IRC:SP:42-2014

GUIDELINES
OF
ROAD DRAINAGE

(First Revision)

INDIAN ROADS CONGRESS
2014

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GUIDELINES OF ROAD DRAINAGE

1 INTRODUCTION

1.1 Adequate drainage is a primary requirement for maintaining the structural soundness and functional efficiency of a road. Pavement structure including subgrade must be protected from any ingress of water; otherwise over a period of time it may weaken the subgrade by saturating it and cause distress in the pavement structure. That is why rapid dispersal of water from pavement and subgrade is a basic consideration in road design. Also, proper drainage takes away the water from pavement surface quickly and reduces the chance of skidding of vehicles. Because of inadequate surface and sub-surface drainage, the structural stability of pavement is undermined by,

1) Weakening of pavement structure and subgrade through infiltration of water from the top, and
2) Erosion of shoulders, verges and embankment slopes caused by water running off the pavement.

1.2 The detrimental effects of water in the pavement system are as under

i) Water in the asphalt surface can lead to moisture damage, modulus reduction and loss of tensile strength. Saturation can reduce the dry modulus of the asphalt by as much as 30 percent or more

ii) Added Moisture in unbound aggregate base and sub base is anticipated to result in a loss of stiffness on the order of 50 percent or more

iii) Modulus reductions of up to 30 percent can be expected for asphalt treated base and increase erosion susceptibility of cement or lime treated base

iv) Saturated fine grained roadbed soils could experience modulus reduction of over 50 percent.

1.3 The role of proper drainage to ensure longevity of pavement has been emphasized in IRC:37 “Guidelines for the Design of Flexible Pavements”. Among the measures mentioned therein, to guard against poorly drained conditions is maintenance of transverse sections in good camber to reasonable cross fall so as to facilitate quick runoff of surface water and provision of appropriate surface and sub-surface drains, where necessary. Some other measures, such as extension of granular sub-base over the entire formation width, provision of drainage layer, adequate height of formation level above HFL/ground level etc. are also mentioned. Infiltration of water under the pavement through adjoining earthen shoulders (or verges) and median is also a major cause of weakening of the pavement. Road design must take this into account.

1.4 A road drainage system must satisfy two main criteria if it is to be effective throughout its design life:

> It must drain surface and subsurface water away from the roadway and dispose it in a way that prevents excessive collection of water in unstable areas and subsequent downstream erosion.

1.5 The design of drainage structures is based on the sciences of hydrology and hydraulics, the former deals with the occurrence and formation of water in the natural environment (precipitation, stream flow, seepage, etc.) while the latter deals with the engineering aspects of liquid in motion.

1.6 If the water present in the surface course is not prevented from entering the road pavement by means of impervious wearing and binder course or a completely impervious bond coat, water will enter the road pavement from above and weaken it, even to the extent of resulting in pavement failure.

1.7 Despite measurers for quick drainage of pavement surface as well as provision of fairly watertight surface, water enters from top through cracks and travels through various pavement layers and gets accumulated at the surface of sub-base/base course and subgrade causing considerable functional problems. While in new road construction, this aspect is usually taken care of by providing a drainage layer at this level, in the existing boxed type pavement construction, this is an acute problem and special measures need to be taken as per actual site requirements for draining out the locked water.

1.8 Also the road pavement itself must be constructed so that it will drain in the event of a failure of the integrity of the surfacing layers, i.e. if water is able to enter the road pavement there must be a path for it to exit. The internal drainage function of a road pavement is usually performed by the GSB and drainage layer, and this layer must be drained in some way.

1.9 A clear idea about internal drainage of a pavement structure and the mechanism of failure on account of inadequate drainage facilities in a pavement system should be understood and suitable remedial measures taken against it to ensure desired performance during the service life of the pavement.

1.10 Considering the importance of drainage, the Embankment, Ground Improvement and Drainage Committee (H-4) of IRC in one of its meeting decided that separate guidelines covering specific requirements for different situation such as rural (plain and rolling), hilly and urban sections of roads and airfield pavement should be prepared. These guidelines on road drainage are the first such guidelines on this subject in this country. They are applicable in non-urban (rural) road sections in plain and rolling terrain.

1.11 First draft of IRC:SP:42 was published in 1994. Considering the practical problems faced in road from many years due to drainage issues, it was decided to revise the draft. As per the decision by H-4 Committee members during the meeting held on 07.04.2012, it was decided to constitute the Sub-group committee of experts in the field of road drainage. Convenor of Sub-group was Prof. S.K. Mazumder and Member-Secretary was Ms. Shabana Khan. The Introduction, Scope and General criteria is revised in line with the decision of Sub-group committee meeting held on 14.06.2012 by Mr. A.K. Srivastava. Chapter 4, Chapter 5 and Chapter 8, Surface, Sub-surface Drainage and Side Drains and Ditches are drafted by Mr. M.C. Venkatesha. Hydrological Design (Chapter 6) is modified by Mr. Subhasis Mukherjee. Hydraulic Design Chapter 7 and 1st Part of Chapter no 9 (Cross-drainage work) are modified by Prof. S.K. Mazumder. Second part of Chapter 9 Bridge Drainage is revised by Ms. Shabana Khan and Mr. S.R. Tambe. Chapter 10 is a new addition which is written by Prof. S.K. Mazumder. Section 4.4.10 Drainage of Reinforced Soil Wall is contributed by Ms. Minimol Korulla and Mr. Anik Chakaroborty.

The Sub-group prepared initial draft and thereafter, same was discussed and deliberated in number of committee meetings. The H-4 Committee approved the draft document in its meeting held on 7th December, 2013 for placing before the Highways Specifications & Standards Committee (HSS).

The composition of Embankment, Ground Improvement & Drainage (H-4) Committee is as given below:

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The HSS Committee in its meeting held on 7th January, 2014 approved this document. The Executive Committee in its meeting held on 9th January 2014 approved the same document for placing before the Council. The IRC Council in its meeting held at Guwahati (Assam) on 19th January, 2014 approved the draft revision of IRC:SP:42 “Guidelines on Road Drainage” for publishing.

2 SCOPE

These guidelines deal mainly with drainage of non-urban (rural section) roads running through plain and rolling areas. The aspects covered are influence of surrounding topography and geography, alignment and geometrics of the road, transverse and longitudinal drainage, drainage of shoulders, verges and median (central verge), internal drainage of pavement structure, drainage of subgrade, drainage of high embankment, surface & subsurface drains and cross drainage with ground water recharging. Examples of estimation of peak run off and hydraulic design of surface drain are also given. However, it may be noted that drainage of urban roads (IRC:SP:50), hill roads, airfield pavements and cross drainage structures have been covered under, separate guidelines on these subjects. A new section on ground water recharge from drainage has been added.

3 GENERAL CRITERIA

Highway construction is an engineering project with the objective of providing a uniform solid surface (road) on which the vehicle can travel with safety and ease preferably in all weather conditions. Water and traffic impact are the main causes of road failure or its distress.

In this code, the aspect of the highway design affected by water is dealt with. The general term used for this is road drainage design.

3.1 Following are the important factors which are required to be kept in mind before designing a drainage system for a road:

i) Expected traffic, importance and configuration of the road (2-lane/4-lane/6-lane)

ii) Sources of water which may reach the road from above, sides and below

iii) Drainage catchment areas and existing drainage systems

iv) Geology, hydrologic and hydro-geologic conditions in the surrounding area of the road

v) Geometric characteristics of the road (alignment, profile and cross-section)

vi) Presence of extreme gradients and cross slope, areas of excavation and land fill, probability of frost formation

vii) Any limitations in and around the road which may affect the design of drainage system

3.2 Reason for Damage to Road Pavement

i) Due to hydraulic pressure of water inside pavement layers or subgrade

Once water has entered a road pavement, damage is initially caused by hydraulic pressure, i.e. vehicles passing over the road pavement impart considerable sudden pressure on the water present in the road pavement. This pressure forces the water further into the pavement matrix and breaks it up. This process can be very rapid once it begins. Water that has entered the pavement and is subject to the process of freezing (expansion) and thawing during the winter also brings about the swift failure of the road pavement. Eventually the water will descend to the subgrade layer below the pavement courses and weaken this layer, and deep seated failure of the road will begin.

ii) Binder stripping in pavement layers due to water

Most aggregates have a greater affinity for water than they do for bitumen, and with the presence of water and movement of the aggregate it is quite possible for the binder film on the aggregate particle to be broken and water to come in contact with the aggregate surface. Once the integrity of the binder layer has been broken it will depend upon the chemical nature of the aggregate particle and the viscosity of the binder as to how long it will be before stripping of the aggregate particles becomes an engineering problem. Depending on the viscosity of the binder and the thickness of the binder film surrounding the aggregate the stripping of the bitumen will occur hardly at all, fairly slowly or quite quickly.

3.3 The selection of type of drain to be constructed on a highway project section depends on following situations:

- i) For highway in cutting
- ii) For highway in embankment
- iii) For highway with hill on one side and valley/plain on the other side

3.4 Roads are Constructed with Two Types of Drainage Systems

i) Surface Drainage

a) Transverse drainage

It is used to provide the continuity of natural water lines, intercepted by the road. It is designed to avoid the flooding of the platform and surrounding areas.

E.g. Aqueducts culvert construction and cross drainage structures

b) Longitudinal drainage

Used to gather and channelize the precipitated water on the road surface and from the side slopes and nearby land thus avoiding its access to the road surface.

E.g. Unlined and lined drains, kerb channel drain

ii) Subsurface Drainage

It is very important to release water trapped inside subgrade and pavement layers. This is because soil resistance to compression may drop substantially if its moisture content increases. Increase in moisture content inside pavement beyond a limit (e.g. Liquid Limit) results in reduction of the load carrying capacity of the road and premature failure and distress of the pavement resulting in reduction in the design life of the pavement.

The changes in moisture content in the subgrade and pavement layers occur because of ingress of sub surface water, change in water table, ingress of water from top through cracks, leaked joints etc.

Following two types of sub surface drains are constructed to dispense trapped water inside the subgrade and pavement layers:

a) Longitudinal interception drains

b) Longitudinal water table lowering drains

3.5 Alignment of the road can have a vital bearing on the problem of drainage. Therefore, in case of new roads, surface drainage should be one of the criteria while fixing the alignment. For example, locations parallel to large streams and running close to them are likely to give rise to constant trouble besides the fact that several converging tributaries/ distributaries would be needed to be crossed. An ideal alignment should avoid steep and heavy cuts/fills as these situations have the potential of throwing up piquant problem of drainage and erosion control. Problems of these types are often prominent in rolling terrain since alternate cuts and fills, unless designed with an eye on the smooth dispersal of surface water, could play havoc with the natural drainage of the area and give rise, among other difficulties, to subterranean flow under and across the road. In each case where cutting is involved meticulous care is needed right at the start to anticipate the volume of water flow so that necessary design measures to avoid instability of the road can be taken. No doubt, surface drainage is just one among many other considerations in road location but it warrants careful attention.

3.6 Normally in plain areas road subgrade elevation in fill sections is so fixed that the top of the subgrade shall be at least 0.5 m above the original ground level - in non-flood area as shown in **Fig. 3.1**. The bottom of the subgrade shall be 0.5 m to 1.00 m above the HFL based on type of soil (**Fig. 3.2**). The HFL should be decided by intelligent inspections, local observations, enquiries and studying the past records. Where it is not possible to assess the HFL, it shall not be lower than the general ground level. IRC:SP:87 allows top of subgrade at 0.5 m above ground.

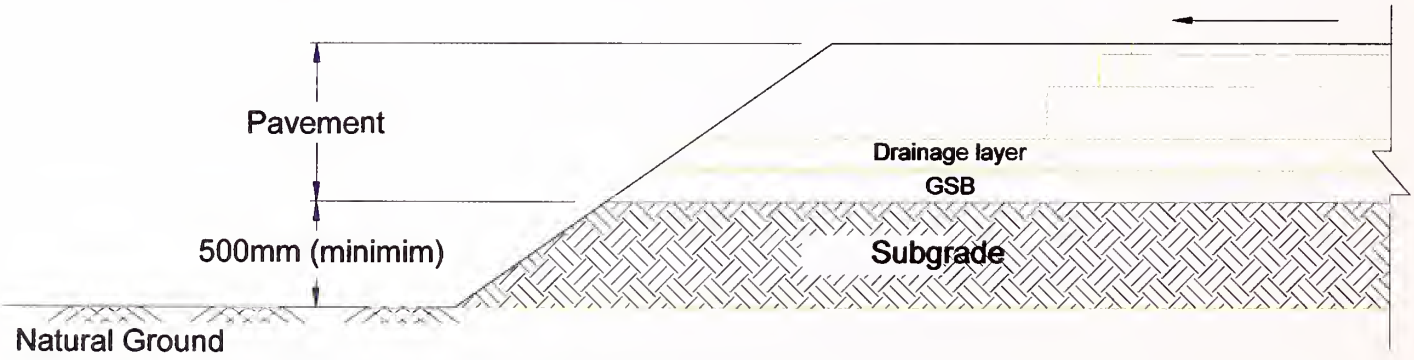


Fig. 3.1 Road Passing Through the Terrain (in Non-Flooded Area)

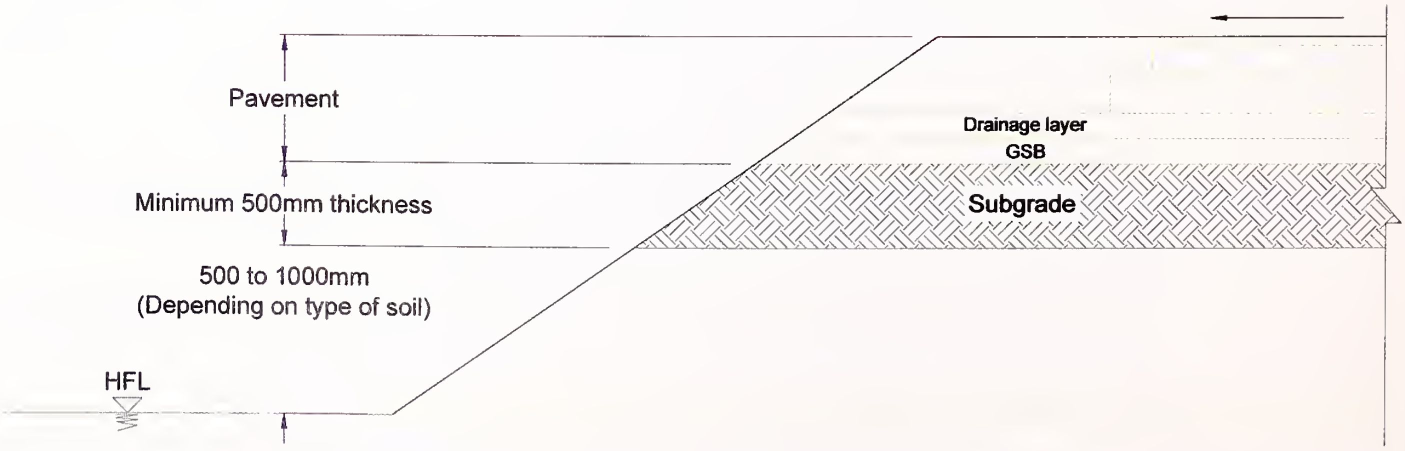


Fig. 3.2 Road Passing Through Terrain (in Flooded Area)

3.7 If a consolidated view is taken, there are three aspects of surface drainage design in which the road engineer is particularly interested. The first concern is with fast dispersal of precipitation on the road surface so as to minimize danger to moving vehicles. This is achieved by proper geometric design of the road, e.g. by crowning the carriageway or side cross fall, giving proper cross slope to the shoulders and verges, providing requisite longitudinal gradient etc. Second requirement is that water from the road and the surrounding area should be successfully intercepted and led away to natural outfalls. This is accomplished by a system of suitable surface drains, shallow ditches by the side of the road (or catch water drains on the hill slopes). Thirdly the engineer must build adequate cross drainage structures at river crossings and minor streams.

3.8 Survey and investigations is a basic necessity for designing a system fulfilling the above objectives. The work may involve:

i) Preparation of alignment plan, longitudinal and cross sections and contour map

ii) Hydrological survey such as rainfall analysis and runoff estimation

iii) High flood statistical information for the region

iv) Hydraulic Design

v) Geotechnical investigation

Recourse to remote sensing methods such as aerial photography and satellite remote sensing may have to be made if necessary facilities are available. The factors which may have a bearing on road drainage such as rainfall, topography and natural drainage of the area, cross fall and longitudinal profile, existing drains and CD works and internal drainage of pavement layers etc. should be recorded.

4 SURFACE DRAINAGE

4.1 General

Drainage of pavement including its adjoining areas is an important aspect of pavement design. When a road is constructed on a natural terrain, the waterways are intercepted and hence necessary measures have to be taken to divert such water from road. Besides, water on road surface received from rain and snowfall has to be disposed of as quickly as possible to keep the road surface free from a sheet of water from safety considerations. Normally side-ditches, lined drains, catch-drains and network of cross-drainage structures are provided as part of the overall surface drainage system. This water received on surface of pavement, medians and shoulders also seeps to lower layers through permeable pavement, cracks, potholes, joints (in the case of concrete pavement) which needs to be got rid of for durability of pavement. Such moisture in the base and sub-base of pavement is disposed of through subsurface drainage system which is discussed in Chapter 5.

This section discusses primarily surface drainage of road pavement, shoulders, side slopes, medians, rotaries, junctions, high embankments etc. A flat pavement surface is not conducive to flow of water and hence it has to be suitably profiled to help quick disposal of precipitated water. A thick film of water on a road surface is a safety hazard as it may result in loss of contact between tyres and road surface due to formation of a wedge under tyres causing skidding of vehicles. This phenomenon known as hydroplaning or aquaplaning is dangerous when vehicles are moving at high speed. Shown in **Photo 4.1** is a typical situation where standing water on pavement surface can cause hydroplaning. Wheels moving partly on water and partly on pavement can cause instability in moving vehicle especially when pavements are kerbed. Danger is more pronounced in such kerbed roads as it creates a 'bathtub' condition as seen in **Fig. 4.1**. During its design, proper camber must be provided to drain the water expediently through kerb and channel or mere kerbs with grated openings or by providing grated manholes.

Photo 4.1 A Film of Surface Water which can Lead to Hydroplaning

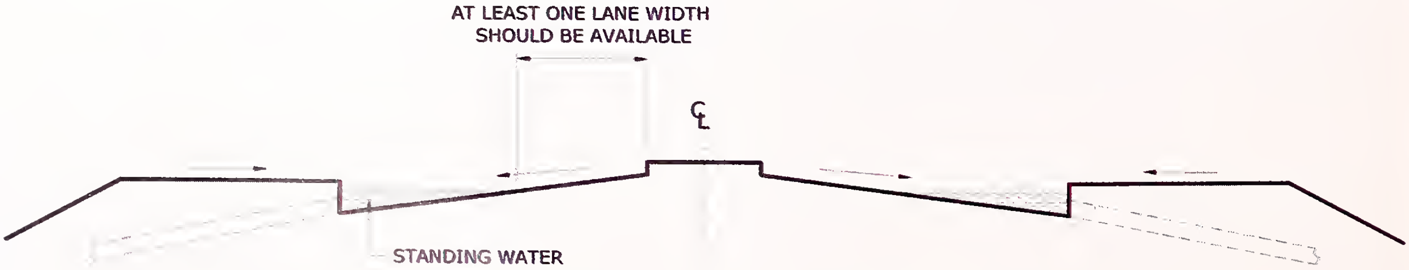


Fig. 4.1 A View of Standing Water on Pavement with Kerbs

4.2 Effect of Standing Water on Pavement

Consequence of standing water differs from pavement to pavement depending upon the type of surfacing provided. Effects of water on flexible and rigid pavements are discussed separately.

i) Flexible Pavement

Standing water remaining on bituminous pavement for a long period of time is not desirable as it tends to cause early deterioration of pavement. It can cause stripping of bitumen from aggregates especially when they are prone to stripping in case of some stones like granite, quartzite, quartz etc. If the bituminous mix is open-graded or poorly compacted or surface has cracks/ potholes, the water seeps to lower layers and accelerates the process of stripping. This water tends to migrate to lower layers of pavement and gets entrapped in granular base and sub-base layers. If the base and sub-base layers are not permeable enough to drain away this water laterally, it results in pavement resting on a waterbed leading to loss of aggregate to aggregate contact thus reducing load dispersal capacity and eventually leading to premature deterioration of pavement. Although bituminous pavement exhibits good skid resistance but it does not readily help in rapid disposal of surface water. This is due to the surface tension and also due to pitted surface without continuity as in the case of textured surface of cement concrete pavement. A typical aged bituminous surface where a layer of water takes more time to get cleared from road surface can be seen in **Photo 4.2**.

Photo 4.2 Texture of a Bituminous Pavement

ii) Concrete Pavement

A well compacted concrete pavement as such is generally impervious to water and does not get affected by standing water. But joints, cracks and shoulders permit moisture to seep through. For example a damaged joint as seen in **Photo 4.3** permits moisture to infiltrate through. Moisture enters through all joints including longitudinal joint formed with shoulder. Full depth cracks are another source through which water seeps under. Seeped water in some cases is ejected to the surface through joints under moving load bringing out fine soil particles thus creating hollow pocket below pavement.

Photo 4.3 A Damaged Joint Groove can Permit Seepage of Water to Lower Layers

This phenomenon is called as "mud pumping". In due course pavement loses support leading to corner cracks. Such moisture can also reach to lower granular layers saturating them thus weakening them leading to premature failure of pavement. Concrete pavement surface is textured for improving the skid resistance and also for facilitating quick surface drainage through tiny channels of texture. Tine and brush textures are the two types of textures applied on concrete surface as shown in **Photos 4.4** and **4.5**. It has been observed that tine texture is more durable than brush texture. Brush texture tends to become bald faster. Tine texture can be applied in both transverse and longitudinal direction but a school of thought considers that tine texture in transverse direction is preferred to on account of its better capacity to drain surface water quickly vis-a-vis in longitudinal direction although noise pollution is said to be less in the latter case.

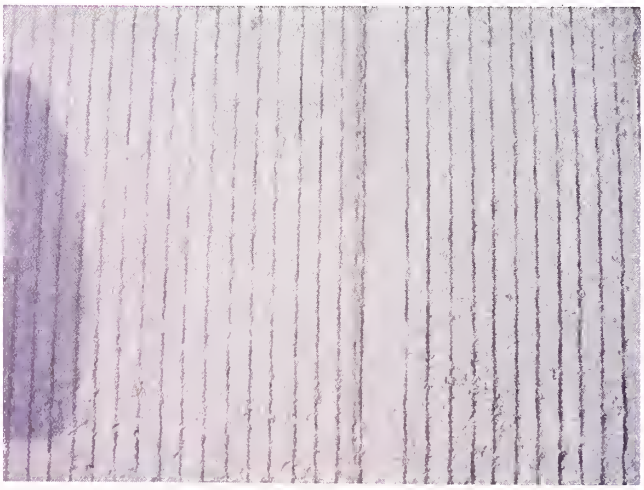


Photo 4.4 Tine Textured Concrete Pavement

Photo 4.5 Brush Textured Concrete Surface

iii) Granular/Earthen Surface

Standing water on granular or earthen surface is not desirable as it seeps to lower layers. Earthen surfaces become slushy making them unusable. Cross-slope of shoulder provided should be steeper so that water can flow expeditiously on such surfaces. Requirement of cross-slope in earthen shoulder, therefore, always has to be more than the paved surface.

4.3 Factors Affecting the Surface Drainage of Pavements

For quick surface drainage to take place the following features of pavement have to be detailed suitably:

i) Geometric features of pavement like longitudinal and transverse slopes
ii) Kerbs and gutters/outlets provided
iii) Type of surface
iv) Texture of pavement
v) Median drains in divided carriageways
vi) Lane widths

4.4 Effect of Geometric Features of the Pavement

4.4.1 *Longitudinal gradient of the pavement*

With a view to facilitate quick removal of rain water, longitudinal profile of the road normally is not designed flat. When the road is provided with kerbs as in the case of urban scenario, flat surface can result in collection of large quantity of water on the road. To avoid this situation a minimum longitudinal gradient of 0.3 percent is considered essential in most conditions.

4.4.2 *Pavement cross-fall or camber*

By providing cross-fall or camber to the pavement, the runoff water gets cleared from the surface rapidly. The cross-slope requirement differs for each pavement type. A mild cross-slope is sufficient in dense surfaces like bituminous concrete surface or concrete pavement but open-graded bituminous surfaces and granular/earthen surfaces require relatively steeper cross-slope for facilitating rapid flow. But steeper cross-slope in the case of granular/earthen surface may lead to erosion of surface. The cross-slopes proposed for adoption in Indian Roads are given in **Table 4.1**.

Table 4.1 Proposed Camber/Cross-Fall

Surface Type	Non-Kerbed Roads	Roads with Kerb
Earthen, Gravelled or WBM Surface	3–5%	–
Thin open graded bituminous surfacing	2.5–3%	2.5–3%
High type bituminous surfacing	2.0–2.5%	2.5%
Cement concrete surfacing	2.0%–2.5% in case of transverse tine or brush texturing	2.5%
	2.5%- in case of longitudinal Tine texturing	2.5%

4.4.3 *Requirement of camber in different pavement configuration*

4.4.3.1 Non-kerbed pavement

Camber requirement varies depending upon the geometric configuration of a road. A few cross-sections of roads are shown in **Figs. 4.2 to 4.6**. In the case of earthen shoulders, the water flowing on surface is guided away from the pavement including in super elevated sections as seen in these **Figs. 4.2 to 4.6**. Normally earthen or granular shoulders are provided with 0.5 percent more cross-slope than the paved surface as shown in **Fig. 4.2**.

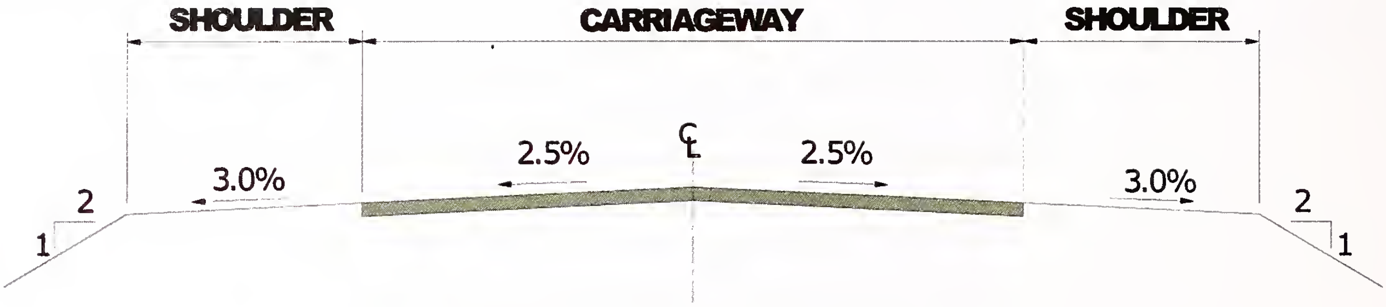


Fig. 4.2 Typical Double Camber

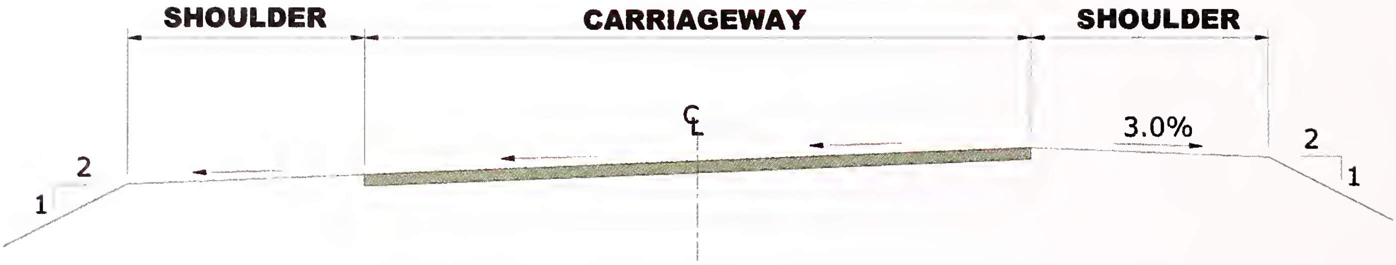
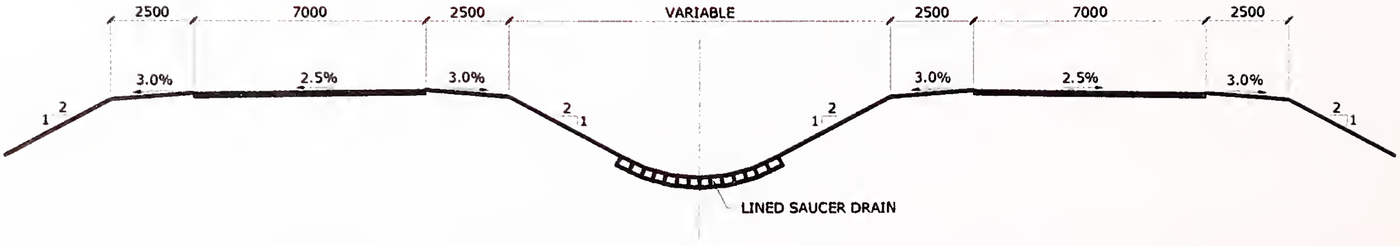
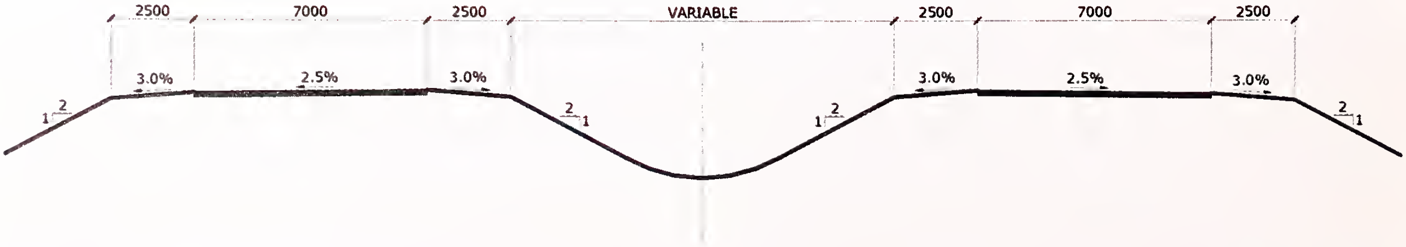


Fig. 4.3 Typical One-Way Camber in Super Elevated Sections



Note:
All Dimensions are mm.

Fig. 4.4 Cross-Section of a Four-Lane Rural Highway with Depressed Median with Lined Saucer Drain



Note:
All Dimensions are mm.

Fig. 4.5 Cross-Section of a Four-Lane Rural Highway with Depressed Median without Lined Saucer Drain

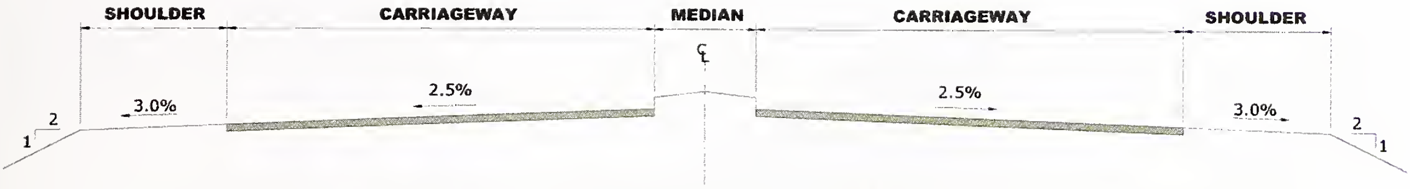


Fig. 4.6 A 4/6-Lane Divided Carriageway with raised Median Having Double Camber

4.4.3.2 *Disposal of water from kerbed pavement surface*

Shown in **Figs. 4.7 to 4.10** are a few typical kerbed pavement sections. In the case of kerbed pavements which are adopted by and large in urban sections where the footpaths are paved, the surface water is guided towards road edge as shown in the **Figs. 4.7 to 4.10**. The surface water thus collected at road edge is disposed of through outlets provided in the kerbs.

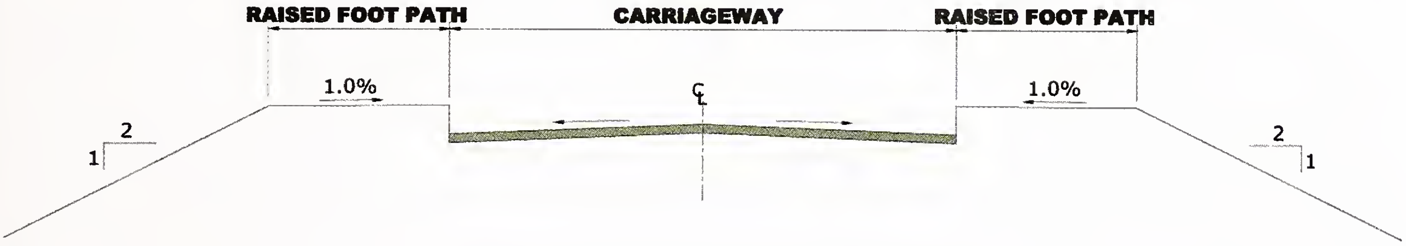


Fig. 4.7 A Typical Cross-Section of Road with Double Camber Provided in a Kerbed Carriageway (Urban Situation)

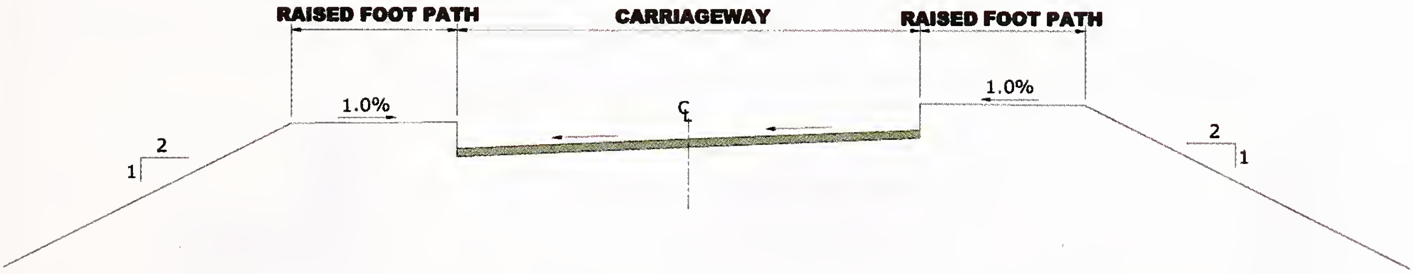


Fig. 4.8 A Typical Cross-Section of Road in Super-Elevated Section with Single Camber Provided In a Kerbed Carriageway (Urban Situation)

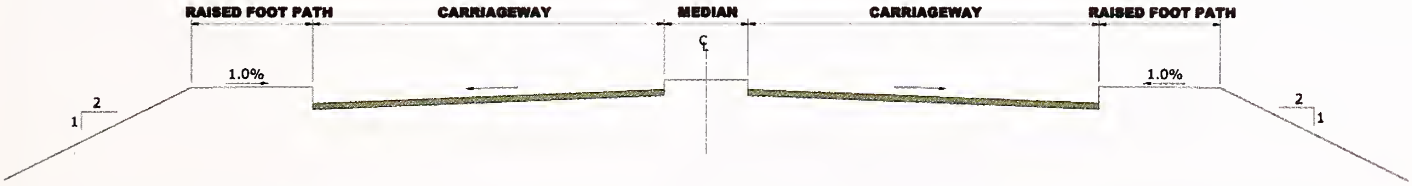


Fig. 4.9 A Typical Cross-Section of Divided Carriageway with Kerbs (Urban Situation)

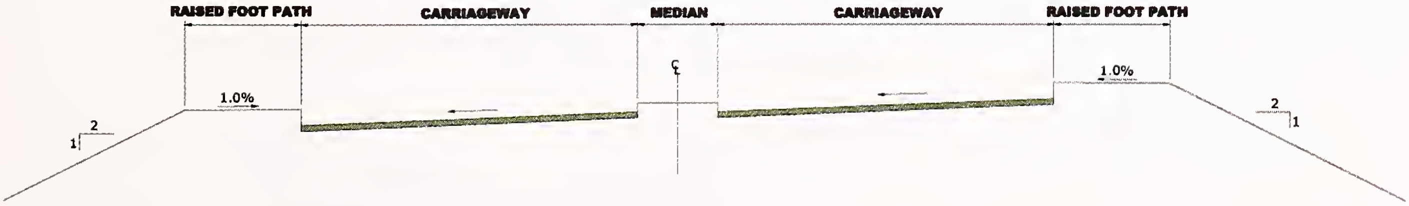


Fig. 4.10 A Simplified Typical Cross-Section of Divided Carriageway in Super Elevated Section with Kerbs (Urban Situation)

There are situations where in super elevated sections in divided carriageway, provision of single camber over entire width may be uneconomical due to increased earthwork. By having staggered camber (**Fig. 4.11**), earth work can be economised and disposal of surface water can be done quickly through central median.

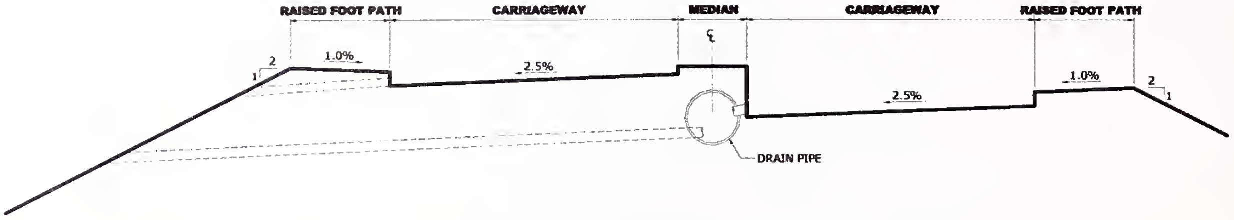


Fig. 4.11 A Typical Cross-Section with a Staggered Camber in a Divided Carriageway

4.4.4 *Types of kerbs and inlets normally provided/embedded*

A few standard kerb designs are shown in **Figs. 4.12 to 4.14**, which are used in urban areas, in junctions etc. The inlet design varies from place to place. In some cases an opening is provided in kerbs for this purpose. A PVC or HDPE pipe of 150 to 200 mm dia is provided to carry the water to side drain through this inlet. The intlets are provided generally with galvanised grating to block the entry of foreign material. Two typical designs of special kerbs are shown in **Figs. 4.15 and 4.16** for blocking entry of trash, paper, plastic bags etc. Two designs of gully traps provided on pavement edge and on footpath are shown in **Figs. 4.17 and 4.18**. In steep longitudinal gradient, as a good engineering practice it is necessary to orient the outlet pipe in the direction of lower gradient as shown in **Fig. 4.19** so that disposal of water is faster. Two types of inlet provided in kerb line can be seen in **Photos 4.6 and 4.7**. **Photo 4.8** shows horizontal grating.

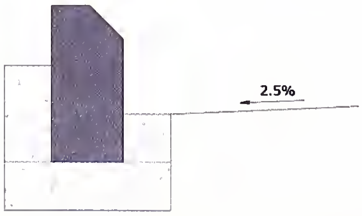


Fig. 4.12 A Standard Design of Non-Mountable Concrete Kerb

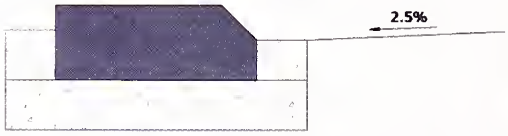


Fig. 4.13 A Standard Design of Mountable Concrete Kerb

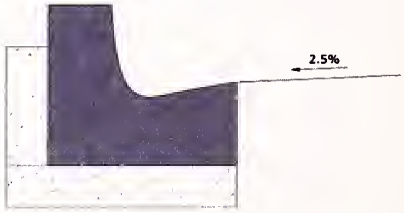


Fig. 4.14 A Standard Design of Concrete Kerb and Channel

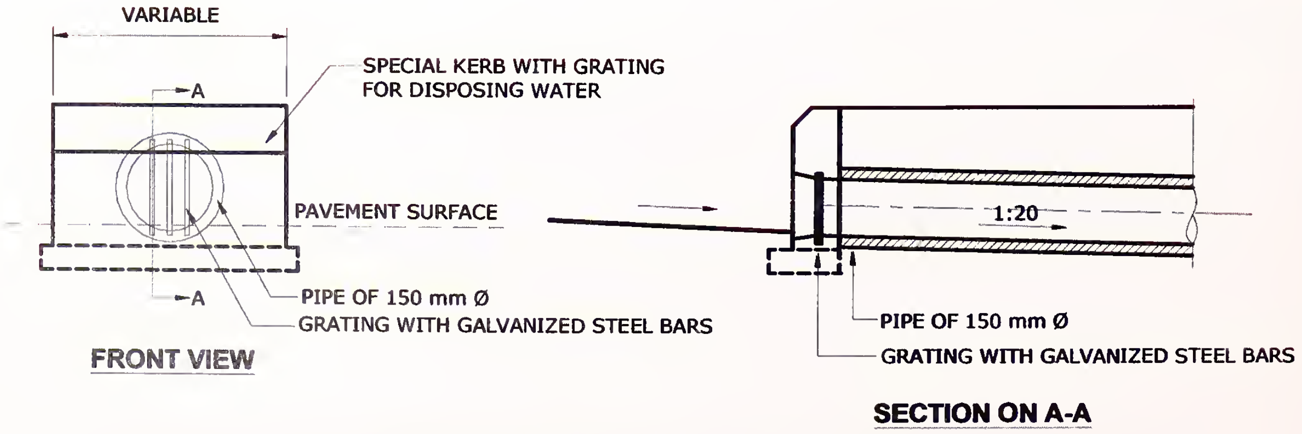


Fig. 4.15 Detail of Grated Inlet in Kerb

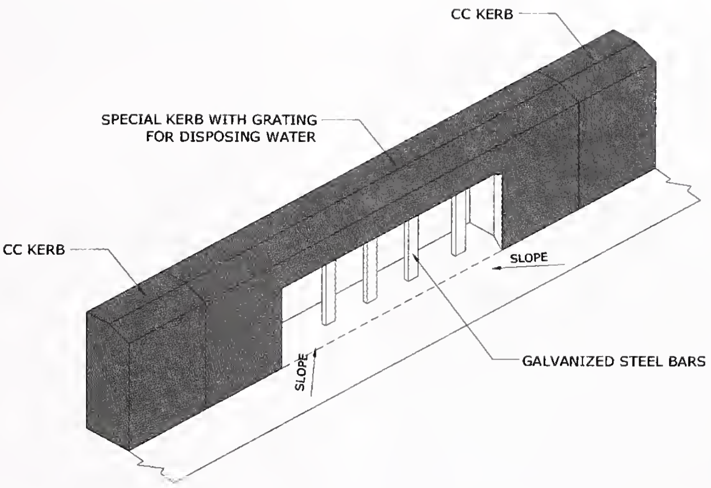


Fig. 4.16 Isometric View of a Special Precast Concrete Kerb with a Grated Opening

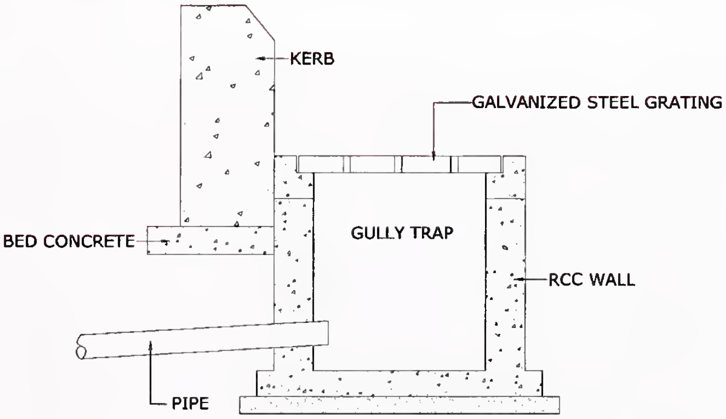


Fig. 4.17 A Sectional View of a Gully Trap Normally Used at Kerb Edge for Surface Drainage

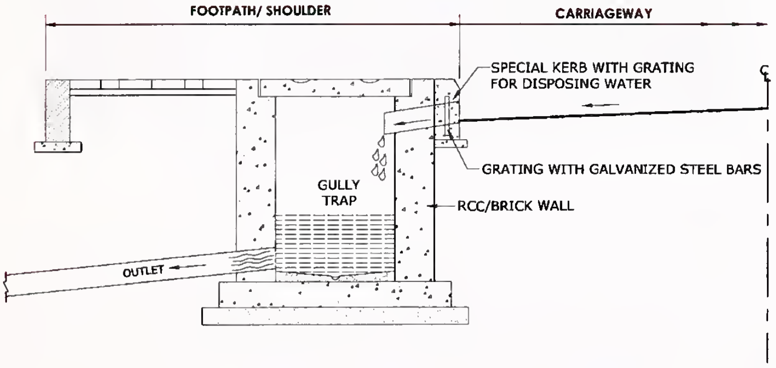


Fig. 4.18 A Sectional View of Gully Trap Provided on a Footpath

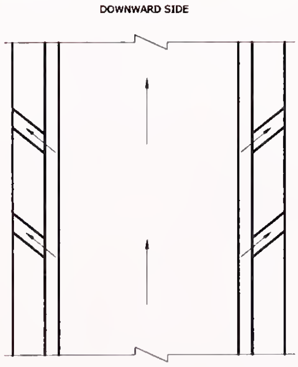


Fig. 4.19 Correct Orientation of Opening of Surface Drains in Longitudinal Gradients

Photo 4.6 Inlets Provided in a CC Kerb

Photo 4.7 Steel Gratings Provided in CC Kerb as an Inlet

Photo 4.8 Horizontal Grating

4.4.5 *Drainage of shoulders*

Black topped shoulders are durable and help in quick disposal of surface water. For economising cost of construction, shoulders are generally constructed with subgrade soil even on highways in India. As surface water cannot flow freely on earthen surface and camber is enhanced from 2.5 percent to 3 percent in normal cross-section.

A few eroded earthen shoulders with rain cuts can be seen in **Photos 4.9 to 4.12**. Silt and clayey soil are generally susceptible to erosion as seen in **Photos 4.9 and 4.10**, whereas good murrum/gravelly soil is relatively less prone to erosion as seen in **Photo 4.11**. Earthen or granular shoulders have to be periodically maintained by levelling and compacting to avoid drop-off (depression at road edge), erosion and consequential channelized flow of water in longitudinal direction as seen in **Photo 4.12**. This operation involves adding of fresh material to compensate for loss of soil due to erosion, vehicle movement etc. and compacting the same after mixing necessary moisture to achieve MDD. Various treatments provided for controlling surface erosion is discussed in Para 4.4.7.

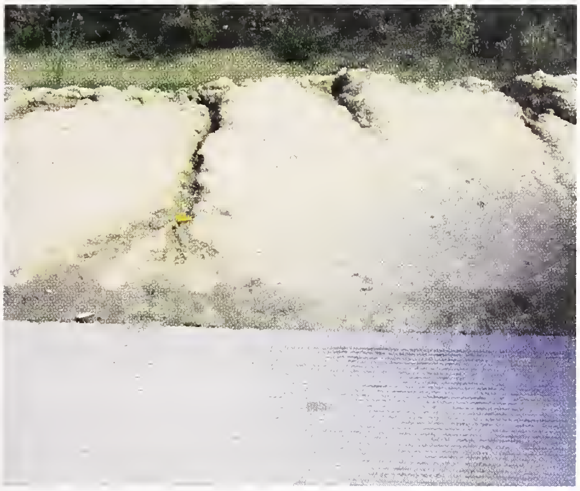


Photo 4.9 Eroded Earthen Shoulder of a Concrete Road

Photo 4.10 Severely Eroded Earthen Shoulder of Concrete Road

Photo 4.11 Limited Erosion Seen on a Shoulder Constructed with Granular Material

Photo 4.12 Earthen Shoulder of a Bituminous Pavement in Neglected Condition

4.4.6 *Treatment of batter*

The longitudinal edge where shoulder and side slope join is known as batter. This junction is highly vulnerable to erosion especially in the case of earthen or granular surfaces. This is the most neglected part of road. Therefore, for reducing erosion, rounding the sharp corner and compacting it as shown in **Fig. 4.20** is helpful. As normal roller cannot compact such location, hand-held plate compactors can be employed for compacting. As a long range measure it is helpful if a concrete kerb or brick-on-edge is placed all along the edge. Even when shoulder is blacktopped as shown in **Fig. 4.21**, kerb provided at batter helps in controlling breaking of edge.

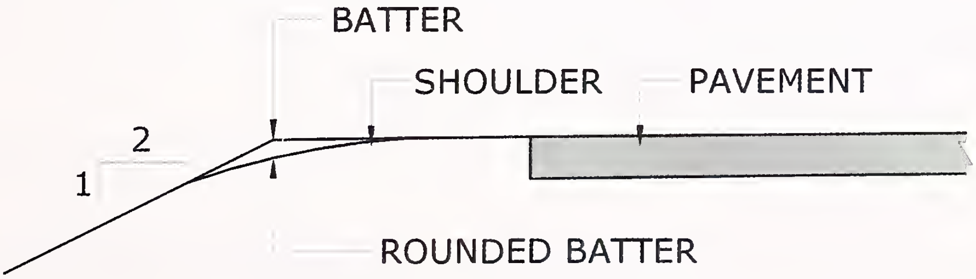


Fig. 4.20 A Rounded Batter for Controlling Erosion

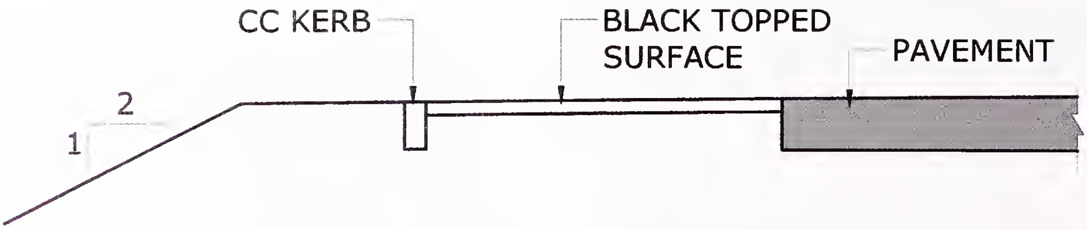


Fig. 4.21 Kerbed Shoulder to Control Erosion

4.4.7 *Control of erosion of shoulder*

4.4.7.1 Surfacing of shoulder

On account of cost considerations shoulders in India are constructed normally with earth used in subgrade. But in the long run, earthen shoulders are expensive to maintain them periodically. In some National Highways part of the shoulders is constructed with full-depth pavement and in some cases thin black topping is done. In some States in India, part of the shoulders are provided with brick-edging which not only protects shoulders but also gives lateral support to the pavement edge thus increasing its life (**Photo 4.13**). Width of brick-edging can vary from 0.3 m to entire width of shoulder depending on the availability of funds. In urban limits use of concrete block pavement on shoulder lately has become increasingly common (**Photo 4.14**). Construction of thin bituminous layer on shoulder is a good proposal to control erosion and drop-off. Depending on the susceptibility of the surface to erosion suitable treatment has to be provided.

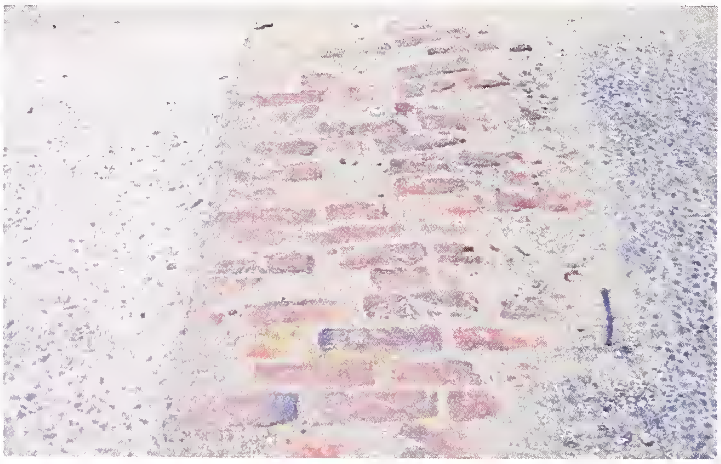


Photo 4.13 Brick Surfaced Shoulder

Photo 4.14 Shoulder Paved with Concrete Blocks

Shoulder surface can be of various types:

i) Paved shoulder with bituminous surface

ii) Paver block shoulder (in urban area mainly) with concrete surface (**Photo 4.14**)

iii) Hard shoulder with grand surface or brick edging (**Photo 4.13**)

iv) Earthen shoulder with soil surface

4.4.7.2 Grade and level control

Erosion of shoulder surface especially the unpaved types can be controlled by maintaining proper grade and level. Adequate camber has to be maintained at all the times as indicated in **Table 4.1**. Besides, shoulder drop should not be allowed to occur as it causes not only damage to the shoulders runoff ability but also permits water to infiltrate into the pavement through the shoulder edge.

4.4.7.3 Turfing

Turfing helps in controlling erosion of earthen shoulder provided it is periodically trimmed and kept clean. Normally due to lack of maintenance, the turf grows to tall height and besides decayed old grass raises the level and obstructs flow of water as seen in **Photo 4.15**. Seen in **Photo 4.16** is a situation where cuts/trenches have been made in the turfed shoulder to drain surface water as turf itself was found obstructing flow of water. The turf seen in the above photos is naturally grown and of wild variety. Some variety of grass which spreads horizontally and does not obstruct flow of water must be selected for protection of shoulders and not the wild variety. Use of a mini CC kerb or brick edging on batter helps in keeping shoulder edge intact (**Fig. 4.21**).

Photo 4.15 A View of Tall Grass Obstructing Surface Drainage

Photo 4.16 Naturally Grown Turf on Earthen Shoulder Causing Resistance to Disposal of Surface Water

4.4.7.4 Use of graded material

Provision of brick edging (as shown in **Photo 4.15**) at the junction of pavement and shoulder will eliminate drop-off. Besides it will help in protecting pavement from edges breaks. Width of brick edging can vary from 0.3 m to entire width of shoulder depending on the availability of funds.

4.4.8 *Drainage of side slopes*

Side slopes are again susceptible for erosion because of steeper slopes and higher velocity of flow. This slope can be protected by providing turfing with Sods/Seeding & Mulching/ Jute Netting/Coir Netting/Geo Netting etc. Guidance can be taken regarding erosion control measures from Clause 307/308 of MORTH Specifications & IRC:56. In high rainfall areas the slopes normally get covered with wild vegetation or grass. Although it protects side slope from erosion, but permits wild growth of vegetation and grass which are to be periodically trimmed and maintained to make the area accessible for cleaning side drains/ditches.

4.4.9 *Drainage of high embankments*

High embankments are vulnerable to erosion of side slopes on account water attaining high velocity. In such cases special arrangement like flumes/chutes are provided at regular intervals so the water collected from the shoulder is channelized to these chutes or flumes. An arrangement for collecting water and diverting it to chute with special kerbs is shown in **Fig. 4.22**. As water flows at high velocity through plain chutes with energy dissipater would be required at the toe as shown in **Figs. 4.23 and 4.24**. But stepped chute (**Fig. 4.25**) is preferable as it is a self-energy-dissipating structure. The spacing of Chutes depends on the intensity of precipitation, gradient and type of side slope surfacing etc. But generally a spacing of 20 m C/C can be considered as reasonable as recommended in IRC:SP:50. The plain chutes are made either of semi-circular RCC pipes or in-situ/precast RCC sections as shown in **Fig. 4.24**. They are set along the slopes on a concrete bed which should be anchored intermittently to avoid sliding of chute. On both sides of the chutes stone pitching is normally done over 1.0 m width. A filter bed, however, is to be provided under pitching. The rest of the slope is normally covered with grass turfing or stone pitching as per the site condition. Two-Dimensional/Three-dimensional erosion control mats or simple bio-engineering mats like jute/coir can be spread for growing turf by using seeds as per Section 5 of IRC:56 and Section 700 Clause 706 of MORTH. Selection of suitable erosion control mats shall be as per the Table mentioned in MORTH Section 700.

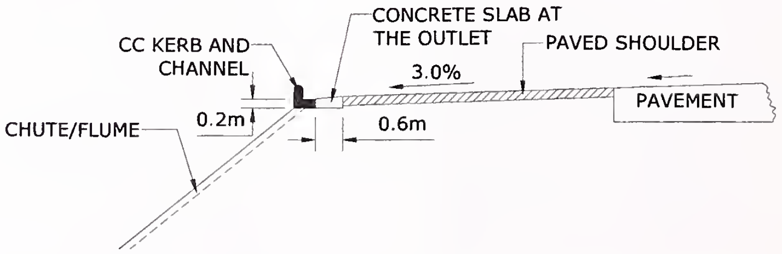


Fig. 4.22 Detail of CC Kerb and Channel Placed at The Edge of the Shoulder of High Embankment for Collecting Surface Water and Diverting it to Chutes

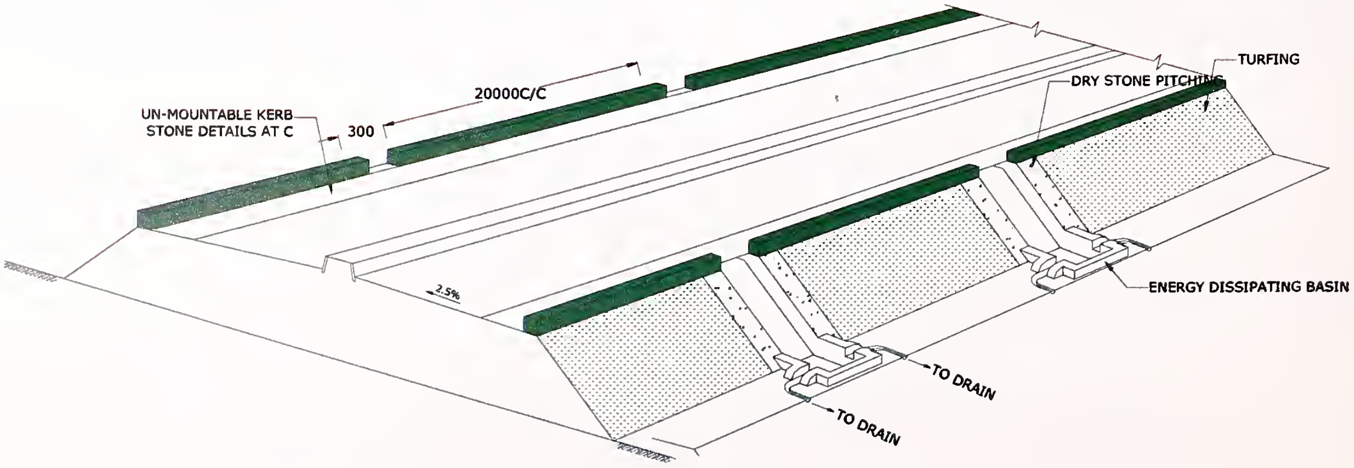


Fig. 4.23 A Schematic View of Slope Protection Arrangement with Plain Chute/Flume

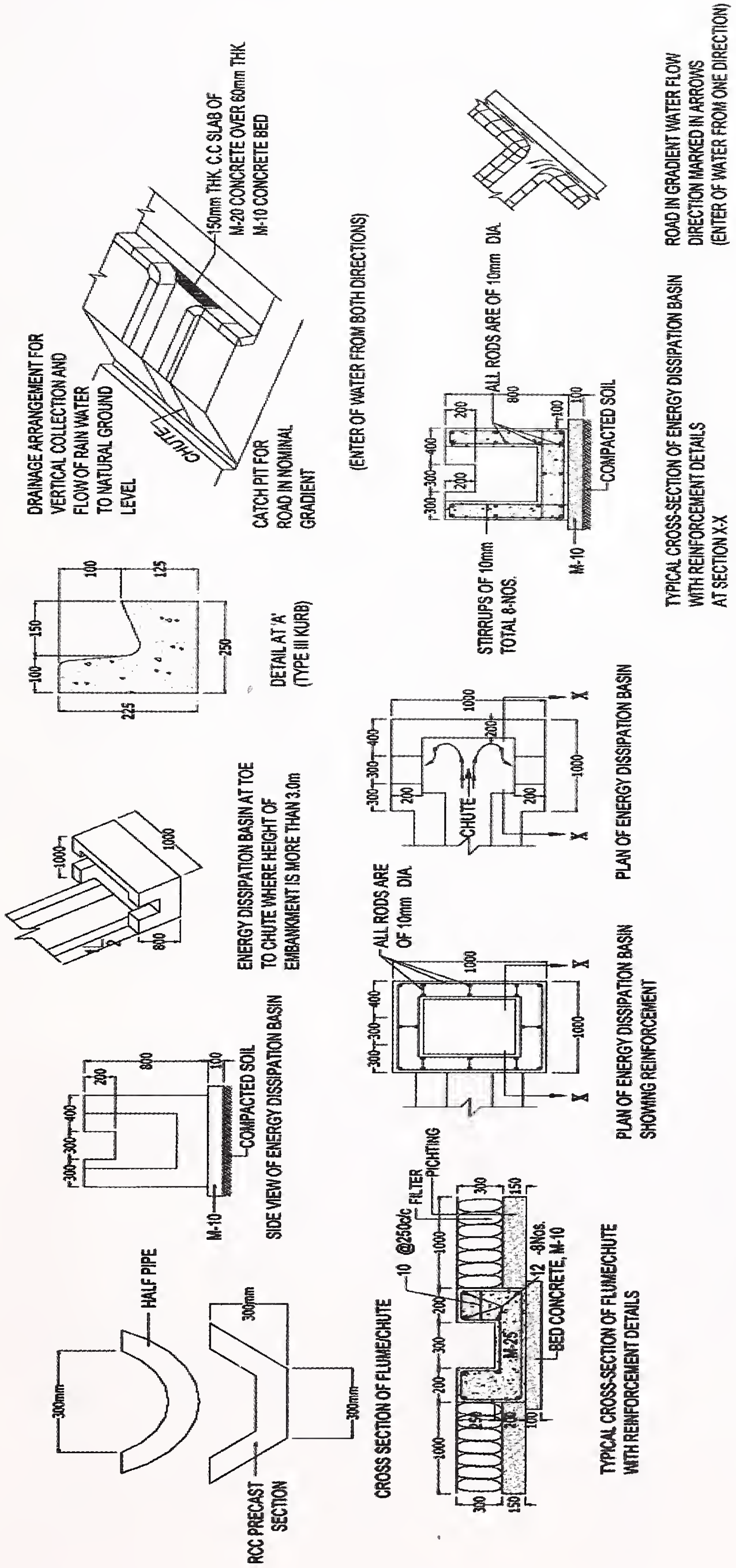


Fig. 4.24 Details of Energy Dissipater as Plain Chutes

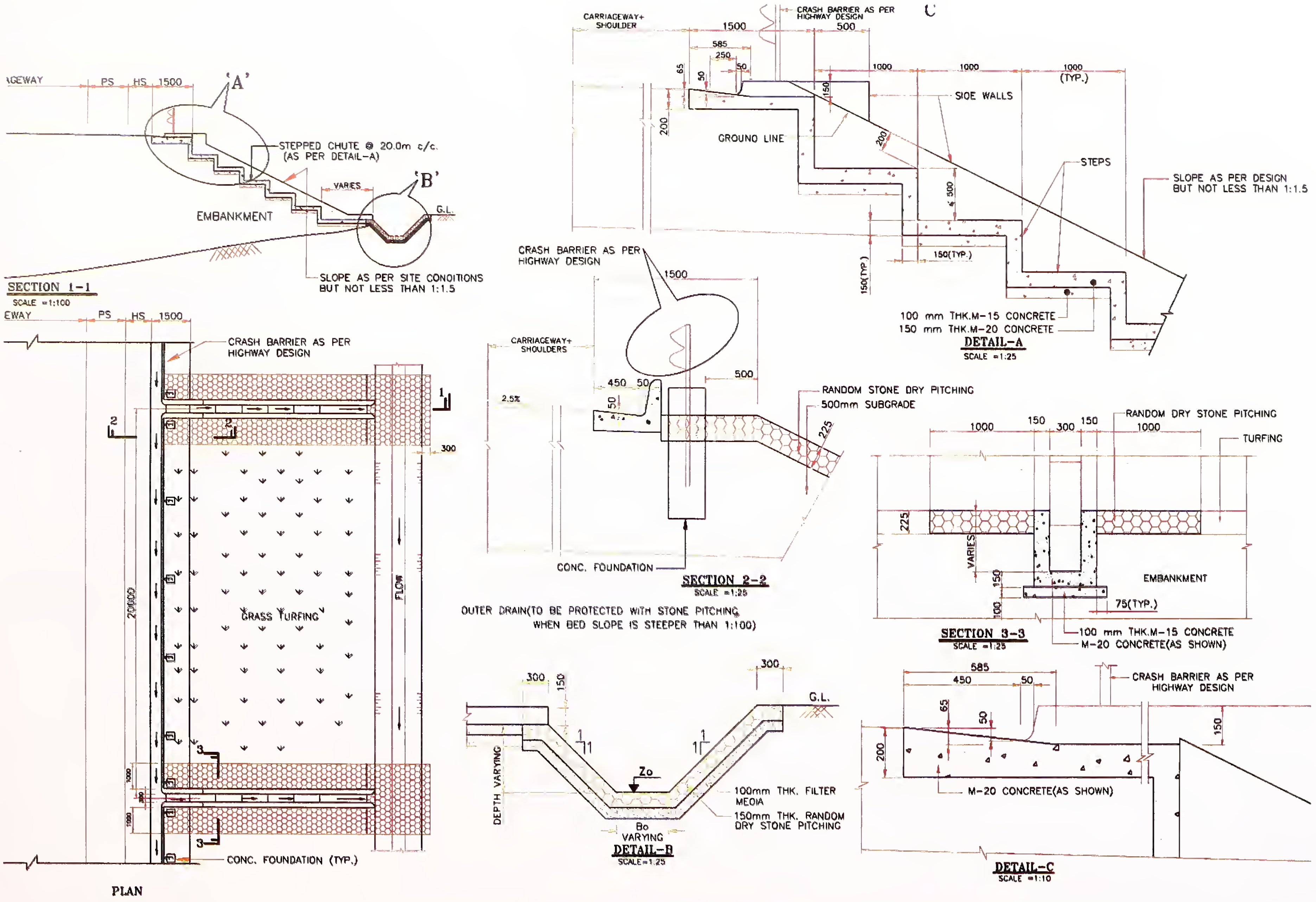


Fig. 4.25 A Schematic View of Slope Protection Arrangement with Stepped Chute/Flume

4.4.10 *Drainage of water when reinforced soil structures are provided in high embankments*

Reinforced Soil walls and slopes are constructed as cost effective and technically viable alternative for all applications in embankments in lieu of conventional gravity, cast in place concrete cantilever retaining walls are needed. This includes bridge abutments as well as locations where conventional earthen embankments cannot be constructed due to right of way restrictions.

A reinforced soil wall system consists of 3 components – A tensile element as reinforcement, a facing unit as a confining unit and soil fill. Prefabricated concrete units like concrete panels or segmental blocks are the most common facia. There are many other possible facia types like mechanically woven steel gabions, Steel woven wire mesh with welded panel as stiffener, wrap around system with Geosynthetic elements or steel elements.

4.4.10.1 Drainage for reinforced soil system-stability considerations

Uncontrolled subsurface water seepage can decrease stability and could ultimately result in failure.

i) Hydrostatic forces on the back of the reinforced zone will decrease stability against sliding failure.

ii) Uncontrolled seepage into the reinforced zone will increase the weight of the reinforced mass and may decrease the shear strength of the soil, thus decreasing stability.

iii) Seepage of water through the reinforced zone can reduce pullout capacity of the reinforcement at the face and increase soil weight, creating erosion and sloughing problems.

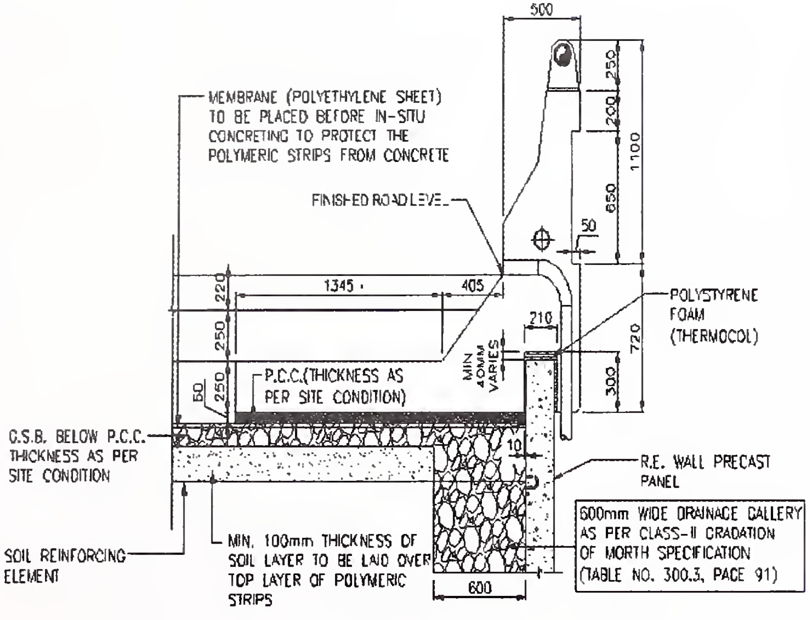
As a precaution, drainage features should be included unless detailed analysis proves that drainage is not required. Drains are typically placed at the rear of the reinforced soil zone to control subsurface water seepage. Surface runoff should also be diverted at the top of the slope to prevent it from flowing over the face.

4.4.10.1.1 External drainage

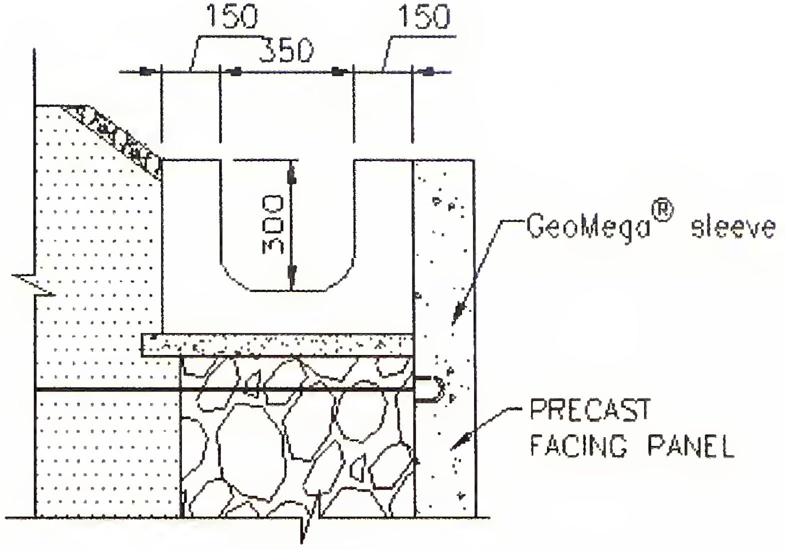
a) Drainage at the Top of the Wall or Slope

Considerable water percolation should not be allowed from the top surface of any reinforced soil system. Provision for collection and channelization of rain water should be provided. For walls which support roads on their fill side, a sealed kerb channel at the back of the paved shoulder/edge of the carriageway should normally be sufficient. Where there is no hard shoulder, a channel with flexibly sealed joints should be provided at the back of the hard strip/edge of carriageway as shown in **Fig. 4.26 (a & b)**.

For Part height walls, a drainage system should be provided at the top of the facing behind the panel top or coping, if used, in order to remove water running on the side slope. This may consist of simple drain channel leading surface water along the wall top to discharge beyond the end of the wall as illustrated in **Fig. 4.27 (a & b)**.



TYPICAL CRASH BARRIER(180 THK PANEL)



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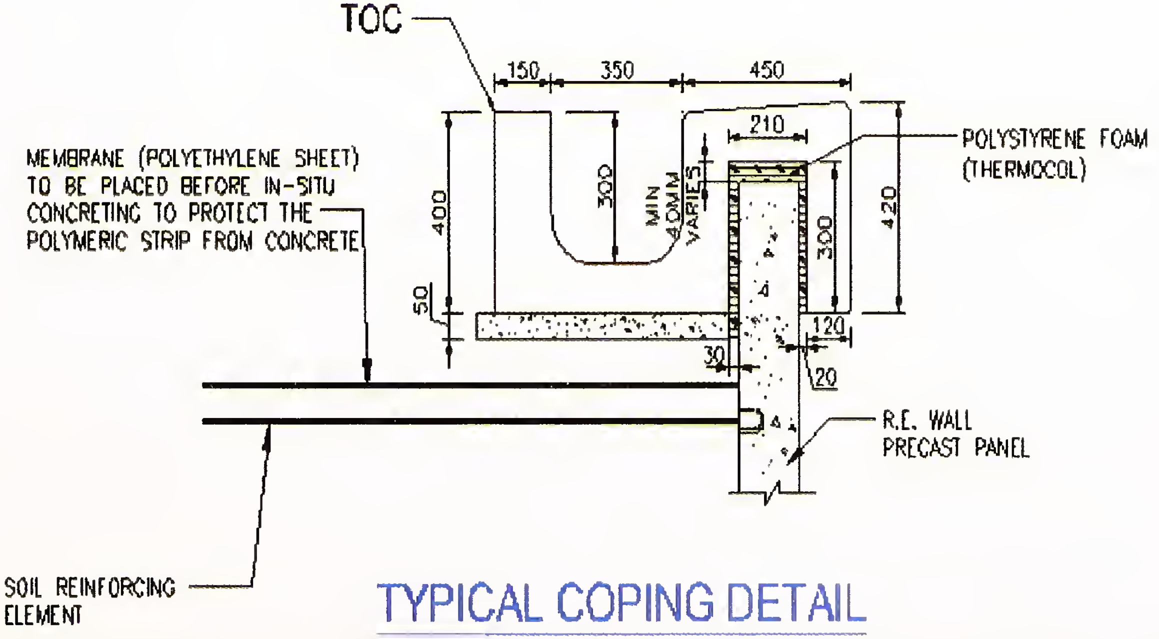
SURFACE DRAINAGE DETAIL



TYPICAL COPING DETAIL

Fig. 4.26 (a) Drainage Arrangement at the Top of Wall-Typical Detail for a Full Height Wall

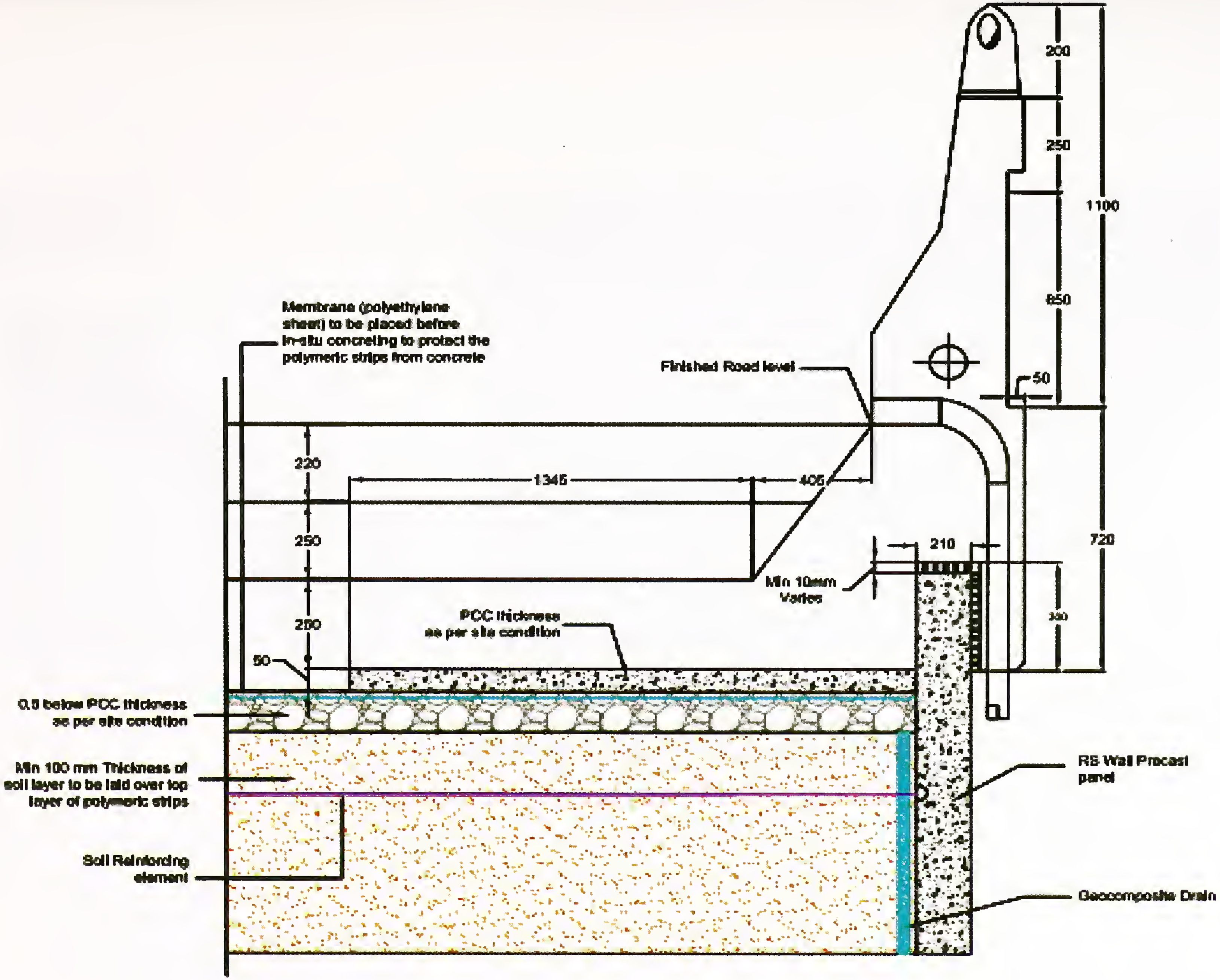
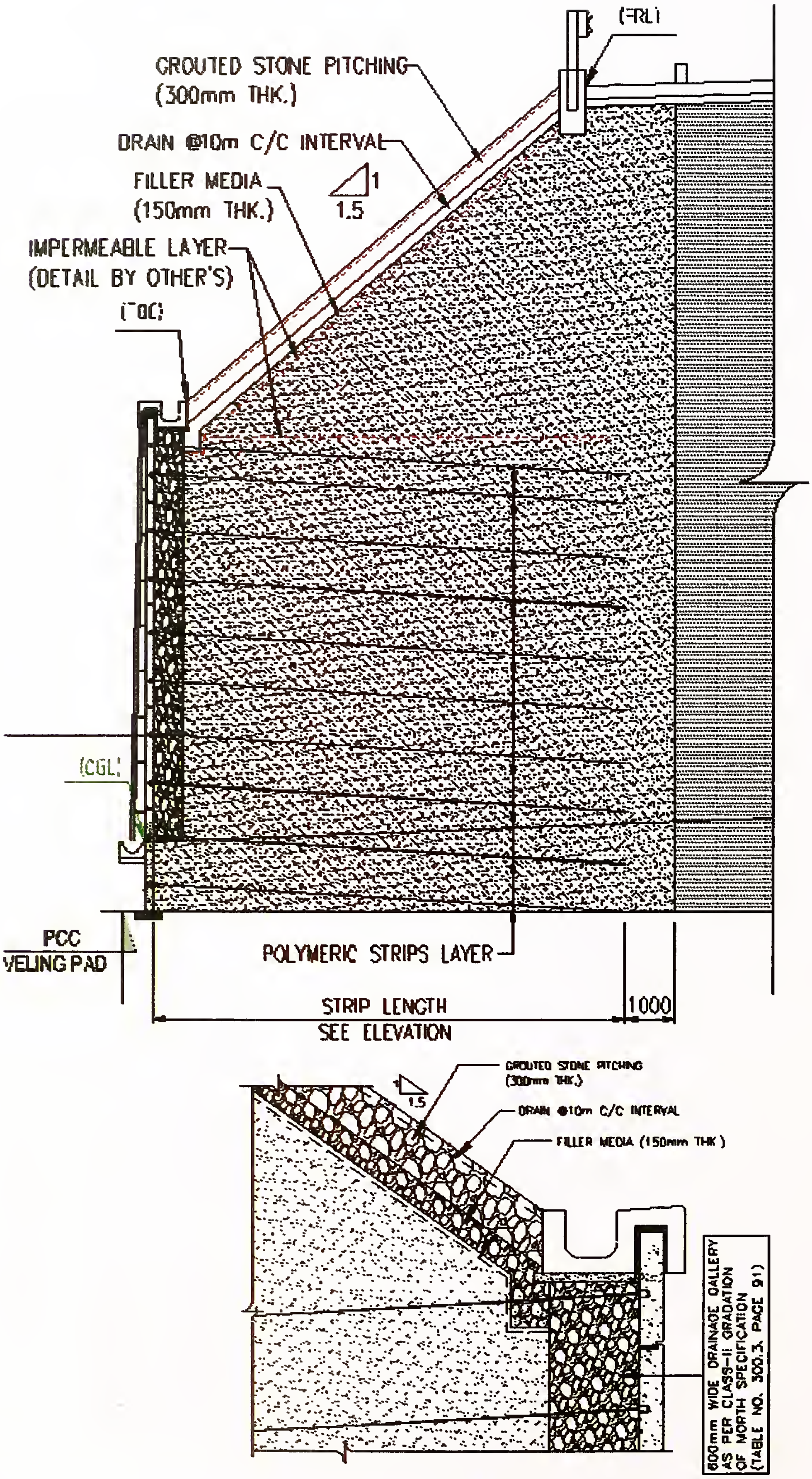


Fig. 4.26 (b) Drainage Arrangement at the Top of Wall-Typical Detail for a Full Height Wall with Drainage Composite



SECTION 2-2

Fig. 4.27 (a) Drainage Arrangement at the Top of Wall – Part Height Wall

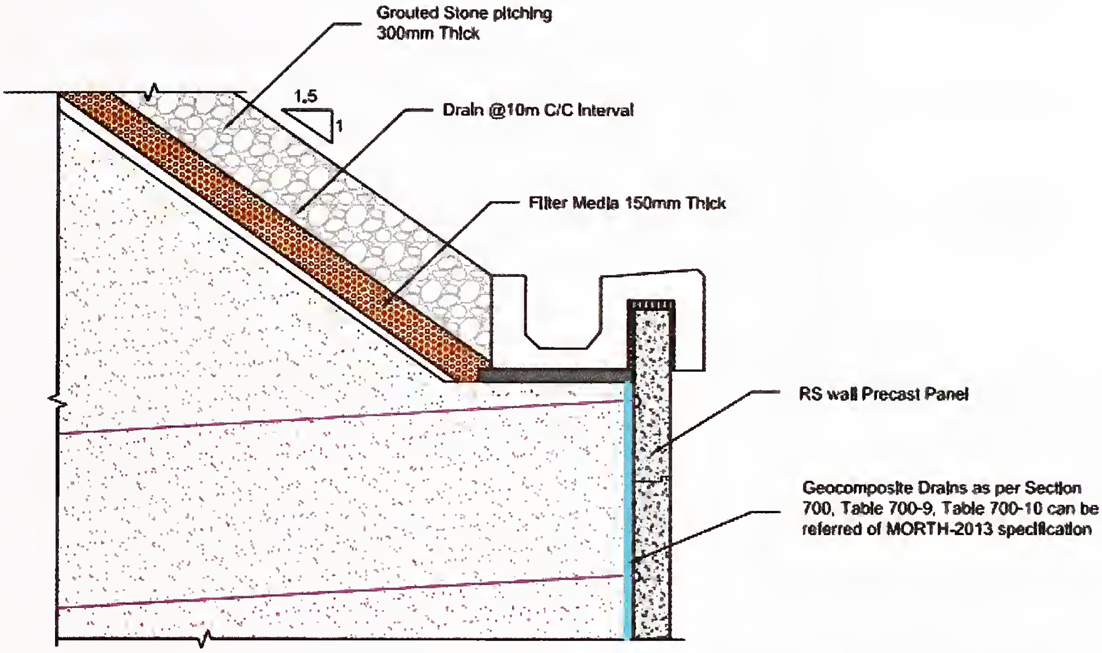


Fig. 4.27 (b) Drainage Arrangement at the Top of Wall – Part Height Wall

b) Drainage of the Wall

In many cases the structural fill in a reinforced soil mass may be effective as a drain without the use of other arrangements. However the free draining characteristic of the fill material need to be verified. If the structure is located on a permeable foundation soil above the water table, any small water seepage will pass into the foundation soils and a drain layer/pipe might not be necessary. However if the base soil is not pervious enough, a longitudinal porous or open jointed pipe of not less than 150 mm diameter should be used to collect water and bring it into the site drainage system (**Fig. 4.28 a & b**).

To enable any seepage to pass through a hard facing, weep holes may be located in selected panels. For discrete facings, the drain path may be easily provided by omission of the vertical joint filler between all panels at the foot of the wall in the embedded depth. A continuous drain at the base of the structure may be required in situations where capillary rise of deleterious ground water might need to be prevented. The layer should connect with the drainage system at the base of the structure.

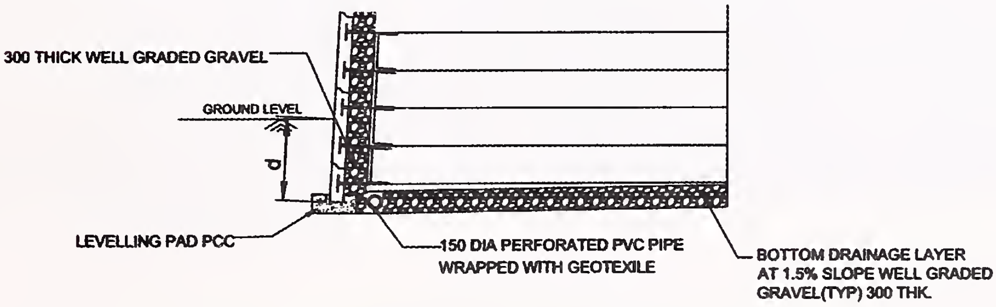


Fig. 4.28 (a) Drainage of Reinforced Soil Wall/Slope

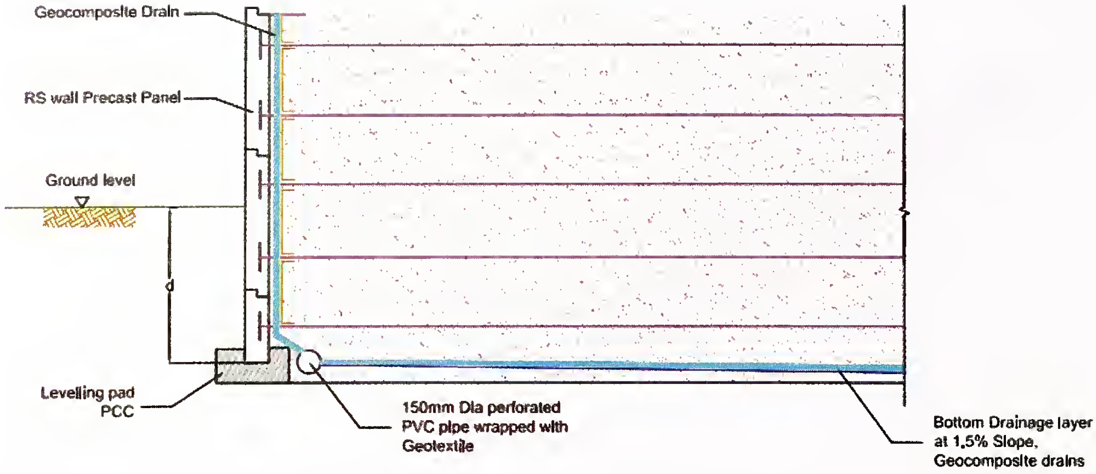


Fig. 4.28 (b) Drainage of Reinforced Soil Wall/Slope

4.4.10.1.2 Drainage of walls supporting cuttings

For locations, where water flow is expected from the retained soil, drainage trenches typically 300 mm thick and 1000 mm wide should be placed at intervals along the wall.

In case of significant water flows, a drainage blanket 300 mm thick may be constructed below the reinforced soil wall and discharged beyond the toe. If necessary, this blanket may be continued up along the face of the temporary excavation for as high as is needed. As an alternative, Geosynthetic drainage composite shall be used.

For cases where downhill discharge is not possible, a toe collector pipe may be used. The dimensions of the drainage trenches and blanket should be designed to suit the anticipated conditions. In all cases the drainage filter material should be designed to avoid loss of reinforced fill or adjacent soil into the drain.

4.4.10.1.3 Special detailing required for drainage in reinforced soil system

- All details for construction around drainage facilities, overhead sign footings, and Abutments (**Fig. 4.29**).

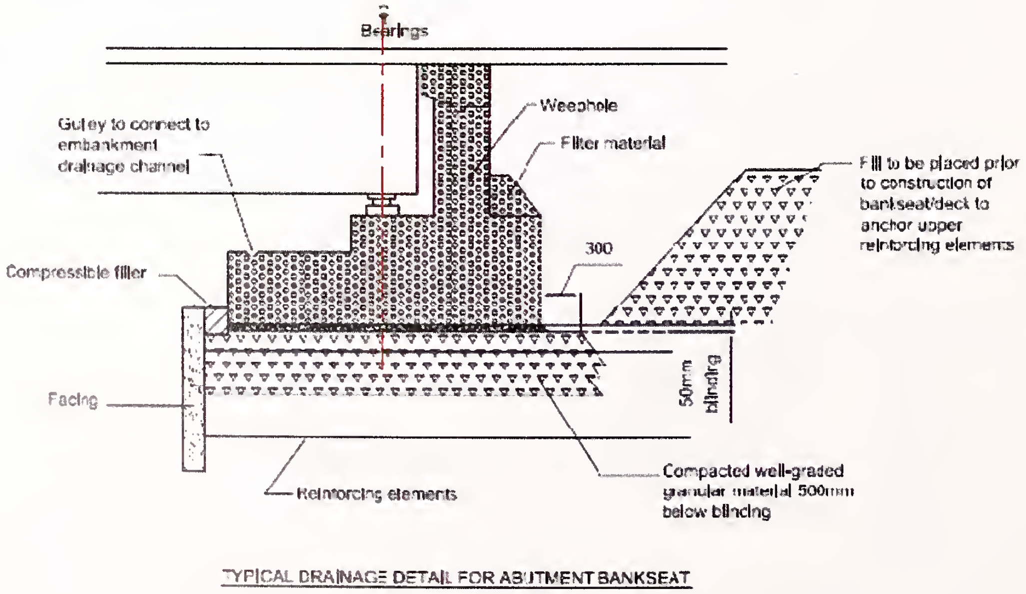


Fig. 4.29 Drainage Detailing for Abutment Bank Seat

- All details for connection to traffic barriers, copings, parapets, noise walls, and attached lighting.
- All details for temporary support including slope face support where warranted.
- All details for wall initiation and termination, and any transitions.

4.4.11 *Drainage of medians*

Central medians are either raised or depressed as shown in **Photos 4.17 and 4.18**. Both such arrangements have their advantages and disadvantages as far as surface drainage is concerned. Earth filling must be flush with kerb and with two-sided camber. If turf is provided on the top there is not much chance of too much water infiltering to lower layers (**Photo 4.17**). But raised median is said to be safety hazards as per experts. Depressed median, although safer, may lead to seepage of water to lower pavement layers unless central drain is lined satisfactorily (**Photo 4.19**). If water stagnates in the median it can seriously impair the longevity of the pavement due to seeped water laterally below pavement layers. Such provision must be avoided where black cotton soil is encountered. A poorly profiled and maintained median with stagnating water can be seen in **Photo 4.20**. This water is bound to infiltrate to pavement layers. When there is divided carriageway with a raised central median, disposal of surface water of super elevated section requires elaborate arrangement. Water can be diverted from one carriageway to other by having an opening/channel in the median as shown in **Photo 4.21**. These are provided at 10 m to 20 m intervals depending upon the intensity of rainfall, road width etc. When both the carriageways are at different levels, median drains have to be provided as shown in **Fig. 4.30**. An open drain or a buried pipe provided for collecting surface water can be disposed of at a nearby cross drainage structure. When pipes are used, RCC manholes have to be provided to collect water from pavement surface. Some alternate designs of median drainage arrangements are shown in **Figs. 4.31 to 4.33**.

Photo 4.17 A View of a 4-Lane Road with Raised Median

Photo 4.18 A View of Depressed Median with Lined Drain. Turfing as Grown Naturally on the Earthen Sections

Photo 4.19 A Depressed Median with Lined Median Drain and Chutes

Photo 4.20 A Raised Median with Pool of Water which Eventually Seeps to Foundation Layers of Pavement

Photo 4.21 A Median Opening Provided in a Super Elevated Section for Draining from One Carriageway to Another

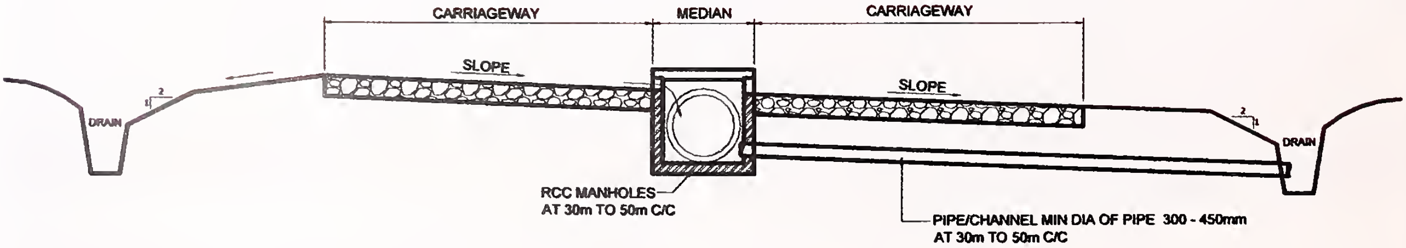
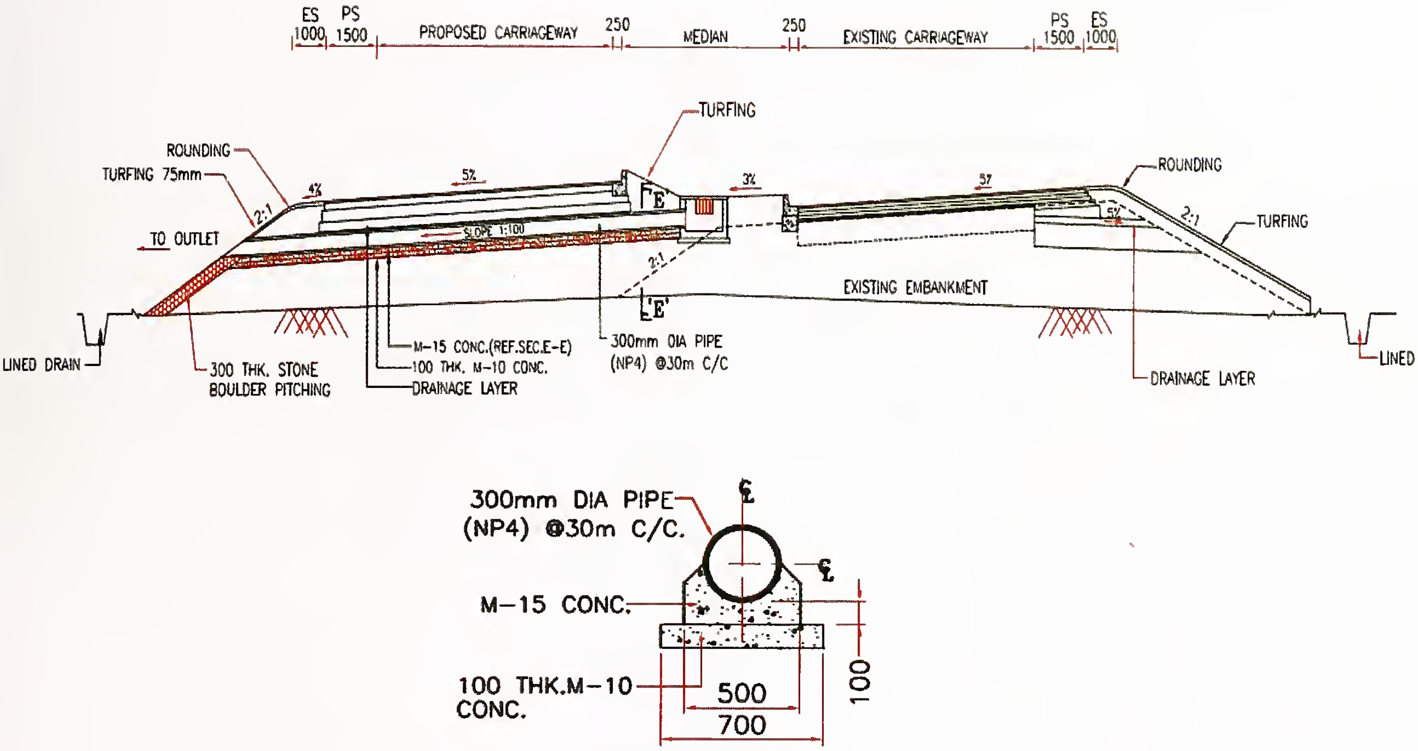


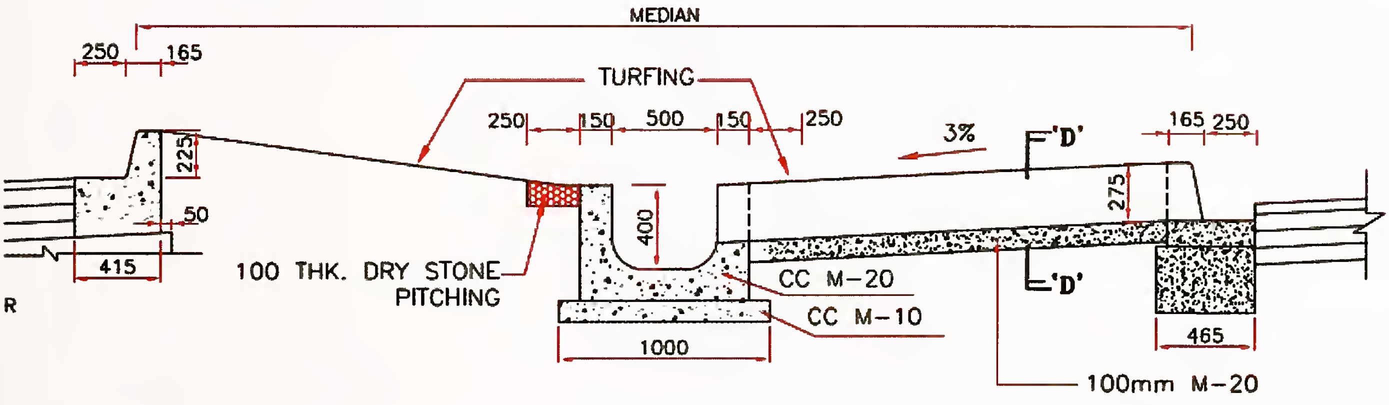
Fig. 4.30 Buried RCC Pipe Provided for Median Drainage



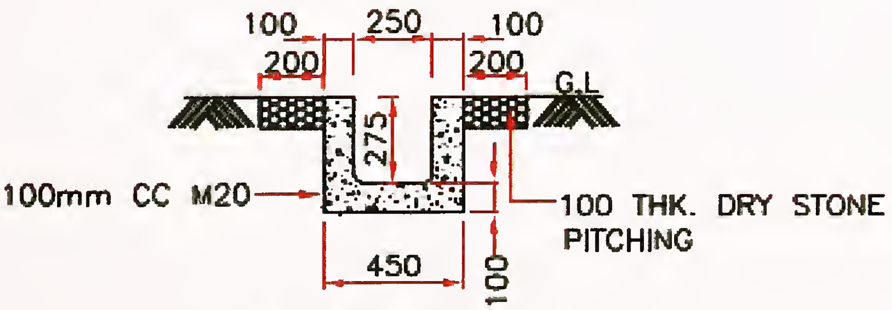
SECTION AT E-E

(SCALE 1:25)

Fig. 4.31 An Alternate Design of Median Drainage System

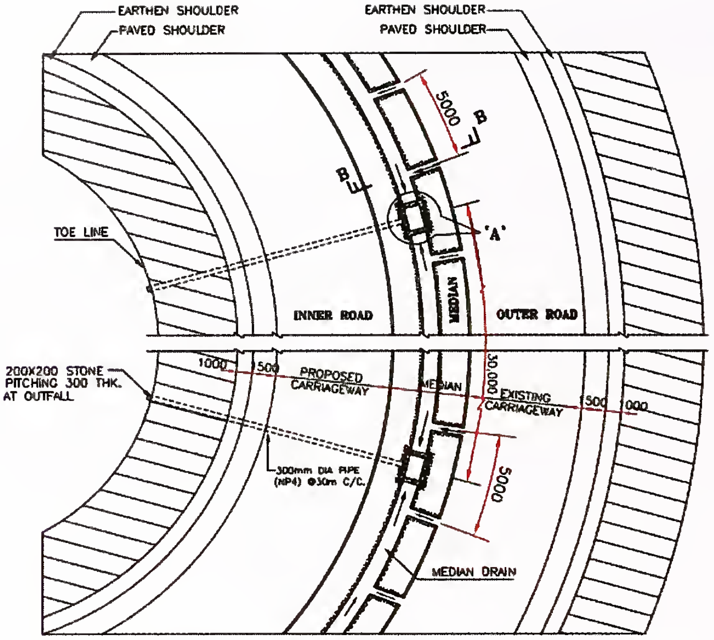


SECTION AT B-B

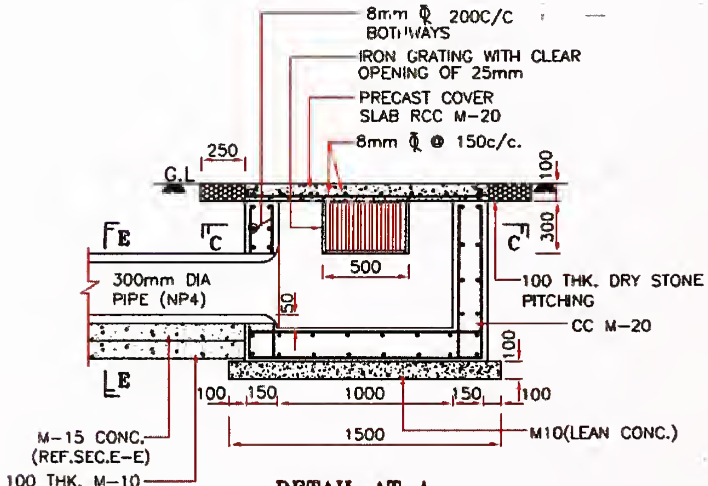


SECTION AT D-D

Fig. 4.32 Another Alternate Design of Median Drainage System



PLAN SHOWING CURVE OF ROAD
(SCALE 1:250)



DETAIL AT A

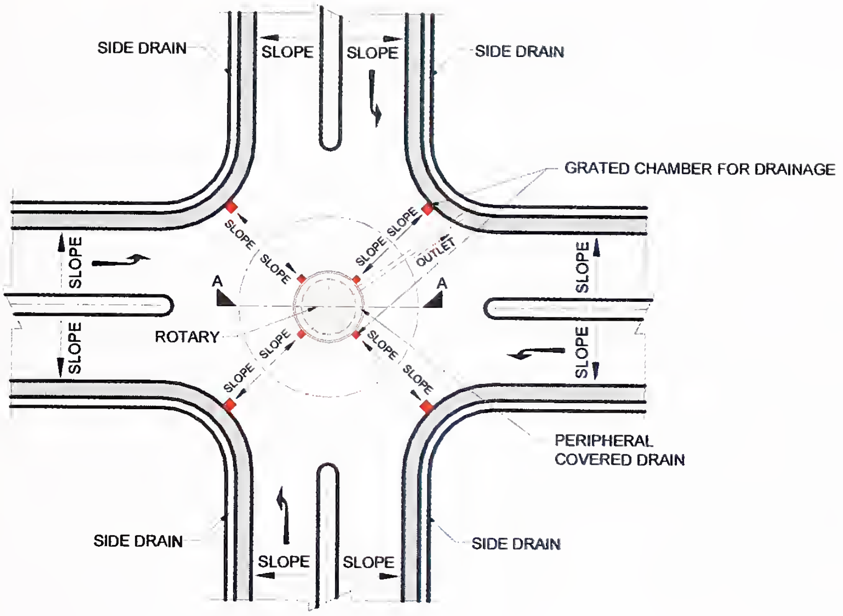
Fig. 4.33 Buried RCC Pipe Provided for Median Drainage

4.4.12 *Drainage of rotaries*

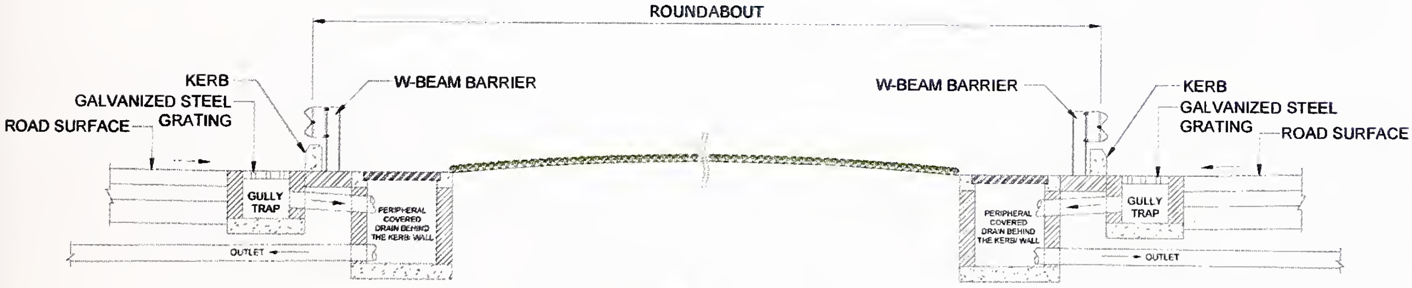
Drainage of rotary requires special treatment as there is super elevation on the inner curve which forces water to collect at the central island. The surface water is collected and disposed of through gullies placed inside or outside of kerb-line of central-island. One such arrangement is shown in **Fig. 4.34** where there are gullies outside the central island for collecting and disposal of water. A cross section of rotary is also given.

4.4.13 *Drainage of intersections*

Similar to rotaries, there are pockets at the edge of slip roads in intersections where water gets accumulated on account of camber provided on all the merging roads. This water normally has to be collected with the help of grated chambers as shown in **Fig. 4.35** and disposed of.



Plan
(Not to Scale)



Section A-A
(Not to Scale)

Fig. 4.34 Drainage Arrangement of a Rotary

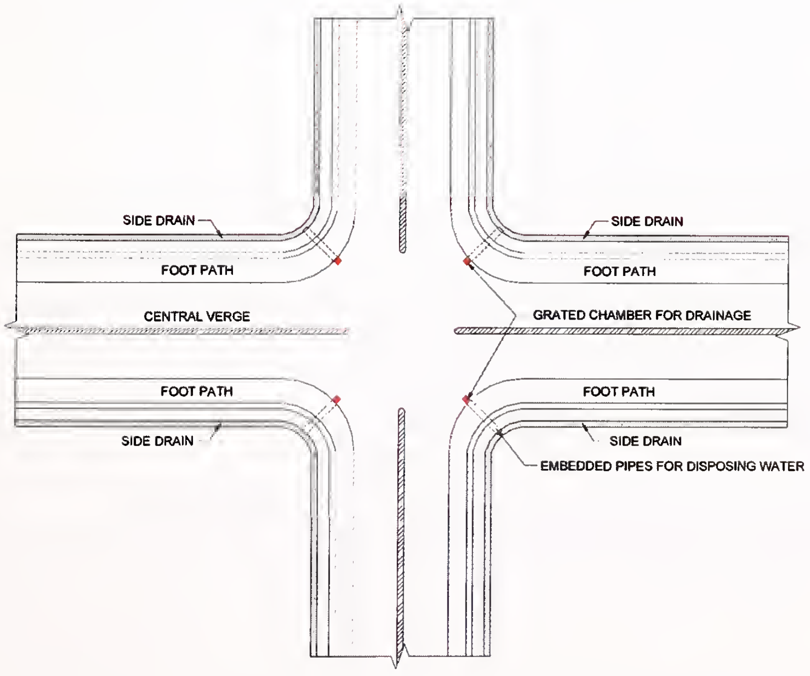


Fig. 4.35 Surface Drainage of a Road Junction (Schematic)

4.5 Maintenance of Side Drains, Medians and Culverts

Maintenance of side-drains and medians is important for satisfactory performance and long life of road.

4.5.1 *Side-drains*

Side drains along the rural highways are normally not lined due to cost considerations. But when the roads pass through towns they are required to be lined. The maintenance of such drains has been dealt in IRC:SP:50 entitled 'Guidelines on Urban Drainage'. Maintenance of unlined drains especially prior to monsoon is essential. Depending upon the type of soil and the rainfall intensity in the area, the drains get silted and clogged. Serious erosion of earthen shoulder takes place in areas where silty soil is encountered which normally clogs the side drains. In high rainfall areas, the growth of grass and vegetation in and around drain causes obstruction to free flow of water and loss in conveying capacity of drain. Ponding of water in side drains due to blockage can adversely affect the areas through which drain passes especially the performance of road built on black cotton soil belt. Moisture can migrate to clayey foundation of road leading to premature failure of pavement.

4.5.2 *Medians*

In divided carriageways the medians provided can be either raised with kerbs or depressed type as shown in **Photos 4.17 and 4.18** respectively. The raised medians on highways, filled with earth, normally is cambered so that water from precipitation which is not soaked by soil-fill flows on the road surface. But in the case of depressed medians chocking of water way should be avoided as it can cause ponding of water. This should be avoided both in the case of unlined or lined drain.

4.5.3 *Maintenance*

As a policy, the drains and culverts have to be cleaned before and after the monsoon for their satisfactory performance. As discussed in IRC:SP:50, the maintenance can be classified into three categories:

i) Continuous maintenance

ii) Periodic maintenance

iii) Special maintenance/repairs

Continuous maintenance involves inspection of side drains on regular basis and maintain them by the Engineer in-charge of the road section.

Periodic maintenance can be taken up whenever the periodic maintenance of the road is taken up.

Special maintenance will involve the repair of breached sections or improvements of the waterway if found inadequate.

5 SUBSURFACE DRAINAGE

Subsurface drainage is as important as surface drainage for long life and better performance of pavement. The moisture which reaches lower layers of pavement from different sources like pavement surface, seepage from shoulders, seepage from adjoining hills and capillary rise of moisture from ground is termed as subsurface moisture. Disposal of this moisture away from the pavement body is termed as subsurface drainage. Consequences of lack of effective subsurface drainage system results in premature failure of pavement with formation of cracks, settlement, rutting and boggy action in the case of bituminous pavement whereas formation of crack, fragmentation and settlement of slab in the case of cement concrete slabs. Moisture reaching lower layers from pavement surface is dealt separately from that of capillary rise of moisture from shallow water table. IRC:34 entitled 'Recommendations for Road Construction in Waterlogged Areas' has dealt this subject in details. The recommendations have been discussed briefly in Para 5.4.

5.1 Sources from which Water/Moisture Reaches Lower Layers of Pavement

i) From poor quality bituminous mixes which are permeable

ii) From the cracks, potholes and joints

iii) From the failed joint seals of cement concrete pavement

iv) Through the longitudinal joint between pavement and shoulder

v) From earth filled medians and shoulders

vi) Seepage water from the adjoining high ground in the cut sections of hilly terrain or from impounded water level higher than the road level in the abutting agriculture fields (e.g. Paddy fields)

vii) From capillary rise of moisture when water-table is high.

5.1.1 *Ingress of water from top of pavement and shoulders*

Cracked and potholed, porous and open graded bituminous layers and joints in concrete pavements, shoulders and medians are primary sources from where moisture seeps to lower layers of pavement. This has been shown schematically in **Fig. 5.1.** Typical cracked bituminous and concrete slabs shown in **Photos 5.1 and 5.2** readily permit moisture to enter to lower layers. In extreme situation the quantum of moisture infiltrating to lower layers through porous and poor quality bituminous mixes in pavement exposed near the edge can be seen in **Photo 5.3**. Pavement edge too is one of the primary sources of water infiltration to lower layers. Two such longitudinal joints with wide openings can be seen in **Photos 5.4 and 5.5**. Collected water in median is another source from where moisture infiltrates to lower layers of pavement (**Photo 4.20**). For reducing the infiltration of water to lower layers from median, the earth fill should be profiled with camber so that part of the water is allowed to flow towards road.

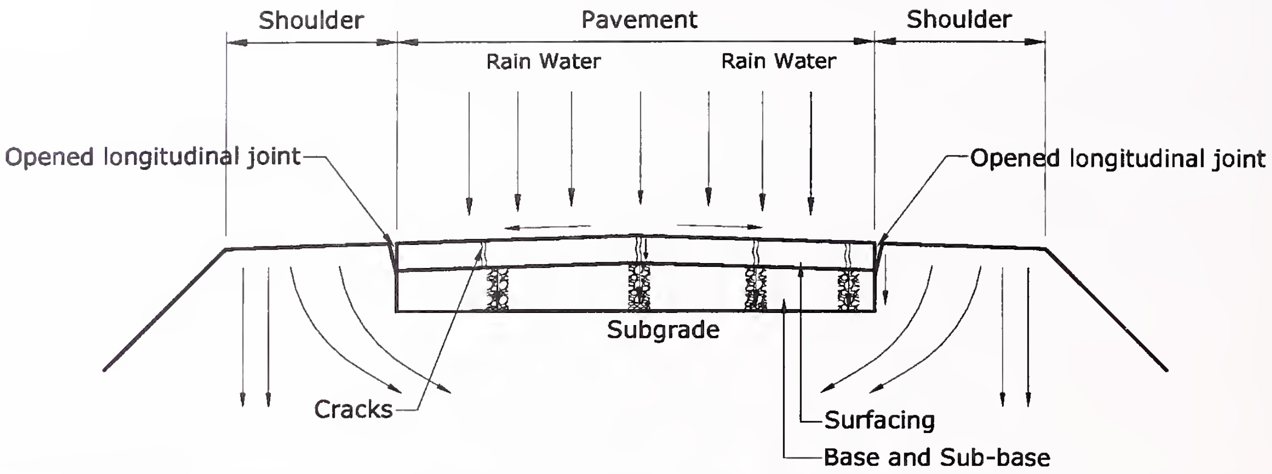


Fig. 5.1 Sources of Ingress of Moisture from Top of Pavement and Shoulders

Photo 5.1 A Cracked and Settled Bituminous Pavement which Permits Seepage of Water

Photo 5.2 A View of a Cracked Concrete Slab which Facilitates Seepage of Water

Photo 5.3 Subsurface Water Found at Subgrade Level in a Road

Photo 5.4 A Large Opening in Longitudinal Joint Between Concrete Pavement and Earthen Shoulder

Photo 5.5 An Open Joint Between Concrete Pavement and Bituminous Shoulder

5.1.2 *Seepage from hills*

Seepage from hill sides in cut sections is a source from where embankment, subgrade, and base/sub-base get soaked. This has been shown schematically in **Fig. 5.2**.

Roads are often damaged in stretches where there is excessive seepage from hills in absence of adequate sub-surface drainage. Further details of surface and sub-surface drainage are available in Hill Road Manual (IRC:SP:48).

5.1.3 *Capillary action*

Some soils like silt, clay, fine sand, chalk and pulverised fly ash (PFA) which are susceptible to formation of capillary tubes, through which moisture migrates upwards due to surface tension when water table is high. This is shown schematically in **Fig. 5.2**. The effect of saturation of lower layers of pavement due to above causes has to be prevented to protect the pavement from premature failure. This issue has been explained in Para 5.2.4.

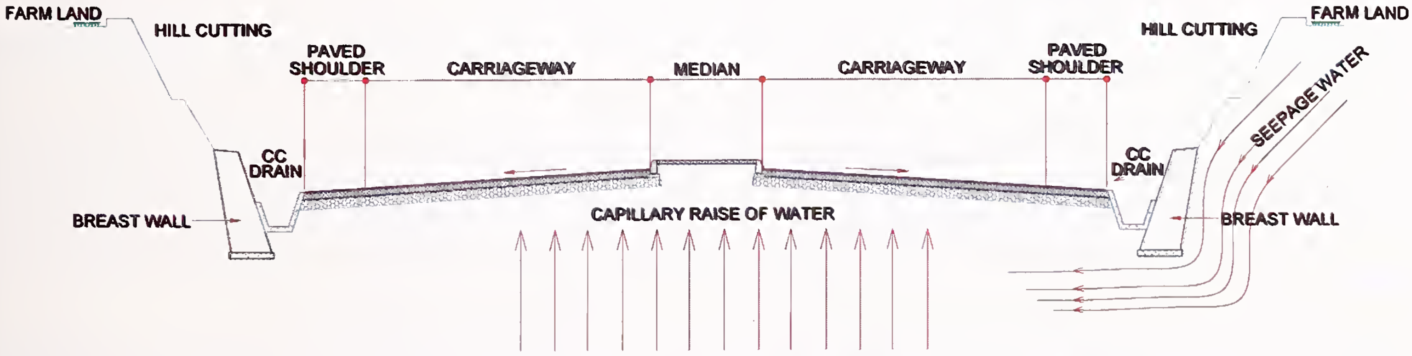


Fig. 5.2 Seepage from Sides and Capillary Rise of Moisture are Shown in the Sketch

5.1.4 *Effect of infiltration, seepage and capillary moisture on pavement layers*

Trapped moisture from all sources in the pavement layers reduces the load taking capacity of the structure thus causing loss of strength leading to premature cracks, rutting, potholes etc. A soaked subgrade does not affect the strength or CBR as pavements are designed based on soaked CBR of subgrade. But loss of aggregate to aggregate contact is a primary factor for loss of strength. And sometimes the pavement exhibits 'boggy action' i.e. the pavement behaves like a spring when moisture is trapped in foundation. Under the load, pavement undergoes large deflection because of dispersal of moisture locally and after the release of load, it bounces back leading to reversal of stress/strain causing premature cracks due to fatigue. Such phenomenon is predominantly observed in clayey and silty soils.

5.2 Treatment of Subsurface Moisture

5.2.1 *Drainage of infiltrated moisture from pavement and shoulder surface*

Subsurface moisture which infiltrates from the pavement surface or shoulders has to be drained out to avoid loss of aggregate to aggregate contact so that load transference is not affected. An upper granular sub-base layer called as Drainage Layer (DL) has been suggested to drain this trapped water lately by both MORTH Specifications and IRC:37. The drainage layer is part of a pavement structure which is considered to perform the function of both structural as well as a drainage layer. GSB layer can be constructed in two layers such that one layer can serve the purpose of Drainage Layer (DL) and the other layer can serve as Granular Sub-Base (GSB). The basic ingredients of both mixes are same but the difference lies in percentage of fines passing in Drainage Layer and GSB mix. Regarding relative placement of DL and GSB layer, both MORTH Specifications for Road and Bridge Works, 2013 and IRC:37 have suggested that DL to be placed above GSB layer as explained below:

i) MORTH Specifications, 2013 has specified six grading for Granular Sub-Base (GSB). But out of that Grading III and IV have been proposed for use as lower sub-base and Grading V and VI for using as sub-base-cum-Drainage Layer. (as given in **Table 5.1**)

ii) Similarly IRC:37 in Para 7.2.1.3 states that the sub-base should be composed of two layers, the lower layer forms the separation/filter layer to prevent intrusion of subgrade soil into the pavement and upper GSB forms the drainage layer to drain any water that may enter through surface cracks. The drainage layer should be tested for permeability and gradation may be altered to ensure the required permeability. Filter and drainage layers can be designed as per IRC:SP:42 and IRC:SP:50. Six gradings suggested by IRC:37 in Annexure V are extracts of AASHTO gradings (1993). Coefficient of permeability ‘k’, of each grading has been given for all six gradings given in Annexure V, Grading-2 mix (as given in **Table 5.2**) has coefficient of permeability ‘k’ of 35 m/day is best suited for drainage layer.

iii) The basic reasoning for providing drainage layer is to dispose of seeped moisture due to gravity from upper layers of pavement in lateral direction as quickly as possible instead of allowing it to seep down to lower layers as shown in **Fig. 5.3**. Without a intercepting free-draining drainage layer (DL), water has a tendency to migrate downwards due to gravity. If a dense GSB layer provided below drainage of low permeability, it is helpful for forcing moisture to flow laterally rather than moving towards downwardly direction. Moisture must not be allowed to accumulate in base and sub-base layers as it can lead to loss of aggregate to aggregate contact essential for load dispersal to lower layers.

iv) No research has been done in India on this crucial subject except some work done in IIT, Chennai. Considerable studies have been carried out in USA both in Laboratory and field on this subject. Two types of drainage layers have been tried by advance countries. i.e. i) free-draining-sub-bases and ii) open-graded sub-bases called permeable sub-bases. They have preferred free-draining sub-bases rather than open-graded sub-bases because of its more durable, more stable nature having permeability k, of 15 to 45 m/day in laboratory tests. The open-graded sub-base having k of 150 to 315 m/day has high degree of voids and has lower stability. Such material was said to have resulted in a layer where it was like paving on marbles. Based on these considerations the grading for the drainage layer having permeability k of 15 to 45 m/day is best suited.

Table 5.1 Grading VI of Granular Sub-base Material Recommended by MORTH Specifications-2013

IS Sieve Designation	Percent by Weight Passing the IS Sieve (Grading VI)
75.0 mm	–
53.0 mm	100
26.5 mm	75-100
9.50 mm	55-75
4.75 mm	30-55
2.36 mm	10-25
0.85 mm	–
0.425 mm	0-8
0.075 mm	0-3

Table 5.2 Grading 2 of IRC:37 (AASHTO–1993)

Sieve Opening, mm	Percent by Weight Passing the IS Sieve (Grading 2)
20	100
12.5	84
9.5	76
4.76	56
2.36	39
2	35
0.84	22
0.42	13.3
0.25	7.5
0.105	0
0.075	0
Coeff. of permeability m/day	35

Out of six grading of sub-bases given in MORTH Specifications and IRC:37 two have been selected for use in drainage layer. Grading-VI of MORTH Specifications and Grading-2 of IRC:37 suggested for use in drainage layer are given in **Tables 5.1 and 5.2**. Coefficient of permeability k of the mix in **Table 5.2** is the physical properties of aggregate used shall comply with Clause 401 for granular sub-base of MORTH Specifications. The loss Angeles abrasion value of aggregate should be less than 40 percent.

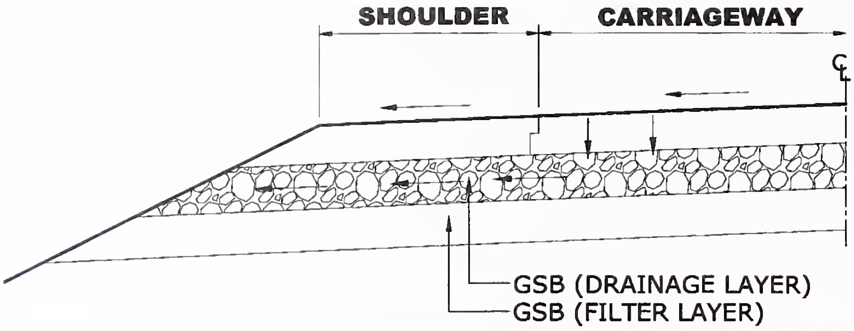


Fig. 5.3 A Pavement Section Showing Day Lighted Drainage Layer

In lieu of aggregate drainage layer, geosynthetic drainage composite (drainage Geonet between two Geosynthetic layers) can also be provided (**Fig. 5.4**) wherever it proves to be cost effective and technically meeting the requirements. The Geotextile will act as a separator and filter also. Drainage composite specifications shall be adopted as per MORTH 704.2 or IRC:34, 4.6.2.

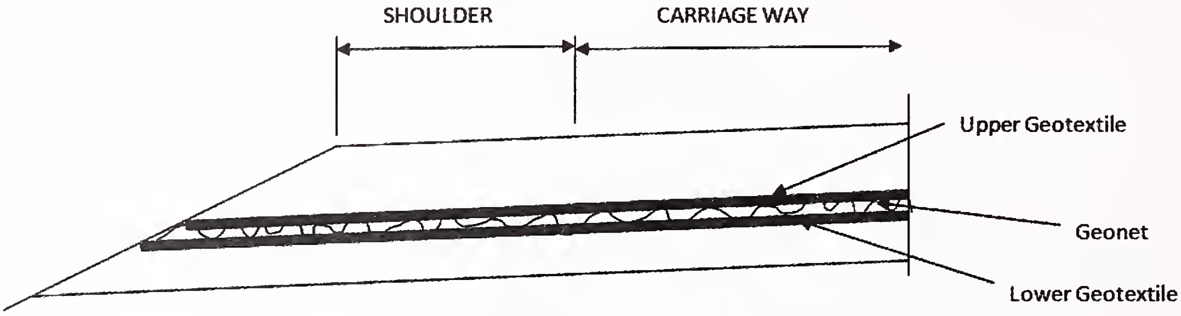


Fig. 5.4 A Pavement Section Showing Day Lighted Drainage Layer (Drainage Composite)

When this drainage and GSB layers are day-lighted i.e. extended up to side slopes, the coarse aggregates in mix tend to get dislodged and roll down from side slope affecting slope stability. To have a stable permeable edge, 0.5 m wide strip of both layers have been suggested in IRC:37 for treating with either 2.5 percent of bituminous emulsion or 2 percent cement. Use of bitumen emulsion or cement will have implication on cost of project and has to be introduced with caution. An arrangement of constructing such a stabilised strip of drainage layer along with a strip of GSB layer is illustrated in **Fig. 5.5**. When there is a lined side drain, PVC or HDPE pipes can be provided at regular interval to drain moisture from DL and GSB layers as shown in **Fig. 5.6**.

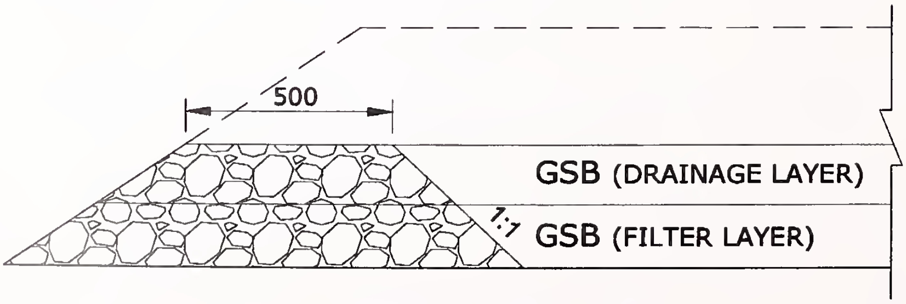


Fig. 5.5 Day Lighted Part of GSB and Drainage Layers

(To be stabilised with either 2.5% bituminous emulsion or 2% cement in a day lighted drainage layer as per IRC:37)

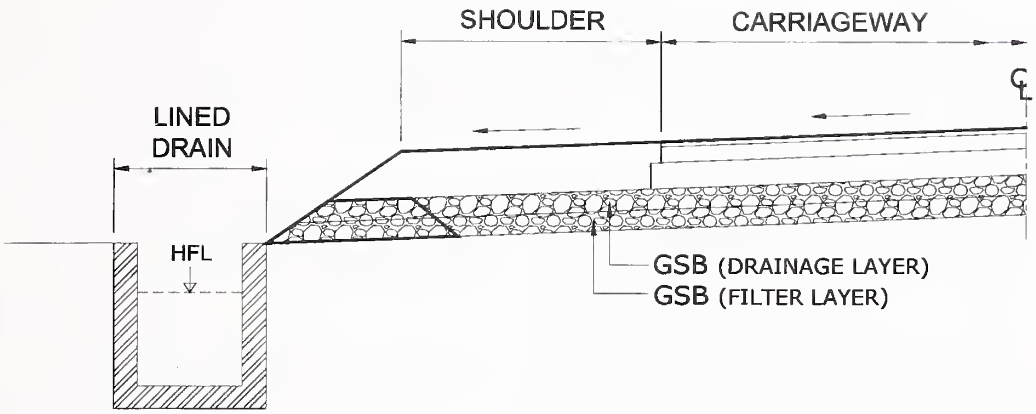
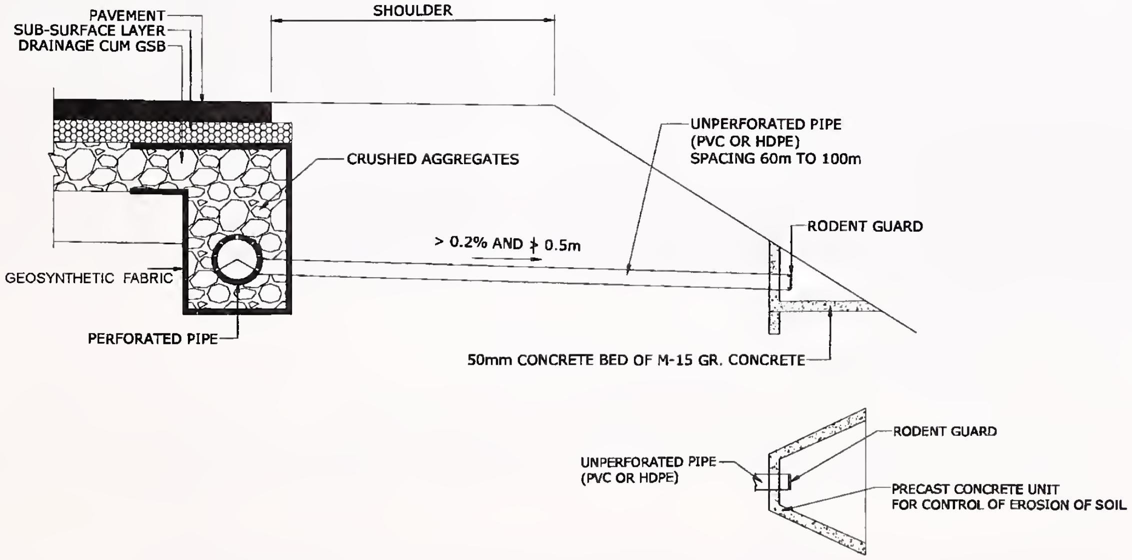


Fig. 5.6 Proposal for Disposal of Subsurface Moisture in Case of Lined Side-Drain

5.2.1.1 *Alternate sub surface drainage system*

Shown in **Figs. 5.7 and 5.8** are cross sections of flexible and rigid pavements showing French Drains where subsurface drain is terminated under the shoulder. Durable crushed aggregates are used as backfill material around partially perforated PVC or HDPE pipe. The grading of backfill aggregates is given in Clause 309.3 of MORTH Specifications. One of the filter materials suggested in Table 309-3 can be adopted. Normally a partially perforated PVC or HDPE Pipe is buried near the bottom to collect and dispose of the moisture collected. While selecting the geosynthetic filter fabric, it shall satisfy filter criteria taking into consideration the properties of soil around it. Clause 702 of MORTH Specifications on geosynthetic filter gives the details. Fin drain can also be provided at the junction of pavement and shoulder for collection of water and disposing it off as shown in **Fig. 5.9**. The fin drain consists of synthetic polymer core wrapped by geosynthetic filter. Because of larger area of fin, more quantity of water can be drained through it. A perforated pipe as shown in **Fig. 5.14** is used to collect water and dispose it off.



Plan of precast concrete unit

Fig. 5.7 A Cross-Section of Road Showing 'Drainage Layer' Terminated at Pavement Edge in a Flexible Pavement

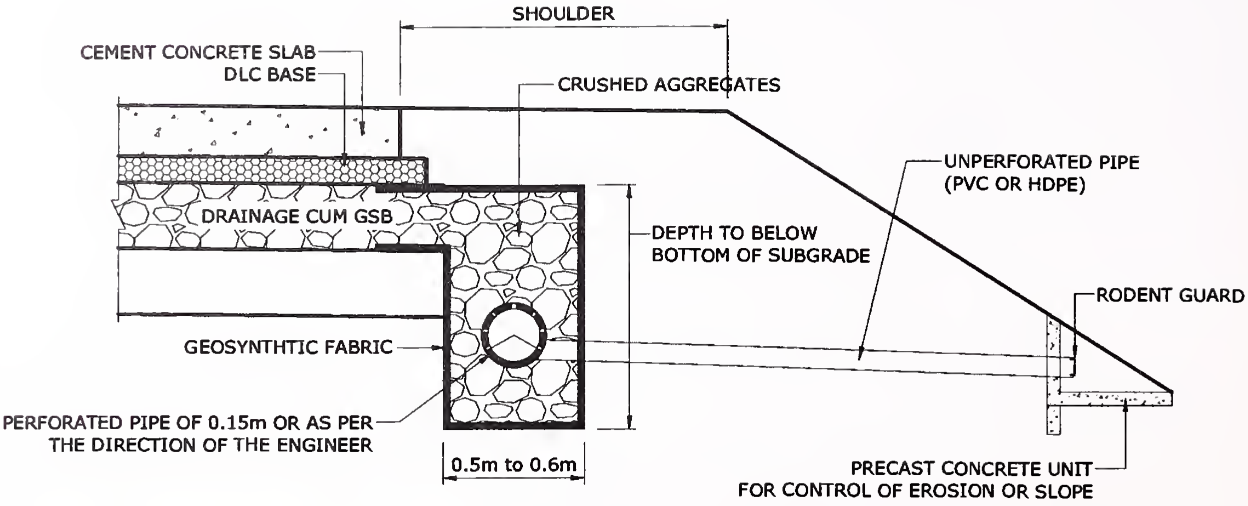


Fig. 5.8 A Typical Cross-Section of Road Showing 'Drainage Layer' Terminated at Pavement Edge in a Rigid Pavement

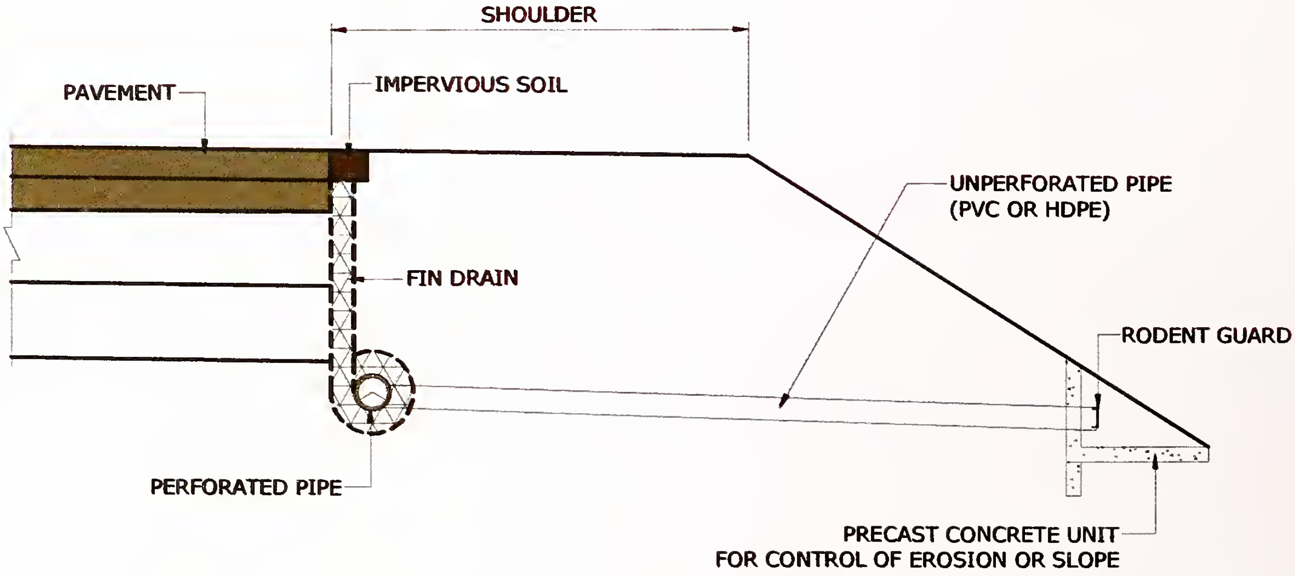


Fig. 5.9 Details of a Fin Drain

5.2.2 *Granular Sub-base Layer (GSB)*

The layer below the drainage layer shall be granular sub-base layer (GSB), which shall be acting as separation/filter layer. The layer shall be constructed in conformity with Clause 401 of MORTH Specifications.

5.2.3 *Use of geotextile for sub-surface drainage*

Geotextile are found to be extremely efficient as separation cum drainage layer and for uniform distribution of load to sub-grade. For detailed specifications MORTH Section 700 shall be referred.

5.2.4 *Management of seepage moisture from hills in cut sections*

There are two situations where seepage moisture affects the performance of road. In the first case when a road is close to a nallah or a channel and the HFL is high, the seepage water can lead to saturation of foundation layers of pavement leading to boggy action especially when there is clayey and silty soil. The other situation is when the road alignment passes through the cut section in a hilly terrain where there is cultivation on hill tops. In both situations intercepting seepage lines and disposing of moisture through subsurface drain is an appropriate solution.

5.2.5 *Seepage from an adjoining nallah or channel*

This condition can lead to premature failure of pavement and may even exhibit boggy action. Solution to such situation rests by raising the road level so that side drains can intercept seepage of moisture from sides thus protecting road foundation. Introducing sand layer below subgrade or replacing it partly with sand sometimes helps in controlling the premature failure of road and boggy action.

5.2.6 *Seepage from an adjoining hill in cut sections*

Seepage water is a serious problem in cut sections of hilly terrain especially when there are farms uphill. During monsoon the problem further gets aggravated. **Photos 5.6 and 5.7** give an idea about the extent of seepage which takes place even in dry season. The quantum of seepage water collected in a side ditch of road in typical hilly terrain can be seen from **Photo 5.7**. A cross-section of a road in hilly section is shown schematically in **Fig. 5.10** showing arrangement of intercepting seepage and surface water.

Photo 5.6 Seepage Taking Place through Soft Sandy Soft Rock

Photo 5.7 Stagnated Seepage Water in a Cut Section in a Hilly Terrain

5.2.7 *Surface drains in cut-sections of hilly terrain*

5.2.7.1 *Surface water from pavement*

Management of surface water from pavement in cut sections of hilly terrain can be done by providing suitable lined drains as shown in **Fig. 5.10**. The details of such drains in cut sections have been discussed in Section 8. If there are stone or precast concrete kerbs, openings have to be provided for water to flow towards side drain as shown in **Fig. 5.10**.

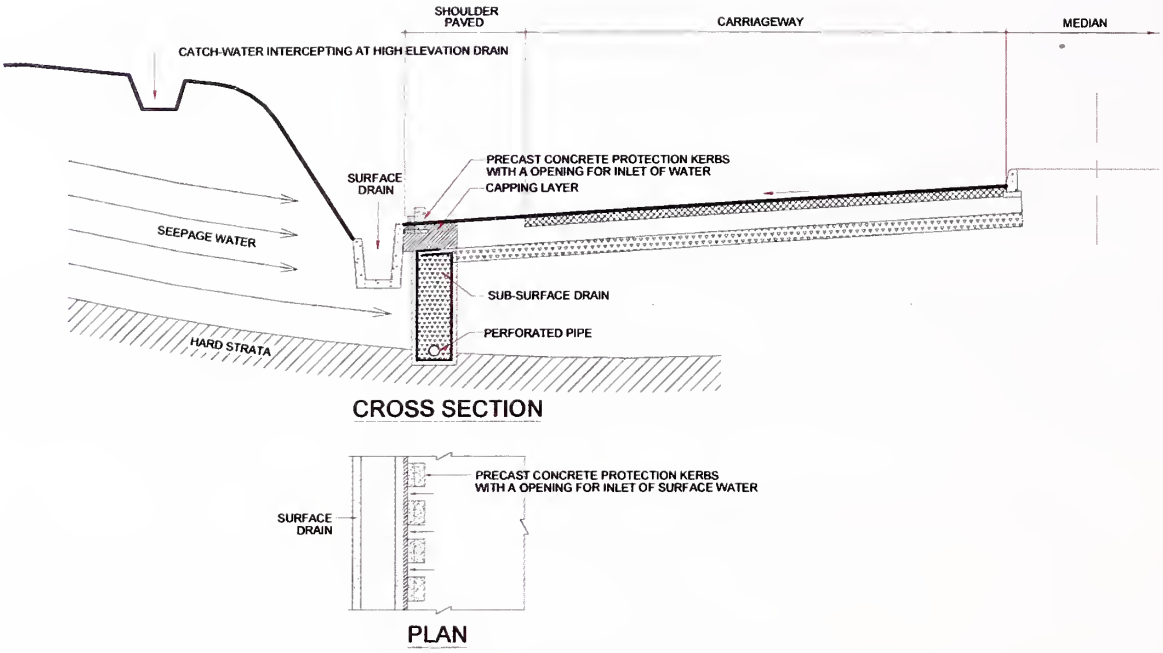


Fig. 5.10 A Sketch Showing an Arrangement to Intercept Seepage Water in a Cut Section in Hill with a Subsurface Drain. Drainage of Surface Water is Taken Care of by Side Drains

5.2.7.2 *Disposal of surface water from hills*

Surface runoff from hills should be intercepted due to following reasons:

i) Water can carry considerable quantity of soil and muck from hill and choke the side-drains of road making it ineffective.

ii) The runoff water may seep into the hilly terrain and trigger landslides.

iii) Surface runoff flowing at high velocity may cause severe erosion unless it is intercepted.

Depending upon the type of soil and area of the hill top, a couple of catch drains may have to be provided parallel to each other. A typical cross-section of cut and fill area is shown in **Fig. 5.11** showing a catch drain, lined side-drain and a retaining wall.

5.2.8 *Details of subsurface drain for intercepting seepage water in hilly terrain*

Intercepting seepage moisture in cut-sections in hilly terrain can be done effectively by installing French drains as shown in **Fig. 5.11** at an appropriate depth to intercept seepage water reaching subgrade and lower layers. Normally the subsurface drain is extended up to hard strata as shown **Fig. 5.10**. In plain terrain subsurface drain can be provided on hill side from where seepage is likely to take place. Whereas when there are hills on both sides, subsurface drain can be provided on both sides. But when there is a steep longitudinal gradient in cut sections, there is a chance of water seeping from higher ground along the middle of carriageway, and hence it is desirable to intercept transverse or diagonal drains as shown in **Figs. 5.12 and 5.13**. The cross-sectional details of longitudinal subsurface drain are given in **Fig. 5.14**. It is a French drain comprising of a perforated HDPE/PVC pipe buried in graded aggregates. The subsurface drain shall be constructed as per Clause 300.9 of MORTH Specifications gives details of subsurface drain. Graded aggregates when placed in the trench surrounded by soil normally will enter graded aggregates. Therefore, a geo-filter fabric is used for wrapping the aggregate to function as separation and filter medium as shown in **Fig. 5.14**. Some details of aggregates, synthetic geo-filter, perforated pipe and sand required for this work are explained in Clause 300.9 of MORTH Specifications. Geo-filter shall conform to Clause 702 of MORTH Specifications.

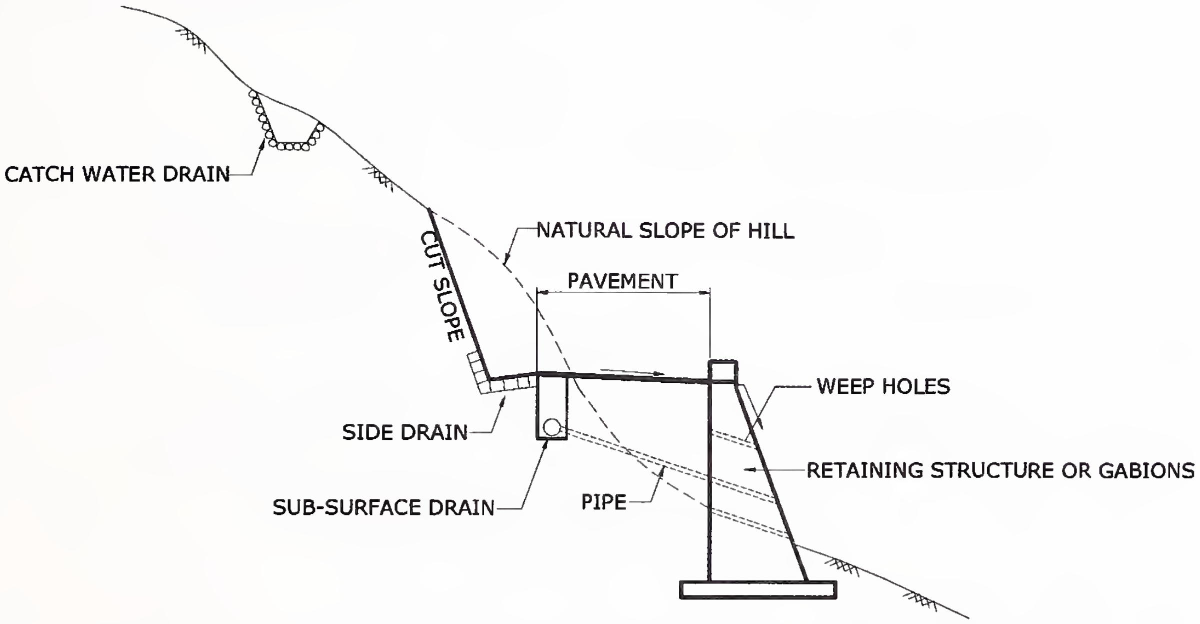


Fig. 5.11 Cut and Fill Sections in a Hilly Terrain Showing Catch Drain, Side Drain and Retaining Wall

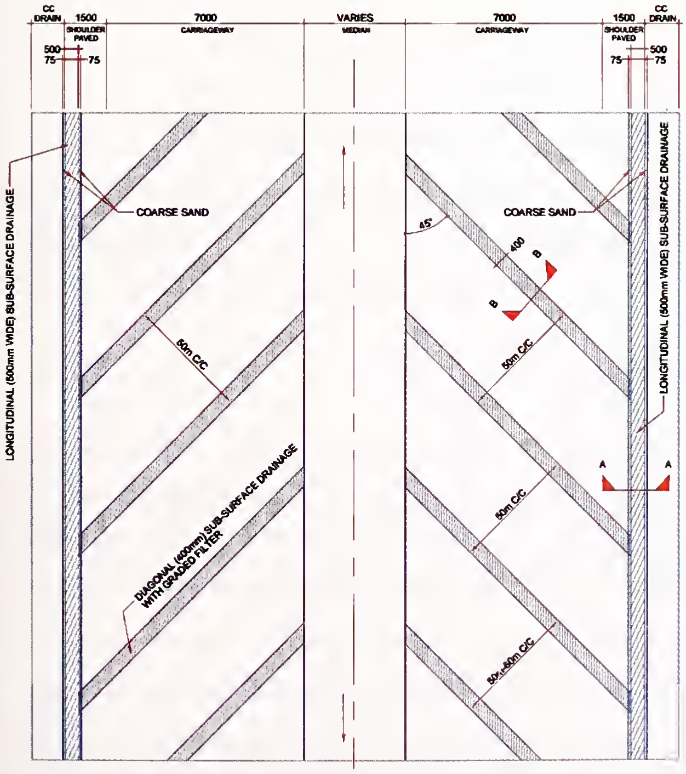


Fig. 5.12 Layout Plan of Longitudinal & Diagonal Subsurface Drains

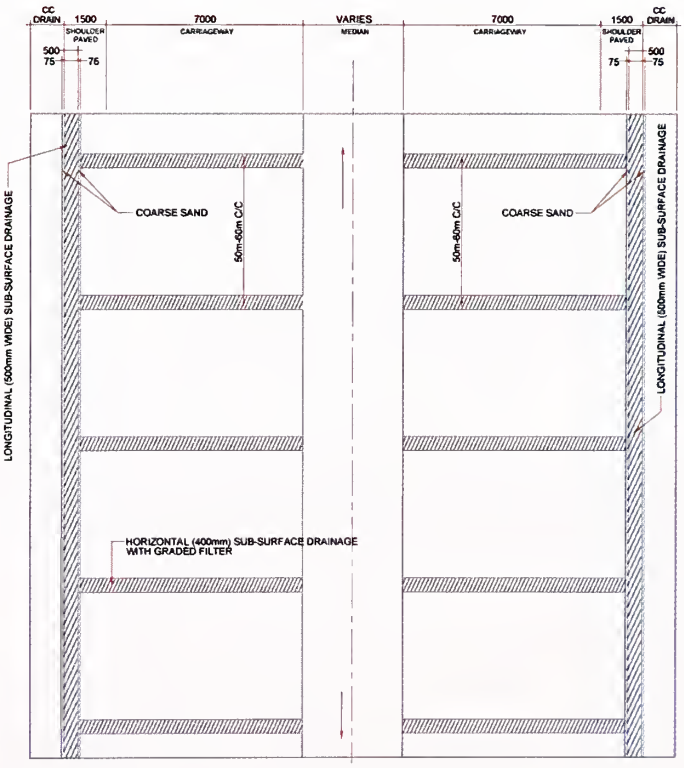
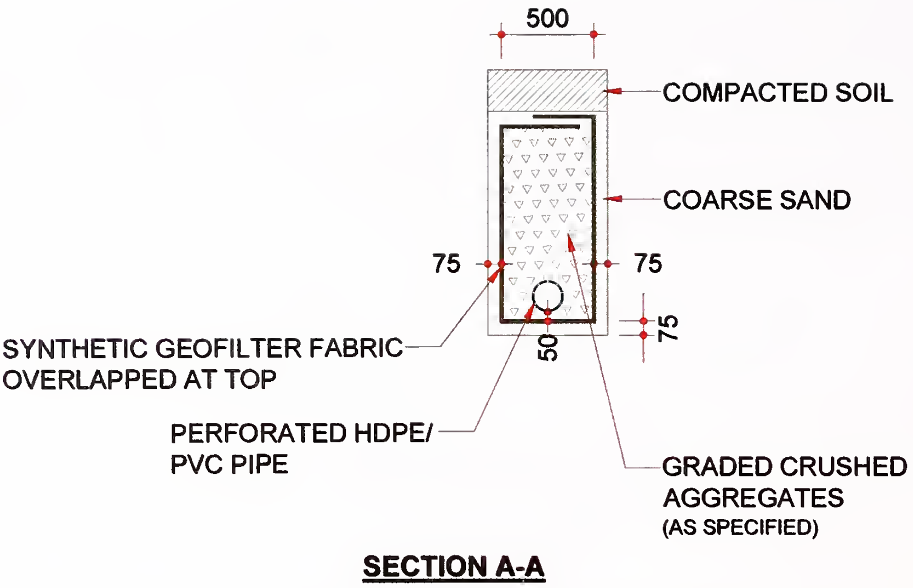
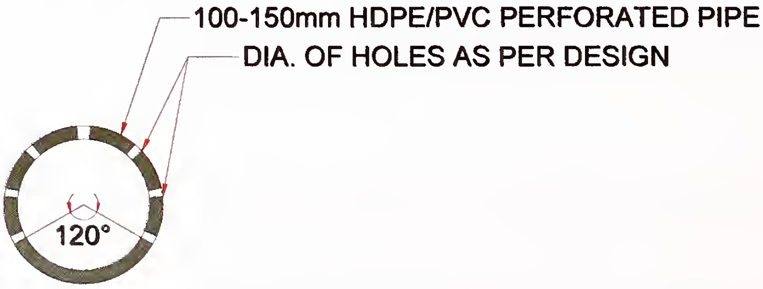


Fig. 5.13 Layout Plan of Longitudinal and Horizontal Subsurface Drains



Cross-section of longitudinal subsurface drain (500mm wide)



Details of perforated HDPE/PVC pipe (with bottom 1/3 without perforation)

Fig. 5.14 Cross-Section Details of Subsurface Drainage System

5.2.9 *Sinking of hill road due to seepage of water underneath the road*

Where sinking phenomenon of road is noticed in hills, depressing the side-drain toward the hill and providing RCC Lining is one of the solutions. Water should not be permitted to seep under the pavement layers. If necessary a couple of more cross-drainage structures should be constructed at such locations.

5.2.10 *RCC box drain to serve as surface cum sub-surface drain*

It is possible to combine both surface and subsurface drains with the help of a RCC Box section as shown in **Fig. 5.15**. The drain will have grated openings for collecting surface runoff from pavement and at the same time it can intercept subsurface water like seepage water from cut section in hilly terrain through well designed weep-holes as shown in **Fig. 5.15**.

5.2.11 *Use of RCC pipe for the purpose of side-drain to dispose of surface water*

In a kerbed pavement use of RCC pipe (preferably NP-3 pipes) can be used for the purpose of surface drainage as shown in **Fig. 5.16**. Manholes shall be constructed at a spacing of 10 to 20 m as per the requirement of site condition so that the water collected at the edges is disposed from the opening provided in kerbs.

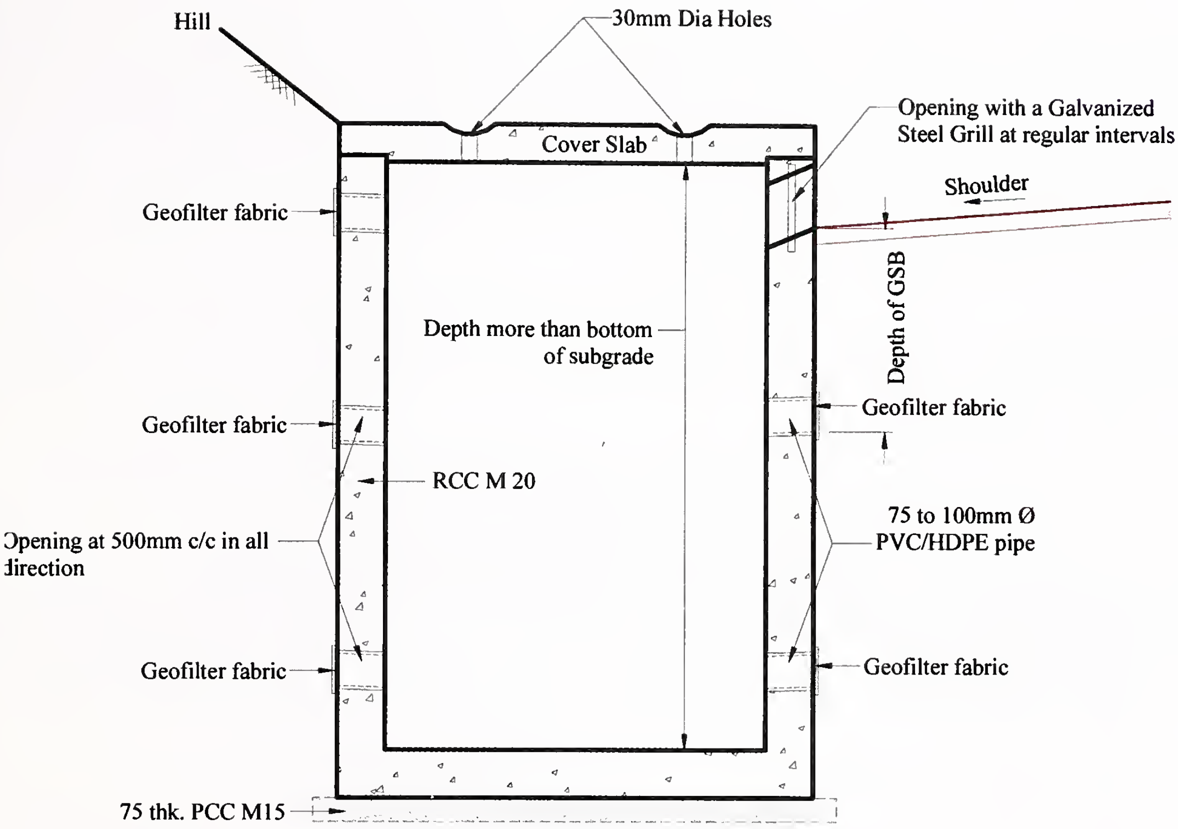


Fig. 5.15 RCC Box Drain

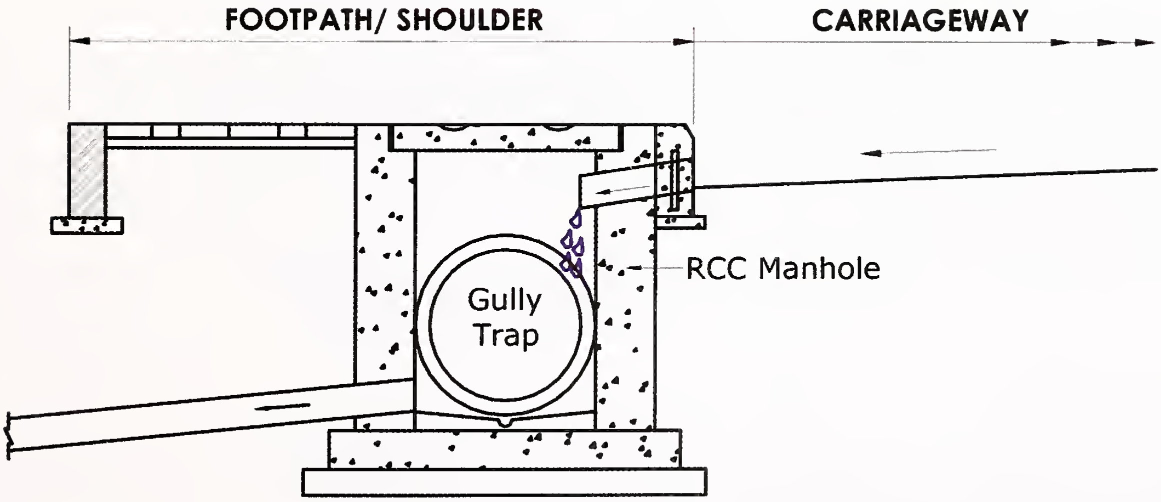


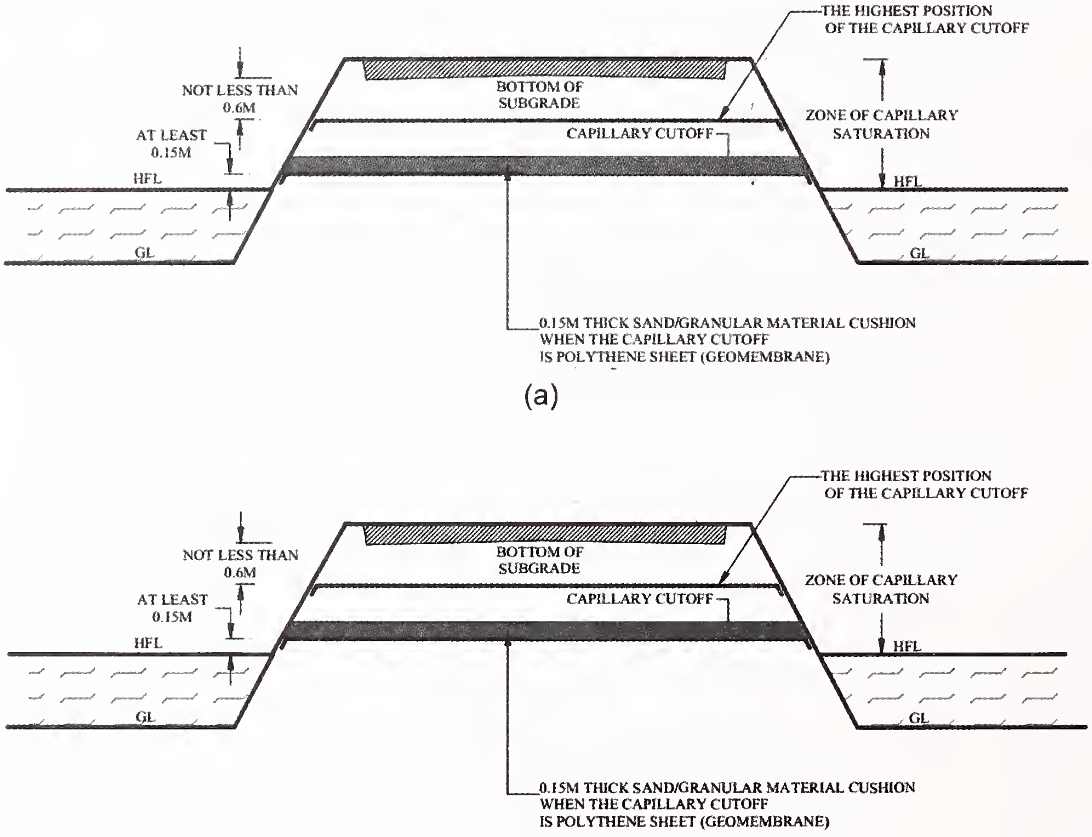
Fig. 5.16 Arrangement of Providing Pipe for Collecting and Disposing Water

5.3 Treatment of Capillary Rise of Water

Locations where water-table or high flood level is too high, it is likely to affect subgrade and embankment and weaken them and hence the IRC:37 recommends that road level should be maintained such that the water table or high flood level should be such that the bottom of subgrade should have a free board of not less than 0.6–1.0 m above design HFL. If increasing of road level is difficult or due to financial implication, a capillary cut-off should be provided. This has been discussed in IRC:34 entitled 'Recommendations for Road Construction in

Waterlogged Areas'. Capillary cut-off suggested in IRC:34 consist of sand blanket, HDPE sheets, drainage composite etc. as explained in Section 7. A cushion of 10-15 cm thick layer of sand or granular material is required to be provided over the capillary cut-off layer. Consequence of not providing capillary cut-off leads to the 'boggy action' i.e. spring action which is common in roads near canals and nallahs especially where soil is predominantly silty or clayey. In the absence of a cut-off layer the pavement fails prematurely with cracks, rutting and potholes etc.

The details of capillary cut-off and a blanket of granular or sand are schematically shown in **Fig. 5.17** are:



(b)

Fig. 5.17 Details of Cut-Off Layer

(The above sketches are from IRC: 34)

5.3.1 *Design of capillary cut-offs (extract of IRC:34)*

The IRC:34 recommends a few measures of providing capillary cut-offs as under:

i) Provision of sand blanket

The thickness of sand blanket proposed (Ref) is as under*:

$$t = \left(\frac{8}{d}\right)^{0.92}$$

---

* This formula was proposed initially by the Public Roads Administration and is published in Highway Research Board Proceedings, Vol. 21, 1941, Page 452.

where,

t = thickness of sand layer in cm

$$d = \frac{2\,d_1 \times d_2}{d_1 + d_2}$$

where,

d = mean particle diameter in mm

d_1 = aperture size of sieve (mm) through which the fraction passes

d_2 = aperture size of sieve (mm) through which the fraction is retained

In the case of sand passing through sieve size of 5 mm and retained on 0.3 mm sieve, the blanket thickness works out to be 12 cm. A layer of 15 cm can be considered for use. As suggested in the IRC:34, a bituminous primer may be applied before the blanket is placed. It is helpful if the sand layer is moistened and compacted before placing upper layers.

ii) Other capillary cut-offs suggested in IRC:34 Section 7.2

5.3.2 *Retrofitting of subsurface drainage system*

5.3.2.1 *Subsurface drainage arrangement*

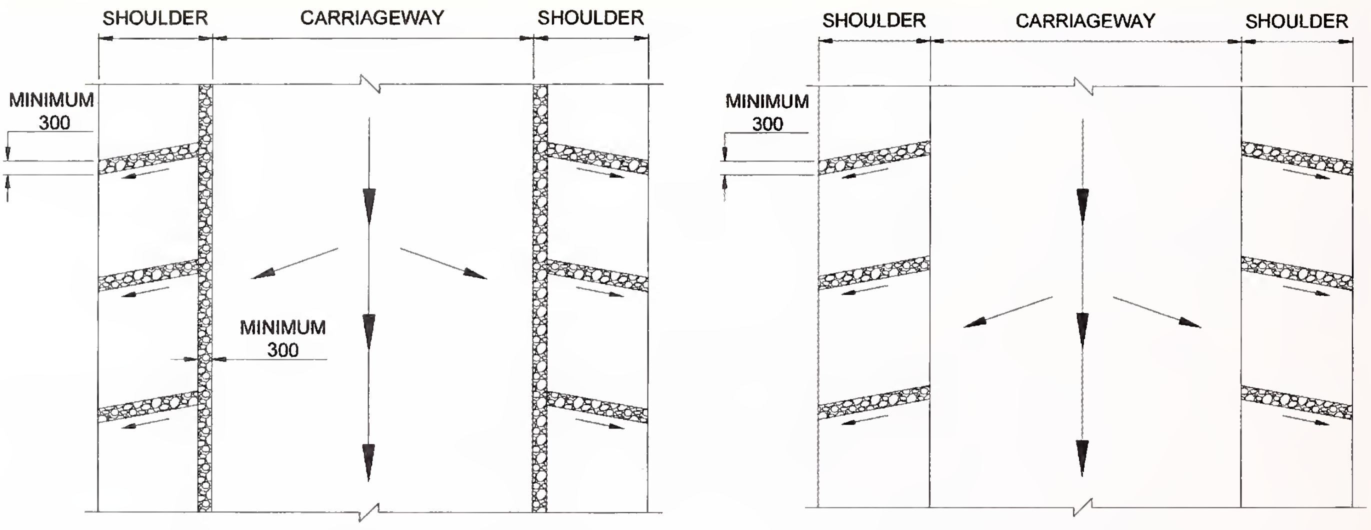
There are situations where old roads are found getting distressed due to lack of subsurface drainage system. Where the longitudinal joints with shoulder has widened as seen in **Photo 5.4** there will be requirement of retrofitting subsurface drainage system or providing bituminous or concrete shoulder which can be sealed. It does not help if the opened joint is filled with fresh soil or granular mix. In such cases construction of subsurface drainage system as shown in **Figs. 5.7 and 5.8** will be helpful.

5.3.2.2 *Aggregate drains*

After completion of a pavement without subsurface drainage arrangement, if subsurface moisture is trapped in granular base and sub-bases, aggregate drains suggested in Clause 309.3.7 of MORTH Specifications can be provided as shown in **Fig. 5.18**. Two types of arrangements can be provided; one with longitudinal drain along the road edge with laterally drains at regular intervals of 5 to 10 m as per site conditions. The minimum width of drain can be 300 mm and should be provided up to the depth of granular layers. Such drain can perform without getting chocked if the aggregates are wrapped with geofilter fabric. The grading of aggregates to be used in drain is given in **Table 5.3** (**Table 300-4** of MORTH Specifications). The grading however is as under:

Table 5.3 Grading Requirements for Aggregate Drains

Sieve Designation	Percent Passing by Weight	
	Type A	Type B
63 mm	-	100
37.5 mm	100	85–100
19 mm	-	0 – 20
9.5 mm	45 – 100	0 – 5
3.35 mm	25 – 80	-
600 micron	8 – 45	-
150 micron	0 – 10	-
75 micron	0 – 5	-



(a) Aggregate Drain Placed Longitudinally and Laterally in Shoulders

(b) Aggregate Drain Placed in Shoulder

Fig. 5.18 Aggregate Drains

6 HYDROLOGICAL DESIGN OF ROADSIDE DRAINS

6.1 General

Hydrological design of road drainage system is the study and analyses of the physical characteristics of catchment, intensity-duration characteristics of rainfall of different frequencies to arrive at a suitable method of predicting design (peak) flood and corresponding HFL. It is a very important step prior to the hydraulic design of road drainage system. Such analysis is necessary to determine the magnitude of flow and the duration for which it would last. It includes the analysis of size and shape of catchment area, topography, land use characteristics, natural storage, soil type, soil cover, drainage pattern, rainfall intensity of the area, time of concentration and the flood peak. Highway drainage facilities range from very small road side drains and culverts to large drain systems comprising minor and major bridges. Roadside drains, though a minor component in terms of cost ensures conveyance of runoff to the outlet points, thus ensuring safety of road embankment and paved surface of road as well.

A longitudinal stretch of a roadside drain originates at a ridge point of natural ground along the proposed alignment of road and ends at a predetermined outfall, be it a proposed culvert or an existing stream. A longitudinal profile of the existing ground on either side of the proposed road alignment should, therefore, be available with the designer for demarcating the existing primary and secondary ridges and valley points (outfalls). The longitudinal profile when studied with the cross slopes of the ground (within ROW for which sufficient survey details need to be available for easy generation of ground level contours) and presence of nearby outfall streams/water bodies if any, would surely bring out the intermittent stretches where longitudinal toe drain may not be required (for carrying runoff from adjacent land).

Upon identification of the ridge and valley points, the lengths of different stretches of roadside drains are determined. With increase in length, the corresponding design discharge and consequently the section of drain go on increasing. Based on the length of stretches (and other general hydro-meteorological/catchment criteria), the designer develops a preliminary idea as to where an intermediate outlet structure (balancing culvert) is to be planned, if at all, so that the length of drain can be reduced and the drain can be designed with a reasonable shape and size.

6.2 Data Requirement and its Source

The data required for the hydrological design include point value and intensity of rainfall of the area concerned, the catchment area characteristics viz. soil type, vegetation cover, land use pattern.

6.2.1 *Rainfall*

The rainfall records of ordinary rain Gauge/Self-Recording Rain Gauge (SRRG) stations are generally available with the India Meteorological Department (IMD). Again, rainfall is measured and records are kept by the State Irrigation PWD Departments for selected areas and zones of their interests. Point values of Daily Maximum Rainfall for different frequencies are available from Isopluvial maps annexed with the Flood Estimation Reports (for different subzones) of Central Water Commission, prepared jointly by CWC, IMD, MORT&H and RDSO. These point values of daily maximum rainfall are useful for estimation of rainfall intensities.

However, it is desirable to collect rainfall data from self-recording gauges, wherever available, and analyze the same to derive Intensity-Duration-Frequency curves.

6.2.2 *Soil type, vegetation cover and land use*

Response of a catchment (runoff) depends primarily on physical characteristics like slope, soil type, vegetation cover, land use pattern and shape of the catchment. Soil type is a major factor as erosion of soil may lead to gradual widening of unlined roadside drain eventually inviting unwarranted risk for the road section.

The soil type, vegetation cover is best ascertained from visual inspection (as effective catchment areas for roadside drains are very small), information on crop produced (in rural section) and enquiry, particularly from farmers/local people. Ongoing excavation works or nearby canals in cutting, if any, may also indicate the type of soil of the catchment area. Geotechnical investigation results for the proposed bridges (of same road project) will provide the designer with vital information regarding soil characteristics. The Flood Estimation Reports of CWC also throws some light on the soil type of the sub zones concerned. This information, studied with available Soil Maps of India (NBSS & LUP) of the area concerned, shall guide the designer about classifying the soil type of different stretches of the proposed road.

Information on the land use pattern of the area may be obtained from the offices of Urban Development Departments.

Data on soil type, vegetation cover can also be gathered from processing of available satellite imageries of the area (and of different seasons of a year), which could be procured from National Remote Sensing Agency (NRSA), Hyderabad.

6.3 Factors Affecting Runoff

6.3.1 *Design rainfall*

Rainfall is the most important factor affecting runoff from a given catchment. Therefore, error in estimating design rainfall results in major inaccuracy in estimated flood peak. Depending on the methods used for estimation of peak runoff, design rainfall is used basically in two forms viz. i) point rainfall or ii) rainfall intensity corresponding to design duration and frequency.

Point Value of Rainfall

A representative point value of rainfall, corresponding to design frequency, is used in some methods of estimation. The point values can be reasonably estimated from the following:

i) Analysis of relevant rainfall series collected from IMD (Daily Maximum values)

ii) Analysis of point rainfall values collected from Isopluvial maps annexed with the Flood Estimation Reports of CWC (Daily Maximum or of Shorter Duration).

For both of the above sources, updated series or data should be used for estimation of rainfall value of requisite Return Period.

Areal Spread Factor

The areal spread factor is conversion of point rainfall values to areal rainfall values. The rainfall occurred in a watershed is not same over the whole watershed. It may be low in a part of watershed and high in other part of watershed and therefore, this should affect the runoff. In order to obtain areal average values for an area, hydrologists/design engineers should adopt a suitable value to convert point rainfall amounts average rainfall amounts over a specified area. The **Fig. 6.1** represents the relation between the spread factor and catchment area.

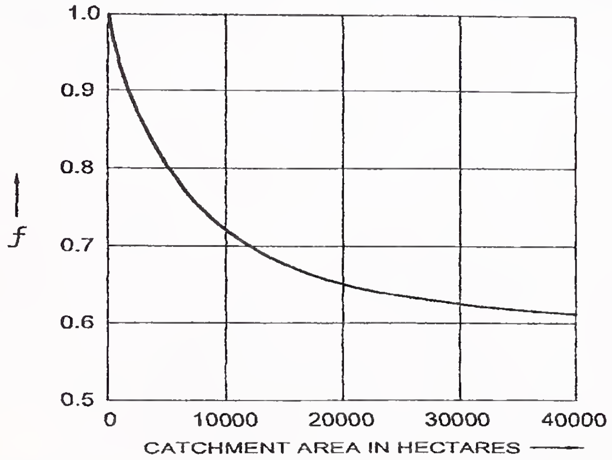


Fig. 6.1 'F' Curve (Extracted from IRC:SP:13)

Shorter Duration Storm

The design duration shall be taken equal to the time of concentration. For roadside drains, the time of concentration is generally of the order of 5, 10, 15, 20, 30 or 40 minutes and it is a general practice in India to collect and measure accumulated rainfall and record values once or twice in 24 hours. It is, therefore, necessary to apply certain conversion factors to daily maximum (or 12 hour maximum) point rainfall values in order to obtain the intensity of rainfall for the desired shorter durations.

The conversion factors for getting values of up to 1 hour duration for different sub zones of India are given in the Flood Estimation Reports of CWC. The steps indicated in IRC:SP:50 may be used to obtain shorter duration rainfall from a continuous record of any particular storm recorded in the station. Using any suitable power relation (generally fits best), the Intensity-Duration-Frequency (IDF) curve can be generated for an area. However, due to scarcity of recording type rain gauges, shorter duration (less than 1 hour) rainfall is difficult to be estimated and the hydrologist shall judiciously adopt a rainfall value either by reasonable interpolation or depending on his experience in rainfall distribution pattern of the area concerned.

Tables 6.1 and 6.2 correlating the intensities of rainfall of shorter durations compared to those of 60 minutes and 24 hours were determined for Lower Gangetic Basin (comprising of part of Bengal and Bihar). The values for other areas might be different.

Table 6.1 Shorter Duration Rainfall Intensities as a Ratio of 60 Minutes Rainfall

Duration minutes	5	10	15	20	30	40	50	60	90	120
Ratio	3.7	2.85	2.4	2.08	1.67	1.33	1.17	1	0.834	0.661

Table 6.2 Relation Percentage of 24 hours Extreme Rainfall to Shorter Duration Extreme Rainfall

Minutes				Hours			
Duration	15	30	45	1	3	6	24
Percentage of 24 hour Rainfall	16	25	31	39	55	65	100

A general equation given in IRC:SP:13, may also be used for deriving intensity for shorter duration. The Eqn. is

$$i = \frac{F}{T}\left(\frac{T+1}{t+1}\right)$$

where,

i = Intensity of rainfall within a shorter period of 't' hours within a storm

F = Total rainfall in a storm in cm falling in duration of storm of 'T' hours.

t = Smaller time interval in hours within the storm duration of 'T' hours.

T = Duration of total rainfall (F) in hours

Return Period

The size of roadside drain depends, apart from other hydraulic parameters, on the volume and peak runoff (discharge) from a catchment which, in turn, depends on the rainfall. Other hydraulic parameters remaining unaltered, the proposed size and consequently, the cost of drain go on increasing when the frequency of design flood becomes rarer or in other words the estimated peak value increases. The size and cost of drain is, therefore, required to be optimized by designing it under a presumed hydro-meteorological circumstances i.e. for a given rainfall (chosen Return Period) or the design rainfall and the consequent estimated flood discharge or the design flood.

The choice of a design return period is based on an economic evaluation in which the costs of providing the drainage works are compared with the benefits derived. However, comprehensive local flood damage data are normally not available to the degree of precision required for cost-benefit analysis. For this reason, a general policy decision based on the location where the drains are going to be constructed, probable damage that might be caused due to failure of drains etc. is taken to adopt the return period for design of roadside drains. Drains in rural area may be designed for a 10 year flood, however, it may be prudent to design a drain in an urban section (failure of drain may cause severe hazards for urban population) for a 25 year return period.

The Return Period, generally adopted in design of roadside drains is given in **Clause 7.1.4**.

Fig. 6.2 illustrates the principle of cost optimization study to find the optimal design return period. Flood estimation report, prepared jointly by CWC, MORTH, IMD and DRDO and published by CWC for different sub-zones in India as shown in **Fig. I.1** in **Annexure I**. Iso-pulvial lines are available for 24 hour rainfall of 25, 50 and 100 year return periods. Rainfall values for shorter duration can be determined using **Tables 6.1 and 6.2**. Typical iso-pulvial lines in sub-zone is shown in **Fig. I.2** in **Annexure I**. Conversion factor for rainfall values for other return periods can be found from intensity-duration-frequency analysis of continuous rainfall records of at least 15 years at that place.

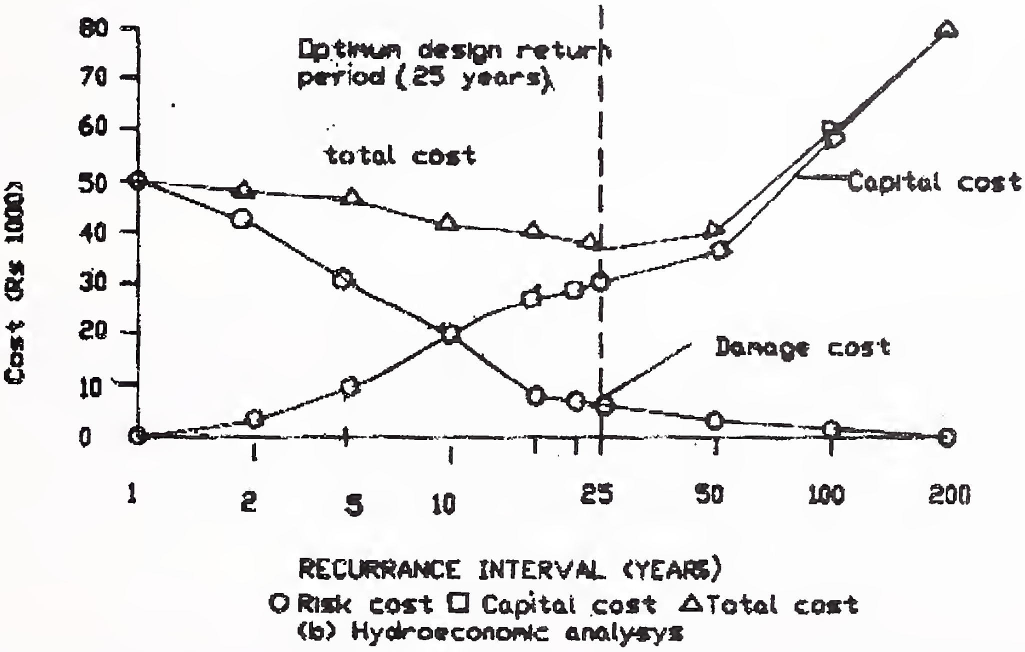


Fig. 6.2 Illustrating Cost Optimization Study for Determining Design Return Period

Check Flood

The Flood event chosen for designing roadside drains is called the Design Flood. Presumption of a given design circumstances naturally brings with it an associated risk because the design discharge, whatever be the estimated value, is susceptible to be exceeded. For a road project, if a section of roadside drain or a cross drainage structure is designed for a flood of 25 years Return Period, it is likely to fail (hydrologically, may not be structurally) if a flood of 50 Years Return Period strikes the area.

It is an accepted international practice to test the anticipated performance of the designed drain section (or any cross drainage structure) against a flood of rarer value, called Check Flood. The anticipated damage, when a check flood hits the area, should not cause irreparable damage to the drain section or structure designed with a flood of lesser peak (Design Flood). The roadside drains are generally provided with a freeboard of 150 mm over design water level. The section might be so designed that Check Flood may pass through the section with say “no” available freeboard. Such a consideration might protect an area from prolonged inundation when a flood rarer that the Design Flood hits the area.

A Check Flood is generally considered as a flood having next higher commonly followed Recurrence Interval. For example, a bridge designed with 50 year design flood should be checked with 100 year flood. Similarly, a drain section designed with 10 year design flood should be checked against 25 year design flood.

6.3.2 *Catchment area*

Delineation of catchment area is a very important step to estimate peak discharge as it has a direct linkage with the flood peak.

Flow from catchment area contributing to roadside drains comprises two parts viz. runoff from road surface and runoff from adjacent land leading to roadside (toe) drain.

Surface of Proposed Road Runoff

Runoff from proposed road depends on the width and camber of proposed road. For straight reaches, half the design width of road may be taken whereas for super-elevated reaches, full design width should be taken (duly considering the proposed paved or unpaved portions in both cases).

Adjacent Land Runoff

Runoff from adjacent land depends on the topographical features (resultant slope towards the drain, in particular) of the area and is not limited to the width of proposed ROW. It is, therefore, necessary to gather information on natural or manmade ridge lines running along the proposed road alignment. These ridges should be considered as boundary for defining catchment area contributing to flow from the adjacent width of lands. It may be reasonable to linearly increase the length of catchment area with increase in length of road and roadside drains.

Contribution of flow from adjacent land shall depend on the transverse slope of land. For a uniform transverse slope across the proposed alignment, roadside drain on one side shall intercept the flow whereas roadside drain on the other side shall carry runoff from road surface only.

Physical survey picking up spot levels to generate contour map of the area is the best option for delineating catchment area. However, this is not a realistic method due to prohibitive cost. The cost effective measures are to study and analyze the following:

i) Digital Elevation Model (DEM) readily obtained from Shuttle Radar Topography Mission (SRTM) data (http://srtm.usgs.gov). These data are freely available and very useful for delineating catchments in GIS platform for small areas in hilly terrain. Even for large catchments in flat terrain, these data are useful.

ii) Google Earth Images are very useful in delineating small catchment areas. The accuracy of manual delineation increases in rolling to hilly terrain. Special care is required for delineating very small catchments in flat terrains. Google Earth Imageries are freely available and widely used these days.

   Annexure II: provides a brief pictorial detail of delineating catchment area on Google Image.

iii) Topo sheets of different scales are available from Survey of India. These data could still be useful in delineating catchments. However, a designer should be very careful while marking ridge line between two contours of very large intervals (generally 20 m interval is available in topo sheets).

6.3.3 *Initial abstractions*

A part of the precipitation gets captured by leaves of vegetative cover and trees, natural depressions and similar features in a watershed. This part, called Initial Abstractions, of the precipitation does not contribute to generate the peak as this either gets evaporated or infiltrated or reaches the outfall of the watershed when the peak has already passed. Vegetative cover, permeability of soil and existence of ditches/ponds etc. thus affect the peak runoff from a catchment. These factors should, therefore, be given due considerations in hydrological design.

Soil Group

The rate of infiltration depends on permeability criteria of soil in the watershed and on the presence of vegetation. For example, precipitation on sandy soils may infiltrate at four to five times the rate of infiltration in clay soils. Thus, the hydrologist/design engineer should gather information on the type of soils. Based on the type and runoff potential, soils are generally classified into four major groups, as detailed in **Table 6.3** below:

Table 6.3 Soil Group

Soil Group	Description of Soil Characteristics
A	Soils having very low runoff potential (deep sands with very little silt or clay)
B	Light soils and/or well-structured soils having above average infiltration when thoroughly wetted (light sandy loams, silty loams)
C	Medium soils and shallow soils having below average infiltration when thoroughly wetted (clay loams)
D	Soils having high runoff potential (heavy soils of high swelling capacity and very shallow soils underlain by dense clay horizons)

Land Use

Land use is about the distribution of impervious and pervious cover in the catchment. Rain water which falls on impervious surfaces, such as paved areas, parking lots and rooftops, will emerge almost fully as runoff. However, rainwater that falls on a pervious surface may infiltrate into soil layers, and not running off immediately or at all. The rate of this infiltration is also related with land use.

Annexures III (a) and (b) reflects the change in design parameters with change in type of soil and land use of the catchment.

6.3.4 *Antecedent Moisture Condition (AMC)*

Antecedent moisture of soil describes the relative wetness or dryness of a catchment before the design storm hits the area. Antecedent moisture conditions can have a very significant effect on the flow responses. The antecedent moisture condition was grouped in to three levels according to the total amount of rainfall in last 5 days before the design storm and is given in **Table 6.4**.

Table 6.4 Antecedent Moisture Conditions

Antecedent Moisture Conditions (AMC)	Rainfall in Previous 5 days (in mm)	
	Dormant Season	Growing Season
I (Dry)	<12.7	<36.0
II (Normal)	12.7 to 28.0	36.0 to 54.0
III (Wet)	>28.0	>54.0

The hydrologist should suitably consider, in his design, the AMC based on the recorded rainfall for the last 5 days. In case records are not available, the rainfall distribution pattern of the area (viz. number of rainy days in a season, duration of a rainfall event, in general) should be studied for judicious selection of AMC in hydrological design.

6.3.5 *Runoff coefficient 'P'*

Some methods of runoff estimation (e.g. the rational method) address the effect of catchment characteristics through the single coefficient of runoff 'P'. The coefficient of runoff 'P' for the given area is not constant but depends on the porosity of the soil, vegetation cover, surface storage, slope, initial soil moisture capacity etc. A hydrologist/engineer should decide an appropriate value of 'P' based on the experience, judgment and the catchment characteristics. Some suggested value of 'P' for use in Rational Formulae is given in **Table 6.5** below:

Table 6.5 Coefficient of Runoff 'P'

Description of Surface	Coefficient of Runoff (P)
Steep, bare rock and watertight pavement surface (concrete or bitumen)	0.9
Steep rock with some vegetative cover	0.8
Plateaus areas with lightly vegetative cover	0.7
Bare stiff clayey soils (impervious soils)	0.6
Stiff clayey soils (impervious soils) with vegetative cover and uneven paved road surface	0.5
Loam lightly cultivated or covered and macadam or gravel roads	0.4
Loam largely cultivated or turfed	0.3
Sandy soil, light growth, parks, gardens, lawns & meadows	0.2
Sandy soil covered with heavy brush or wooded/forested areas	0.1

Time of Concentration

The storm duration chosen for design purposes is equal to the "time of concentration", and is based on the assumption that the maximum discharge at any outfall point occurs when the entire catchment is contributing to the flow. The time of concentration for any watershed is the time required for a given drop of water from the hydrologically most remote part of the watershed to reach the point of exit. They may have two components; (i) entry time, and (ii) time of flow. If the drainage point under consideration is at the entry of the drainage system. Then the entry time is equal to the time of concentration. If, however, the drainage point is situated elsewhere, then the time of concentration is sum of the entry time and the time required by the raindrop to traverse the length of the drainage system to the point under study.

For roadside drains, the entry time indicates time of entry either from road surface or from the nearest ridge (manmade or natural) to any point of the stretch of drain. Time of flow indicates the flow time through the drain to reach the nearest outfall.

The time of concentration can be estimated with reasonable accuracy with the help of common equations of hydraulics. All that it calls for is desk study of the valley lines of the watershed to trace the flow path and estimate the velocity of water in various sections.

Travel Time

Travel time (T_t) is the time it takes for water to travel from one location to another in a catchment area. T_t is a component of time of concentration (T_C). T_C is computed by summing all the travel times for consecutive components of the drainage conveyance system. Water moves through a catchment area as sheet flow, shallow concentrated flow, open channel flow, or some combination of these.

a) Shallow Concentrated Flow

Shallow concentrated flow travel time is computed as:

$$T_{t1} = \frac{L}{3600 * V}$$

where,

T_{t1} = Travel time in hours

L = Flow length in m

V = Channel Velocity in m/s

3600 = conversion factor from seconds to hours

The flow velocity V could be calculated from following formula:

$$V = KS^{0.5}$$

where,

S = channel slope in percent and k is a function of land cover.

Some values of k for selected land covers are given in following **Table 6.6**.

Table 6.6

k	Land Cover
0.076	Forest with heavy ground litter, hay meadow (overland flow)
0.152	Trash fallow or minimum tillage cultivation, contour or strip cropped, woodland (overland flow)
0.213	Short grass pasture (overland flow)
0.274	Cultivated straight row (overland flow)
0.305	Nearly bare and untilled (overland flow), alluvial fans in western mountain regions
0.457	Grassed waterway (shallow concentrated flow)
0.491	Unpaved (shallow concentrated flow)
0.619	Paved area (shallow concentrated flow), small upland gullies

b) Sheet Flow

Sheet flow travel time is computed as:

$$T_{t2} = 0.092\ \frac{(nL)^{0.8}}{P_2^{\ 0.5} S^{0.4}}$$

where,

T_{t2} = Travel time in hours

L = Flow length in m

n = Manning's roughness coefficient

P_2 = 2-year, 24 hours rainfall in mm

S = Slope of the catchment area (m/m).

Table 6.7 Manning's Roughness Coefficient n for Sheet Flow

S. No.	Surface Descriptions	Manning's 'n'
	Surface Description	
1)	Smooth surfaces (concrete, asphalt, gravel, or bare soil)	0.011
2)	Fallow (no residue)	0.05
3)	Cultivated soils:	
4)	Residue cover <20%	0.06
5)	Residue cover >20%	0.17
	Grass:	
6)	Short grass prairie	0.15
7)	Dense grasses	0.24
8)	Bermuda grass	0.41
9)	Range (natural)	0.13
	Woods:	
10)	Light underbrush	0.4
11)	Dense underbrush	0.8

A hydrologist/design engineer can suitably adopt the value 'n' depending upon the catchment characteristics, which generate surface flow regime.

c) Channel Flow

Channel flow travel time is computed by dividing the channel distance by the flow rate obtained from Manning's equation. This can be written as:

$$T_{t3} = \frac{L}{3600 * \left(\frac{1}{n} R^{2/3} S^{1/2} \right)}$$

where,

T_{t3} = Travel time in hour

L = Flow length in m

V = Channel Velocity in m/s

n = Manning's roughness coefficient

R = Hydraulic radius in m

S = Slope of the catchment area (m/m).

Therefore, the time of concentration is computed as:

$$T_C = T_{t1} + T_{t2} + T_{t3} + \ldots\ldots\ldots\ldots\ldots$$

IRC:SP:13 Formula

The formula described in IRC:SP:13 can be used to estimate the time of concentration:

$$T_C = \left(0.84 * \frac{L^3}{H} \right)^{0.385}$$

where,

L = the distance from the most remote point to the outlet in km

H = the fall in level from the most remote point to the outlet in m

Kirpich Equation

For the calculation of time of concentration (in minutes) by Kirpich Equation, T_c is expressed as follows;

$$T_C = 0.01947 \frac{L^{0.77}}{S^{0.385}}$$

where,

L = the distance from the most remote point to the outlet in m

S = Slope of the catchment area.

6.4 Design Methodologies

To estimate the peak runoff requiring disposal at a given instant, the engineer must have information regarding the rainfall within the catchment area and frequency with which this precipitation would produce peak runoff. Knowledge must be coupled with experience, if data are to be correctly interpreted. Some of most popular methods used worldwide for estimation of peak runoff are the Empirical Formulas, Rational Method, SCS Curve Number Method. Unit Hydrograph approach, is not used for roadside drainage design as the catchment areas are too small to demand such precision.

6.4.1 *Dickens formula*

One of the most popular empirical formula, which is used very significantly in various part of India for the estimation of flood peak, is the Dickens Formula. This formula is directly related with the flood peak to the drainage area. The expression of this formula is given as follows:

$$Q = C\,A^{3/4}$$

where,

Q = Maximum Flood Peak in Cumecs

A = Catchment Area in Km^2

C = Dickens constant with value between 6 to 30

The engineer should decide the value of 'C' based on the judgment and local experience. The following table describes some selection of constant 'C' in India:

Region	Dickens Constant 'C'
North – Indian Plain	6
North – Indian Hilly Regions	11-14
Central India	14-28
Coastal Andhra and Orissa	22-28

6.4.2 *Rational method*

The rational method is appropriate for estimating peak discharges for small drainage areas of up to about 25 sq. km. The idea behind the Rational Method is spatially and temporally uniform critical rainfall intensity, which continues indefinitely. The runoff at the outlet of a catchment will increase until the time of concentration T_C, when the whole catchment is contributing flows to the outlet. The peak runoff is given by the following expression:

$$Q = 0.028\,P f A\,I$$

where,

Q = Maximum runoff in cumecs

A = Catchment area in hectares

I = Design Rainfall intensity in cm/hr for the selected frequency and for duration equal to the time of concentration

P = Coefficient of runoff for the given catchment characteristics (Given in **Table 6.5**)

f = Spread factor for converting point rainfall into areal mean rainfall.

6.4.3 *SCS method (runoff curve number method)*

The SCS (Soil Conservation Services) Method (or Runoff Curve Number method) of estimating direct runoff from storm rainfall is based on methods developed by U.S Soil Conservation Services hydrologists. The principal application of the method is in estimating quantities of runoff in flood hydrograph or in relation to flood peak rates. These quantities consist of one or more of channel runoff, surface runoff, subsurface flow or base flow. All types do not regularly appear on all catchments.

In drainage design, the SCS methods can be effectively used to estimate direct runoff by means of Runoff Curve Number (CN) as per **Table 6.8**.

If records of natural rainfall and runoff for a large storm over a small area used, a plot of accumulated runoff verses accumulated rainfall will show that runoff starts after some rain accumulates, which is the initial abstraction consisting of interception, infiltration and depression storage. For the simpler storm the relation between rainfall, runoff, initial abstraction and potential maximum retention can be expressed as:

$$Q = \frac{(P - I_a)^2}{(P - I_a) + S}$$

where,

Q = storm runoff in mm

P = storm rainfall in mm

I_a = initial abstraction in mm

S = potential maximum retention in mm

For the simplicity of the above equation for estimating runoff, the relation between I_a and S was developed by means of rainfall and runoff data from experimental small catchments. The empirical relation is:

$$I_a = 0.2\ S$$

The Initial abstraction I_a can be selected from **Table 6.9** for different values of curve numbers.

Therefore, the above equation for estimating the storm runoff is expressed as:

$$Q = \frac{(P - 0.2\ S)^2}{P + 0.8\ S}$$

The potential maximum retention S is related to a curve number (CN) by the empirical expression:

$$S = \frac{25400}{CN} - 254$$

6.4.3.1 *Curve number*

The curve numbers depend on the soil type, general hydrologic condition of watershed, land use & treatment, and Antecedent Moisture Condition (AMC). The curve number for Average Antecedent Moisture Condition (AMC-II) is given in **Annexure III (a)** and developed primarily for humid and sub humid watersheds. The curve number for Average Antecedent Moisture Condition (AMC-II) developed primarily for arid and semi-arid watershed is given in **Annexure III (b)**.

The **Table 6.8** shows the Curve Numbers (CN) for wet (AMC-III) and dry (AMC-I) corresponding to the Average Antecedent Moisture Condition (AMC-II) and $I_a = 0.2$ S.

Table 6.8 Curve Numbers (CN) for wet (AMC-III) and dry (AMC-I) Corresponding to the Average Antecedent Moisture Condition (AMC-II)

CN for AMC-II	Corresponding CN's	
	AMC-I	AMC-III
100	100	100
95	87	98
90	78	96
85	70	94
80	63	91
75	57	88
70	51	85
65	45	82
60	40	78
55	35	74
50	31	70
45	26	65
40	22	60
35	18	55
30	15	50
25	12	43
20	9	37
15	6	30
10	4	22
5	2	13

6.4.3.2 Peak runoff

SCS method can be used to estimate the runoff volume as well as the peak discharge. For design of roadside drains, estimation of peak discharges if of prime importance. The peak discharge should be estimated by first identifying the appropriate SCS 24 hour rainfall distribution type over the watershed. **Fig. 6.3** shows the graphical representation of various SCS 24 hour rainfall distribution types. The hydrologist/design engineer may adopt the rainfall distribution pattern appropriate for the catchment concerned.

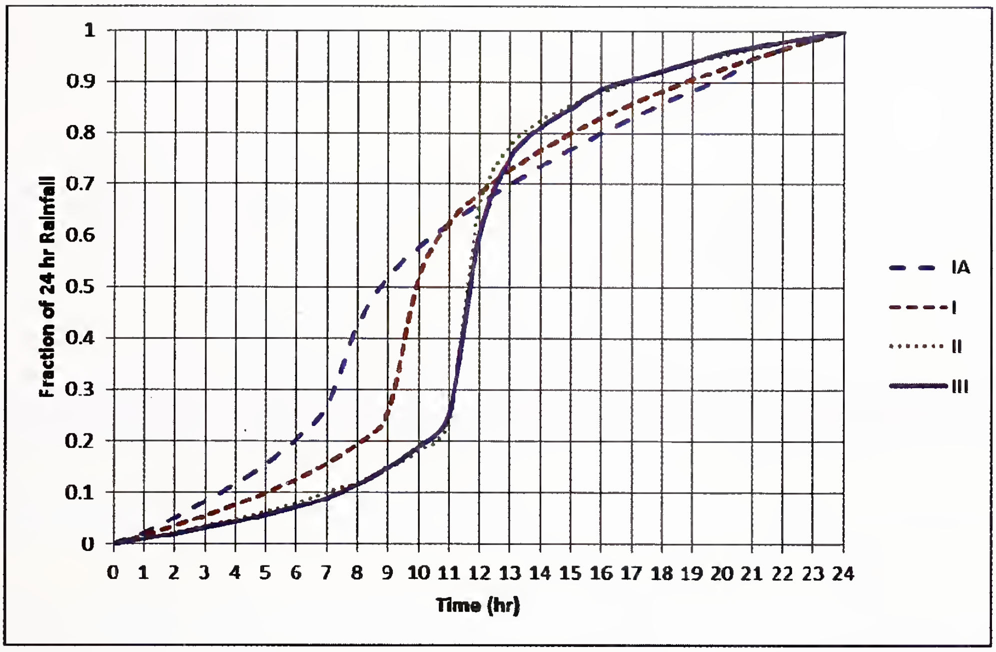


Fig. 6.3 SCS 24 hour Rainfall Distributions Over the Watershed

The peak runoff can be computed as:

$$Q_p = (q_u * A * Q * F_p)$$

where,

Q_p = Peak discharge in cumec

q_u = Unit peak discharge in cumec/km²/mm

A = Catchment area in km²

Q = Runoff volume in mm

F_p = Pond and swamp adjustment factor

The pond and swamp adjustment factor (F_p) are given in following table:

Percentage of Pond and Swamp Area	F_p
0	1
0.2	0.97
1	0.87
3	0.75
5	0.72

The unit peak discharge q_u may be calculated by analytical formula or by Graphical method. The following formula given in the FHWA-Highway Hydrology Report of Federal Highway Administration is an easy method to estimate unit peak discharge:

$$q_u = 0.000431 * 10^{C_0 + C_1 \log(T_c) + C_2 (\log(T_c))^2}$$

where,

q_u = Unit peak discharge in cumec/km²/mm

T_c = Time of concentration in hours,

and C_0, C_1, C_2 are constants and given in **Annexure III (c)** for various I_a/P ratios and different rainfall distribution types.

Graphical Approach (TR 55)

The unit peak discharge q_u can also be taken from the **Figs. IV.1 to IV.4** in **Annexure IV** (reproduced from Technical Release 55 of SCS) for all four types of SCS rainfall distribution in csm/in (Cusec per square mile per inch).

Table 6.9 I_a values for Runoff Curve Numbers

CN	I_a (mm)	CN	I_a (mm)	CN	I_a (mm)
40	76.2	60	33.9	80	12.7
41	73.1	61	32.5	81	11.9
42	70.2	62	31.1	82	11.2
43	67.3	63	29.8	83	10.4
44	64.6	64	28.6	84	9.7
45	62.1	65	27.4	85	9
46	59.6	66	26.2	86	8.3
47	57.3	67	25	87	7.6
48	55	68	23.9	88	6.9
49	52.9	69	22.8	89	6.3
50	50.8	70	21.8	90	5.6
51	48.8	71	20.6	91	5
52	46.9	72	19.8	92	4.4
53	45.1	73	18.8	93	3.8
54	43.3	74	17.9	94	3.3
55	41.6	75	16.9	95	2.7
56	39.9	76	16.1	96	2.1
57	38.3	77	15.2	97	1.6
58	36.8	78	14.3	98	1
59	35.3	79	13.5	99	0.4

6.5 Compilation and Presentation of Design Output

These days, it has become mandatory for NHAI projects to submit drainage profile along with the Detailed Project Reports of new projects or upgrade of existing Highway projects. An easy and acceptable approach to prepare drainage profile may be standardizing the runoff potential of the study area by classifying the areas into different zones on the basis of hydro-meteorological and physical characteristics of the study area. Runoff from zones, thus classified, may be estimated in correlation with the length of drain and tabulated. Such discharge table, when made available to the hydraulic engineer, can be readily used for hydraulic analysis for final sizing of the drains for different stretches (of varying slopes) along the project road.

7 HYDRAULIC DESIGN OF ROAD DRAINAGE

7.1 General

7.1.1 *Data collection*

Designer of road drainage system must be familiar with (i) the terrain through which the road is passing (ii) the natural drainage system prevailing before the road construction (iii) rivers and its tributaries draining the area (iv) ponds and other water bodies (v) topographic features like habitats, industries, marketing places, institutional buildings, existing roads, foot tracks, cable lines, gas, electrical and telephone lines, railway lines etc. (vi) details of existing drainage, canals , marshy land, waterlogged and flooded areas, forest areas, agricultural areas, rural and built up areas (with future expansion) etc. (vii) rainfall and runoff (viii) soil, subsoil and cover conditions, high water marks etc. including taking of photographs at site. Although most of this information are available from the relevant updated topo-sheets of the area, a site visit by the drainage engineer is obligatory. He/She can collect many of the vital information needed for drainage design by interacting with local people, panchayats and district authorities, central and state Govt. organizations (e.g. PWD, Irrigation, Agriculture etc.) who may be in possession of similar data to meet their own requirement. Broadly, the data may be grouped as follows:

Topographic Data

Various topographic features as stated above are available from topo-sheets prepared and sold by Survey of India and other local bodies. Google earth software prepared from satellite imageries are extremely useful in finding natural drainage systems and their catchment areas, different topographic features, terrain slope, soil and sub-soil conditions, vegetative cover etc.

Survey Data

As per TOR prescribed by the road authorities, it is mandatory to conduct road survey to fix up alignment of the road indicating general features, streams, canals, water bodies like ponds etc. crossing/adjacent to the proposed road. Levels are taken for preparing L-sections and cross-sections of the road indicating ground levels. Contour maps are prepared for every kilometer of the road by interpolation using suitable softwares. This information collected from site together with the topo-sheets (either from SOI or from Google earth) form the backbone for planning and designing the drainage works, both longitudinal and cross drainage.

Hydrological Data

It includes intensity, duration and frequency of rainfall needed for estimation of flow of different return periods. Hydrological design of drainage is discussed separately under **Section-6**.

Stream Data

L-section and cross-sections of all the streams/nallas/canals etc. are to be plotted indicating bed and bank levels, ground levels, HFL/FSL etc. for the design of drainage and cross-drainage works like bridges and culverts. In case Gauge-Discharge (G-D) stations are there on the streams, annual peak flow and corresponding HFL data should be collected from the competent authorities. Stream flow data like depth, discharge, HFL etc. are also available from Water Users Association (WUA) in many a states. Morphological characteristics of the streams, their meandering, tortuisity and skewness to road alignment, debris carried during flood season, weeds and jungles growing in the stream bed and bank etc. are very vital information needed for the design of drains and cross drainage structures.

Sediment Data

Besides water, all streams carry sediments either as bed load or as suspended load. Many of the CWC/State G-D stations have arrangements to measure the size and mass rate of sediment flow, especially during flood seasons when most of the sediments flow. Sediment sample should be collected from stream bed and banks for determining mean size (d_{50}) of the sediments by sieve analysis.

Soil and Ground Data

The flow running through the drains and culverts are often found to scour the unlined bed and bank causing flow tortuosity and damage to the road and road structures. It is, therefore, necessary to broadly group the soil to find the roughness and maximum permissible velocity as per **Table 7.1**, essentially needed to decide which stretches of the road drain require lining or protective works. Usually, the bed slope of the drain follows the existing ground slope along the road. Ideally, top level of the drain should coincide with ground level at as many points as feasible in order to avoid excessive cutting or filling. It may be necessary to change the bed slope wherever ground slope changes. In steeply sloping ground, it may be necessary to construct drop structures or provide drain with stepped bed/chutes.

Sub-Soil Data

Sub-soil data e.g. depth of water table, soil texture, permeability of sub-soil etc. will be useful for the design of sub-soil drainage system and GSB layer. Sand and gravel filled sub-soil drainage trenches covered with graded filter or geo-synthetic/geo-jute textiles are very effective in sub-soil drainage, especially in the waterlogged and marshy areas. Such highly pervious trenches filled with sand and gravel and protected with textiles permitting unidirectional flow movement (i.e. from sub-soil under the paved road towards the shoulder only and not vice-versa) constructed at the junction of paved road surface and unpaved shoulders help in controlling moisture content of soil under the pavement thereby reducing the possibility of differential settlement and undulation of road surface.

7.1.2 *Drainage requirement*

For hydraulic design, the first requirement is to prepare a statement of the drainage requirements in the different reaches of the road from the data collected and information gathered from the site visit. When the road runs along a ridge or water shade lines, the cost of road embankment and the drainage works is the least. However, unlike a canal, a road has to connect rural and urban areas and it may not be always possible to align it along the ridgelines all along the road. No drain is needed in reaches where the road runs along the ridge/watershed line. In hilly and sub-hilly terrains, intercepting drains are required only along the foot of the hills. In areas where the road is in cut, drains are needed on both sides of the road. In a sloping terrain, intercepting drain is needed on the upstream side only. Usually unlined drains are provided in rural and agricultural areas where land is cheap and available

ROW is sufficient to accommodate unlined drains having larger size compared to lined ones. In the urban and built up areas where cost of land is high and land is not readily available, lined drains or covered concrete drains are preferred from the viewpoints of land availability, need for regular cleaning of the open drains (used mostly as garbage bins by public), as well as from hygienic/aesthetical considerations. Where the road runs on high embankments, runoff from the road surface should be collected in a road side gutter and disposed through the intermittent drainage chutes at suitable intervals so that the water flowing in the gutter does not spread out to the road surface beyond a permissible limit. Since stepped chutes are self-dissipating structures, no additional energy dissipater is required at the toe of road. Where service roads are required in built up areas, it is desirable to provide an inner drain at the junction between the carriageway and the service road in addition to a covered outer drain top of which can be used as footpath. In the super elevated reaches, special arrangements are needed to collect the water in the median and direct the flow to the countryside through buried pipes.

Fig. 7.1 illustrates a typical road section in urban/built up areas with inner and outer drains. **Figs. 7.2 and 7.3** illustrate typical ditch sections without and with lining in mild and steep sloping terrains respectively. **Fig. 7.4** shows typical longitudinal Ditches on either side of a road in Cut section. **Fig. 7.5** Shows Typical Plan and Section of a road passing through an urban area.

7.1.3 *Drainage discharge*

The drainage plan and profile should be plotted on the plan and profile of the road indicating type of drains (or no drain), slope, outlet points (at culverts and bridges), change points (change in slope or change in flow direction), invert levels etc. After deciding the types and arrangements of drainage discussed under **Section-4**, design discharge for the drains (Inner & outer drains, road side gutters, inlets, median etc.) in straight and super elevated reaches in rural and built up areas should be found (by using hydrological principles discussed under **Section-6**) in a tabular form given below. While preparing the table, the stretches of road should be sub-divided in to different sections depending upon change points and outfalls, indicating chainages, slope, type of drain, flow direction, cross-drainage structures etc.

Where there are inner drains in between the carriageway and service road, the design discharge for inner drains is to be found based on the drainage area of carriageway and median. The flow into the outer drain is usually from catchment area consisting of service road and the countryside. In case the catchment area beyond ROW is large, runoff from the service road may be diverted towards inner drain by providing camber towards the inner drain. In the super elevated stretches, the inner drains towards the inner side of the road are to carry the flow from the whole of carriageway. Distribution of runoff amongst the inner and outer drains in straight and super-elevated reaches should be carried out carefully as per the road surface profile.

Chainages		Length of Drain in m	Type of Drain Lined/Unlined	Bed Slope +/-	Inflow Q in m^3/s	Direction of Flow	Outfall Point	Remarks
From	To							

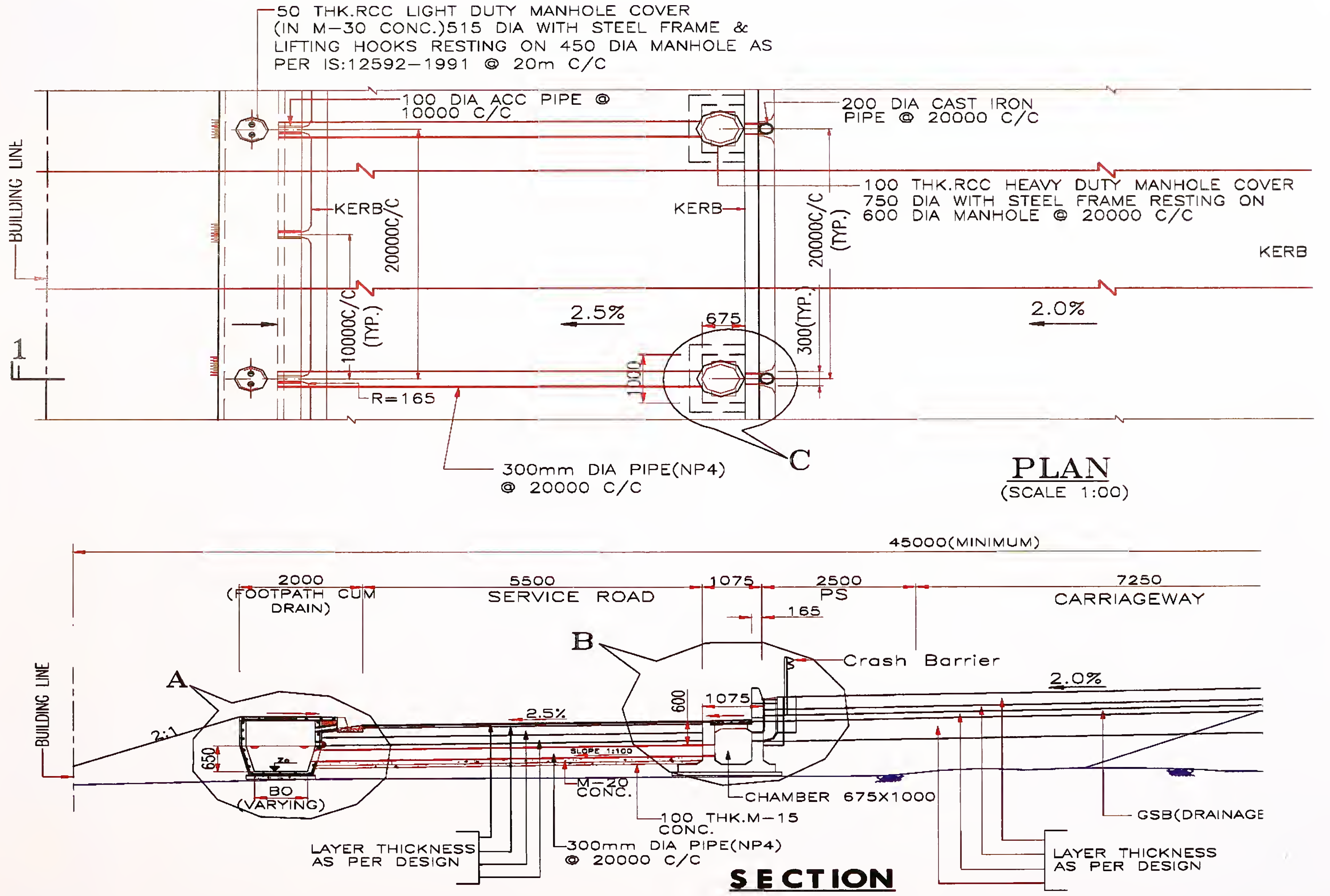
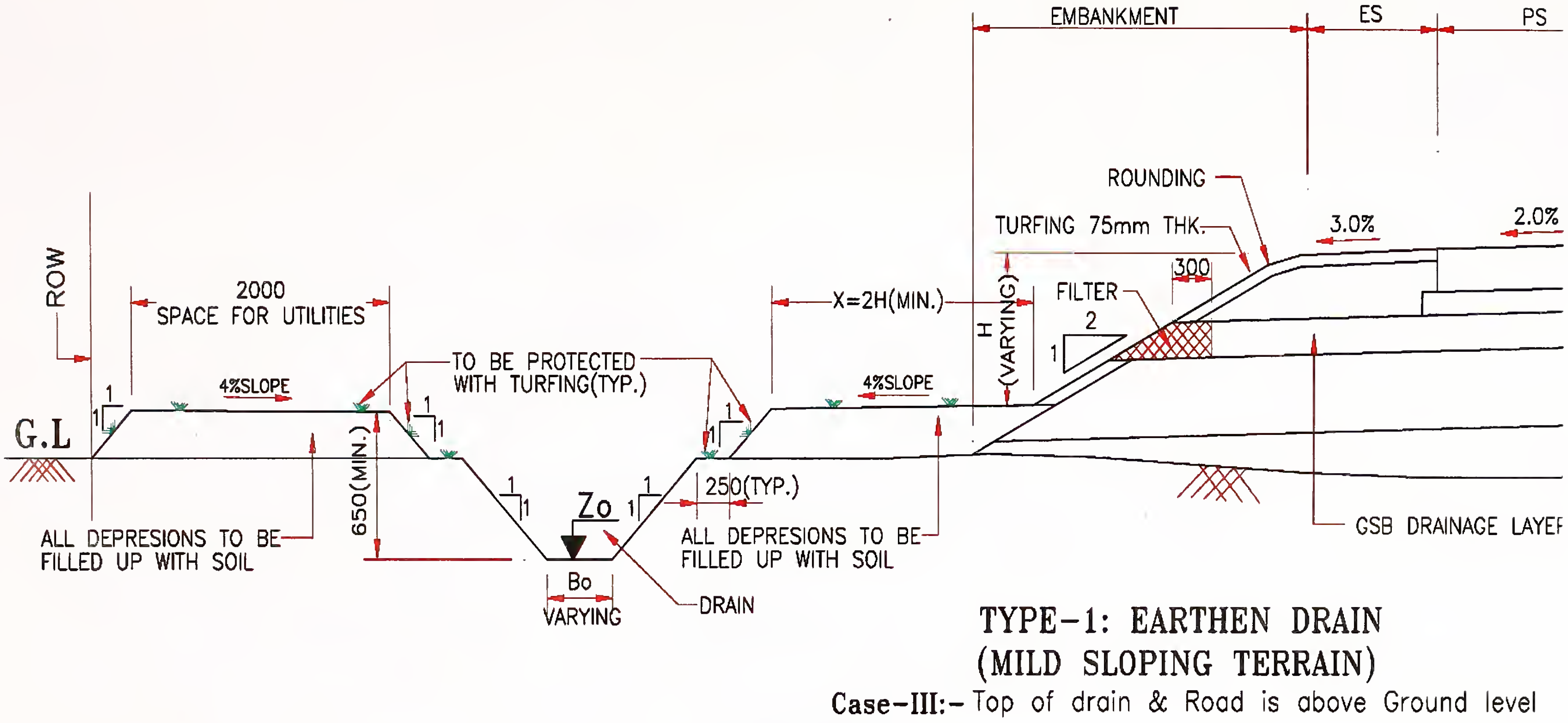
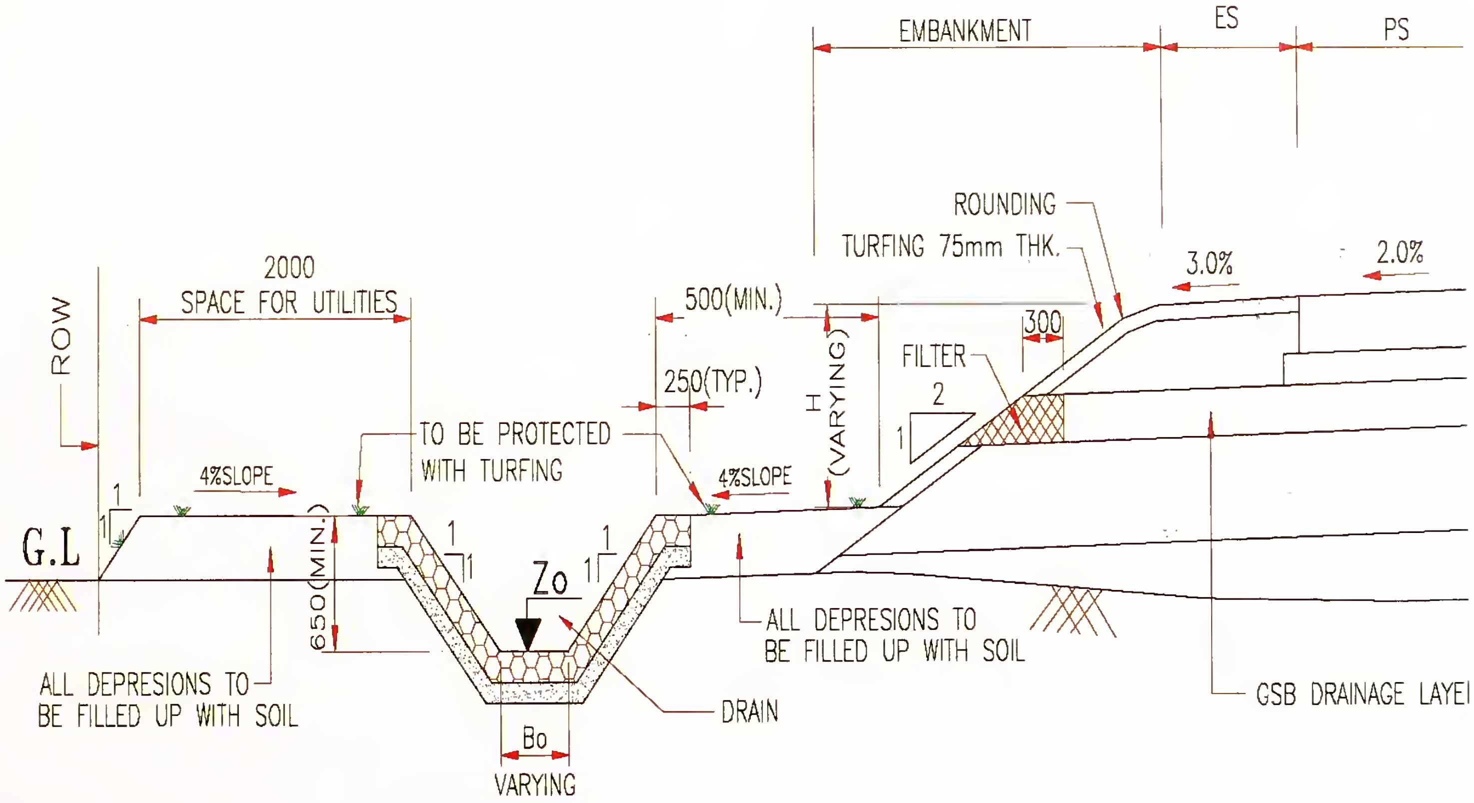


Fig. 7.1 Plan & Section Showing Drainage Arrangements in Urban Areas with Service Road



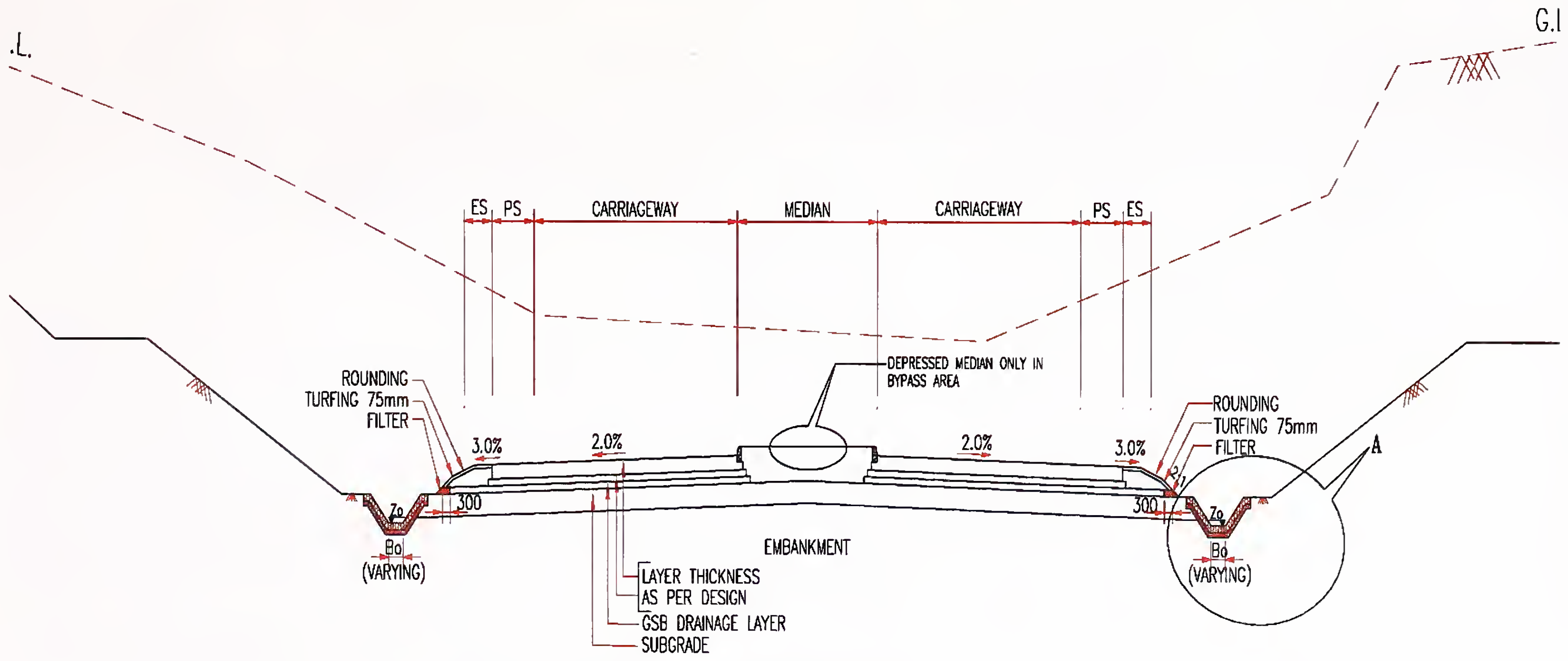
TYPE-1: EARTHEN DRAIN
(MILD SLOPING TERRAIN)
Case-III:- Top of drain & Road is above Ground level

Fig. 7.2 Showing Typical Cross-Section of a Road in Rural Areas



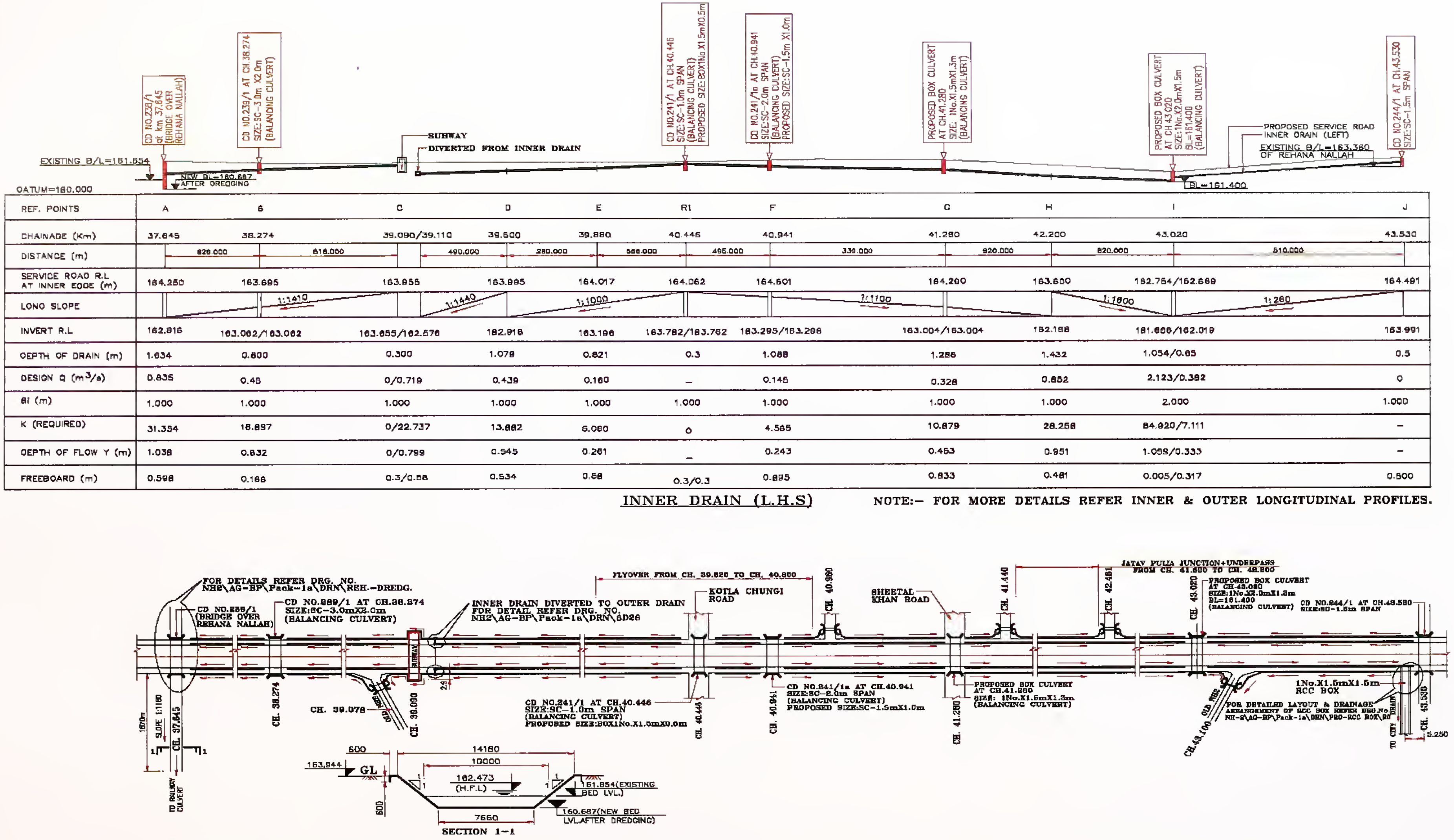
TYPE-2: STONE PITCHED DRAIN
(STEEP SLOPING TERRAIN)
Case-III:- Top of drain & Road is above Ground level

Fig. 7.3 Typical Cross-Section of a Road Showing Stone Pitched Drain



TYPICAL CROSS SECTION
(SCALE 1:150)

Fig. 7.4 Showing Longitudinal Drains on Either Side of a Road in Cut Sections



REF. POINTS	A	B	C	D	E	R1	F	G	H	I	J
CHAINAGE (Km)	37.645	38.274	39.090/39.110	39.500	39.880	40.446	40.941	41.280	42.200	43.020	43.530
DISTANCE (m)		629.000	816.000	490.000	280.000	566.000	495.000	339.000	920.000	820.000	510.000
SERVICE ROAD R.L AT INNER EDGE (m)	164.250	163.695	163.955	163.995	164.017	164.062	164.601	164.280	163.600	162.754/162.669	164.491
LONG SLOPE			1:1410	1:1440	1:1000			?:1100		1:1600	1:280
INVERT R.L	162.816	163.062/163.062	163.655/162.576	162.916	163.196	163.762/163.762	163.295/163.296	163.004/163.004	162.168	161.666/162.019	163.991
DEPTH OF DRAIN (m)	1.634	0.600	0.300	1.079	0.821	0.3	1.088	1.286	1.432	1.054/0.65	0.5
DESIGN Q (m^3/s)	0.835	0.45	0/0.719	0.439	0.160	–	0.145	0.328	0.882	2.123/0.382	0
BI (m)	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	2.000	1.000
K (REQUIRED)	31.354	16.897	0/22.737	13.882	5.060	0	4.565	10.879	28.258	84.920/7.111	–
DEPTH OF FLOW Y (m)	1.036	0.832	0/0.799	0.545	0.261	–	0.243	0.453	0.951	1.059/0.333	–
FREEBOARD (m)	0.598	0.166	0.3/0.58	0.534	0.58	0.3/0.3	0.895	0.833	0.481	0.005/0.317	0.500

INNER DRAIN (L.H.S)

NOTE:– FOR MORE DETAILS REFER INNER & OUTER LONGITUDINAL PROFILES.

Fig. 7.5 Showing a Typical Plan and Section of a National Highway Passing through an Urban Area

Once the quantity of runoff has been determined, the stage is set for the next step of hydraulic design of the drain. It is convenient to discuss the design of side drains for urban and rural areas separately.

7.1.4 *Urban area*

Side drain sections in urban areas are generally restricted to right triangular sections due to the provision of a vertical kerb at the end of the carriageway or the shoulder. The gutter section is normally 0.3 to 1 m wide having a cross slope steeper than that of the adjacent surfacing, usually 1:12 or the cross slope of the pavement might continue to the kerb. The kerb confines the storm runoff to the gutter section. The overflow spills to the adjacent paved surface, when the gutter capacity is exceeded. The capacity of a gutter depends upon its cross-section, grade and roughness. At intervals the water is removed from the gutter section by outlets. The spacing of the outlets is determined by the design discharge, the carrying capacity of the gutter and the allowable spread of water on travelled way. A suggested assumption is that the flow should not encroach on the outside lane by more than 1.8 m for a storm of 20 minutes duration and one year return period. It is reasoned that storms of shorter duration have such high intensities that vehicles must travel slowly since vision is obscured by rain pelting on the windshields.

The following design frequencies and water spread in different categories of roads may be adopted for design similar to the recommendation by AASTHO for different categories of roads in USA.

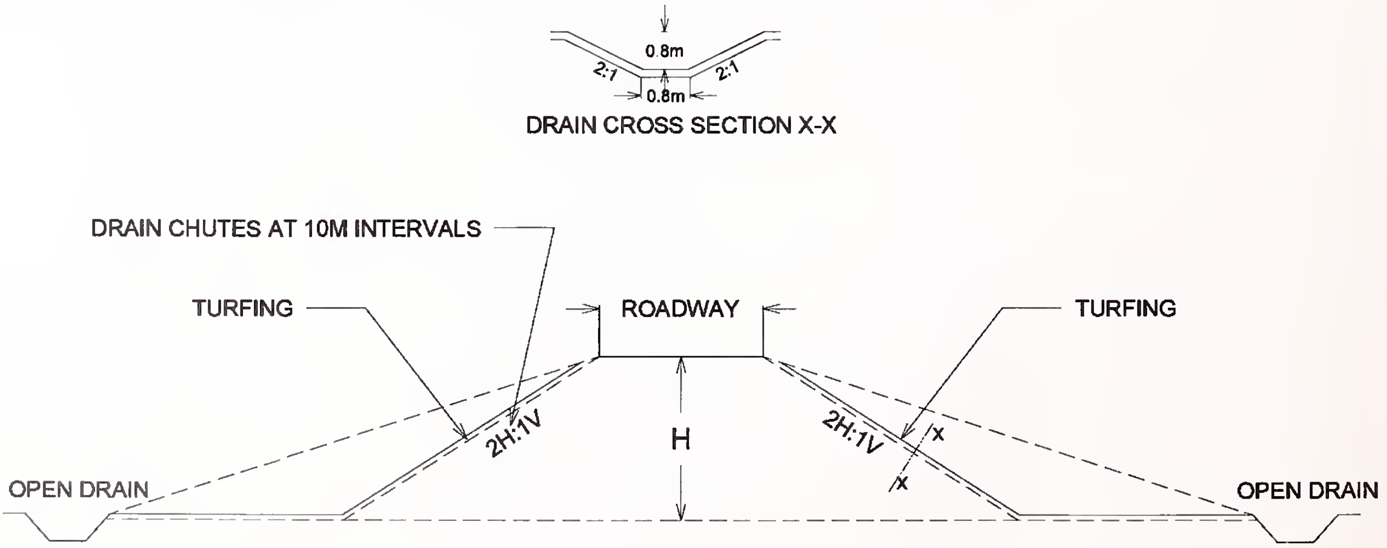
Category of Road	Permissible Design Spread	Design Return Period
National & State Highways	Shoulder + 1m	10 year
National & State Highways (at Valley Points)	Shoulder + 1m	25 year
District Roads	Shoulder	5 year
District Roads at Valley Point	½ driving lane	10 year
Village Roads including Valley Point	½ driving lane	5 year
Culverts for National & State Highways	Up to 2 m span	25 year
Culverts for National & State Highways	For 2 to 6 m Span	50 year
Culverts for District & Village Roads	Up to 2 m span	10 year
Culverts for District & Village Roads	For 2 to 6 m Span	25 year

7.1.5 *Rural area*

In rural highways, side ditches are normally placed alongside the roadway in order to intercept surface water running off the carriageway and shoulders. In cut sections they also serve to prevent water running down the cut slopes and invading the roadway. Side ditches are usually V-shaped or trapezoidal in cross-section. On low-cost roads the V-ditch is very often favoured because it can be more economically formed. If equipment is available, the same is also amenable to quick and economic maintenance with the help of a motor grader. V-shaped drains are very popular in India in hill sections. On high type of roads, the trapezoidal section is generally preferred because of its greater carrying capacity. Right triangle ditches are also sometimes used on rural highway where a kerb is placed on the outer edge of the surfaced shoulder on a fill section when water cannot be permitted to run down the embankment slope. Care should always be taken to ensure that the water surface level in the road side ditches during intense storms is below the sub-grade level.

On important roads, however, the hydraulic capacity of ditches should be checked to ensure that they are able to handle the expected flows without danger either to traffic, the embankment or the road structure. This is especially important of the ditches carrying water from adjacent back slopes as well as from the roadway. Vehicle safety considerations usually govern the ditch side-slopes on important roads, preference being given to the use of relatively flat slopes, especially on the side closest to the carriageway. Capacity of a ditch can better be increased by widening than by deepening the channel so that velocity and erosion are also reduced. In reaches where the velocity corresponding to design discharge in the road side ditches is found to be higher than the maximum permissible velocity (**Table-7.1**), the drain should be lined to avoid erosion and damage to toe of the road. Unlined open drains subject to erosion usually causes meandering and damage to toe. In reaches where the terrain slope is steep, either stepped bed or flumed chutes made of concrete may be adopted to avoid erosion.

To prevent erosion of lined drains due to free flowing water down the embankment slope, unlined drain should be located at minimum distance of 2H from the toe of the embankment, where H is the height of road top above ground as shown in **Fig. 7.6**.



1. THE FINAL SIZE AND SPACING OF DRAINS SHOULD BE DECIDED ON THE BASIS OF ACTUAL RAINFALL SURFACE AREA ETC,
2. IF OPEN DRAIN IS PROVIDED WITHIN 4h:1v LINE THE OPEN DRAIN SHOULD BE LINED WITH STONE/BRICK MASONARY OR CONCRETE
3. THE OPEN DRAIN AT GROUND LEVEL SHOULD BE CONNECTED TO A NATURAL WATERCOURSE
4. INSTEAD OF CONCRETE CHANNEL PIPE CAN ALSO BE PROVIDED ON SLOPE

Fig. 7.6 Typical Cross-Section of Approach Embankment

7.2 Open Channel Design

7.2.1 *Continuity and manning's equations*

For steady uniform flow in open channels, the basic relationships are expressed by use of Continuity and the Manning's equations:

Continuity Equation

$$Q = A_1V_1=A_2V_2 \quad \text{... Eqn. 1}$$

Manning's Equation

$$Q = 1/n\ AR^{2/3}\ S^{1/2} \quad \text{... Eqn. 2}$$

$$V = 1/n\ R^{2/3}\ S^{1/2} \quad \text{... Eqn. 3}$$

Channel Conveyance

$$Q = KS^{1/2}$$

where,

Q = discharge in cum/sec.

V = mean velocity of flow in m/sec.

K = Channel conveyance = $1/n\ (AR^{2/3})$

n = Manning's roughness coefficient

R = hydraulic radius in m which is area of flow cross section divided by wetted perimeter.

S = energy slope of the channel, which is roughly taken as slope of drain bed.

A = Area of the flow cross-section in m^2.

Subscripts 1 and 2 refer to successive cross-sections in the uniform flow path

In design of roadside channels, the flow of water is assumed as sub-critical flow. The slope and velocity are kept below the critical level. Critical depth of flow 'd_c' in open channel is that depth at which specific energy is minimum. On mild slope flow is sub-critical and normal depth of flow "d_n" is more than critical depth. For rectangular channel $d_c = (Q^2/b^2g)^{1/3}$ where 'g' is acceleration due to gravity and b is width of channel. If $d_n<d_c$, the slope and channel section should be redesigned so that $d_n>d_c$. Stepped Chutes should be provided where ground slope is steep.

Values of "n" for various channel surfaces are given in **Table 7.1**. The soil classification used in the Table is the Extended Casagrande Classification. Also shown are the maximum permissible velocity values for various types of ditch lining. Velocity values in excess of these will cause erosion in the ditches, which will not only increase the maintenance cost, but also, in the case of side ditches may weaken the road structurally.

Open-channel design can be accomplished by solving the Manning's equation numerically. As this procedure is tedious and time consuming, chart solutions have been developed to solve the problems commonly occurring. Solution can be found very quickly using excel program in computer.

Table 7.1 Manning's 'n' Values and Maximum Permissible Velocities for Drain

S. No. (1)	Ditch Lining (2)	Manning's 'n' (3)	Allowable Velocity to Prevent Erosion m/sec. (4)
1	**Natural Earth**		
A.	**Without Vegetation**		
	i) Rock		
	Smooth & Uniform	0.035-0.040	6
	Jagged & irregular	0.04-0.045	4.5-5.5
	ii) Soils (Extended Casagrande Classification)		
	G.W.		
	G.P.	0.022-0.024	1.8-2-1
	G.C.	0.023-0.026	2.1-2.4
	G.F.	0.020-0.026	1.5-2.1
	S.W.	0.024-0.026	1.5-2.1
	S.P.	0.020-0.024	0.3-0.6
	S.C.	0.022-0.024	0.3-0.6
	S.F.	0.020-0.023	0.6-0.9
	CL and CT	0.023-0.025	0.9-1.2
	MI and ML	0.022-0.024	0.6-0.9
	OL and OI	0.023-0.024	0.9-1.2
	CH	0.022-0.024	0.6-0.9
	MH	0.022-0.023	0.6-0.9
	OH	0.023-0.024	0.9-1.5
	Pt	0.022-0.024	0.6-0.9
		0.022-0.025	0.6-0.9
B.	**With Vegetation**		
	Average turf		
	Erosion resistant soil	0.050-0.070	1.2-1.5
	Easily eroded soil		
	Dense turf	0.030-0.050	0.9-1.2
	Erosion resistant soil		
	Easily eroded soil	0.070-0.090	1.0-2.4
	Clean bottom with bushes on sides		
	Channel with tree stumps	0.040-0.50	1.5-1.8
	No sprouts	0.050-0.080	1.2-1.5

S. No. (1)	Ditch Lining (2)	Manning's 'n' (3)	Allowable Velocity to Prevent Erosion m/sec. (4)
	With sprouts		
	Dense weeds		
	Dense brush		
	Dense willows	0.040-0.050	1.5-2.1
		0.060-0.080	1.8-2.4
		0.080-0.012	1.5-1.8
		0.100-0.140	1.2-1.5
		0.150-0.200	2.4-2.7
2	**Paved**		
A.	**Concrete with all Surfaces, Good or Poor**		
	i) Trowel finished		
	ii) Float finished	0.012-0.014	6
	iii) Formed, no finish	0.013-0.015	6
		0.014-0.016	6
B.	**Concrete Bottom, Float Finished, with Sides of**		
	i) Dressed stone in mortar		
	ii) Random stone in mortar	0.015-0.017	5.4-6
	iii) Dressed stone or smooth concrete rubble (Rip-rap)	0.017-0.20	5.1-5.7
	iv) Rubble or random stone (Rip-rap)	0.020-0.025	4.5
		0.025-0.030	4.5
C.	**Gravel bottom with sides of**		
	i) Formed concrete	0.017-0.020	3
	ii) Random stone in mortar	0.020-0.038	2.4-3
	iii) Random stone or rubble (Rip-rap)	0.023-0.033	2.4-3
D.	**Brick**	**0.014-0.017**	**3**
E.	**Bitumen (Asphalt)**	**0.013-0.016**	**5.4-6**

7.2.2 *Road side gutter*

Curbing with roadside gutter at the outside edge of pavements is a normal practice for low speed, urban highway facilities. In rural areas too, where the road runs in high embankment and storm water is not allowed to flow over embankment slopes (to avoid erosion), roadside gutter with kerb at the edge is a must. Gutters may be triangular, V-shaped, curved or of composite cross-slopes as illustrated in **Figs. 8.1 to 8.6** given in **Section 8**.

Hydraulic design principles of some of the roadside gutter are discussed underneath.

Triangular Channel Section

The Manning equation cannot be used without modification to compute flow in right triangular sections as used in urban or hilly areas because the hydraulic radius does not adequately describe the drain section particularly when the top width of water surface may be more than 40 times the depth (d) of curb. To compute drain flow, the Manning equation for an increment of width is integrated across the width Zd and the resulting formula is:

$$Q = 0.315/n \quad F_1 (Z) d^{8/3} S^{1/2} \qquad \text{... Eqn. 4}$$

where,

Z = Reciprocal of cross slope

d = Depth of Channel in m

T = Spread of water in m

$$F_1 (Z) = \frac{Z^{5/3}}{\left(1+\sqrt{1+Z^2}\right)^{2/3}}$$

In terms of spread width (T in **Fig. 7.7**), the equation becomes

$$Q = (0.317/n) (S_x^{5/3} S^{1/2} T^{8/3}) \qquad \text{... Eqn.5}$$

V-Shaped Channel Section

Manning's formula is

$$Q = 1/n\ F_2 (Z)\ d^{8/3} S^{1/2} \qquad \text{... Eqn. 6}$$

where,

$$F_2 (Z) = \frac{0.63\ Z^{5/3}}{\left(Z^2+1\right)^{1/3}} \qquad \text{... Eqn.7}$$

This equation could be corrected to give depth of flow 'd' as

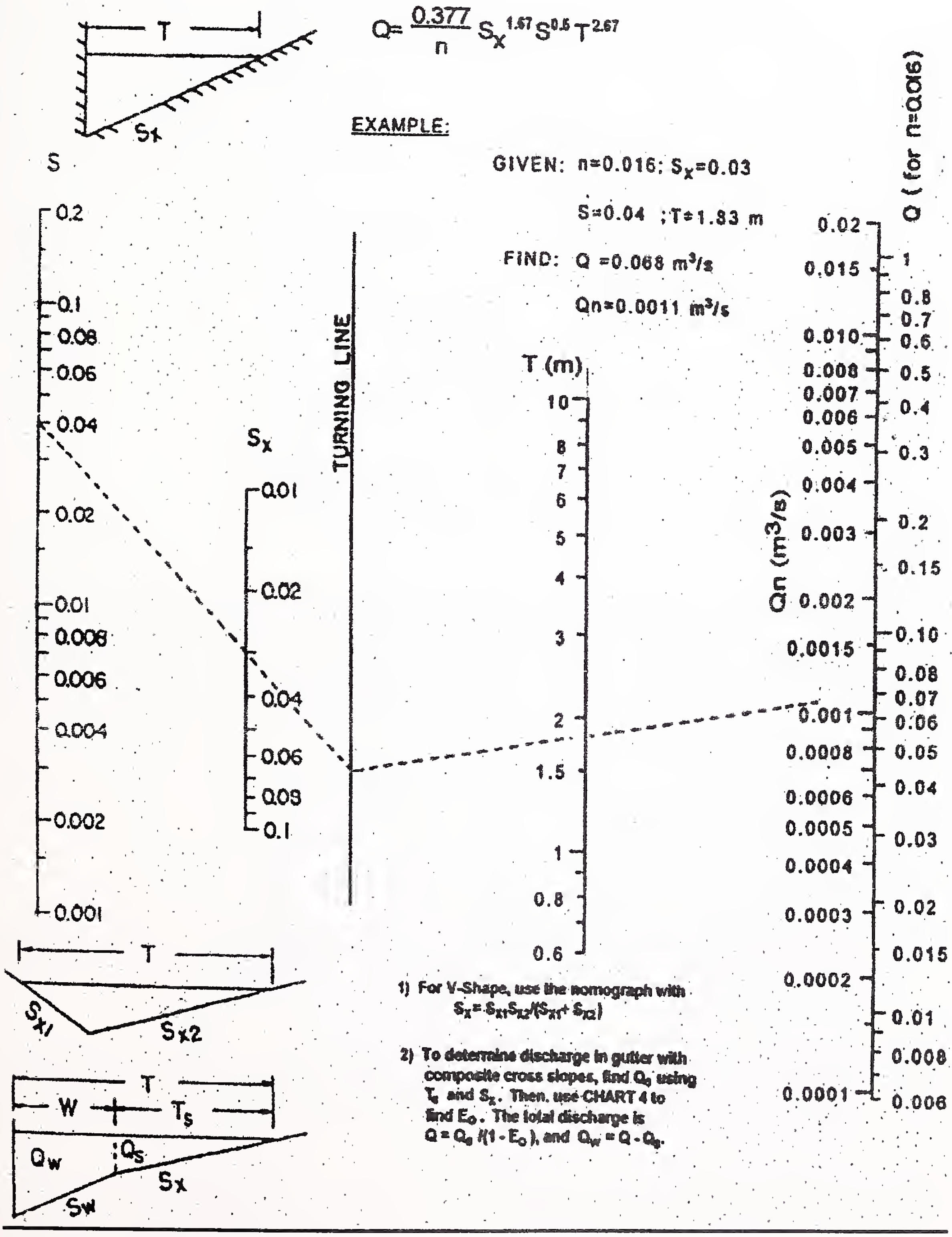
$$d = 1.1892 \left[\frac{Q.n}{\sqrt{5}}\right]^{3/8} \left[\frac{Z^2+1}{Z^{5/8}}\right]^{3/8} \qquad \text{... Eqn.8}$$

In terms of spread width (T in **Fig. 7.8**), the equation is the same as Eqn. 5 with S_x defined as

$$S_x = S_{x1}.S_{x2}/(S_{x1} + S_{x2}) \qquad \text{... Eqn.9}$$

The hydraulic analysis of channel provides the depth and mean velocity of flow at which a given flow will pass through the channel of known geometry, roughness and slope. Depth and velocity of flow are necessary for the design or analysis of channel linings and highway drainage structures

Gutter with composite cross-slope (Fig. 7.7)



1) For V-Shape, use the nomograph with $S_x = S_{x1}S_{x2}/(S_{x1}+S_{x2})$

2) To determine discharge in gutter with composite cross slopes, find Q_s using T_s and S_x. Then, use CHART 4 to find E_o. The total discharge is $Q = Q_s/(1-E_o)$, and $Q_w = Q - Q_s$.

Fig. 7.7 Flow in Triangular Gutter Section

To determine discharge in gutter with composite cross-slope, find Q_S using T_S (for T) and S_X in Eqn. 5

Then use **Fig. 7.8** to find E_0. The total discharge is given by

$$Q = Q_S/(1-E_0) \text{ and } Q_W = Q-Q_S$$

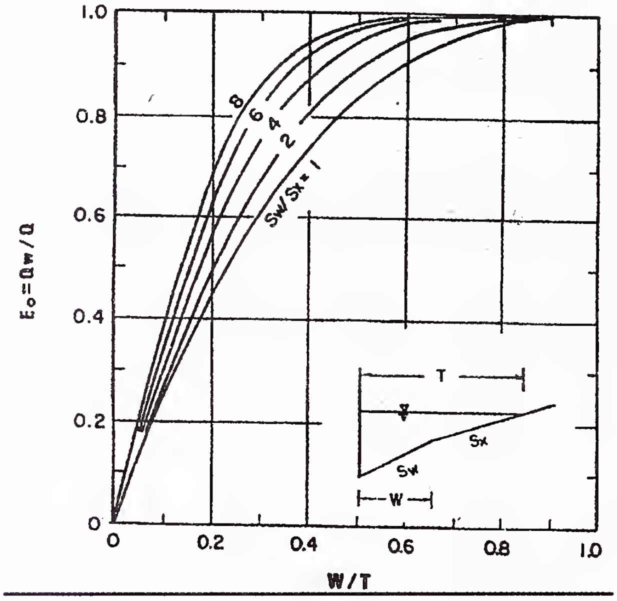


Fig. 7.8 Ratio of Frontal Flow of Total Gutter Flow

7.2.3 *Inlets*

Inlets are drainage structures utilized to collect surface water through grate or curb openings and convey it to storm water drains or direct outlet to culverts or side ditches. Grate inlets subject to traffic shall be made safe for the passage of bicycles, and shall be load bearing. Appropriate frame is to be provided where required. Inlets used for gutters can be divided into four major groups. They are:

a) **Curb opening inlets-** They are vertical openings in the curb and may be covered by a top slab

b) **Grate Inlets-** They are openings in the gutter covered by grates

c) **Combination inlets-** They consist of both curb-opening inlet and grate inlet placed in a side–by-side configuration. Curb opening may be located in part upstream of grate

d) **Slotted drain-** They consist of a slotted opening along the curb with bars perpendicular to the opening. Slotted inlets function essentially in the same manner as curb inlets i.e. as weirs with flow entering from the side.

e) **Flanking inlets-** Where significant ponding can occur, in locations such as underpasses and in sag vertical curves in depressed sections, flanking inlets are provided on each side of the inlet at the lowest point in the sag. The flanking inlets should be placed so that they limit spread of water on low gradient approaches and act in relief of the inlet at lowest point if it is clogged or if the design spread is exceeded.

Various types of inlets are shown in **Figs. 7.9 to 7.12**. Detailed hydraulic design of inlets with nomograph is given in HEC-15.

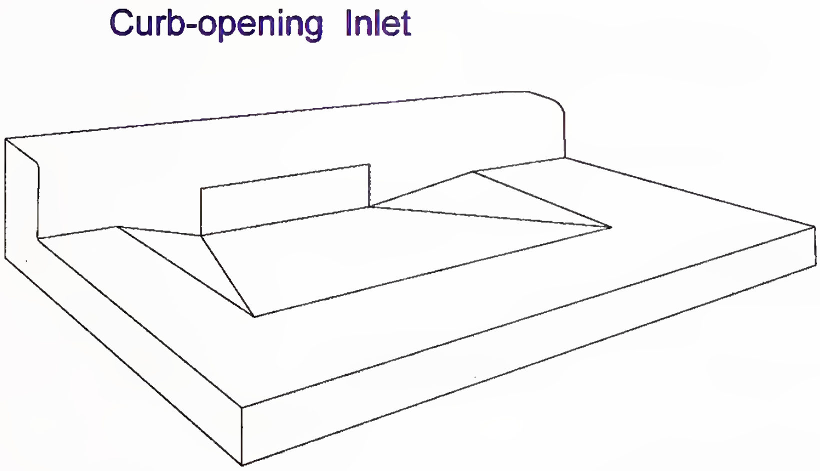


Fig. 7.9 Curb Opening Inlet

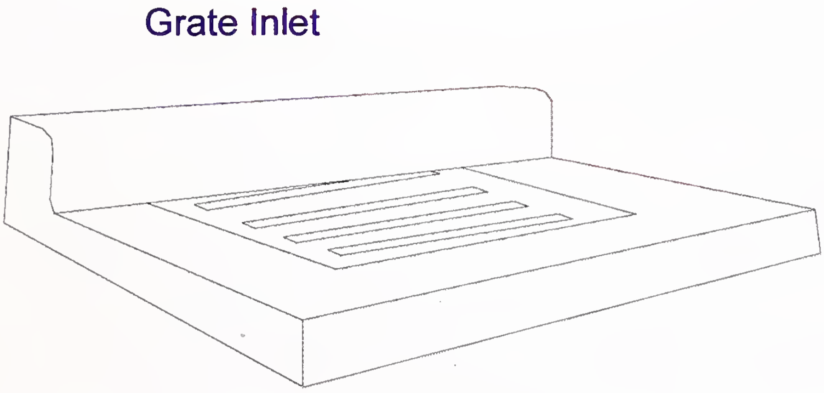


Fig. 7.10 Grate Inlet

Fig. 7.11 Combination Inlet

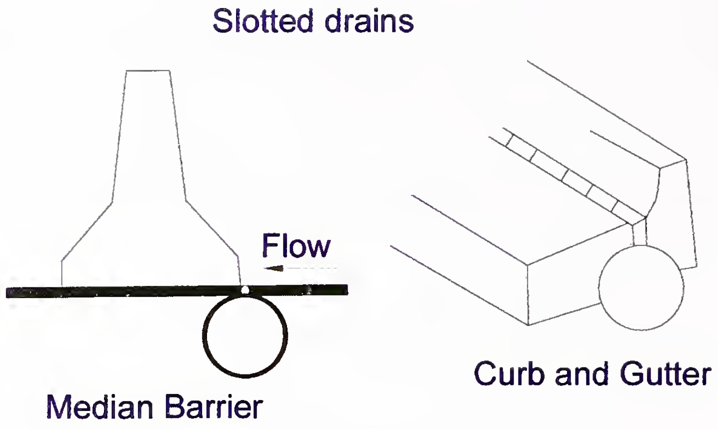


Fig. 7.12 Slotted Drains

7.2.4 *Design steps*

Each project is unique, but the following design steps are normally applicable for design of road side drains:

Step-1: Establish a Road Side Plan

- i) Collect site data
- ii) Prepare existing/proposed plan and profile layout showing highway, bridges, culverts etc.
- iii) Plot on the plan the natural basin divides, outlets etc.

Step-2: Establish Cross-Section Data

- i) Determine channel width and depth adequate to carry surface/sub-surface flow
- ii) Find safe side slope including economics, soil, aesthetics and access
- iii) Ensure that the conveyance of the channel is adequate to carry design flow
- iv) Identify features that may restrict design due to right way limits, trees, utilities, existing drainage facilities etc.

Step-3: Determine Channel Grade

- i) Plot grade on plan-profile layout (grades in cuts are usually controlled by highway grade)
- ii) Provide a minimum grade of 0.3 percent (The grade need not be equal to highway grade but normally follow existing ground profile to avoid deep cut or fill). Provide falls/chutes, if necessary
- iii) Consider influence of grade on type of lining necessary to prevent erosion when the velocity of flow exceeds the maximum permissible velocity given in **Table 7.1**.
- iv) Avoid features that may influence or restrict grade such as utilities etc.

Step-4: Check Flow Capacity and Adjust as necessary

- i) Compute the design discharge at the downstream end of different reaches/ segments as per hydrologic computations discussed in **Section-6**

ii) Set preliminary values of channel size, roughness coefficient(n) and grade

iii) Determine maximum permissible value of channel depth including freeboard which is usually kept as 0.1 m to 0.15 m.

iv) Check conveyance of the channel using Manning's equation. If capacity of channel is found to be inadequate, make possible adjustments like increased bottom width, flatter side slopes, steeper grade, smoother channel lining, provision of drop inlets with parallel storm drain pipe beneath the channel to supplement channel capacity, providing smooth transitions at change in channel sections, upstream storage to replace the floodplain storage with a view to reduce peak discharge etc.

Step-5: Determine Channel Lining/Protection Needed

i) Select suitable lining when the actual flow velocity exceeds permissible maximum velocity

ii) Estimate flow depth and choose an initial value of Manning's n from **Table 7.1**

iii) Calculate normal flow depth "d_n" at the design discharge using Manning's equation and compare with estimated depth. If they do not agree, repeat steps (ii) and (iii)

iv) Compute the mean velocity of flow at normal depth and compare with permissible maximum velocity for the given type of lining

v) If the actual velocity exceeds the permissible velocity, consider the options like

  a) More resistant lining like concrete, stone, gabion etc.
  b) Decrease channel grade
  c) Drop structures/stepped chutes
  d) Increased channel width/flatter side slope

Step-6: Analyze Outlet Points and Downstream Effects

i) Identify any adverse impact to upstream and downstream properties due to high afflux, high flow velocity, sheet flow, change in outlet water quality, increase in flow, diversion flow from another catchment etc.

ii) Try to mitigate the above impact by

  a) Enlarging outlet capacity
  b) Installing velocity control structures
  c) Improved lining
  d) Installing weirs or other outlet devices in order to redistribute concentrated flow
  e) Installing sedimentation/infiltration basins

Few illustrative examples of computing design discharge and drain sections are given in **Annexure V**.

8 ROAD SIDE DITCHES AND DRAINS

8.1 The Purpose

The water collected primarily from surface runoff is required to be collected and disposed of in a nearby culvert or bridge on a rivulet or river. To facilitate disposal of surface water, earthen side-ditches or lined drains are provided on both sides of the pavement. Depending upon the type of soil encountered, whether road is in cut or a fill section or in an urban or rural location, the type of side-drain/ditch is planned.

8.2 Cross-section of Side Ditch/Drain

There are a few typical cross-sections which are adopted viz. triangular, rectangular, parabolic, saucer shaped and trapezoidal as shown in **Figs. 8.1 to 8.6**. Side ditches in natural ground provided are either rectangular or trapezoidal. These trenches can be formed either manually or by trench cutter. Lately these trenches can be formed by trench cutter using electronic sensor for achieving the required gradient and invert level accurately. Of all the designs, parabolic section is hydraulically efficient and it is erosion resistant although it is difficult to form. The triangular section is easy to form, but it gets silted fast and thus blocking the water flow requiring constant maintenance. The rectangular section is commonly used in urban areas where it is normally lined with RCC. This section is easy to clean and maintain. Lined drains can be designed to place a RCC slab or steel grating so that pedestrians and vehicles can move on it. But unlined rectangular drains tend to erode and collapse in the presence of flowing water.

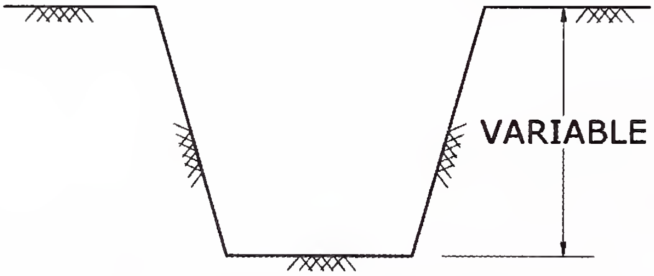


Fig. 8.1 Trapezoidal Cross-Section

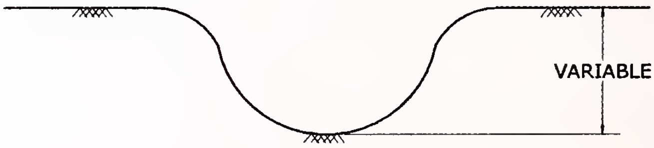


Fig. 8.2 Parabolic Cross-Section of a Drain

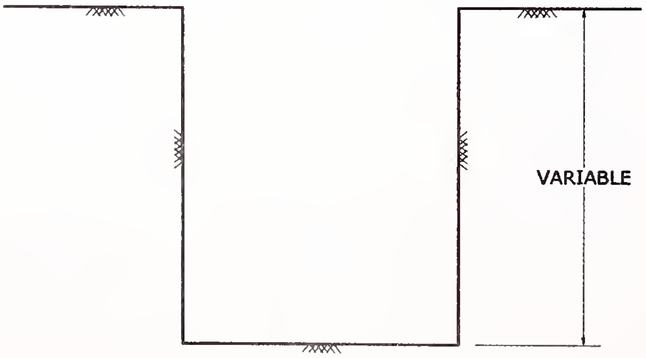


Fig. 8.3 Rectangular Cross-Section

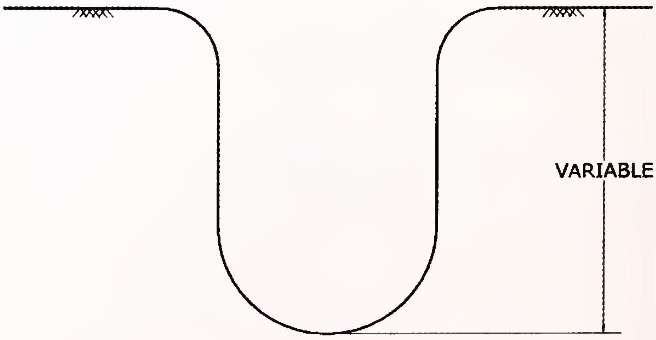


Fig. 8.4 U-shaped Drain

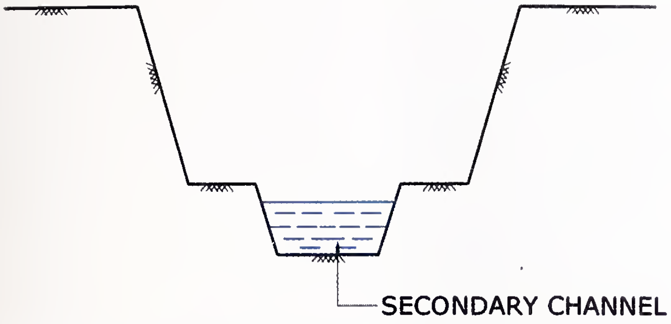


Fig. 8.5 A Trapezoidal Drain With a Secondary Channel

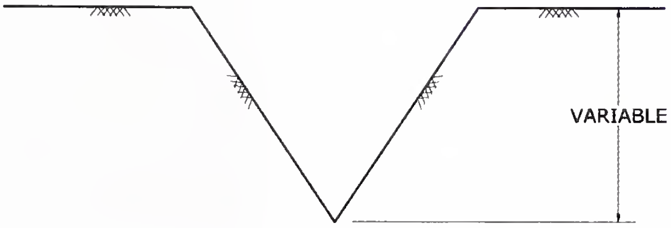


Fig. 8.6 V-Cross-Section of a Drain

The size of the side drain is decided by the quantity of water to be discharged using Manning's formula which is explained in **Section 7**. Normally the longitudinal gradient of invert shall be as much as possible parallel to the road profile but it may change where it cannot be maintained. For facilitating easy cleaning, the width at bottom should be at least 0.3 m. The invert level of drain should preferably be kept such that the water surface corresponding to design discharge remain at least 0.3 m to 0.6 below the bottom of drainage layer of the pavement. The earthen drains, if found inadequate to carry the discharge, can be widened after observing its performance after first monsoon. The earthen drain must not be allowed to run full for long duration as it may lead to erosion of sides.

8.3 Drain Linings

Earthen ditches, unless they are flat and shallow, tend to get eroded. In the case of urban roads, however, due to constraint of space and safety considerations of pedestrians they have to be lined. The material used for lining varies from RCC, stone slabs, bricks, precast sections, stone masonry, stone slabs, turfing, geosynthetic material covered with grass etc. The option of lining depends on the availability of construction material locally, and cost consideration etc.

8.4 Reinforced Cement Concrete Lining

RCC lining is suitable for drain of any cross-section. Precast concrete (RCC) linings are randomly easy to construct and the work can be done faster. The RCC lining tends to crack due shrinkage and hence needs to be provided with sealed joints at 8 to 10 m interval or as specified in the contract. All the joints have to be sealed effectively with sealants in order to stop seepage of water. Open drains are normally covered in urban stretches for safety of pedestrians and for using the area for footpath etc.

A view of a RCC lined trapezoidal drain can be seen in **Photo 8.1**. Lack of maintenance has resulted in growth of vegetation inside drain affecting free flow of water as seen in the **Photo 8.1**.

Photo 8.1 A View of Precast RCC Lined Drain

8.4.1 *Lining with rubble/coursed masonry*

Lining of drain can be done using random rubble or coursed masonry, dry-stones and stone slabs. Coursed rubble stone lining is aesthetically more appealing and allows water to flow smoothly but it is costly. Where stone is available nearly this type of lining works out to be economical. Use of brick is popular where stones are not available. In some South Indian States use of stone slabs is very common. A typical cross section of a drain with random rubble masonry is given in **Fig. 8.7**.

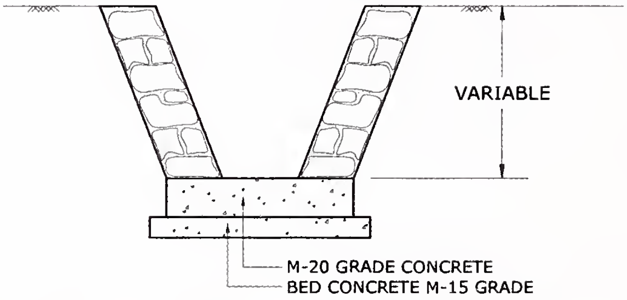


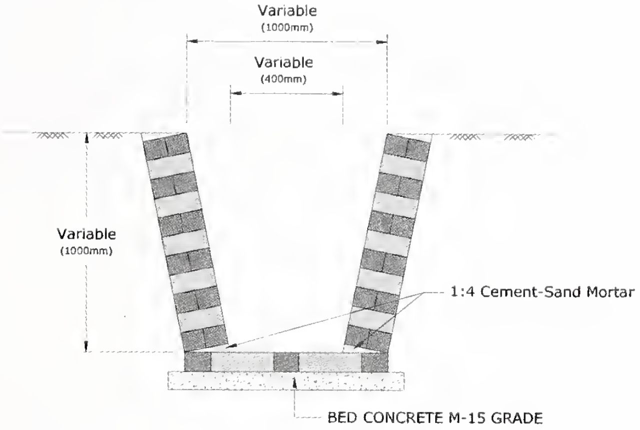
Fig. 8.7 A Drain Lined with Random Rubble Masonry

8.4.2 *Brick lining*

Brick is another material which is used extensively for lining as shown in **Photos 8.2 and 8.3**. The drain bottom can be constructed with nominally reinforced concrete slab or brick. Brick can be used in trapezoidal as well as rectangular sections economically (**Fig. 8.8**). Rectangular sections can be used where RCC cover or steel grating is required to be placed on the top (**Fig. 8.9**).

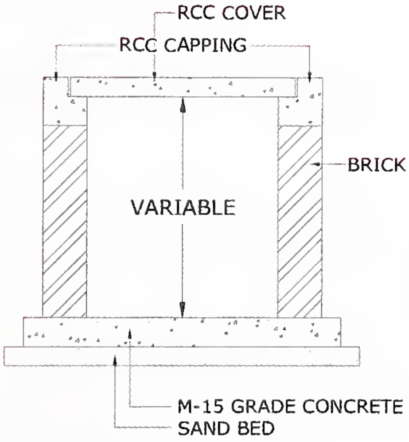
Photo 8.2 A Brick Lined Drain Provided with Smaller Secondary Channel

Photo 8.3 An Open Side-Drain with Brick Lining



Note:
Figures in brackets are indicative.

Fig. 8.8 A Brick Lined Drain of Trapezoidal Section

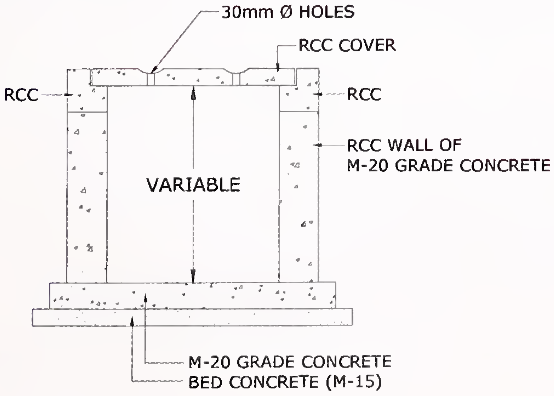


Note:
1. The RCC cover and capping shall be designed.
2. Depending on the height of drain height of drain, the wall thickness brick lining shall be increased.

Fig. 8.9 A Rectangular Brick Lined Drain

8.4.3 *Concrete lined drains*

A few RCC lined drains are shown in **Figs. 8.10 and 8.11**.



Note:
The RCC cover and capping shall be designed.

Fig. 8.10 A Rectangular RCC Drain

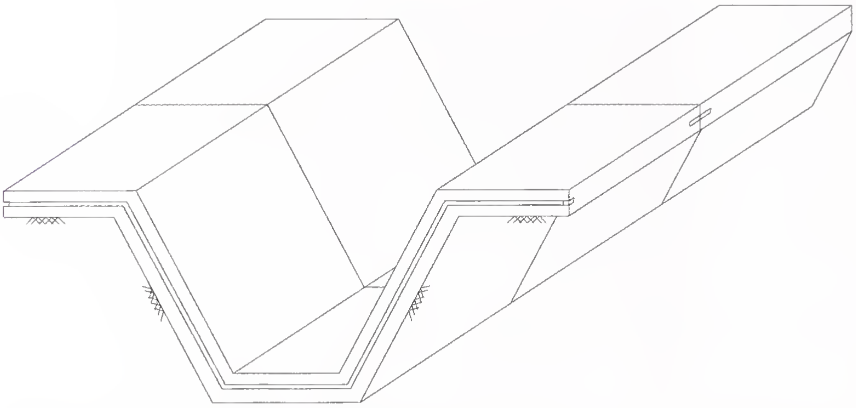


Fig. 8.11 A Schematic View of a Precast Concrete Drain

8.4.4 *Stone lined drain*

Where stone slabs are available in some South States it is economical to use stone slabs as shown in **Fig. 8.12**.

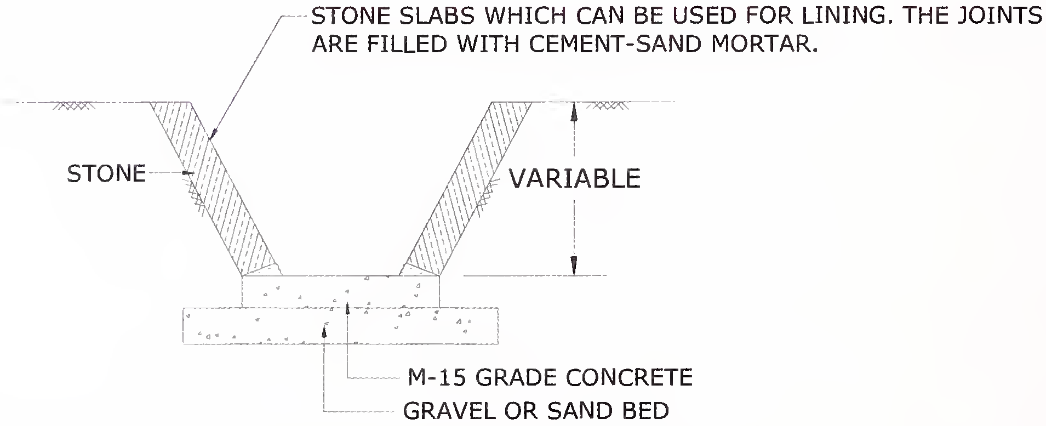


Fig. 8.12 Drain Lined with Stone Slabs
(This is common in places where granite stone available locally)

8.4.5 *Drains in hilly terrain*

Flow of water in side drains in hilly terrain remains at high velocity due to steep gradient causing erosion of drain. As a precaution sometimes no-fines-concrete dykes or stone or concrete benches can be provided on the bottom of lined drain to control the velocity as shown in **Fig. 8.13**.

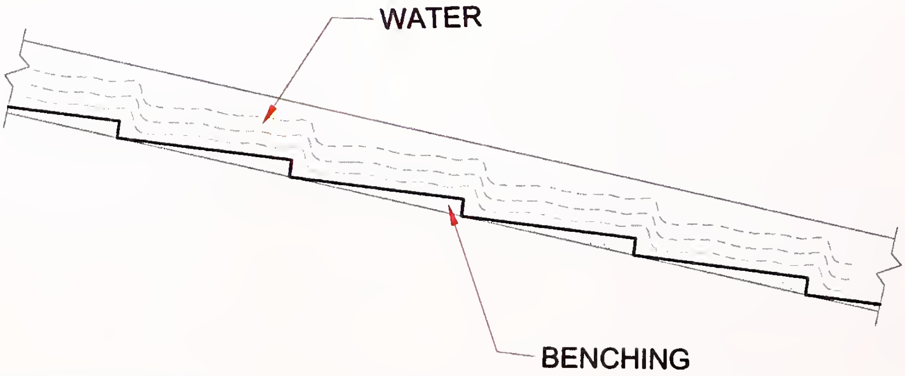
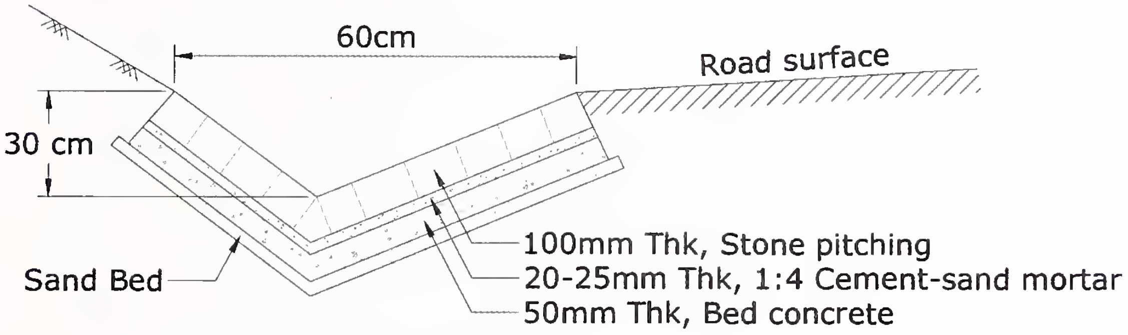


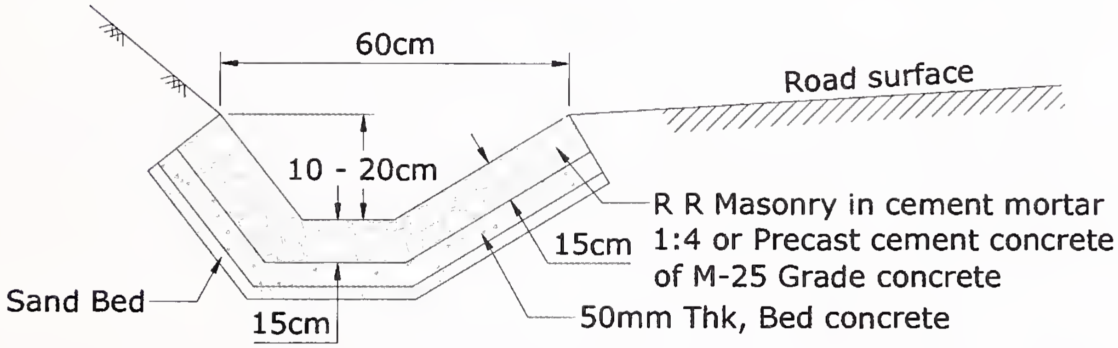
Fig. 8.13 Concrete Dykes or Benches in Steep Slope Provided to Reduce Velocity

8.4.6 *Lined side drains in hill terrain*

Two typical side drains normally adopted in cut-sections of hilly terrain are shown in **Fig. 8.14**. In case where there is rock below, stone pitching can be done after the undulating rock surface is levelled to required grade and level with M-15 or M-20 concrete.



(a) Triangular drain



(b) Trapezoidal drain

Note : If the side drain are to be prepared on rock surface, sand bed and bed concrete are not required.

Fig. 8.14 Two Designs of Side Drains Adopted in Hilly Terrain

8.5 Special Requirements of Drainage in Hilly Roads

8.5.1 *Surface drainage*

When a road passes through a hilly terrain, it has usually hill on one side and valley on the other side. Runoff coming from the hill side must be intercepted by providing a ditch at the foot of the hill and disposed of in the valley side by providing drainage culverts at suitable intervals. If drainage is not adequate, the runoff water will flow above the road surface resulting in damage of the road as shown in **Fig. 8.15**. Often debris and stones fall into the drain blocking it and causing overflow of the drain and road. V-shaped shallow drains as shown in **Figs. 8.6** and **8.14(a)** are normally provided for safety of vehicles. The drains are lined with concrete or stone masonry to avoid erosion since the longitudinal slope of drain is quite high and rolling stones cause high friction. As these shallow drains have limited conveying capacity, culverts are required at closer intervals compared to those in plain areas. Spacing of the culverts is governed by the rainfall intensity, width of terrain (normal to road) contributing to runoff, slope of the ditches etc. Typical inlet of a pipe culvert and optimum spacing of culvert designed for a hilly road in Northeast is illustrated in **Figs. 8.16** and **8.17**. Culverts are required at innumerable streams crossing the road for passage of fishes and stones brought by these streams. The outlets of culverts need proper arrangement for flow diffusion, energy dissipation and anti-erosion measures.

Unlike plain terrain, culvert inlets must be properly designed so that the stones do not block the culverts and they can easily be cleared of debris and stones. When deep rectangular or trapezoidal drains are required to be provided to increase conveyance, the drain should be covered with perforated slabs on top for safety of traffic. Width of road side ditches is normally restricted to 60 cm since wide drains require large volume of cutting on hill side which is not only costly but it causes instability of hill side slope requiring costly retaining walls. Stepped chutes/baffles are to be provided where the longitudinal bed slope exceeds critical stage to prevent supercritical flow resulting in shock waves in curved areas, change in direction, change in width etc.

8.5.2 *Sub-surface drainage/Intercepting drains at higher altitude*

Water table in a hilly region follows more or less the gradient same as that of hill slope. When a cut is made in the hill to accommodate a road, there is seepage flow into the side ditch. Suitable weep holes are to be provided to take care of the seeping water. Otherwise, pore-water pressure will build up resulting in slope failure with failure of retaining walls.

Where the width of terrain (at right angle to the road) contributing to flow in to the drain is very high, additional intercepting drain at higher elevations may be needed to reduce the inflow into the road side ditches of limited conveying capacity. (see **Fig. 5.11**)

Further details of drainage arrangements in a hilly terrain are given in Hill Road Manual (IRC:SP:48). A long-section of a typical culvert in hilly terrain is given in **Fig. 8.16**. Extensive damage caused in hilly road due to inadequate drainage can be seen in **Fig. 8.15**.

Fig. 8.15 Damage to Road Surface Due to Inadequate Drainage

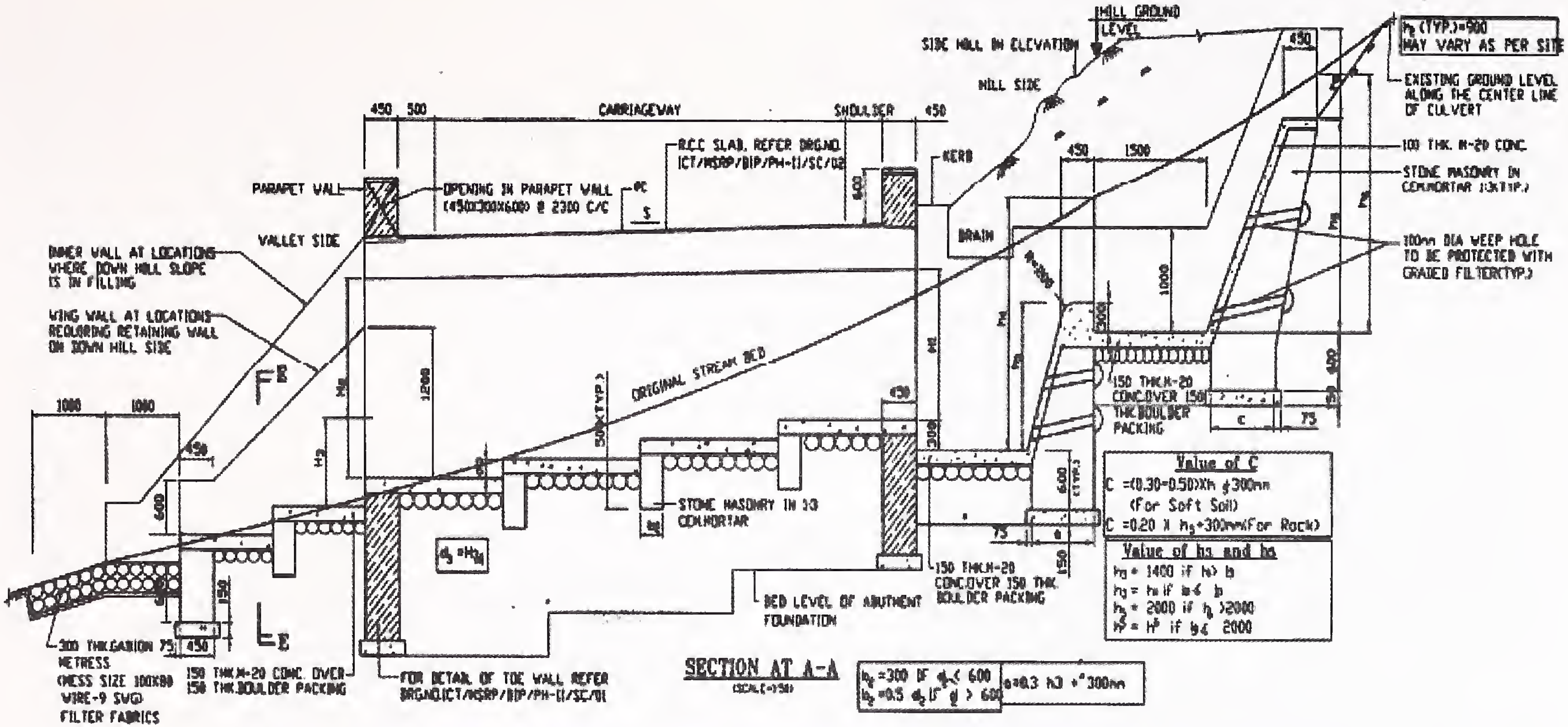


Fig. 8.16 Sectional Elevation of Typical Pipe Culvert with Improved Inlet in a Hilly Terrain

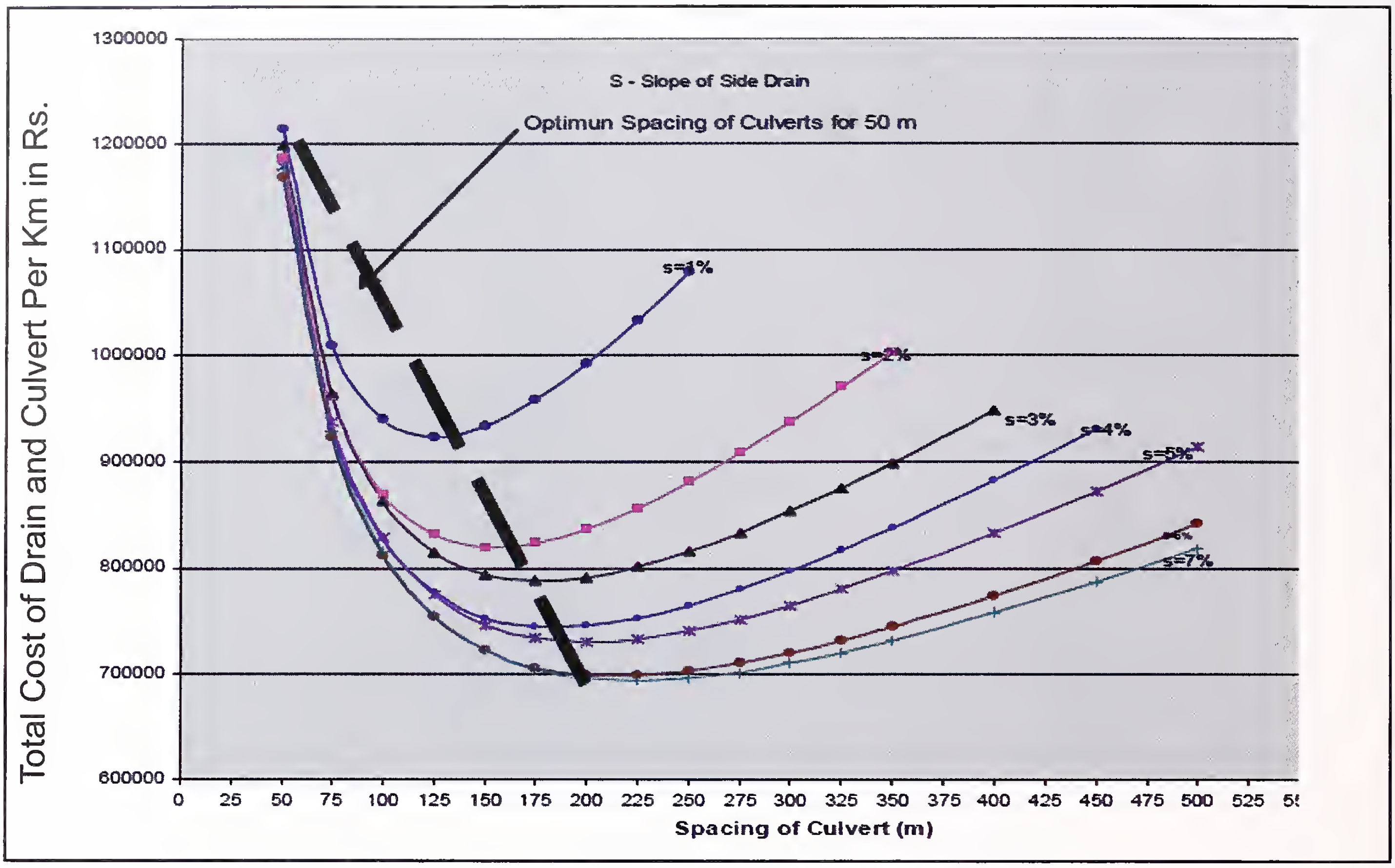


Fig. 8.17 Optimum Spacing of Culvert for Mizoram Project

9 CROSS-DRAINAGE WORKS AND DRAINAGE OF BRIDGE DECK

9.1 Necessity of Drainage Culverts

Construction of a road embankment unavoidably obstructs and interferes with the natural overland flow and flow through the natural channels e.g. rivers, nallas, canals, drains etc. Suitable cross-drainage works like bridges and culverts under the road must be provided across these channels with a view to pass the peak discharge through the channels without causing harmful afflux and disturbing the natural flow regime. Provision of adequate numbers of culverts and outfall points of appropriate size is a prerequisite for a healthy road. Submergence and overtopping of road not only causes damage to the road and road structures, it results in disruption of traffic, loss of travel time and miseries to many of the poor people who take shelter on roads during floods in many parts of our country.

Overland flow, which would otherwise meet the natural stream at some downstream point, must be intercepted in longitudinal drains and discharged back into the nearest natural drainage channel through culverts and bridges. The local drainage arrangements consisting of longitudinal drains and culverts shall have to be designed to carry the runoff from the road surface too.

Where a road runs in an undulating terrain, causeways or dips are often provided in valleys to avoid road in high embankment. Frequent dipping down from high road levels to the ground produces a very undesirable road profile. Constructing bridges and culverts under road in high embankment is a better proposition than providing so many dips and causeways leading to disruption in traffic movement during flood season. Bridges, culverts and underpasses are often used by local people and livestock to cross the busy roads like national and state highways in high embankments. They also act as passage for up and down movement of fish and other aquatic animals. Sediments and debris carried by the stream, especially during floods, must freely move downstream through these openings to avoid aggradations and other interrelated problems. For existing roads, it is not uncommon to find silted barrels of existing culverts and culverts having inadequate capacities causing overtopping of the road embankments. In a very flat terrain, most of the streams are shallow and the banks are spilled with flood water moving in wide flood plains. In the absence of road, the spill flow moving over the land surface constitutes a substantial amount of peak flood. When a road is built in such a terrain with wide flood plains, the entire flood water has to move across the road through the bridge opening of limited span, resulting in very high afflux and other problems. Usually, the spill water is found to move along the toe of the road causing scouring and damage to road embankment. Provision of relief culverts on either side of the bridges in such flood plains are very helpful in the quick disposal of spill flood across the road which results in less afflux and ensures safety of the road embankment.

9.2 Planning of Culverts for Effective Road Drainage

Design of an efficient cross-drainage system is a prerequisite for success of new road projects and for rehabilitation projects as well. Proper planning of culverts is a very important aspect of road design from the point of view of safety of the road - new or existing one. Planning generally covers selection of location, type, numbers and size of culverts. To be most effective, location of culverts have to be very carefully decided after studying the terrain and collecting relevant information from topo sheets and other sources. Field visit and consultation with local people and local authorities conversant with local topography and drainage problem of the area is extremely useful.

A drainage culvert should be placed in a natural depression or valley points. These locations are easily identifiable in hilly/rolling terrains but very difficult to be identified in plains. An easy method of identifying the depression/valley and direction of flow is contour study of the project road corridor and a site visit to study drainage pattern of the area. The ground level elevations along the toe of the road on upstream and downstream (L-Profile) should identify the natural dips and thus suitable culvert locations and direction of flow. It is mandatory to ensure a path for the runoff to reach the outfall point from culvert outlet either through existing channel or roadside ditches or by overland flow. Flow coming out of the culvert must not get accumulated at its outlet jeopardizing the safety of the road embankment. Downstream canalization, wherever feasible, may also be thought of to avoid such accumulation of water.

In order to reduce cost of drains and culverts, often the drain water is discharged into local ponds, causing pollution of pond water which may be objected by the local people. In such situations, the drainage water may be directed to ground water recharge pits and the effluent may be discharged into the ponds after appropriate treatment.

In the hilly terrains, culvert locations are identified directly from the presence of streamlets, not big enough to be spanned by a bridge. In the stretches where the road is planned by cutting hill slopes, innumerable streamlets come down the hill slopes and cross the proposed road. Runoff water and sediments from such streamlets must be disposed of either directly through culverts at the crossings and/or intercepted by longitudinal drains and disposed off in to the valley through closely spaced intermediate culverts with a view to limit the drain size.

Box or slab type culverts or small bridges are suitable for free movement of the incoming water when it carries a lot of sediments and debris. It is necessary that the span of culverts should be equal to or a little more than the linear waterway at design HFL for such streamlets flowing at supercritical velocity.

In the plains, however, the available longitudinal slope along the proposed alignment is generally very flat and roadside ditches are commonly aligned with available longitudinal slope for economy. If the existing dips are long apart, the distance between an existing dip and an adjacent ridge becomes too long entailing a bigger size of the ditch and acquisition of more land. In such cases, intermediate culverts, also called balancing culverts, are proposed just to reduce the length and size of the roadside ditches. In fact, most of the culverts in plains are balancing in nature. However, all natural dips may not be used as suitable culvert locations. It depends on the available longitudinal slope and consequently the required size of the roadside ditches that govern the locations to be utilized as suitable culvert points. If the available longitudinal slope is good enough to carry the roadside ditches for a longer distance with reasonable size, some intermediate minor dips may be crossed over without having to provide a culvert structure.

For roads planned alongside a major river (say Ganga/Yamuna Expressways), it is frequently observed that spill from the river originates from some upstream point, comes into the countryside and again goes back and meets the river at some downstream point. Each of these spills crosses the proposed road alignment (running almost parallel to river bank) at two or more points - one at upstream point where from the spill channel originates and comes to the countryside and the others at the downstream point where it goes back and meets the river again. It is a standard practice to plug the upstream crossing points and span the downstream crossing locations with suitable culvert or bridge structure, depending on the size of the spill. The countryside length of the spill channel, past the plugging point, shall carry the runoff from the local countryside catchment and the runoff must be disposed into the river through the downstream opening.

The proposed alignment of the new road may also cross some small size irrigation field channels and drains. These small sized canals and drains must be spanned by culverts/ syphons at their crossing points with the road.

For a road upgrading project, the task of selecting culvert locations reduces to selection of locations for additional culverts only. Even if the conveying capacity of some of the existing culverts is not hydraulically adequate, replacement of such culverts by a bigger size culvert or a small bridge shall be made in the existing locations only. For additional culverts, the locations shall be based on the natural dips along the stretches of existing road vulnerable to overtopping. An inventory of existing culverts has to be prepared indicating chainage, type and size of culverts, invert levels at entry and exit of culverts, ground level and stream bed level, condition of culverts, ponding level, submergence of land, overtopping of road and extent of overtopping etc. Such detailed inventory of culverts is very helpful in preparing an adequacy statement for cross-drainage works and deciding which of the existing culverts/ bridges require replacement by larger size culverts or bridges and to decide whether additional culverts will be needed or not.

9.3 Types and Size of Culverts

Culverts may be of several types and geometry, namely, Pipe Culverts (circular and elliptic), Box culverts (square and rectangular), Slab and Arch culverts (with or without bottom slab) etc. Selection of type and geometry of culverts inter-alia depends on the required width and area of opening, height and vertical clearance required, length of culvert and height of embankment decided from geometrics of road design. While it is easier to decide between a pipe culvert and box/slab culvert, selection between box and slab culvert is a matter of cost optimization. For minor crossings, circular hume pipe culverts suffice hydraulically. However, a pipe culvert has more joints owing to smaller length of precast pipe units manufactured in the market. The more the carriageway width of the road more will be the length of culvert and consequently more will be the number of joints. As such it has now become a common practice for the major concessionaires to avoid pipe culverts for new major projects like Ganga/Yamuna expressway. However, for many other new projects in India, hume pipes having minimum diameter of 1200 mm are being used.

For mountainous regions, the culverts are generally provided at frequent interval. Pipe culverts are, therefore, very common in hilly stretches of roads. However, in stretches where the streamlets carry large size cobbles and boulders, there is a fair possibility of pipes getting damaged/choked. Pipe culverts are, therefore, avoided in such stretches and either slab type or box type culverts are preferred. For crossings where pipe culverts may not be feasible from hydraulic point of view, box or slab culverts are chosen for installation. From structural definition, a box culvert is a reinforced box structure with rigid joints whereas a slab culvert is one where a simply supported reinforced slab is placed over abutments. Generally, for medium height of embankments, both of the options viz., box culverts with road embankment supported on roof slab and slab culvert with roof slab directly supporting the wheel loads, are feasible. One of the options is chosen on the basis of LTEC (Least Total Expected Cost) method. For high embankments (for example near approach of bridges), however, box culverts are preferred to slab culverts from both structural and economic considerations. Box and slab culverts are suitable for mountainous reaches where the streamlets carry large sized cobbles and boulders.

To avoid excessive scour in slab/Arch culverts, bed may be lined or unlined depending on flow velocity and type of bed materials. Lining of bed helps in preventing growth of weeds which drastically reduces the conveying capacity of culvert due to high resistance offered by such weeds and jungles.

The size of the culvert is designed on the basis of the following considerations from the points of view of:

a) Peak flow and hydraulic conveyance requirement

b) Ease of maintenance and desilting operation

c) Permissible velocity for fish movement where the channel carries fish

d) Movement of debris, gravels, boulders etc.

The required size of the culvert is decided on the basis of hydrologic, hydraulic and structural analysis. However, the minimum size of the culvert is fixed on the basis of ease in maintenance, movement of fish, debris etc. For upgrading projects, hume pipe culverts having diameter less than 900 mm are to be replaced with a minimum diameter 1200 mm as recommended by IRC:SP:13.

9.4 Data Collection

Data may be collected from site investigation/study of topo sheets/Satellite Imagery/local enquiry and from records maintained by Government agencies like CWC, IMD, RDSO and Irrigation/PWDs. Broadly, the several data required for the design of drainage culverts are:

- Topographic maps showing contours, nature and slope of terrain, soil and cover conditions, physical features in the vicinity of the proposed culverts etc.
- Existing stream and canal network in the project area crossing the road indicating direction of flow and the drainage area contributing flow to the culverts.
- Stream data e.g. L-section and cross-sections of the stream upstream and downstream of the point of crossing, gauge-discharge data, HFL from flood marks and local enquiry.
- Soil and sub-soil data for computation of runoff from the drainage basins
- Hydro-meteorological data like amount, intensity, duration and frequency of rainfall
- Roadway alignment, L-section and cross-sections of the road near the cross-drainage sites
- Fish passage requirement, if any
- Debris and sediments to be passed through the culverts
- Points of flow accumulation and areas of prolonged submergence, if any
- Nearest human habitation/property, places of worship, places of strategic importance etc.
- In case the proposed alignment runs parallel to any existing major road, it is very helpful to study the drainage particulars and performance of culverts on the existing road to have an idea about the required numbers and size of culverts for the proposed road from the drainage efficiency of the existing road.
- Information regarding likely damage to habitats, crops etc. due to ponding upstream
- Maximum permissible velocity at the outlets of culvert to determine nature of protective works to be adopted.

Most of the above data are available from topo sheets and satellite imageries as well as survey data collected from field and from local enquiry. Flood estimation reports published by Central Water Commission (CWC), Govt. of India and flood estimation methods published by RDSO (1990), Ministry of Railways, Govt. of India, provide valuable hydro-meteorological data for different regions of India.

In case of road up-gradation schemes, the following additional data are to be collected during road survey :

- Inventory and condition survey of the existing culverts indicating size, shape, slope, invert levels, siltation (choking), sediments and debris carried by the stream.

- Maximum Pond level and damages upstream and downstream, if any
- Scour and protective measures adopted
- A separate inventory of culverts/syphons carrying irrigation supply and details of irrigation/drainage canals e.g. bed width, FSL, side slope, bank level, ground level etc.
- Stretches of roads where overtopping of flood water takes place during flood season, maximum depth of such overtopping water and its location

Further details about hydrologic and hydraulic design of culverts and bridges are available in IRC:SP:13 and IRC:5, IRC:78 and IRC Hand book, 2000 (Pocket Book for Bridge Engineers).

Computations for design discharges for culverts by using SCS method by USGC is given in example 4 in **Annexure V**.

9.5 Bridge Drainage

Bridge drainage is important from two aspects, first is drainage and other is road safety. It is important to provide the effective drainage of runoff on bridges to avoid flooding of deck, which may leads to traffic safety hazards and can severely limit the life span of concrete deck. The uncontrolled flows of water, will lead to corrosion of concrete and steel surfaces below deck level.

Considering drainage aspect, it is enough if all the water that is precipitated on the bridge in design rainfall is drained away quickly without allowing the traffic to stop. Particularly if the bridge is located in a valley curve or in a valley on the road, the surface water from the adjoining stretches of road are likely to flow to it and cause ponding which may stop the traffic at least for a short duration

9.6 Design Consideration

The drainage system for bridges are design as Open Drainage system, i.e. allowing the free fall of water when bridges pass through the water way i.e. River, Creek, Nallah etc. and Closed drainage system in which proper channelized Pipe conduit system are provided to take the water to main drain applicable for Grade separator, side walk and rail road right of way beneath the bridges. Designer shall suitably select the appropriate drainage system based on the project characteristics.

The design of a drain should be such that its inlet is large enough to admit lot of water easily. It is to be remembered that due to the grill on top, the effective area of inlet is reduced to half. Moreover the velocity of water entering the drain is low. Hence the opening should be flared to at least twice the size of the pipe. The type design of the MORTH in which the opening at top is 30 cm X 30 cm for a 15 cm dia drain is good from this angle (**Figs. 9.1 to 9.3**).

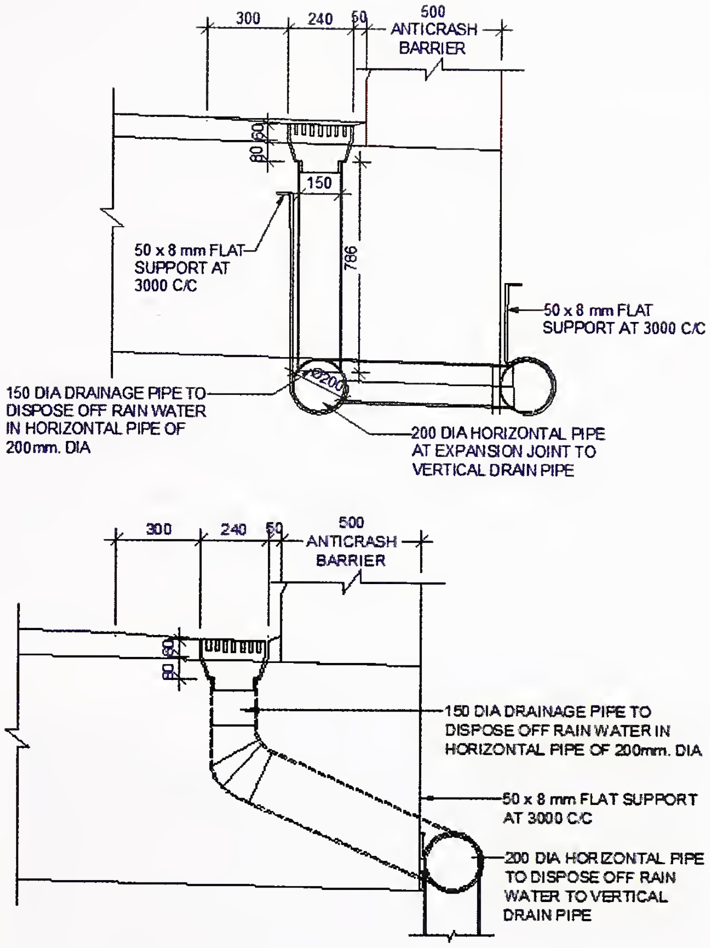
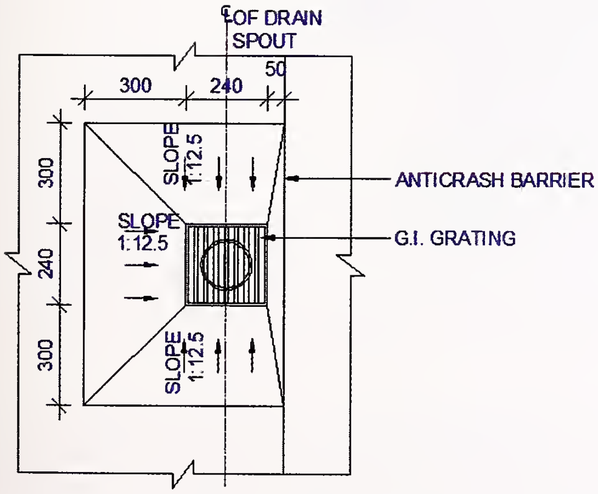


Fig. 9.1 Cross-Section of Drainage Spout



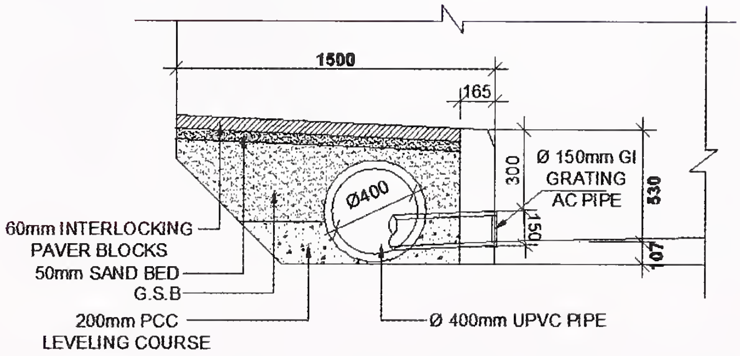


Fig. 9.2 Plan Showing the Drainage Spout

Fig. 9.3 Details of Footpath Drain

In case of wider bridges the numbers of drainage spouts will have to be increased to match the increased area to be drained. In very wide bridges of 4x4 divided carriageways with a central divider, it may be better to provide a crown in each carriageway and camber in both direction and then to provide drainage spouts along both edges of each carriageway.

Deck Slab Drainage Inlet : To ensure effective drainage of the bridge deck a minimum cross slope of 1 percent and a minimum longitudinal grade of 0.5 percent should be provided with a gutters grading at 1 percent. The collected runoff water shall be taken by pipes through the deck at regular interval. Grating the inlet points are necessary aids for achieving the efficient drainage.

Drainage is especially important in the case of earth-filled arch spans and obligatory span as inadequate drainage would saturate the earth filling and decrease the load bearing capacity of the structure. Special drains will also be necessary at natural low spots of piers of arch bridges to tap accumulated water and allow it to flow out.

9.7 Sloping Ramps of Bridges and Flyovers

In case of sloping ramps of bridges or flyovers, it is often said that due to the steep longitudinal slope, it is no use providing drainage spouts on the ramps, which creates pool of water at the start of bridge approach. Considering the situation such as, a driver of a smaller car trying to go up an approach ramp of a flyover or bridge in heavy rains faces a daunting situation with a heavy stream of rainwater rushing towards him through which he has to drive his car. An example of this is shown in **Photo 9.1**. So whatever 10 or 20 percent water that can be taken out by drains on sides will be a big help.

Photo 9.1 Pool of Water at the Start of Bridge Approach

In case of curved bridges (and roads too) due to super elevation, water tends to accumulate near the central median, forming a small pond. A fast vehicle coming round the bend suddenly sees the pond. Then either there will be a big splash or the vehicle will swerve suddenly to avoid the pond. These possibilities both create an accident situation. Cross drains provided at the valley curve covered with robust steel grating will help in disposing of surface water.

9.8 Spacing of Drainage Spout

In the olden days the standard practice was to provide drainage spouts at a spacing of 3 m on both edges of a two lane bridge. But the inlets were of the same diameter as the drain pipes. Some of these used to get choked due to debris or garbage fully or partly. Sometimes during renewal of road surface, some of them used to get closed also. Design must cater to all such contingencies. The drain openings should be in the deck slab. In case of submersible bridges the discontinuous kerb provides ample drainage facilities.

In a segmental construction, it is easier to provide a drain hole in each segment instead of providing the drains at odd spacing which will result in some of the segments with drain holes and some without drains. Hence it is suggested to provide the drain hole in each segment.

9.9 Disposal of Drain Water

The water coming out of the spout can fall into the river or creek below. But the outlet should be shaped so that it does not fall on the superstructure. It could be pointed away from the bridge. There was a trend to provide long down take pipes to ensure that the water discharged does not splash on to sides of main beams. But when it is raining heavily the entire surroundings are wet and moist. Hence long down take pipes are not favoured.

In case of a flyover or approach viaduct of a bridge or flyover, if there is movement or existence of other traffic or people below on at grade roads, the water coming out of drainage spouts must be collected and led away. Such a collector system must be of large diameter, there must be enough elbow plugs provided to facilitate frequent cleaning to prevent clogging. The down take pipe if taken through the body of the solid pier (**Photo 9.2**) must be large enough to avoid choking. Ultimately the water must be led to the city drainage system. Anti-theft measures must be in place to prevent vandalism or thefts of pipes. Small things but they can be very damaging if not corrected.

Photo 9.2 Water Channelization

9.10 Maintenance of Drainage System

It is very important to maintain the drainage system in good working order. This mainly consists of looking at all the drainage inlets frequently to see that they are not choked or clogged. The elbow plugs must be opened and the pipes cleared of any material like paper, plastic etc. which might have got lodged in the pipes. Any piece of pipe which might have got damaged or taken away must be replaced forthwith. This aspect must be checked during the pre-monsoon inspection of bridge structures and corrected wherever necessary.

The cost of drainage spouts as compared to that of the bridge is minuscule. The public judges the work not by the strength of concrete but by the alignment of parapet, the condition of road surface, the expansion joints and the efficiency of drainage system. Hence it is not prudent to try to economize on it at the cost of a water free bridge.

10 GROUND WATER RECHARGE FROM ROAD DRAINAGE

10.1 Introduction

The annual precipitation (including snowfall) in India is of the order of 4000 BCM and the natural runoff in the rivers is computed to be about 1869 BCM. The utilizable surface water and replenish able ground water resources are of the order of 690 BCM and 433 BCM respectively. Thus, the total water resources available for various uses, on an annual average basis, are of the order of 1123 BCM. Although the per capita availability of water in India is about 1300 cubic meters as in 2012 against the benchmark value of 1000 cum (signifying 'water-starved' condition), there is wide disparity in basin-wise water availability due to uneven rainfall and varying population density in the country. The availability is as high as 14,057 cum per capita in Brahmaputra/Barak Basin and as low as 307 cum in Sabarmati basin. Many other basins like Mahi, Tapi, Pennar are already water stressed.

Indiscriminate ground water development has led to substantial ground water level declines both in hard rocks and alluvial areas threatening sustainability of this resource. Long-term decline of ground water tables is being observed in many areas, mostly in the states of Rajasthan, Gujarat, Tamil Nadu, Punjab, Delhi and Haryana. Apart from this, in most of the cities depending on ground water for drinking water supplies, water level decline up to 30 m and more have been observed. Traditional water harvesting methods, which were in vogue in arid and semi-arid areas of the country have either been abandoned or have become defunct in most cases. There is an urgent need to revive these methods.

Excessive ground water development/use has resulted in deterioration of ground water quality through salinity and other salt contamination e.g. arsenic/iron/fluoride/boron etc. and saline water ingress in coastal areas. Ground water development, therefore, needs to be regulated and augmented through suitable measures to provide sustainability and protection. Dependence on use of ground water for agriculture due to monsoon failures is accelerating ground water depletion in rural areas also. Excessive withdrawal of ground water is further compounding the stress on ground water system due to free/subsidized power in some states. In order to tackle the burgeoning problem of water table decline and depletion of ground water storage, it is necessary to take up schemes for water conservation and artificial recharge to ground water on priority basis.

Ground water resources in several areas of the country are getting polluted due to over application of fertilizers and pesticides, indiscriminate disposal of effluents from industries and urban sewerage. Surveillance studies to determine the type and migration of pollution and measures for its control have become an absolute necessity from the point of view of long-term sustainability of ground water resources. Dilution of pollutant concentration through ground water recharge can be one of the effective ways to mitigate the hazards of high concentration of these constituents. It is also desirable that rural water supply schemes be formulated and arrangements made to utilize fluoride/arsenic rich water for purposes other than drinking.

Change in highway practice to take the soil of desired strength from other places leaves no scope to have local natural ditches by road sides augmenting ground water recharge. It is essential and will most certainly be encouraging to use storm water drain outflow that is free from pollution to pass through a series of artificial recharge pits/wells by the road sides or at other suitable places through a network of tertiary, secondary and primary drains.

There are several urban areas in the country where water supply systems are based mainly on ground water resource. Sustainability of urban water supply is one of the core issues the planners across the country are facing at present. The problem may get aggravated in near future with the rapid pace of urbanization being witnessed in India. Potable drinking water is an important input for providing municipal supply to the urban complexes. Due to steep increase in population, the stress on ground water system has increased tremendously resulting in steep water level declines in and around these cities. These problems could be solved to some extent by

i) Rain Water Harvesting - The principle of "catch rain water where it falls".

ii) Shifting of ground water pumpage from the center of the cities to the floodplain areas having proven capabilities of sustaining high yielding tube wells wherever possible,

iii) Recycling and reuse of water,

iv) Dual water supply/disposal systems for drinking, domestic and sewage water,

v) Roof top and road top Rain Water Harvesting(RWH) and

vi) Regulatory measures through proper pricing and metering of water supplied.

10.2 Storm Water Management & Benefits of Ground Water Recharge

The storm water during rainy season causes drainage problem and often roads are damaged by rainfall runoff. This problem is serious in big cities and industries, where most of the open area is covered by roads or some concrete structures without proper drainage. The water on roads during rains remains stagnant for hours together due to poor storm water management and results into damage of roads. In our country, industries and cities are facing water crises due to over exploitation of ground water and no provision for recharge of aquifers. Declining water tables are also responsible for consumption of more energy in lifting the water and reduction in green coverage.

Solution of managing storm water on roads in urban and industrial areas lies in channelizing the surface runoff to ground water system in a hygienic manner. This method not only helps in controlling the devastating effects of storm water, but also improve ground water regime both in terms of rising of water table and increase in ground water availability. The techniques will also increase life of roads and reduce cost on maintenance and repairs. Besides, better plant growth is envisaged with less water requirement due to moist condition of surface soil through percolation structures. The following benefits can be accrued due to ground water recharge:

- Reduction in runoff which chokes storm drains.
- No flooding of roads and increase in life of roads.
- Augmentation of ground water storage and control of decline of water levels.
- Improvement of quality of ground water.
- Reduction of soil erosion.
- Surviving water requirement during summer in cities and industrial areas.
- Increase in plantation, and maintaining eco-balance

In designing ground water recharging system, capturing rainfall runoff from the roads and creating artificial connectivity to sub-surface water in a hygienic manner is the key concept.

The effectiveness of the concept lies in reasonable cost, coverage of large areas and immediate implementation, reducing the cost of maintenance and repairs of roads and many fold increase in life of road. Storm water harvesting from drainage along both the sides of roads with the help of suitable, simple structures, would not only control storm water hazards in cities, but will enhance ground water availability 8 to 10 times more compared to natural process of rainfall infiltration. The location and design of sustainable ground water recharging system require hydro geological study of the area as well as sub surface investigation of most permeable zone. Besides, average rainfall and rainfall intensity need to be analysed as per climatic zones. Based on normal rainfall and peak rainfall intensity, the ground water recharging system is designed in such a way that 70-80 % runoff of roads and paved area is sent back to ground water regime after natural filtration process based on rate of recharge. Recharge test on existing wells/pits must be carried out before the commencement of project.

10.3 Artificial Recharge of Ground Water

The term artificial recharge has different connotations for various practitioners. Artificial recharge of ground water is defined as the recharge that occurs when the natural pattern of recharge is deliberately modified to increase recharge rate. The process of recharge itself is not artificial. The same physical laws govern recharge, whether it occurs under natural or artificial conditions. What is artificial is the availability of water supply at a particular location and a particular time. In the broadest sense, one can define artificial recharge as "any procedure, which introduces water in a pervious stratum". The term artificial recharge refers to transfer of surface water to the aquifer by human interference. The natural process of recharging the aquifers is accelerated through percolation of stored or flowing surface water, which otherwise does not percolate into the aquifers. Artificial recharge is also defined as the process by which ground water is augmented at a rate exceeding that under natural condition of replenishment.

Therefore, any man-made facility that adds water to an aquifer may be considered as artificial recharge.

Artificial recharge can also be defined as a process of induced replenishment of the ground water reservoir by human activities. The process of supplementing may be either planned such as storing water in pits, tanks etc. for feeding the aquifer or unplanned and incidental to human activities like applied irrigation, leakages from pipes etc.

10.3.1 *Need for artificial recharge*

Occurrence of rainfall in India is mostly limited to about three months in a year. The natural recharge to ground water reservoir is restricted to this period only in a major part of the country. Artificial recharge techniques aim at extending the recharge period in the post-monsoon season for about three or more months, resulting in enhanced sustainability of ground water sources during the lean season.

In arid regions of the country, rainfall varies between 150 and 600 mm/year with less than 10 rainy days. A major part of the precipitation is received in 3 to 5 major storms lasting only a few hours. The rates of potential evapo-transpiration (PET) are exceptionally high in these areas, often ranging from 300 to 1300 mm. In such cases, the average annual PET is much higher than the rainfall and the annual water resource planning has to be done by conserving the rainfall, by storing the available water either in surface or in sub-surface reservoirs. In areas where climatic conditions are not favourable for creating surface storage, artificial recharge techniques have to be adopted for diverting most of the surface storage to the ground water reservoirs within the shortest possible time.

In hilly areas, even though the rainfall is comparatively high, scarcity of water is often felt in the post-monsoon season, as most of the water available is lost as surface runoff. Springs, the major source of water in such terrains, are also depleted during the post monsoon period. In such areas, rainwater harnessing and small surface storages at strategic locations in the recharge areas of the springs can provide sustainable yields to the springs as well as enhance the recharge during and after rainy season.

10.3.2 *Purposes and principles of artificial recharge*

From the point of view of artificially storing water for future use, the basic requirement is to be able to obtain water in adequate amounts and at the proper times in order to accomplish this goal. Some schemes involve the impoundment of local storm runoff, which is collected in ditches, basins or behind dams, after which it is placed into the ground. In other localities, water is sometimes brought into the region by pipeline or aqueduct. In the latter case, the water is an import and represents an addition to whatever natural water resources occur in the region. Another approach is to treat and reclaim used water being discharged from sewer systems or industrial establishments.

In certain coastal areas of the world, artificial recharge systems for blocking inland encroachment of seawater are in operation. Most of these schemes rely on the injection of fresh water through wells in order to build up a pressure barrier that will retard or reverse encroachment of salt water resulting from excessive withdrawals from the wells. In such schemes, most of the injected water is not directly available for use, but serves as a hydraulic mechanism to allow better use of existing ground water reserves.

10.3.3 *Advantages of artificial recharge*

Following are the main advantages of artificially recharging the ground water aquifers:

- No large storage structures needed to store water. Structures required are small and cost-effective
- Enhance the dependable yield of wells and hand pumps
- Negligible losses as compared to losses in surface storages
- Improved water quality due to dilution of harmful chemicals/salts
- No adverse effects like inundation of large surface areas and loss of crops
- No displacement of local population
- Reduction in cost of energy for lifting water especially where fall in ground water table is substantial
- Utilizes the surplus surface runoff which otherwise drains off
- Subsurface storage space is available free of cost
- It has no adverse social impacts such as displacement of population, loss of scarce agricultural land etc.
- Water stored underground is relatively immune to natural and man-made catastrophes

10.3.4 *Sources of water for ground water recharge*

Before undertaking a recharge scheme, it is important to first assess the availability of adequate water for recharge. Following are the main sources, which need to be identified and assessed for adequacy:

- Precipitation over the demarcated areas e.g. roads, buildings, playground, parks etc.
- Large roof areas from where rainwater can be collected and diverted for recharge
- Streams/nallas/canals from which surplus water can be diverted for recharge, without violating the rights of other users
- Properly treated municipal and industrial wastewaters. This water should be used only after ascertaining its quality and treatment, if necessary assessment of the available sources of water would require consideration of the following factors:
- Available quantity of water
- Time for which the water would be available
- Quality of water and the pre-treatment required

- Conveyance system required to bring the water to the recharge site
- Capacity of aquifers in which water is to be recharged

10.4 Data Collection

For successful implementation of ground water recharging projects, several scientific inputs are needed. Some of the principal data required are:

i) Survey data showing topographic features including storm drains, and defunct wells

ii) Climatic data like temperature, humidity etc.

iii) Hydrological data like rainfall, runoff, flood, and drought

iv) Soil and Sub-soil data like type of soil, porosity, infiltration rate

v) Hydro-geological data like depth of water table and characteristics of aquifer

vi) Estimation of sub-surface storage capacity of the aquifers and quantification of water required for recharge

vii) Land use and land classification

10.5 Various Considerations for Ground Water Recharge Projects

10.5.1 *General considerations*

i) Water availability

ii) Favourable Topographic, Physiographic and Hydrogeological set up

iii) Infiltration and percolation characteristics of vadose zone

iv) Hydrologic characteristics of the aquifers such as capacity to store transmit and yield water

v) Technical feasibility

vi) Economic viability

10.5.2 *General recharge methods/structures*

Type of recharge system to be adopted is site specific and depends largely on depth of aquifers.

As illustrated in **Fig. 10.1** the various methods of recharging are:

i) Water Spreading by Nala bunding, Contour bunding, Check dams etc.

ii) Percolation tanks

iii) Trenches/Contour trenching

iv) Pits and Shafts

v) Groundwater dams

vi) Induced recharge by Pumping

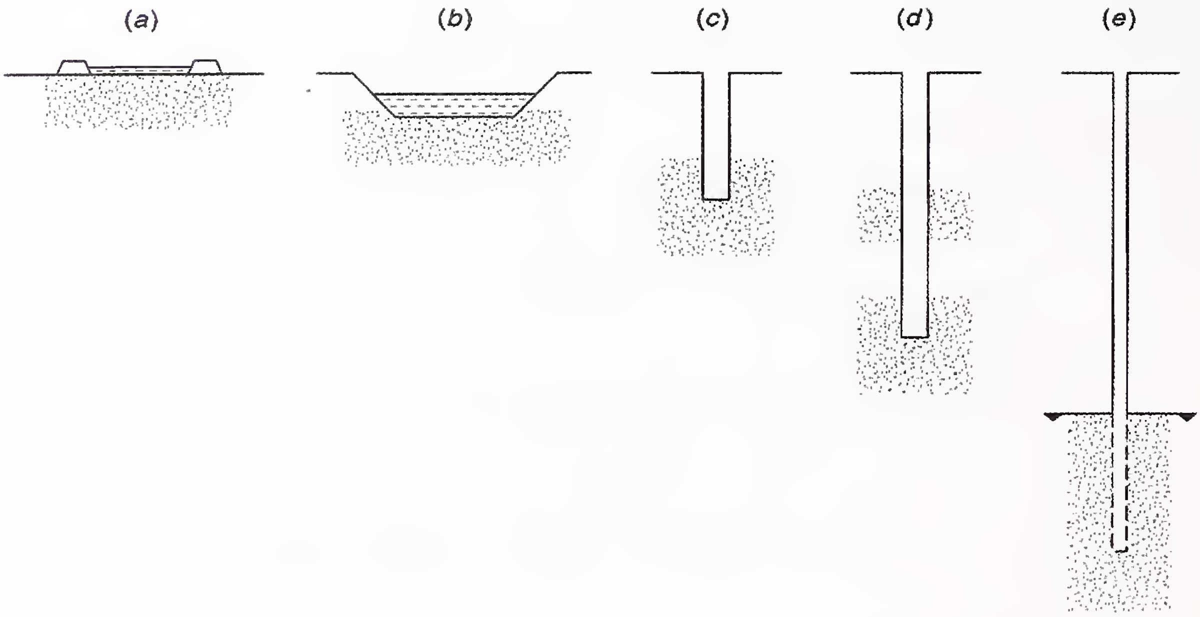


Fig. 10.1 Showing Recharges Systems for Increasingly Deep Permeable Materials (a) Surface Basin, (b) Excavated Basin, (c) Trench, (d) Shaft or Vadose Zone Well and (e) Confined Aquifer Well

General suitability of recharge methods

Lithology	Topography	Type of Structures Feasible
Alluvial or rock up to 40 m depth	Plain Area or gently undulating area	Spreading Pond, Ground water Dams, Irrigation tanks, check dams, Percolation tanks, Unlined canal system
Hard Rock down up to 40 m depth	Valley Slopes	contour bunds, percolation trenches
Hard Rocks	Plateau regions	Recharge Ponds
Alluvial or hard with confined aquifer(40 m depth)	Plain area or gently undulating area	Injection Wells, Collecting Wells
-Do-	Flood Plain Deposits	-Do-
Hard Rock	Foot Hill Zones	Farm Ponds, Recharge Trenches
Hard Rock or Alluvium	Forested Area	Ground Water Dams

10.6 Ground Water Recharge Test

The design of recharging is based on average annual rainfall and its intensity and the intake capacity of the water by the first aquifer. In order to determine intake capacity of water by the aquifer, recharge test is to be carried out on an existing bore well/open well. In this test, water at varying rate is injected till there is spillover. For example - at an injection rate of 500 liters in 3 min, water column developed is recorded. The rate of dissemination of water column periodically measured till original static water level is reached are found to be (**Table 10.1**).

Table 10.1 Record of Water Level Dissemination in an Open Well

Time in min. (t)	Water Level in Meters (h)	Head in Meters
4	6.12	0.08
5	6.14	0.06
6	6.16	0.04
7	6.17	0.03
8	6.18	0.02
9	6.2	0

10.6.1 *Recharge test record*

Static water level without injection = 6.20 m
Vol. of water injected = 500 liters (in 3 min.)
Initial water column observed = 5.21 m
Diameter of Well = 15 cm
Depth of well = 30 m
Total water dissemination period = 7 min.

Rate of water intake works out to be 0.055 m^3/min. i.e. 3.3 m^3/hour.

Therefore, the individual design can be made for accumulation of 79 m^3 of water & hence the dimensional parameter of each structure is kept as 5 m (length) x 5 m (width) x 3.25 m (depth) with 8” dia injection well/recharge shaft.

10.6.2 *Approximate values of infiltration rate for different types of soils*

For preliminary estimation of infiltration approximate infiltration rates without clogging effect for different types of soils may be taken as follows:

Type of Soil	Infiltration Rate in m/day
Clay	0.1
Loam	0.2
Sandy Loam	0.3
Loamy Sand	0.5
Fine Sand	1.0
Medium Sand	5.0
Coarse Sand	>10

10.7 Storm Water Harvesting Methods

10.7.1 *Drain water collection from road*

Storm water harvesting methods from road side drains will vary from place to place. A typical device of storm water collection from road side drain is illustrated in **Fig. 10.2**.

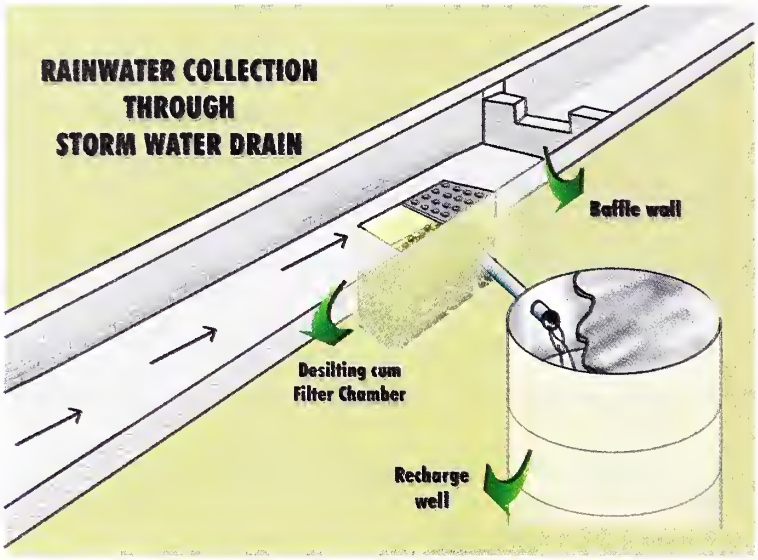


Fig. 10.2 Showing Water Collection from Storm Water Drain

Various cases of storm water harvesting from road side drains are briefly discussed below.

10.7.2 *Case-1: The area with soil/weathered rock having vertical permeability up to water level zone (Fig. 10.3)*

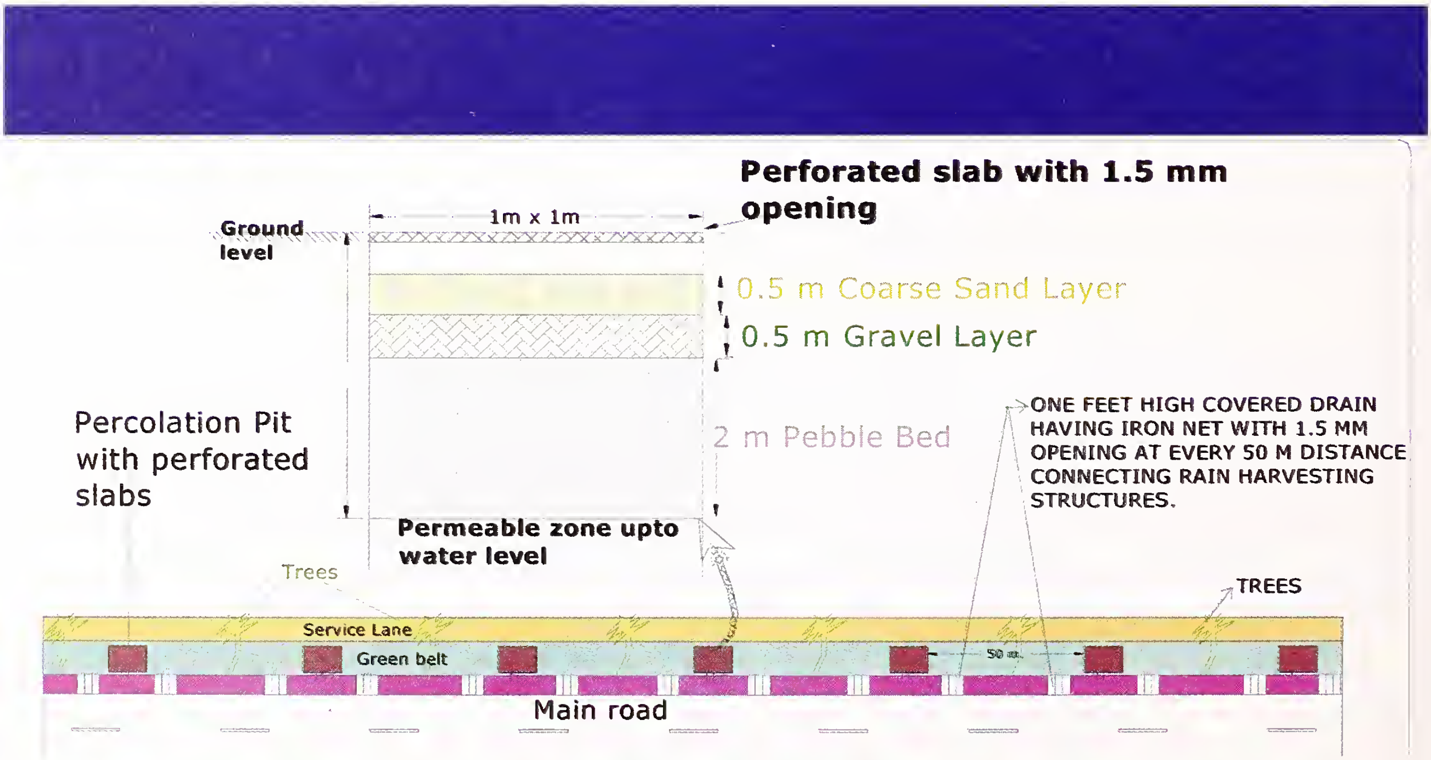


Fig. 10.3 Showing Recharge of Storm Water from Road-Case-1

In this kind of situation, the percolation pit method would be suitable. In this method, the pits of suitable dimensions can be made along the roads between side lanes and main road. These pits may be made along both sides of the road at suitable interval based on estimated runoff. The pits should have natural filtration media of coarse sand, gravels and pebbles and should be covered with perforated slabs as shown in **Fig. 10.3**. The road should have 1 degree slopes towards these pits from the divider.

10.7.3 *Case-2: The area having impermeable zones prior to water table, like clays, solid rocks etc. and having relatively clean catchment (Fig. 10.4)*

In this type of areas, the rainwater harvesting system will have recharge shaft via storage tanks and filtration tanks reaching 10 to 15 meters above water level. The design is self-explanatory as per **Fig. 10.4**. Here, water is diverted to ground water reservoir through recharge shaft via filtration media crossing the impermeable zone.

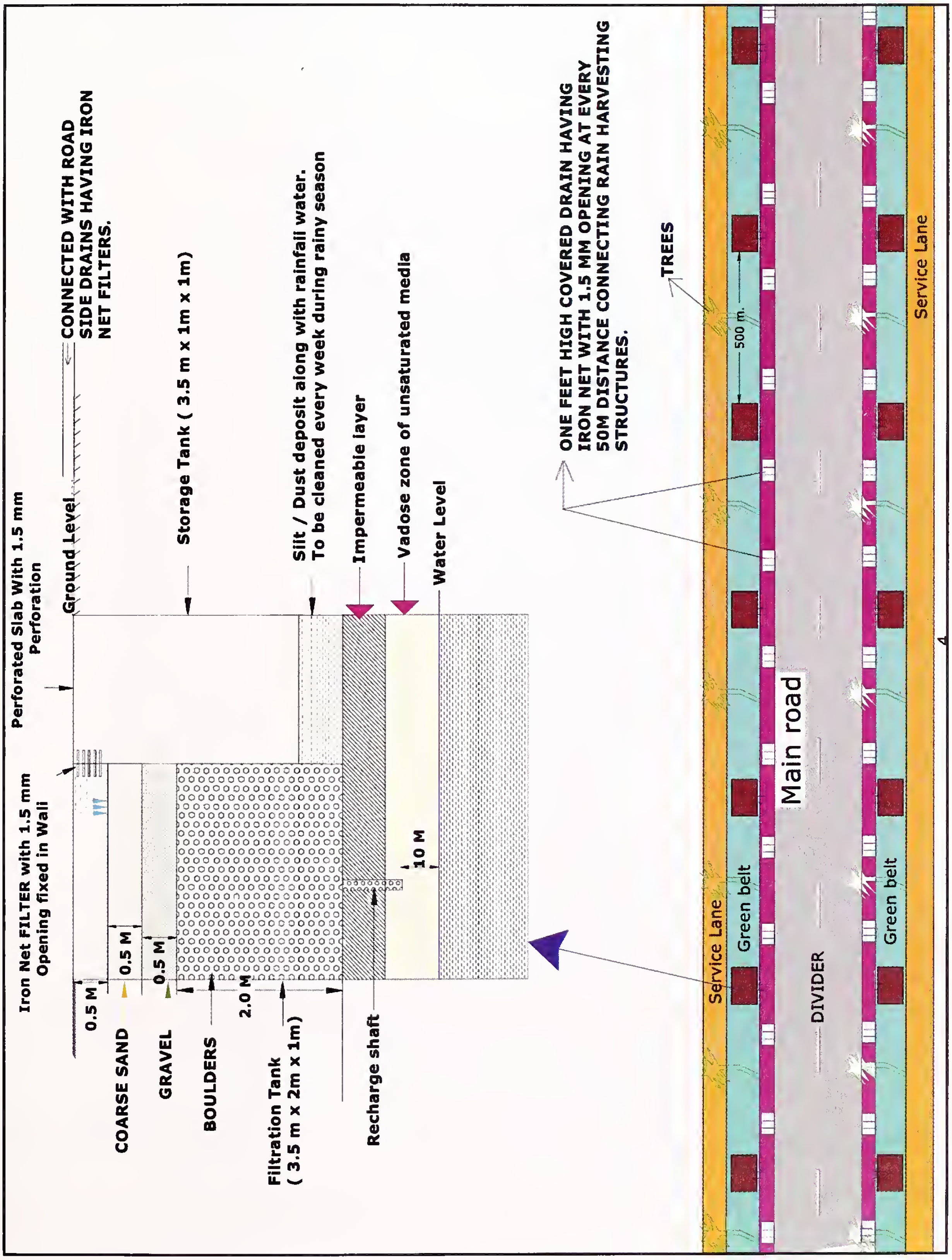


Fig. 10.4 Showing Recharge of Storm Water from Road-Case-2

10.7.4 *Case-3: Artificial recharge reservoir (Fig. 10.5)*

The storm water generated in cities & industries with large catchment can be diverted to scientifically design artificial pools based on runoff generated at peak rainfall intensity and recharge potential of sub-surface strata as shown in **Fig. 10.5**.

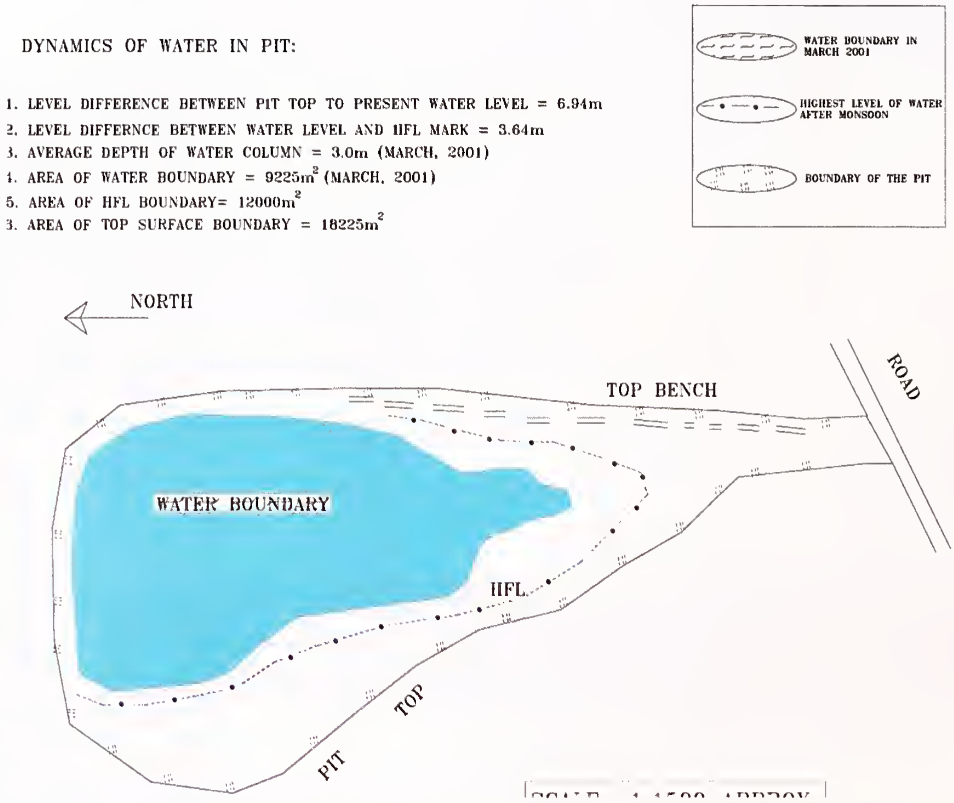


Fig. 10.5 Showing Recharge from Pools by Diversion of Flood Water from Road - Case-3

10.7.5 *Case-4: Artificial recharge tube well*

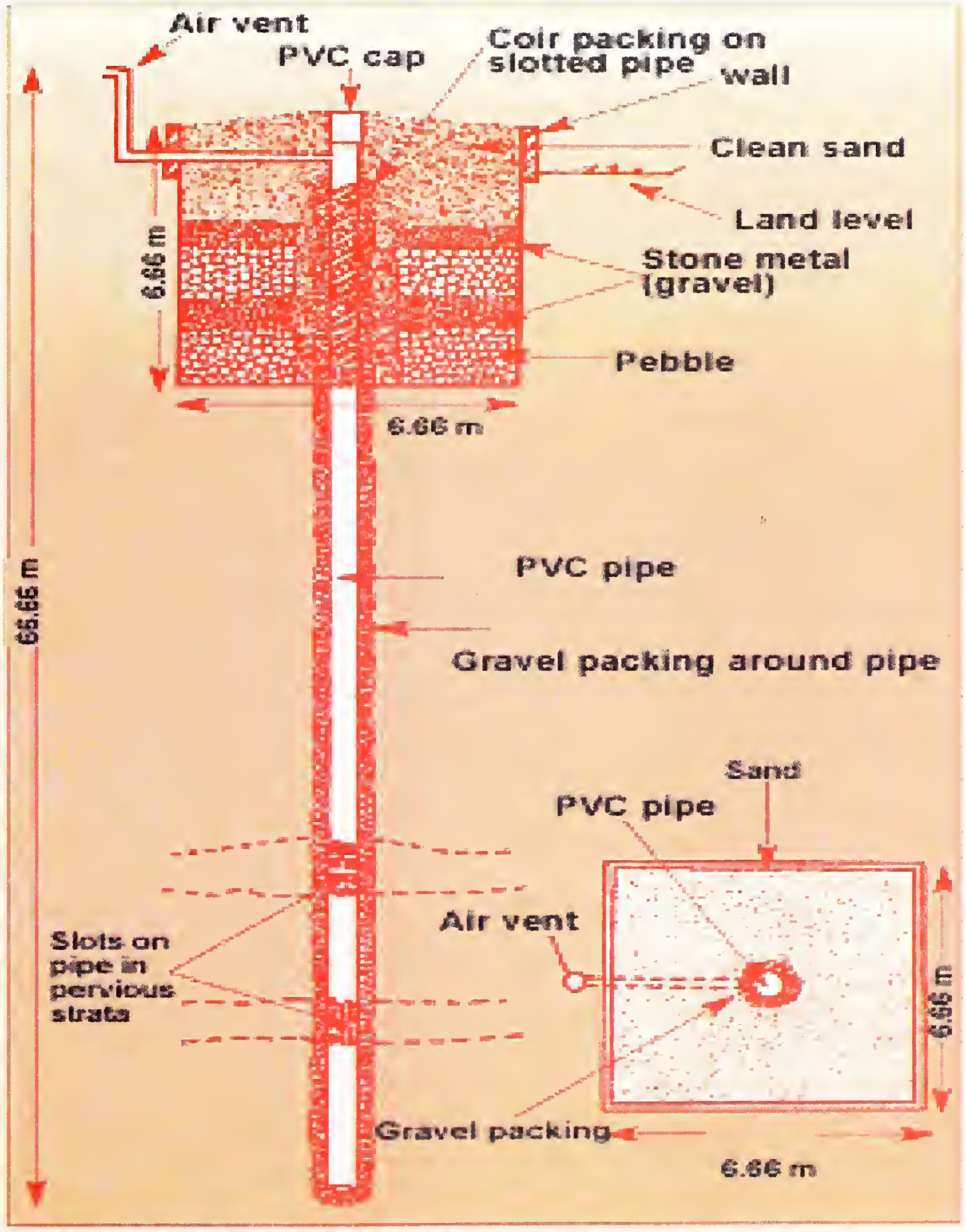
In case of higher infiltration capacity of vadose & unsaturated zone, percolation pits with recharge shaft/Tube well can be planned for increased recharge from surface water storage as shown in **Fig. 10.6**.

10.8 Quality of Recharging Water

RWH mainly has 3 Cs: 1st C is for collection, 2nd C is to make it clean and the last C is termed as charging. However, one of the most important criteria for selection of source is the quality of recharging water. The physical, chemical and biological quality of the recharge water affects the planning and selection of recharge method. Physical quality of recharge water refers to the type and amount of suspended solids, temperature, and the amount of entrapped air whereas chemical quality refers to type and concentration of dissolved solids and gases. Biological quality refers to type and concentration of living organisms e.g. bacteria.

Polluted water either by sewage or industrial effluents can be used only after required treatment. Growth of algae and bacteria during recharge can cause clogging of infiltration surfaces which will reduce the efficiency of the recharged system and may lead to the production of gases that further hinder recharge rate. Although surface spreading removes most bacteria and algae by filtration before the recharge water reaches the aquifer, surface clogging can reduce the infiltration rate considerably. Injection of water containing bacteria and algae through wells is generally not recommended because it causes clogging of well screens or aquifer materials, which is difficult and costly to remedy. A typical recharge tank with desilting device is shown in **Fig. 10.7**.

Recharging tubewell
A design for rapid recharge



Note: PVC: Polyvinyl Chloride m: metres
Source: Making water everybody's business. Page no. 252

Fig. 10.6 Showing Recharge Through Tube Well by Diversion of Road Water - Case-4

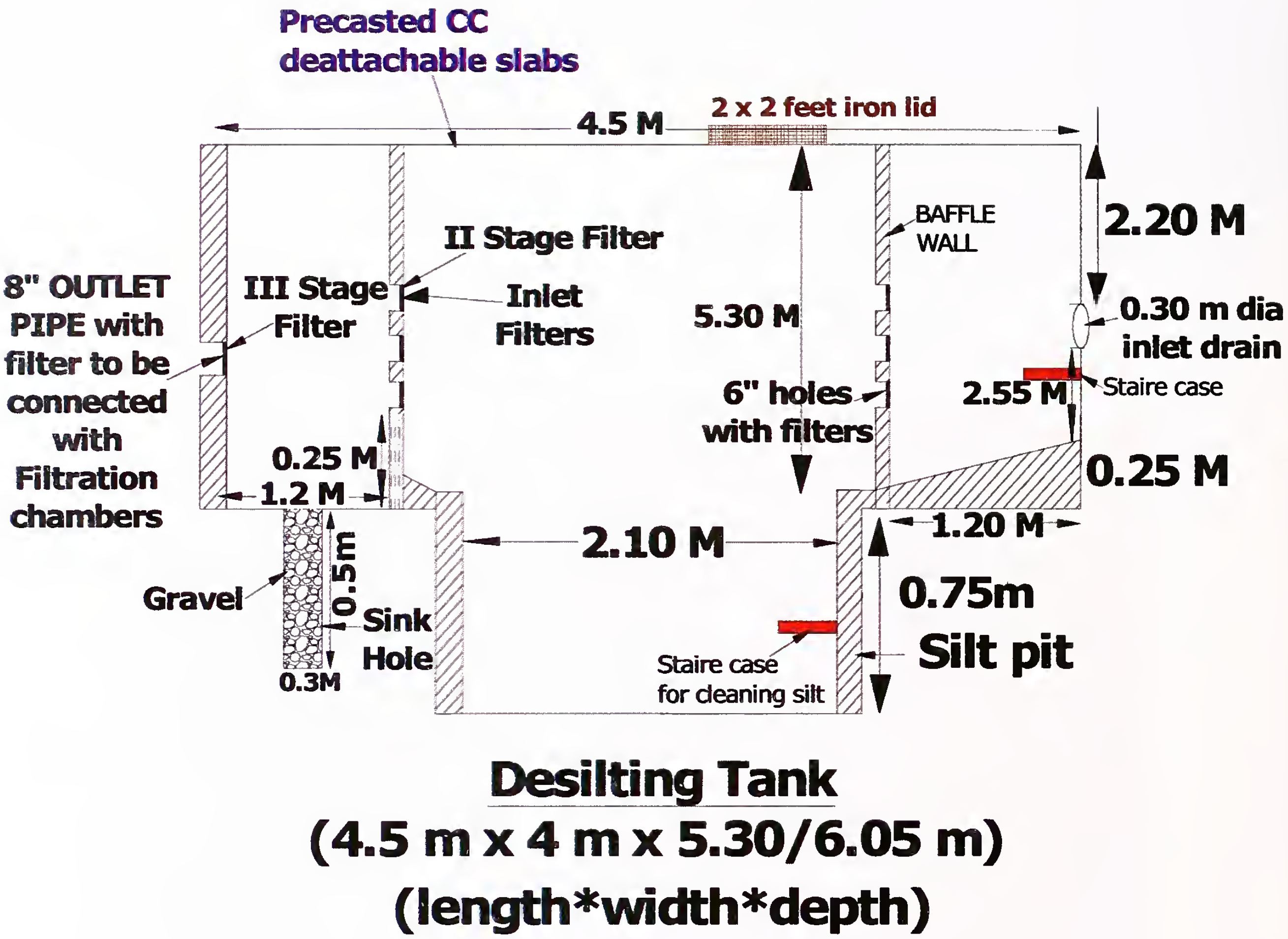


Fig. 10.7 Recharging Tank with Desilting Arrangement

Annexure I

(Refer Clause 6.3.1)

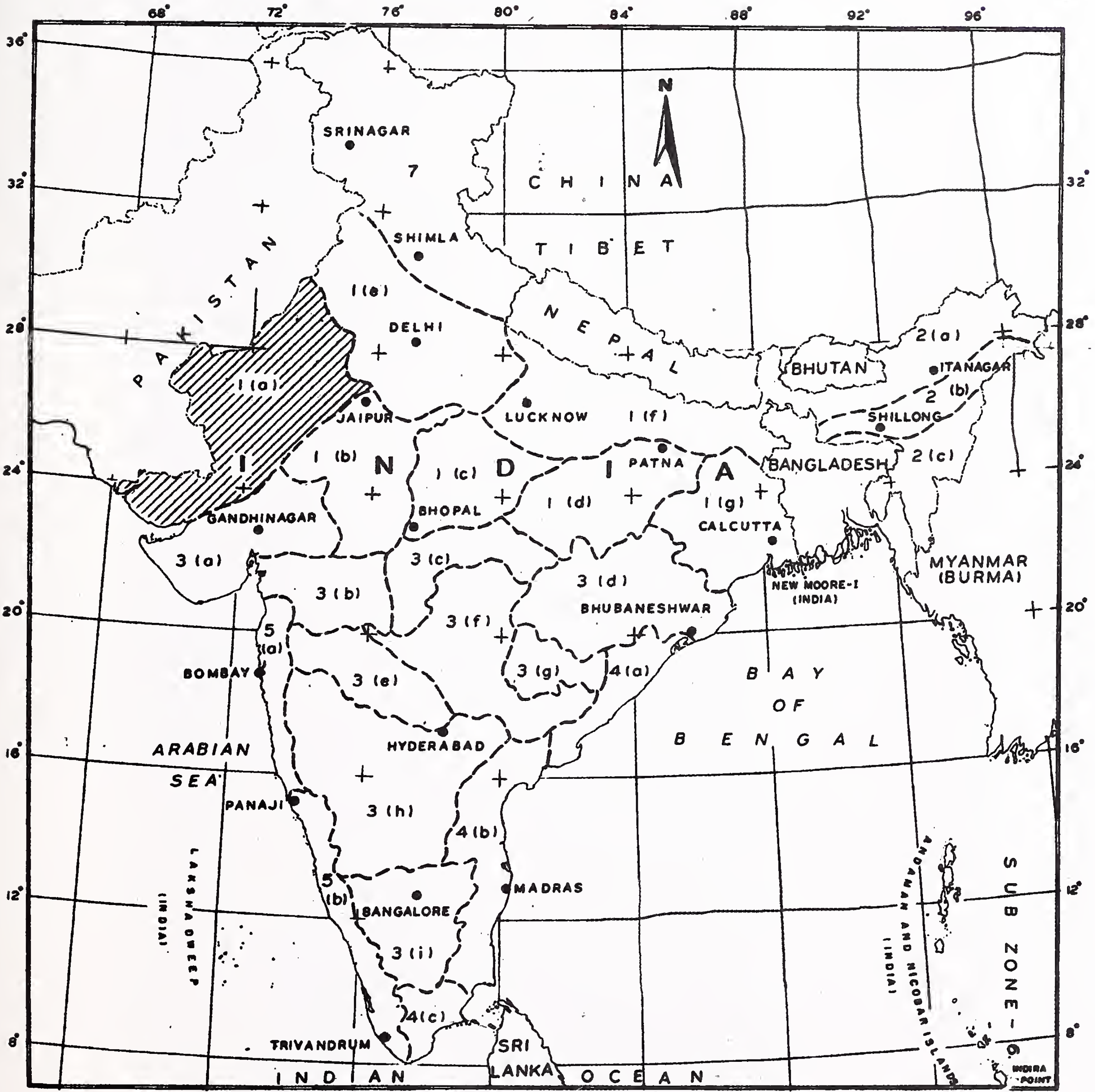


Fig. I.1 Map of India Showing Sub-Zones and State Boundaries

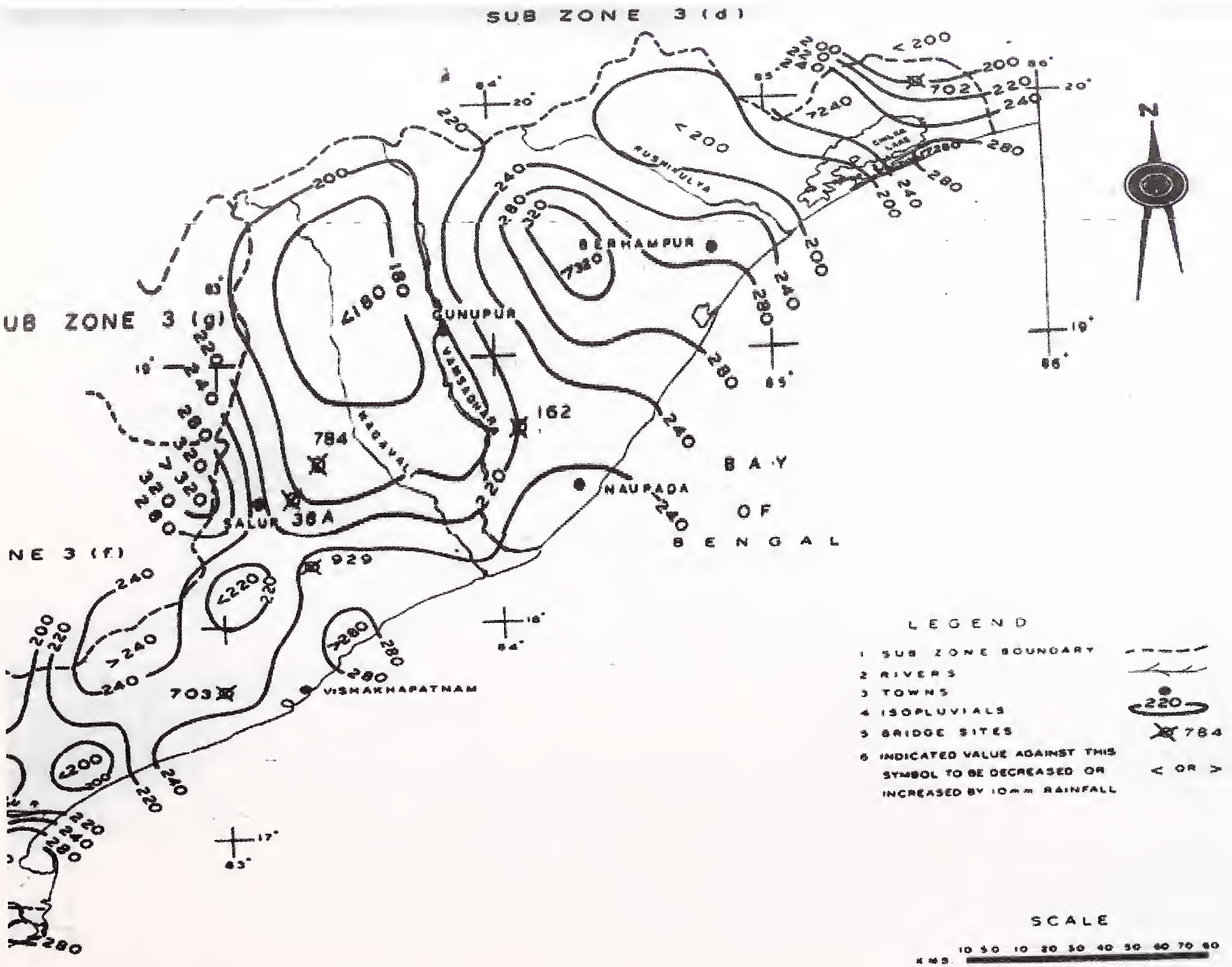
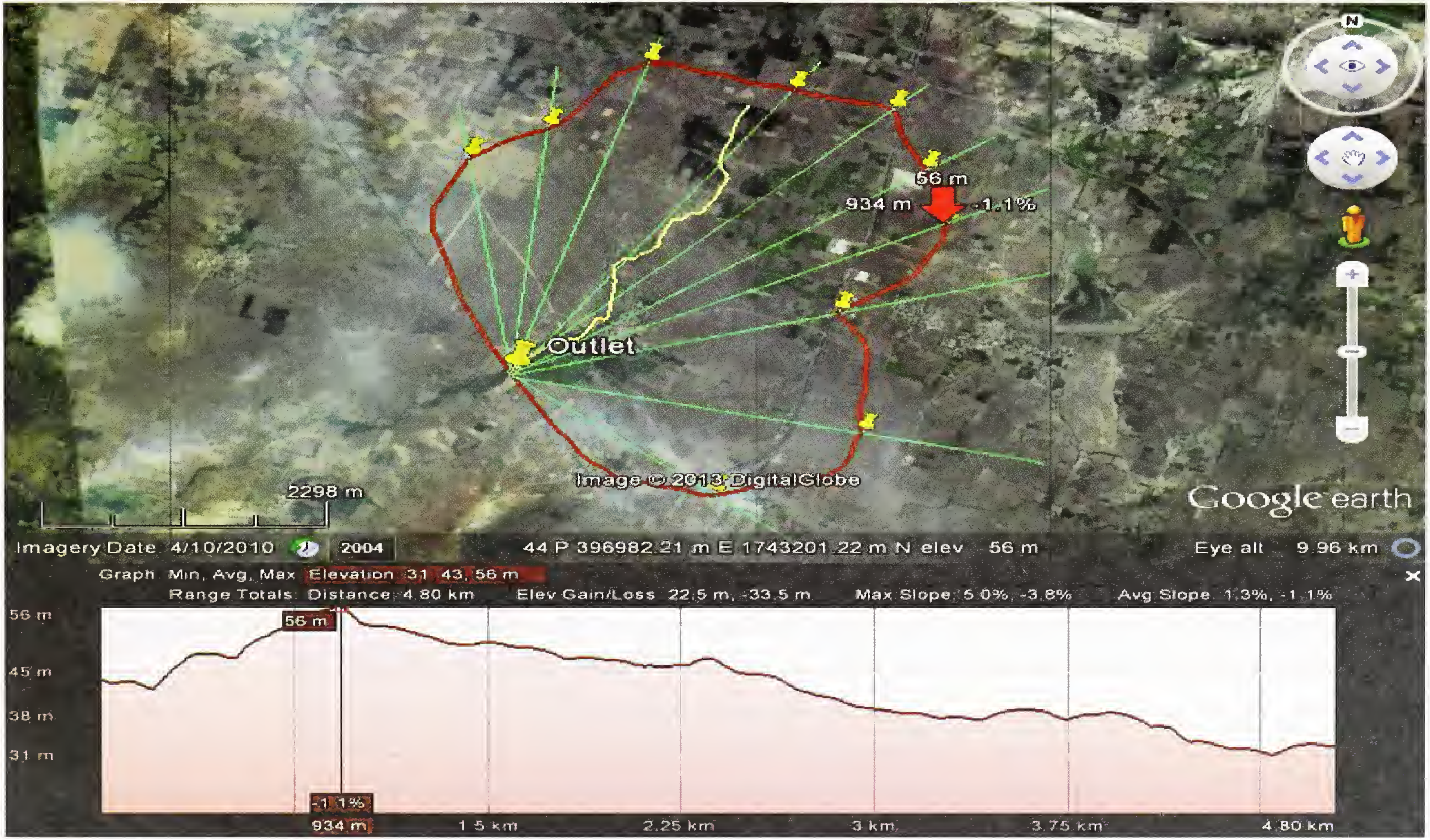


Fig. I.2 Showing Typical Iso-Pluvial Lines For Sub-Zone-3(d) in India (From Flood Estimation Report published by CWC)

Annexure II

(Refer Clause 6.3.2)

Pictorial Detail of Delineating Catchment Area on Google Earth



Annexure III (a)

(Refer Clause 6.3.3)

Runoff Curve Numbers for Hydrologic Soil Cover Complexes (AMC-II and $I_a = 0.2$ S) for humid and sub humid watersheds (table extracted from FHWA-Highway Hydrology Report)

Cultivated Agricultural Land					
Cover Type	**Hydrologic Condition**	**Hydrologic Soil Group**			
		A	**B**	**C**	**D**
Fallow					
Straight row	.....	77	86	91	94
Row crops					
Straight row	Poor	72	81	88	91
Straight row	Good	67	78	85	89
Contoured	Poor	70	79	84	88
Contoured	Good	65	75	82	86
Contoured and terraced	Poor	66	74	80	82
Contoured and terraced	Good	62	71	78	81
Small grain					
Straight row	Poor	65	76	84	88
Straight row	Good	63	75	83	87
Contoured	Poor	63	74	82	85
Contoured	Good	61	73	81	84
Contoured and terraced	Poor	61	72	79	82
Contoured and terraced	Good	59	70	78	81
Close-seeded legumes or rotation meadow					
Straight row	Poor	66	77	85	89
Straight row	Good	58	72	81	85
Contoured	Poor	64	75	83	85
Contoured	Good	55	69	78	83
Contoured and terraced	Poor	63	73	80	83
Contoured and terraced	Good	51	67	76	80
Other Agricultural lands					
Pasture, grassland, or forage for grazing	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Meadow-continuous grass protected from grazing	Good	30	58	71	78
Brush-weed-grass mixture with brush the major element	Poor	48	67	77	83
	Fair	35	56	70	77
	Good	30	48	65	73

Woods-grass combination	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
Woods	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	25	55	70	77
Farmsteads – buildings, lanes, driveways	.....	59	74	82	86
Urban Areas					
Cover Type and Hydrologic Condition	**Average Percent Impervious Area**	**Hydrologic Soil Group**			
		A	**B**	**C**	**D**
Open space (lawns, parks, golf courses etc.)					
Poor (Gross Cover < 50%)	.....	68	79	86	89
Fair (Gross Cover 50% to 75%)	.....	49	69	79	84
Good (Gross Cover > 75%)	.....	39	61	74	80
Impervious areas					
Paved parking, roofs, driveways etc. (excluding right-of-way)	.....	98	98	98	98
Street and Roads					
Paved; curbs, storm sewers (excluding right-of-way)	.....	98	98	98	98
Paved; open ditches (including right-of-way)	.....	83	89	92	93
Gravel (including right-of-way)	.....	76	85	89	91
Dirt (including right-of-way)	.....	72	82	87	89
Western desert urban areas					
Natural desert landscaping (pervious area only)	.....	63	77	85	88
Artificial desert landscaping (impervious paved barrier, desert shrub, gravel mulch, basin borders)	.....	96	96	96	96

Urban districts					
Commercial and business	85	89	92	94	95
Industrial	72	81	88	91	93
Residential districts by avg. plot size					
0.05 hectares or less	65	77	85	90	92
0.1 hectares	38	61	75	83	87
0.135 hectares	30	57	72	81	86
0.2 hectares	25	54	70	80	85
0.4 hectares	20	51	68	79	84
0.8 hectares	12	46	65	77	82
Developing urban areas					
Newly graded areas (pervious area only, no vegetation)	…..	77	86	91	94

Annexure III (b)

(Refer Clause 6.3.3)

Runoff Curve Numbers for Hydrologic Soil Cover Complexes (AMC-II and $I_a = 0.2 S$) for arid and semi-arid watersheds (table extracted from FHWA-Highway Hydrology Report)

Cover Type	Hydrologic Condition	A	B	C	D
Mixture of grass, weeds and low growing brush, with brush the minor element	Poor		80	87	93
	Fair		71	81	89
	Good		62	74	85
Mountain brush mixture of small trees and brush	Poor		66	74	79
	Fair		48	57	63
	Good		30	41	48
Small trees with grass understory	Poor		75	85	89
	Fair		58	73	80
	Good		41	61	71
Brush with grass understory	Poor		67	80	85
	Fair		51	63	70
	Good		35	47	55
Desert shrub brush	Poor	63	77	85	88
	Fair	55	72	71	86
	Good	49	68	79	84

Annexure III (c)

(Refer Clause 6.4.3.2)

Coefficients for Calculation of Unit Peak Discharge q_u (table extracted from FHWA-Highway Hydrology Report)

Rainfall type	I_a/P	C_0	C_1	C_2
I	0.1	2.3055	-0.51429	-0.1175
	0.2	2.23537	-0.50387	-0.08929
	0.25	2.18219	-0.48488	-0.06589
	0.3	2.10624	-0.45695	-0.02835
	0.35	2.00303	-0.40769	0.01983
	0.4	1.87733	-0.32274	0.05754
	0.45	1.76312	-0.15644	0.00453
	0.5	1.67889	-0.0693	0
IA	0.1	2.0325	-0.31583	-0.13748
	0.2	1.91978	-0.28215	-0.0702
	0.25	1.83842	-0.25543	-0.02597
	0.3	1.72657	-0.19826	0.02633
	0.5	1.63417	-0.091	0
II	0.1	2.55323	-0.61512	-0.16403
	0.3	2.46532	-0.62257	-0.11657
	0.35	2.41896	-0.61594	-0.0882
	0.4	2.36409	-0.59857	-0.05621
	0.45	2.29238	-0.57005	-0.02281
	0.5	2.20282	-0.51599	-0.01259
III	0.1	2.47317	-0.51848	-0.17083
	0.3	2.39628	-0.51202	-0.13245
	0.35	2.35477	-0.49735	-0.11985
	0.4	2.30726	-0.46541	-0.11094
	0.45	2.24876	-0.41314	-0.11508
	0.5	2.17772	-0.36803	-0.09525

Annexure IV

(Refer Clause 6.4.3.2)

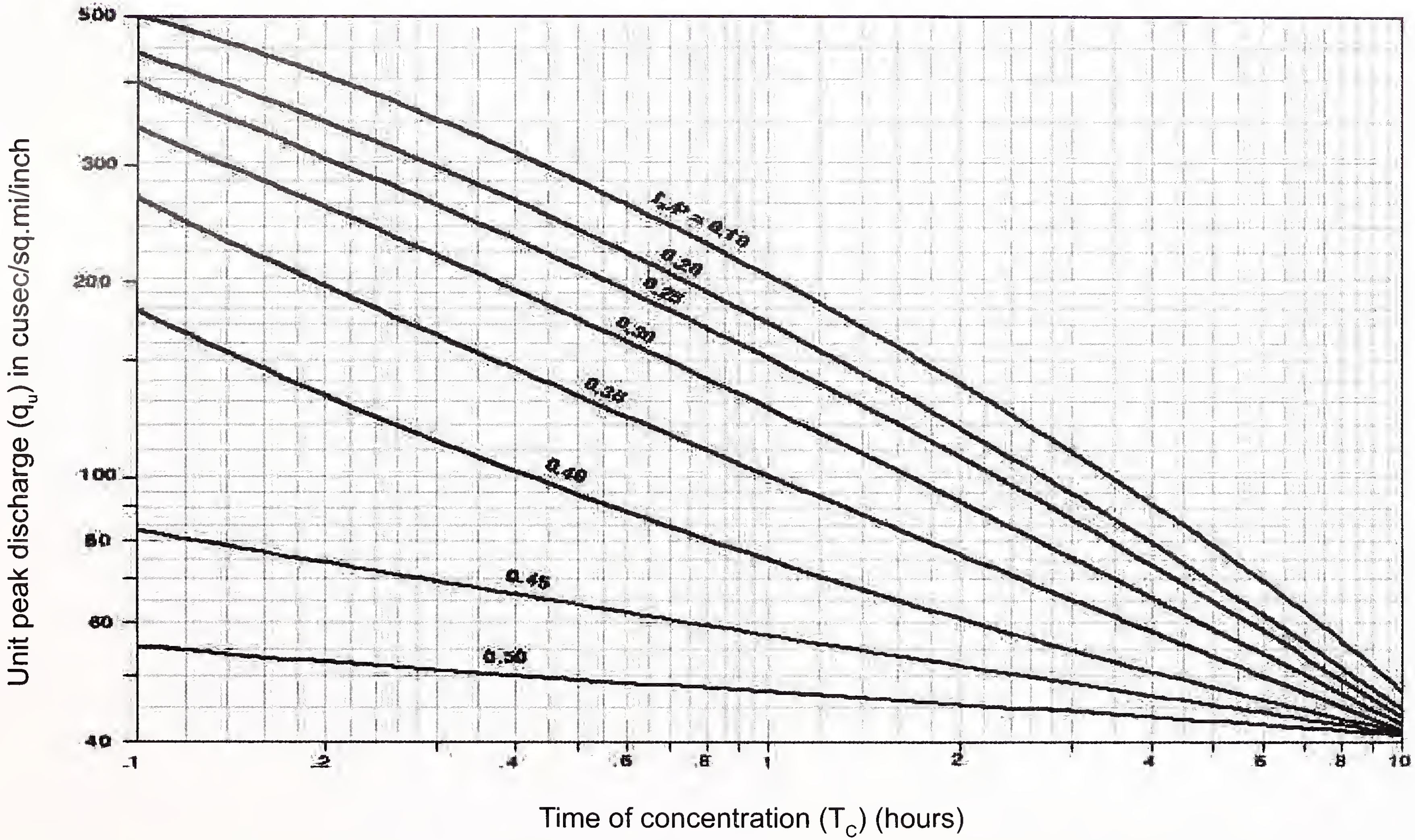


Fig. IV.1 Unit Peak Discharge (q_u) For SCS Type I Rainfall Distribution (Extracted from U.S. Soil Conservation Service, Technical Release 55: Urban Hydrology for Small Watersheds, June 1986)

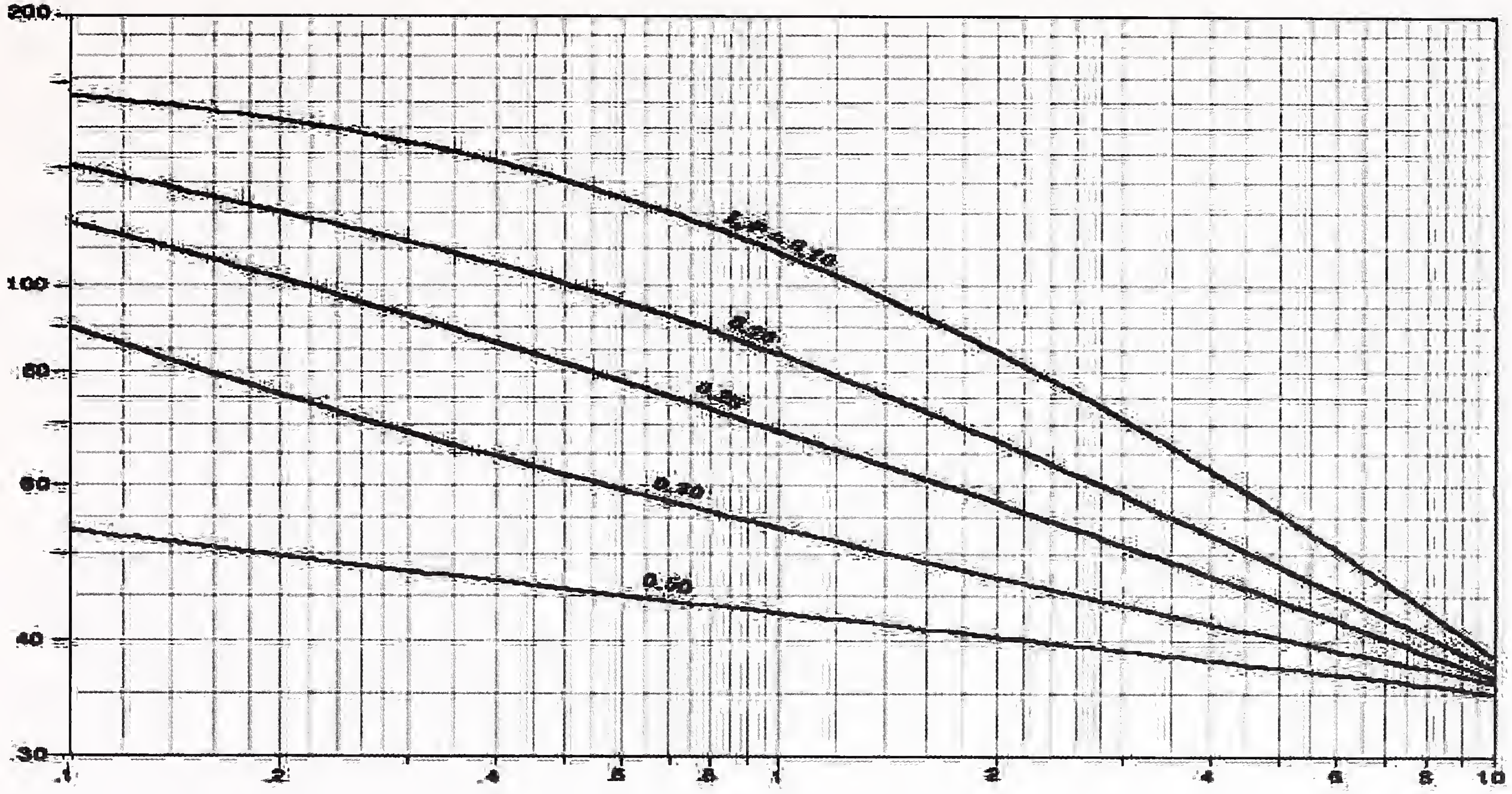


Fig. IV.2 Unit Peak Discharge (q_u) for SCS Type IA Rainfall Distribution (Extracted from U.S. Soil Conservation Service, Technical Release 55: Urban Hydrology for Small Watersheds, June 1986)

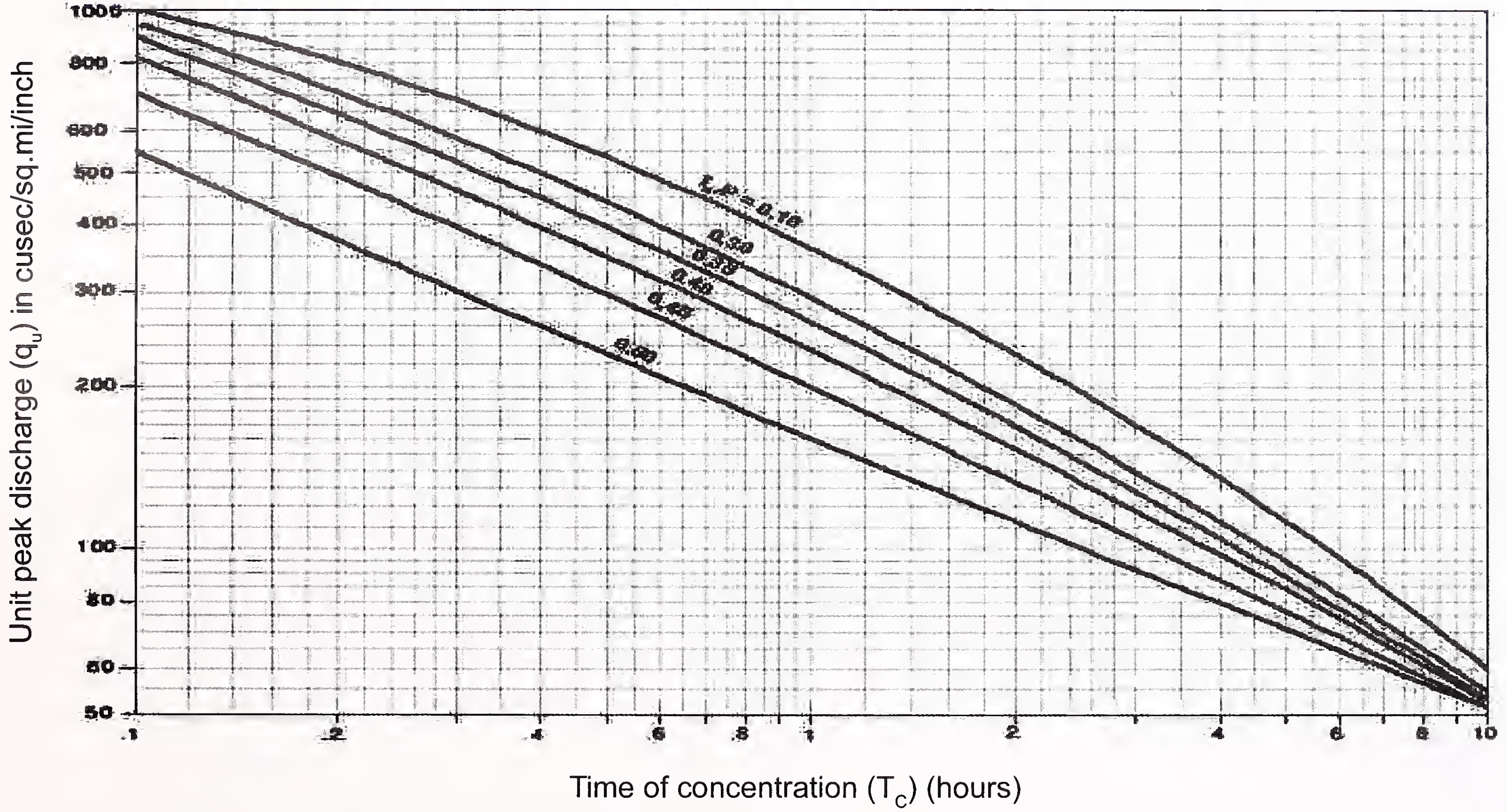


Fig. IV.3 Unit Peak Discharge (q_u) for SCS Type II Rainfall Distribution (Extracted from U.S. Soil Conservation Service, Technical Release 55: Urban Hydrology for Small Watersheds, June 1986)

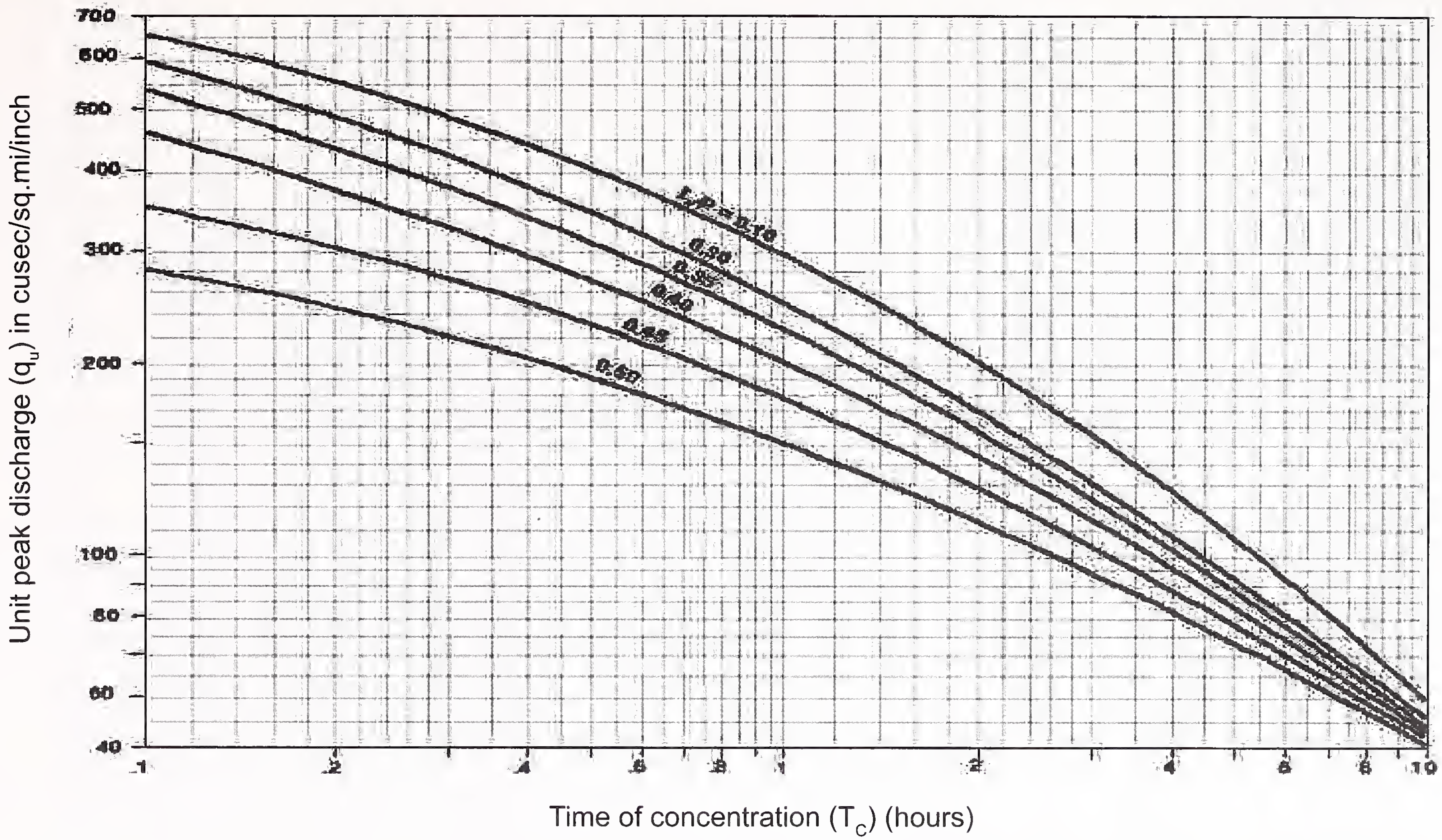


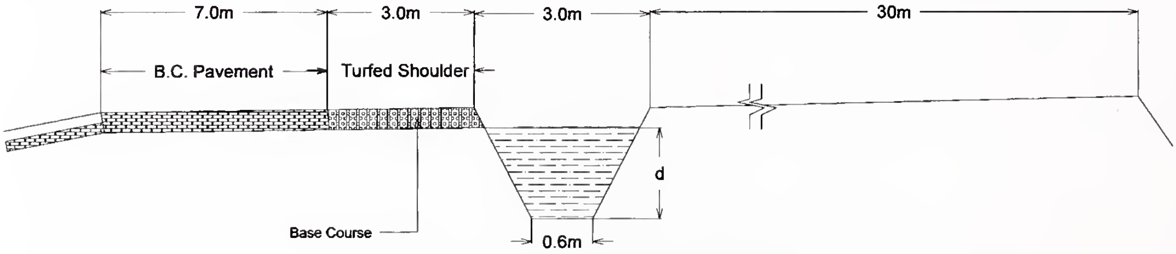
Fig. IV.4 Unit Peak Discharge (q_u) for SCS Type III Rainfall Distribution (Extracted from U.S. Soil Conservation Service, Technical Release 55: Urban Hydrology for Small Watersheds, June 1986)

Annexure V

(Refer Clause 7.2.4)

Illustrative Design Examples

Example-1: A typical Highway Cross-Section as shown in Fig. below at a place with continuous longitudinal grade of 1 in 100.The drain is unlined having loamy soil. The drain is unlined with side slope 2(H):1(v). If the bed width of the drain is 60 cm, find the minimum depth of drain.



Typical Highway Cross-Section

I Discharge computation by rational method

a) Mean co-efficient of runoff

Since the drain is carrying runoff from half the roadway width and 30 m width of agricultural land, the mean runoff coefficient from the different surfaces (as per the figure) shall be

$$P_m = (0.9 \times 7 \times L + 0.3 \times 6 \times L + 0.4 \times 30 \times L)/(7L + 6L + 30L) = 0.46$$

where,

L is the length of road under consideration and the runoff coefficients from different surfaces from **Table 6.5** are:

Bituminous pavement surface - 0.9

Turfed shoulder – 0.3

Agricultural land with loamy soil - 0.4

b) Time of Concentration (T) in Minutes

The hydro logically remotest point in the given section of road is the end point of the agricultural land (with 5 percent slope) and the time required for water to reach the drain from the remotest point is

$$T_{c1} = 30/V = 500 \text{ sec} = 8.33 \text{ min.}$$

Taking K = 0.274 (from **Table 6.6**), and S = 0.05, V = 0.06 m/s ($V = KxS^{0.5}$)

Assuming a mean velocity of 0.3 m/s in the unlined drain

$$T_{c2} = L/0.3 \text{ sec} = L/18 \text{ min}$$

$T_c = T_{c1}+T_{c2}$ = (8.33 + L/18) min. and hence L = (T – 8.33) x 18 m . The lengths for different values of T_c are:

T_c (min)	10	15	20	30	40	50	60	90	120
L (in m)	30	120	210	390	570	750	930	1470	2010

c) Area of catchment in Hectare (ha)

Area of catchment contributing flow to the drain at any point at a distance L from the starting point is

$A = 43 \times L\ m^2 = 43\ (T - 8.33) \times 18\ m^2 = 774\ (T - 8.33)\ m^2 = 774\ (T - 8.33)/10{,}000\ ha = 0.0774\ (T - 8.33)\ ha$

T_c (min)	10	15	20	30	40	50	60	90	120
A (in ha)	0.129	0.516	0.930	1.677	2.451	3.225	3.999	6.321	8.643

d) Design Rainfall Intensity - I (in cm/sec)

From iso-pluvial map of the given sub-zone (CWC Flood Estimation report) in which the road lies, it is found that 24 hour rainfall of 50 year return period in the area is 236 mm and from **Table 6.2**, corresponding 1 hour rainfall of 50 year return period is 39 percent of 24 hour rainfall. So, 1 hour rainfall of 50 year return period is 0.39 x 236 = 92 mm = 9.2 cm/hour i.e. I_{60} = 9.2 cm/hour.

For a length of drain L = 30 m

T_c = 10 min - From (b) above and

The ratio of 10 min. rainfall to 60 min rainfall is 2.85- from **Table 6.1**

Design rainfall intensity for L = 30 m, I_{10} = 2.85 x 9.2 = 26.2 cm/hour for 50 year return period.

From frequency analysis of available rainfall data at the given place, the following conversion factors for other return periods and the design rainfall for L = 30 m and T_c = 10 min. are found to be as follows:

Return Period (In year)	Conversion Factor	1-hr Rainfall (I_{60}) in mm	Design Rainfall Intensity (I_{10})in cm/hr
50 year	1	92	26.2
25 year	0.86	79	22.5
10 year	0.67	62	17.7
5 year	0.53	49	14
2 year	0.39	36	10.3

e) Design Discharge for L = 30 m, T_c = 10 min.

Applying Rational Formula: $Q = 0.028\ P_m xI\ xA$, Design Discharge for L = 30 m and t = 10 min. (from a, b, c, d above)

$Q_{50} = 0.028 \times 0.46 \times 26.2 \times 0.129 = 0.0435$ cumec

$Q_{25} = 0.028 \times 0.46 \times 22.5 \times 0.129 = 0.037$ cumec

Q_{10} = 0.028 x 0.46 x 17.7 x 0.129 = 0.029 cumec

Q_5 = 0.028 x 0.46 x 14 x 0.129 = 0.023 cumec

Q_2 = 0.028 x 0.46 x 10.3 x 0.129 = 0.017 cumec.

Where the subscript of Q_n (n = 50, 25…2 indicate return period of flow i.e. 50 yr, 25 yr…. 2 yr.)

Same procedure illustrated above may be followed to determine design discharge for other different lengths of the drain

II Computation of Drain Section (by using Manning's Equation, See 7.2.1)

(For 30 m Length of Drain, Bottom width B_0 = 0.6 m, T_c = 10 min)

Corresponding to 10 year return period, Q_{10} = 0.029 cumec,

For the given soil with little vegetative growth (well maintained), assume n = 0.03 –From **Table 7.1**,

Permissible maximum velocity, V_{max} = 0.9 m/sec- from **Table 7.1**, Bed slope, S=0.01, Side Slope-2:1, m = 2

Let d bc the depth of flow in the drain bed in m

Area of flow section, $A_f = (B_0 + md)d = (0.6 + 2d)d$

Wetted Perimeter, $P = [B_0 +2 (m^2 + 1)d] = 0.6 + 2\sqrt{5}\ d$

Hydraulic Radius, $R = A/P = (0.6 + 2d)d/(0.6 + 2\sqrt{5}\ d)$

Using Manning's Formula, $Q = (1/n)\ A_f\ R^{2/3}\ S^{1/2}$, and Q = 0.029

$0.029 = (1/0.03) \times (0.6d + 2d)d \times [(0.6 + 2d)d/(0.6 + 2\sqrt{5}\ d)]^{2/3} \times 0.01^{1/2}$

Solving the above equation by trial, d = 0.08 m = 8 cm and $V = 1/nR^{2/3}\ S^{1/2} = 0.55$ m/s < 0.9 m/s, o.k.

With a minimum of 10 cm freeboard, the minimum depth of the drain below its top should be 18 cm.

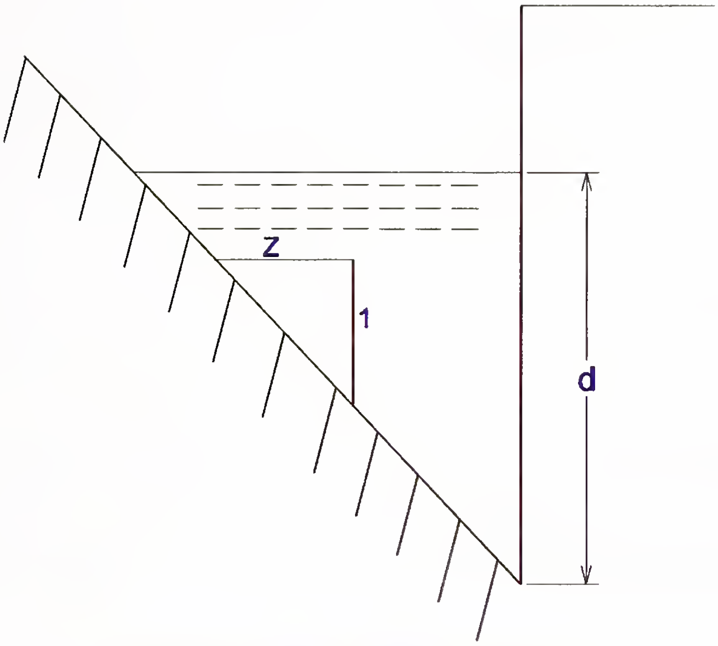
Check for Flow Condition in the drain

As mentioned in **Section 7.2**, flow in open drain should be at sub-critical state. For this the Froude's number of flow should be less than 1, preferably below 0.7 above which the flow surface becomes wavy. Froude's No. $Fr = V/\sqrt{(g\ D)}$, where $D = A_f/T$ and $T = B_0 + 2\ md = 0.6 + 2 \times 2 \times .08 = 0.92$ m, $A_f = (0.6 + 2 \times .08) \times .08 = .0608$

$D = .0608/.92 = 0.066$ m, V = 0.55 m/s, $Fr = 0.55/\sqrt{(9.8 \times .08)} = 0.62 < 0.7$ o.k.

Drain sections for other different lengths (L) and corresponding values of, T_c, I, Q can be found in the same manner as illustrated above.

Example-2 : A concrete road side gutter of triangular section is to be designed for a design Q_{10} = 0.03 cumec. If the road section has a cross- slope of 2.5 percent (1 in 40 i.e. Z = 40) and longitudinal grade is 1 in 100 (S = 0.01). Determine the flow depth and flow encroachment on the road.



Shallow right triangular channel

For concrete surface with trowel finish, n = 0.014 (From **Table 7.1**)

$Q = (0.315/n) \times F_1(Z) \times d^{8/3} \times S^{1/2}$ & $F_1(Z) = Z^{5/3}/[1 + (1 + Z^2)^{0.5}]^{2/3} = 40^{5/3}/ [1 + (1 + 40^2)^{0.5}]^{2/3} =$ 39.3…. From **7.2.2**

$0.03 = (0.315/0.014) \times 39.3 \times d^{8/3} \times (0.01)^{0.5}$

$d^{8/3} = 3.39 \times 10^{-4}$ and d = 0.05 m = 5 cm

Water spread on the road = Z x d = 40 x 0.05 = 2 m Assuming kerb width as 1 m, encroachment on carriageway is 1 m which is permissible as per **7.1.4**, o.k.

Example-3 : Hydrological and Hydraulic computation for design of a Trapezoidal unlined drain in a two lane section -by rational method.

Hydrological and Hydraulic Design of Roadside Drain (Unlined Trapezoidal Section) for Two Lane Section without Service Roads

a) Catchment Area (A)

Half of Median	0.00	m
Half of Carriageway	3.50	m
Paved Shoulder	1.50	m
Earthen Shoulder	1.00	m
Turfing	4.00	m
Adjacent built-up land width	30.00	m
Total width contributing	40.00	m
Total length contributing - L	500.00	m
A	2.0000	hectare

b) Average coefficient of runoff (P_{av})

Type of surface	Coefficient of runoff (P)	Width of road [m]
Paved	0.90	5.00
Unpaved	0.40	5.00
Adjacent built-up land	0.30	30.00
P_{av}	0.3875	

c) Time of concentration (t_c)

$$t_c = \left(0.87 \text{ x } \frac{L^3}{H}\right)^{0.385}$$

L - distance from the most remote point to outlet in km

H - fall in level from most remote point to outlet in m

t_c	23	minute

e) Critical Rainfall intensity (I_c)

25 year-24 hour rainfall (mm) from Flood Estimation Report	140	mm
I_c, as per IRC:SP:13	10.54	cm/h

f) Discharge

$$Q = 0.028\ P_{av} \text{ x f x A x } I_c$$

A - Catchment Area

P_{av} - Coefficient of runoff for the given catchment characteristics

f - spread factor of converting point rainfall into areal mean rainfall

I_c - Rainfall intensity in cm/hr

Q (25-yr frequency)	0.23	m^3/s
Design Discharge	0.24	m^3/s

g) Hydraulic Parameters

Target discharge	0.24	m^3/s
Longitudinal slope	0.003	= 1 in 333.33
Bed width (B)	0.50	m
Side slope (H:1V)	1.00	= 0.79 rad
Top width (T)	1.30	m
Depth of flow (d)	0.40	m
Area (A)	0.36	m^2
Wetted perimeter (P)	1.63	m
Hydraulic radius (R)	0.22	m
Manning's coefficient (n)	0.030	

$v = 1/n \times R^{2/3} \times S^{1/2}$

Velocity (v)	0.67	m/s
Discharge achieved (Q_a)	0.24	m^3/s

Check for criticality

Critical velocity (v_c)	1.64	m/s
Normal velocity	0.67	m/s
Flow regime		Subcritical

h) Recommendation

Adopted bed width of drain	0.50	m
Adopted depth of flow	0.40	m
Free board	0.15	m
Adopted depth of drain	0.55	m
Top width of drain	1.60	m
Discharge of drain	0.24	m^3/s

Example-4 : Typical computation of design discharge for a culvert using SCS method by USGS

Catchment Area 0.316 Km^2	Catchment Area 0.316 Km^2
50- Yr Point	100- Yr Point
Rainfall **P** 127 mm	Rainfall **P** 142 mm
Curve No. CN 84	Curve No. CN 84
Length of Stream 1.07 Km	Length of Stream 1.07 Km
Potential Maximum Retention S	
$S = \frac{25400}{CN} - 254$	
S 48.38	**S 48.381**
Storm Runoff Qu = $\frac{(P-0.2S)}{P+0.8S}$	
Q 83.07 mm	**Q 96.90 mm**
Overland time of flow (from graph) T_{c1} 0.25 Hr	Overland time of flow (from graph) T_{c} 0.25 Hr
Travel time for Channel flow T_{c2} 0.198 Hr	Travel time for Channel flow T_{c2} 0.198 Hr
$T_{c2} = \frac{L}{3600 \times v}$	
L - Flow length in m	
v - channel velocity in m/s = 1.5m/s	
$Tc = T_{c1}+T_{c2}$	
T_c 0.448 Hr	T_c 0.448 Hr
I_a 9.7	I_a 9.7
I_a/P 0.076378	I_a/P 0.06831
q_{50} (from Graph) 0.1620 cumec/100 ha/mm	q_{100} (from Graph) 0.172 cumec/100 ha/mm
0.1620 cumec/Km^2/mm	0.172 cumec/Km^2/mm
$Q_p = Q_u \times A \times Q \times F_p$	
Q_p - Peak discharge in cumec	
q_u - Unit peak discharge in cumec/km2/mm	
A - Catchment area	
F_p - Pond and swamp adjustment factor - 1	
Q - Runoff volume	
Q_{50} 4.25 Cumec	**Q_{100} 5.27 Cumec**
A 4m X 2m Slab Culvert will do here.	

Example-5 : Cost effective solutions for design of road side ditches (Lined and Unlined) for different ground slopes and lengths of road .

SELECTION OF LONGITUDINAL TRAPEZOIDAL DRAIN SECTION ON THE BASIS OF EXISTING LONGITUDINAL GROUND SLOPE AND LENGTH OF DRAIN BETWEEN LOCAL RIDGE AND NEAREST CULVERT.

PROJECT : STRETCH : FROM KM.......... TO KM ....

Drain Length (m)	**AVERAGE GROUND SLOPE ALONG TOE OF PROPOSED EMBANKMENT (LONGITUDINAL SLOPE OF DRAIN)**						
	0.10%	**0.20%**	**0.30%**	**0.40%**	**0.50%**	**0.70%**	**0.90%**
100	🟨 0.43 (0.37)*	🟨 0.36 (0.31)*	🟨 0.33 (0.3)*	🟨 0.31 (0.3)*	🟨 0.3 (0.3)*	🟨 0.3 (0.3)*	🟨 0.3 (0.3)*
200	🟨 0.59 (0.53)*	🟨 0.51 (0.44)*	🟨 0.46 (0.4)*	🟨 0.43 (0.37)*	🟨 0.41 (0.35)*	🟨 0.38 (0.32)*	🟨 0.35 (0.3)*
300	🟨 0.7 (0.63)*	🟨 0.6 (0.54)*	🟨 0.55 (0.48)*	🟨 0.51 (0.45)*	🟨 0.49 (0.43)*	🟨 0.45 (0.39)*	🟨 0.42 (0.37)*
400	🟩 0.72	🟨 0.68 (0.61)*	🟨 0.62 (0.55)*	🟨 0.58 (0.51)*	🟨 0.55 (0.49)*	🟨 0.51 (0.45)*	🟨 0.48 (0.42)*
500	🟩 0.8	🟩 0.68	🟨 0.68 (0.61)*	🟨 0.64 (0.57)*	🟨 0.61 (0.54)*	🟨 0.56 (0.5)*	🟨 0.53 (0.47)*
600	🟩 0.86	🟩 0.73	🟩 0.66	🟨 0.69 (0.62)	🟨 0.65 (0.59)*	🟨 0.61 (0.54)*	🟩 0.51
700	🟩 0.91	🟩 0.77	🟩 0.7	🟩 0.66	🟨 0.69 (0.62)*	🟨 0.64 (0.57)*	🟩 0.54

CELL VALUES ARE DEPTH OF FLOW IN DRAIN FOR TRAPEZOIDAL SECTION

For Unlined Section	For Lined Section	Limiting top width of drain = 3m.
Limiting Velocity = 1.65 m /sec	Limiting Velocity = 3.00 m /sec	

	Bed Width (mm)	Side Slope	Type of Lining	
🟨	500	1.5 H : 1 V	Unlined	May be replaced with lined section (See Note 1)
🟩	500	1 H : 1 V	Lined	

Minimum Bed Width of Drain = 500mm

Minimum Depth of flow = 300mm

Notes:

1. * For easy maintenance and serviceability, it is recommended to avoid Unlined Drains. (Unlined sections may be replaced with Lined sections with Side Slope = 1H : 1V and flow depths as mentioned in bracket).
2. Where existing ground slopes are steeper than design slope, it is recommended to provide stepped falls in the bed of drains with longitudinal slopes modified to suit the design range.
3. Flow Depth may be interpolated between intermediate ranges of Long Slope and Drain Length.

SELECTION OF LONGITUDINAL TRAPEZOIDAL DRAIN SECTION ON THE BASIS OF EXISTING LONGITUDINAL GROUND SLOPE AND LENGTH OF DRAIN BETWEEN LOCAL RIDGE AND NEAREST CULVERT.

PROJECT :

STRETCH : FROM KM.......... TO KM ....

Drain Length (m)	AVERAGE GROUND SLOPE ALONG TOE OF PROPOSED EMBANKMENT (LONGITUDINAL SLOPE OF DRAIN)						
	0.50%	1%	1.50%	2%	2.50%	3%	4%
100	0.37 (0.31)*	0.31 (0.3)*	0.31 (0.3)*	0.3 (0.3)*	0.3	0.3	0.3
200	0.61 (0.44)*	0.43 (0.37)*	0.33	0.31	0.31	0.3	
300	0.6 (0.54)*	0.45	0.41	0.3	0.3		
400	0.68 (0.61)*	0.52	0.39				
500	0.68	0.57	0.41				
600	0.74	0.62					
700	0.79						

CELL VALUES ARE DEPTH OF FLOW IN DRAIN FOR TRAPEZOIDAL SECTION

For Unlined Section Limiting Velocity = 1.65 m /sec		For Lined Section Limiting Velocity = 3.00 m /sec		Limiting top width of Drain = 3m.
	Bed Width (mm)	Side Slope	Type of Lining	
🟨	500	1.5 H : 1 V	Unlined	May be replaced with lined section (See Note 1)
🟩	500	1 H : 1 V	Lined	
🟦	700	2 H : 1 V	Lined	

Minimum Bed Width of Drain = 500mm

Minimum Depth of flow = 300mm

For Longitudinal slope flatter than 0.5%, use minimum section of drain.

Notes:

1. * For easy maintenance and serviceability, it is recommended to avoid Unlined Drains. (Unlined sections may be replaced with Lined sections with Side Slope = 1H : 1V and flow depths as mentioned in bracket).
2. Where existing ground slopes are steeper than design slope, it is recommended to provide stepped falls in the bed of drains with longitudinal slopes modified to suit the design range.
3. Flow Depth may be interpolated between intermediate ranges of Long Slope and Drain Length.

(The Official amendments to this document would be published by the IRC in its periodical, 'Indian Highways' which shall be considered as effective and as part of the code/guidelines/manual, etc. from the date specified therein)