

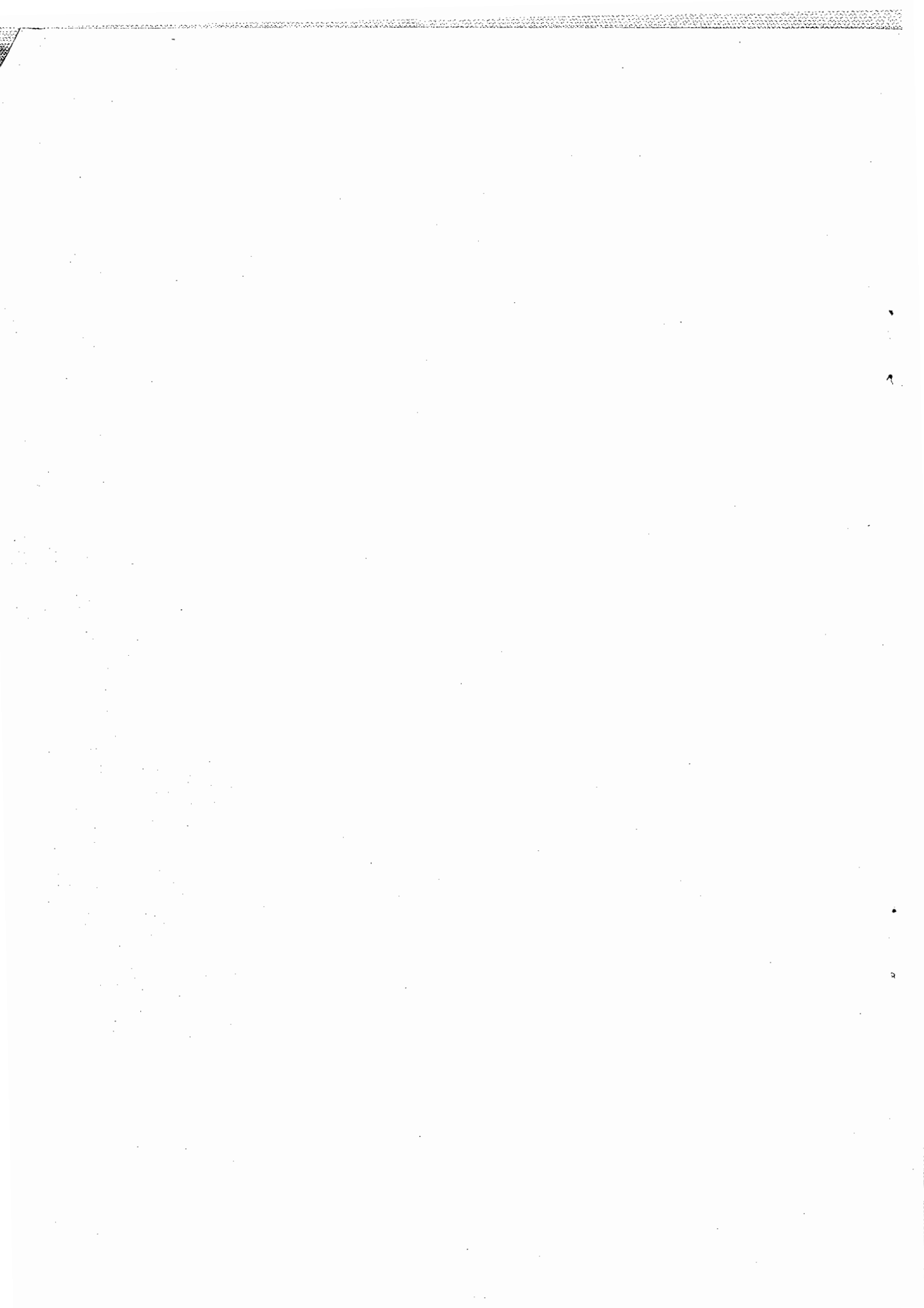
Anil Kumar Sharma

RAIN WATER HARVESTING AND CONSERVATION

MANUAL



**GOVT. OF INDIA
CONSULTANCY SERVICES ORGANISATION
CENTRAL PUBLIC WORKS DEPARTMENT
NIRMAN BHAWAN NEW DELHI-110011**



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FOREWORD

Shortage of water for industrial and domestic use and even for drinking purpose is a cause of concern through out the world specially in d eveloping and under developed countries. India is already experiencing water shortage and the problem will become very acute in the near future unless preventive measures are taken on a substantial scale. Rain Water Harvesting and Conservation is needed on a massive scale. A comprehensive treatise on this crucial topic is need of the hour. Although guidelines have been issued from time to time by various organizations it is for probably the first time that the existing guidelines have been compiled at one place in a user friendly manual.

The Govt. of India is laying emphasis for rain water harvesting and conservation, it has therefore been felt necessary that the officers of CPWD should also have easy and ready access to such guidelines issued by the Department/Ministry on this subject and to enable them to take timely and appropriate action. The publication of this Manual fulfils this important requirement.

Even though the "**Rain Water Harvesting & Conservation**" Manual has been compiled basically for the use in CPWD it may also be useful to a large number of Government Organisations and Public Sector Undertakings. I am sure this will herald an era of water conservation and the peril of water shortage will be suitably contained.

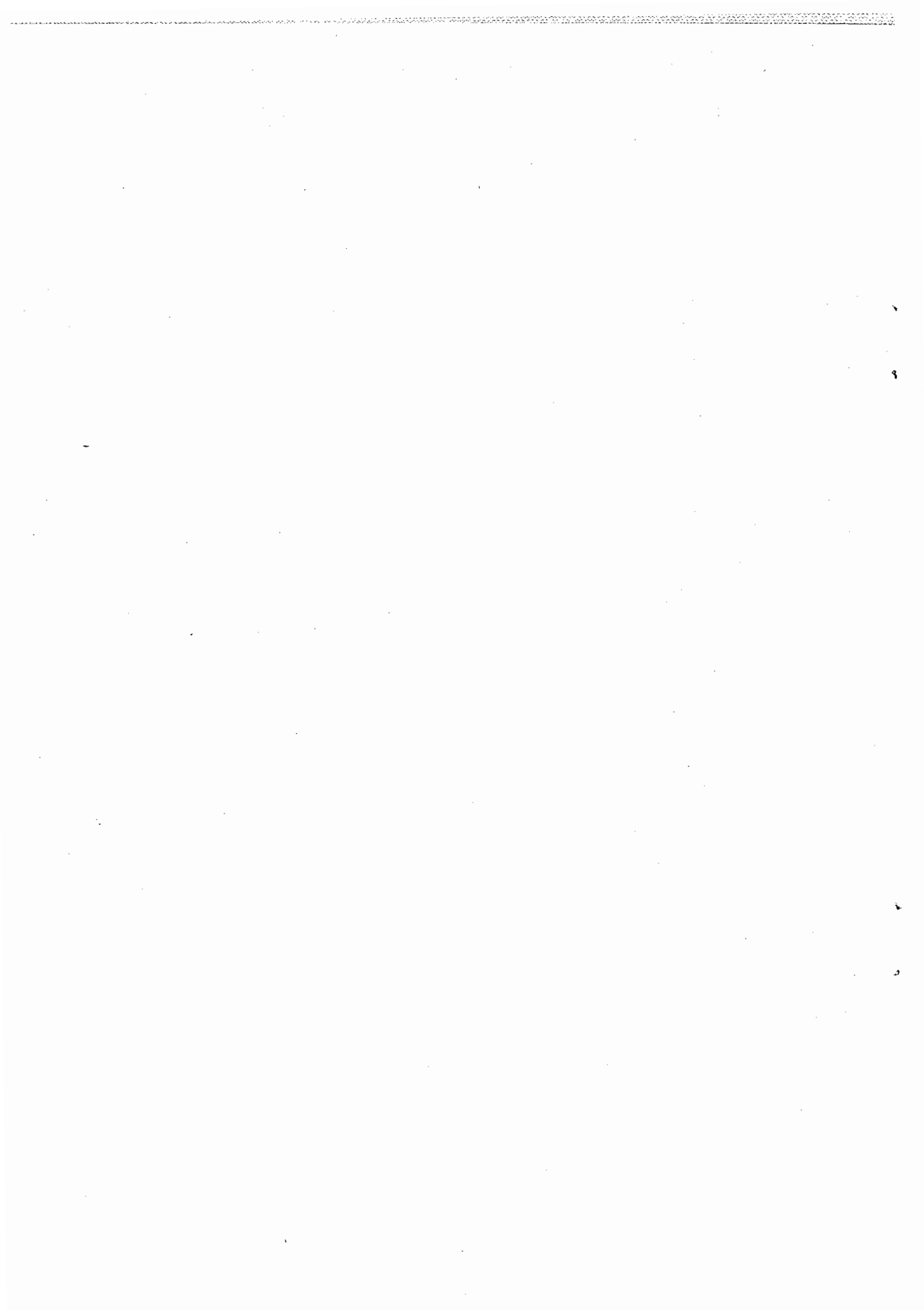
This Manual is a result of combined efforts of a large number of officers. I would like to express my appreciation to the guidance given by Shri H.K. Munjal, ADG(TD) and the efforts put in by the Committee consisting of Shri N.M.D. Jain, E.D., CSO, Shri C.B. Lal, C.E., (SPG) Project, Shri A.K. Sinha, S.E. CSC, Shri Ashok Khurana, S.E., CPWD, Shri Abhai Sinha, Director, CSO, CPWD.

The manual is one more step on the path of technical excellence to which CPWD is perpetually committed.



(Er. Krishan Kumar)
Director General (Works)

New Delhi.
Dated: 11.06.2002.



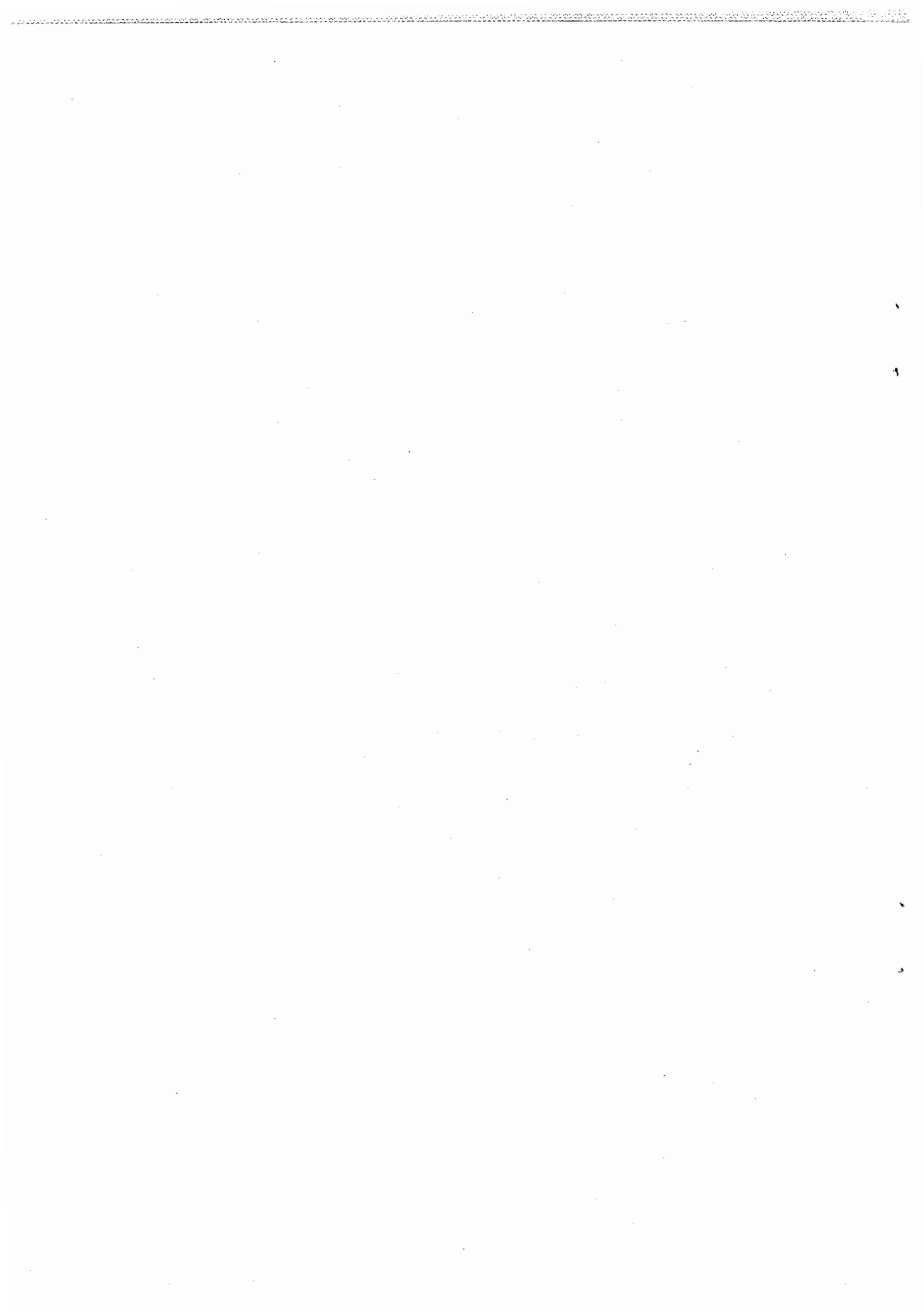
PREFACE

There is an increasing trend towards construction of buildings for residential as well as non residential purposes in urban areas and making the open areas as pucca for parking etc. This trend has decreased drastically infiltration of rain water into the sub soil and recharging of ground water has diminished due to over development which has depleted the aquifers. Surface water is inadequate to meet our demand and we have to depend on ground water. Thus there is need to recharge the ground water. The artificial recharging of ground water is a process by which ground water reservoir is augmented at a rate exceeding that obtained under natural conditions. The artificial recharge techniques enhance the sustainable yield in area and utilizes the rainfall runoff which otherwise goes to sewer or storm water drains. The conservation and storage of access surface water for future requirements is necessary because these requirements often change within a season or a period so the basic purpose of artificial recharging of ground water is to restore supplies from aquifers depleted due to excessive ground water development. Rain water harvesting can be done by storage of rain water on surface for future use and recharging of ground water. **The "Consultancy Services Organisation" CPWD has brought out a Manual entitled "Rain Water Harvesting & Conservation"** which is a compilation of guidelines for optimum utilization of Rain Water. The Rain water Harvesting & Conservation is nothing but means understanding the importance of rain and to make optimum use of rain water at the place where it falls.

It has been possible to bring out this Manual on account of efforts of Shri N.M.D. Jain, ED(CSO), Shri Jagmohan Swarup, Director (CSO), Shri Abhai Sinha, Director (CSO) and their team (Shri P.S. Bassi, EE(CSO), Shri Rajesh Kumar, Architect (CSO) & Shri PP Mohanakumaran, PA to Dir (CSO)I.


11/6/02
(Er.H.K. Munjal)
Addl. Director General(TD)

New Delhi.
Dated: 11.06.2002



CHAPTER 1

INTRODUCTION

- 1.1 In spite of astonishing achievements in the field of Science & Technology, nature remains to be a mystery for human beings. Though water is also being obtained through desalination, artificial rain by cloud seeding etc. in some of the developed countries, the shortage of water even for drinking purpose is a perpetual phenomenon throughout the world, especially in developing and underdeveloped countries. India is likely to experience 'Water Stress' from the year 2007 onwards it will be pertinent to shift the thrust of the policies from 'Water Development' to 'Sustainable Water Development'. A vital element of this shift in strategy is the increasing importance of Water Harvesting and Artificial Recharge of Ground Water.
- 1.2 Countries like Slovakia, Israel, use water about 4-5 times before disposing off, however, in India it is used only once before being disposed. This is certainly not a very encouraging situation.
- 1.3 The never-ending exchange of water from the atmosphere to the oceans and back again is known as the hydrologic cycle. This cycle is the source of all forms of precipitation (hail, rain, sleet and snow), and thus of all water. Precipitation stored in streams, Lakes, and soil evaporates while water stored in plants transpires to form clouds, which store the water in the atmosphere.
- 1.4 Making the most efficient use of our State's limited and precious resources is essential. This includes using appliances and plumbing fixtures that conserve water, not wasting water and taking advantage of alternative water sources such as grey water reuse and rainwater harvesting.
- 1.5 Water is essential for life and plays a major role in creating earth's climate. By modifying land use, the proportion of the different pathways, evaporation, percolation and run off change. A change in evaporation from a region has impacts upon climate. Changes in percolation change ground water availability, both for humans, and natural springs and streams. Changes in run off will change stream flow and erosion patterns, which in turn modifies the sediment load of stream.
- 1.6 Rain Water Harvesting & Conservation, is the activity of direct collection of Rain Water. The conservation of Rain Water so collected can be stored for direct use or can be re-charged into the Ground Water. The main goal is to minimize flow of Rain Water through Drains / Nallahs to the Rivers without making any use of the same. It is a known fact that the Ground Water level is depleting and going down and down in the last decades. Thus Rain Water Harvesting & Conservation aims at optimum utilization of the natural resource, that is, Rain Water, which is the first form of water that we know in the hydrological cycle and hence is a primary source of water for us. The Rivers, Lakes and Ground Water are the secondary sources of water. In present times, in absence of Rain Water harvesting and conservation, we depend entirely on such secondary sources of water and in the process it is forgotten that rain is the ultimate source that feeds to these secondary sources. The value of

this important primary source of water must not be lost. **Rain Water Harvesting & Conservation means to understand the value of rain and to make optimum use of Rain Water at the place where it falls.**

- 1.7 **The artificial recharge to ground water is a process by which the ground water reservoir is augmented at a rate exceeding that obtained under natural conditions of replenishment. Any man made scheme or facility that adds water to an aquifer may be considered to be an artificial recharge system. Theoretically this will imply that the vertical hydraulic conductivity is high, while the horizontal hydraulic conductivity is moderate.**
- 1.8 **In Artificial recharge techniques normally address to following issues:**
- (i) To enhance the sustainable yield in areas where over development has depleted the aquifer.
 - (ii) To utilize the rainfall runoff, which is going to sewer or storm water drain.
 - (iii) Conservation and storage of excess surface water for future requirements, since these requirements often change within a season or a period.
 - (iv) Surface water is inadequate to meet our demand and we have to depend on ground water.
 - (v) Due to rapid urbanization, infiltration of rainwater into the sub soil has decreased drastically and recharge of ground water has diminished.
 - (vi) To arrest seawater ingress.
 - (vii) To improve the vegetation cover and reduce flood hazard
 - (viii) To raise the water levels in wells and bore wells that are drying up. To remove bacteriological and other impurities from sewage and waste water so that water is suitable for reuse.
 - (ix) To improve the quality of existing Ground Water through dilution.
 - (x) To reduce power consumption.
- 1.9 **The basic purpose of artificial recharge of Ground Water is to restore supplies from aquifers depleted due to excessive Ground Water development.**
- There are two main techniques of rainwater harvesting:**
- (i) Storage of rain water on surface for future use
 - (ii) Recharge to ground water
- 1.10 **Rain Water Harvesting from Roofs Consists of collecting, storing and putting to use rooftop rainwater from houses or any construction is rooftop rainwater harvesting.**
- 1.11 **Rainwater harvesting can also be collecting, filtering and recharging Ground Water through percolation pits, open wells or bore wells.**
- 1.12 **The sub-surface reservoirs are very attractive and technically feasible alternatives for storing surplus monsoon run off, the sub-surface reservoirs can store substantial quantity of water. The sub-surface geological formations may be considered as**

Warehouse for storing water that come from sources located on the land surface. Besides suitable litho logical conditions, other considerations for creating sub-surface storages are favorable geological structures and physiographic units, whose dimensions and shape will allow retention of substantial volume of water in porous and permeable formations. The sub-surface reservoirs, located in suitable hydro geological situations, are environment friendly and economically viable proposition. The sub-surface storages have advantages of being free from the adverse effects like inundation of large surface area, loss of cultivable land, displacement of local population, substantial evaporation losses and sensitivity to earthquakes. No gigantic structures are needed to store water.

- 1.13 The storage of rainwater on surface is a traditional technique and structures used were underground tanks, ponds, check dams, weirs etc. Recharge to ground water is a new concept of rain water harvesting and the structures generally used are:
- 1.14 The Need: Rain Water Harvesting and Conservation can be understood by the fact that even CHIRAPUNJI, which receives about 11000 mm rain fall annually, suffers from acute shortage of drinking water due to the reasons that Rain Water is not harvested and conserved and is allowed to drain away.

The annual rainfall over India is computed to be 1.170 mm, which is much higher than the global average of 800 mm. However, this rainfall in India occurs during short periods of high intensity and because of such high intensity and short duration most of the rain falling on the surface tends to flow away fast leaving little scope for re-charging of Ground Water resulting thereby lack of water in most part of the country even for domestic uses.

It is needed to implement measures to make sure that Rain Water falling over a region is tapped to the maximum possible extent through Rain Water harvesting and conservation, either by recharging it into the Ground Water resources or storing it for direct use.

(a) Pits, (b) Trenches, (c) Dug Wells, (d) Hand pumps, (e) Recharge wells, (f) Recharge shafts, (g) Lateral shafts with bore wells, (h) Spreading techniques.

All these structures with their specifications and situations where these are to be used are detailed in chapter No.5

- 1.15 The Govt of India has also realized the importance and necessity of rain water harvesting so Ministry of Urban Development & Poverty Alleviation has issued Gazette Notification of making suitable provision in the building bye-laws 1983 to ensure that the buildings that are erected in Delhi provide for the water harvesting through storing of rain water run off to recharge underground aquifer. The copy of the Gazette Notification is as on page -
- 1.16 The Ministry of Environment & Forest, Govt of India has also issued notification for Rain Water Harvesting with draft proposal. The copy of the notification dated 6th Oct. 2000 is on page -

The copy of the Gazette Notification issued by Ministry of Urban Development & Poverty Alleviation vide No.N-11011/9/98-DDVI(Pt.)/DDIB dtd 28th July, 2001 regarding modifications / additions to the building bye laws 1983 is as under:-

NOTIFICATION

S.O.—Whereas the issue of making suitable provision in the Building Bye laws 1983 to ensure that the buildings that are erected in Delhi provide for the water harvesting through storing of rain water runoff to recharge underground aquifers has been under the consideration of the Government.

Whereas the following modifications/additions which the Central Government proposed to make in the Building Bye-laws, 1983 in this regard were published for public information vide Public Notice dated 20th June, 2001 and were advertised in the leading newspapers on 30.6.2001. In all five objections/suggestions were received and they were examined by a Committee under the convenorship of Chief Planner of Town and Country Planning Organisation.

Whereas after thorough consideration of the report Central Government has decided to make the following Modifications/additions in the Building Byelaws, 1983.

Now, therefore, in exercise of the powers conferred by sub-section (2) of Section 11A of Delhi Development Act, 1957, the Central Government hereby makes the following modifications/additions to the Building Bye-laws, 1983 with effect from the date of publication of this notification in the Gazette of India.

MODIFICATIONS

1. Clause 22.4 Part – III (Structural Safety and Services) of the Building Bye-laws, 1983.
2. 22.4.1 Water harvesting through storing of water runoff including rain water in all new buildings on plots of 100 sq. mtrs and above will be mandatory. The plans submitted to the local bodies shall indicate the system of storm water drainage along with points of collection of rain water in surface reservoirs or in recharge wells. These provisions will be applicable as per the Public Notice (s) of Central Ground Water Authority issued from time to time.
3. 22.4.2 All buildings having a minimum discharge of 10,000 litres and above per day shall incorporate waste water recycling system. The recycled water should be used for horticultural purposes.

Note: These modifications/amendments will be applicable from the date of Notification.

(No.N-11011/9/98-DDVI(Pt) DDIB)

Sd/-

(Devendra Kumar Goel)

Under Secretary to the Govt of India

Annexure – A

Certificate: The following certificate is to be submitted along with the building drawings while submitting the plans.

3. Certified that the building plans submitted for approval satisfy the water harvesting requirements as well as minimum anticipated discharge of waste water as stipulated under clause 22.4.1 , 22.4.2 and the information given therein is factually correct to the best of our knowledge and understanding.

Signature of owner with date

Name in Block Letters

Address

Signature of Architect with date

Name in Block letters

Address

Copy of the Draft Gazette Notification of dated 6.10.2000 proposed to be issued Ministry of Environment & Forests regarding Rain Water Harvesting in Hilly Region is as under:

NOTIFICATION

S.O 916(E)—The following notification which the Central Government proposes to issue in exercise of the powers conferred by sub-section (1) read with clause (v) of sub-section (2) of section 3 of the Environment (Protection) Act, 1986 (29 of 1986) is hereby published as required under sub-rule (3) of rule 5 of the Environment (Protection) Rules, 1986 for information of all persons likely to be affected thereby and notice is hereby given that the said draft notification will be taken into consideration after the expiry of a period of sixty days from the date on which copies of the Gazette of India containing this notification are made available to the public.

Any person desirous of making any objection or suggestion in respect of the said draft notification may forward the same in writing for consideration of the Central Government within the period so specified to the Secretary to the Government of India, Ministry of Environment and Forests, Paryavaran Bhawan, CGO complex, Lodhi Road, New Delhi – 110003.

DRAFT PROPOSALS

It is proposed to issue a notification to protect and improve the quality of environment in the Himalayas, which would include the States of Arunachal Pradesh, Jammu & Kashmir, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, Tripura, and Districts of Dehra Dun, Haridwar, Almorá, Pithoragarh, Chamoli, Pauri Garhwal, Nainital, Uttar Kashi, Udham Singh Nagar, Rudra Prayag, Bageshwar, Tehri Garhwal and Champawat of Uttar Pradesh and Darjeeling district of West Bengal in the scope of this notification.

In order to ensure environmentally sound development of hill towns, the following restriction and conditions are proposed for all future activities in the areas in the Himalayan region.

Location Planning In Urban Areas in Hills

- (i) No construction should be undertaken in areas having slope above 30° or areas which fall in hazard zones or areas falling on the spring lines and first order streams identified by the State Governments on the basis of available – scientific evidence.
- (ii) Construction should be permitted in areas with slope between 10 to 30° or spring recharge areas or old landslide zones with such restrictions as the competent local authority may decide.
- (iii) Tourist resorts, commercial complexes and institutional buildings should be located in areas with surplus water and electricity so as not to affect the rights of existing users without their prior consultation.
- (iv) Where cutting in an area causes ecological damage and slope instability in adjacent areas, such cuttings shall not be undertaken unless appropriate measures are taken to avoid such damages.
- (v) An integrated development plan may be prepared taking into consideration environmental and other relevant factors including ecologically sensitive areas, hazard zones, drainage channels, steep slopes and fertile land. Areas rich in ground water may not be diverted for construction activities.

RAIN WATER HARVESTING

- (i) All buildings to be constructed in future in urban areas should have provision for roof top rain water harvesting commensurate with its plinth area with minimum capacity of 5 KL for plinth area above 200 sqm , 2KL for plinth area of 200 sqm or below in case of – residential buildings and minimum capacity of 0.01 cum per sqm of plinth area in case of commercial and institutional buildings such as tourist complexes, hotels, shopping complexes, and Government buildings.

Provided that minimum standards for commercial and institutional buildings shall also apply to such buildings in areas not covered within the limits of urban areas.

- (ii) Where minimum standards have already been laid down by the State Governments, such standards shall take precedence.
- (iii) The institutional and commercial buildings should not draw water from existing water supply schemes which adversely affects water supply to local villages or settlements.
- (iv) In rural areas rain water harvesting should be undertaken through such structures as percolation tanks and storage tanks and any other means.
- (v) Spring sanctuary development should be undertaken in the spring recharge zones to augment spring water discharge.
- (vi) Rain water collected through storm water drains should be used to clean the waste disposal drains and sewers.
- (vii) Ground water aquifer recharge structures should be constructed wherever such structures do not lead to slope instabilities.

HILL ROADS

Instructions to be issued by the State Governments for construction of Hill Roads:

- (i) For construction of any road in the Himalayan region of more than 5 km (including extension/widening of existing roads) length where the same may not be tarred roads and environmental impact assessment is otherwise not required, environmental impact assessment should be carried out in accordance with instructions to be issued for this purpose by the State Governments.
- (ii) Provisions should be made in the design of the road for treatment of hill slope instabilities resulting from road cutting, cross drainage works and culverts using bioengineering and other appropriate techniques by including the cost of such measures in the cost estimate of the proposed road.
- (iii) Provisions should also be made for disposal of debris from construction sites in appropriate manner at suitable and identified locations so as not to affect the ecology of the area adversely, further, the dumped material should be treated using bio engineering and other appropriate techniques and the cost of such measures should be included in the cost estimate of the proposed road.
- (iv) Wherever hot mix plants are used they should be set up at least 2 km away from settlements and minimum area of 200 sqm surrounding the site should be devoid of vegetation.

- (v) No stone quarrying should be carried out without proper overall management and treatment plan including rehabilitation plan and financial provision for rehabilitation of the site should be included in the cost of the management plan.
- (v) All hill roads should be provided with adequate number of road side drains and these drains shall be kept free from blockage for runoff disposal in the event that this is not done and this fact leads to damages that could otherwise have been prevented, the persons responsible should be liable for prosecution/damages, further, the cross drains shall be treated suitably using bioengineering and other appropriate technologies so as to minimize slope instability.
- (vii) The runoff from the road side drains should be connected with the natural drainage system in the area
- (viii) Fault zones and historically land slide prone zones should be avoided during alignment of a roads, where for any reason it is not possible to do so notice should be given providing full justification and the construction should be carried out only after sufficient measures have been taken to minimize the associated risks.
- (ix) Notice should be given about all fault zones and land slide zones along the roads indicating the beginning and the end of such areas.
- (x) Ridge alignment should be preferred to valley alignment
- (xi) Alignment should be selected so as to minimize loss of vegetal cover
- (xii) South or South west alignment should be preferred to avoid moist areas
- (xiii) Appropriate design standards should be followed while designing the roads including mass balancing of cut and fill and avoidance of unnecessary cutting.
- (xiv) Encouragement should be provided for use of debris material for local development.

CHAPTER 2

RAIN WATER HARVESTING

- 2.1 Rain Water Harvesting can be defined as activity of direct collection of Rain Water and storage of Rain Water as well as other activities aimed at harvesting and conserving surface and Ground Water, prevention of loss through evaporation and seepage and other hydrological studies and engineering inventions aiming at most efficient utilization of the Rain Water towards best use for the humanity.
- 2.2 Glossary of Terms:
- 2.2.1 Aquifer (also called ground water aquifer) any underground formation of soil or rock which can yield water.
- 2.2.2 Artificial recharge: Any man made scheme or facility that adds water to an aquifer is artificial recharge system
- 2.2.3 Bore well: Small diameter wells, which are generally deeper than open wells.
- 2.2.4 Dug Wells: Traditionally used large diameter wells. Defined precisely as pits excavated in the ground until the water table is reached, supported on the sides by RCC/Bricks/Stones Walls, Diameters could vary from 0.6 metres onwards.
- 2.2.5 Ground Water: The water retained in the intergranular pores of soil or fissures of rock below the water table is called ground water
- 2.2.6 Masonry: A wall or other structures made using building blocks like bricks or stone with binding materials like cement or lime.
- 2.2.7 Open Wells: Same as dug well. These wells were kept open in earlier days for manual withdrawal of water. Today, with electrical or diesel/petrol pumps, these can be fully covered.
- 2.2.8 Runoff: Runoff is the term applied to the water that flows away from a surface after falling on the surface in the form of rain
- 2.2.9 Recharge: The process of surface water (from rain or reservoirs) joining the ground water aquifer
- 2.2.10 Water Table: The level of water within it granular pores of soil or fissures of rock, below which the pores of the host are saturated.
- 2.3 Central PWD has been constructing and maintaining very large number of government buildings and there is enormous scope for the department to contribute towards this process of Rain Water harvesting and conservation.
- 2.4 The decision whether to store or recharge water depends on the rainfall pattern of a particular region. In a region where rain fall through out the year, barring a few dry periods, in such situations a small domestic sized water tank for storing rainwater can be used. Since the period between two spells of rain is short.

In other region where total annual rain fall occurs only during three to four months of monsoon, the water collected during monsoon has to be stored throughout the year which means that huge volumes of storage container are required so it is feasible to use rain water to recharge ground water aquifers rather than for storage.

2.5 Quantity of Rain Water & General Arrangement

The quantity of Rain Water, which can be harvested depends upon the annual rainfall, the area of the plot (catchment area) and soil characteristics. The amount of water infiltrated into the soil varies with the condition of soil surface and the moisture content of the soil at the time of rainfall. The total amount of water infiltrated depends on the infiltration opportunity time, which depends mainly on the slope of the land and the field structures like contour bunds, terraces and other structures, which tend to hold the runoff water over long periods on the land surface.

Rainfall data for major cities are as given on the next page Table No.1 (source Climatological tables of observations in India (1951-1980)).

2.6 Artificial Recharge Structures for Surface Run Off.

2.6.1 Ditch and furrow method (Refer Drawing No.01)

In areas with irregular topography, shallow, flat- bottomed and closely spaced ditches or furrows provide maximum water contact area for recharge water from source stream or canal. This technique requires less soil preparation than the recharge basins and is less sensitive to silting.

2.6.2 Lateral ditch pattern (Refer Drawing No.01)

The water from stream is diverted to the feeder canal/ditch from which smaller ditches are made in right angles. The rate of flow of water from the feeder canal to these ditches is controlled by gate valves. The furrow depth is kept according to the topography and also with the aim that maximum wetted surface is available along with maintenance of uniform velocity. The excess water is routed to the main stream through a return canal along with residual silt.

2.6.3 Percolation tanks (PT) Spreading, Basin (Refer Drawing No.02)

These are the most prevalent structures in India as a measure to recharge the ground water reservoir both in alluvial as well as hard rock formations. The efficacy and feasibility of these structures is more in hard rock formations where the rocks are highly fractured and weathered. In the states of Maharashtra, Andhra Pradesh, Madhya Pradesh, Karnataka and Gujrat, the percolation tanks have been constructed in plenty in basaltic lava flows and crystalline rocks. Percolation tanks are also constructed to recharge deeper aquifers where shallow or superficial formations are highly impermeable or clayey with certain modification.

While taking decision on construction of percolation tanks following points should be kept in mind.

- (i) In semi arid region the storage capacity of percolation tanks should be such that the water should percolate to ground water reservoir before onset of summer because during summer season evaporation losses would be higher.

- (ii) The percolation tank should be provided in the catchment where submergence area are smaller and such submergence area should be in un-cultivable land.
- (iii) Percolation tank should be located in highly fractured and weathered rock for speedy re-charge. In case of alluvium soil, the boundary formation(natural bunds) is ideal for locating percolation tank.
- (iv) The aquifer to be recharged should have sufficient thickness of permeable zone to accommodate the recharge.
- (v) The percolation tank should be provided in a region where sufficient number of wells and cultivatable land is there, to take advantage of recharge water.
- (vi) Normally 50% of total quantum of rain fall in catchment area should be considered to beside the number and size of percolation tanks.
- (vii) Suitable provision in the form of waste weir or spill – way to be made to allow the flow of surplus water which is in excess of maximum capacity of percolation tank in a particular day.
- (viii) To avoid erosion of embankment due to ripple action stone pitching to be provided up to high flood level in up stream side.

Table No. 1—Rainfall Data for Major Cities

[Source Climatological tables of observations in India (1951-1980)
by Indian Metrological Department].

S. No.	City	Annual rain fall (mm)(R)	S.No.	City	Annual rain fall (mm)(R)
A-1 Class					
1	Mumbai	2146.6	38	Solapur	750.8
2	New Delhi (Safdarjung)	797.3	39	Thiruvananthapuram	1827.7
3	New Delhi (Palam)	794.0	40	Tiruchirappali	880.2
A-Class					
4	Ahmedabad	803.4	41	Varanasi	1025.4
5	Bangalore	970.0	42	Vishakhapatnam	968.8
C-Class					
6	Calcutta	1641.4	43	Portblair	3168.8
7	Chennai	1333.8	44	Dibrugarh	2588.7
8	Hyderabad	812.5	45	Tezpur	1768.3
B-1 Class					
9	Bhopal	1146.7	46	Chapra	1028.3
10	Indore	1008.3	47	Jamshedpur	1320.7
11	Jaipur	673.9	48	Muzaffarpur	1239.8
12	Kanpur	832.6	49	Bhuj	413.6
13	Lucknow	1021.5	50	Karnal	814.1
14	Ludhiana	752.3	51	Simla	1424.8
15	Nagpur	1112.7	52	Bidar	981.1
16	Pine	721.7	53	Hoshangabad	1225.9
17	Surat	1209.4	54	Ratlam	1033.5
B-2 Class					
18	Agra	776.5	55	Ujjain	934.1
19	Allahabad	1017.7	56	Kolhapur	1138.5
20	Amritsar	681.2	57	Imphal	1353.1
21	Aurangabad	688.05	58	Shillong	2050.5
22	Bareilly	1071.9	59	Kohima	1856.0
23	Chandigarh	1059.3	60	Bhubaneshwar	1542.2
24	Coimbatore	631.0	61	Cuttack	1475.3
25	Gorakhpur	1228.1	62	Pathankot	1319.0
26	Guwahati	1717.7	63	Alwar	774.6
27	Gwalior	899.0	64	Vellure	1004.4
28	Jabalpur	1331.6	65	Agartala	2178.6
29	Kochi	3228.3	66	Aligarh	781.6
30	Kota	761.4	67	Dehradun	2315.4
31	Madurai	873.3	68	Roorkee	1156.4
32	Meerut	901.0	69	Darjiling	2667.1
33	Nasik	703.0			
34	Patna	1003.4			
35	Rajkot	726.9			
36	Ranchi	1431.6			
37	Salem	1014.0			

2.7 Sample Calculation for Quantity of Rain Water which can be harvested

2.7.1 How much water can be harvested

The total amount of water i.e. received in the form of rainfall over an area is called the rainwater endowment of that area. Out of this the amount that can be effectively harvested is called the rainwater harvesting potential.

Rain water harvesting potential	=	Rain fall (mm) x collection efficiency
Annual rain fall of any city / place	(Say)	600 mm (Ref Table No.1)
Area of Roof Catchment		100 Sqm
Height of rain fall		0.6m
Vol. Of rain fall over the plot		= Area plot x height of rain fall
Rain water endowment of that area		= 100 Sqm x 0.6 m = 60 cum =60,000 litres (Say 'A')

Sample calculation for effectively harvested water from total rainfall

- (i) Considering roof catchment is having tile finish so coefficient for roof surface can be adopted as 0.85 (Ref Table No.2)
- (ii) Another constant coefficient for evaporation, spillage and first flush wastage can be considered as 0.80 (for all situations)

Statistically and approximately only effectively harvested water quantity may be considered as = Rain Water endowment of that area ('A') x 0.80 x Surface efficient (to be obtained from Table No.2)

$$= 60,000 \times 0.80 \times 0.85$$

$$= 40,800 \text{ litres}$$

This volume is about twice the annual drinking water requirement of a 5 member family. The average drinking water is required per person per day is 10 litres.

2.7 The collection efficiency accounts for the facts that all the rain water falling over an area cannot be effectively harvested because of evaporation, spillage etc. Factor like run off coefficient as stated for various types of roof and land surfaces etc. as shown in Table No.2 and the first flush wastage i.e. first spell of rain is flushed out, evaporation and spillage does not enter the system so a constant co-efficient of 0.80 may be adopted for all situations. This is done because the first spell of rain carries with it a relatively larger amount of pollutenants from the air and catchment surface.

TABLE No. 2
RUNOFF CO-EFFICIENT OF VARIOUS SURFACES

1. Roof Catchment		Co-efficient
1.1	Tiles	0.8-0.9
1.2	Corrugated metal sheets	0.7-0.9
2. Ground Surface Covering		
2.1	Untreated Ground Catchments	
2.1.1	Soil on slope less than 10%	0.0-0.3
2.1.2	Rocky material catchment	0.2-0.5
2.1.3	Business Area	
2.1.3.1	Down town	0.70- 0.95
2.1.3.2	Neighbourhood	0.50 - 0.70
2.2	Residential Complexes in Urban Areas	
2.2.1	Single family	0.30 - 0.50
2.2.2	Multiunits, detached	0.40 - 0.60
2.2.3	Multiunits, attached	0.60 - 0.75
2.3	Residential Complexes in Suburban Areas Apartments	0.50 - 0.70
2.4	Industrial	
2.4.1	Light	0.50 - 0.70
2.4.2	Heavy	0.60 - 0.90
2.5	Parks, cemeteries	0.10 - 0.25
2.6	Play grounds	0.20 - 0.35
2.7	Railroad yard	0.20 - 0.35
2.8.	Unimproved Land Areas	0.10 - 0.30
2.9	Asphaltic or concrete pavement	0.70 - 0.95
2.10	Brick pavement	0.70 - 0.85
2.11	Lawns, sandy soil having slopes	
2.11.1	Flat 2%	0.05 - 0.10
2.11.2	Average 2 to 7%	0.10 - 0.15

2.11.3	Steep 7%	0.15 - 0.20
2.12	Lawns, clayey soil having slopes	
2.12.1	Flat 2%	0.13 - 0.17
2.12.2	Average 2 to 7%	0.18 - 0.22
2.12.3	Steep 7%	0.25 - 0.35
2.13	General Driveways and walls	0.15 - 0.30

(Source ASCE and WPCF 1969)

Whereas the use of the runoff coefficients implies there is a constant ratio of rainfall to runoff, the actual ratio will vary over the course of a storm due to condition of the area and the variability of the rainfall pattern. A common practice is to use average coefficients for various types of areas and assumed that the coefficients will be constant throughout the duration of the storm.

CHAPTER 3

ROOF TOP RAIN WATER HARVESTING

3.1 Domestic Rain Water harvesting or roof top Rain Water harvesting is the technique through which Rain Water is captured from roof catchments and stored in tanks/reservoirs/Ground Water aquifers. It consists of conservation of roof top Rain Water in urban areas and utilizing it to augment Ground Water storage by artificial recharge. It requires connecting the outlet pipe from roof top to divert collected water to existing well/tube well/bore well or a specially designed well.

The details of such sample schematic arrangements under few typical type of colonies have been shown in Drawing No.03 to 08 for general guidance.

3.2 The approximate volume of water available for harvesting with respect to roof top area and annual rain fall of that area has been shown in Table No .3 on page - or designing the Rain Water Harvesting Structures.

3.3 Roof Top Rain Water Harvesting & Conserving Systems, both small and large are comprised of six basic components as described below:

- (i) **Catchment Area/Roof:** Surface upon which rain falls
- (ii) **Gutters and Downspouts:** transport channels from catchment surface to storage
- (iii) **Leaf Screens and Roof Washers:** Systems that remove contamination and debris.
- (iv) **Cisterns or Storage Tanks:** where collected Rain Water is stored
- (v) **Conveying:** the delivery system for treated Rain Water, either by gravity or pump
- (vi) **Water Treatment:** filters and equipment and additives to settle, filter and disinfect.

3.4 The system involves collecting water that falls on zinc, asbestos or tiles roof of a house during rain storms, and conveying it by an Aluminium, PVC wood or plastic drain or collector to a nearby covered storage unit or cistern. Rain Water yield varies with the size and texture of the catchment area. A smoother, cleaner and more impervious roofing material contributes to better water quality and greater quantity.

TABLE NO.3
AVAILABILITY OF RAIN WATER THROUGH ROOF TOP
RAIN WATER HARVESTING

Rainfall(mm) Roof top area (Sqm)	Harvested Water from Roof Top (cum)												
	100	200	300	400	500	600	800	1000	1200	1400	1600	1800	2000
20	1.6	3.2	4.8	6.4	8	9.6	12.8	16	19.2	22.4	25.6	28.8	32
30	2.4	4.8	7.2	9.6	12	14.4	19.2	24	28.8	33.6	38.4	43.2	48
40	3.2	6.4	9.6	12.8	16	19.2	25.6	32	38.4	44.8	51.2	57.6	64
50	4	8	12	16	20	24	32	40	48	56	64	72	80
60	4.8	9.6	14.4	19.2	24	28.8	38.4	48	57.6	67.2	76.8	86.4	96
70	5.6	11.2	16.8	22.4	28	33.6	44.8	56	67.2	78.4	89.6	100.8	112
80	6.4	12.8	19.2	25.6	32	38.4	51.2	64	76.8	89.6	102.4	115.2	128
90	7.2	14.4	21.6	28.8	36	43.2	57.6	72	86.4	100.8	115.2	129.6	144
100	8	16	24	32	40	48	64	80	96	112	128	144	160
150	12	24	36	48	60	72	96	120	144	168	192	216	240
200	16	32	48	64	80	96	128	160	192	224	256	288	320
250	20	40	60	80	100	120	160	200	240	280	320	360	400
300	24	48	72	96	120	144	192	240	288	336	384	432	480
400	32	64	96	128	160	192	256	320	384	448	512	576	640
500	40	80	120	160	200	240	320	400	480	560	640	720	800
1000	80	160	240	320	400	480	640	800	960	1120	1280	1440	1600
2000	160	320	480	640	800	960	1280	1600	1920	2240	2560	2880	3200
3000	240	480	720	960	1200	1440	1920	2400	2880	3360	3840	4320	4800

(Extract from CGWB Guide) Central Ground Water Board

- 3.5 The broad idea about the particular dia of pipe which will be required to cater the certain roof surface area for given average rate of rain fall in millimeter per hour is shown in Table No. 4 is on page -

TABLE NO.4
SIZING OF RAIN WATER PIPES FOR ROOF DRAINAGE

S.No.	Diameter of pipe (mm)	Average rate of Rain Fall (mm per hour)					
		50	75	100	125	150	200
		Roof Area (Sqm)					
(i)	50	13.4	8.9	6.6	5.3	4.4	3.3
(ii)	65	24.1	16.0	12.0	9.6	8.0	6.0
(iii)	75	40.8	27.0	20.4	16.3	13.6	10.2
(iv)	100	85.4	57.0	42.7	34.2	28.5	21.3
(v)	125	-	-	80.5	64.3	53.5	40.0
(vi)	150	-	-	-	-	83.6	62.7

(Extract from SP-35)

This Table will help in determining the number of pipes of particular dia are required for given roof surface area and average of rate of rain fall in millimeter per hour for that area.

- 3.5 The graph No.1 shown on page No. gives fair idea about amount of peak precipitation may likely to happen (shown in Y - axis) for different duration of rain falls shown in curved lines with respect to recurrence intervals shown in the years (along X – axis). This will give idea about peak rain fall intensity for a particular station for which settlement time are to be designed for 15 minutes duration of peak rain falls.

CHAPTER – 4

DESIGN OF STORAGE / SETTLEMENT TANKS

4.1 Design for Storage Tanks

The quantity of water stored in a water harvesting system depends on size of the catchment area and the size of the storage tanks. The storage tanks has to be designed according to the water requirements, rain fall and catchment availability. The rain water is to be stored for drinking purpose in a situation shown in para 2.4

4.2 Basic Data

- (i) Avg annual rainfall
- (ii) Size of catchment
- (iii) Drinking water requirements

Suppose the system has to be designed for meeting drinking water requirement of a 5 member family living in a building with a roof top area of 100 Sqm. Avg. annual rain fall is 600 mm. Daily drinking & cooking water requirement per person is 10 litres.

We shall first calculate the maximum amount of rain fall that can be harvested from roof top.

Area of Roof top	= 100 Sqm
Average annual rain fall	= 600 mm
Runoff co-efficient for tiles surface (typical case)	= 0.85 (Ref Table No.2)
Co-efficient for evaporation, spillage and first flush etc. annual water harvesting potential from	= 0.80 (Ref Para 2.9)

100 Sqm roof top = (Area of roof top) x (Annual rain falls in metre) x (Run off coefficient to be obtained from Table No.2) x (Constant co-efficient Refer Para 2.8)

$$= 100 \times .60 \times .85 \times 0.80 = 40.8 \text{ cum} = 40,800 \text{ litres}$$

The tank capacity has to be designed for dry period i.e. the period between two consecutive rainy season. With monsoon extending over 4 months the dry season is of 245 days has been considered.

Drinking water requirement for family for dry season $245 \times 5 \times 10 = 12,250$ litres

As a safety factor, the tank should be built 20% larger than required i.e. 14700 litres = (1.2 x 12250)

This tank can meet the basic drinking & cooking water requirement of a 5 member family for the dry period.

4.2 Design parameters for settlement tank

Settlement tanks are used to remove silt and other floating impurities from rain water. Settlement tank is like an ordinary container having provision for in flow, out flow and over flow. Settlement tank can have an unpaved bottom surface to allow standing water to percolate into the soil. Apart from removing silt from water the desilting chamber acts like a buffer in the system.

For designing the optimum capacity of the tank following aspects have to be considered:

- (i) Size of catchment
- (ii) Intensity of rainfall
- (iii) Rate of recharge

Since the desilting tank also acts as buffer tank, it is designed such that it can retain a certain amount of rainfall, since the rate of recharge may not be comparable with the rate of run off. The capacity of tank should be enough to retain the run off occurring from conditions of peak rain fall intensity. In Delhi peak hourly rain fall 90 mm. The rate recharge in comparison to run off is a critical factor. However, since accurate recharge rate are not available without detailed Geo-hydrological studies. The rates have to be assumed.

The capacity of recharge tank is designed to retain runoff for at least 15 minutes of rainfall of the peak intensity (for Delhi 22.5 mm/ per 15 minutes say 25 mm per 15 minutes)

Suppose the following data is available

Surface Area of roof top catchment (A)	100Sqm
Peak rainfall in 15 min (r)	25 mm
Runoff co-efficient (C)	0.85

Then capacity of tank = $A \times r \times C = 100 \times 0.025 \times 0.85 = 2.125 \text{ cum} = 2,125 \text{ litres}$.

To obtain indicative peak rain fall for various stations the basic rain fall data for that station may be collected from Indian Metrological Office and refer para 3.5 and Graph No.1 (from which peak rain fall for different duration of rain fall can be obtained for given recurrence interval in years and this recurrence interval can be related to the expected life of settlement tank structure.

4.3 Options for settlement tank

Any container with adequate capacity of storage can be used as a settlement tank. Generally masonry or concrete underground tanks are preferred. Since they do not occupy any surface area. For over ground tanks pre-fabricated PVC or ferro cement tanks can be used and prefabricated tanks are easier to install so it should be preferred.

CHAPTER – 5

RE-CHARGE STRUCTURE AND ITS DESIGN

5.1 Re-charge structures :

The basic purpose of artificial recharge of Ground Water is to restore supplies from aquifers depleted due to excessive Ground Water development and usage.

Detailed knowledge of geological and hydrological features of the area is necessary for adequately selecting the site and type of recharge structures. In particular, the features parameters and data to be considered are: geological boundaries, hydrological boundaries, inflow and outflow of water, storage capacity, porosity, hydraulic conductivity, transmissivity, natural discharge of springs, water resources available for recharge, natural recharge, water balance, lithology, depth of aquifer, tectonic boundaries. The aquifer best suited for artificial recharge are those aquifers which absorb large quantity of water and do not release the same to quickly.

5.2 The various type of recharge structures are :

- (i) Recharge Through Abandoned Dug Well
- (ii) Recharge Through Hand Pump
- (iii) Recharge pit
- (iv) Recharge Through Trench
- (v) Gravity Head Recharge Tube Well
- (vi) Recharge Shaft

5.3 DESIGN GUIDELINES:

In general the recharge structures are designed with total volume as twice the peak discharge as detailed below:

5.3.1 ABANDONED DUG WELL (Ref Drawing No9 & 10)

- (i) A dry/unused dug well can be used as a recharge structure
- (ii) The recharge water is guided through a pipe to the bottom of well or below the water level to avoid scouring of bottom and entrapment of air bubbles in the aquifer.
- (iii) Before using the dug well as recharge structure, its bottom should be cleaned and all the fine deposits should be removed
- (iv) Recharge water should be silt free as far as possible.
- (v) It should be cleaned annually preferably.

- (vi) It is suitable for large building having the roof area more than 1000 Sqm
- (vii) Cost Rs.5000 to Rs.8000 as per prevailing rates in the year 2000 in Delhi.
- (viii) The run off of 1st rain should not be allowed to go percolate to the rain water harvesting structure and allowed it to go to the drain by making suitable by-pass arrangement in water carrying pipe systems.

5.3.2 ABANDONED / RUNNING HAND PUMP (Ref Drawing No.11)

- (i) An abandoned/running hand pump can be used for recharge
- (ii) The structures are suitable for the small building having the roof area upto 150 Sqm
- (iii) Water is diverted from rooftop to the hand pump through pipe of 50 to 100 mm dia
- (iv) For running hand pump a closing valve is fitted in conveyance system near hand pump to avoid entry of air in suction pipe
- (v) Recharge water should be silt free
- (vi) The run off of 1st rain should not be allowed to go percolate to the rain water harvesting structure and allowed it to go to the drain by making suitable by-pass arrangement in water carrying pipe systems.
- (vii) Cost Rs.1500/- to Rs.2500/- as per prevailing rates in the year 2000 in Delhi.

5.3.3 RECHARGE PIT (Ref Drawing No.12)

- (i) Recharge pits are constructed for recharging the shallow aquifer.
- (ii) These are constructed generally 1 to 2 m wide and 2 to 3 m deep
- (iii) After excavation, the pits are refilled with pebbles and boulders
- (iv) Water to be recharged should be silt free as far as possible.
- (v) Cleaning of the pit should be done annually preferably.
- (vi) It is suitable for small buildings having the roof top area upto 100 Sqm
- (vii) Recharge pit may be of any shape i.e. circular, square or rectangular.
- (viii) The run off of 1st rain should not be allowed to go percolate to the rain water harvesting structure and allowed it to go to the drain by making suitable by-pass arrangement in water carrying pipe systems.
- (ix) If the pit is of trapezoidal shape, the side slopes should be steep enough to avoid silt deposition.

- (x) Cost Rs.2500/- to Rs.5000/- as per prevailing rates in the year 2000 in Delhi.

5.3.4 RECHARGE TRENCH (Ref Drawing NO.13& 14)

- (i) It is constructed when permeable strata of adequate thickness is available at shallow depth
- (ii) It is a trench of shallow depth filled with pebbles and boulders
- (iii) These are constructed across the land slope
- (iv) The trench may be 0.5 to 1 m wide 1 to 1.5 m deep and 10 to 20 m long depending upon the availability of land and roof top area
- (v) It is suitable for the buildings having the roof area of 200 to 300 Sqm
- (vi) Cleaning of trench should be done periodically.
- (vii) Cost Rs.5000 – 10,000/- as per prevailing rates in the year 2000 in Delhi.

5.3.5 GRAVITY HEAD RECHARGE WELL (Ref Drawing No15 TO 19)

- (i) Bore wells/tube wells can be used as recharge structure
- (ii) This technique is suitable where
 - (a) Land availability is limited
 - (b) When aquifer is deep and overlaid by impermeable strata (clay)
- (iii) The roof top Rain Water is channelised to the well and recharges under gravity flow condition
- (iv) Recharge water should be silt free as far as possible.
- (v) The well can also be used for pumping
- (vi) Most suitable for the areas where Ground Water levels are deep
- (vii) The number of recharging structures can be determined in limited area around the buildings depending upon roof top area and aquifer characteristics.
- (viii) The run off of 1st rain should not be allowed to go percolate to the rain water harvesting structure and allowed it to go to the drain by making suitable by-pass arrangement in water carrying pipe systems.
- (ix) Cost Rs.50,000/- to Rs.80,000/- as per prevailing rates in the year 2000 in Delhi.

5.3.6 RECHARGE SHAFT (Ref Drawing No.20 to 22)

- (i) A recharge shaft is dug manually or drilled by the reverse/direct rotary method
- (ii) Diameter of recharge shaft varies from 0.5 to 3 m depending upon the availability of water to be recharged
- (iii) It is constructed where the shallow aquifer is located below clayey surface.
- (iv) Recharge shaft is back filled with boulders, gravels and coarse sand
- (v) It should end in more permeable strata (sand)
- (vi) Depth of recharge shaft varies from 10 – 15 m below ground level
- (vii) Recharge shaft should be constructed 10 to 15 m away from buildings for the safety of building
- (viii) It should be cleaned annually preferably by scraping the top layer of sand and refilling it accordingly.
- (ix) Cost Rs.60,000/- to Rs.85,000/- as per prevailing rates in the year 2000 in Delhi.

5.4 Maintenance of recharge structure

Roof Top Rain Water Harvesting for Ground Water recharge involves injection of rain water in to the aquifer through recharge trench cum tube wells under gravity flow. The surface water although treated through the filter bed may cause clogging after comparatively short periods of injection. In this case through the precaution is taken, there is a probability of silt being injected into the recharge wells and may cause clogging. Short periods of pumping quickly remove the clogging particles and improve the recharge capacity. Annual redevelopment of recharge wells by air compressor is recommended for improving the recharge capacity of trench cum recharge wells. Moreover silt deposited on sand bed also reduce the recharge rate. This also needs periodic removal of the finer material by scraping.

5.5 The type of Recharge structure to be considered for different areas (Alluvial areas or Hard Rock areas) in Delhi for various roofs are shown in Table – 5.

The whole complex/colony can be suitably divided in various clusters and one of the above system appropriate to roof size and underground characteristics may be selected for use/execution.

5.6 General Recommendations for Rain Water Harvesting

5.6.1 Guidelines for action plan for artificial recharge project .

- (i) Collect basic data on topography , rainfall pattern of that area , hydro-geology aquifer situation, land-source water availability. Identify the methods which is most suitable.

TABLE NO. 5

Roof Area Sq.m	Total Rainfall Volume for considering Delhi.	Vol. Available for recharge 80% Cum	Type of Structure recommended for recharge	
			Alluvial Area	Hard Rock Area
50	30	24	Recharge pit/hand pump	Recharge pit/hand pump
100	60	48	"	"
150	90	72	"	"
200	120	96	Trench	Trench/hand pump
300	180	144	"	"
400	240	192	Gravity head recharge well	Gravity head recharge well
500	300	240	"	"
600	360	288	"	"
800	480	384	"	"
1000	600	480	"	"
1500	900	720	"	Recharge shaft/dug well
2000	1200	960	"	"
2500	1500	1200	Recharge shaft/ dug well	"
3000	1800	1440	"	"
4000	2400	1920	"	"
5000	3000	2400	"	"

(Source : Central Ground Water Board)

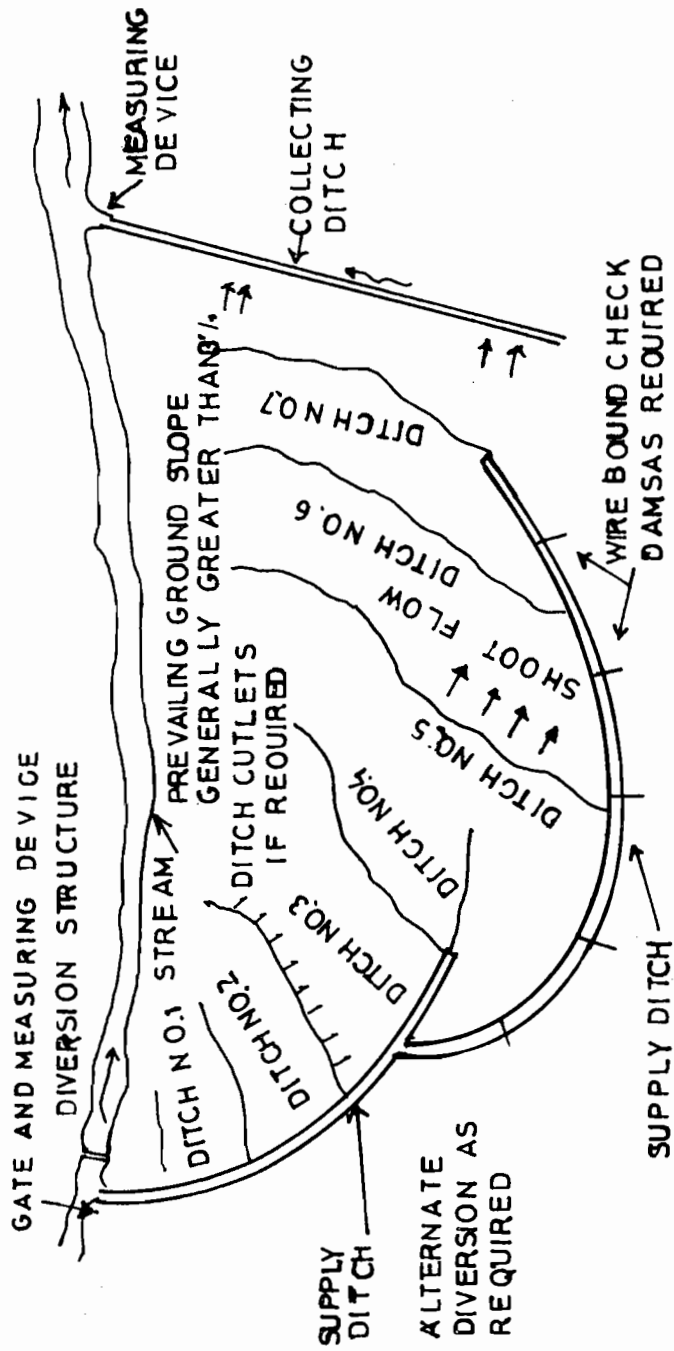
- (ii) With reference to the local conditions of the area, further identify the most appropriate techniques of artificial recharge suitable at various sites/ locations on the basis of total available volume of rainwater which can be harvested and the location of available aquifer. whether it is at shallow depths i.e. 6 to 8 meters from ground level or at sufficient depths i.e. more than 8 meters from ground level.
- (iii) Determine the number of each type of artificial recharge structure needed to achieve the quantitative targets. The recharge structure should be designed with volume of water it may store for equivalent of 24hours rainfall and surface area of run-off for which the recharge structure has been considered, without giving any allowance for percolation during this period of 24 hours.
- (iv) For individual structure at different locations ,finalise the design specifications from the details given in case studies. If required ,the necessary advice from local Geological Department or Central Ground Water Board may be obtained.

- (v) Finalise the design of the conveyance system required to bring the source water to the recharge structure site and the treatment required in the form of settlement tanks.
 - (vi) Plan the required monitoring system to evaluate the efficiency of recharge scheme and ensure regular maintenance of recharge structures before onset of monsoon every year.
- 5.6.2 In a given plot attempt should be made to keep the maximum plot area as katcha area which allows rain water for percolation to ground water.
- 5.6.3 The rain water from seasons first rain should normally not be used for percolation to recharge structure because it contains pollutants from the air and catchment surface. For such water suitable arrangement for by-pass in pipe system should be introduced.
- 5.6.4 A suitable provision should be made if possible to allow rain water to percolate to ground water after passing it through settlement tank because such rain water contains silt which is deposited on sand bed and reduces the percolation rates.
- 5.6.5 The recharge structure should be made on a plot at the places of lower levels / elevations so that rain water may flow towards it under normal gravitation flow.
- 5.6.6 On a vast and sloppy land patch, the contour bunds preferably of mud with height varying from 15 cm to 30 cm should be made to store run off temporarily over the katcha land area, thus allowing more time for percolation of water to the ground water and arresting the flow of run off to the drains / sewers.
- 5.6.7 For recharge of run off from roads suitable arrangements in the foot path by introducing some katcha area should be made.
- 5.6.8 In large residential and office complexes the drive ways, pucca path and areas should had some katcha area which may facilitate rain water to percolate to ground water.
- 5.6.9 Ideal conditions for rain water harvesting and artificial recharge to ground water Artificial recharge techniques are adopted where:
- (i) Adequate space for surface storage is not available specially in urban areas.
 - (ii) Water level is deep enough (more than 8 mtr) and adequate sub- surface storage is available.
 - (iii) Permeable strata is available at shallow/moderate depth upto 10 to 15 mtr.
 - (iv) Where adequate quality of surface water is available for recharge to ground water
 - (v) Ground water quality is bad and our aim is to improve it
 - (vi) Where there is possibility of intrusion of saline water especially in coastal area.

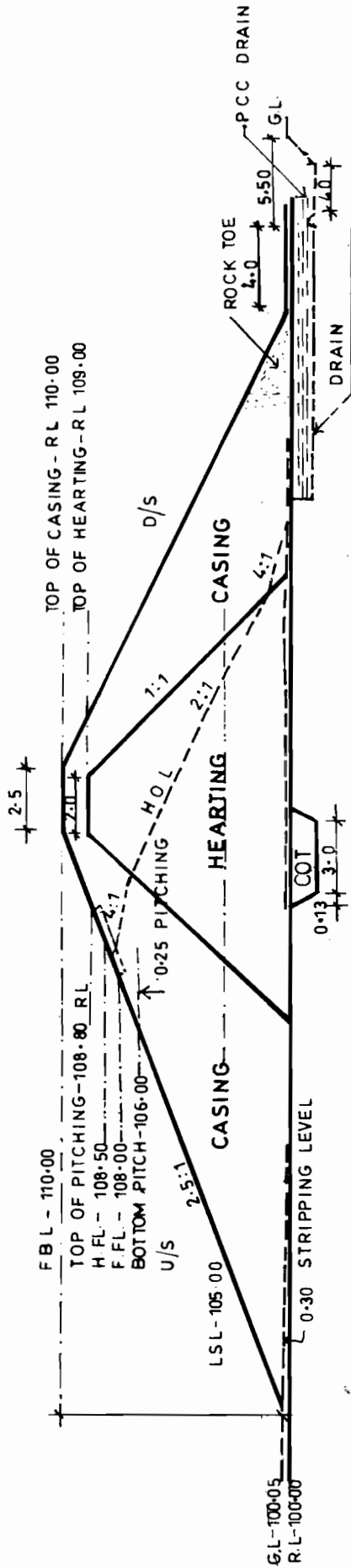
(vii) Where the evaporation rate is very high from surface water bodies.

5.6.10 The decision whether to store or recharge rain water depends on the rain fall pattern of a particular region.

- (i) If the rain fall period between two spells of the rain is short i.e. two to four months, in such situation a small domestic size water tank for storing rain water for drinking and cooking purpose can be used.
- (ii) In other regions where total annual rain fall occurs only during 3 to 4 months of monsoon and the period between two such spells is very large i.e. 7 to 8 months, so it is feasible to use rain water to percolate to the ground water aquifers rather than for storage which means that huge volumes of storage container are required.

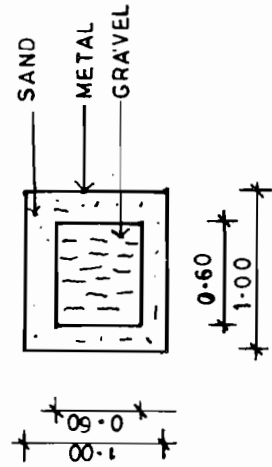
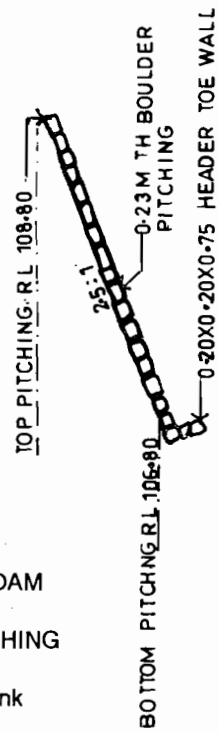


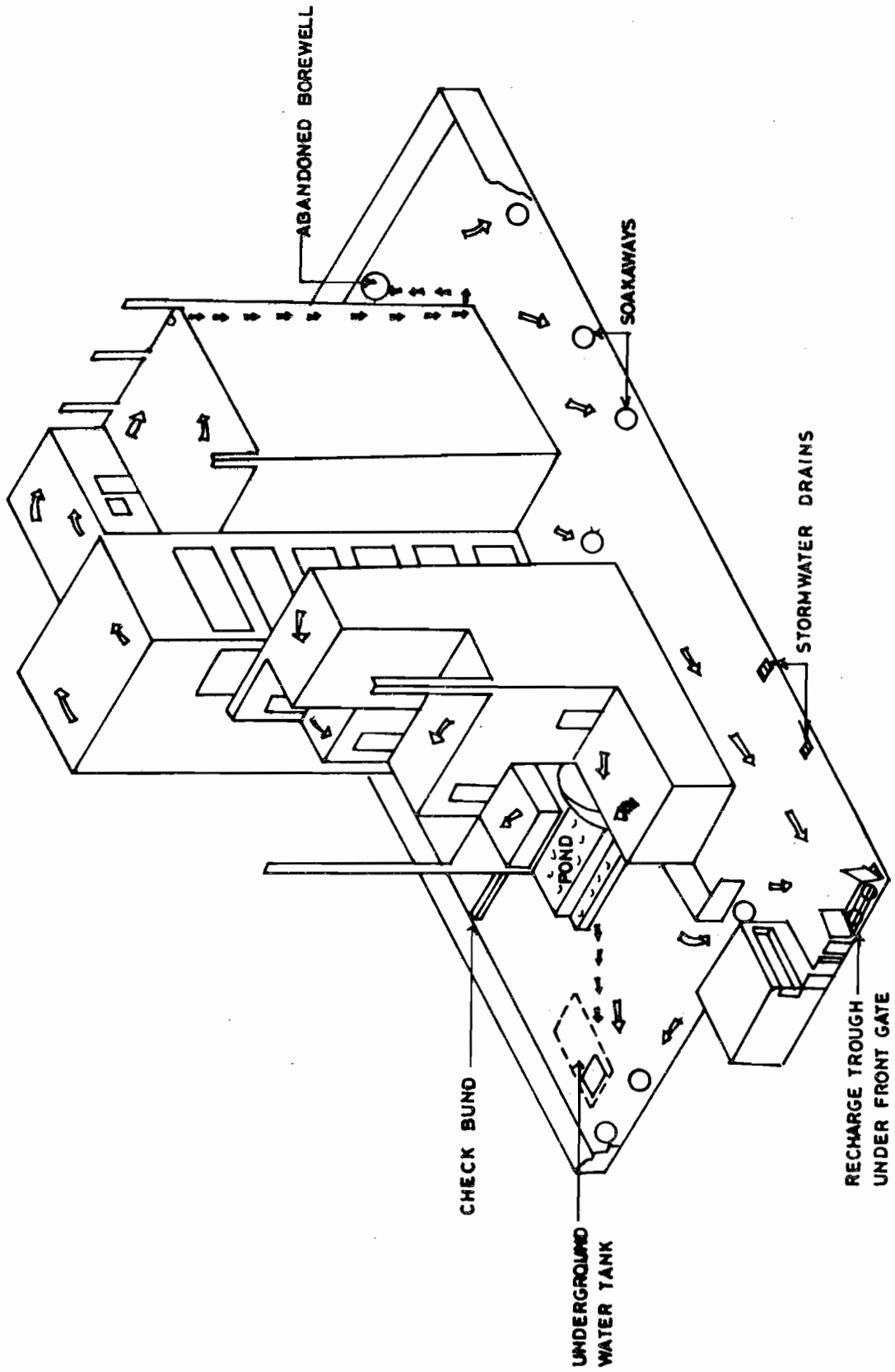
Drg-01: Ditch and furrow method



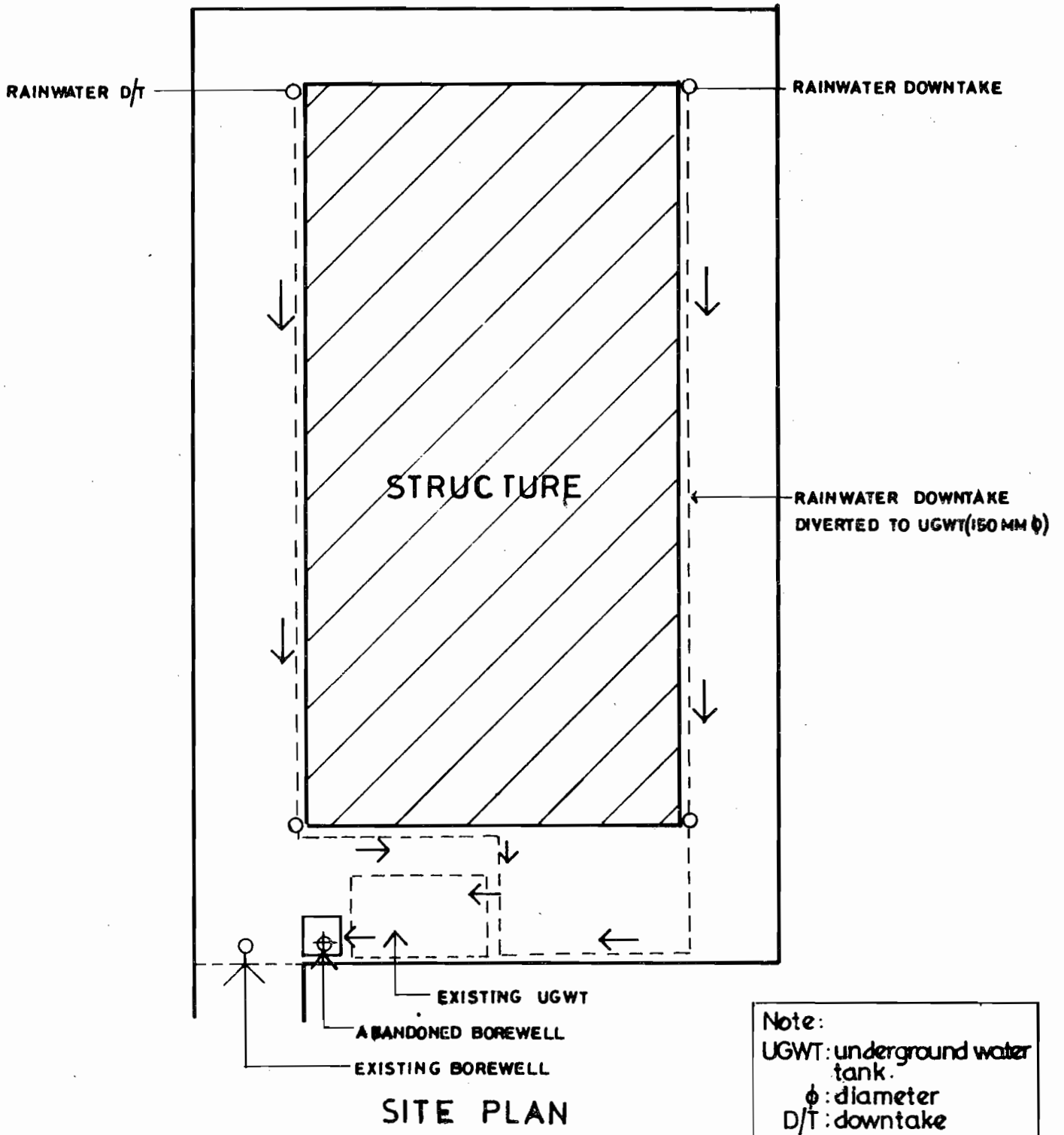
CROSS SECTION OF DAM
 DETAIL OF STONE PITCHING

Drg-02: Percolation tank

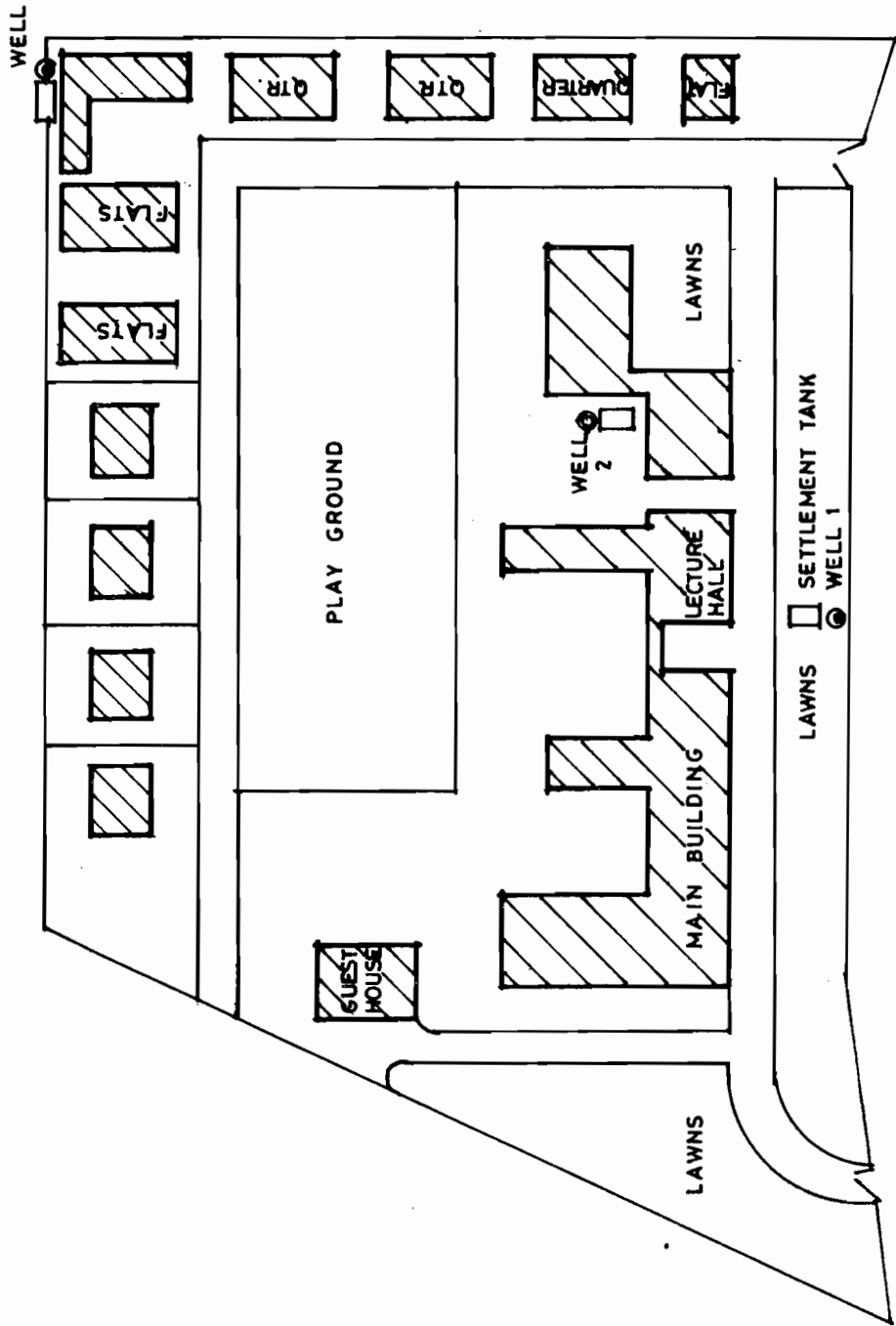




Drg-03: The water harvesting system in the building

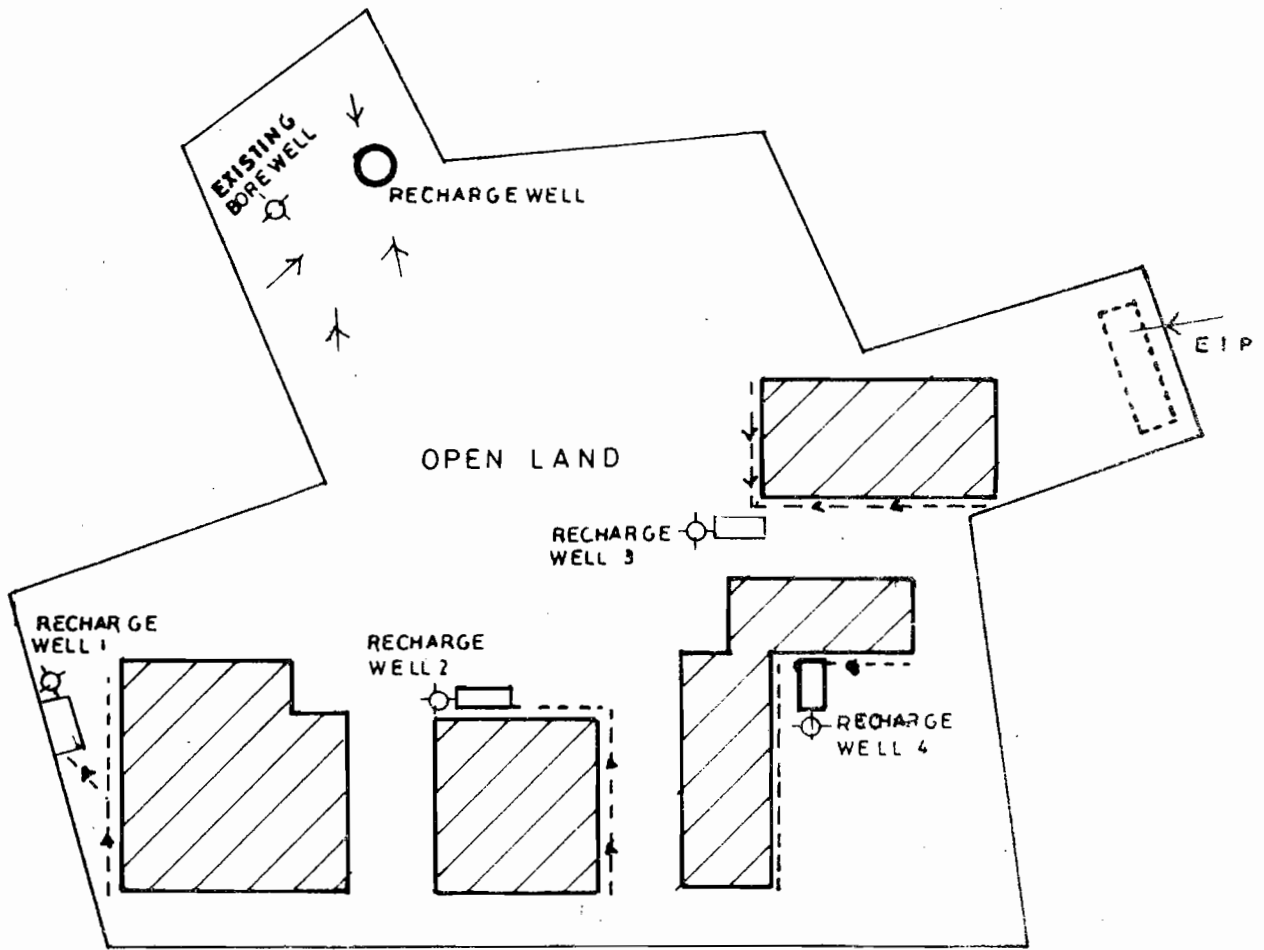


Drg-04: Scheme for water harvesting

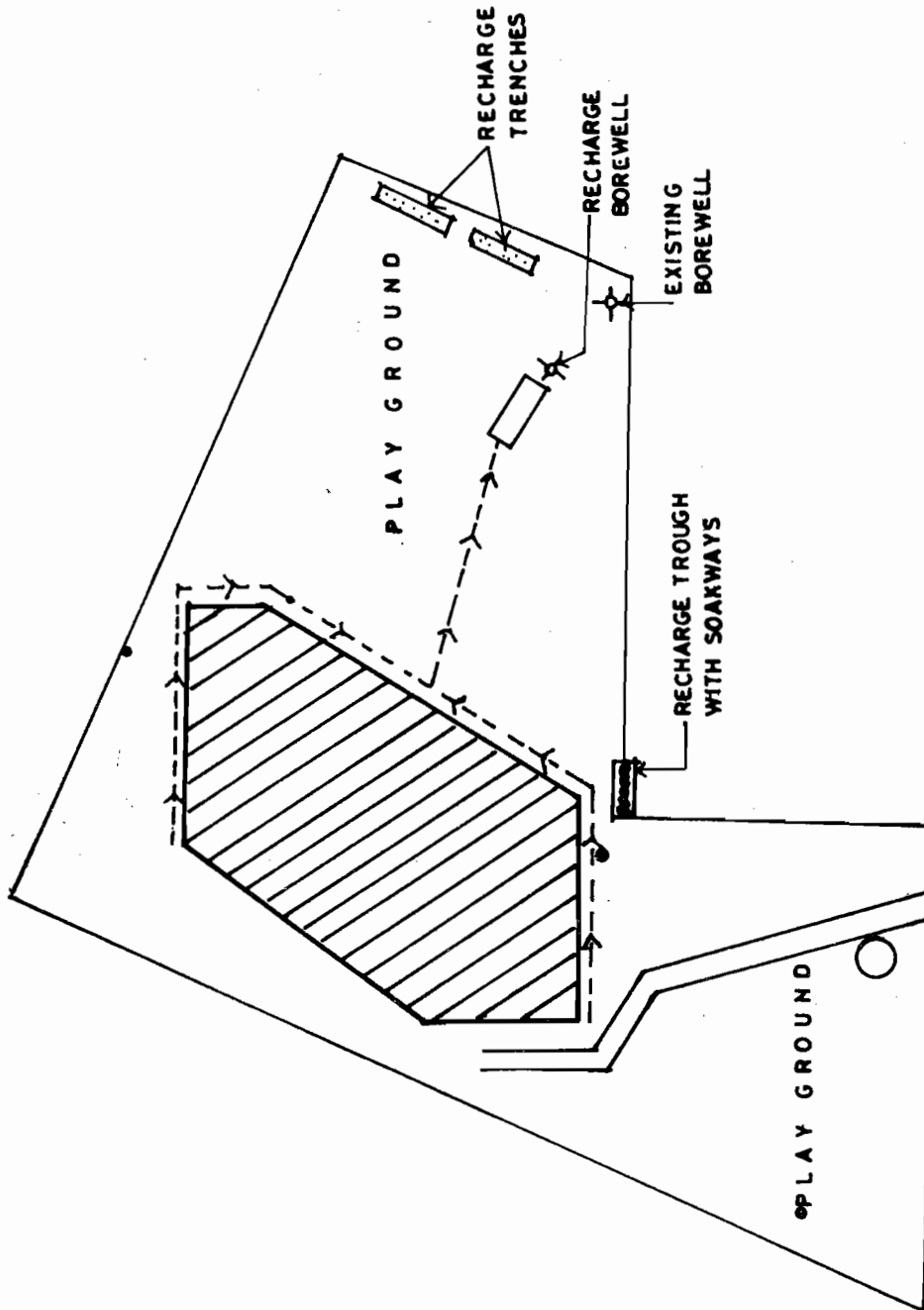


SITE PLAN

Drg-05: Scheme for water harvesting

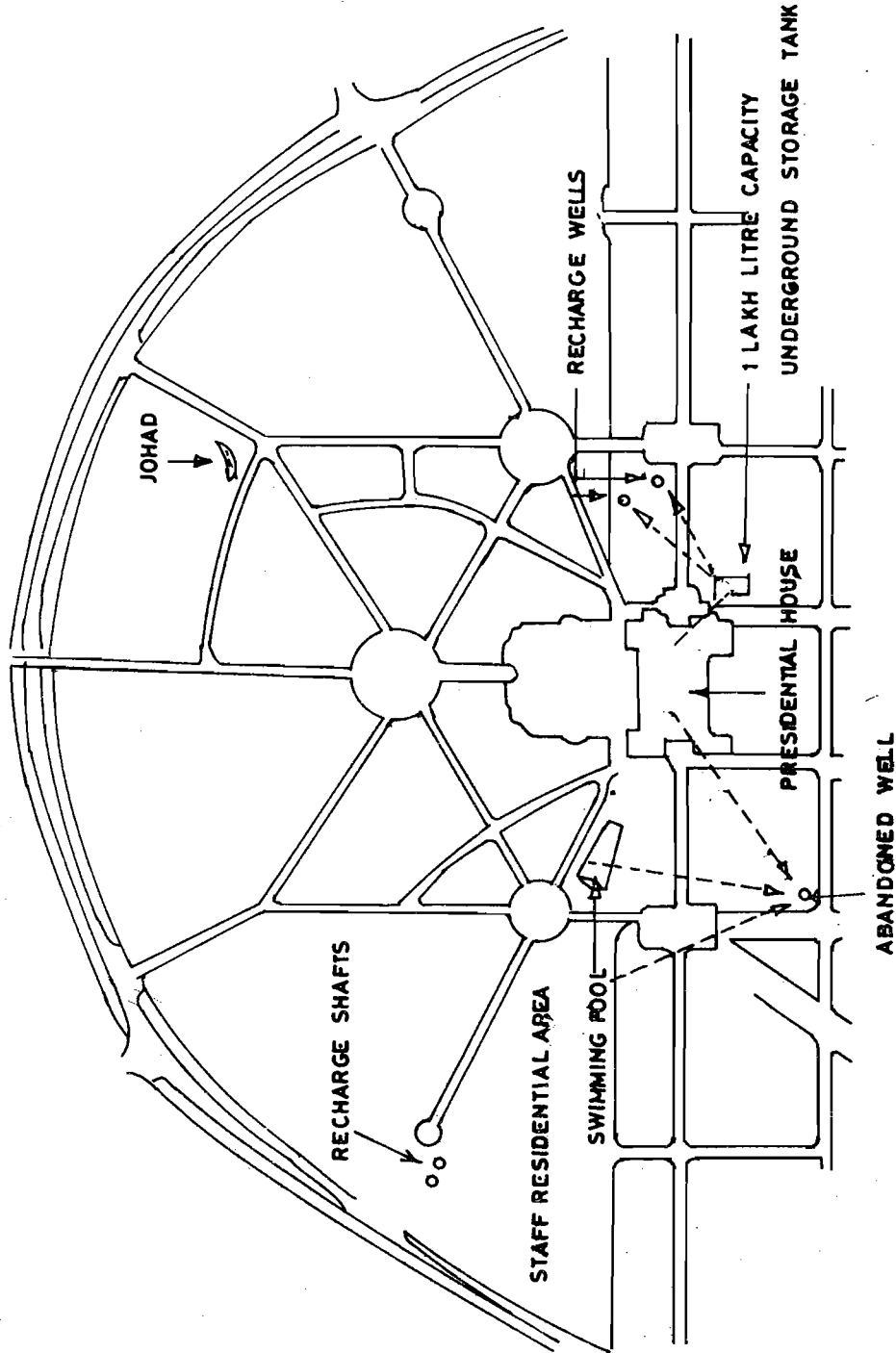


SITE PLAN



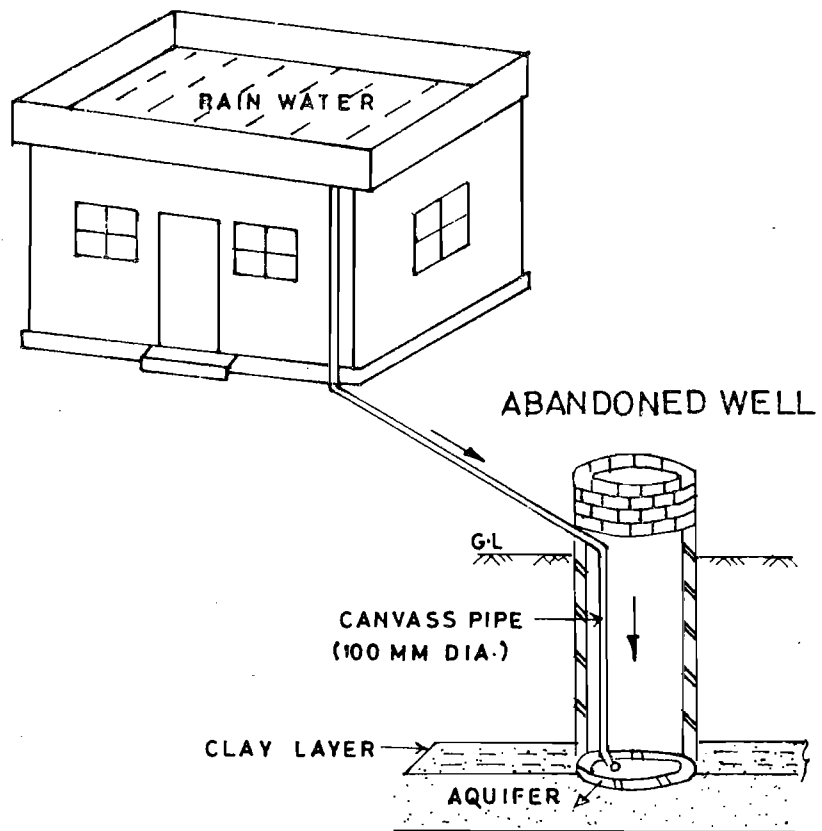
SITE PLAN

Drg-07: Scheme for water harvesting

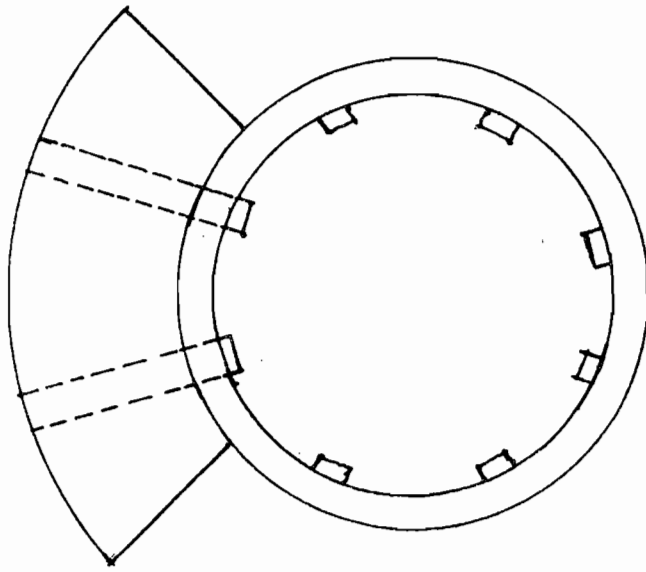


SITE PLAN

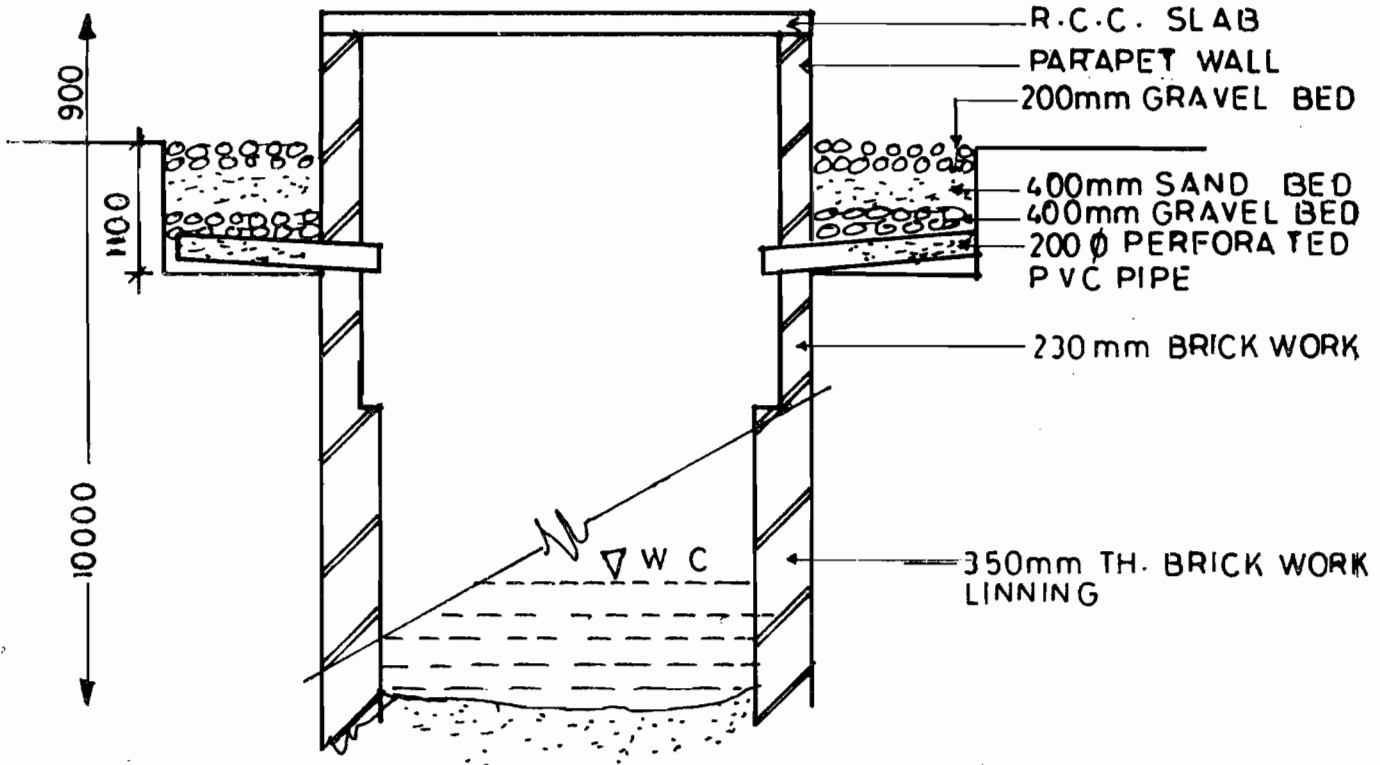
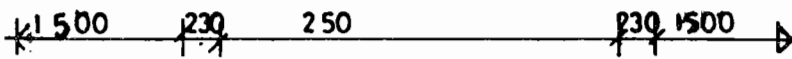
Drg-08: Scheme for water harvesting



Drg-09: Recharge through abandoned dug well

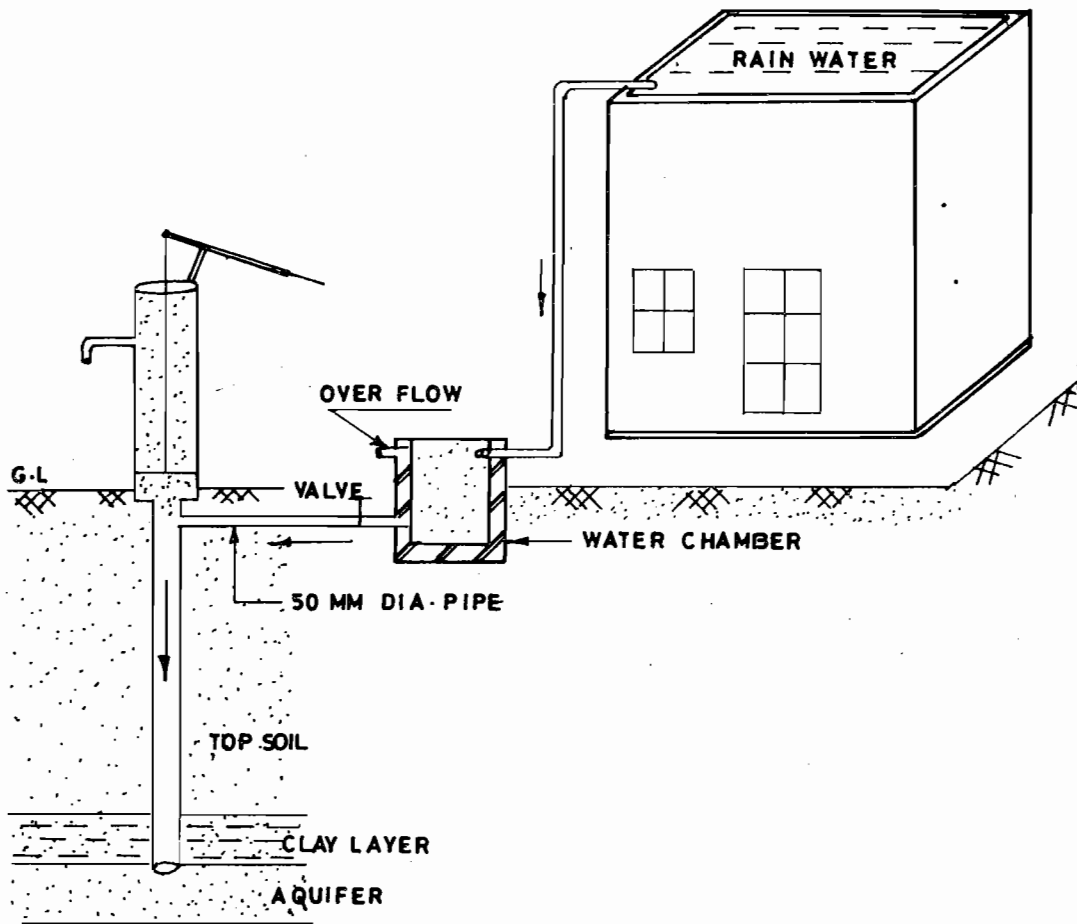


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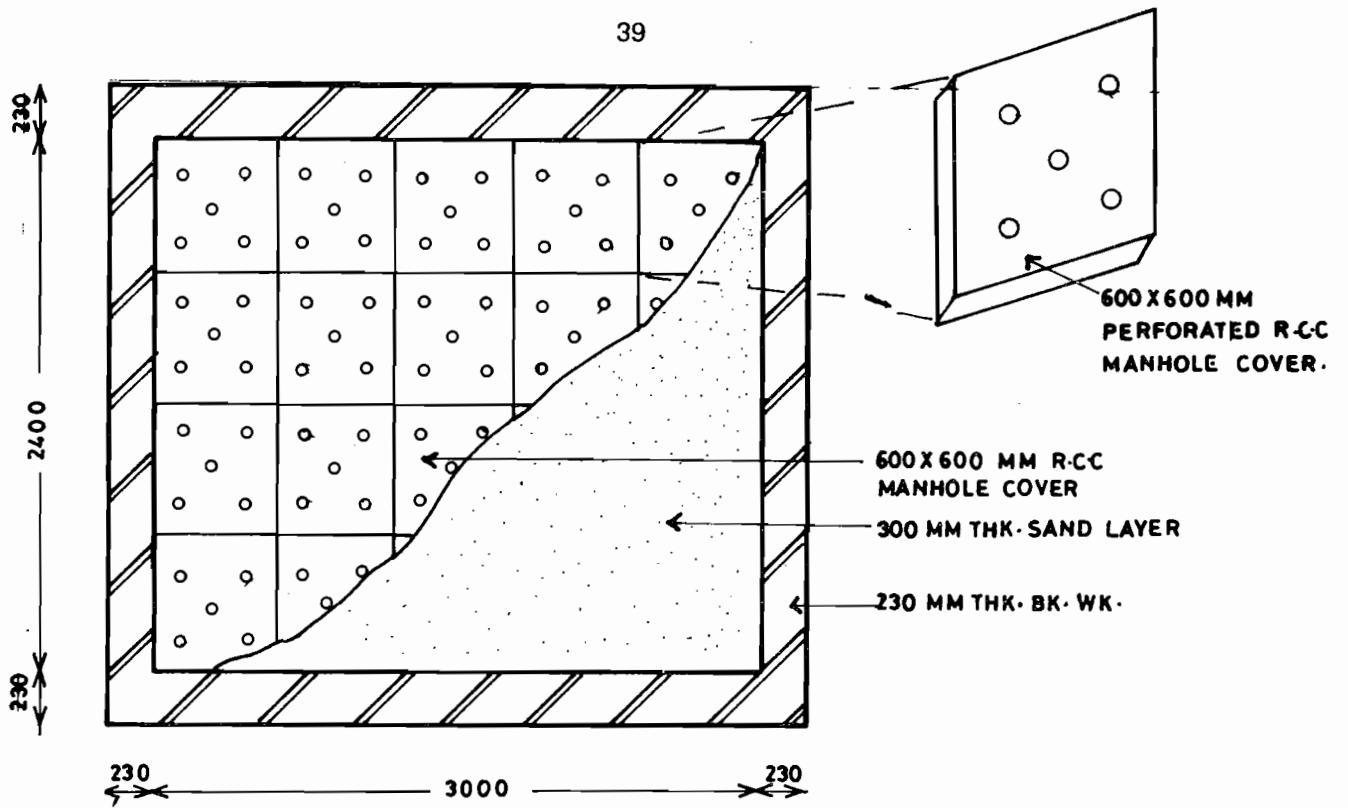


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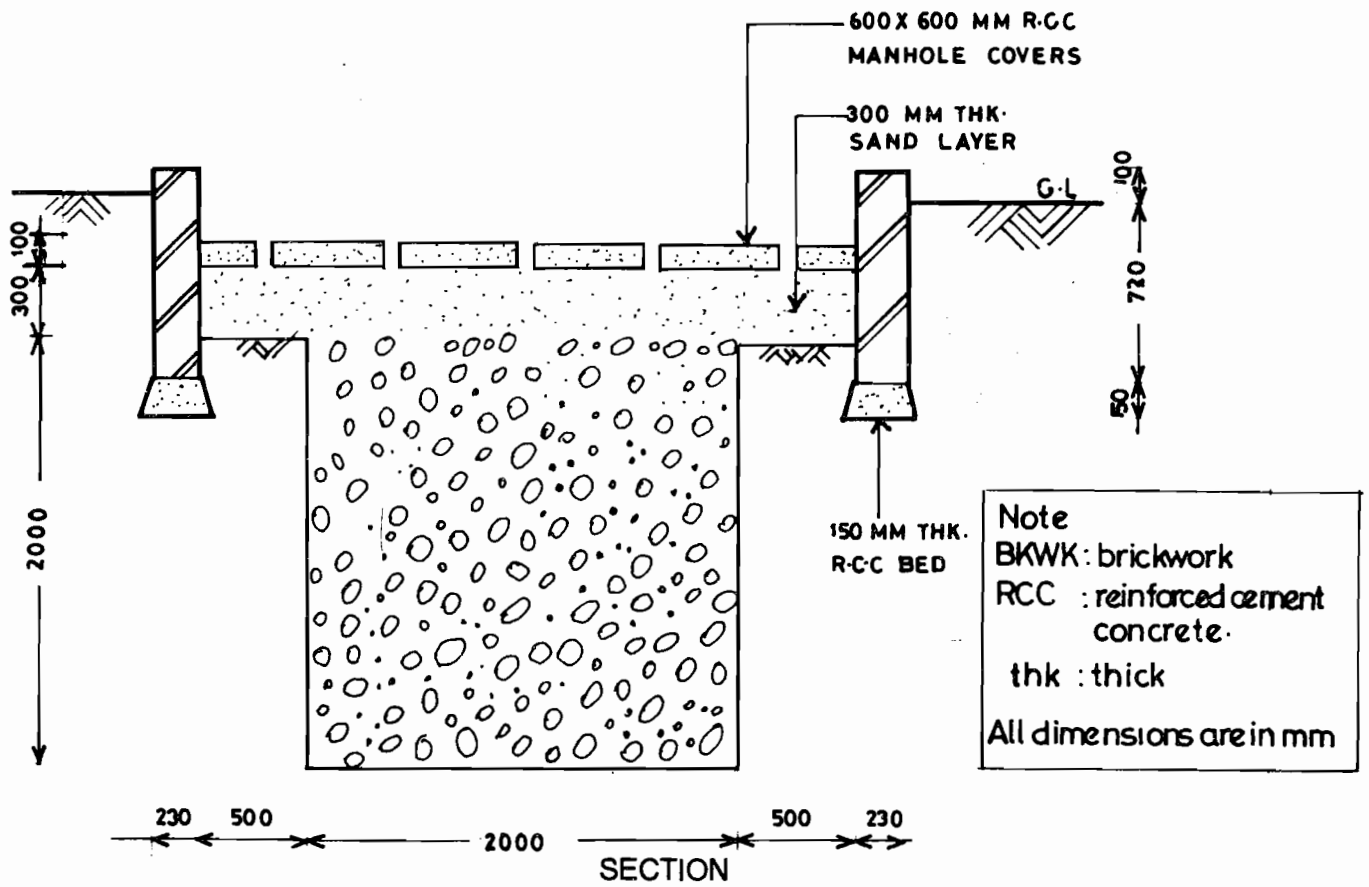
Drg-10: Details of recharge dugwell



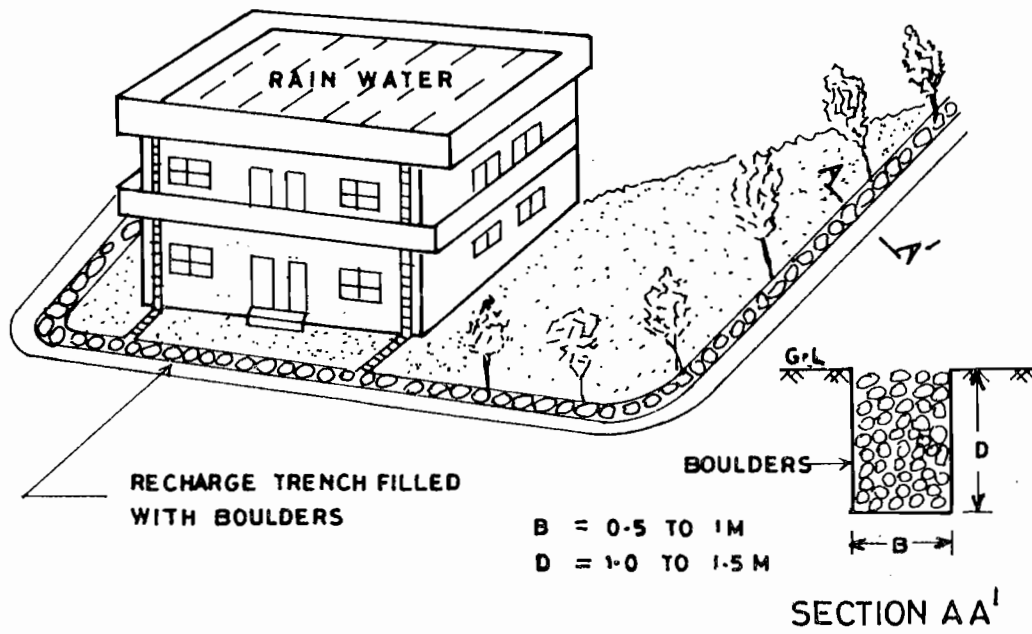
Drg-11: Recharge through hand pump



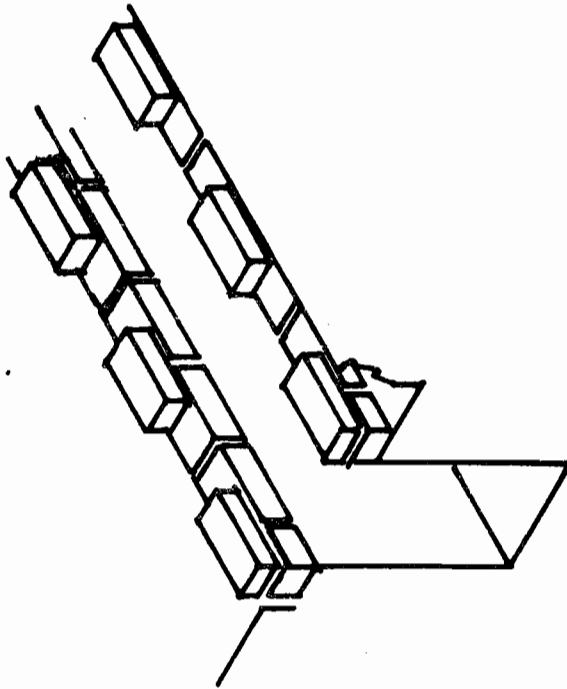
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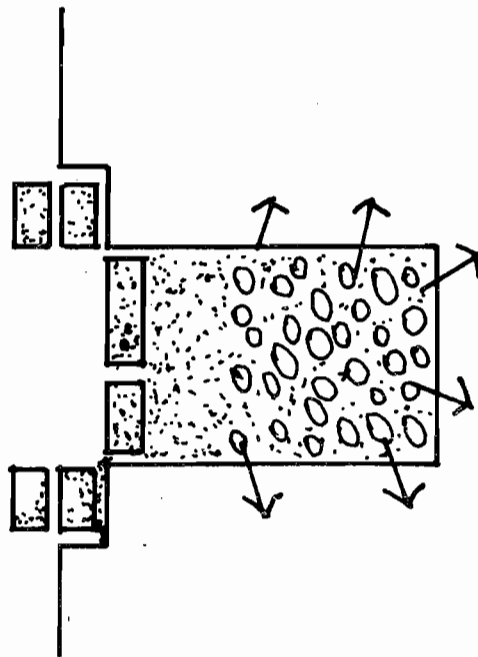
Drg-12: Details of recharge pit



Drg-13: Recharge through trench

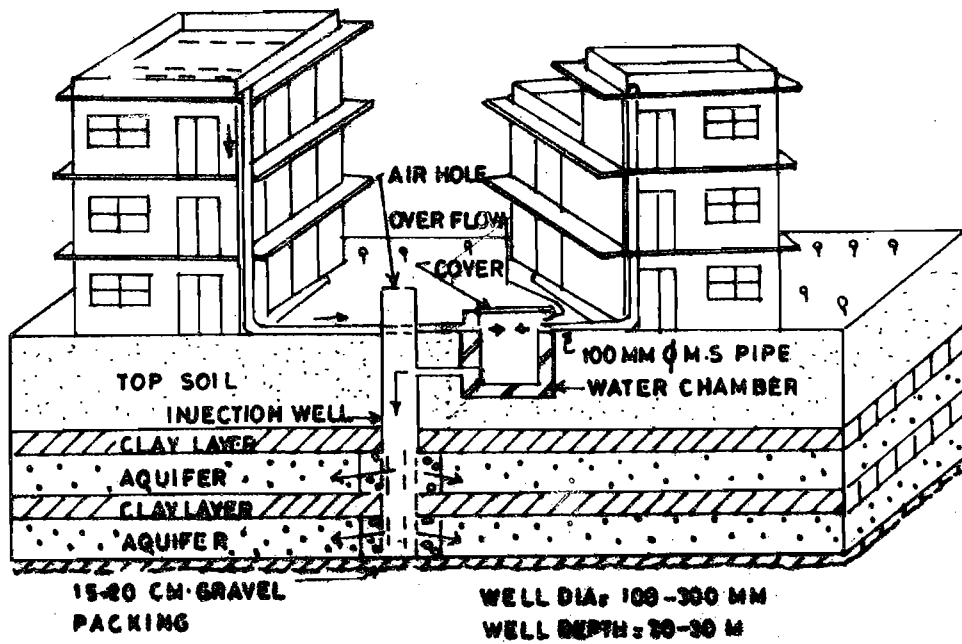


SECTIONAL VIEW

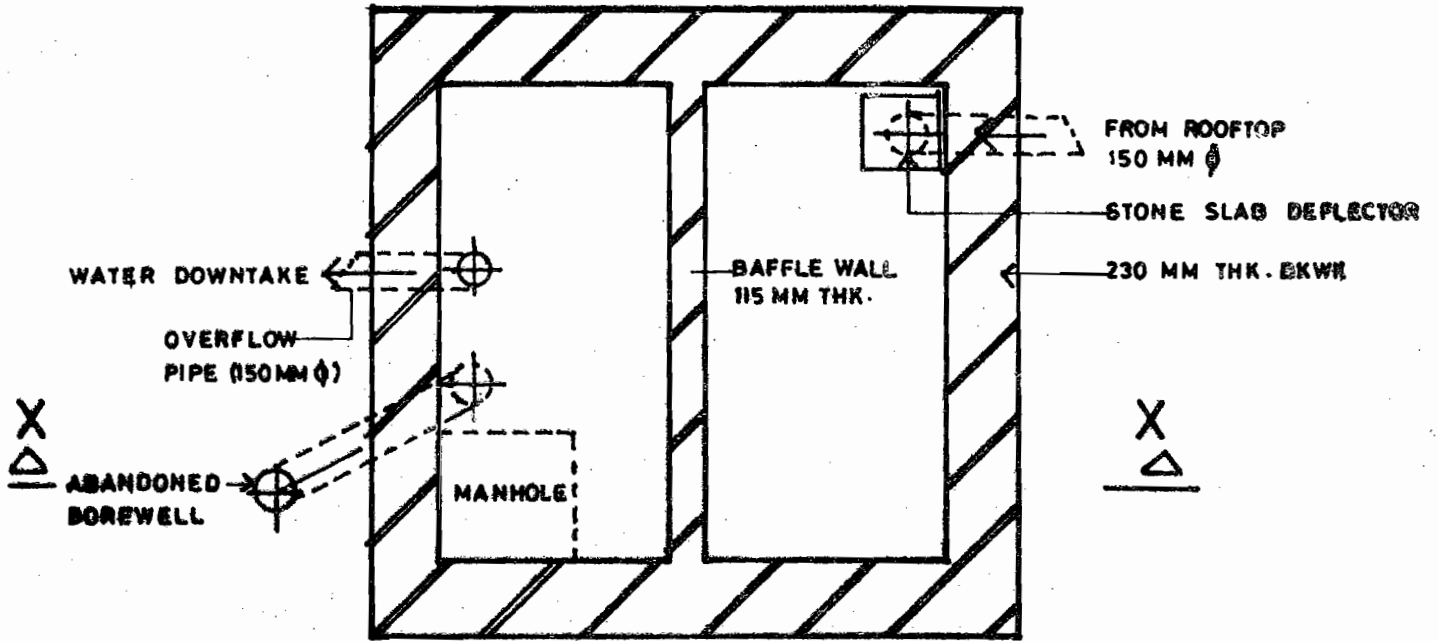


SECTION

Drg-14: Details of recharge trench

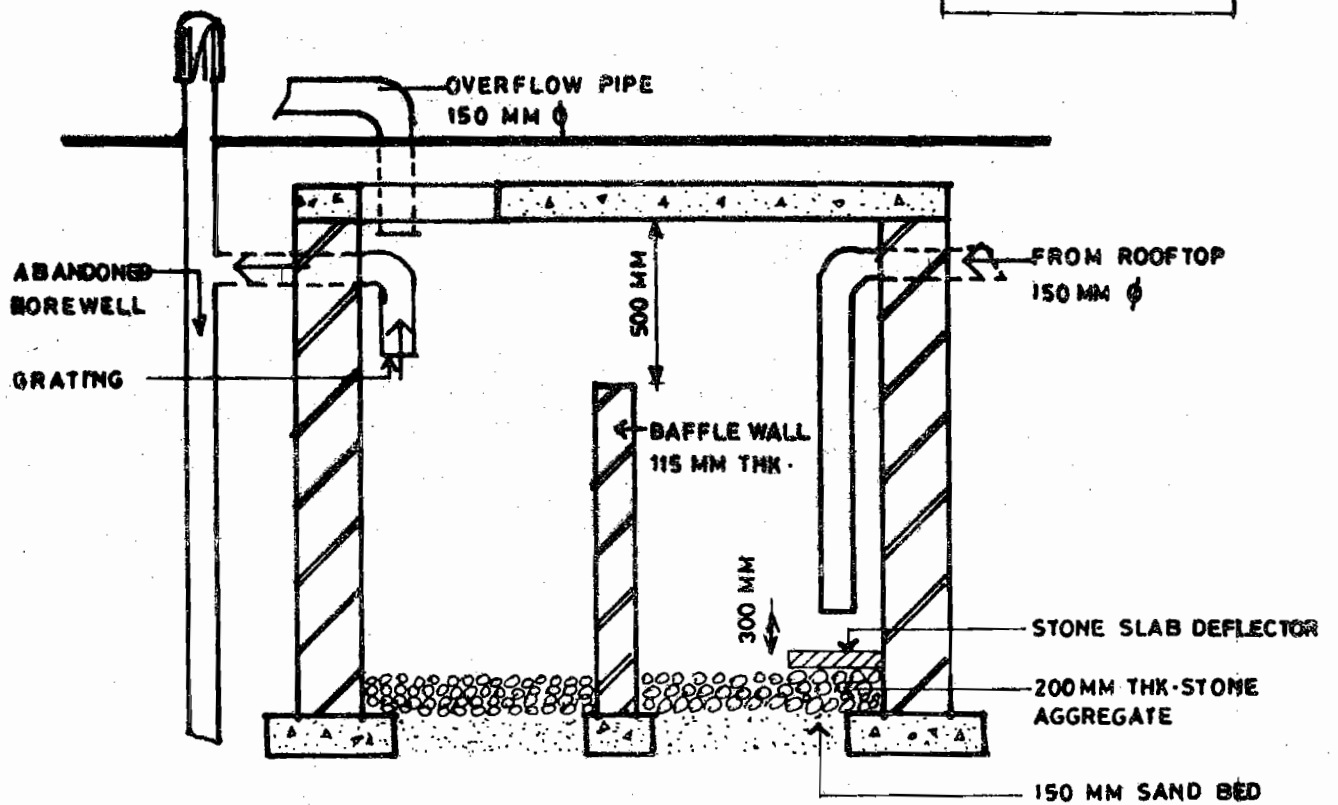


Drg-15: Gravity head recharge tube well



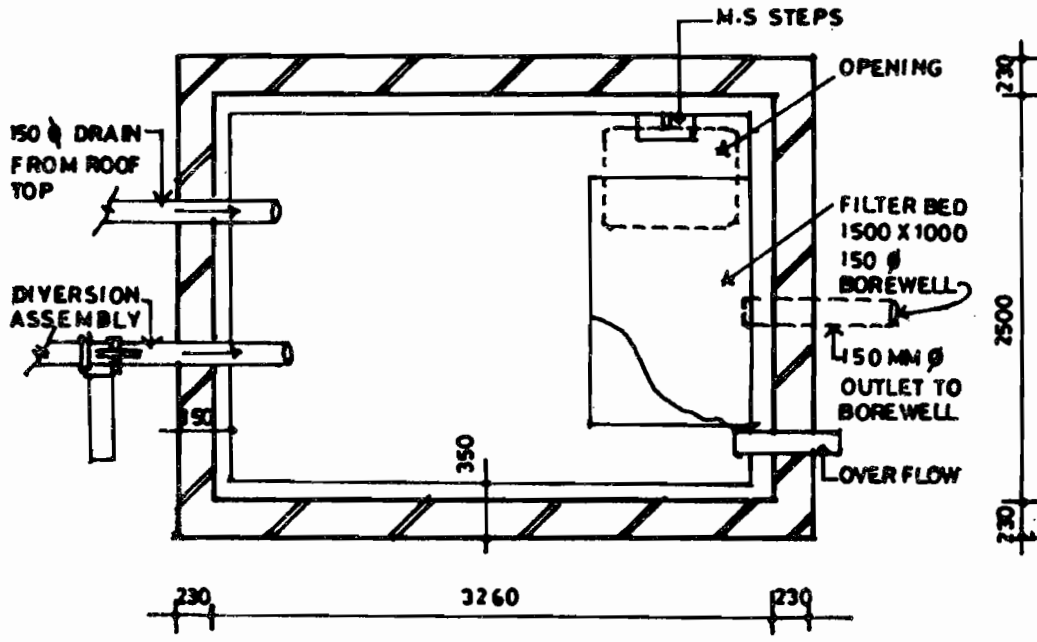
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Note:
 BKWK: brickwork
 Ø: diameter
 thk: thick

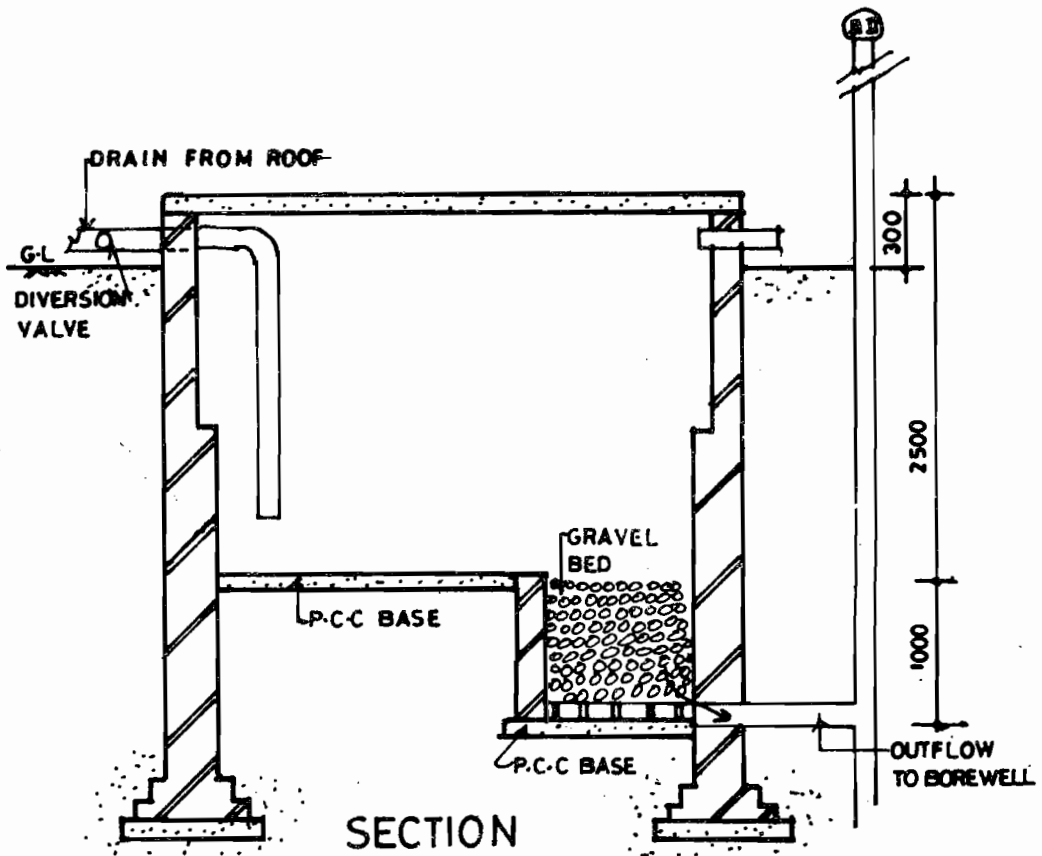


Drg-16: Details of recharge borewell and settlement tank

SECTION (X X)

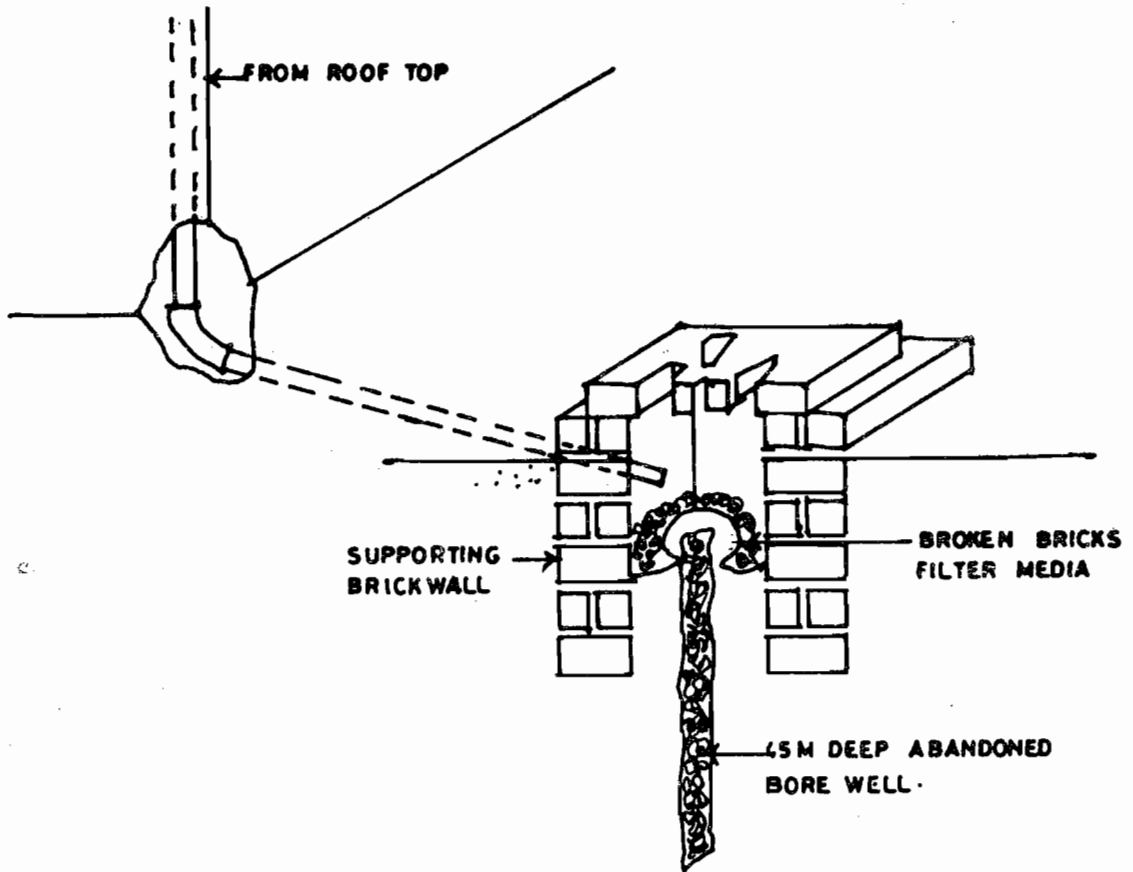


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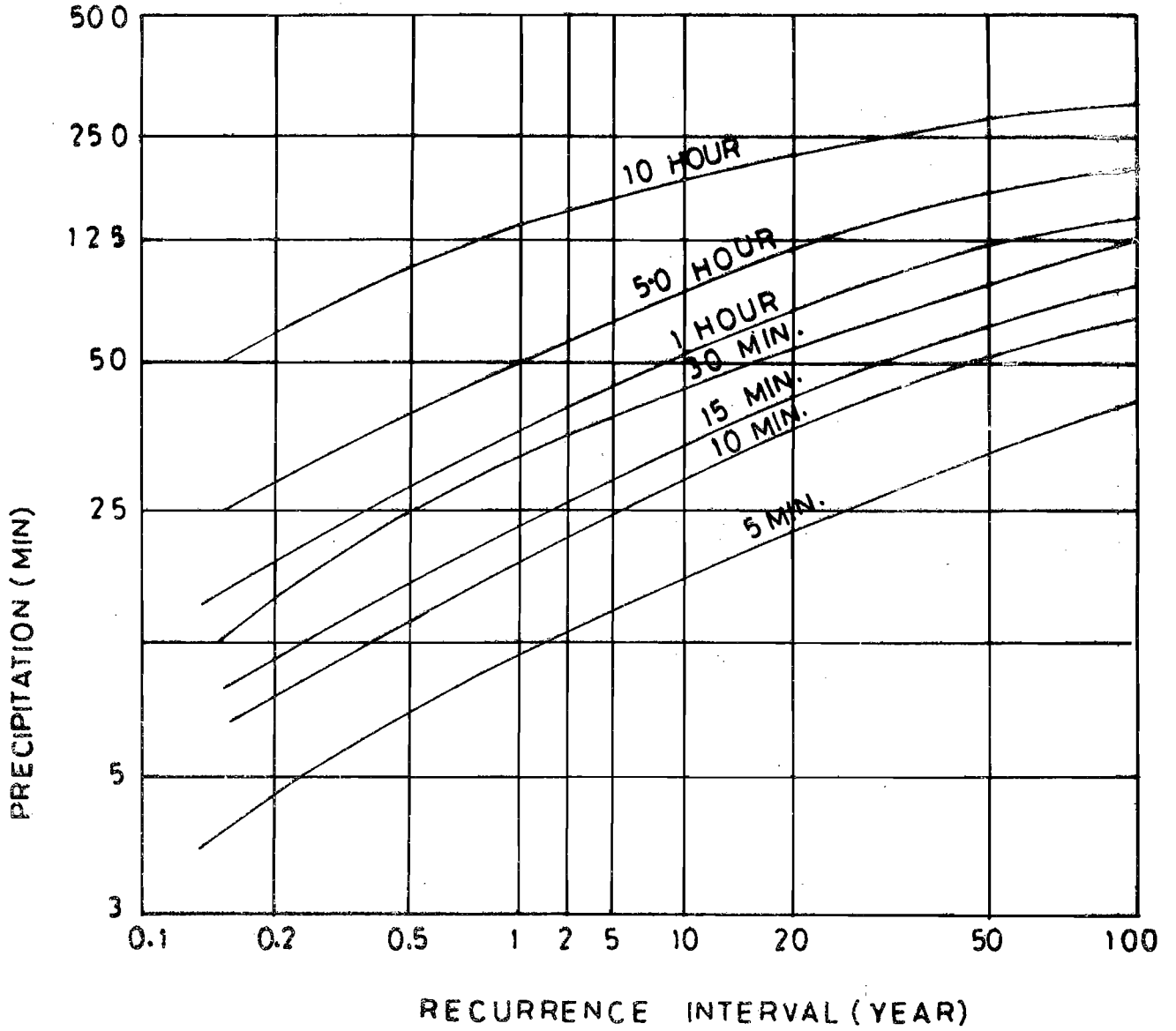


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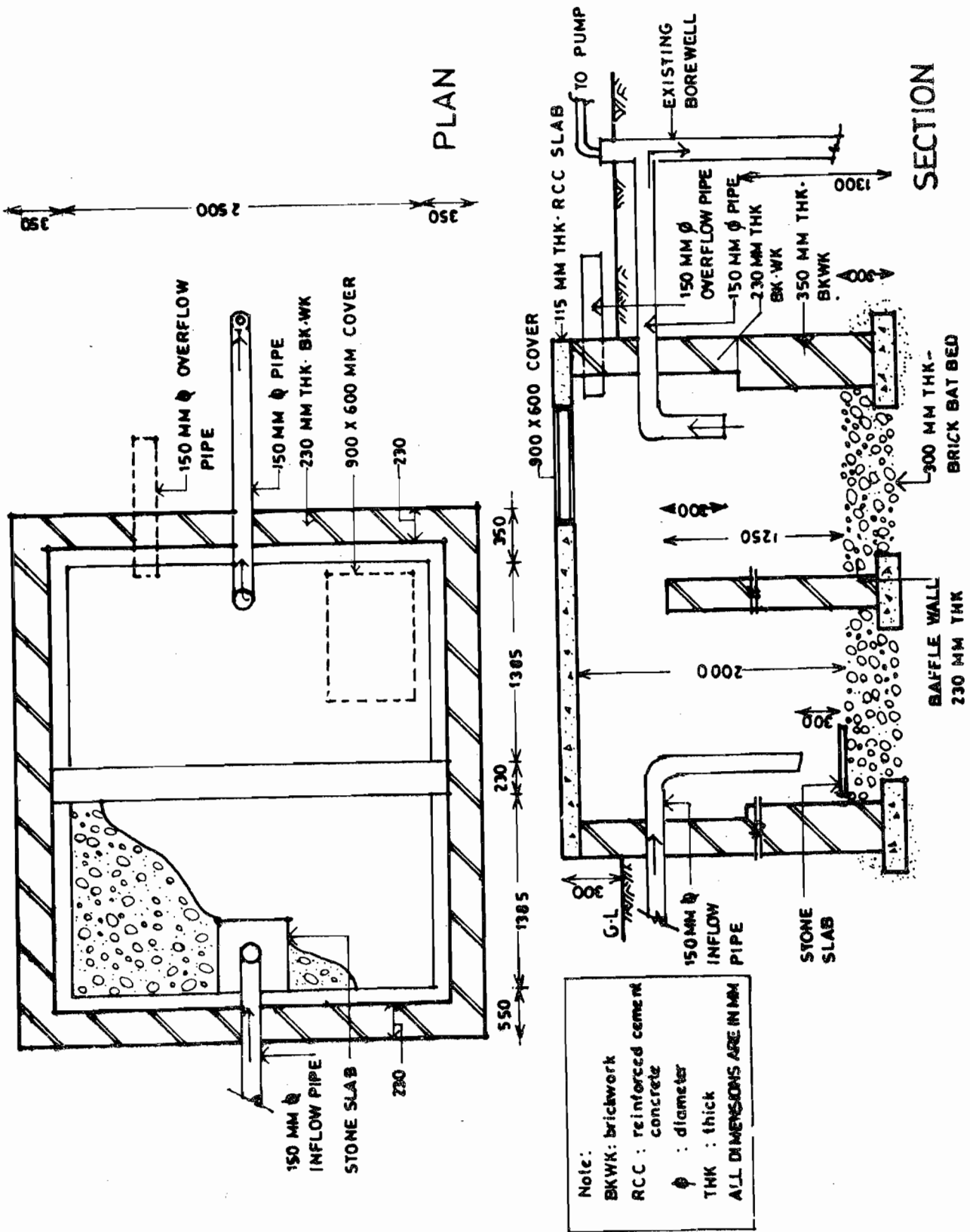
Drg-17: Details of recharge borewell & filtration tank



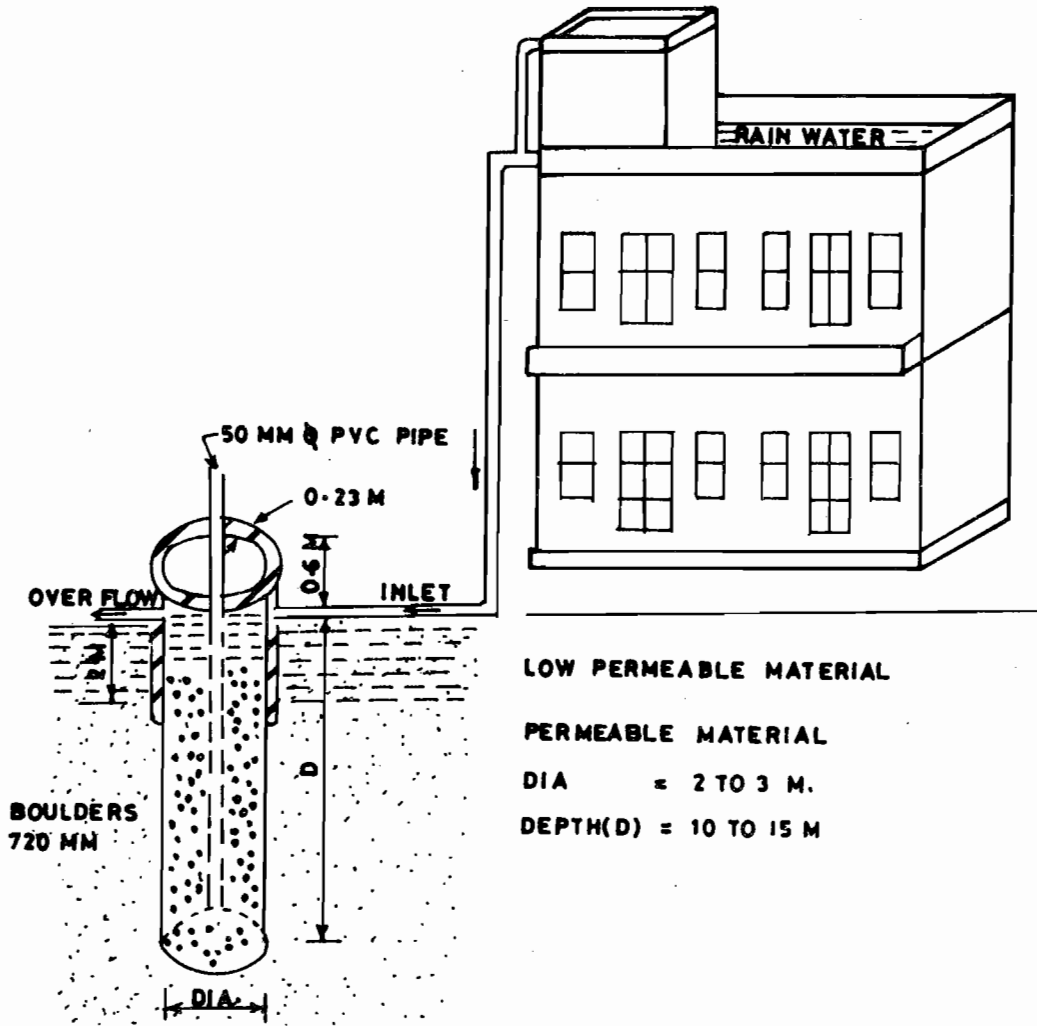
Drg-18: Detail of abandoned boerwell recharging



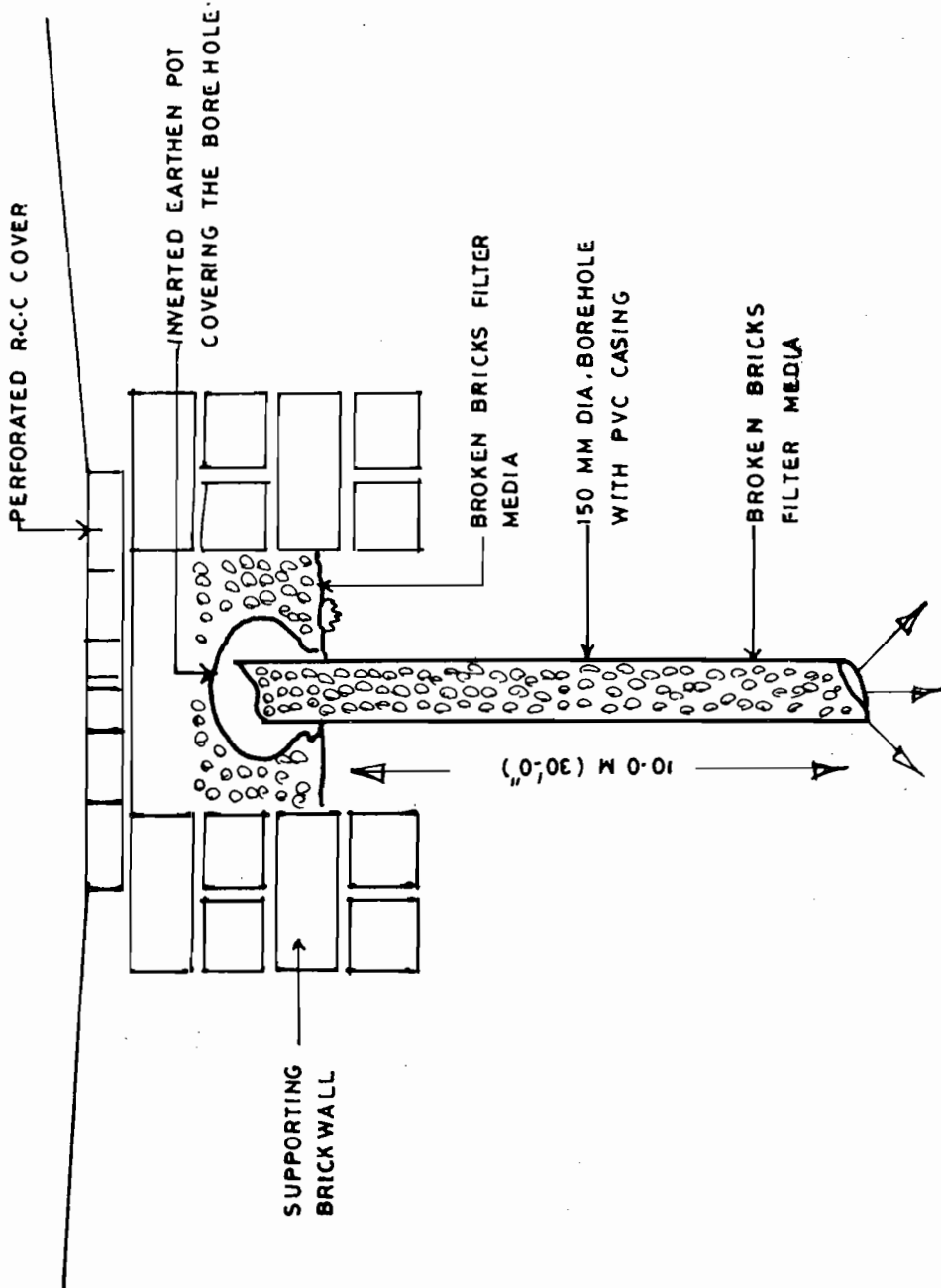
Graph No. 1: Rain Fall Intensity - Duration - Frequency Relationship



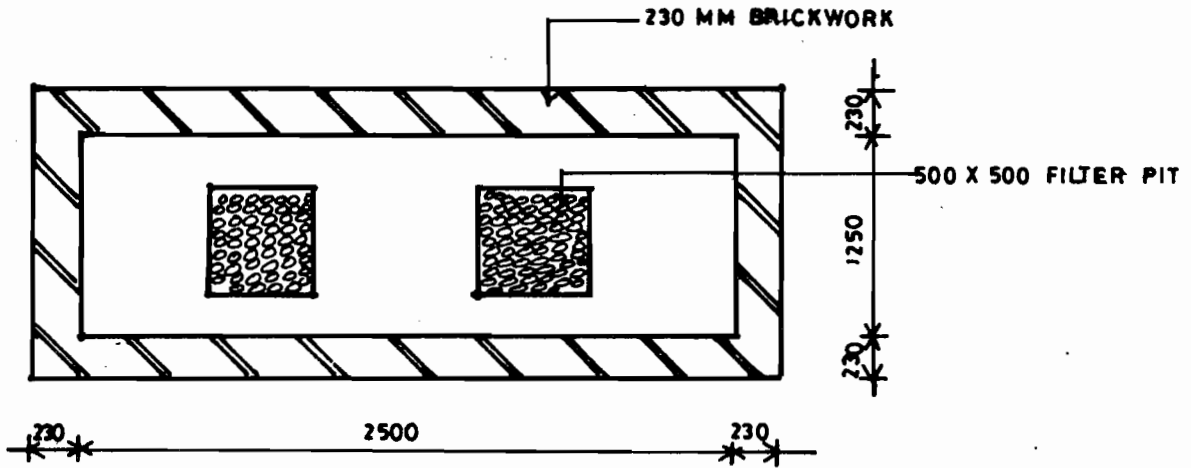
Drg-19: Details of recharge borewell & settlement tank



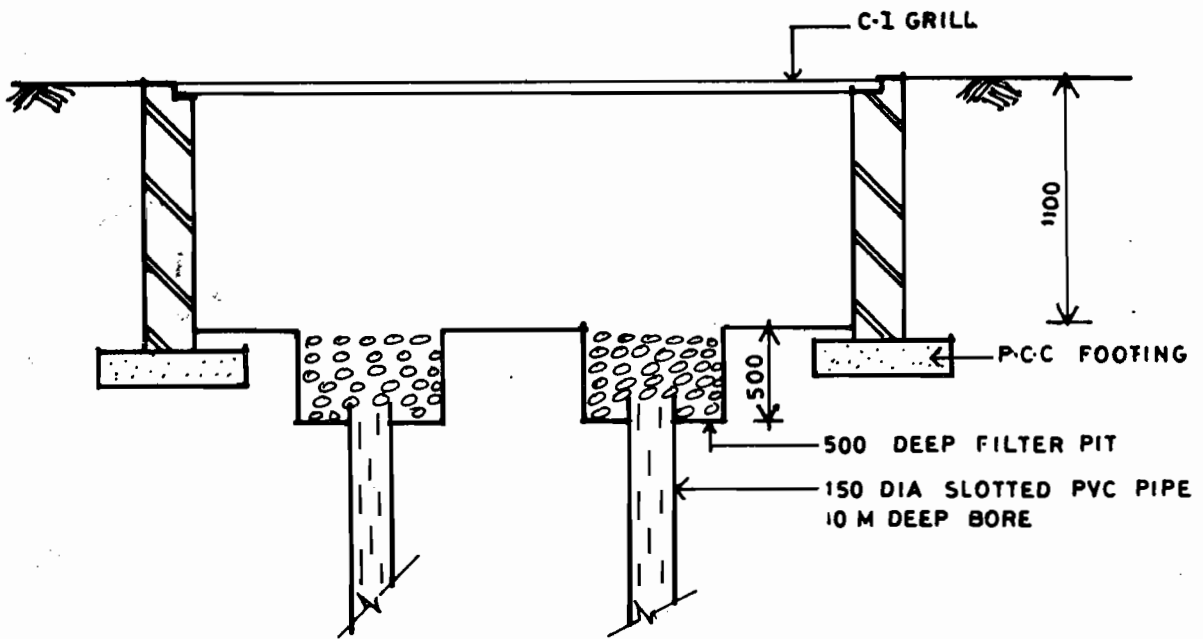
Drg-20: Recharge Shaft



Drg-21: Detail of soakway



PLAN



SECTION

Drg-22: Detail of recharge through & soakway

CHAPTER – 6

CASE STUDIES

Case No. 1 SPG Project at Dwarka (Papan Kala), New Delhi.

6.1.0 The Rain Water Harvesting & Conservation Techniques have been successfully executed in recently completed SPG Project at Dwarka, New Delhi. The details of items executed and the drawings followed are attached in Annexure - (Case Studies). Salient features of Artificial recharge to ground water are as under:

(i) Average Annual rain fall	611.8 mm
(ii) Total area	47.5 Hectre
(iii) Depth to water level	5.75 m bgl
(iv) Water available for recharge	112419 cubic metre/annum
(v) Expected recharge	80,000 cubic metre/annum

6.1.1 Aims & Objectives:

The main objectives of the schemes are as follows:

- (i) Augment the ground water recharge through surplus water available in the area.
- (ii) To arrest the rate of decline of ground water levels.
- (iii) To Monitor the effect and rate of ground water recharge
- (iv) To develop the technology for artificial recharge is specially in urban areas and also quantify the volume of recharged water.
- (v) To evaluate cost benefits of various recharge techniques adopted
- (vi) To create awareness in the society for proper management of ground water resources.

6.1.2 Availability of water

Total area complex	=	47.48Hectare
Average annual rain fall is	=	611.8 MM
Total run off available for recharging the ground water	=	112419Cubicmetre per annum
Expected run off at hourly Rain fall intensity of 40mm / hour is	=	7350.06Cubic metre

S No.	Area Type	Area in Sqm	Normal rain fall in mtr. Year	Runoff co-efficient	Total runoff available in cubic mtr/ Annum	Runoff at hourly rain fall intensity of 40 mm / hour
1	Roof Top	55227	0.6118	0.90	30409.09	1988.172
2	Roads	55559	0.6118	0.80	27192.80	1777.888
3	Paved Area	50000	0.6118	0.85	26001.50	1700.00
4	Parks & Green Belts	314000	0.6118	0.15	28815.78	1884.00
Total:		474786			112419.16	7350.06

The ground water occurs in sandy silt horizon and predominantly kankar horizon which are potential aquifer zones in the area.

6.1.3 Type of artificial recharge structures proposed

Recharge trenches cum recharge wells are proposed. The design of these structures are given in Drawing No.23.

Recharge wells will be used for pumping wherever recharge source water is not available.

The pumping may take care of cleaning the silt which may enter the well during recharge.

6.1.4 Benefits of scheme:

- (i) Proper utilisation of available run off
- (ii) Arresting decline ground water and intrusion of brackish water in fresh water aquifers
- (iii) Saving in energy for lifting of water.
- (iv) To provide the sustainability to sum extend to the existing near by ground water structures.

6.1.5 Attributes of Ground Water:

- (i) There is more ground water than surface water
- (ii) Ground water is less expensive and economic source
- (iii) Ground water is sustainable and reliable source of water supply
- (iv) Ground water is relatively less vulnerable to pollution, high bacteriological purity, free of pathogenic organism, needs little treatment before use
- (v) Ground water has no turbidity and colour, universally available
- (vi) Ground water source can be instantly developed and used
- (vii) Ground water has distinct health advantage as an alternative for lower sanitary surface water.

- (viii) There is no conveyance losses in ground water based supplies
- (ix) Ground water has low vulnerability to drought
- (x) Ground water is key to life in arid and semi - arid regions
- (xi) Ground water is source of dry weather flow in rivers and streams.

Case No. 2 Scheme for Artificial recharge to ground water at NH IV area, Faridabad (Haryana)

Normal annual Rain fall 564.3 mm

Normal Monsoon Rainfall 487.4 mm in on an average 21.8 days

Geological formation – alluvial and quartzite

Depth to water level – About 26 mtr below ground level.

6.2.1 Purpose:

- (I) To recharge the available runoff which accumulates around quarters and creates inconvenience to the residents
- (II) To arrest the decline of the ground water levels in the area
- (iii) To create awareness in the society for proper management of rain water through harvesting.
- (iv) Hydrology – The area is characterized by alluvial under lain by quartzite. Sand mixed with hampers in alluvium acts as very good repository for ground water. Depth to water level in the area is about 26 m below ground level.

6.2.2 Availability of surface water:

The annual normal rain fall of the area is 564.3 mm, out of which 487.4 mm occurs during monsoon period in on an average 21.8 days. The runoff availability for each block, playground and for market area is assessed as below:

S.No.	Area Description	Area contributing run off (sqm)	Runoff availability (cubic metre)
1	Type IV Qrs	189.04 x 35=6616	90x35=3150
2	Type V Qrs	312.82x13=4067	150x13=1950
3	Type VI Qrs	459.5x4=1838	220x4=880
4	Play Ground	151500	6000
5	Market area	6050	1700
Total		170071	13680

Thus about 13680 cum runoff is available annually for recharge to ground water.

6.2.3 Artificial recharge structures:

The structures should be constructed only at those places where water accumulates during monsoon period. The proposed recharge structures may be constructed at lower elevations keeping the topography into consideration.

6.2.4 Benefits of scheme:

- (i) Proper utilisation of the available run off which accumulates around the quarters
- (ii) To increase soil moisture
- (iii) Sustaining the green areas
- (iv) Arresting the declining ground water level
- (v) Provide sustainability to the existing ground water absorption structures in the area.

Structures I, 2,3 (Ref. Drawing No. 24 to 26) Recharge pit with Bore

Structure – 4 (Lateral shaft with bore wells) (Ref. Drawing No.27)

Case No. 3 Salient feature of artificial recharge at Sewa Bhawan, RK Puram, New Delhi.

Average Annual rain fall	712.2 mm
Average Monsoon rain fall	605.2 mm
Geological formation	Older alluvial
Depth to water level	16 – 20 m bgl.
Water available for recharge	4500 cum
Expected recharge	4000 cum

Recharge structures proposed 4 recharge trench with injection wells.
See Drawing No.28 & 29.

Case No. 4 Salient Features of Artificial Recharge proposal at HUDCO Place, Andrews Ganj, New Delhi.

1	Total Campus area	11.61 hectare
2	Normal Annual rainfall	712.2 mm
3	Normal Monsoon rain fall	605.2 mm
4	Geological formation	Alluvium

5	Depth to water level	About 24 m bgl
6	Water available for recharge	50350 cum
7	Recharge structure proposed	Trench cum bore wells – 7
8	Specification of Filter Material	(See Drawing No.30 & 31).
	a) Coarse Sand	1.5 to 2 mm size
	b) Gravel	5 to 10 mm size
	c) Boulders	Rounded and 5 to 20 cm
9	Depth & Dia of Recharge wells	32 m & 12" (303 mm)
10	Design of Recharge wells	

S. No.	Depth range	Assembly
1.	0.00 to 0.50 m agl	303 mm dia MS blank pipe
2.	0.00 to 1.5 m bgl	303 mm dia MS blank pipe
3.	1.5 to 2.5 m bgl	303 mm dia slot pipe of 3 mm size
4.	2.5 to 10.00 m bgl	303 mm dia M.S. blank pipe
5.	10.00 to 18.00 m bgl	303 mm dia MS slot pipe of 1.59 mm size
6.	18.00 to 20.00 m bgl	303 mm dia blank pipe
7.	20.00 to 30.00 m bgl	303 mm dia slotted pipe of 1.59 mm size
8	30.00 to 32.00 m bgl	303 mm dia blank pipe with bail plug

11. The main objectives of the scheme :

- (I) To augment the ground water recharge through surplus water available in the area.
- (II) To arrest the decline of the ground water levels in the area.
- (III) To create awareness in the society for proper management of ground water resources.

12. Hydrology

The area is a plain country having a very gentle northerly slope. The general elevation of the area is 214 mtr above Mean Sea level. The area is underlain by alluvial soil consisting of mostly clay silt mixed with kankar with occasional Badarpur Sand and Gravel. The thickness of alluvial layer varies between 70 mtr – 100 mtr below G.L. Depth of water level in the area is about 24 mtr. Bgl.

13. Availability of surface Water

Structure No.	Area in Sqm	Runoff Cum
1	11772	5220.00
2	9300	4251.00
3	13273	3618.00
4	9640	4486.00
5	11250	5045.00
6	11250	5046.00
7	49615	22684.00
Total	116100	50350.00

14. Artificial recharge structure

To harness the available runoff, 7 recharge trench cum borewells are proposed. The location and design of these structures are given in Drawing No. 30 to 31.

15. Benefits of the Scheme

- (i) Proper utilisation of available run off
- (ii) To increase soil moisture
- (iii) To sustain green areas
- (iv) To arrest the declining ground water level
- (v) To provide sustainability to the existing ground water abstraction structures in the area.

Case No. 5 Ground Water recharging works at Dewas

Recharging of ground water table depends upon the rain intensity total rainfall, coefficient of permeability of soil and time available for run water to percolate into the ground. The rainfall is very limited soil is very impervious, percolation of rain water is very limited. As per report of CGWB rate of vertical percolation is 0.3 cm/day hence it is essential to make previous vertical drains or to tape rain water direct to the ground water table for recharging. The existing soil was black cotton soil.

6.5.1 Harvesting of Roof Water (Ref Drawing No.32)

Roof drainage pipe connected to pipes and these pipes connected to tank or tube wells. The PVC/RCC pipes of various dia have been used based on surface area of roofs. When Water taken to the land no filtration has been done, when outlet is connected to the tube well, a filter bed of sand and aggregate has been used for filtration of water and bottom of the filter bed has been connected to the tube well.

6.5.2 Drain Water Harvesting (Ref Drawing No.32)

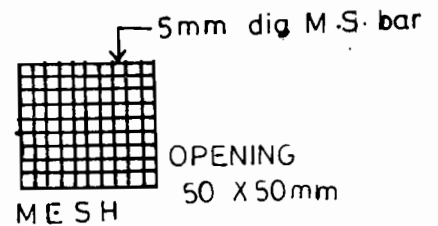
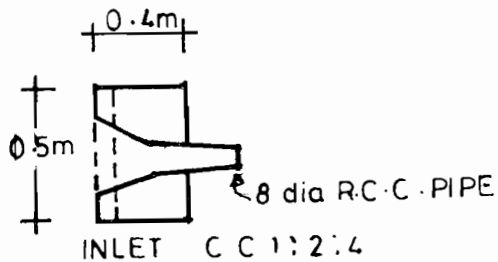
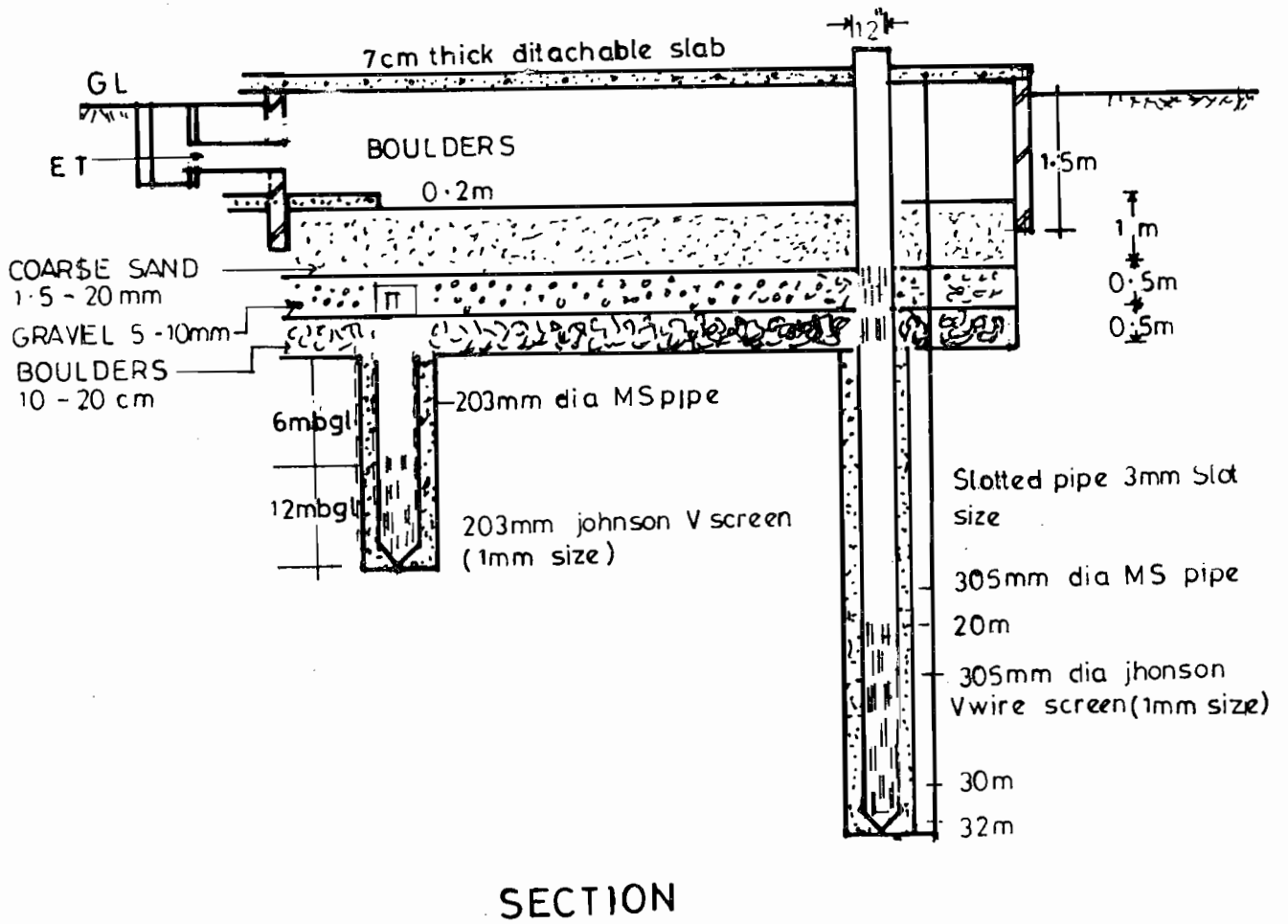
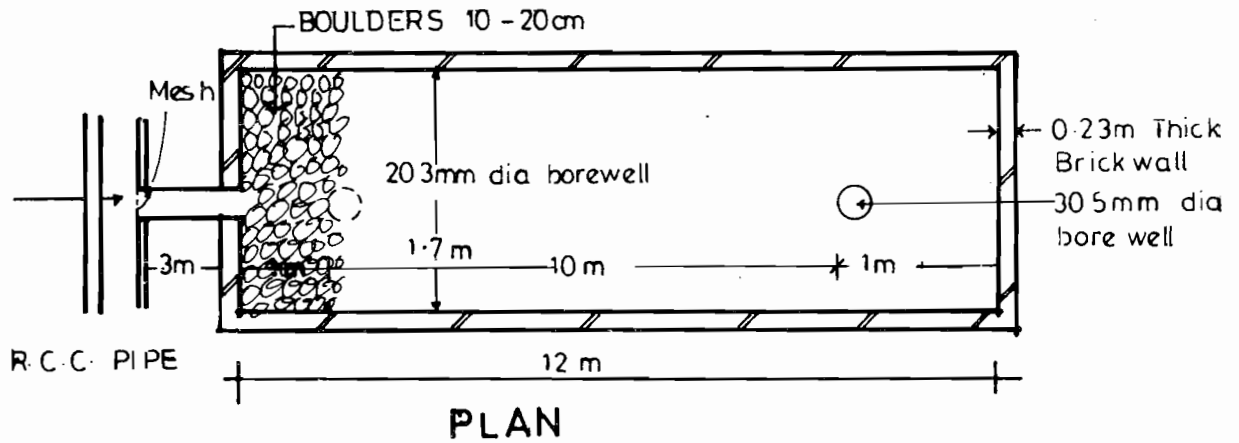
To tap rain water from drains, the katcha drains connected to designed filter around a bore well. The bore well has 150 mm dia, 45 mtr deep perforated pipes:

6.5.3 Construction of tanks having sand piles at bottom (Ref Drawing No.33)

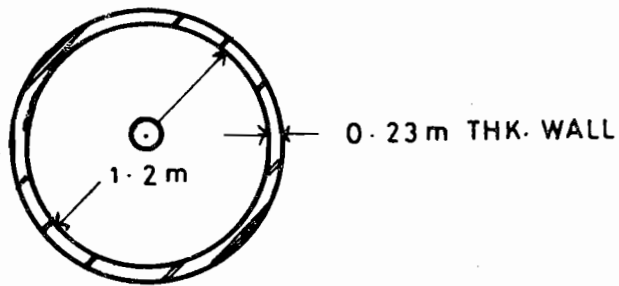
Tank size 60 mtrs x 50 mtr x 1.6 mtr and 90 mtr x 60 mtr x 1.5 mtr.

Sand piles at bottom of dia – 300 mm of Depth 3.5 mtr at a

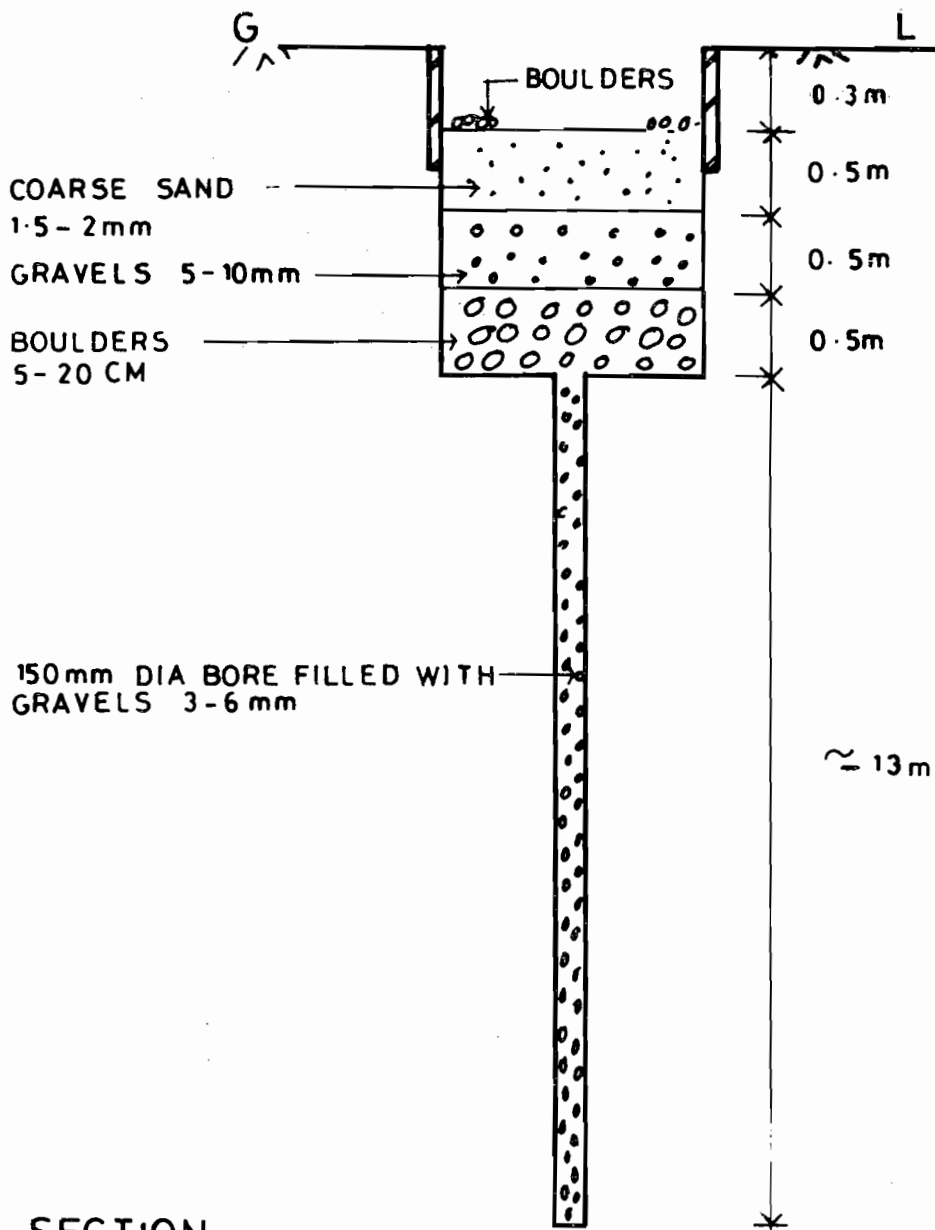
Spacing @ 5 mtr either direction.



Drg-23: Sign of recharge trench cum recharge wells

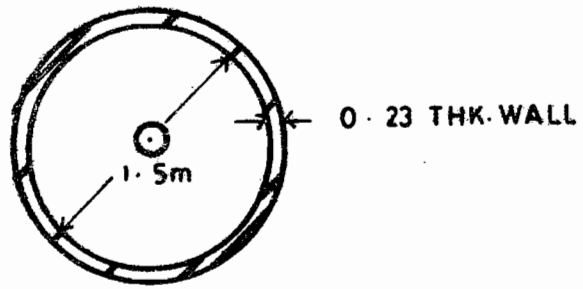


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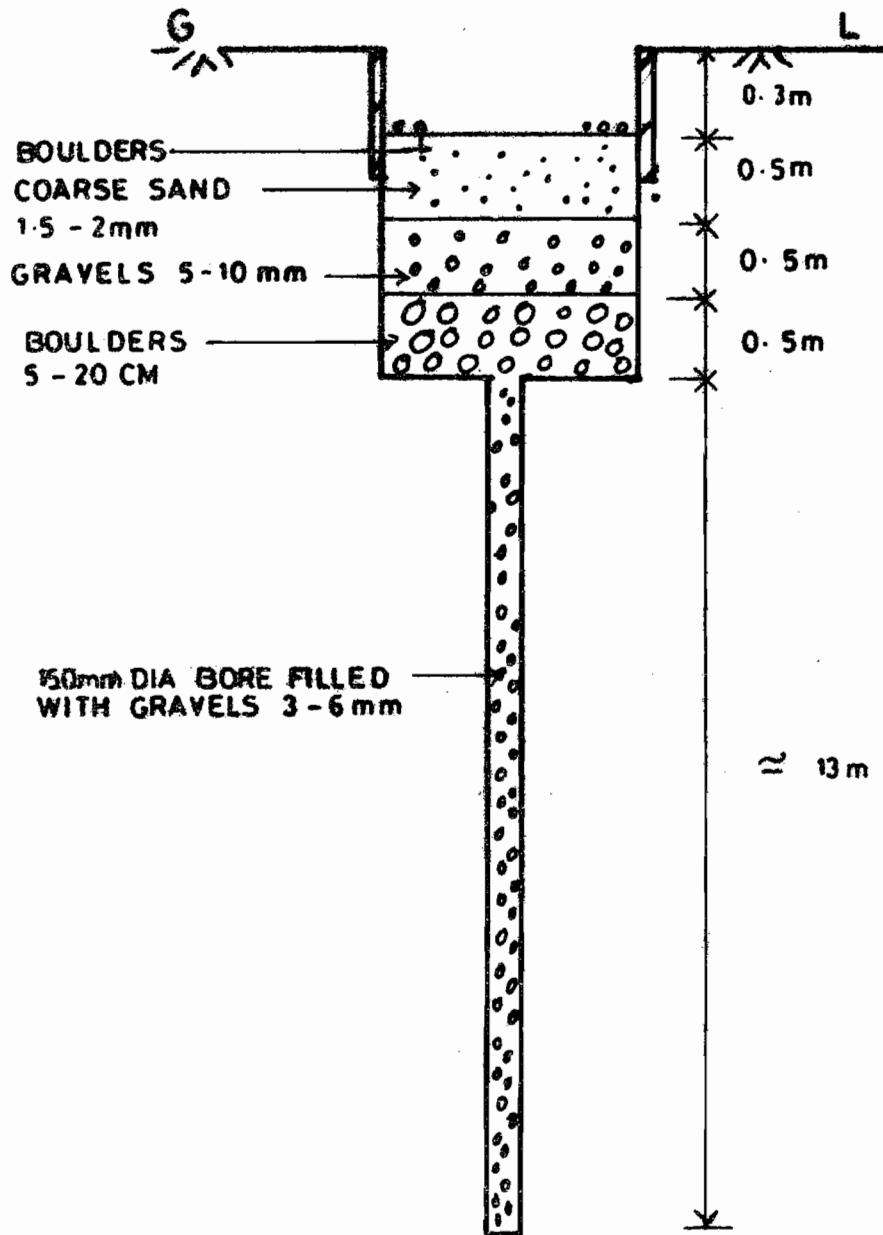


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Drg-24: Structure - 1 (recharge pit with bore)

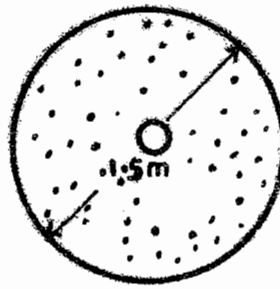


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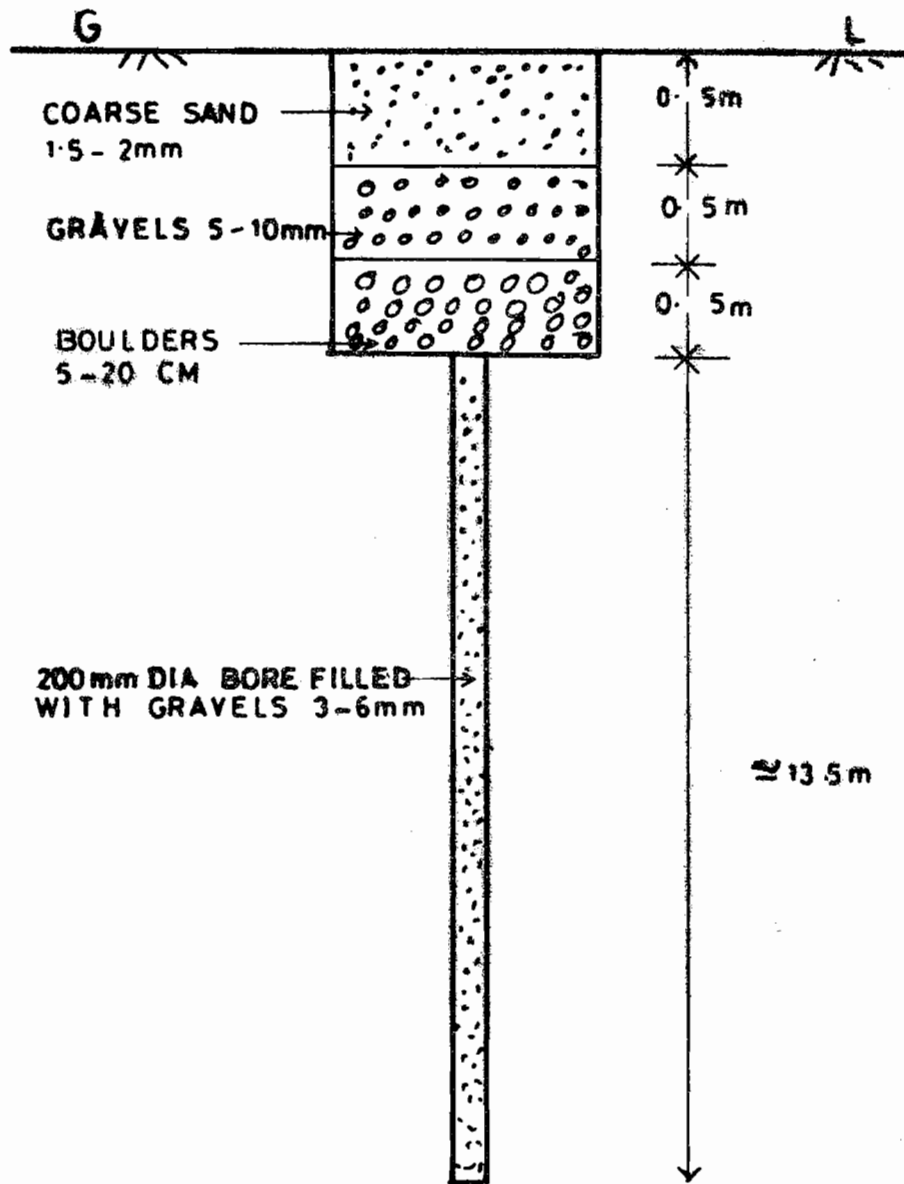


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Drg-25: Structure-2 (recharge pit with bore)

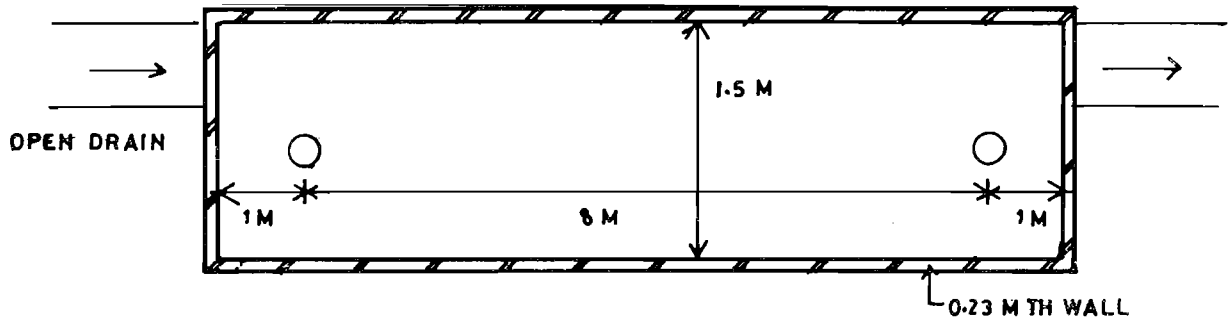


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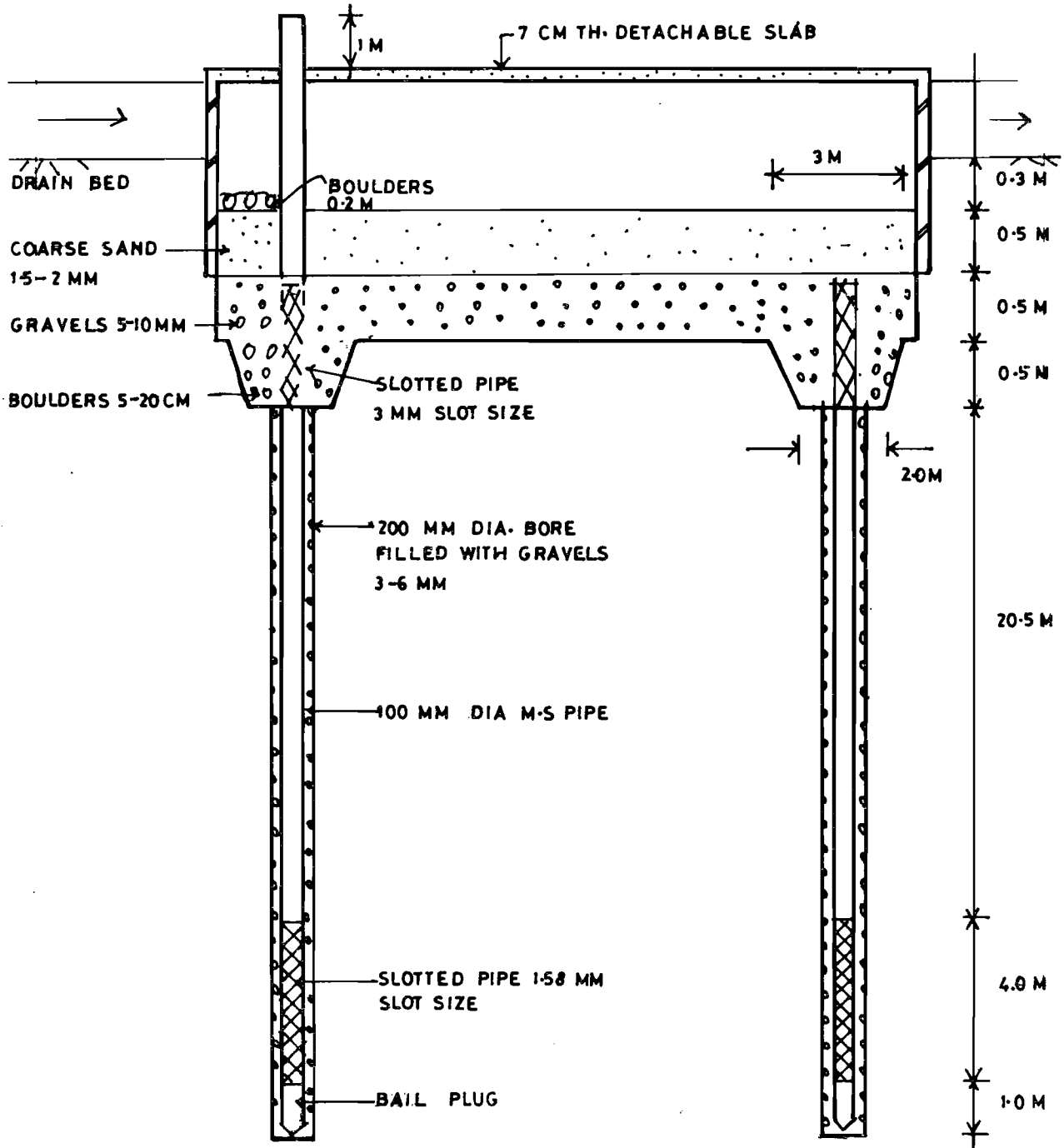


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Drg-26: Structure — 3 (recharge pit with bore)

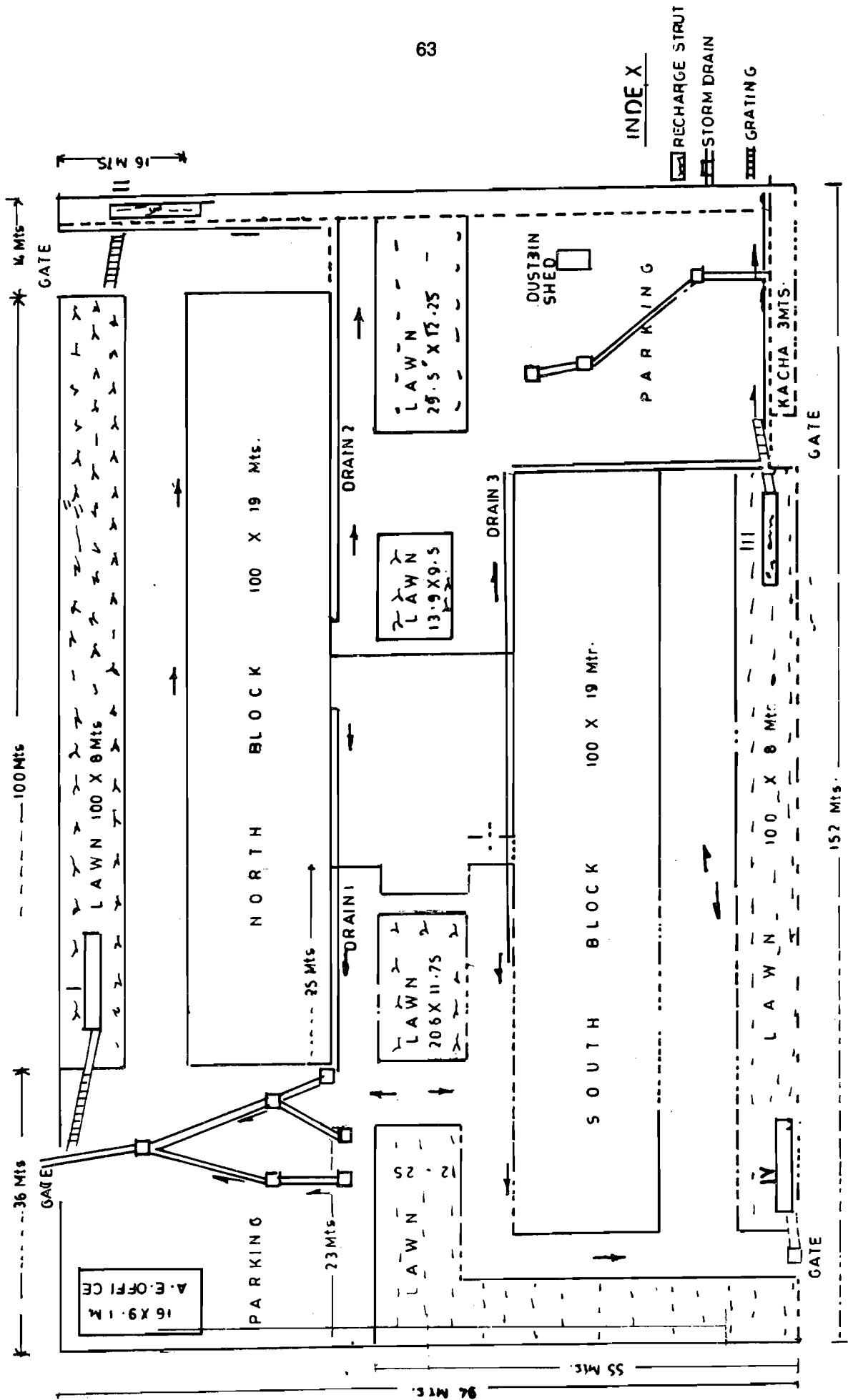


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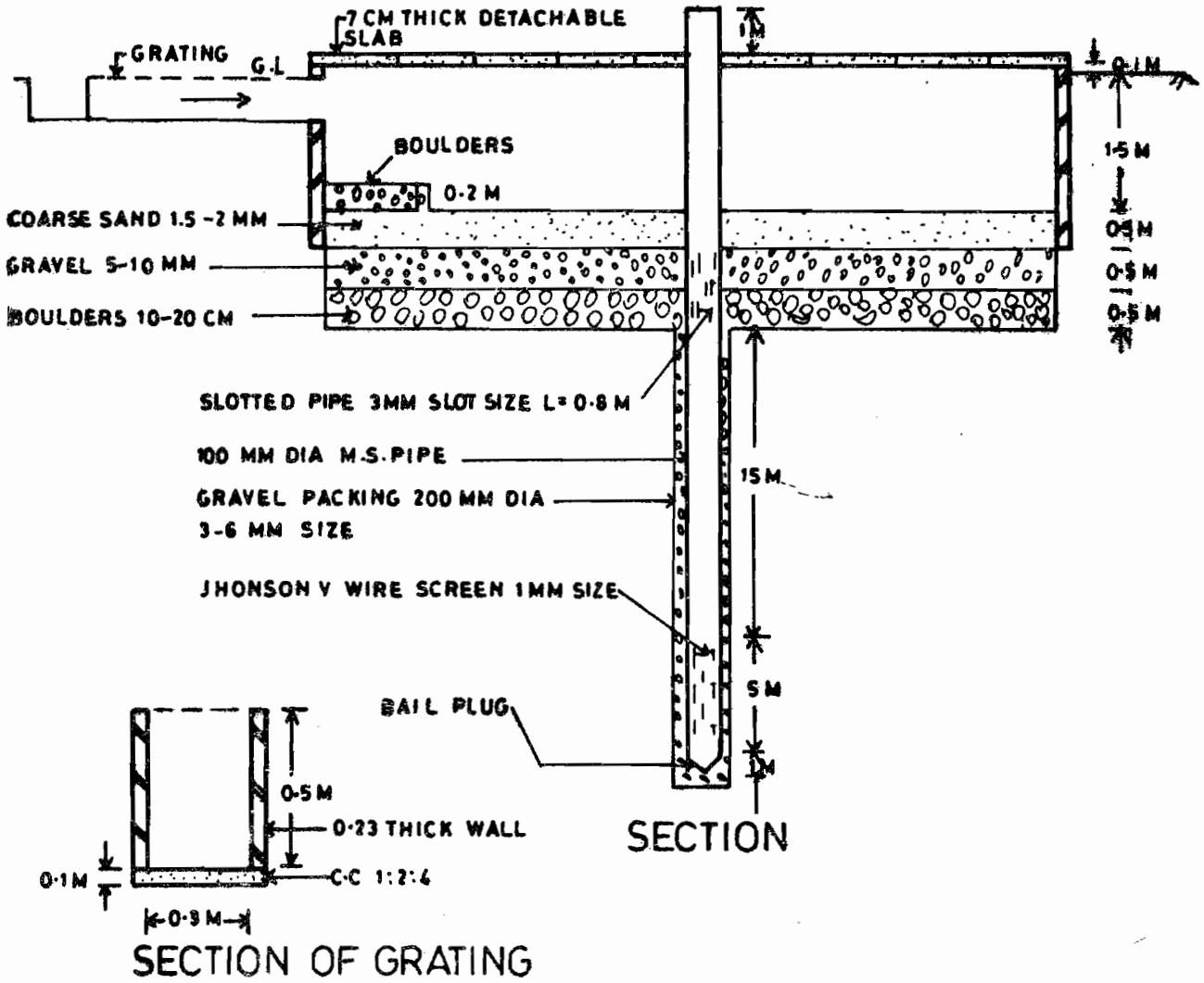
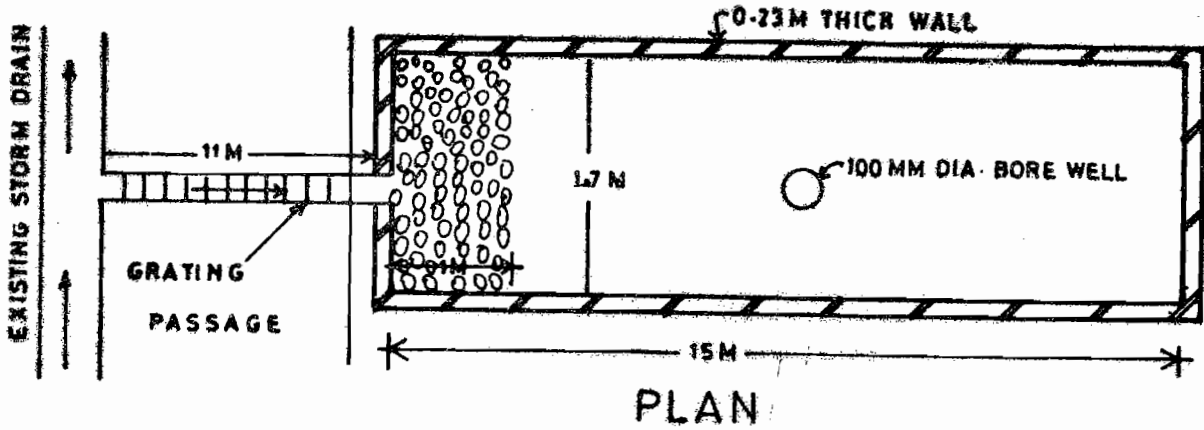
Drg-27: Structure -- 4 (lateral shaft with bore wells)



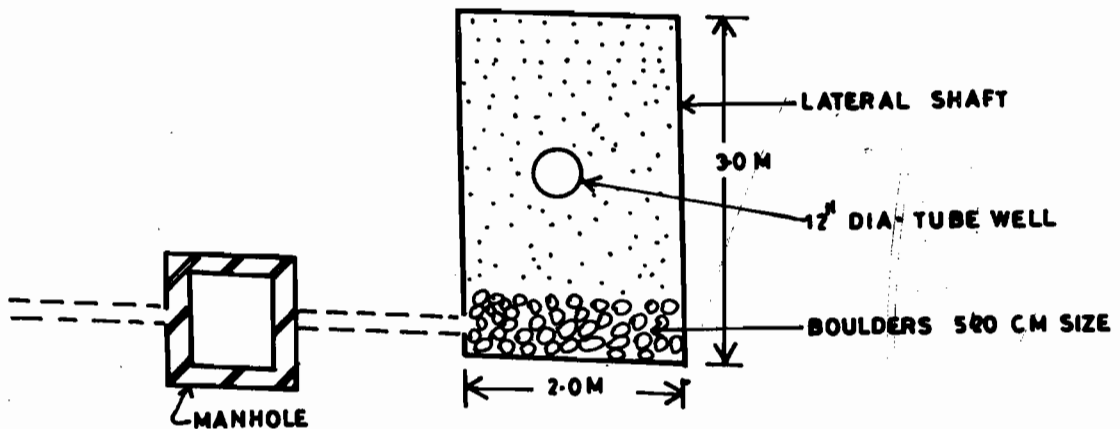
INDEX X

RECHARGE STRUT
STORM DRAIN
GRATING

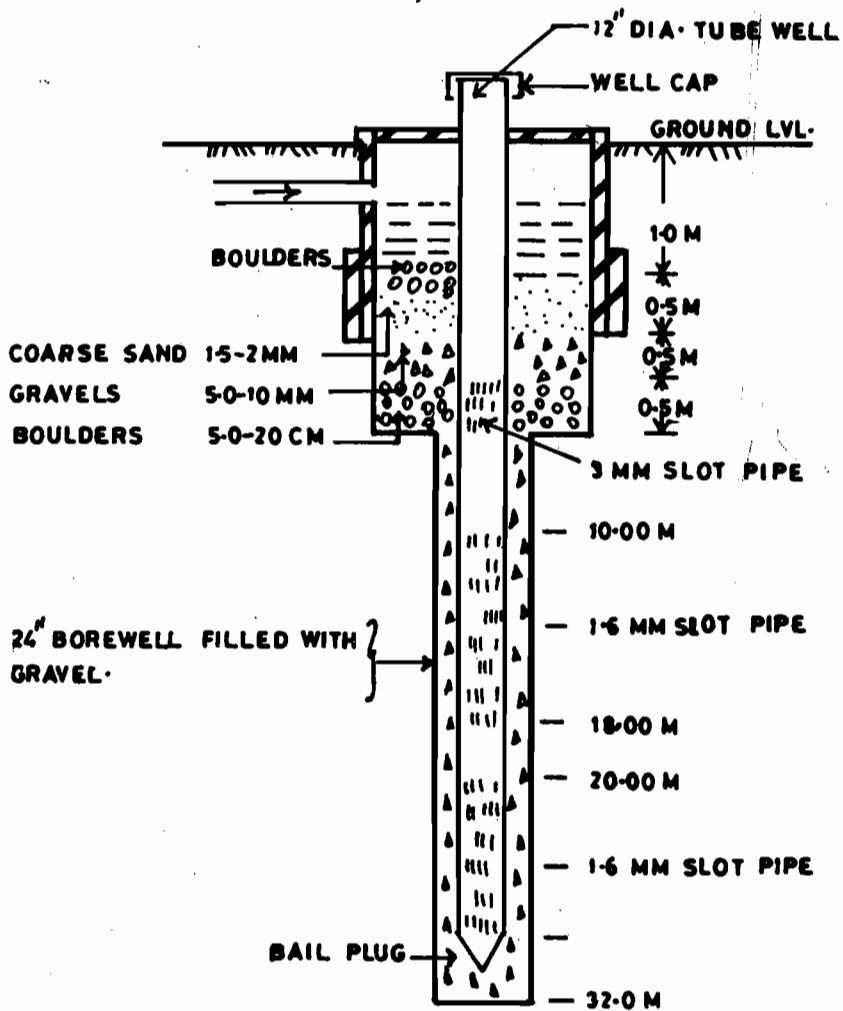
Drg-28: Location of recharge structures at sewa bhawan R.K. Puram



Drg-29: Design of recharge trench 1. (at sewa bhawan New Delhi)

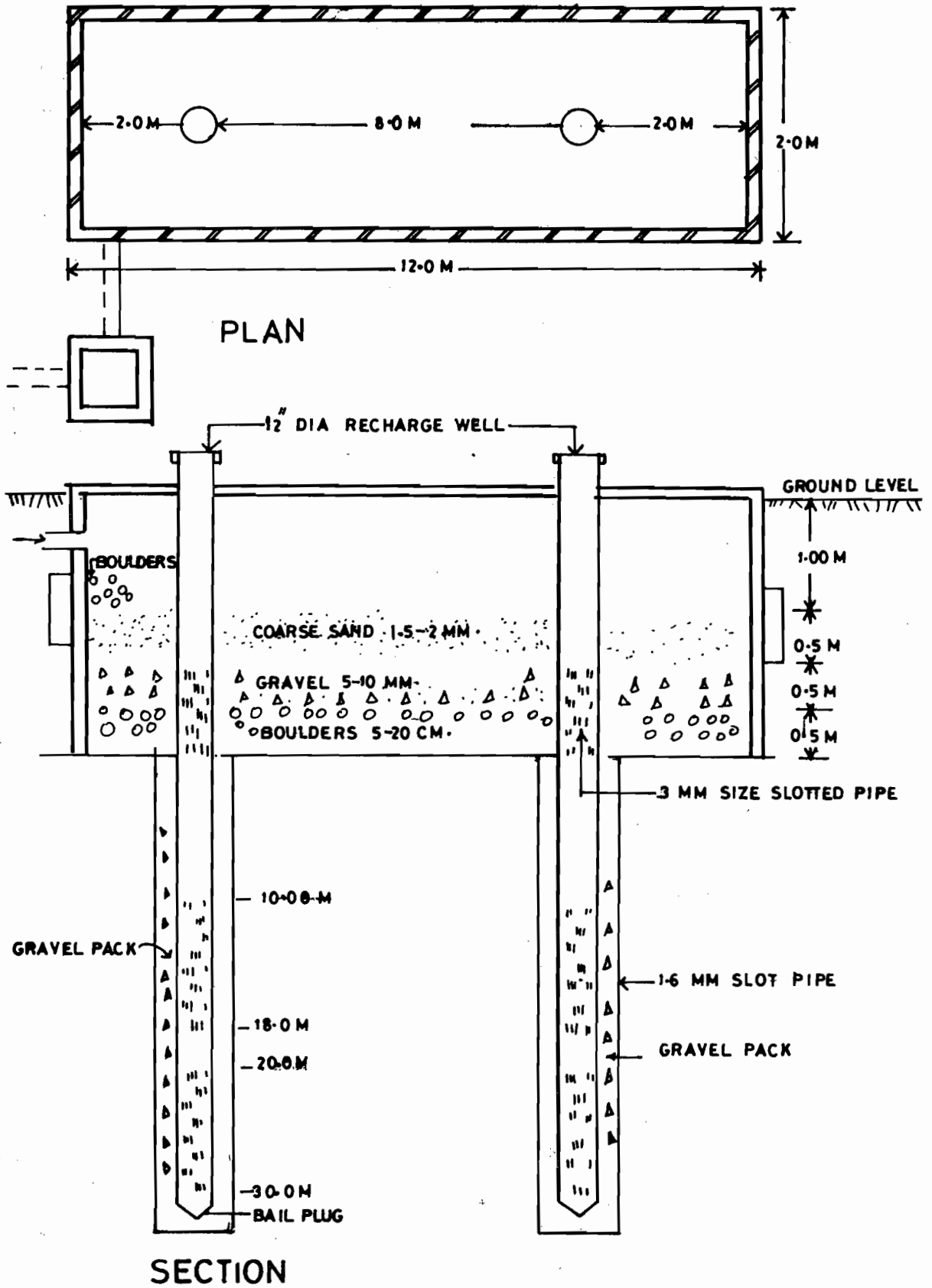


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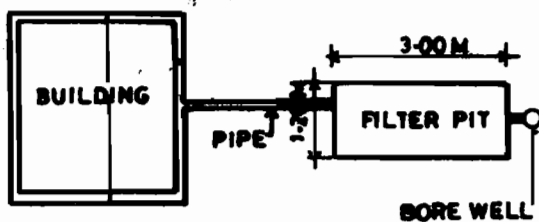


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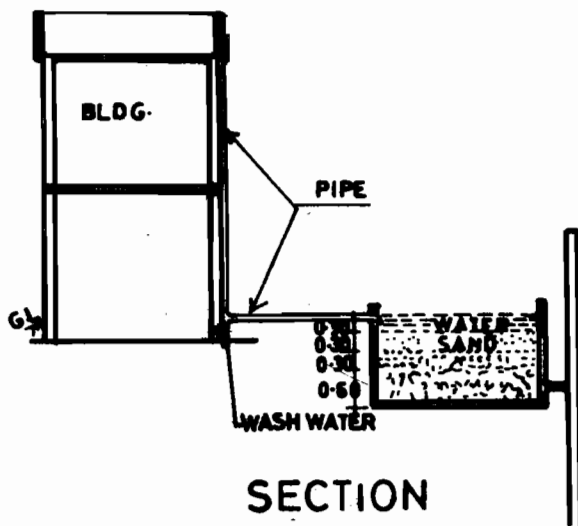
Drg-26: Design of lateral shaft 1,2,4,5&6



Drg-31: Design of alteral shaft 3 & 7

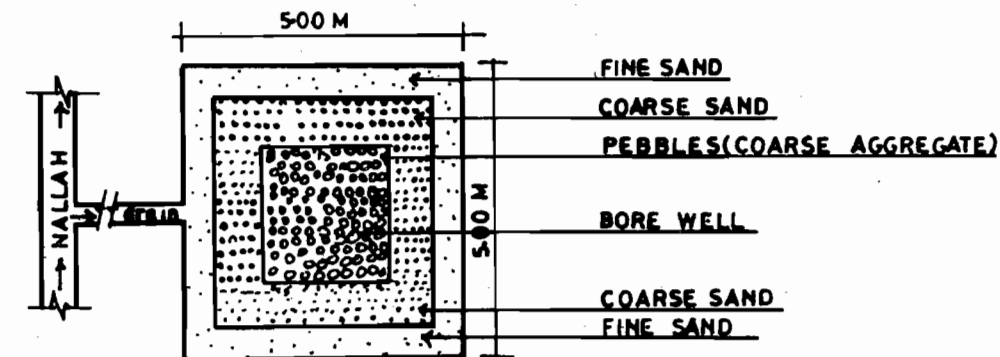


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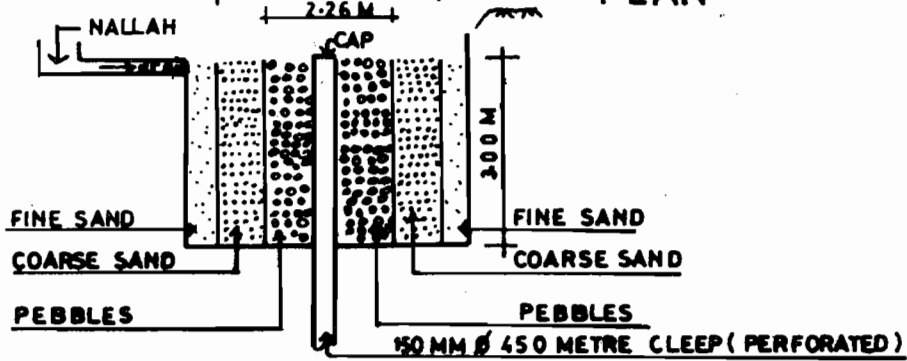


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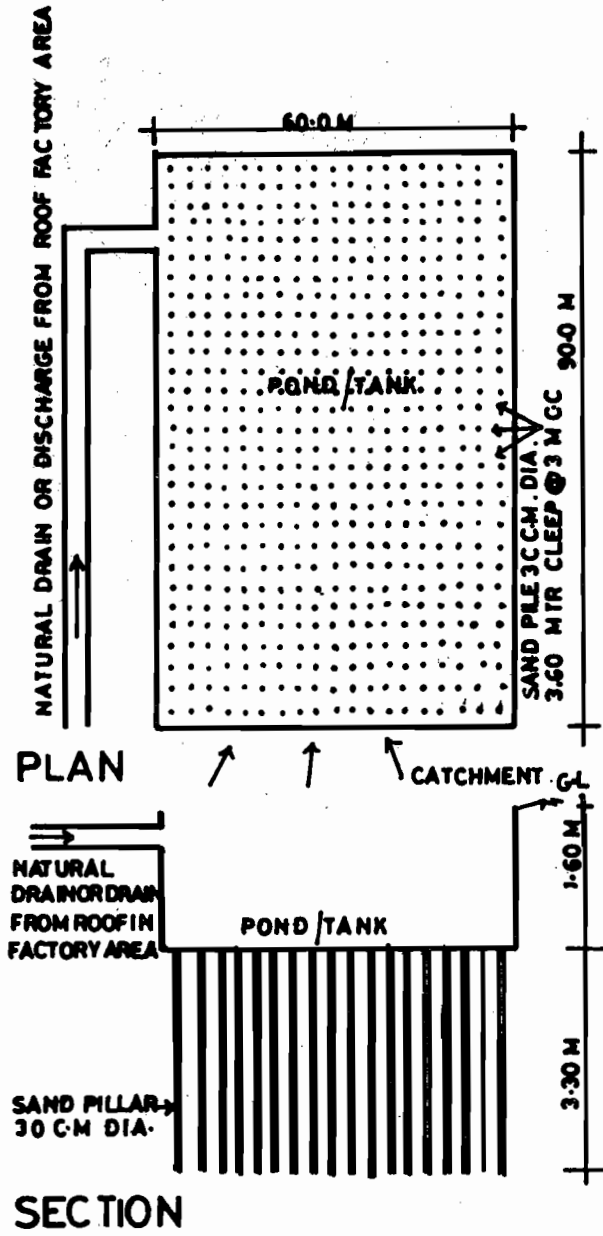
Harvesting of Roof Water



PLAN



SECTION



Drg-33: Drain water harvesting with ponds/tanks

Concise
CPWD MANUAL
ON
RAIN WATER HARVESTING



RAIN WATER HARVESTING

0.0 Introduction

Rainwater harvesting is a technique recognized to conserve naturally available pure water through rainfall. In view of scarcity of potable water largely seen in most of the Metropolitan towns and also in areas not frequented by adequate rainfall, a necessity has been felt by the Govt of India to conserve natural water resource by this technique. Accordingly Central Govt has issued modifications in Unified Building Byelaws 1983 vide notification issued vide no 110011/9/93-DDV (Pt) DDIB dated 28.7.2001 (Annexure) making Rainwater Harvesting mandatory for buildings on plot size of 100 sqm. and above.

1.0 Definition

Rainwater harvesting is a system to

- Recharge the aquifer by rainwater through an artificial system at a rate more than that obtained under conditions of natural replenishment and/or
- Collect and store rain water.

2.0 Artificial Recharge of the Aquifer.

2.1 Techniques employed are:

2.1.1 Pits

Recharge pits are constructed for recharging the shallow aquifers. These are constructed 1 to 2 m. wide and 2 to 3 m. deep which are back filled with boulders, gravels and coarse sand.

2.1.2 Trenches

These are constructed when the permeable strata is available at shallow depths. Trench may be 0.5 to 1 m. wide, 1 to 1.5 m. deep and 10 to 20 m. long depending on the availability of water and the permeability of soil strata. These are back filled with filter materials.

2.1.3 Dug Wells

Existing dug wells may be utilized as recharge structure and water should pass through filter media before putting into dug well.

2.1.4 Hand Pumps

The existing hand pumps may be used for recharging the shallow/deep aquifers, if the availability of water is limited. Water should pass through filter media before diverting it into hand pumps.

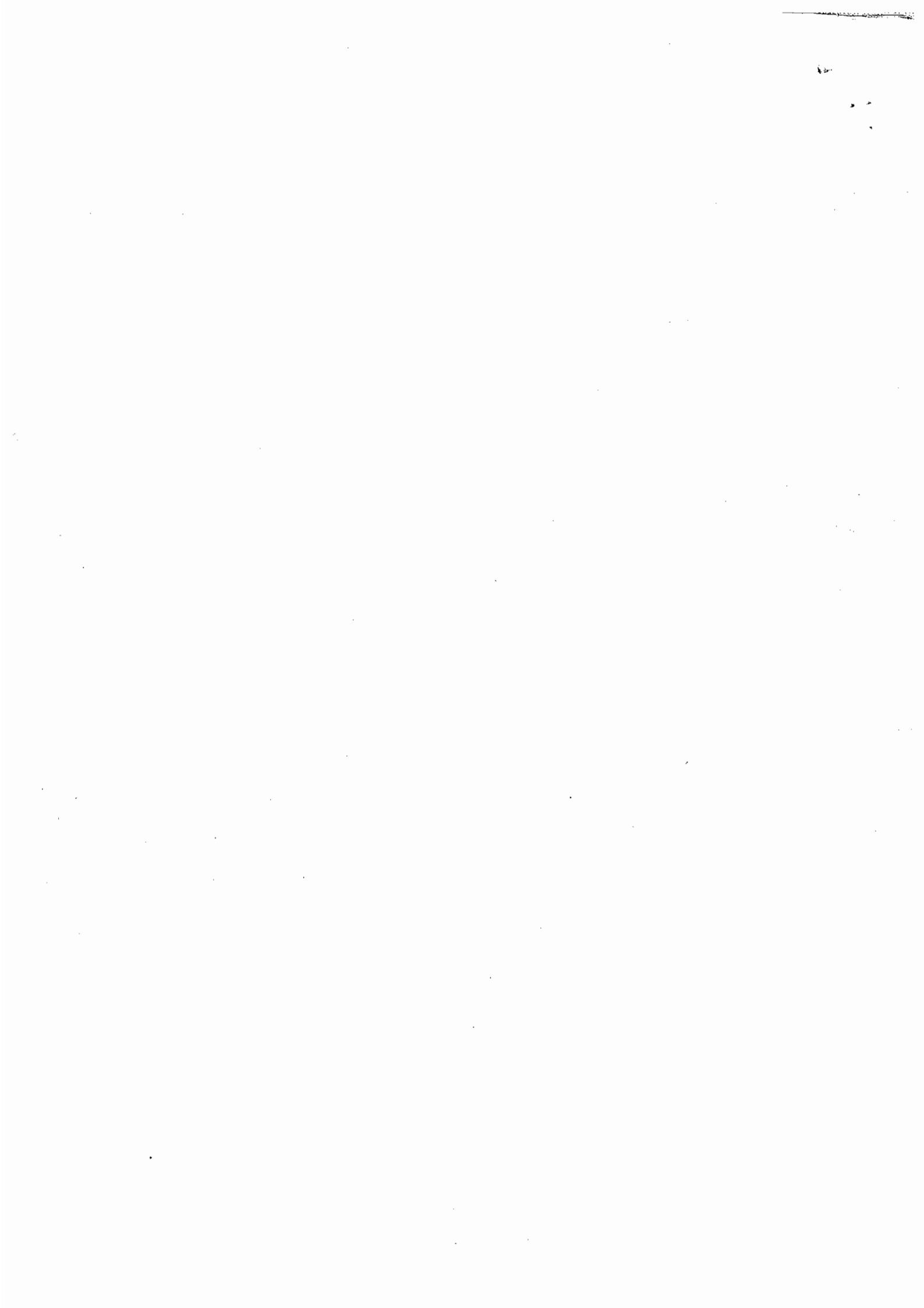
2.1.5 Recharge Wells

Recharge wells of 100 to 300 mm. diameter are generally constructed for recharging the deeper aquifers and water is passed through filter media to avoid choking of recharge wells.

2.1.6 Recharge Shafts

For recharging the shallow aquifers, which are located below clayey surface, recharge shafts of 0.5 to 3 m. diameter and 10 to 15 m. deep are constructed and back filled with boulders, gravels & coarse sand.

2.1.7 Lateral Shafts With Bore Wells



For recharging the upper as well as deeper aquifers lateral shafts of 1.5 to 2 m. wide & 10 to 30m. long depending upon availability of water with one or two bore wells are constructed. The lateral shafts are back filled with boulders, gravels & coarse sand.

2.1.8 Spreading

When permeable strata starts from top then this technique is used. Spread the water in streams/Nalas by making check dams, nala bunds, cement plugs, gabion structures or a percolation pond may be constructed.

3.0 Collect and Store Rain Water

Underground or Surface storage tank connected to the roof top or similar water collection system with piping and storage pit through graded filter and charcoal. The under ground or surface water storage tank, to store treated rainwater, could also be connected with the water supply and distribution system as an alternative source of supply.

4.0 Criteria Necessitating Rain Water Harvesting

4.1 Artificial Recharge of the Aquifer.

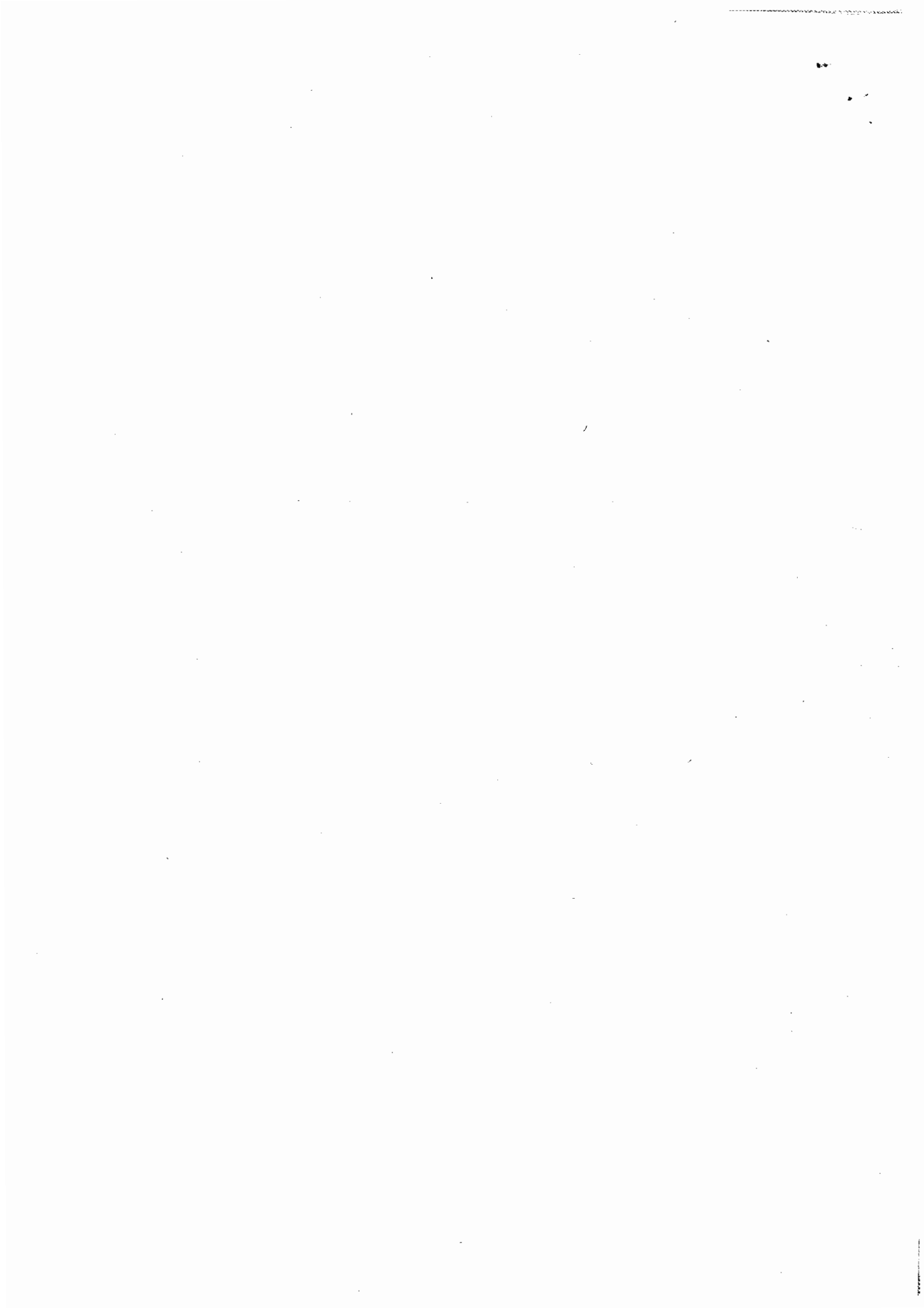
Under any one or more of the following conditions, rain water harvesting by artificial recharge can be resorted to:

- 4.1.1 Ground water table is continuously getting lowered in identical months of the year when compared with past.
- 4.1.2 The source of supply is ground water drawn from tube wells or dug wells.
- 4.1.3 Quality of ground water is poor and it needs to be improved by artificial recharge. This is also necessary where possibility of intrusion of saline water is there, as is the case in coastal regions.
- 4.1.4 Permeable aquifer is available at shallow to moderate depth.
- 4.1.5 Depth of ground water table from the natural ground level from structural considerations is more than
 - a. 3 metres in case of load bearing construction,
 - b. 5 metres in case of framed construction with single basement
 - c. 8 metres in case of framed constructions with double basement
- 4.1.6 Sufficient depth of ground water table (more than 8 metres) for sub surface storage is available.
- 4.1.7 Where rate of evaporation is very high as is the case in dry and arid areas.
- 4.1.8 Adequate space for surface storage is not available, which is more common in urban areas.

4.2 Collect and store rain water:

Under the following circumstances, the rainwater could be collected and stored for future use.

- 4.2.1 Depth of ground water table is very deep.
- 4.2.2 Quality of ground water is very poor and unfit for human consumption. Simultaneously, it is also assessed that recharge to the ground water reservoir is not likely to improve its quality due to the nature of sub soil strata.



- 4.2.3 Annual rainfall is far lower than the requirement of water for human consumption.
- 4.2.4 Enough roof top area or clean water collection system is available.
- 4.2.5 Sufficient rainwater storage capacity that could be provided either in the form of impervious surface or underground tank or ground surface storage system in the form of impervious check-dams, ponds, etc

5.0 Data for Design of Artificial Recharge of the Aquifer

Following data is generally essentially required for design of system of artificial recharge of the aquifer.

- i. Average annual rainfall
- ii. Average monsoon rainfall.
- iii. Period of monsoon.
- iv. Maximum hourly rate of rainfall
- v. Bore log of sub soil with soil properties at least up to the lowest ground water table.
- vi. The depth of ground water level during the leanest season.
- vii. Possible recharge structure types, as stated in para 3.0 above, that could be provided.
- viii. Contoured lay out plan of the area.
- ix. Chemical analysis of available ground water during leanest season.

6.0 Design of Artificial Recharge of the Acquirer

The rain water harvesting system by artificial recharge of the aquifer shall be designed based on design data given in para 5.0 above and other considerations discussed herein above. The design shall be carried out considering that the system shall recharge the ground water without further contamination due to impurities and dissolved chemicals, if any, due to sources other than from rain.

