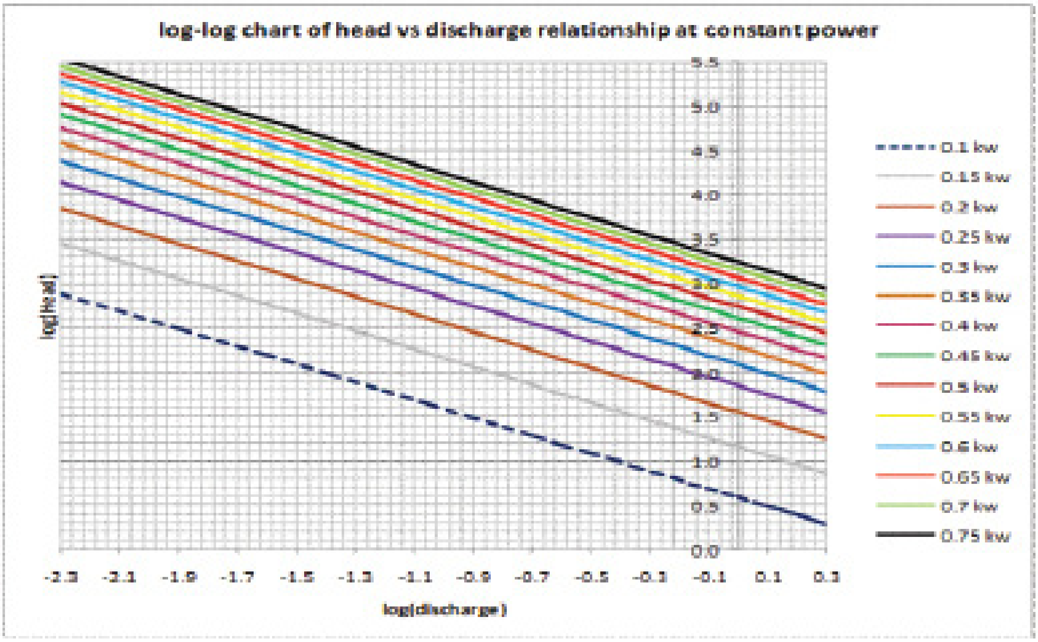


Figure 4.7 Log-Log chart of head versus discharge relationship

For the discharge rates selected above, the required pump operation hour to meet the demand requirement will vary based on the motor power type selected and the configuration of the system.

4.6.2 Solar Power Source

Sun light is converted to solar electric power through the Photovoltaic conversion principle which is the direct conversion of sunlight into electricity with no intervening heat engine.

Detailed information about solar radiation availability at any location is essential for the design and economic evaluation of a solar energy system. For the present report, Surface meteorology and Solar Energy (SSE) data sets compiled by NASA, ATMOSPHERIC SCIENCE DATA CENTER and spanning 22 years from July 1, 1983 through June 30, 2005 were used.

Solar energy is in the form of electromagnetic radiation with the wavelengths ranging from about 0.3 mm (10–6 m) to over 3 mm, which correspond to ultraviolet (less than 0.4 mm), visible (0.4 and 0.7 mm), and infrared (over 0.7 mm).Most of this energy is concentrated in the visible and the near-infrared wavelength range.

The incident solar radiation, sometimes called insolation, is measured as irradiance, or the energy per unit time per unit area (or power per unit area). The units most often used are kilo-watt hours per meter squared per day (kwh/m2/day) and watts per square meter (W/m2).

The amount of solar radiation falling on a surface normal to the rays of the sun outside the atmosphere of the earth (extraterrestrial) at mean Earth–sun distance (D) is called the solar constant, I0 and as per Measurements made by NASA the value of the solar constant is estimated to be 1377 W/m2.

4.6.2.1 Solar Modules

Solar modules which convert sunlight into Direct Current (DC) electricity are solid state photovoltaic devices. Therefore, they are rugged and simple in design and require very little maintenance. At present, module efficiencies are as high as 15~17%.

On the I–V curves of PV modules, there is a single point on each curve at which the power delivered by the cell is a maximum. This point is called the maximum power point of the cell. The maximum power point of the cell remains at a nearly constant voltage as the illumination level of the cell changes.

Because individual cells have output voltages and current is limited to approximately 0.5V and 7A respectively, it is necessary to combine cells in series and parallel to obtain higher voltages and currents. A typical PV module consists of 36 cells connected in series in order to produce a maximum power voltage of approximately 17 V, with a maximum power current of approximately 7 A at a temperature of 25 °C. Such a module will typically have a surface area of about 1 m2.

Modules also exist with 48 or more series cells so that three modules in series will produce the same output voltage and current as four 36-cell modules in series. Other larger modules combine cells in series and in parallel to produce powers up to 300 W per module.

It is important to realize that when PV cells with a given efficiency are incorporated into a PV module, the module efficiency will be less than the cell efficiency, unless the cells are exactly identical electrically.

When modules are combined to further increase system voltage and/or current, the collection of modules is called an array. For the same reason that the efficiency of a module is less than the efficiencies of the cells in the module, the efficiency of an array is less than the efficiency of the modules in the array.

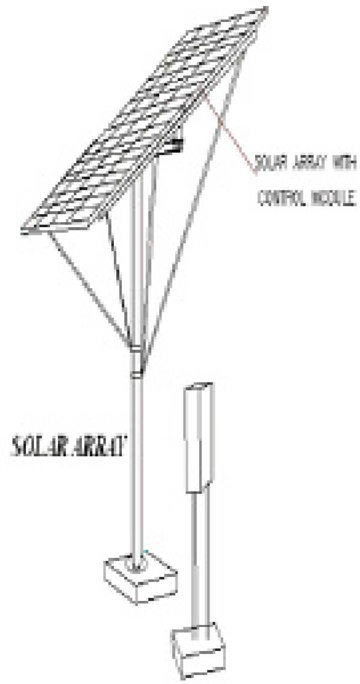


Figure 4.8 Typical Solar Panel with control module

4.6.3 Solar Resource

Depending on the hydraulic power and total power needed, there is a range of pumping systems, for which a power source is economical. PV is estimated to be the most economical for small power systems.

However, the solar resource at the selected location should be greater than 3kWh/m2/day for the system to be economically viable.

Generally a PV system should be considered when the hydraulic power (Q times H) is from 200 to 1,500 m-m3/day. Based on this criterion, for systems with a power rating of 0.5kw or less, the best selection is a PV system.

For systems with a power rating above that, while PV is not the most viable system (wind is supposed to be most economical for mid seized systems), but is still economical. Thus, the above selection of PV system rating is the optimal selection for the 5 and 10 m3 per day demand ranges.

assumed to be fixed and equal to the latitude degree plus fifteen for an optimal average insolation rate over the year.

Based on the data an average insolation of 5.8kwh/m2/day is selected for seizing solar array requirements. But this figure should be replaced by the value shown for the particular location when making a location specific design.

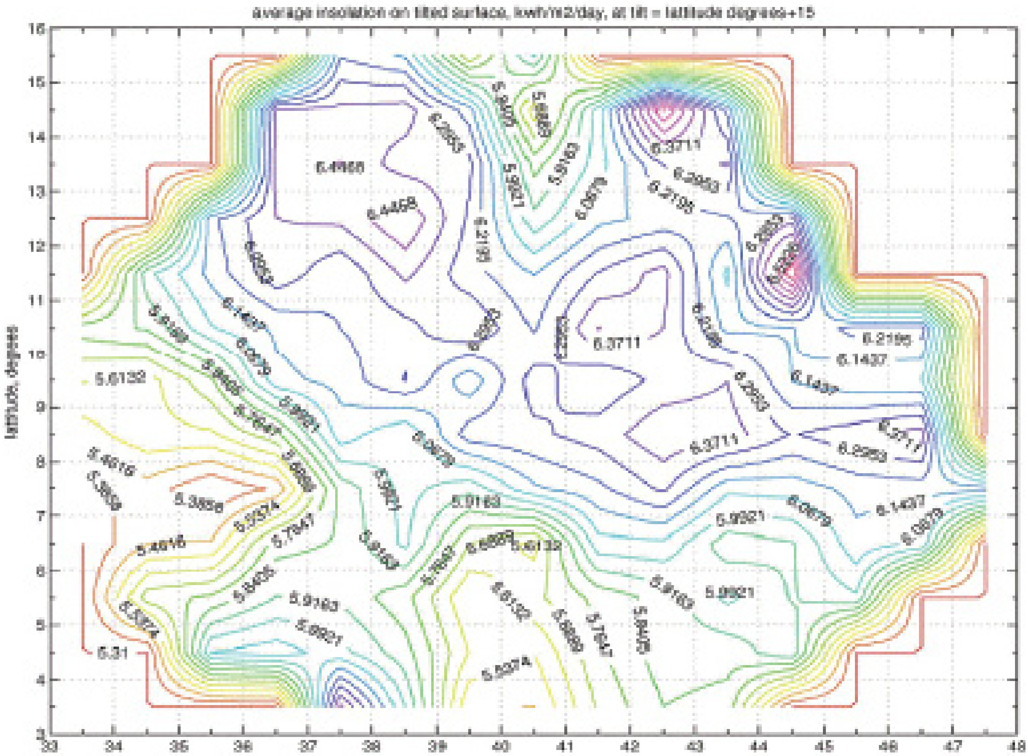


Figure 4.9 Average Insolation on tilt surface, kwh/m2/day

For specific location, average Insolation (incident solar radiation) can be interpolated from the above drawing. Example how to read the above figure is given below.

- Abi-Adi; is at 39.01o Longitude and 13.53o Latitude and Insolation is 6.37kwh/m2/day
- Adola; is at 39.08o Longitude and 5.91o Latitude and Insolation is 5.765kwh/m2/day
- Yabelo; is at 38.10o Longitude and 4.88o Latitude and Insolation is 5.916kwh/m2/day

- Gode; is at 44.56o Longitude and 5.10o Latitude and Insolation is 5.954kwh/m2/day
- Bati (Kursa); is at 40.00o Longitude and 11.20o Latitude and Insolation is 6.2195kwh/m2/day
- Ogolcho; is at 39.03o Longitude and 8.06o Latitude and Insolation is 6.0679kwh/m2/day
- Debre-Birhan; is at 39.50o Longitude and 9.633o Latitude and Insolation is 6.2195kwh/m2/day

4.6.3.1 Storage

Since the sun's power at a location varies with the time of day and crucially varies with the weather condition. Power on overcast days is around 10% of that on sunny days with clear sky.

One solution to ensure a steady supply is to install a battery bank with the system so that the PV array could charge the battery bank during high power conditions. The battery would be used to run the pump on overcast days.

This alternative is not considered here as maintenance of the battery is troublesome and is not feasible in the remote locations where the system could be installed in Ethiopia.
The alternative considered here is over sizing the PV array, pump and storage reservoir to ensure a steady supply.

Minimum and maximum insolation in a five consecutive day range is considered for the estimation of the over sizing required. The data of the minimum and maximum insolation in a five consecutive day range is shown below.

Based on the data shown above, a mean deficit of 30% over the average insolation rate is assumed. Therefore, the pump and array are oversized by 30 % over the rated requirement.

The reservoir is also required to be oversized, to carry the extra volume which is pumped during normal working times so that it could be used during deficit insolation periods. A reservoir size of 2-2.5 times the demand range is recommended for the demand envisaged in this report.

4.6.4 Solar module and pump selection

The primary considerations for the design of a PV system are:

- The load, (calculated above)
- The available solar resource in the desired location,
- The size of array required

4.6.4.1 Load

The table below shows the required motor kw rating, taken from the discharge vs head vs power charts shown in Figure 4.5 and Figure 4.6/4.7 above, for the estimated demand range of 3 to 10m3/day and a design head of approximately 50 meters.

Table 4.4 Motor rating for HC as per the water demand

Demand, m3/day	3.00	5.00	7.50	10.00
Motor rating, kw	0.30	0.45	0.65	0.75

4.6.4.2 Average day insolation

For a solar pumping alternative, the working hours are limited by the average day insolation, which has the same value as the peak sun hour (psh) which is in the 5~6 hour range, the possible pumping rates are limited by this range. Based on the data shown in the tables and charts, an average day insolation of 5.8kwh/m2/day is adopted as a mean value for the country as a whole. But during system design for a particular site the average day insolation value for the particular site should be taken from the tables and charts.

4.6.4.3 Seizing of PV array

The energy production for the PV system is estimated as follows:
For a fixed array, the energy day can be estimated as:
Ed = Es * Ec * Ind * A

Where:

Es= system efficiency = 70%
Ec =cell efficiency = 11%
Ind- average insolation
A, = required array area.

Another method is to use the average-day insolation (map value, tilt at latitude) and the power rating of the module.

ED = ES * RP * HS

Where

RP =the rated power, and
HS = the average number of sun hours.=Ind

demand, m3/day	3.00	5.00	7.50	10.00
motor rating, kw	0.30	0.45	0.65	0.75
	1.30	1.30	1.30	1.30
oversized motor for water storage reserve, kw	0.39	0.59	0.85	0.98
selected motor rating, kw	0.40	0.60	0.58	1.00
average insolation, hours	5.80	5.80	5.80	5.80
system requirement in watt hours	2262.00	3393.00	4901.00	5655.00
factor for heat and various losses=1/Es	1.43	1.43	1.43	1.43
actual system requirement in watt hours/day	3231.43	4847.14	7001.43	8078.57
array size, watt	557.14	835.71	1207.14	1392.00
module size, watt	125.00	150.00	200.00	240.00
no of modules	6.00	8.00	8.00	8.00
voltage, Voc, V	21.60	43.20	43.20	43.20
voltage, Vmp, V	17.20	34.40	34.40	34.40
current, Isc, A	7.63	5.00	5.00	7.70
current, Imp, A	7.27	4.40	4.40	6.98
check	Ok	Ok	Ok	Ok
total power, watthour/day	3231.43	4847.14	7001.43	8078.57
module, watt	125.00	150.00	200.00	240.00
area lxw	0.89	1.07	1.44	1.72
no of modules	6.00	8.00	8.00	
total area, m2	5.34	8.56	11.52	13.96
Ind=average day, kwh/m2/day	5.80	5.80	5.80	5.80
Es,system efficiency, %	70.00	70.00	70.00	17.00
Ec, cell efficiency, %	15.00	15.00	15.00	15.00
Ed = Es*Ec*INd*A, kwh/day	3.25	5.21	7.01	8.50
watthour/day	3252.83	5212.10	7013.19	8503.12
watts	650.57	1042.42	1402.64	1700.62

4.6.4.4 System Selection Summary

A water pumping system consisting of a PV array as calculated above, a DC motor driven pump working at the voltages and currents specified above and a controller will be installed. Additionally riser and transmission pipes and tanks seized for the demand range will be installed.

The module or panel will consist of

- Transparent top surface -- glass
- Encapsulant -- thin sheets of ethyl vinyl acetate that hold together the top surface, solar cells, and rear surface
- Rear layer -- thin polymer sheet, typically Tedlar, to seal module

- Frame -- aluminum
- Electrical connection
- The performance of the module will be as per the following standards
- Standard test conditions -- (STC) 1,000 W/m2, 25°C

4.6.5 Solar module and pump Operation &Control

Dust must be removed from the glass plates of the module regularly. In addition, external wires, the supporting structure of the array, covers for the electronic components and a fence may need occasional repairs. Wood or metal parts that are sensitive to corrosion must be painted every year. Much of the additional electrical and electronic equipment should function automatically for at least 10–15 years, although batteries, AC/DCconverters, engines and pumps may need more frequent servicing.

Local organization can be very simple, consisting mainly of appointing a caretaker. However, an adequate number of technicians for repairing such systems must be available at regional or national level.

4.6.5.1 Main Operation &Maintenance activities

Regularly

- Clean the module surface. Water. Cloth, bucket.

Occasionally

- Repair or replace additional Engine brushes, spare battery, AC/DC Spanners, screwdriver, pliers, etc. components; converter, other complete components.
- Repair the fence. Wood, nails, wire. Hammer, machete, pliers.

Rarely

- Repair the mounting structure; Cement, wood.
- Repair the wiring. Electricity cable, insulation tape. Knife, pliers.

Potential problems

- vandalism, theft, or cattle damage to the cells, modules or system;
- the storage batteries wear out relatively quickly;
- the initial investment is high;
- The system is not feasible for areas with daily radiation amounts below 3 kWh/m2

4.6.6 Wind Power

The primary causes of atmospheric air motion, or wind, are uneven heating of the Earth by solar radiation and the Earth's rotation. Differences in solar radiation absorption at the surface of the Earth and transference back to the atmosphere create differences in atmospheric temperature, density, and pressure, which in turn create forces that move air from one place to another.

The available power in the wind with air density ϱ(1.2kg/m3 at sea level), passing through an area A, perpendicular to the wind, at a velocity v, is given by

$$P = \varrho A v^3/2 \text{ watt}$$

The actual power is dependent on the wind turbine design but the maximum power that can be extracted from the wind is limited to less than 60% in principle. The power coefficient Cp, takes this limit, turbine type and turbine efficiency into consideration. Thus, actual power produced is given by:

$$P_a = C_p \varrho A v^3/2 \text{ watt}$$

Cp=–0.5 to 0.59for lift type turbines

Cp=–0.2 to 0.3for drag type wind mills

Air density decreases with increasing temperature and increasing altitude above sea level. The effect of temperature on density is relatively weak and is normally ignored because these variations tend to average out over the period of a year.

The density difference due to altitude, however, is significant; it does not average out and cannot be ignored. For example, the air density at an elevation of 1600 m, above sea level, is approximately 14% lower than at sea level, so the wind at 1600masl contains 14% less power than wind of the same velocity at sea level. From the equation it is obvious that the most important factor in the available wind power is the velocity of the wind—an increase in wind velocity of only 20%, e.g., from 5 to 6 m/s, yields a 73% increase in available wind power.

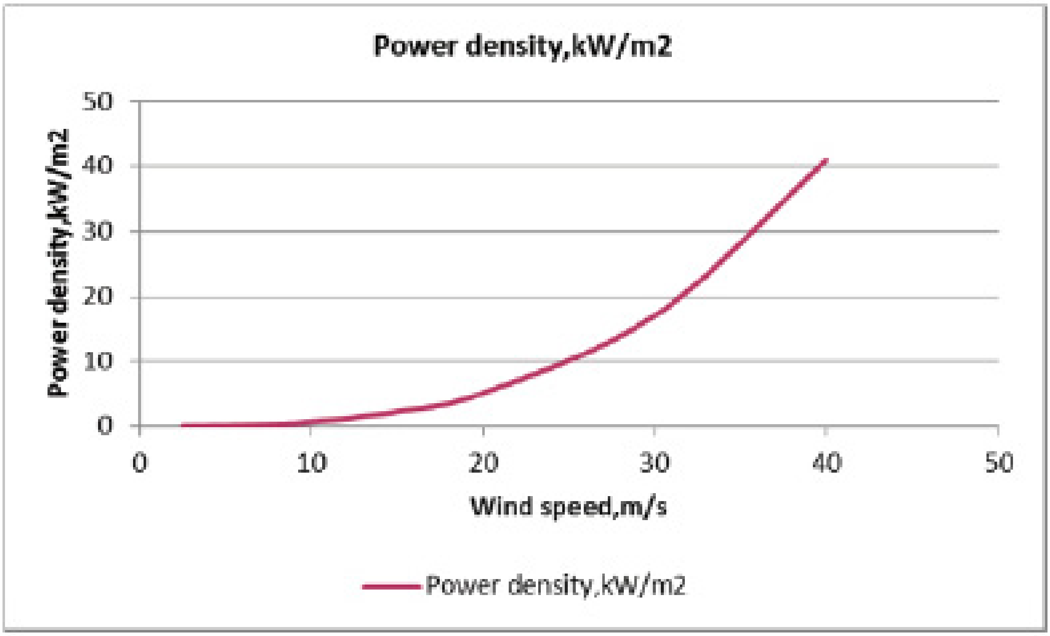


Figure 4.10 Power Density relationship

This indicates the very high variability of wind power, from around 10W/m2 in a light breeze up to 41kW/m2 at 40m/s. This extreme variability greatly influences virtually all aspects of system design.

It makes it impossible to consider trying to use winds of less than about 2.5m/s since the power available is too diffuse, while it becomes essential to shed power and even shut a windmill down if the wind speed exceeds about 10-15m/s as excessive power then becomes available which would damage the installation.

4.6.6.1 Wind Shear

Wind moving across the Earth's surface is slowed by trees, buildings, grass, rocks, and other obstructions in its path. The result is a wind velocity that varies with height above the Earth's surface—a phenomena known as wind shear.

For most situations, wind shear is positive (wind speed increases with height), but situations in which the wind shear is negative or inverse are not unusual. In the absence of actual data for a specific site, a commonly used approximation for wind shear in an open area is:

$v/v0 = (H/H0)\alpha$

where:

v = estimated wind speed at height H

v0 =wind speed at the reference height H0

α =wind shear exponent ~ 0.14

The wind shear exponent, α, varies with terrain characteristics, but usually falls between 0.10 and 0.25. Wind over a body of open water is normally well modeled by a value of ~ 0.10; wind over a smooth, level, grass-covered plain~ 0.14; wind over row crops or low bushes with a few scattered trees ~ 0.20; and wind over a heavy stand of trees, several buildings, or hilly or mountainous terrain ~ 0.25. The available wind power at a site can vary dramatically with height due to wind shear.

The amount of energy available in the wind (the wind energy resource) is the average amount of power available in the wind over a specified period of time, commonly one year.

If the wind speed is 20 m/s, the available power is very large at that instant, but if it only blows at that speed for 10 h per year and the rest of the time the wind speed is near zero, the resource for the year is small. Therefore, the site wind speed distribution, or the relative frequency of occurrence for each wind speed, is very important in determining the resource.

This distribution is often presented as a probability density function. The probability that the wind occurs in any given wind speed range is given by the area under the density function for that wind speed range. If the actual wind speed probability density distribution is not available, it is commonly approximated with the Rayleigh distribution formula.

The actual wind resources in any specific area can vary dramatically from the resource estimates and should be determined by measurement on site over an extended period.

Wind speed, direction, distribution, and shear can vary significantly over fairly short distances in the horizontal or vertical directions, so in order to get the best possible estimate of the wind energy resource at a particular location, it is important to measure the wind resource at the specific site and height of interest. A comprehensive site characterization normally requires measuring the wind for at least 12 months.

4.6.7 Wind Turbine Configurations

Although there are many different configurations of wind turbines, most of them can be classified as either horizontal-axis wind turbines (HAWTs), which have blades that rotate about a horizontal axis parallel to the wind, or vertical-axis wind turbines (VAWTs), which have blades that rotate about a vertical axis.

They both contain the same major components, but the details of those components differ significantly. The terms "horizontal" and "vertical" associated with these classifications refer to the driving shaft on which the rotor is mounted.

HAWTs usually have all of their drive train (the transmission, generator, and any shaft brake) equipment located in a nacelle or enclosure mounted on a tower. Their blades are subjected to cyclic stresses due to gravity as they rotate, and their rotors must be oriented (yawed) so the blades are properly aligned with respect to the wind. HAWTs may be readily placed on tall towers to access the stronger winds typically found at greater heights.

The most common type of modern HAWT is the propeller-type machine, and these machines are generally classified according to the rotor orientation (upwind or downwind of the tower), blade attachment to the main shaft (rigid or hinged), maximum power control method (full or partial-span blade pitch or blade stall), and number of blades (generally two or three blades).

VAWTs, on the other hand, usually have most of their drive train on the ground; their blades do not experience cyclic gravitational stresses and do not require orientation with respect to the wind. However, VAWT blades are subject to severe alternating aerodynamic loading due to rotation, and VAWTs cannot readily be placed on tall towers to exploit the stronger winds at greater heights.

4.6.8 Wind Resource

Sites of wind power class 4 or above (at least 200 W/m2 at 10 m height or 400 W/m2 at 50 m height) are often considered economic for utility-scale wind power development with available wind technology.

Sites of wind power class 3 (150–200 W/m2 at 10 m height or 300–400 W/m2 at 50 m height) are not considered economic for utility development today but are likely to become economic with near-term wind technology advances.

Sites of wind power class 2 or lower (less than 150 W/m2 at 10 m height or 300 W/m2 at 50mheight) are usually considered economic only for remote or hybrid wind power systems.

Detailed information about the wind resource at any location is essential for the design and economic evaluation of a wind power system. For the present report, Surface meteorology and Solar Energy (SSE) data sets compiled by NASA, ATMOSPHERIC SCIENCE DATA CENTER and spanning 10 years of wind speed data were used.

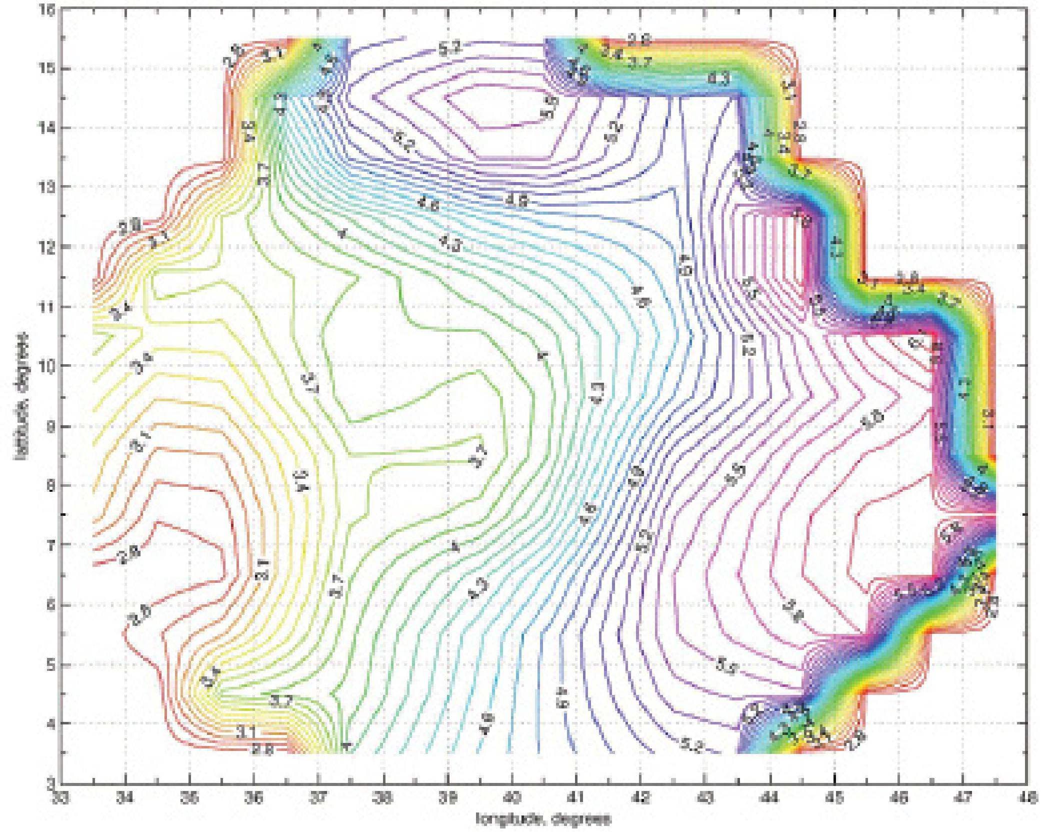


Figure 4.11 Average wind speed at 50 meters above the surface of the earth.m/s

The location of HC or HP can be found by GPS reading and the average wind speed can be interpolated from the above figure. Sample of interpolation is shown below:-

- Abi-Adi; is at 39.01o Longitude and 13.53o Latitude and average wind speed is 5.2m/s.
- Adola; is at 39.08o Longitude and 5.91o Latitude average wind speed is 4.25m/s.
- Yabelo; is at 38.10o Longitude and 4.88o Latitude and average wind speed is 4.05m/s.
- Gode; is at 44.56o Longitude and 5.10o Latitude and average wind speed is 5.6m/s.
- Bati (Kursa); is at 40.00o Longitude and 11.20o Latitude and average wind speed is 4.2m/s.
- Ogolcho; is at 39.03o Longitude and 8.06o Latitude and average wind speed is 3.74m/s.
- Debre-Birhan; is at 39.50o Longitude and 9.633o Latitude average wind speed is 3.75m/s.

4.6.9 Wind Turbine Selection

Wind pumps are one of the most cost-effective options (compared with engines or any other prime-movers) for pumping in locations with mean wind speeds exceeding about 4m/s, but, conversely, they are not at all cost-competitive where mean wind speeds are significantly below 2.5m/s."

Because the wind can be unreliable, it is recommended that there be water-storage facilities with enough water to last for 3–4 days.

Items exposed to the wind are subjected to forces in both the drag direction (parallel to the air flow) and the lift direction (perpendicular to the air flow). For predominantly drag machines, larger numbers of blades result in higher drag and produce more power; therefore, these machines tend to have many blades.

Wind turbines use the lift generated by the blades to produce power. Because the blades must be widely separated to generate the maximum amount of lift, lift-type machines have a small number of blades.

The power extraction efficiency of a wind device may be expressed as the ratio of the power extracted by the device to the power available in the wind passing through the area occupied by the device (the projected area of the device), a ratio known as the power coefficient, Cp.

A well-designed lift-type machine may achieve a peak power (based on the area covered by the rotating turbine blades) of 0.5–0.59, while a pure drag-type machine may achieve a peak power coefficient of no more than 0.2.

Some of the multi bladed drag-type windmills actually utilize a blade shape that creates some lift, and they may achieve power coefficients of 0.3 or slightly higher.

The translation (or blade) velocity of the drag type device must always be less than the wind velocity or no drag is generated and no power is produced. The drag machines rotate slowly (the blade translation velocity cannot exceed the effective wind speed) and produce high torque, whereas the lift machines rotate quickly (to achieve a high translation velocity) and produce low torque.

The slow-rotating, high-torque drag machines are very well suited for mechanical power applications such as milling grain and pumping water. On the other hand, fast-rotating, lift-type machines are much easier to adapt to electrical generators.

Thus for the pumping requirements set out in this report, three alternatives can be considered:

1) A drag type wind mill with a drive gear box, which changes the rotary motion of the windmill to a reciprocating motion, mounted on the tower and a reciprocating pump installed in the well. Pump and drive head connected by a drive shaft.

2) A drag type wind mill with a drive gear box, which changes the rotary motion on a horizontal axis of the windmill to a rotary motion on the vertical axis of the pump shaft pump and drive gear mechanically coupled through a drive shaft.

3) A lift type wind turbine coupled to an ac electric generator supplying power to a submersible pump.

Alternative 1 is mostly suitable for high head and low discharge situations and could possibly be employed in deep well type water sources.

Alternative 2 is mostly suitable for low head high discharge applications and could possibly be used in shallow drilled wells and hand dug wells.

Alternative 3 is suitable for all water source types where a submersible pump or a surface centrifugal pump could be installed.

In addition alternative 3 has the added advantage of superior performance and high efficiency and less maintenance requirement when compared to alternatives 1 & 2. Thus alternative 3 is the recommended option from the available wind power options.

4.6.9.1 Wind Power Density

Because of the cube relationship between wind speed and energy availability, which is true for any optimally matched wind pump, and wind regime, the economics of wind pumps are very sensitive to wind speed. The wind power density variation with wind speed is shown in the following table and chart.

Table 4.5 Wind power density

Wind speed, m/s	2.50	5.00	7.50	10.00	15.00	20.00	30.00	40.00
Power density, kw/m2	0.010	0.080	0.270	0.640	2.200	5.100	17.00	41.00

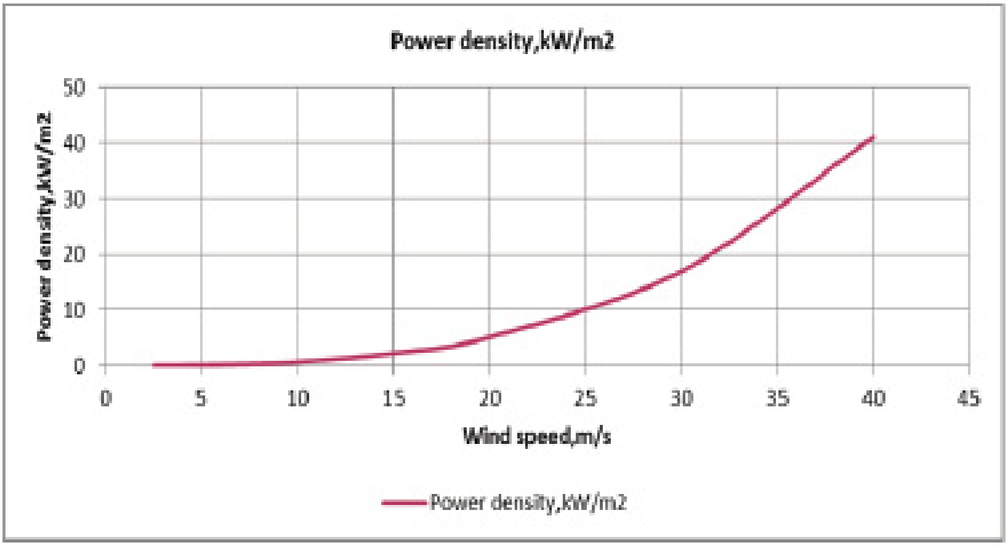


Figure 4.12 Wind power density

For locations above sea level, the correction required for the air density parameter, in the calculation of the power available in the wind resource is shown in the following table.

Air Density correction factor

Table 4.6 Correction factor due to altitude

masl, m	0	760	1,520	2,290	3,050
density correction factor	1.00	0.91	0.83	0.76	

For the seizing of the wind turbine, it is assumed that the wind turbine would be running for 18 hours per day. The required pump discharge and motor kw rating is shown in the following table.

Table 4.7 Pump discharge and motor rating

pump working hour=18				
demand, m3/day	3.00	5.00	7.50	10.00
l/s	0.05	0.08	0.11	0.18
pump kw	0.09	0.13	0.18	0.24
p in watt	90.00	125.00	180.00	240.00

In the least windy month the wind speed could fall to around 60 to 70% of the annual mean wind speed and the available wind energy in the least windy month can go down to as little as 20% of the annual average wind speed.

The selection of an 18 hour work day effectively over sizes the wind turbine by one third to take into account the variation in the mean wind speed.

Based on the wind resource charts shown above, a general mean annual wind speed of 3.4m/s is assumed for the seizing of the wind turbines, based on the demand range listed elsewhere as shown below.

This value should be replaced by the particular wind speed value of the location of installation.
The selected rotor diameters for each demand range, based on a mean annual wind speed of 3.4m/s are shown shaded in the table below.

The wind turbine will drive a dc generator, which will provide power to the dc motor driving the pump. Alternatively the generator and motor could be alternating current type, but the dc type generator and motor are the preferred and widely available options in the envisaged demand range.

The pump type could be surface centrifugal or submersible type based on whether the source is a spring or a shallow drilled well/hand dug well.

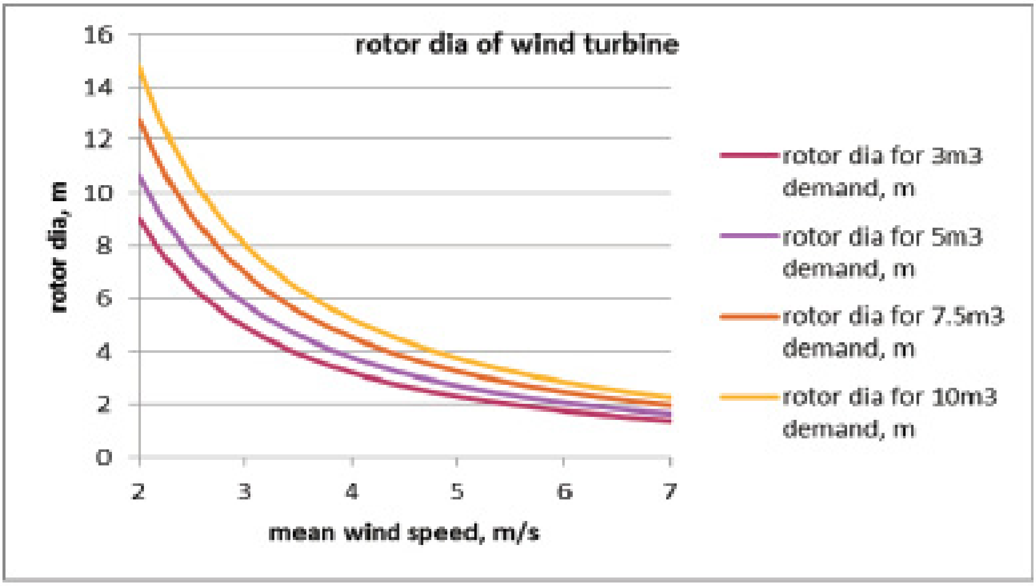


Figure 4.13 Rotor diameter of wind turbine

Figure 4.14 Typical wind turbine

4.6.10 Wind Turbine Control

All turbines incorporate some method of regulating or limiting the peak power produced. The entire turbine, including the rotor, the transmission and the generator, must be sized to handle the loads associated with peak power production. While high winds contain large amounts of available power, they do not occur very often, and the power that can be captured is very small.

The power density is the power per unit of rotor area (normalized to yield a value under the curve of unity) that is available for capture by a wind turbine. This takes into account the amount of time that the wind actually blows at each wind speed

Generators and transmissions operate most efficiently at their design conditions, typically close to their maximum capacity. These efficiencies drop off quickly at conditions below design. Cost trade-off studies reveal that it is far more cost effective to limit the maximum power level to that achieved at, the maximum capacity of the generators and to shut the turbine down completely at a cutout wind speed, than to try to capture the maximum amount of power at the higher wind speeds. Under these conditions, the transmission and generator are operating near design conditions for a significant portion of the time, and the turbine can be built with far less material than would be required for a turbine that generates peak power at higher wind speeds.

The additional energy captured due to the increase in generator and transmission efficiencies at the lower wind speeds is usually many times greater than that lost due to limiting the peak power at the rather infrequent high speed winds.

Nearly all modern large horizontal-axis turbines now use blade pitch control, where either the entire blade or a portion of it is rotated about the longitudinal axis to change the angle of attack and, therefore, the power output of the turbine, to limit peak power.

Small turbines, which are of primary interest with regard to the stated requirements, frequently incorporate passive features, such as tail vanes and furling, that turn the rotor so the rotor axis is no longer aligned with the wind, to limit peak power production in high winds.

With full-span blade pitch control, the blade may be rotated about its longitudinal axis to decrease the effective angle of attack as the wind speed increases (commonly referred to as pitch-to-feather), causing decreased blade lift and limiting the peak power at the desired level.

4.6.10.1Main Operation & Maintenance Activities

Operation is often automatic. Some windmills require manual release of the furling mechanism after excessive wind. When no pumping is needed, the windmill may be temporarily furled out of the wind by hand. Windmill and pump should be checked regularly and any abnormality corrected.

Every month, the windmill and pump must be checked visually. The bolts on the pumping rods tend to come loose, and loose nuts and bolts should be tightened and moving parts greased, as necessary. Paintwork should be maintained annually, and the lubrication oil changed in the gear box (if one is used). Poor maintenance will lead to the bearings wearing out rapidly and the wind will then damage the rotor and other pump parts.

Maintenance for a windmill-driven piston pump is comparable to that for a heavily-used hand pump. Usually, one person is responsible for the windmill, pump and storage system. This person has to be trained for the job and may receive a caretaker's fee. Good preventive maintenance may extend the life of a windmill to well over 20 years, while bad maintenance may cause serious damage within a year.

Maintenance List
Monthly

- visually check the pump and windmill;
- Tighten nuts and bolts; Spanners, wrench.
- Lubricate the moving parts. Oil or grease. Lubricator, funnel, container for used oil, spanners.

Occasionally

- Repair the furling mechanism; Special parts, nuts, bolts, rope. Spanners, wrench.
- Replace worn bearings. Bearing. Spanners, wrench, screwdriver.

Annually

- Paint the windmill. Anticorrosive paint. Steel brush, paintbrush.

Potential problems
Poorly-trained caretakers may accidentally block the furling mechanism, which can lead to the windmill being damaged in high winds;

- moving parts may wear out quickly, because they are inadequately lubricated;
- when wind speeds are lower than 2 m/s most windmills cannot pump, and many windmills are not economically viable when the average wind speed is below 3 m/s;
- to avoid problems with pump quality and performance, choose a local manufacturer or supplier with a proven track record, and who supplies a good-quality brand of windmill.

4.6.11 IC Engine

Diesel and petrol generators are frequently used as a stationary power source. Diesel engines differ from petrol engines in that they do not have spark-plugs to ignite the fuel mixture, and work at much higher pressures.

Diesel engines need less maintenance than petrol engines, and they are more efficient. IC engines can differ in size (from 1–6 cylinders or more) and speed (revolutions per minute), and by the number of engine cycles (2-stroke, or 4-stroke). In general, low-speed four-stroke engines last longer, and high-speed two-stroke engines produce more power per kg of engine weight. Water-cooled engines generally need less maintenance than air-cooled engines.

- diesel engines are well-suited for stationary, high-power output;
- with good maintenance they are dependable energy sources;
- It is important to select a brand that has a good reputation, and for which servicing and spare parts are locally available.

Diesel engines are efficient and reliable whereas Petrol engines are light, mobile and relatively cheaper.

A comparison between petrol, kerosene, high speed diesel and low speed diesel engines is shown in the following table.

Table 4.8 Comparison between different type of engines

	petrol	kerosene	diesel/high speed	diesel/low speed
Average fuel to shaft efficiency (%)	10-25	10-25	20-35	
Weight per kW of rated power(kg)	3-10	4-12	10-40	
Operational life (typical)	2000-4000h	2000-4000h	4000-8000h	8000-20000h
Running speed (rpm)	2500-3800	2500-3800	1200-2500	
Typical daily duty cycle (h)	0.5-4	3-6	2-10	

Due to the above listed reasons, a slow speed diesel engine is generally preferable for a permanent installation for the pumping requirements as stated elsewhere in the report.

While diesel engines can be mechanically coupled to work with pumps such as helical rotor pumps, the preferred pumping equipment for the requirements listed in this report are electric motor driven submersible pumps or electric motor driven surface centrifugal pumps. Thus the diesel power is required to drive a coupled ac generating set, which will supply power to the electric motors driving the pumps.

4.6.12 IC Power Selection

The pump sizing for the diesel power alternative is taken, with the assumption that the pump and power unit will work for 8 hours per day, corresponding to the daily work hour. No over sizing of the pumps is required as the power supply is steady as long as fuel is available.

The selected pumps could be three phase or single phase electric motor driven pumps. The pump type could be surface centrifugal or submersible type based on whether source is a spring or a shallow drilled well/hand dug well.

pump working hour=8				
demand, m3/day	3.00	5.00	7.50	
l/s	0.11	0.18	0.26	
pump kw	0.25	0.35	0.45	
p in watt	250.00	350.00	450.00	

In general for small three phase ac generating sets the generators are seized from 2.5-3 times the load requirement to overcome any starting surges and wiring resistances. Since the pump loads are small a single selection is made for the largest pump load of 0.6kw which would cover all required demand ranges

$$\text{Generator kw} = 0.6 * 2.5 = 1.5\text{kw}$$

If an engine is run continuously at its Rated Power, premature wear will occur. All engines therefore require to be de-rated from the manufacturer's rated power which is the maximum power output the engine can achieve for short periods. Small engines are usually de-rated to about 70-80% of their rated power.

$$\text{Actual Generator kw} = 1.5/0.75 = 2\text{kw}$$

While, the main reason for de-rating an engine is to prevent premature wear, also the optimum efficiency for most engines is achieved at a speed corresponding to about 70-80% of its speed for maximum power. Therefore, de-rating an engine usually improves its specific fuel consumption.

Also, a further 10% de-rating is recommended for each 1000m above sea level, plus 1% for each 5°C temperature rise above 16°C at the engine air intake.

4.6.12.1Main Operation & Maintenance Activities

A diesel engine must be operated by a trained caretaker, and every engine has its own operating instructions.

- Before starting the engine, the levels of fuel, oil and cooling water should be checked, and topped up if any are low.
- During the operation of the engine, check the fuel level and oil pressure, and that the pump and generator are functioning properly.
- Check moving parts, may need to be lubricated manually.
- Check engine speed, if it is too low, the engine will have a low efficiency and carbon rapidly builds up in it. This will increase the frequency with which the engine
  needs to be serviced.
- Record all data on fluid levels and running hours in a logbook.
- Clean the outside of the engine, in dusty conditions, the air filter must be checked and cleaned.
- In moderately dusty conditions, oil-bath air filters are cleaned once a week.
- If the engine is connected to a pump or generator with a v-belt, the belt will need to be replaced regularly.
- Once a year, the engine house must be painted and repaired.
- The engine is serviced for preventive maintenance according to the number of hours it has run.
- Every 50 hours, the clutch (if present) must be greased.
- Every 250 hours, the filters must be cleaned or replaced, the oil changed, and the nuts, bolts and exhaust pipe checked.
- Every 1500 hours, a major service overhaul will be needed, that includes decarb-urizing the engine, adjusting the valve clearance, etc.

4.6.12.2Maintenance Check List

Daily

- Check fluid levels, and top-up if Fuel, engine oil, cooling liquid. Funnels, containers for liquids.
- necessary;
- start and stop the engine;
- Keep a logbook. Paper, pen

Weekly

- Check the air filter, and clean or New, dry paper filter, kerosene and Wrench.
- Replace it if necessary; engine oil.
- check for oil and fuel leaks;
- Tighten any loose nuts and bolts. Spanners.

Every 500–2000 hours

- decarbonizes the engine, clean Spanners, brass wire brush, special injector nozzles, adjust valves, etc. tools

Occasionally

- Replace engine parts; Nozzles, injectors, gaskets, bearings, Depends on the part to be replaced, fuel pump, etc.
- Repair the engine mounting and Cement, sand, gravel, nuts and bolts, Trowel, bucket, hammer, chisel, housing nails, galvanized corrugated iron saw, spanners, etc. sheets, wood, etc.

Possible problems

- the generator wears excessively, because O&M is poorly carried out, or neglected;
- the engine is run at less than full loading, which leads to rapid carbon build-up and low engine operating efficiency;
- the drive belts break;
- maintenance is required frequently;
- fuel is difficult to get and its cost is high;
- from time to time, a specialist mechanic will be needed to service and repair the generator.

5. Sanitation and Hygiene for Health Institutions

Latrines for health centers are structures used for managing human excreta at the health centre level. Usually, health centre latrines, depending on the number of the health centre staff and patients visiting the health centre, will have a number of compartments with holes in each compartment to serve the staff and patients of the health centre. The latrines will be constructed by digging long pits and then covered with concrete on top. Compartments are then constructed separating the number of squat holes.

The health centre latrine structure should be of permanent building materials (greater durability) is necessary because of greater usage and of appropriate design to prevent pit collapsing and small children from falling in the hole. For this reason the health centre latrines will be provided with durable lining material such as stone or concrete, concrete floor slab, hollow block walls and corrugated iron sheet roofs.

The sanitation technology options for human excreta disposal covers a range of alternatives from simple and economical technologies such as latrines to more complicated sewerage systems. In the latrine technologies a distinction is made between systems which do not need water (dry systems) and systems which need water for functioning (wet system).

The following technologies are listed in ascending orders from simple technologies such as traditional pit latrines to more complicated sewerage systems.

Dry systems

- Traditional or Improved Traditional pit latrine
- Ventilated improved pit latrine
- Double –vault compost latrine
- Bored hole latrine

Wet systems

- Pour-flush latrine with leaching pit
- Septic tank and aqua privy
- Small bore or settled sewerage system
- Vacuum tanker
- Drainage field
- Conventional sewerage system

From the technology systems described above the most appropriate ones for use for health institutions will be mainly the dry systems as the others require water connection system or adequate water located close by for flushing. Furthermore, the day to day operation doesn't involve the input of manpower except janitorial service. Therefore in this document only the most recommended dry systems are described.

5.1 Ventilated Improved Pit Latrine

The ventilated Improved Pit (VIP) latrines are designed to reduce two of the problems that are frequently encountered by traditional/improved traditional pit latrines namely smell and production of insects. A VIP latrine differs from a traditional latrine by a vent pipe covered with fly screen. Wind blowing across the top of the vent pipe creates a flow of air which sucks out the foul smelling gases from the pit. As a result fresh air is drawn into the pit through the drop hole and the superstructure is kept free from smells.

The vent pipe also has an important role to play in fly control. Flies are attracted to light and if the latrine is dark inside they will fly up the vent pipe to the light. They cannot escape because of the fly screen, so they are trapped at the top of the pipe until they dehydrate and die. Female flies, searching for an egg-laying site, are attracted by the odors from the vent pipe but are prevented from flying down the pipe by the fly screen at its top.

VIP latrines are a hygienic, low-cost, and indeed sophisticated form of sanitation, have minimal fly and mosquito nuisance, and have only minimal requirements for user care. Figure 5.1 shows typical VIP latrine arrangement.

5.1.1 Site Selection

Latrines should be located away from drinking water sources preferably down slope from boreholes or water wells. The following should be considered in sitting latrines:

- At least 50 m away from any water source to avoid risk of pollution.
- A minimum of 6 m away from the health centre block for patients not to travel long distance and yet not to create nuisance or bad odor.
- Avoid locating a VIPL up-hill of a water source to avoid gravity transmission of pollutants via ground water aquifer.
- Located where the soil is firm in order that the structure will not collapse.
- Located on raised ground in order that rain water can drain away easily.
- Located in relation to the appropriate wind direction in order that odor is dispersed away from the latrine surrounding.

5.1.2 Capacity

It is recommended that one squatting pit will be for every twenty patients. According to Healthcare waste generation and its management system: the case of health centers in West Gojjam Zone, Amhara Region, by Muluken Azage, Abera Kumie, published in Ethiopian Journal of Health Development, the mean patient flow per day in all sections and outpatients in each health center was 186. If one caregiver is attending every patient, 186 peoples are expected accompanying the patients. Assuming one squatting hall for 50 people, 4 squatting rooms are recommended for HC.

Figure 5.1 Typical VIP latrine for Health Centre

5.1.3 Construction of VIP Latrine

The size of the pit can be calculated using the following standard procedure. The volume of the pit required for excreta per year per capita is 0.04 to 0.06 cubic meters. Minimum depth of groundwater table level for the latrines is 1.5m.Taking the mean patient flow per day:-

- Volume of pit required for five years operation will be 46.5m3.
- Internal width of the pit is 2.8 meters
- Internal length of the pit to accommodate four separate squatting rooms will be 5.52 meters.
- Depth required to accommodate the above volume will be 3.0 meters.
- Providing 0.5 meter free board,
- Total depth of the pit will be 3.5 meters.
- Location of VIP latrine must be away from the prevailing wind direction.

It is recommended to line pit using stones. Use dry bonding at the bottom of the pit or use mortar but honey-comb the walls up to one meter from the ground level, then do a solid wall.

Reinforced concrete slab is recommended for the floor. The slab will be provided with a hole on the floor close to the wall of the superstructure for insertion of vent pipe. Squatting plates should be cast in an oiled timber mould for ease of construction.

The vent pipe should be 75 - 200 mm, preferably 110mm in diameter. Both the pipe and the screen must be made from corrosion-resistant materials (e.g. fiberglass, PVC). The vent pipe preferably can be plastic with black color or painted black to minimize the deterioration effect by the sun light and absorb heat and increase the temperature inside the vent and expedite the ventilation process.. It should be located in the sunny side of the latrine superstructure allowing the air inside the pipe heat up and create an updraft with a corresponding downdraft through the squatting plate; thus the superstructure will remain odorless. The pipe should be increased to 600 mm if the pipe cannot be located on the sunny side of the superstructure.

The vent pipe should extend for about 0.8m above the roof level and covered with fly-proof netting (thick net that does not allow flies to pass through) material. The pipe can be installed outside the superstructure attached to the wall and passing through the roof structure. The pit can also slightly offset to make room for an external vent pipe.

The VIPL superstructure mainly consists of walls and roofs. The walls could be made from bricks, stone, hollow concrete blocks (HCB) or iron sheets. The roofs could be made from iron sheets or tiles. The entrance to the latrine must be provided with a door.

Figure 5.2 VIP latrine for Health Post

5.1.3.1 Health Centre/Post Hand Washing Facilities

Health centre hand washing facility uses the water from elevated reservoir placed at the left or right elevation of the health centre/post. Hand washing facility promotes the practice of hand washing by patients and staff after they have used a latrine. The practice to hand washing after using the toilet is one of the most effective ways of preventing diarrhea.

A masonry structure with a water supply line from the elevated reservoir is designed. The facility is located at the right or left side of the latrine.

If elevated water tanker is not available, use steel or plastic drum with tap (usually 1000 litre tanks) are used.

The tank should be elevated to provide sufficient pressure for the flow of water and ease of washing hands using the little water available at the bottom of the tank when the tank is not full. This can be achieved by lifting the tank for about 1 meter above ground.

If the health centre tank cannot be connected to water supply line then a borehole or hand dug well should be constructed for safe water supply systems. Afridev pump can be used to fill the bucket whereby labor will be used to fill the tanks and this can be organized by the health centre or a stronger pump such as Climax pump will be used to lift the water to the tank.

5.1.4 Operation and Maintenance of VIP Latrine

5.1.4.1 Operation

A big concern is the keeping of health centre latrines tidy and clean. This is because patients who are already week from other illnesses must not be infected by other diseases from poor sanitation condition of health centre latrines.
Operation of the VIP latrines consists of the following:

- Regular cleaning of the slab with water and a little disinfectant, if available, is required to remove any excreta and urine.
- Wash hands properly once you have cleaned latrines.
- The door must always be closed so that the superstructure remains dark inside.
- The hole should never be covered as this would impede airflow.
- Use of appropriate anal cleansing materials should be available in or near the latrine.

- Ensure you defecate in the hole when using a latrine.
- Wash hands well with soap after each use of a latrine.
- The material used for cleaning / sweeping latrines should never be kept inside the VIPL and should never be used to clean floors in the HC.
- Dispose of children's as well as bedridden or critically ill person's faeces as well as animal waste safely, and wash hands properly soon after disposing the waste.
- Do not throw materials like stones, glass, plastic, rags, etc. into the pit as they reduce the effective volume of the pit.
- Regularly fill the water to hand washing facility, if there is no connected water system
- Seats, raising/support handle for inclusive rooms should be included incorporated and managed properly

5.1.4.2 Maintenance

The following should be practiced regarding maintenance of latrines:

- Check and maintain the slab for cracks.
- Check the superstructure for damage and maintain if any.
- Check that the vent pipe and fly screen are not corroded or damaged.
- Repair of the superstructure (especially light leaks) may be necessary.
- Ensure that surface water continues to drain away from the latrine.
- When the contents of the pit reach the level of 0.5 m below the slab, a new pit has to be dug, Depending on the availability of free space in the Health Institution.
- Transfer the slab and superstructure to the new pit.
- Cover the old pit with at least 0.5m of top soil to hygienically seal it off.

5.1.4.3 Operation and Maintenance Requirement

The VIP latrine is used by patients in the health institution and arrangements should be made for the operation and maintenance of the latrines. The following table shows operation and maintenance requirements for a VIP latrine.

Table 5.1 Operation and Maintenance Requirement of a VIP Latrine

Activity	Frequency	Human Resources	Materials & Spare Parts	Tools & Equipment
Clean drop hole, seat and superstructure	daily	Assigned personnel	Water soap	Brush, bucket
Inspect floor slab, vent pipe and fly screen	monthly	Assigned personnel		
Clean fly screen and vent inside	Every one to six month	Assigned personnel	Water	Twig or long bendable brush
Repair slab, seat, vent pipe, fly screen or superstructure	occasionally	General service of HC	Cement, sand, water, nails, local building material	Bucket or bowl, trowel, saw, hammer, knife
Close pit with soil, dig a new pit, transfer slab and superstructure (if applicable)	Every five years	General service of HC	Soil, possibly cement, bricks, nails, and other local building materials	Shovels, picks, bucket, hammer, saw, etc.

5.1.5 Problems and Limitations for Use of VIP Latrine

5.1.5.1 Frequent Problems are:

- Bad quality of the floor slab due to inappropriate materials or improper curing o f concrete.
- Inferior quality fly screens get damaged easily by the effects of solar radiation and foul gases.
- Flooding and undermining of improperly sited latrines.
- Children may be afraid to use the latrine because of the dark or because of fear of falling into the pit.
- If the superstructure allows too much light to come in, flies will be attracted by the light coming through the squat hole and may fly out into the superstructure which will jeopardize the whole VIP concept.
- Odor problems may occur during the night and early morning hours in latrines relying more on solar radiation for the air flow in the vent pipe than on wind speed.
- Leakage between pits can occur because the dividing wall is not impermeable or soil is too permeable
- Collapsing because lack of proper casing or pit lining,

5.1.5.2 Major limitations are:

- In hard soils it may be impossible to dig a proper pit
- Pits often fill up too quickly with low infiltration and leaching capacity.
- VIP latrines cannot prevent mosquitoes breeding in the pits.

5.2 Double-Vault Compost Latrine

The double-vault compost latrine consists of two watertight chambers (vaults) to collect feces. Urine is collected separately in a container as the contents of the vault have to be kept relatively dry. Initially, a layer of absorbent organic material is put in the vault and after each use, the feces is covered with ash (or sawdust, shredded leaves or vegetable matter) to deodorize the feces, soak-up excessive moisture and improve C/N (carbon nitrogen) ratio, which ensure that sufficient nitrogen is retained to make a good fertilizer. When the first vault is three quarters full, it is completely filled with dry powdered earth and sealed so that the contents can decompose an aerobically. The second vault is used until it is three quarters full and the first vault is emptied by hand, the contents are used as fertilizer. The vaults have to be large enough to keep feces for at least a year in order to become pathogen free.

Double-Vault compost latrine can be used where people are motivated to handle and use humus of human excreta as a fertilizer and where no water is used for anal cleansing.

5.2.1 Site Selection for Double-Vault Compost Latrine

The latrine can be built anywhere as there is no pollution coming from the watertight chambers to pollute the surroundings. Where there is rock or a high water table, the vaults can be placed above ground. However for safety, to avoid risk which may result from poor workmanship, it would be better to locate the latrine away from drinking water sources at a distance of not less than 50 m down slope side of the source.

5.2.2 Dimensions for Double-Vault Compost Latrine

The volume of the single pit of the double vault compost latrine must not be less than the volume required for one year to allow the alternate use of the pit to keep feces for at least a year in order to become pathogen free. The dimensions for the double vault compost latrine can be calculated taking the minimum volume requirement and can be made bigger depending on affordability of the construction cost. Taking the mean patient flow per day:-

- Internal width of the pit is 2.8 meters
- Internal length of the pit to accommodate four separate squatting rooms will be 5.52 meters.
- Volume of pit for one meter depth will be 15.46m3.

5.2.3 Construction of Double-Vault Compost Latrine

The superstructure is built over both vaults with squat hole over each vault which can be sealed off. The superstructure mainly consists of walls and roofs. The walls for the latrine could be made from bricks, hollow concrete blocks or iron sheets. The roofs could be made from iron sheets or tiles. The entrance to the latrine must be provided with a door.
The walls of the pit must be kept straight from top to bottom. Line the walls of the pits and the separation wall with water tight structures such as both sides plastered brick, masonry or concrete structures.
Floor will be from reinforced concrete slabs and finished with cement screed. Seats should be provided on the two holes to only allow the faeces into the holes without urine which has to be collected separately.

5.2.4 Operation and Maintenance of Double-Vault Compost Latrine

5.2.4.1 Operation

Operation of the Double vault compost latrine consists of the following:

- Initially some absorbent organic material is put in the empty vault.
- After each use and whenever available wood ash and organic material are to be added.
- When urine is collected separately it is often diluted with 3-6 parts of water and utilized as fertilizer. If it is not diluted, it may cause a health hazard and should be avoided. Adding ash lime or ash may help, but there is no guarantee that the urine will then be safe.
- Regular cleaning of the slab with water (and a little disinfectant if available) to remove any excreta. Water used for cleaning should not be allowed to go into the latrine as it will make the contents too wet.
- Wash hands properly once you have cleaned latrines.
- Ensure you defecate in the hole and urine is collected separately.
- Wash hands well with soap after each use of a latrine.
- The material used for cleaning / sweeping latrines should never be kept inside the home and should never be used to clean floors in the home.
- Dispose of children's and bedridden or critically ill person's feces as well as animal waste safely, and wash hands properly soon after disposing the waste.
- Do not throw materials like stones, glass, plastic, rags, etc. into the pit as they reduce the effective volume of the pit and the decomposing process.
- Hand washing facility

5.2.4.2 Maintenance

The following should be practiced regarding maintenance of double vault compost latrines:

- Check and maintain the slab for cracks.
- Check the superstructure for damage and maintain if any.
- Ensure that surface water continues to drain away from the latrine.
- When the contents of the pit reach three quarters full, the contents are leveled with a stick, after which dry powdered earth is added till the vault is full.
- The squat hole is then sealed and the other vault emptied with spade and bucket, after which it can be taken into use.
- The removed contents can be used safely as a fertilizer.
- Household may grow insect repelling plants like citronella around the latrine.

5.2.5 Operation and Maintenance Requirement

Extensive investigation among potential users is needed to find out if the system is culturally acceptable and if they are motivated and capable to operate and maintain the system properly. Prolonged support by the health office is needed to ensure that users understand the system and execute operation properly.

The following table shows operation and maintenance requirements for a double vault compost latrine.

Table 5.2 Operation and Maintenance Requirement of a VIP Latrine

Activity	Frequency	Human Resources	Materials & Spare Parts	Tools & Equipment
Clean drop hole, seat and superstructure	daily	Assigned personnel	Water, lime ash	Brush, bucket
Add ashes or other organic material	After each defecation and whenever available	Assigned personnel	Wood ashes and organic material	Pot to contain the material, small shovel
Inspect floor, s uperstructure and vault	monthly	Assigned personnel		
Repair floor, superstructure and vault	When necessary	General service of HC	Cement, sand, water, nails, local building material	Bucket or bowl, trowel, saw,
Close full vault after leveling and adding soil, empty other vault, open its squat hole and add 1 00mm of absorbent organic material before taking into use, store humus or use directly	Depending on size and number of users	General service of HC	Water, absorbent organic material	Shovels and bucket

5.2.6 Problems and Limitations in the Use of Double-Vault Compost Latrine

5.2.6.1 Frequent Problems are:

- Proper operation needs full understanding of the concept, if not, results in contents to be too wet making the vault difficult to empty and malodorous.
- Where people are eager to use the contents as fertilizer, they may not allow sufficient time to become pathogen free.
- Flooding and undermining of improperly sited latrines.

5.2.6.2 Major limitations are:

- Only to be used where people are motivated to use human excreta as a fertilizer.
- The system is not appropriate where water is used for anal cleansing (washers).
- The construction cost of a double vault compost latrine is much higher in comparison to traditional pit latrines and VIP latrines.

5.2.7 Recommended Use of Double-Vault Compost Latrine

The use of double vault compost latrine for health institutions may not be practical as the institutions require large volume of hole and the difficulty in handling the latrines.

5.3 Health Centre/Health Post Water Points

Adequate drinking water should be supplied for the patients and the caregivers or attendants during their stay in the health institutions. Access to water can be only through water points constructed for this purpose.

A masonry structure with two faucets is designed to serve this purpose. The water supply line will be from the elevated reservoir and the spilling water on the apron is connected to the drainage pipe or the water can be used for watering the green area. The detail should be done based on the specific site condition

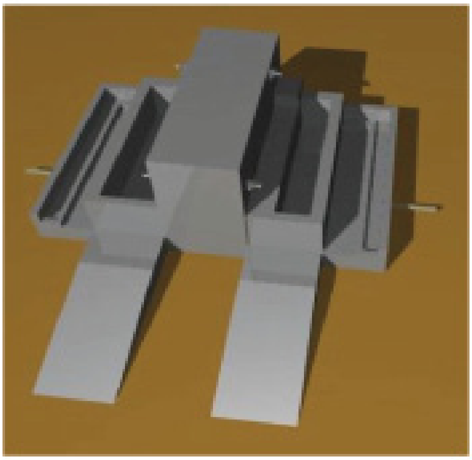


Figure 5.3 Typical Water point

5.4 Cloth Washing Basin

Health center and health post cloth washing basins are structures that are used for washing clothes of the inpatients and their caregivers. The existence of washing slabs will encourage washing their clothes which are spoiled by blood from wounds or any other dirt before leaving the health institutions. Washing slabs are designed near the water point and the final location will be confirmed during the construction period. The water supply line is connected to the pipe from elevated reservoir and the dirty water from the washing slab will be drained to the sock away pit or septic tank

Figure 5.4 Typical clothes washing basin

5.5 Shower Room

The provision of a shower room in health institutions is to encourage the use of safe water sources when bathing instead of bathing in rivers and lakes. The super structure is designed to be built with similar construction material as the VIPL. The pipe for water supply is connected to the elevated water tanker and the wastewater with the sewer line to septic tank or sock away tank.

Figure 5.5 Typical shower Room

5.6 Septic Tank and Soak Away Pits

The waste collected from the various buildings is conveyed by 80 mm diameter sewer to partitioned septic tank for partial biological treatment. The effluent from the first compartment, after a maximum of 3 days detention, is lead to the second compartment for further detention and biological treatment.

From the second compartment the supernatant or effluent is discharged to soak pits for final filtration and disposal as infiltration to ground.

The septic tank for the HC or HP shall be located at convenient places in the compound. Standard size of septic tank designed by FMoH is adopted.

The effluent from the septic tank is not fully treated, therefore before final there is a need for secondary treatment. The secondary treatment is achieved through soak away pits, filled with filter media.

5.7 Health Centre Refuse Disposal

Health institution solid wastes are generated as a result of activities related to the practice of medicine and sales of pharmaceuticals. Some of the health-care solid wastes coming from any particular institution are similar in nature to domestic solid wastes, and may be called "general health-care wastes". The remaining solid wastes are plastic syringes, tissues, bandages; cloths, etc and pose serious health hazards because of their physical, chemical or biological nature, and so are known as "hazardous healthcare wastes". In many cases the most dangerous items in healthcare solid wastes are needles from syringes and drips, because the needles shield the viruses from chemical disinfectants and a harsh external environment and the sharp point allows easy access for the viruses into the blood stream of anyone who is pricked by the needle. The key to improving healthcare solid waste management is to provide better methods of storage and to train the staff to adopt safer working practices and segregate as hazardous healthcare wastes from general health-care wastes.

5.7.1 Quantity of Solid Waste from Health Centers

According to Healthcare waste generation and its management system: the case of health centers in West Gojjam Zone, Amhara Region, by Muluken Azage, AberaKumie, published in Ethiopian Journal of Health Development, The daily mean (± SD) healthcare waste-generation rate was 1.79 ± 0.54 kg, which was equivalent to 0.035 ± 0.05 kg/outpatient/day. About 0.93 ± 0.3 kg/day (52.0%) was general and 0.86 ± 0.33 kg/day (48.0%) was hazardous waste. The mean healthcare waste generation rate among health centers did not significantly vary.

A design study for a sanitary landfill for Barhir Dar by Metaferia Consulting Engineers in 2005 revealed that a cubic meter of high-density waste weighs approximately 370 kg.

Based on the above data, the annual average solid waste generation from health center is 1718.6Kg from which 893.7 is general waste and 824.9Kg is hazards waste. The total general waste generated in two years time is 1787.4Kg or 4.83m3.

5.7.2 Segregation, Storage and Transportation

Prior to final disposal, all wastes must be stored safely and transported to respective disposal sites. It is important that different types of waste are stored separately in order to prevent contamination of 'clean' waste by infectious or pathological wastes, and to allow easy transportation.

5.7.2.1 Segregation

The first step is to determine how waste should be separated or segregated. This will depend on the composition and quantities of waste generated, and how they are to be disposed of. The fact that this may change over time should be considered on-going monitoring should occur.

In general, it is recommended that each treatment, diagnosis and consultation area of the medical centre (including wards, laboratories and immunization points) has a set of three segregated containers: the first for general waste; the second for infectious and pathological waste; and the third for sharps. If pathological wastes such as placentas are to be disposed of separately from infectious waste, for example in a placenta pit, then a fourth type of container should be provided for this and disposal should take place immediately.

5.7.2.2 Storage

All containers should have lids and should be water tight in order to hold liquid. Open cardboard boxes are not recommended since these can easily be tipped over and they disintegrate easily. The size of container will depend on the volume of waste generated in each location but should be easy to handle and transport. It is recommended that containers of uniform color are provided for each type of waste throughout the HC, This facilitates ease of identification and helps to avoid confusion. In addition, containers may be labeled, especially when containing infectious waste or sharps.

It is recommended that needles are stored in specially designed containers. These containers should be disposed of together with their content to eliminate further handling of potentially hazardous needles.

Simple sharps containers can be made from empty pharmaceutical or medicine containers. The lid of plastic container is glued or taped shut and a small triangular slot is cut in the lid. Following and injection the user inserts the needle and syringe in the slot, slides it to the narrow point of the slot and pull the syringe away leaving the needle safely in the container. This prevents any handling of used needle.

5.7.2.3 Transportation

Segregated storage containers should be designed so that they can be carried directly to the final disposal point. Containers must therefore be easy to carry, preferably with handles and a tight-fitting but easy-to-remove lid. Where waste is disposed of in an incinerator or pit this should be designed so that it is relatively easy to empty the container without spillage.

5.7.3 General Solid Waste Pits

The appropriate technology to dispose general waste is to excavate a pit within the compound of the health institution. Refuse pit and compost- heap systems could also be practiced at the health centre if appropriate segregation of the general waste is performed.

A pit 2meters long, 2.5meters wide with a depth of 1 meter can accommodate the estimated waste for two years. It is recommended to cover this pit with soil and prepare another one for the preceding two years operation.

The pit can be prepared larger to handle the total amount of garden waste collected. The waste which cannot be composted will be burnet and buried with the ash from incinerators.

5.7.4 Incineration

Incineration is an efficient and effective way to reduce organic and combustible waste to inorganic matter. A medical waste incinerator is designed to disinfect and render hazardous waste safe. Incinerators can be built from a disused oil drum or from brick and concrete with iron or metal doors. Incinerators constructed by brick are highly effective for disposing of sharp, and infectious and pathological wastes. Refuse pit is recommended for dumping the ash from incinerators.

5.7.4.1 Construction of Incinerator

The size of the incinerator is usually determined based on the volume of waste to be incinerated.

For the standard Health Center and health Post the minimum dimension can be used Excavate a foundation with 2.5 meters width and 2.5 meters length with a depth of not more than 0.5 meters. Excavation depends on the type of soil.

- Construct the foundation and the ash pit with reinforced concrete.
- The minimum dimension of the ash pit should be 0.96 meters length and 0.96 meters width having a depth of 0.3meters
- Construct combustion chamber with burnt brick and covered with reinforced concrete..
- Construct brick chimney having a minimum height of 1.5 meters.
- The location of the ash pit should be in front of the incinerators, with an ash removal door for easy removal of combusted wastes.
- Location of Incinerator must be away from the prevailing wind direction (always at the back of the facility)

Figure 5.6 Typical Incinerator

5.7.5 Sharp Pits

Where it is not appropriate to construct a proper incinerator, sharps should be disposed of in a specially built and sealed sharps pit. A sharp pit can be a lined or unlined pit in the ground with a sealed cover. The cover is normally constructed from reinforced concrete and has a small hole left in the middle. A tube or pipe rises vertically from the hole. This can be made from steel, asbestos or uPVC and should be approximately 200mm in diameter.

5.7.6 Placenta Pits

The construction of the Placenta Pits includes digging two meters deep and around two the meters and a half long wide hole. Then the walls are constructed with stone masonry and the whole building is finished with a one and a half meter high "chimney" closed with a cover on top. On one side, there is a fifty centimeters aluminum door where the placenta can be easily thrown. The door prevents the odors from escaping. Everything is painted in yellow to be discreet and nice.

Another very simple way to build the placenta pits is digging a hole and putting inside a big concrete drainage pipe usually minimum one meter in diameter. The door and the chimney can be similar to the conventional placenta pit. This type of pit is recommended for health posts.

5.7.6.1 Construction Placenta Pits

Placenta pits are usually constructed below the natural ground level.

- Excavate a circular hole having a diameter of 2.70 meters and a depth of 2 meters
- Provide masonry lining to the internal wall. The masonry structure should have 0.6 meters thickness at the bottom and 0.4 meters at the top with the vertical face to the interior of the pit.
- The internal diameter of the pit should be 1.5 meters.
- Place 30 cm thick gravel at the bottom and a second layer of 20 cm thick course sand acting as a filter media. The liquid from the placenta will seep to the underlying soil through the filter media.
- Construct reinforced concrete cover with access hole to damp the placenta and a vent hole.
- Provide manhole cover and diameter 800 mm vent pipe with vent cap.

5.7.6.2 Operation of Placenta Pits

- Don't close placenta pits with a key , they have to be accessible,
- Throw only placentas inside the pit.
- Place a big sticker in the placenta pit saying, "Beware, Placenta Pits, please throw placenta only and nothing else especially plastic bags"

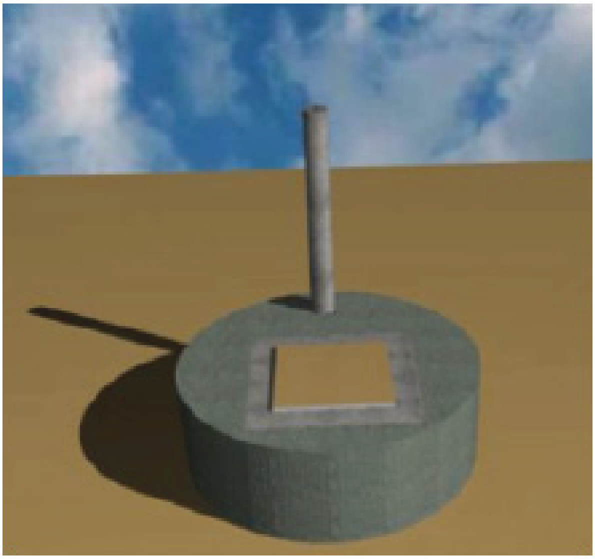


Figure 5.7 Typical Placental Pit

5.7.7 Education and Training

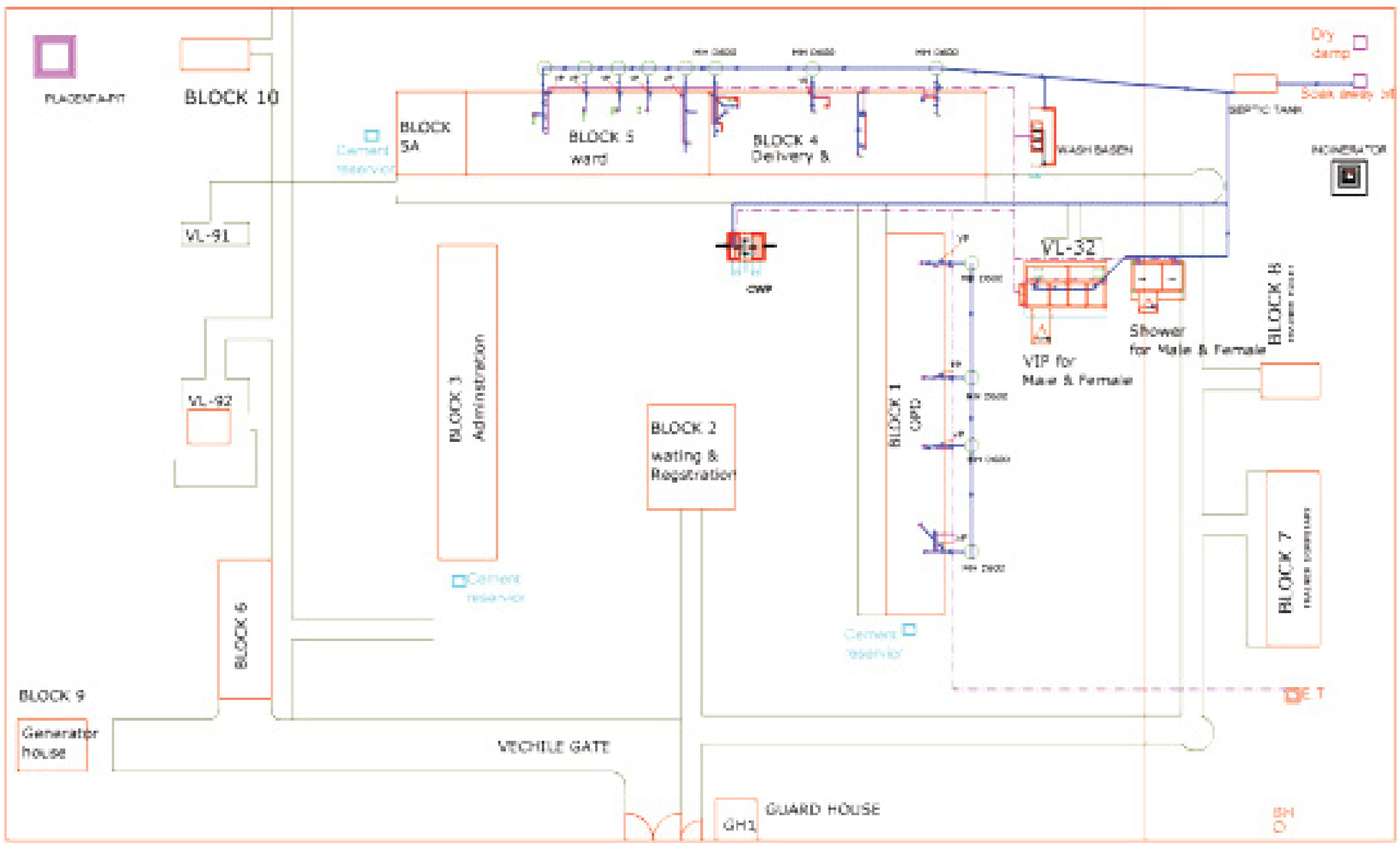
A key aspect of the management of waste from medical centers is appropriate education of all those who may come into contact with waste and training of those who are responsible for handling waste, segregation, storage and transportation procedure be well known among all medical and related staff. Sign and color coding should be used extensively within all Health Centers and health Post. A senior member of medical or sanitation staff should be given overall responsibility for the management of the system.

5.7.8 Key Recommendation for Waste Management

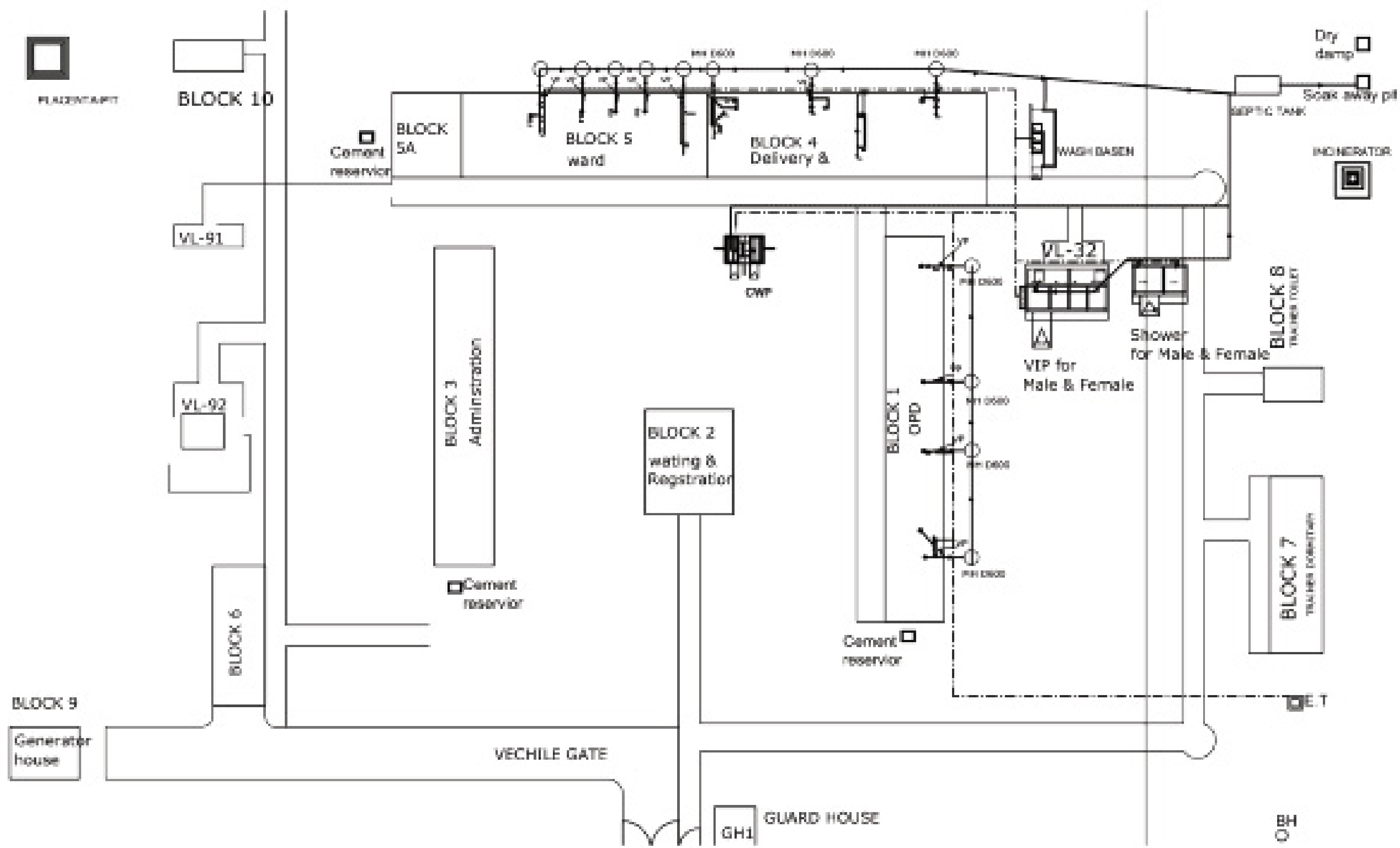
- Improve practices at all stages of the waste stream
- Separate the different types of waster at source.
- The separation and sale of reusable but non-hazardous materials can successfully take place under controlled conditions at source.
- Be prepared to improve the systems.
- Establish a distinct management responsibility.
- Provide all staff with training on handling waste.
- Work out detailed procedures for storage, handling, transfer and disposal of waste according to its characteristics and potential risks

6.DETAILED DESIGNS

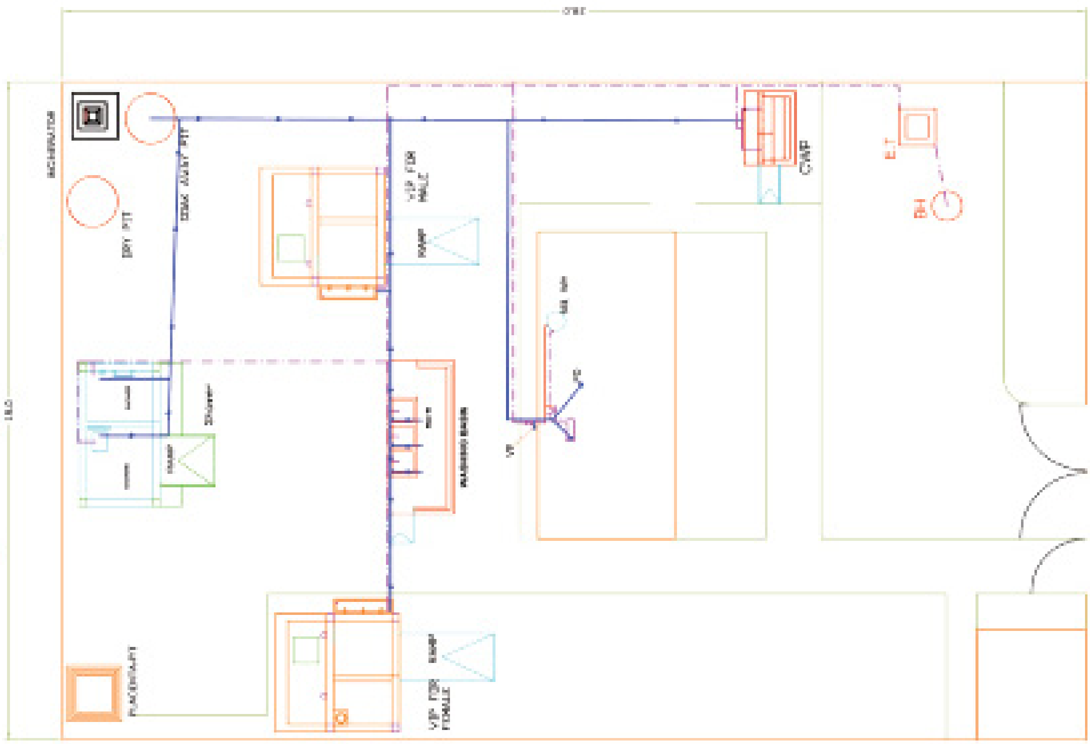
Health center site plan file 1 Layout COL



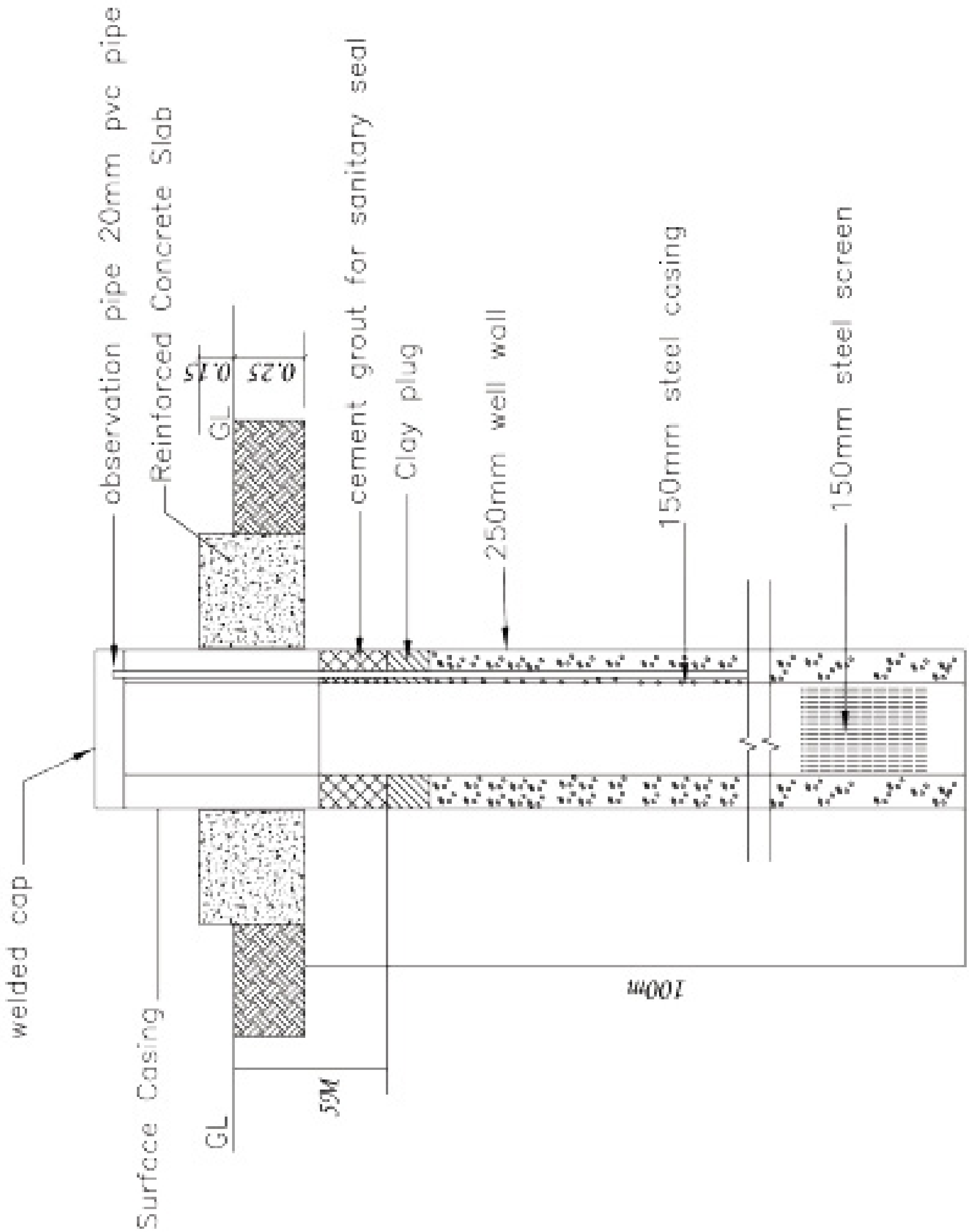
Health center site plan file 1 Layout1



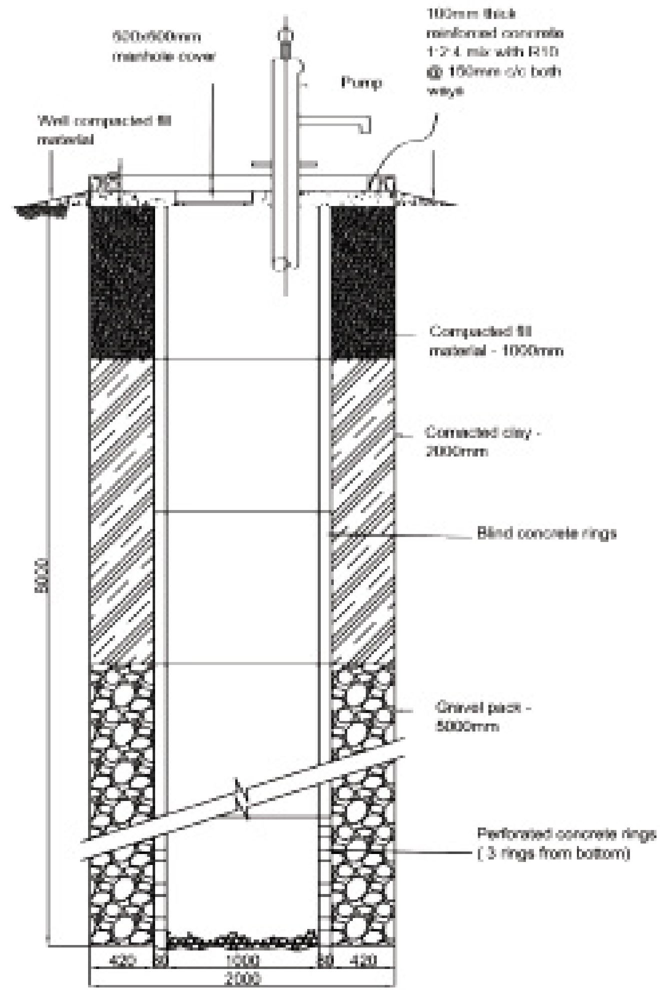
Health post site plan file 2 Layout1



Well-design & well-head Layout1

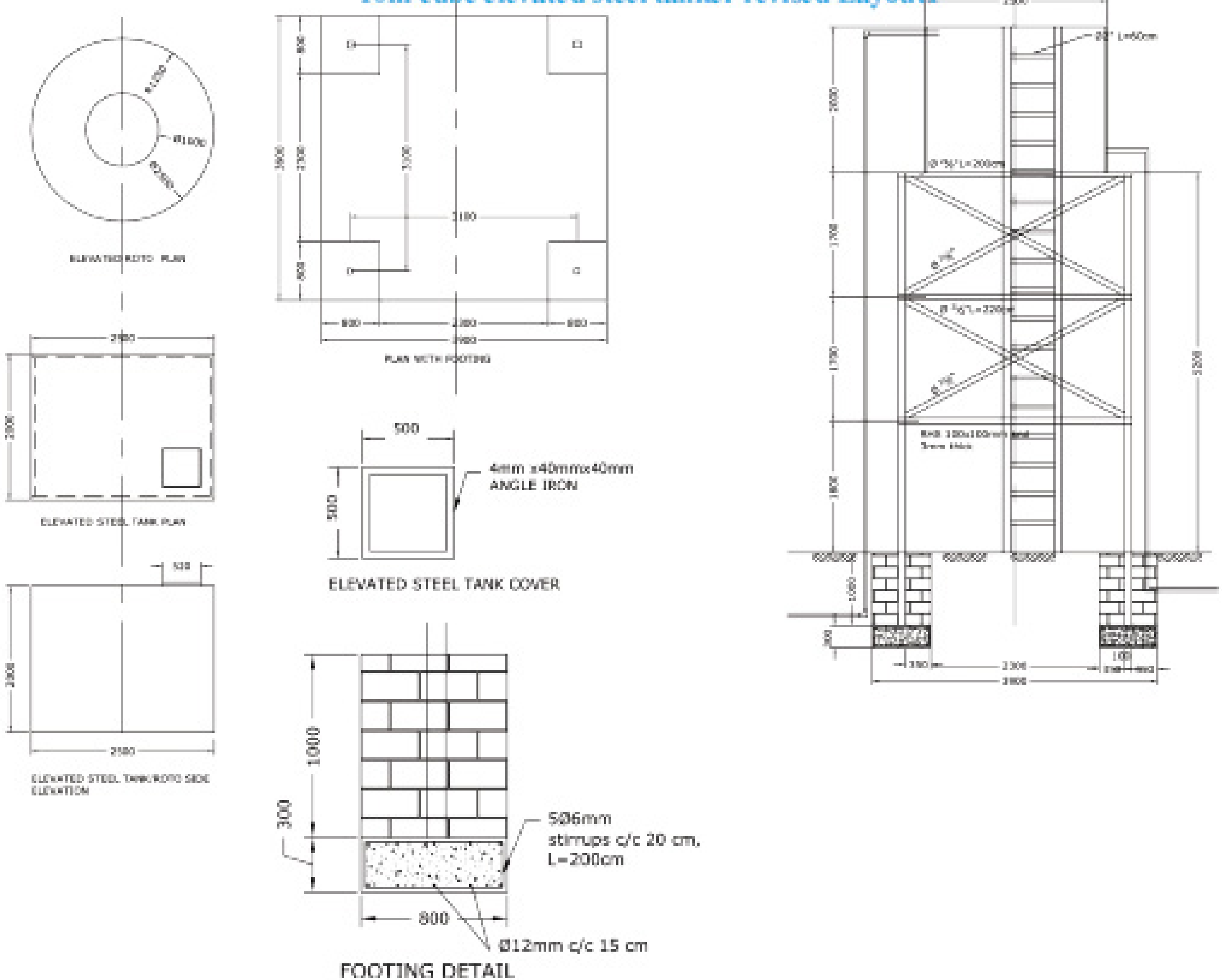


HAND DUG WELL A3 - HUND DUG

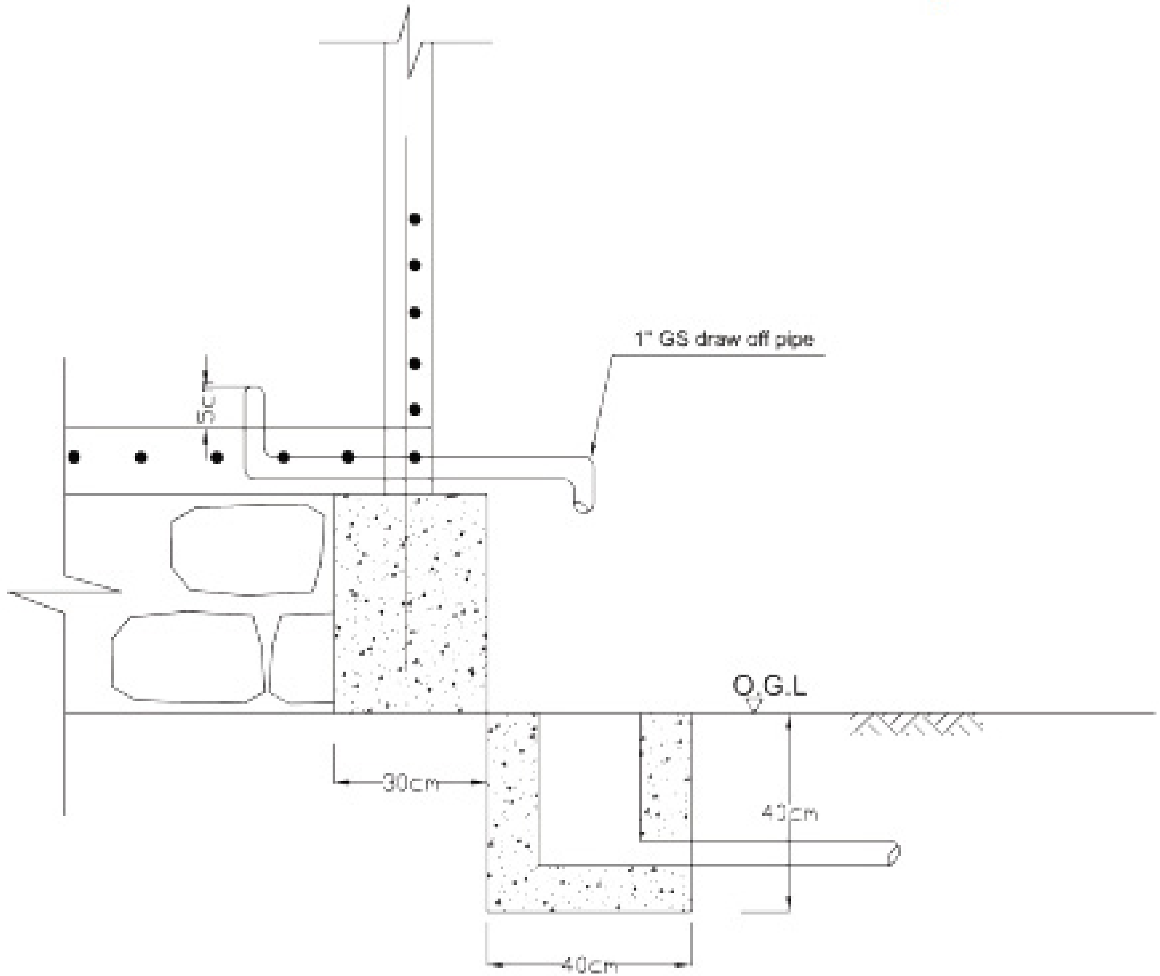


SECTION A-A

10m cube elevated steel tanker revised Layout1

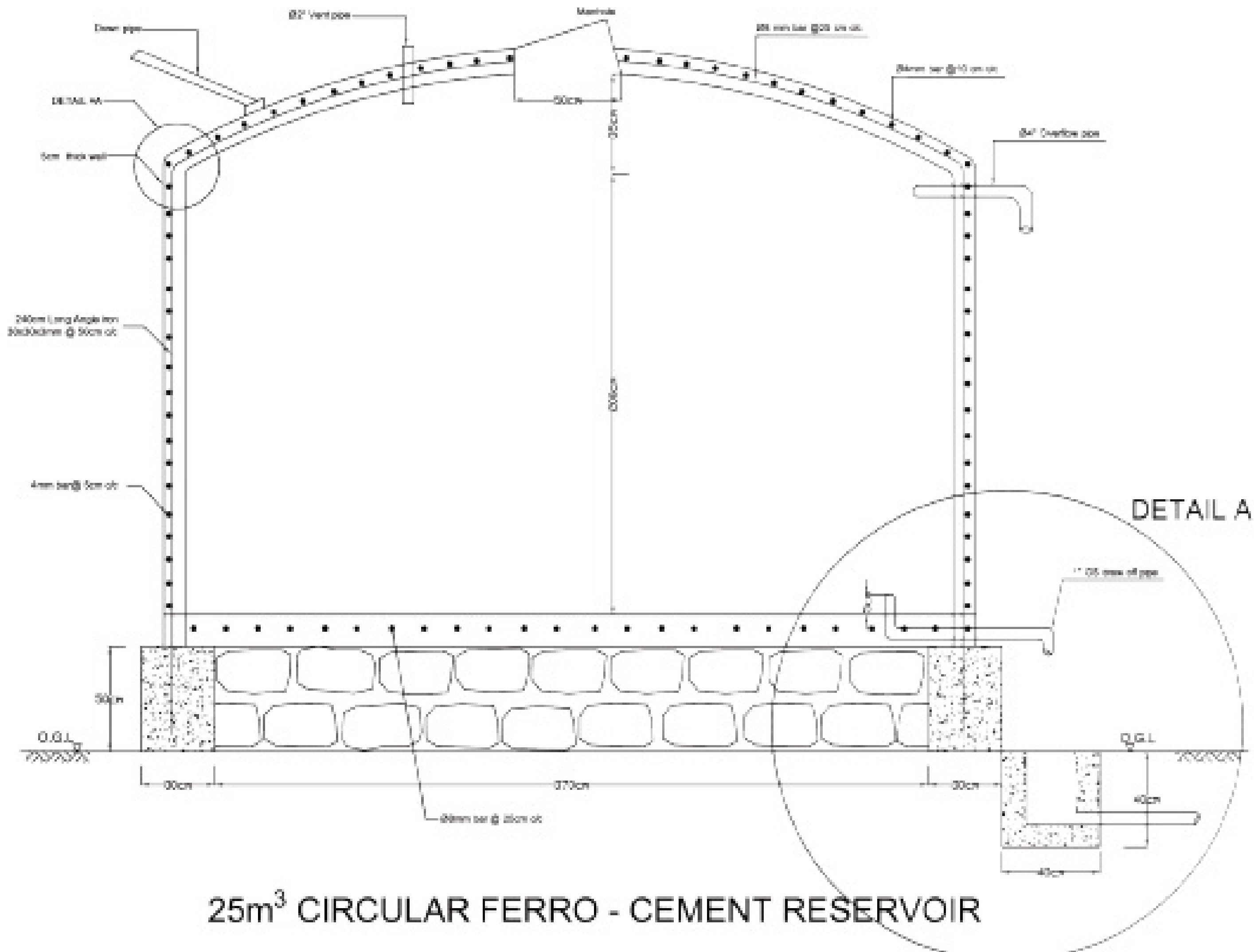


7-10 Circular ferro Cement Resrvoir for Rain Water Layout-2



DETAIL A

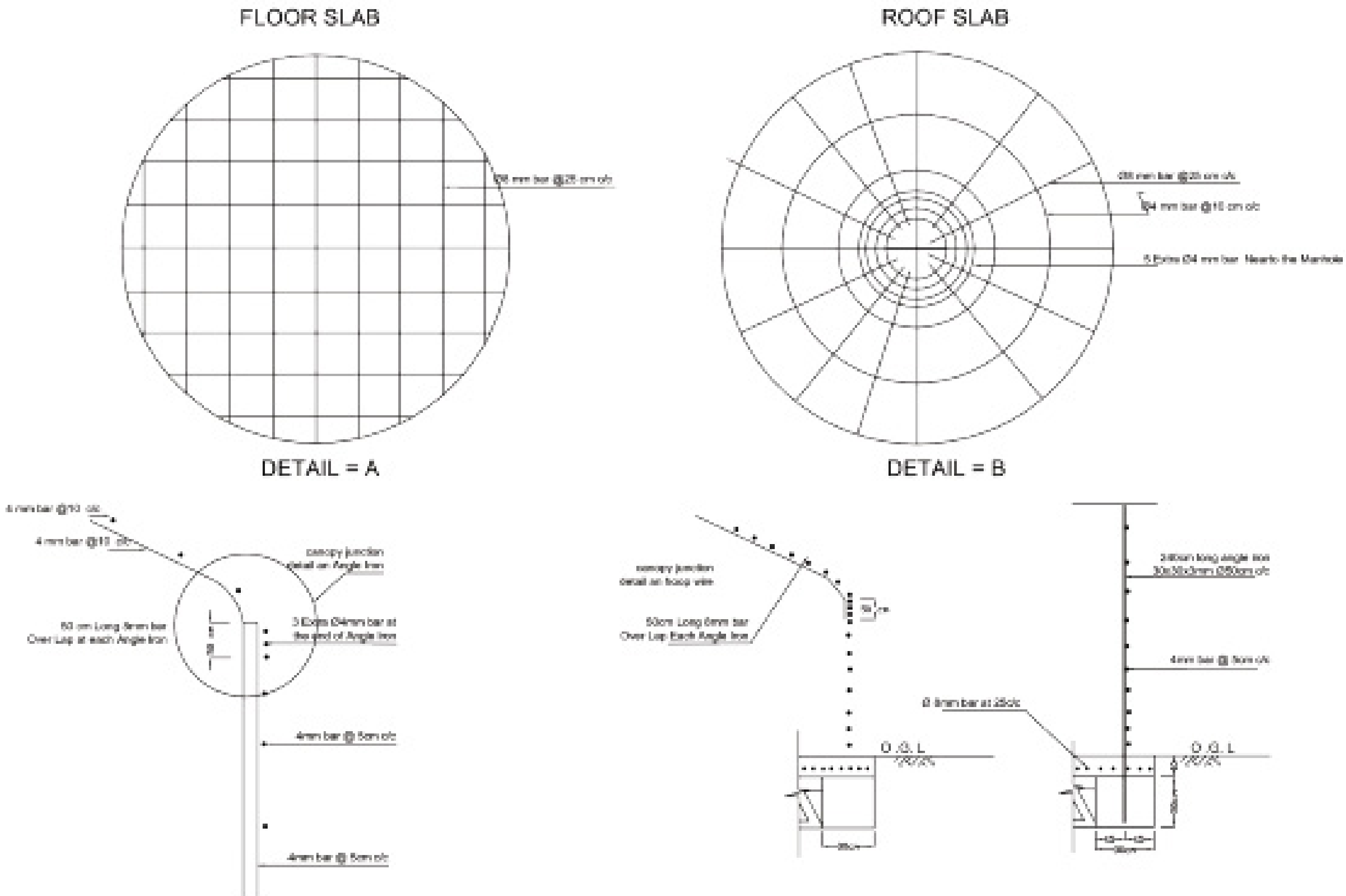
10 Circular ferro Cement Resrvoir for Rain Water Layout1



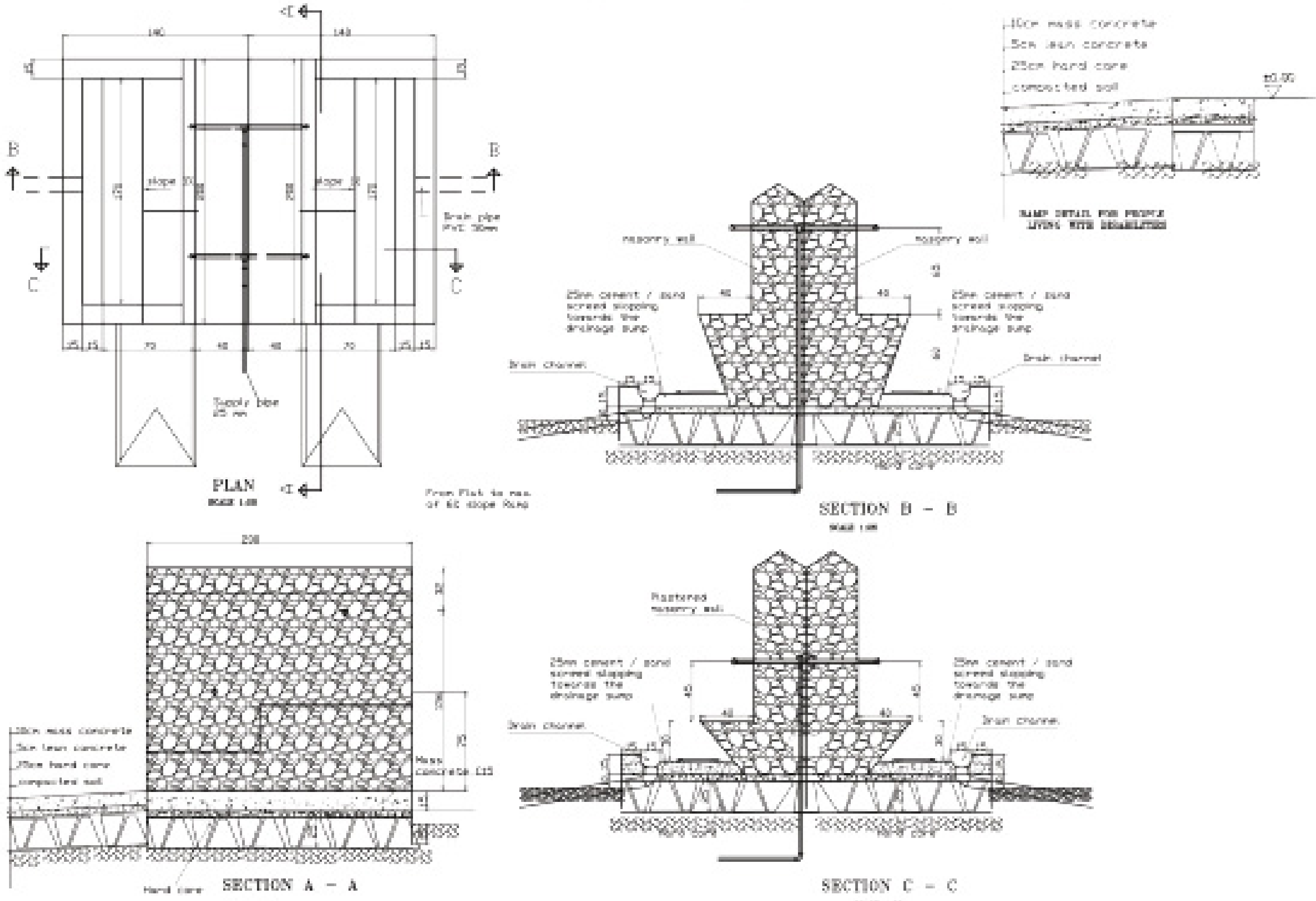
25m^3 CIRCULAR FERRO - CEMENT RESERVOIR

Circular ferro Cement Resrvoir for Rain Water Layout3

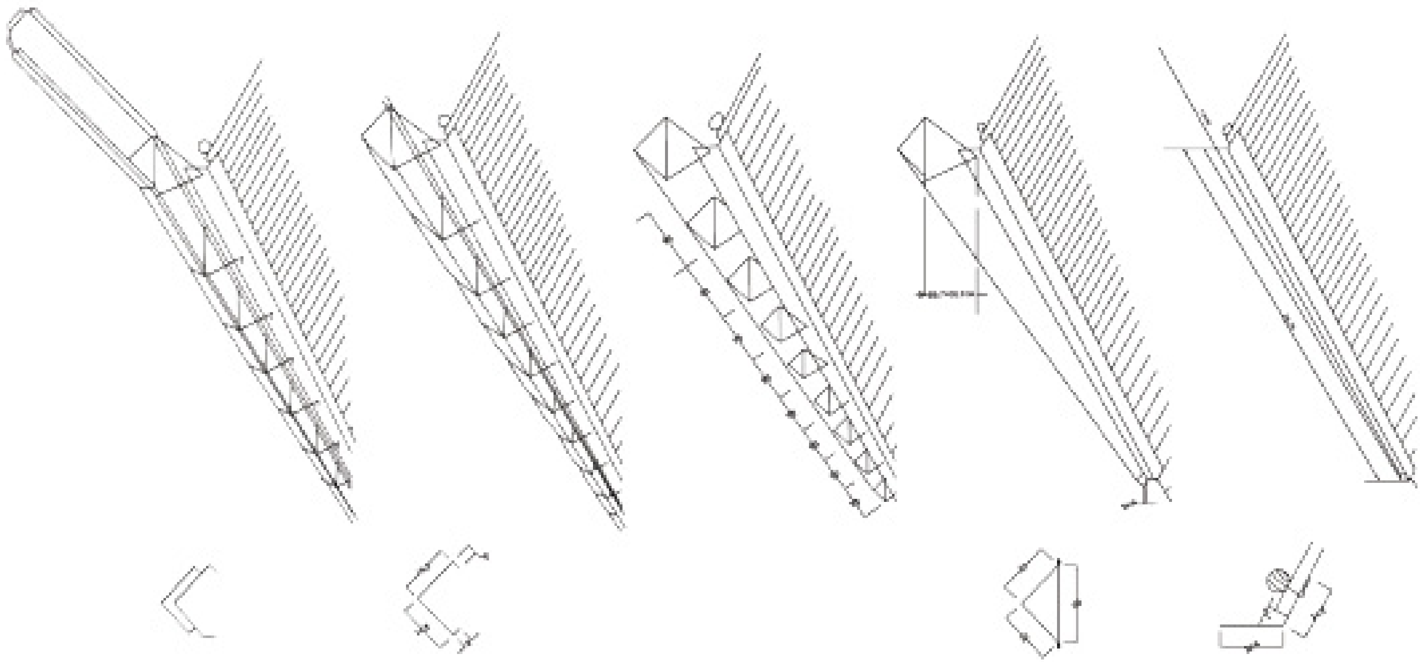
REINFORCEMENT DETAIL



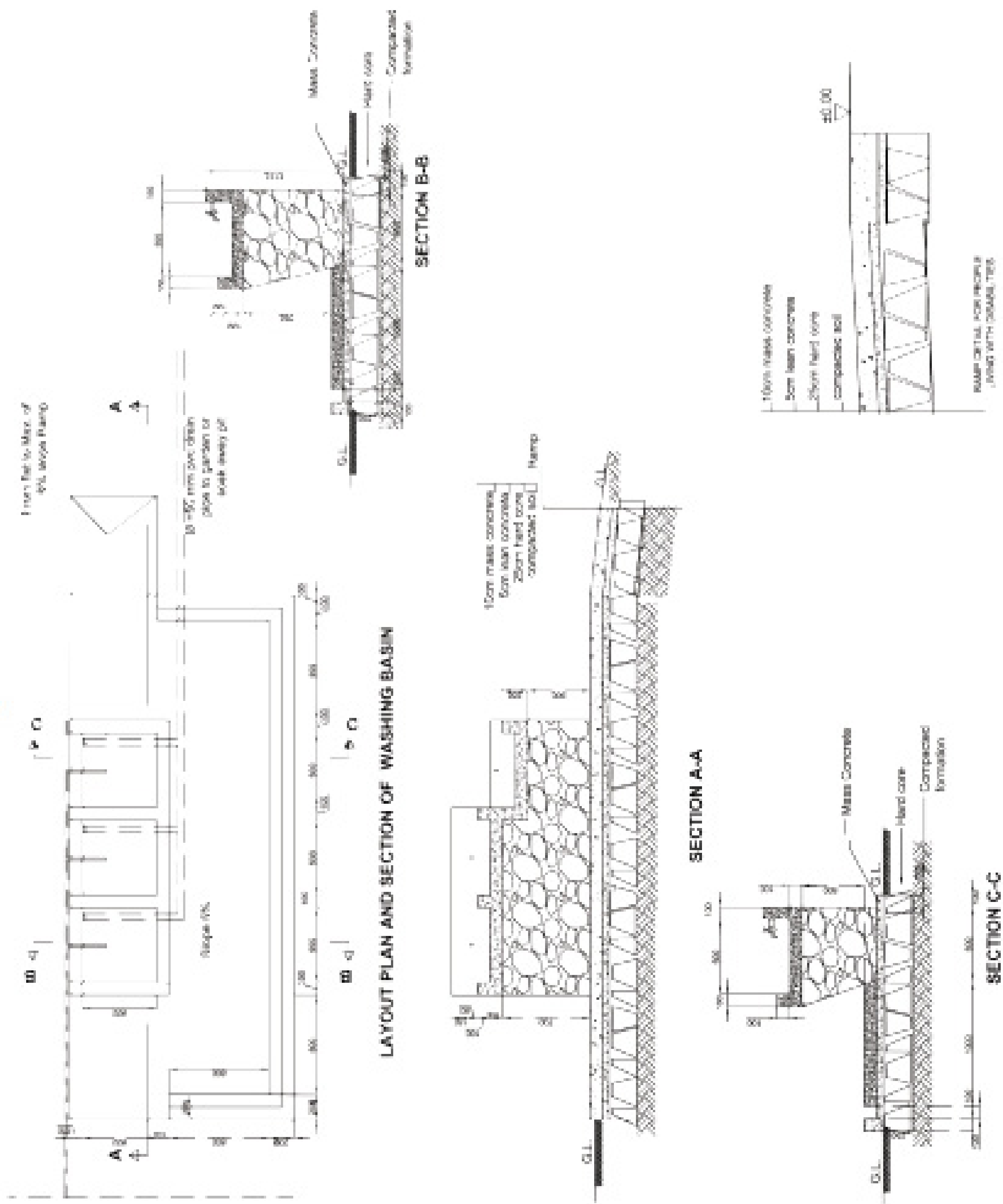
Communal water point footingl REVISED Layout1



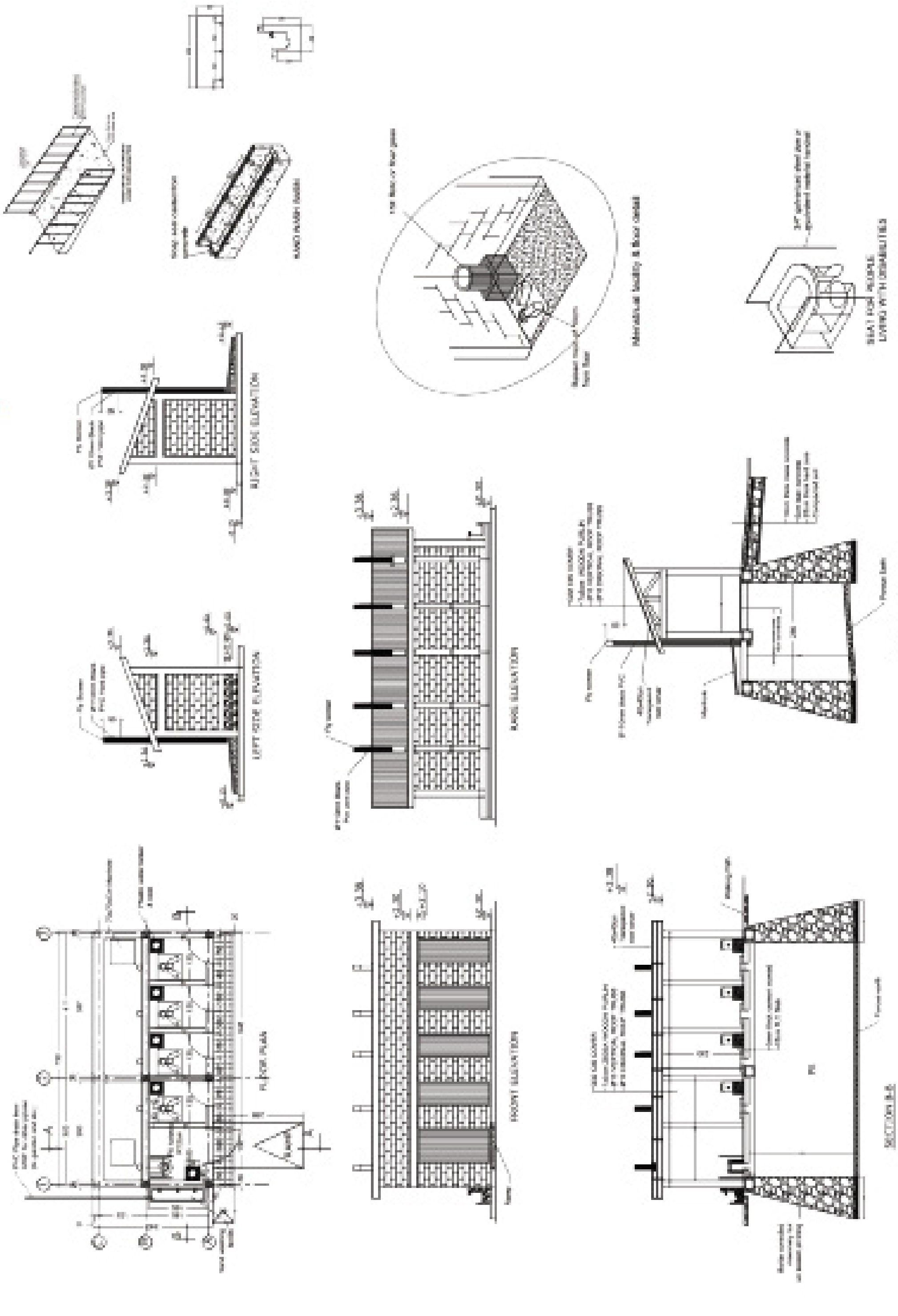
Circular ferro Cement Resrvoir for Rain Water Layout4



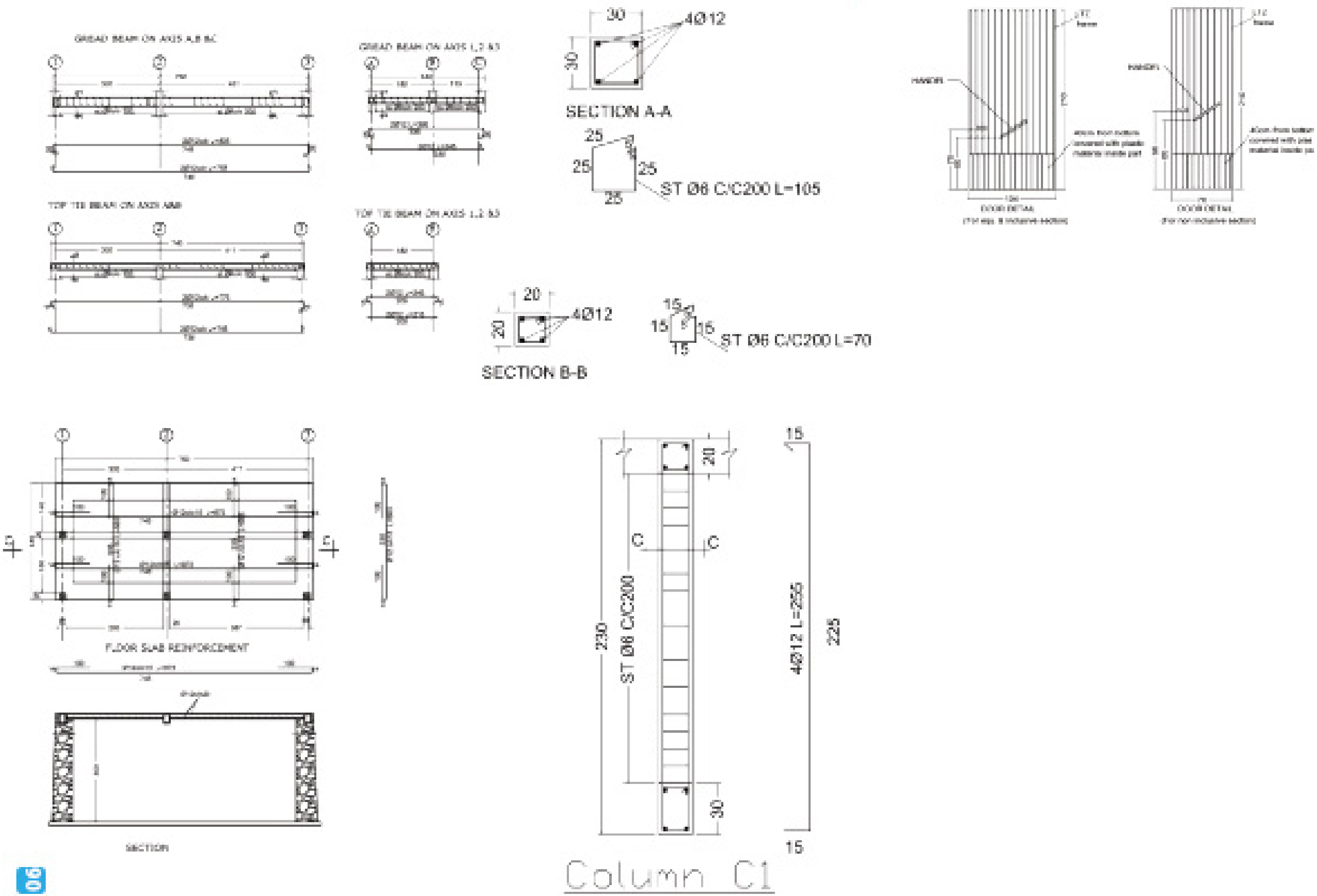
Washing Basin A3 - CONCRETE PAD



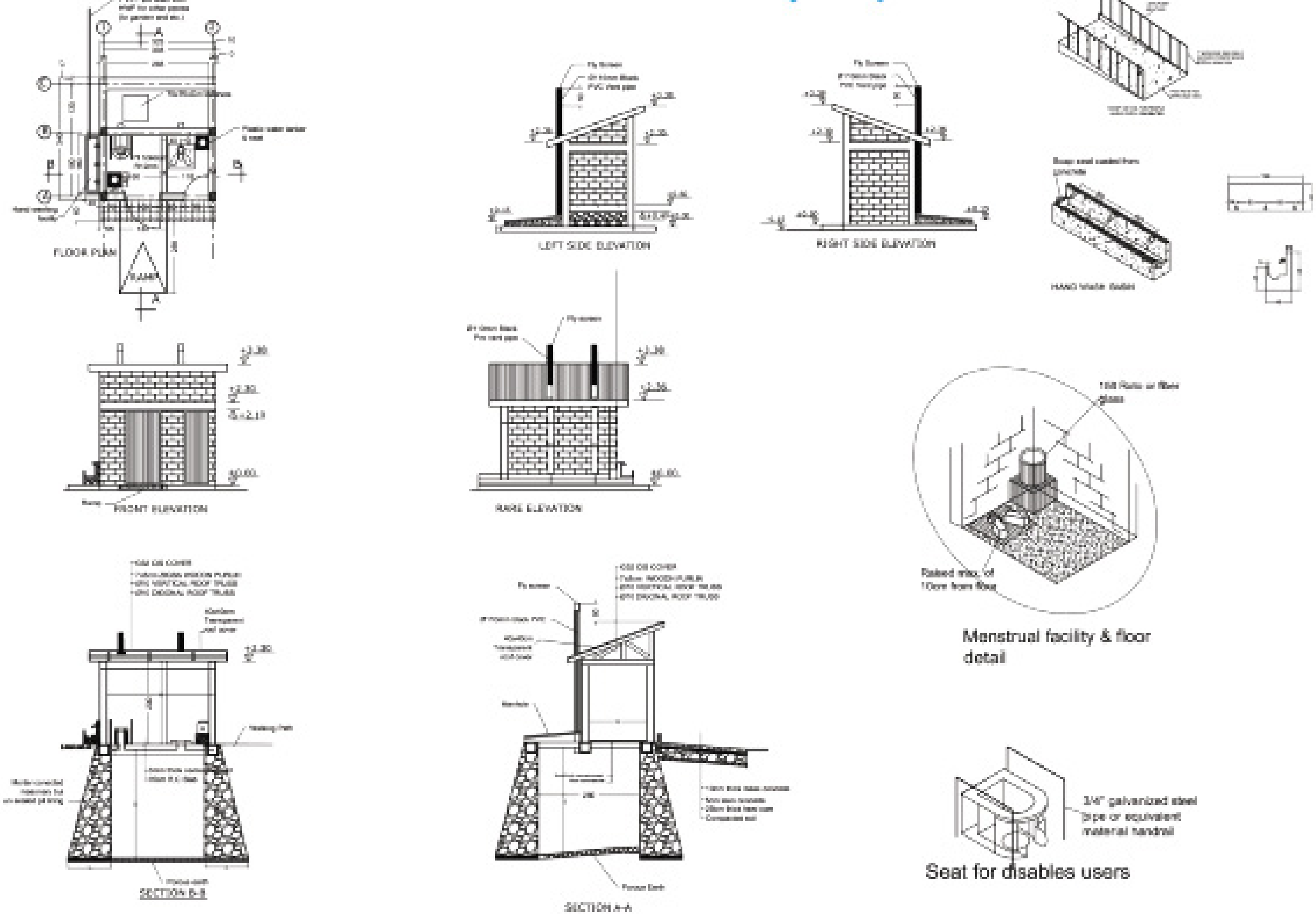
VIP for male and female Revised Layout1-1



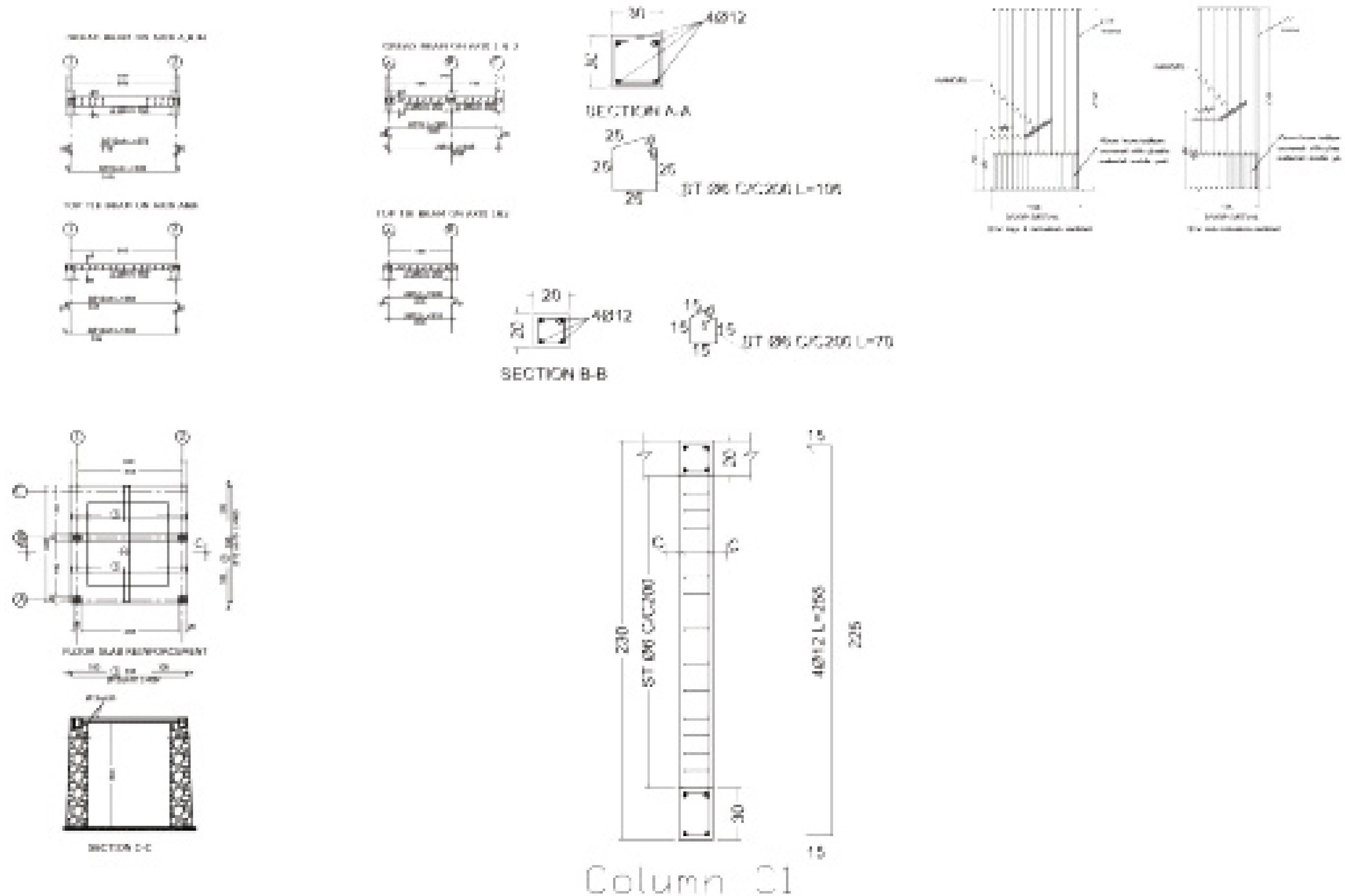
VIP for male and female Revised Layout1-2



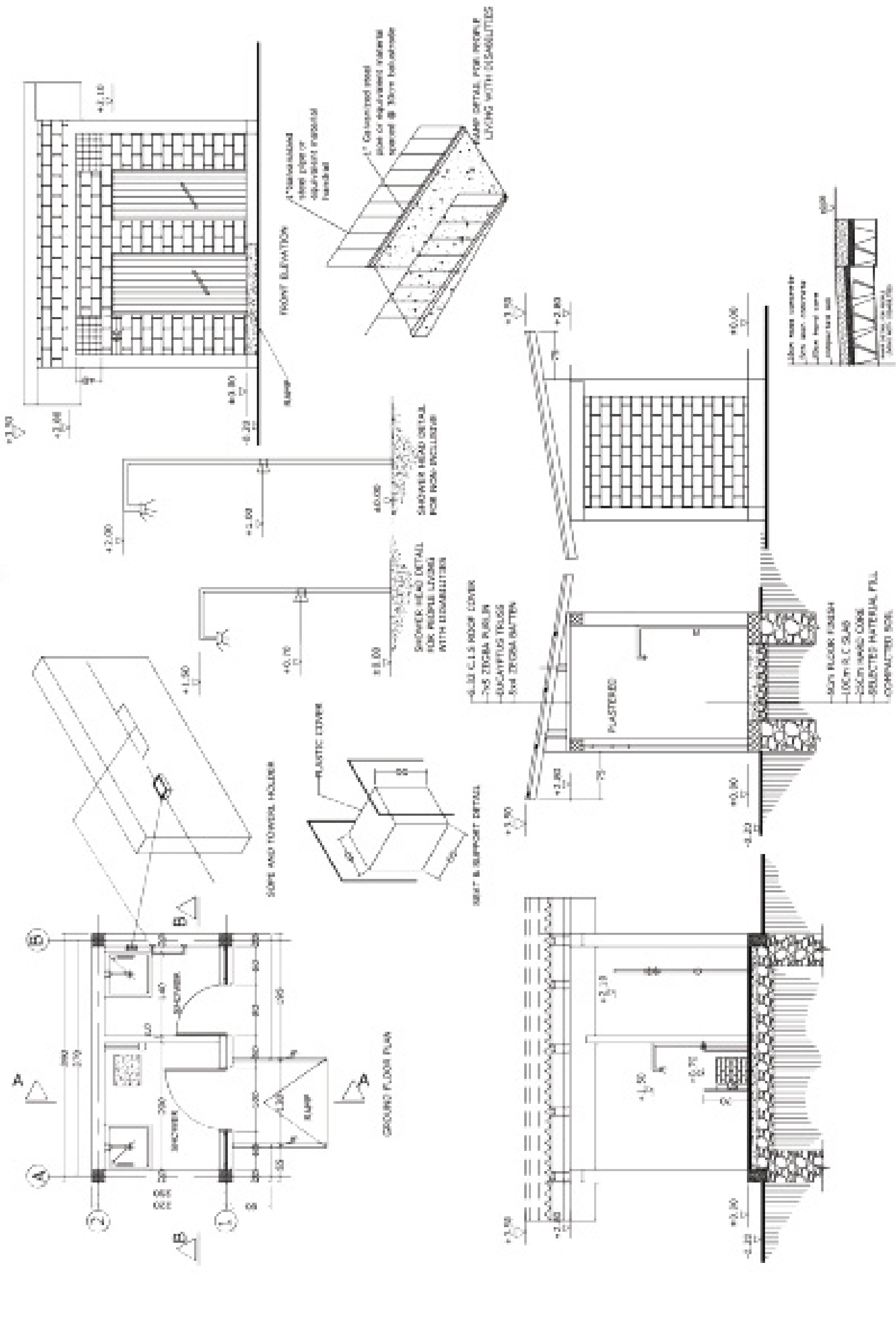
VIP for male and female health post Layout1-1



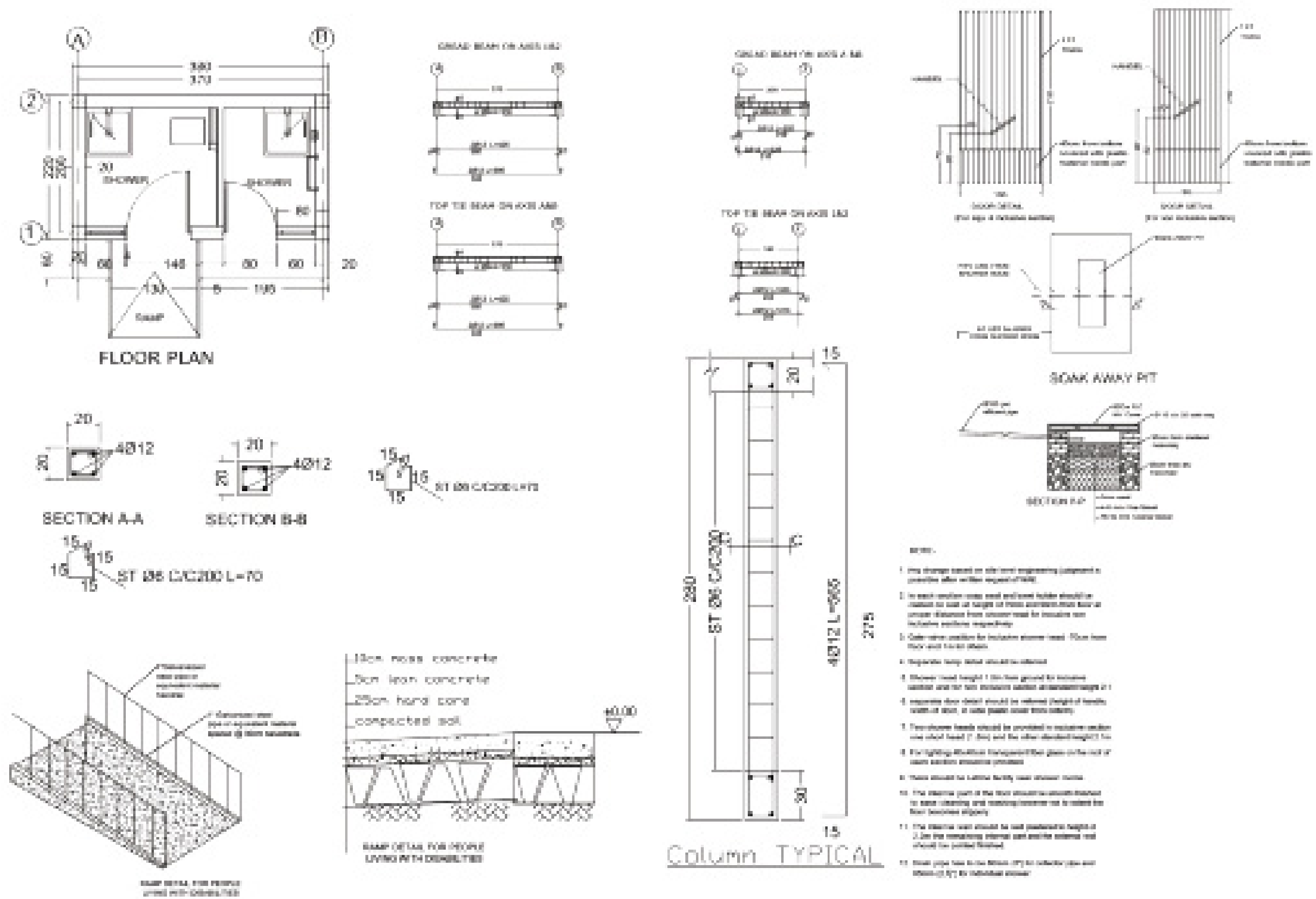
for male and female health post Layout1-2



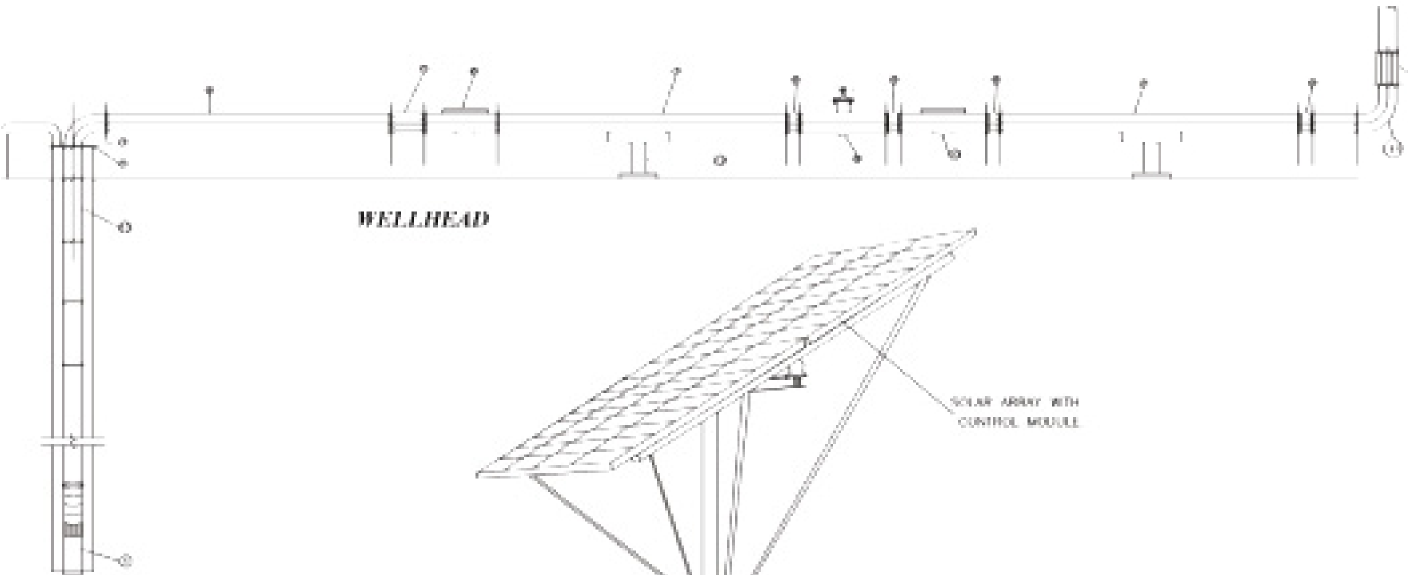
shower Layout1



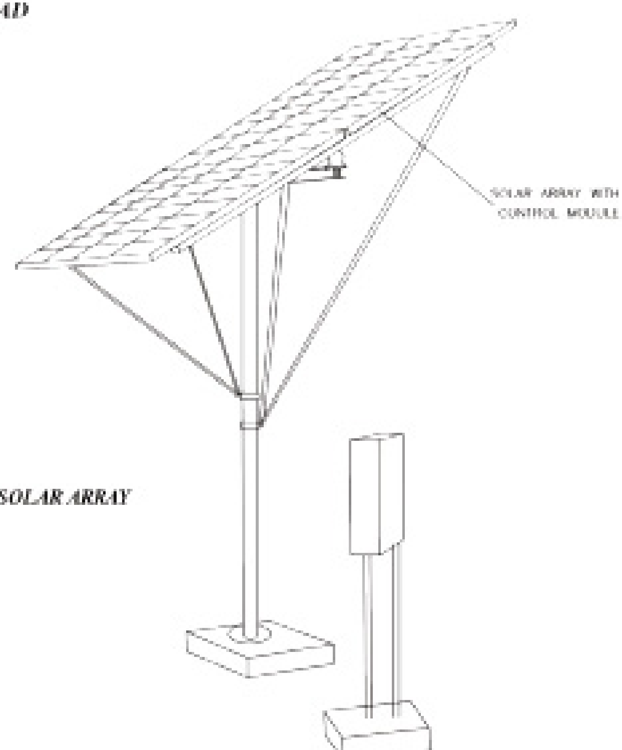
Shower reinforcement for male and female Layout1



solar pumpsystem P1



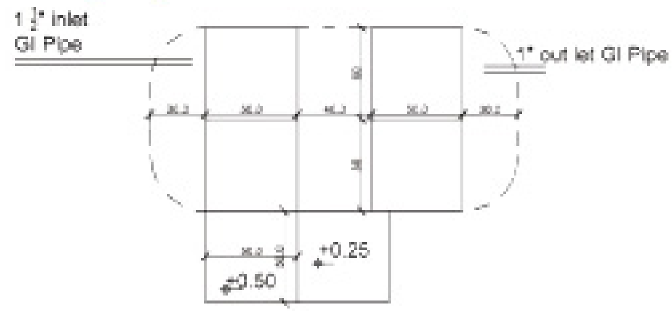
WELLHEAD



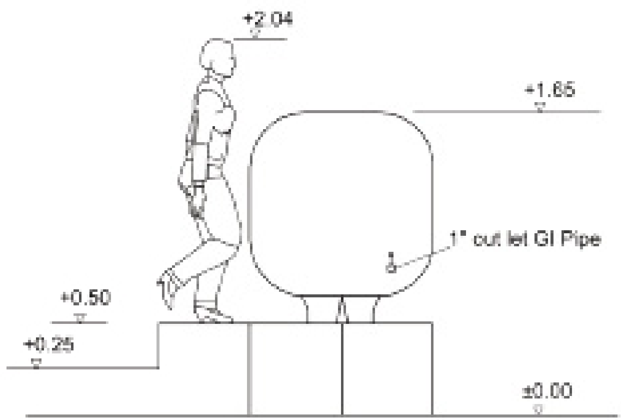
SOLAR ARRAY

No.	DESCRIPTION
1	SUB PUMP, WITH MOTOR
2	GS FLANGE TO BE WELDED ON CASING,diameter=casing dia.
3	WELLHEAD,dia.=casing dia. GS, WITH SHORT SOCKET 1 1/4" & ELBOW FEMALE THREADED WELDED ON OPPOSITE SIDES.
4	GS, SHORT PIECE, MALE THREADED 1 1/4"
5	UNION, 1 1/4".
6	WATER METER 1 1/4".
7	GS, SHORT PIECE, FEMALE THREADED 1 1/4".
8	NIPPLE 1 1/4".
9	GATE VALVE 1 1/4", FEMALE THREADED
10	CHECK VALVE 1 1/4", FEMALE THREADED
11	ELBOW MALE & FEMALE THREADED 1 1/4"
12	SUPPORT
13	GS, RISER PIPE 1 1/4", [illegible]
14	INLET PIPING GS, 1 1/4"
15	OUTLET PIPING GS, 1 1/2".
16	OVER FLOW & DRAIN PIPING GS, 2"
17	FAUCETS & PIPING, GS, 3/4".
18	TOWER FOR PVC TANK MADE OF ANGLE IRON OR STEEL PIPE [illegible], HEIGHT [illegible].
19	PVC TANK([illegible] TANK)
20	SOLAR ARRAY WITH CONTROL MODULE

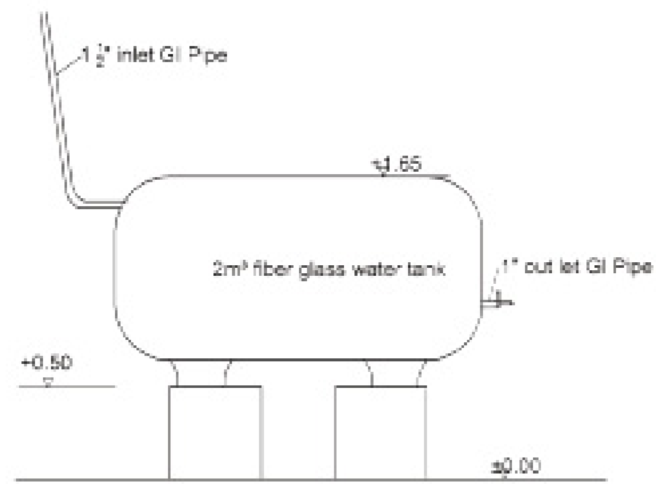
rain water harvesting Layout1



Floor Plan

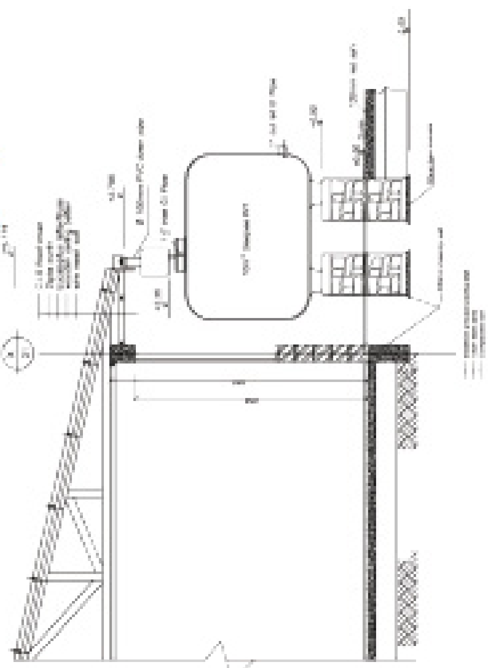


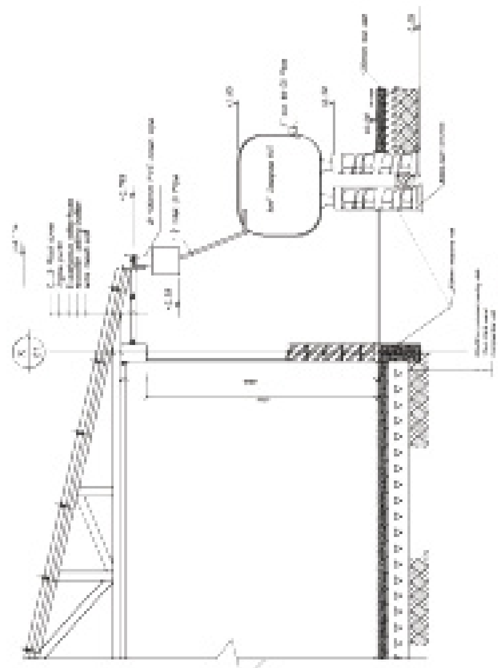
Side Elevation



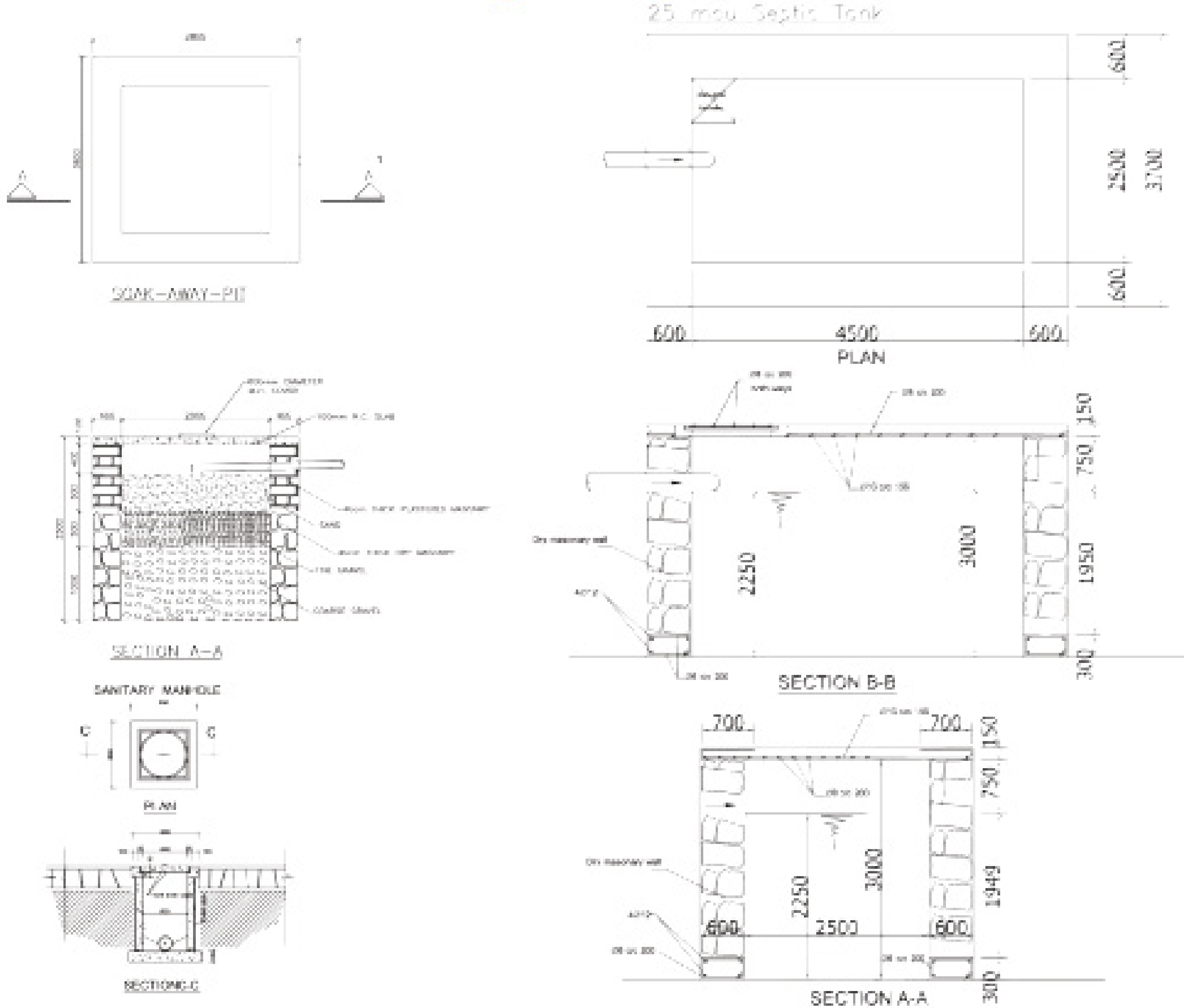
Front Elevation

ain water harvesting Layout1-2

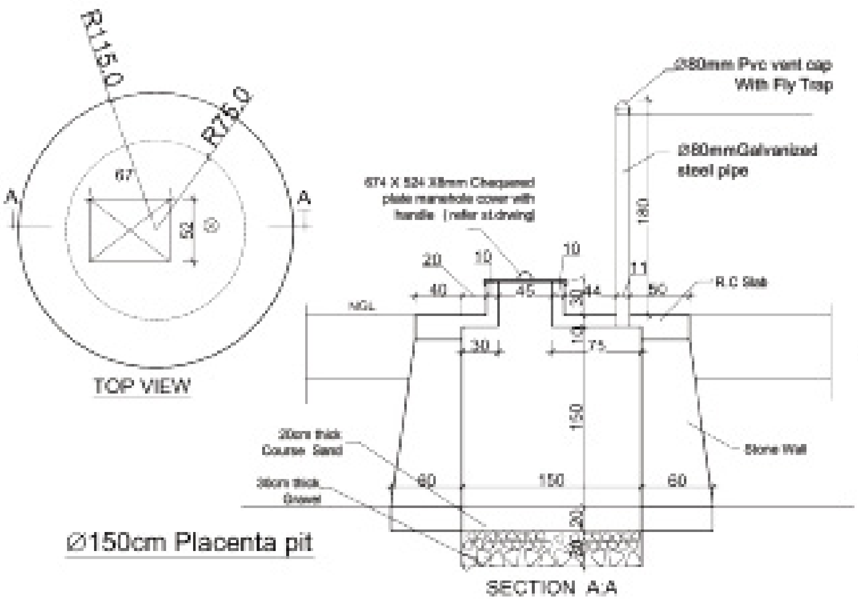




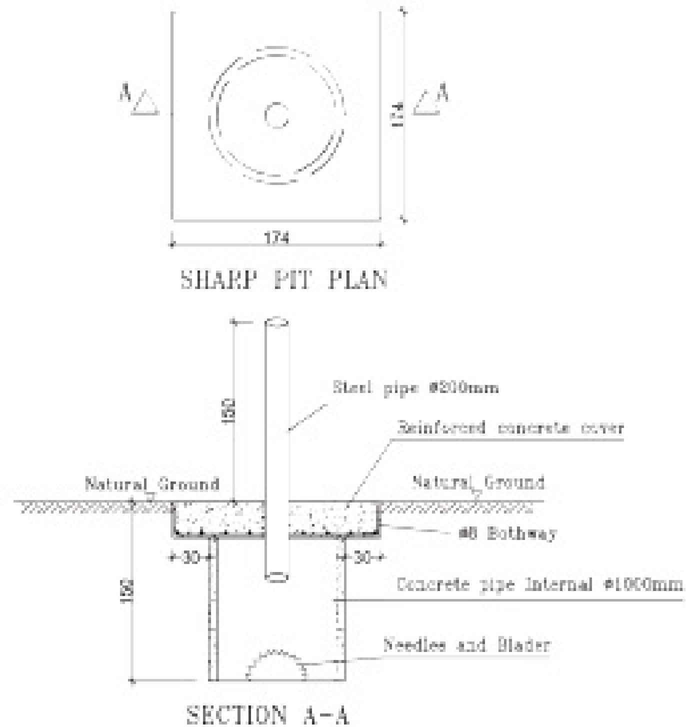
Septic Tank Layout1



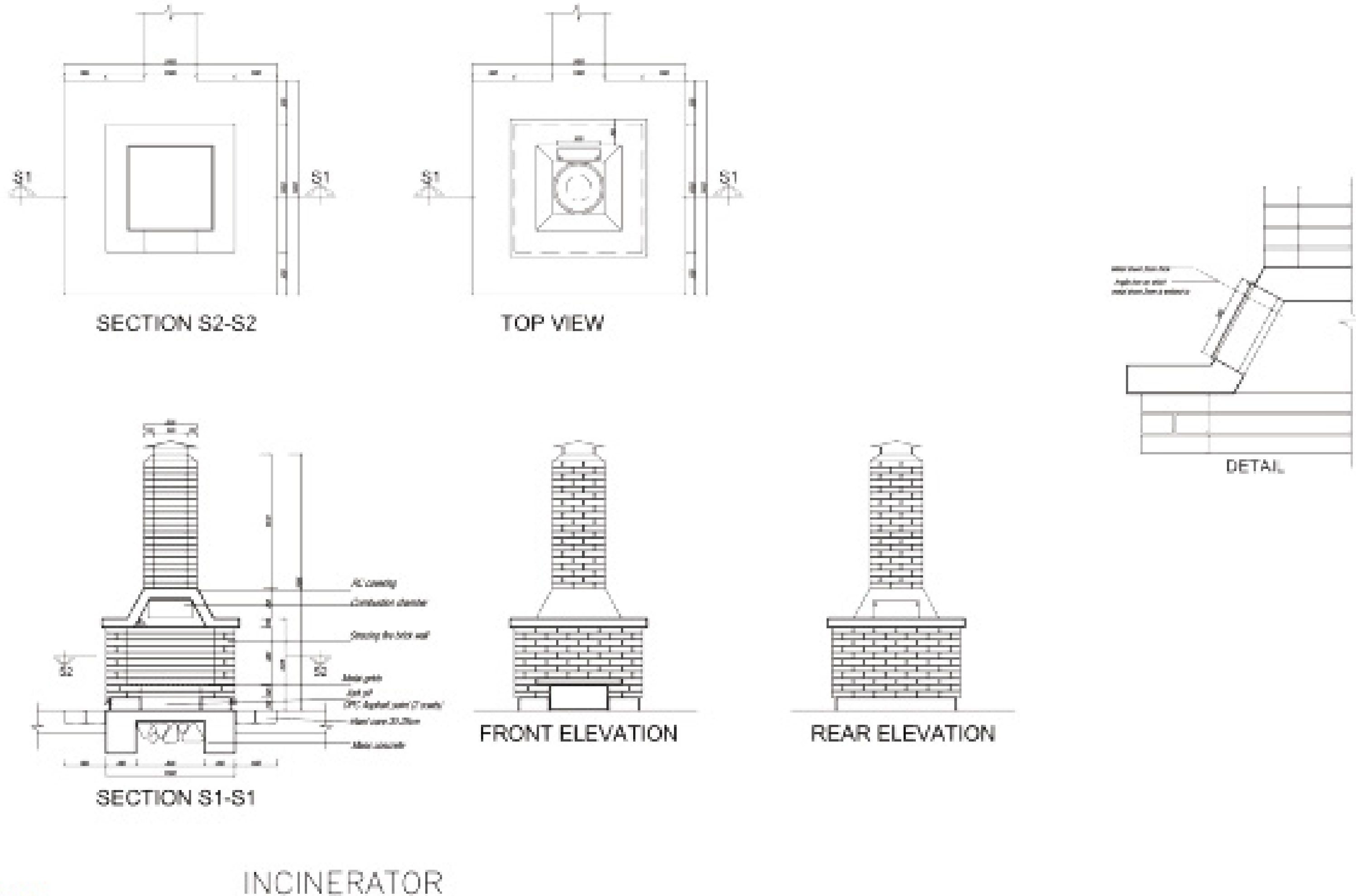
placenta and sharp pit Layout1



Ø150cm Placenta pit



100 Incentrator Layout 1



Bill of Quantity for VIP Latrine construction for Health Centre

ITEM	DESCRIPTION	UNIT	QTY.	Unit Price	Total Price
	A.Sub Structure			0.65	0.75
1	Site and Earth Work				
1.1	Clearing and grubbing of shrubs and trees including stumps and roots on the construction site	m2	77.00		
1.2	Excavation of soil for Latrine construction to a depth not exceeding 1.5 meters below strip ground level.	m^3	78.30		
1.3	Ditto, but below 1.5 meters and not exceeding 3.5 meters	m^3	104.40		
1.4	Ditto, but for strip foundation	m^3	10.20		
1.5	Back filling around the masonry wall with selected excavated material	m^3	43.00		
1.6	Carting away excess excavated material within the site boundary	m^3	150.00		
	Sub Total				
2	Concrete works				
2.1	5cm thick lean concrete class c-5, 150 kg cement/m3 of concrete, under masonry foundation wall.	m^3	34.00		
2.2	Reinforced concrete, c-20, 320 kg cement / m3 of concrete filled in formwork and vibrated around reinforcement. Reinforcement steel measured separately				
2.2.1	For floor slab 15 cm thick	m^3	2.85		
2.2.2	Ditto but for grade beam	m^3	1.50		
2.3	Supply cut, bend & fix in position steel reinforcement as per the detailed drawing. Price includes all incidental works to execute the job				
2.3.1	dia 12mm	kg	352.00		
2.3.2	dia 6mm	kg	40.00		
2.4	Provide cut and fix in position sawn zigba or equivalent wooden formwork				
2.4.1	For grade beam	m^2	20.00		
2.4.2	For floor slab	m^2	25.50		
	Sub Total				
3	Masonry work				
	Trachytic or equivalent stone masonry wall as a wall f or the latrine pit as per the detail drawing bedded in cement mortar (1:4) in full joints. Price includes scaffolding and all other supports to execute the job in the pit.	m^3	77.00		
	Stone pitching walk away around the latrine	m^2	25.00		

	Sub Total				
	B. Super Structure				
4	Concrete Works				
4.1	Reinforced concrete, c-25, 360 kg cement / m3 of concrete filled in formwork and vibrated around reinforcement. Reinforcement steel measured separately				
a	In elevation column	m^3	1.50		
b	In top tie beam	m^3	1.00		
4.2	Provide, cut and place in position sawn zigba or equivalent wooden formwork				
a	In elevation column	m^2	2.00		
b	In top tie beam	m^2	8.00		
4.3	Cut, bend & fix in position steel reinforcement as per the detailed drawing for top tie beam and column. Price includes all incidental works to execute the job				
a	diam 6mm	kg	40.00		
b	diam 12mm	kg	160.00		
	Sub Total				
5	Block Work				
5.1	20x20x40cm class C hollow concrete block wall in cement sand mortar 1:3 both side left for plastering. Price includes scaffolding or any support to execute the job up to the roof level.	m^2	28.00		
5.2	Ditto, but partition wall 15x20x40 cm class c HCB wall bedded in cement mortar 1:3 both side left for plastering. Price includes all incidental works to execute the job up to the roof level	m^2	17.00		
5.3	San plate (60x60 cm2) one for each toilet room	pcs	4.00		
5.4	Supply and place squatting plate for disables users as shown in the detailed drawings. Price includes 3/4 inch galvanized steel pipe or equivalent material handrail	LS	1.00		
5.5	Supply and place menstrual facility as shown in the d etailed drawings with 15 liters Roto or fiber glass container. Fitted with tap.	LS	1.00		
	Sub Total				
6	Roof Work				
6.1	Roof cover in G32 CIS nailed to 5x7 cm battens as per the drawing. Price includes all incidental works to execute the job				
6.2	Supply and fix G-32 galvanized sheet metal gutter and dawn pipe	m^2	25.00		
a	Gutter 60cm development length	m	6.50		
b	Dawn pipe 33cm development length	m	7.00		

6.3	Supply and fix diam 100mm uPVC vent pipe including vent cup and fly screen as shown in the drawing	No	4.00		
	Sub Total				
	Carpentry work				
7.1	All structural truss members shall be in seasoned eucalyptus wood and painted two coats of anti termite solution and shall be tightly fixed to top tie beam with 6 mm plain bar				
7.2	Diameter 10cm eucalyptus upper and lower chord	m	30.00		
7.3	Diameter 10 cm eucalyptus vertical and diagonal member	m	20.00		
7.4	50 x 70 mm zigba or equivalent purlin	m	38.00		
	Sub Total				
	Metal Work				
8.1	All metal doors are manufactured from locally produced LTZ steel profile frames. All works shall be cut and assembled to sizes and shapes of the door schedule upon submitting shop drawings to be approved by the supervisor. Price includes cylinder lock or similar, door stoppers and all other accessories to complete the work to acceptable standard.				
8.1.1	Type size 70 x 210 cm	pcs	3.00		
8.1.2	Type size 100 x 210 cm	pcs	1.00		
	Sub Total				
	Plastering and Pointing works				
9.1	Pointing all internal and external HCB wall surface with cement sand mortar 1:2	m^2	85.00		
9.2	Apply three coat of plastering to beam and column surface in cement sand mortar 1:3	m^2	4.50		
9.3	5 cm thick roughened cement sand screed floor finish with 0.1 aggregate mix. Price includes chiseling of floor in cement, sand and aggregate mix 1:2:3	m^2	14.50		
9.4	Supply and installation of Electrical items				
	Sub Total				
	C Miscellaneous works				
	Hand Washing				
1.1	10 cm thick concrete strip footing for masonry structure	m^2	0.70		
1.2	Supply and construct trachytic or equivalent stone masonry structure for hand washing above ground level bedded in cement mortar (1:3) in full joints	m^3	0.50		
1.3	Apply three coats of plastering to the exposed surface of the structure.	m^2	2.00		
1.4	Supply and install 1/2" faucet connected to the pipe line from elevated reservoir	pcs	3.00		
1.5	Supply and install 50 mm uPVC drain pipe and connect to the sewer pipe of the compound. Price includes all accessories	m	2.00		

	Sub Total				
	Rump entrance				
2.2	Supply and place 25cm hardcore on compacted soil at the rump entrance of the latrine providing a maximum of 6% slope	m^2	2.00		
2.2	Place 5cm thick lean concrete class c-5, 150 kg cement/m3 of concrete.	m^2	2.00		
2 2.3	Supply and place class c-20 concreter 10 cm thick rump floor with minimum cement content of 320 kg / m3 of cement	m^2	2.00		
2.4	Supply and fix 1" galvanized steel pipe or equivalent material hand rail spaced at 30 cm c/c.	m	7.50		
2.5	Supply and fix precast concrete manhole cover as shown on the drawing	pcs	2.00		
	Sub Total				
	Total VIPL				

MATERIAL BREAKDAWN

Item	Material description	UNIT	QTY.	Unit Price	Total Price
	Cement	Quintals	50.00		
	Sand	m^3	15.00		
	Aggregate	m^3	10.00		
	Stone	m^3	70.00		
	HCB 200mm	No	400.00		
	HCB 150mm	No	230.00		
	Reinforcement Steel				
	dia 12mm	Kg	512.00		
	dia 6mm	Kg	80.00		
	Timber for formwork	m^2	45.00		
	Nails of different diameter	Kg	15.00		
	San plate (60x60 cm2) one for each toilet room	No	4.00		
1.1	squatting plate for disables users with galvanized steel pipe or equivalent material handrail	No	1.00		
1.2	15 liters Roto or fiber glass container	No	1.00		
	G32 CIS Roofing sheet	No	36.00		
	Roofing nail	Kg	5.00		
1.3	Gutter 60cm development length	m	6.50		
1.4	Dawn pipe 33cm development length	m	7.00		
	diam 100mm uPVC vent pipe	No	2.00		
1.5	Diameter 10cm eucalyptus upper and lower chord	m	30.00		
	Diameter 10 cm eucalyptus vertical and diagonal member	m	20.00		
	50 x 70 mm zigba or equivalent purlin	m	38.00		
	Metal door Type size 70 x 210 cm	No	3.00		
	Metal door Type size 100 x 210 cm	No	1.00		
	Supply and install 1/2" faucet connected to the pipe line from elevated reservoir	No	3.00		
	Diam. 50 mm uPVC drain pipe.	m	2.00		
	Supply and fix 1" galvanized steel pipe or equivalent material for hand rail	m	7.50		

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