



Government of Rajasthan
Forest Department



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Technical Manual on Soil & Water Conservation



राजस्थान वानिकी एवं जैव विविधता विकास समिति (आर.वी.जे.वी.वी.एस.), पी.एम.यू., आर.एफ.बी.डी.पी.

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Technical Manual on Soil & Water Conservation

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Preface

As we navigate the intricate relationship between soil, water, and the diverse ecosystems they support, we recognize their fundamental role in sustaining life. In this context, the Forest Department of Rajasthan has launched the "Rajasthan Forestry Biodiversity and Development Project" (RFBDP), a pivotal initiative aimed at promoting sustainable development and biodiversity conservation across our state.

In pursuance to our longstanding commitment to soil and water conservation (SWC), we have observed need of formulating standardized practices and comprehensive guidelines. To address this critical gap, we are proud to present this technical manual, meticulously developed to serve as a key resource for our forest officers and field functionaries.

This manual consolidates best practices and methodologies for SWC, ensuring that our efforts are consistent and effective. Written in clear, accessible language, it aims to empower our teams with practical guidance, complemented by illustrative images and tips that make complex concepts easier to understand.

I firmly believe that this manual will be an invaluable tool in our ongoing mission to enhance livelihoods, mitigate forest degradation, and strengthen biodiversity conservation. It is our collective responsibility to protect these precious resources, and this initiative marks a significant step forward in that endeavour.

I extend my heartfelt appreciation to the Project Management Unit (PMU) for their tireless dedication to this project. Together, I am confident that we can make a lasting impact on the conservation and sustainable management of Rajasthan's rich biodiversity.

T. J. Kavitha, IFS
Project Director, RFBDP
& APCCF

Abbreviation

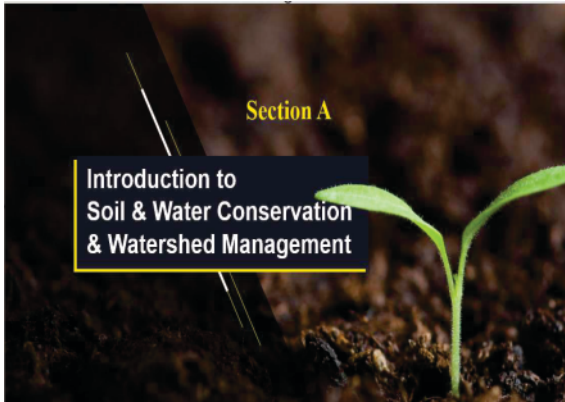
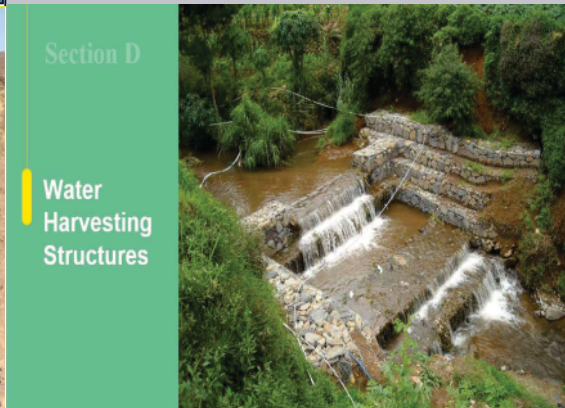
AFD	French Development Agency
ANR	Assisted Natural Regeneration
BS	Backsight
BW	Base Width
BW	Bottom Width
CCT	Continuous contour trench
C/S	Cross Section
CGWB	Central Ground Water Development Board
DCB	Ditch Cum Bund
DDP	Desert Development Program
DoLR	Department of Land Resources
DPAP	Drought Prone Area Program
D/S	Downstream
DLT	Drainage Line Treatment
FS	Foresight
EAP	Externally Aided Projects
EDM	Electronic Distance Meter
F.B	Free Board
FD	Forest Department
FMUs	Field Management Units
FS	Foresight
FRL	Full Reservoir Level
GIS	Geographical Information System
GPS	Global Positioning Systems
H.I	Horizontal Interval
HW	Head Wall
HWE	Head Wall Extension
HFL	Highest flood level
IS	Intermediate Sight
IWDP	Integrated Watershed Development Project
LSCD	Loose Stone Check Dam
LULC	Land Use Land Cover Map
m	Meter
mm	Milli Meter
MFL	Maximum Flood Level
MJSA	Mukhya Mantri Jal Swablamban Abhiyan
MoRD	Ministry of Rural development
NRSA	National Remote Sensing Agency
PRA	Participatory Rural Appraisal
PMKSY	Pradhan Mantri Krishi Sinchayee Yojana
RFD	Rajasthan Forest Department
RDF	Rehabilitation of Degraded Forest
RFBDP	Rajasthan Forestry & Biodiversity Development Project
R.I	Recurrence Interval
RM	Running Meter
SMC	Soil & Moisture Conservation
SWC	Soil & Water Conservation
SGT	Staggered Trench

TBL	Top Bund Level
TP	Turning Point
TW	Top Width
u/s	Upstream side
V.I	Vertical Interval
WAT	Water Absorption Trench
WD & SC	Watershed Development & Soil Conservation
WHS	Water Harvesting Structure

About Technical Manual on Soil & Water Conservation

Rajasthan Forest Department (RFD) is implementing Rajasthan Forestry and Biodiversity Development Project (RFBDP) with financial support of AFD (French Development Agency). This technical manual is meant for the DMU (Divisional Management Unit) and field management unit (FMU) level. It serves as a guide for the forest functionaries.

The "**Technical Manual on Soil & Water Conservation**" is organized into four main sections and sixteen chapters.

 Section A Introduction to Soil & Water Conservation & Watershed Management	 Section B Non-Arable Land Development Measures
▶ Provides foundational knowledge on technical prerequisites for comprehending SWC and watershed management. ▶ Outlines the planning processes essential for implementing SWC measures.	▶ Details SWC measures for treatment of non-arable land. ▶ Provide user-friendly tips for constructing high-quality structures by adhering to technical standards.
 Section : C Drainage Line Treatment Measures	 Section D Water Harvesting Structures
▶ Details SWC measures for drainage line treatment ▶ Provide user-friendly tips for constructing high-quality structures by adhering to technical standards.	▶ Explore technical insights, construction methodologies, and practical advice for building water harvesting structures and percolation tanks.

Section A: Introduction to Soil & Water Conservation & Watershed Management



Contents

- 1 Introduction to Watershed management
- 2 Introduction to RFBDP
- 3 Hydrologic cycle
- 4 Soil erosion
- 5 Planning in Soil & Water conservation



By delving into these chapter, practitioners will gain a comprehensive understanding of the Soil & water conservation and watershed management subject and enabling them to apply this knowledge in quality implementation of Soil & water conservation efforts.

Chapter 1: Introduction to Watershed Management

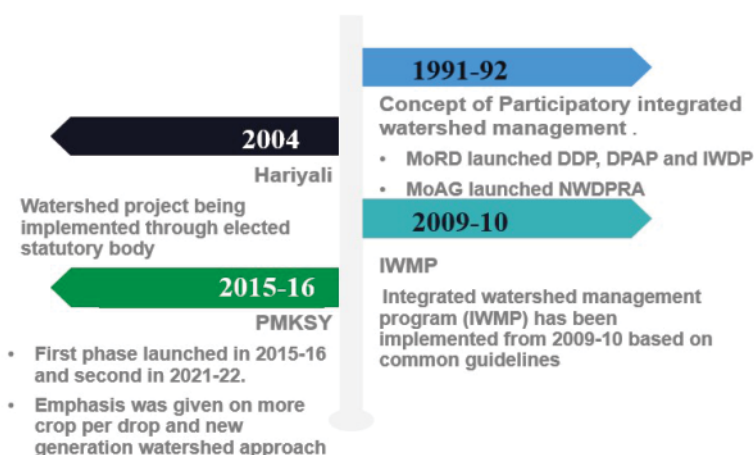
1.1 History of Watershed Development Program in Rajasthan

History of Soil and water conservation (SWC) efforts began in the mid-1960s through several projects aimed at combating land degradation.

- ▶ Soil conservation programs in the state commenced in the 1950s, initially spearheaded by the agriculture department, focusing solely on soil conservation efforts on an individual field basis.
- ▶ By the early 1970s, the focus shifted towards the adoption of high-potential crop varieties and moisture conservation practices.
- ▶ Towards the late 1970s, the emphasis transitioned to water conservation and the development of water harvesting techniques.
- ▶ In the early 1980s, attention was directed towards low-cost technologies employing a sectoral approach, where Forestry, Horticulture, Soil Conservation, Agriculture, Animal Husbandry, and other sectors were planned and executed independently.
- ▶ The mid-1980s saw the introduction of the integrated watershed management concept, employing a comprehensive approach.
- ▶ The early 1990s marked a shift to participatory integrated watershed management, emphasizing community involvement.
- ▶ The Department of Watershed Development & Soil Conservation (WD & SC) was established in 1991 to further these initiatives.
- ▶ In 2004, watershed programs under various schemes began to be implemented through the elected statutory body, the Gram Panchayat, following the 23rd constitutional amendment.
- ▶ The *Mukhya Mantri Jal Swavlambaan Abhiyan* (MJSA) was launched in 2013, operating on the Integrated Watershed Management Program (IWMP) approach from 2013 to 2018.
- ▶ In 2018, the watershed project was incorporated under the Pradhan Mantri Krishi Sinchayee Yojana (PMKSY), adopting a new-generation watershed approach.

Figure 1: History of watershed programs

Important era in the history of watershed development programs



1.2 Watershed Program in Context of Rajasthan

Rajasthan¹, India's largest state, spans 342 lakh hectares and is bisected by the Aravalli range, creating an arid west and a semi-arid east. This natural divide also marks a significant water divide, with the east having integrated drainage systems and the west hosting the sparse Luni system amidst vast desert expanses. The Thar Desert constitutes 61% of the state, with two-thirds facing severe wind erosion. Soil quality is poor, with low water retention and nutrient levels, leading to reduced agricultural productivity. Conversely, the southeast and east are fertile yet vulnerable to water erosion. Rajasthan's wastelands, accounting for 30% of its area and 18% of India's, are a concern (NRSA, Hyderabad).

With only 1.16% of India's water resources and erratic monsoon patterns, water management is critical. The state experiences rainfall ranging from 150 mm in the west to 900 mm in the east, with 71% of the cropped area receiving less than 600 mm annually. *Consequently, rainwater harvesting, groundwater recharging, and moisture conservation are are need of hour and watershed activities are solution for sustainable livelihoods.*

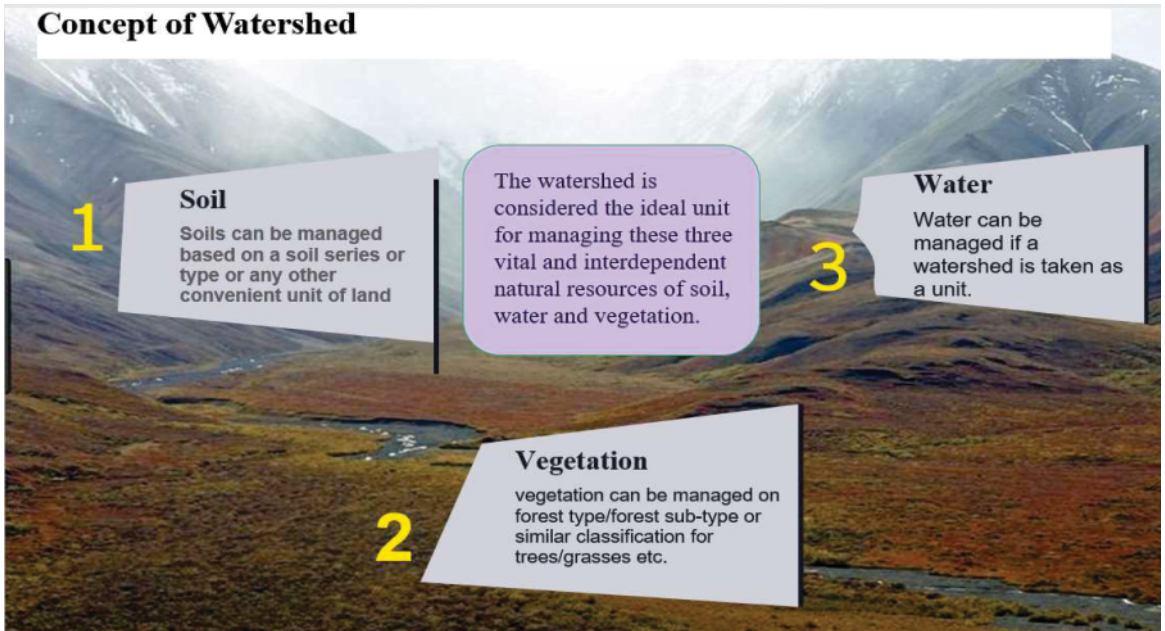
Watershed department perspective plan for 18 years developed in 2008 indicated that out of 342 Lac hectares geographical area of state about 245 Lac hectares area requires watershed development treatment (Watershed works are taken in those areas where assured irrigated land (canal irrigated) is less than 30%). So far about 66Lac hectare area has been sanctioned and out of this about 53 lac hectares has been treated under various watershed development. Hence 179 Lac hectare area of the state still requires treatment.

According to land use classifications, half the area is cultivated, 13.27% of land is Culturable Waste, 10.75 % Fallow Land, 7.76 % under Forest, 5 % under Pastures and Grazing Land and 12.6 % is put to Non-agricultural Uses/not available for cultivation.

For optimal biomass production, it is essential to manage the three key natural resources—soil, water, and vegetation—not only efficiently but also in a unified manner. Identifying the appropriate management unit is crucial for the effective, collective, and simultaneous stewardship of these resources. *The watershed stands out as the quintessential unit for this purpose, integrating the management of these vital and interdependent resources.*

¹ Department of watershed & soil conservation, 18 years perspective plan
<https://water.rajabsthan.gov.in/wdsc/#/sm/department-order/141596/143/23/2907/31488>, accessed on 20 July 2024

Figure 2: Concept of watershed



1.3 What is a Watershed?

Watershed is that area from which all precipitation flows to a single stream. Synonyms are “*catchment area*”, “*drainage basin*”, “*natural hydrological boundary*” and “*water imparting boundary*”.

Figure 3, mentioned below, helps to understand the concept of a watershed in a simple manner. The top of the watershed from where the slope start is called ridge. Because it is the dividing line that partition water watershed from another. The valley is the point of lowest elevation from where water drains through a common outlet.

Figure 3: Image of a watershed



1.4 Watershed Management

The concept of integrated and participatory watershed development and management has emerged as the cornerstone of rural development in the dry and semi-arid regions and other rain fed regions of the world and is a paradigm shift from earlier plot-based approaches to soil and water conservation. Management of natural resources at watershed scale produces multiple benefits in terms of increasing food production, improving livelihoods, protecting environment, addressing gender and equity issues along with biodiversity concerns.



Soil & Water Conservation (SWC)

- SWC are those practices have been evolved to address the issue of land degradation and maintain or enhance the productive capacity of land including soil, water, and vegetation in areas prone to degradation through prevention or reduction of soil erosion and conservation of water through agronomic measures as well as mechanical measures.



Watershed Management

- It is the process of implementing land use practices and water management practices to protect and improve the quality of land and water and other natural resources within a watershed.
- Watershed management integrates various technologies and constitute a holistic approach within a watershed to foster sustainable agriculture, maximize the efficient use of rainwater, improve livelihoods of people and environmental sustainability .
- It is an integrated approach leveraging land, water, and plant resources within a catchment area to sustainably fulfil people's needs. More than just agricultural land, it covers the entire watershed area, from the highest ridge to the outlets of water bodies

1.5 Classification of Watersheds in India

Watersheds could be classified into several groups depending upon the mode of classification. The common modes of categorization are the size, drainage, shape, and land use pattern. Based on size, generally a workable size of around 500-100 hectare is preferred.

Table :1 Size of watershed

Unit	Size	Unit	Size
Region	Above 300	Watershed	0.5 to 2
Basin	30 to 300	Sub watershed	0.1 to 0.5
Catchment	10 to 30	Milli watershed	0.01 to 0.1
Sub Catchment	2 to 10	Micro watershed	0.001-0.01

Note: Classification of hydrological units (In Lakh hectare)

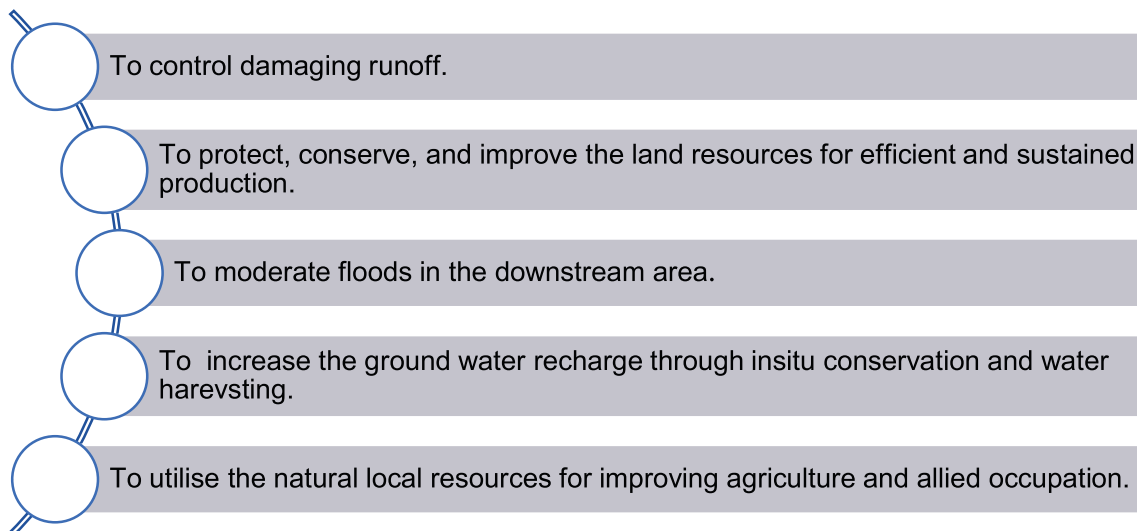
Table :2 Fast facts about watershed area of Rajasthan state

Particulars	Data	Particulars	Data
Total no. of districts	33	Total area covered under pre IWMP schemes	43.13
Total no. of blocks	352	Total area covered under schemes of other ministry	46.42
Total number of micro watersheds	45026	Total area covered under PMSKY -1	45.86
Total geographical area	342.87	Total area proposed under PMSKY 2	7.69
Total untreatable area	75.33	Total area under assured irrigation	20.16
Net treatable area			104.26

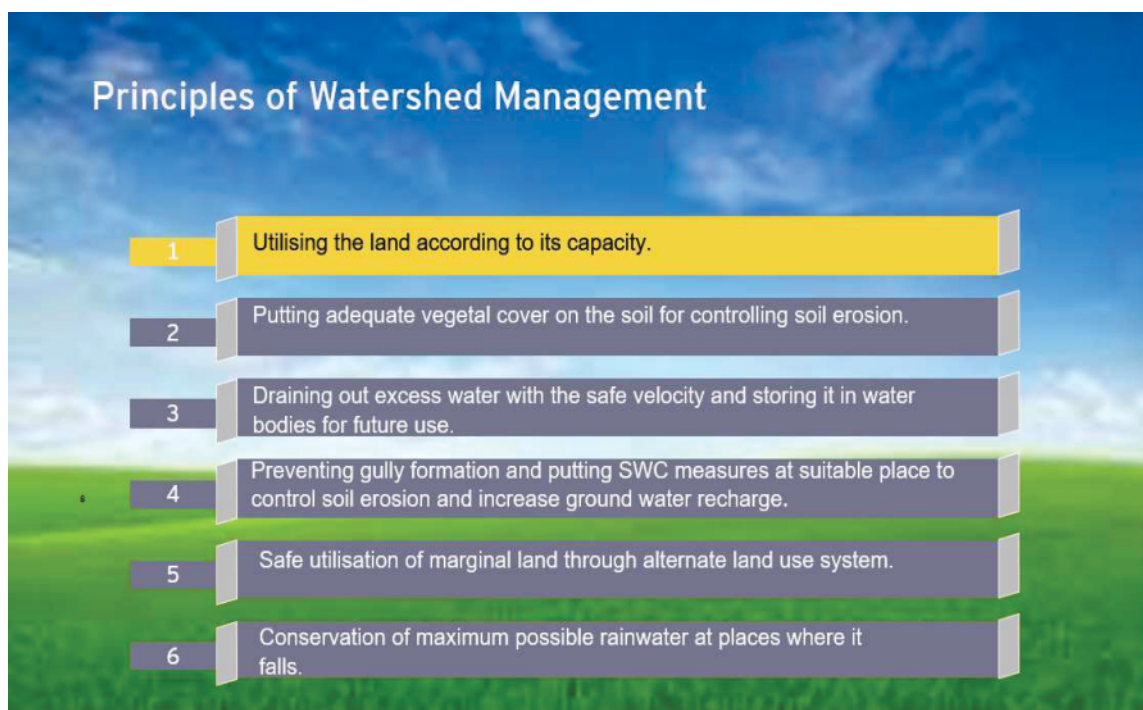
Source: Website of PMKSY, DoLR, MoRD

1.6 Objectives of Watershed Management

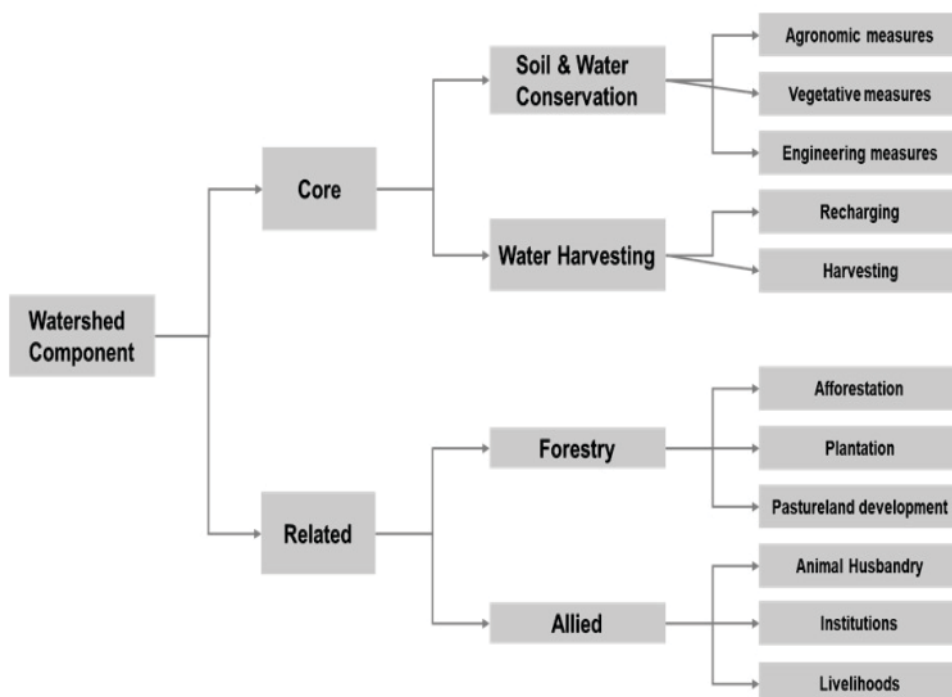
The broad objective of watershed management is “*proper use of all the available resources of a watershed for optimum production with minimum impact on natural resources*”.



1.7 Principles of Watershed Management



1.8 Components of a Watershed



1.9 Watershed Approach

Approach

- 1 Watershed as a hydrological unit select for development
- 2 Ridge to Valley approach for treatment (Top to down approach)
- 3 Treatment of rainfed areas to prevent land degradation and conserve Soil and water resources
- 4 Following integrated strategy for the optimal use of natural resources to achieve holistic development and sustained production for the wellbeing of people residing in watershed area.
- 5 Implementation of SWC works in conjunction with agriculture, animal husbandry, livelihood enhancement and other component.

1.10 Drainage System

Channels that flowing rainwater drains into are called drainage lines. Gullies, streams, and rivers are all drainage lines. The water flowing through several small gullies make a small stream, many small streams combine to make a larger stream and these larger streams flow into a big rivulet and rivulet flow into a river and so on. The smallest stream is called the first order stream. Two 1st order streams join to make a 2nd order stream. Similarly, two 2nd order streams join to make a 3rd order stream and so on.

Figure 4: Stream order



Chapter 2: Rajasthan Forestry & Biodiversity Development Project (RFBDP)

2.1 Need for the Project

Soil and water are the most important natural resources that meet all human needs and protect the environment and the civilization. Ever increasing demands for land and water resources due to burgeoning population cause the degradation of these two precious natural resources. Land degradation is, therefore, posing, a serious threat to sustained agricultural production, which leads to poverty, migration, and jeopardizes food security not only for the present generation but also for the future generations. The eastern part of Rajasthan is facing comparatively severe threats in terms of degradation of land, negative impact to biodiversity and water scarcity.

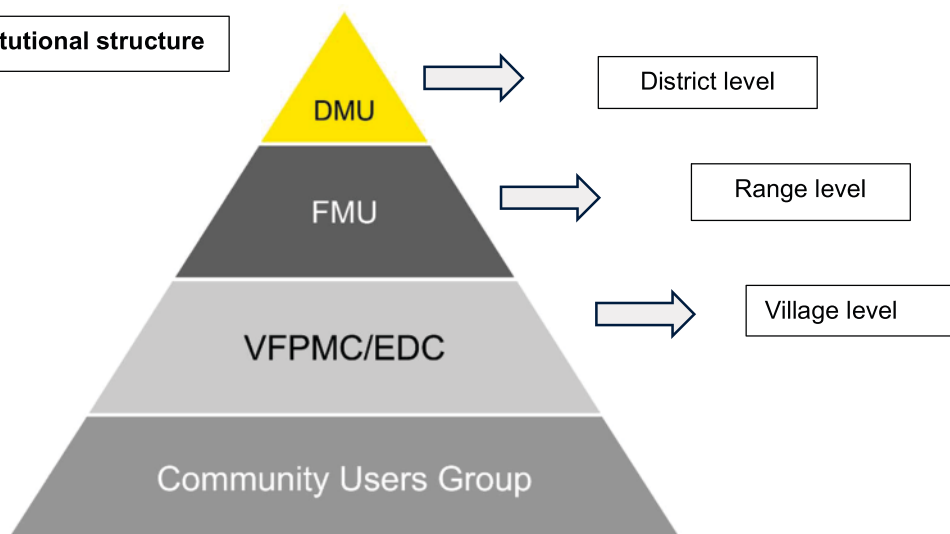
Considering the challenges and accomplishments of earlier Externally aided projects (EAP) undertaken by the forest department and looking to the substantial opportunities for implementing soil and moisture conservation efforts in the eastern area of Rajasthan to address the challenges of land degradation and water scarcity, Soil & Moisture Conservation (SMC) component has been included in the Rajasthan Forestry & Biodiversity Development Project (RFBDP). The Forest Department has dedicated a substantial budget to implement a range of Soil & Water Conservation (SWC) measures, including the construction of water harvesting structures, check dams, silt detention dams, gabions, percolation tanks, and bunds. The launch of these SWC efforts is aimed at increasing water accessibility and combating soil erosion within the designated project zones.

2.2 About RFBDP: At A Glance

- Financial aid: The French Development Agency
- Project coverage : Thirteen districts of Rajasthan
- Project duration : Eight Years
- Components : Afforestation, Agro Forestry, Soil & Water conservation, Biodiversity conservation & Development, Livelihoods, Capacity building and community Mobilization
- Project Implementing agency : Forest Department

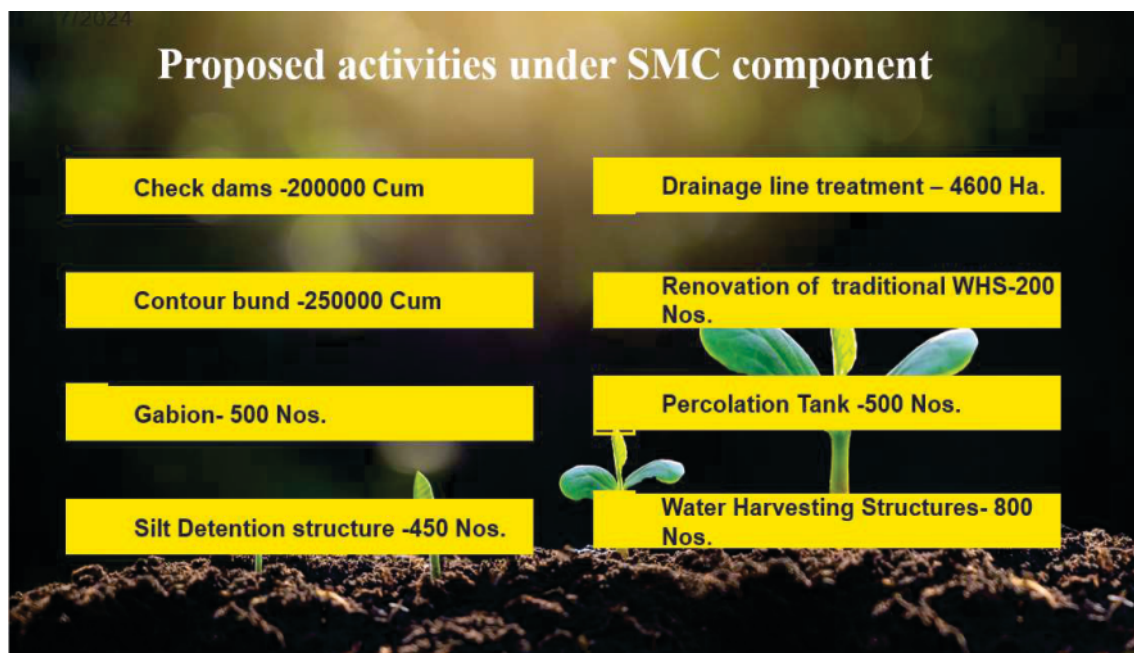
Goal	Objectives	Focus Area
➤ To promote the conservation of plant species diversity and increase the green cover. ➤ To improve the soil and moisture condition of degraded forest areas, pasturelands and other non-forest areas by soil moisture conservation work. ➤ Conservation of Biodiversity and Reduction in Man Animal Conflict. ➤ To maintain capacity of ecosystems to deliver goods and services and support livelihoods.	➤ Protect and develop natural forests of Project area ➤ Improve the conservation status of threatened taxa ➤ Restore grasslands in arid regions for fodder management and enhancing carbon sequestration ➤ Improve the biological diversity and preservation and restoration of habitats including wetlands ➤ Strengthen forest administration, community organisations, livelihood, and other stakeholders' management to ensure sustainable forest management.	➤ Protection and Development of natural forests of Rajasthan through appropriate afforestation models and implementing required Soil and Moisture Conservation measures. ➤ Enrichment of old plantations . ➤ Development of Plant Micro Reserves (PMR) ➤ Protection, development and conservation of Sacred Groves (Oran) ➤ Development of wildlife areas for reducing man animal conflict. ➤ Livelihood promotion ➤ Community Mobilisation

Figure 5. Institutional structure



A total of 10 SWC interventions have been proposed in the RFBDP. These interventions come under category of non-arable land development, drainage line treatment, and water harvesting structures primarily aimed at in-situ moisture conservation, water conservation and water harvesting.

Figure 6: Proposed activities plan for SMC component



2.3 Need for the Technical Manual under the RFBDP Project

The Forest Department has a longstanding commitment to technical excellence in SWC measures. Recognizing the need for enhanced support, there is an opportunity to enrich guidance documentation and develop a comprehensive handbook tailored for field application. This initiative will better equip the department to navigate the distinct topographical, geomorphological, and hydrologic conditions pertinent to forest areas. By bolstering the technical capacity and human resources within the Field Management Units (FMUs), the department is poised to more effectively implement technical approaches and scientific procedures in their conservation efforts.

Recognizing the need for consistency, the PMU has initiated the creation of a technical manual to standardize procedures across FMUs. This manual will serve as a unified resource for the Forest Department, enhancing the effectiveness of SWC measures and supporting land development and biodiversity conservation with greater coherence and reliability.

2.4 About the Technical Manual

The manual comprises a structured set of sections that describe SWC measures. It outlines the fundamentals of Integrated Watershed Management, including basic knowledge of soil and water management/conservation, as well as procedures for planning, implementation, and of SWC measures.

Features

Easy : Both in Hindi and English language

Specific: Designed for specific interventions to project area

Adhere: Adhere to sound technical principles

Simple: Complete technical content articulated through visuals

Target Group

FMU : Rangers, Forester and Guard

The officers of forest department directly involved in planning and implementation of SWC measures.

DMU: DFO

The officers, who facilitate and guide the FMU in whole process

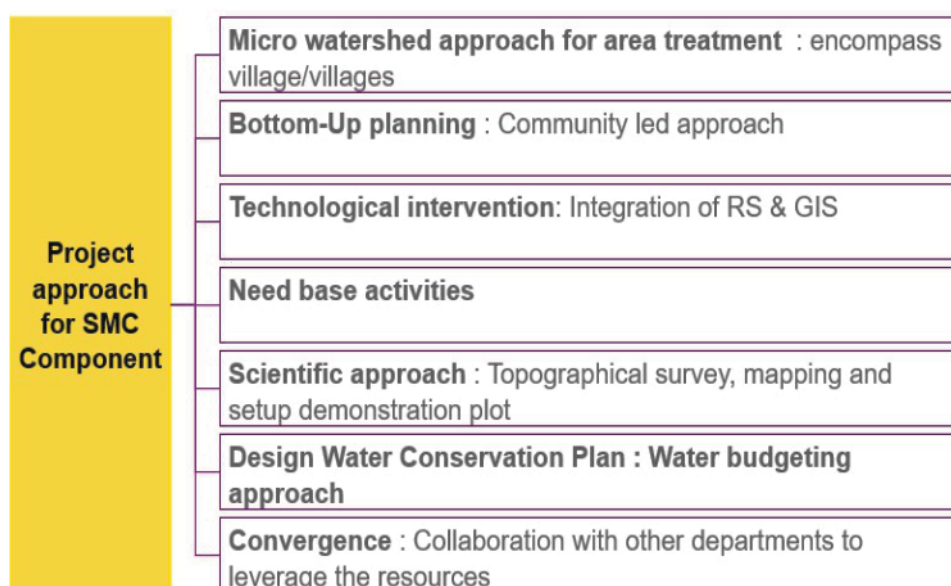
Objectives of Technical Manual

- To acquire a fundamental understanding of integrating watershed management with the basics of soil and water conservation.
- To comprehend the technical aspects of soil and water conservation (SWC) measures, including their application and suitable locations.
- To learn about the different types of data, their sources, collection methods, and the essential techniques for monitoring and evaluation.
- To assist and support the forest department in the implementation of high-quality and cost-effective SWC measures, ensuring proper workmanship and adherence to a watershed approach.
- To standardized the process for design of Water Conservation plan.

2.5 RFBDP Project Approach

RFBDP has selected the village as the fundamental unit for development to streamline the implementation of its project. This strategy aims to enhance the integration of project activities with the initiatives of other line departments and align with the government's overarching development policies. Nevertheless, when it comes to the intervention of soil and water conservation measures, *a micro-watershed approach would be adopted*. To facilitate this, a base map for planning will be created by superimposing various maps—contour, drainage, slope, and soil—onto the cadastral map. This process will involve adjusting the scales of these maps to ensure uniformity for accurate superimposition.

Figure 7: RFBDP approach for SMC component



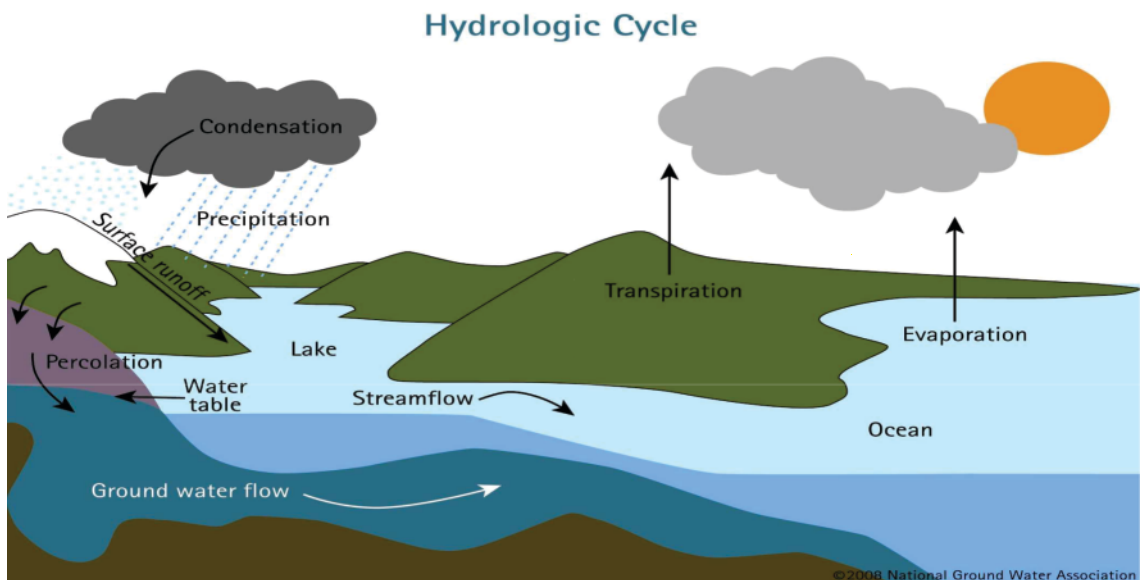
Chapter 3: Hydrological Cycle

Understanding the hydrological cycle is important for better planning and implementation of any watershed project. It helps in comprehending water resources, the process of water movement, and the importance of each step.

3.1 What is the Hydrological Cycle²

The hydrological cycle is the sum of all the processes in which water moves from the land and ocean surface to the atmosphere and back in form of precipitation. It is also known as *water cycle*. In the atmosphere water occurs in the form of vapour and on the surface as snow, ice or as water. Below the earth surface, it occurs as soil moisture, and ground water. The major processes of the hydrological cycle are precipitation, infiltration, runoff, evaporation, and evapotranspiration.

Figure 8: Hydrological cycle



3.2 How Does the Hydrological Cycle works?

Surface water evaporates from the energy of the sun. The water vapor then forms clouds in the sky. Depending on the temperature and weather conditions, the water vapor condenses and falls to the earth as different types of precipitation (rain, snow, sleet, hail). Some precipitation moves from high areas to low areas on the earth's surface and into surface water bodies. This is known as surface runoff. Other precipitation seeps into the ground and is stored as groundwater.

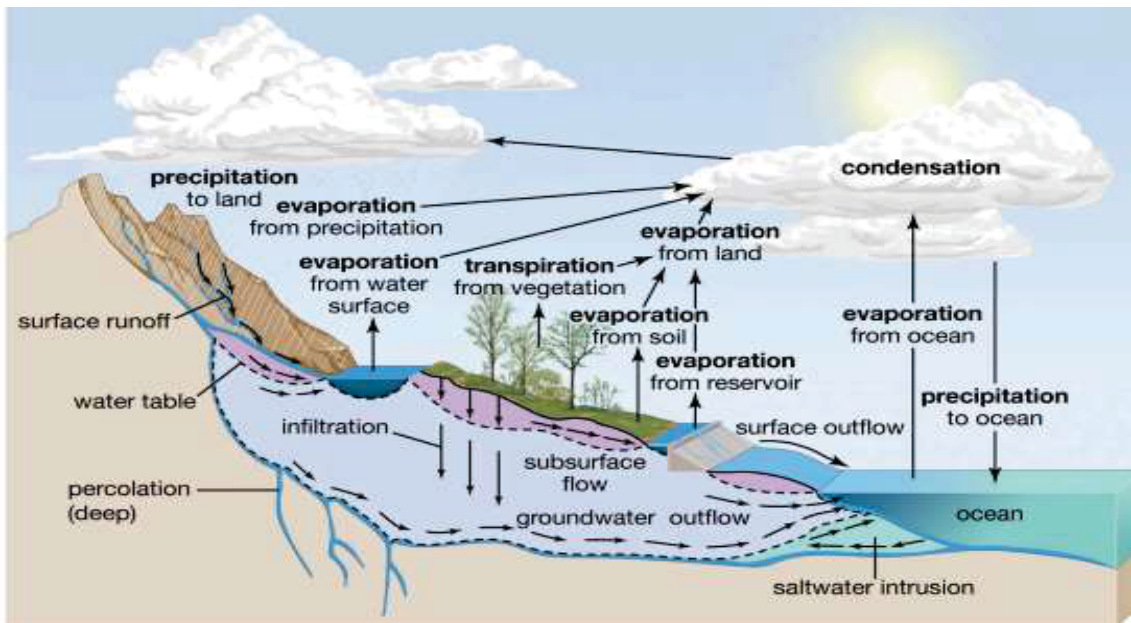
In the hydrological cycle³, there is no water gained or lost, but the amount of water available to sustain life on earth may fluctuate, mainly because of variations in the delivering system of

² The hydrological cycle, <https://wellowner.org/resources/groundwater/the-hydrologic-cycle> accessed on 22 July 2024

³ Hydrological cycle process, <https://www.britannica.com/science/water-cycle> accessed on 22 July 2024

precipitation. These variations can cause recurrent droughts condition, which is one of the major constraints in agriculture.

Figure 9: Process of Hydrological cycle.



3.3 Water Balance Identity

Precipitation (P) that falls is partly absorbed by the surface of the soil and is held as stored soil moisture (ST). The water that flows over the land is called surface runoff (RO). Part of the rain that percolates into the soil goes deeper and merges with the stock of groundwater as groundwater recharge (GW). Evaporation (E) takes place from all wet surfaces exposed to the atmosphere. Plants drink up a portion of soil moisture for their consumptive use and ultimately transpire it to the atmosphere while producing biomass. In areas with vegetative cover, water movement into atmosphere takes place both from the leaves (transpiration) and from the wet surface below vegetation (evaporation). It is difficult to separate the two. The combined impact of this evaporation and transpiration is called evapo-transpiration (ET). The water balance identity can, therefore, be written as,

$$P = E + ET + RO + GW + ST$$

3.4 Runoff in the Hydrological Cycle

The figures below briefly mention the stages of hydrological cycle and types of runoffs.

Figure 10: Stages of hydrological cycle

Evaporation	Condensation	Precipitation	Interception	Infiltration
Evaporation is the primary pathway that water moves from the liquid state back into the water cycle as atmospheric water vapour	Condensation is the change of the state of matter from the gas phase into the liquid phase and is the reverse of vaporization.	Precipitation is any product of the condensation of atmospheric water vapour that falls under gravitational pull from clouds.	Interception refers to precipitation that does not reach the soil, but is instead intercepted by the leaves, branches of plants and the forest floor.	Infiltration happens when water soaks into the soil from the ground level. It moves underground and moves between the soil and rocks.



Runoff in Hydrologic cycle

Surface Runoff

- ▶ Also called overland flow .
- ▶ Surface runoff is the water which travels over the ground surface to a drainage channel.
- ▶ This can occur when the ground is saturated or when the rate of precipitation exceeds the rate at which the ground can absorb it.
- ▶ Surface runoff is the rapid flow of water over the land surface.
- ▶ Surface runoff also includes that precipitation that falls directly on water flowing in the channel.

Interflow

- ▶ Also called subsurface storm flow.
- ▶ Surface water that infiltrates the surface layer and moves laterally beneath the surface to a channel.
- ▶ Interflow might occur in shallow soils filled and loosened by tree roots, rock debris covering the ground surface, or surface soils loosened by any cause.
- ▶ Interflow does not move as rapidly as surface runoff

Direct runoff

- ▶ Usually considered to be the sum of surface runoff and interflow.
- ▶ Direct runoff is frequently equated with surface runoff

Baseflow

- ▶ Baseflow, refers to the slow, steady flow of water from the ground into streams and rivers.
- ▶ It comes from the gradual release of water stored in the soil and in underground aquifers.
- ▶ Baseflow tends to sustain streamflow during dry periods when there is little or no surface runoff.
- ▶ It is the flow contributed to the stream/channel by ground water.

3.5 Four Waters Concept

Hanumantha Rao developed an innovative method of watershed management, known as the “*Four Waters concept*” which provides a comprehensive mechanism for rainwater harvesting by capturing surface runoff right from upper reaches, which resulted in increasing groundwater levels and to retain soil moisture. This technique is based on proven aspects pertaining to five scientific disciplines namely, agriculture, soil conservation, groundwater, surface water and geo-engineering.

This model was successfully implemented in Telangana and Andhra Pradesh and recently in Rajasthan in MJSA. He focused on earthen works (excavation works) and vegetative measures. There is no cement work required for concrete, masonry, plastering etc. Four water concepts focus on mini percolation tank, sunken gully pits, CCT, ST, contour bunds, percolation tank and sub surface dam.



Four Waters Concept	Current Approach
Innovative approach which provides a comprehensive mechanism for rainwater harvesting by four waters	Not following as such any comprehensive approach
Cost per hectare is very low	Cost per hectare is comparatively high
Focus on only earthen and agronomic and vegetative measures. No cement work	Focus on masonry work. Most of the structure are constructed through use of cement
More environment friendly	Comparatively less
More community led participatory approach	Comparatively less
No contractor involved	Contractor involved

Chapter 4: Soil Erosion

This chapter provides a concise overview of soil erosion, detailing its various types, manifestations, and the significant losses it causes. Despite considerable efforts to combat land degradation, the persistent challenge of soil erosion is still deeply concerning. The support from international funds, governmental initiatives, and corporate projects is insufficient in isolation; it is imperative to raise public awareness about the contributing factors of soil erosion to effectively address this environmental concern.

4.1 Introduction to Soil Erosion

About Soil : Soil is the uppermost weathered and disintegrated layer of earth crust, which is composed, of mineral and several organic matters. This is most important natural resource for sustainability of agriculture and our surrounding environment.

Soil erosion status at a glance

53%

Of the total geographical area of 328 M Ha is affected by Land degradation.

18 & 15 %

This is extremely serious because India supports 18% of the world's human population & 15 % of World livestock population.

2.4%

But India has only 2.4 % of World Land area

What is Soil erosion

This is a natural process. It is defined as detachment and transportation of soil particle from one place to another through action of wind, water in action or by beating action of raindrops

Impact of Soil erosion

- it affecting soil quality (loss of organic matter and mineral content).
- Promote land degradation.
- Sedimentation in reservoir.
- Hamper agriculture productivity.
- Negative impact on environment

Erosive agents

Wind, Water, Animal, Human, Ice, Plant

In Rajasthan⁴, 67% of the area is affected by land degradation and/or desertification. Wind erosion (44.2%) is the maximum contributor followed by water (11.2%), vegetal degradation (6.25%) and salinization (1.07%)

Out of 19029 hectares of cultivable area in Rajasthan which got affected due to soil erosion, 10,268-hectare land got affected in 2018-19 a government of India data sourced from desertification and land degradation atlas of India (SAC 2021) stated. Eastern Rajasthan which covers majority of the RFBDP project area, water erosion induced erosion is a severe problem. The figure below mentioned about the stages of erosion and area covered in it.

⁴ Soil Erosion and Desertification: What are their Implications on Agricultural Land of Rajasthan in International Journal for Modern Trends in Science and Technology, 7(10): 92-99, 2021 accessed on 15th July 2024

Figure 11: area under different classes of water erosion in eastern Rajasthan

Erosion class	Range of soil loss (t ha ⁻¹ yr ⁻¹)	Area ('000 ha)	Area (%)
Very slight	< 5	1341.5	09.98
Slight	5-10	3128.7	23.28
Moderate	10-15	2600.0	19.35
Moderately severe	15-20	1578.4	11.75
Severe	20-40	2786.9	20.75
Very severe	40-80	1323.0	9.85
Extremely severe	>80	678.6	5.05

4.2 Types of Soil Erosion

Soil erosion can be classified into two types.

Figure -12 Types of soil erosion

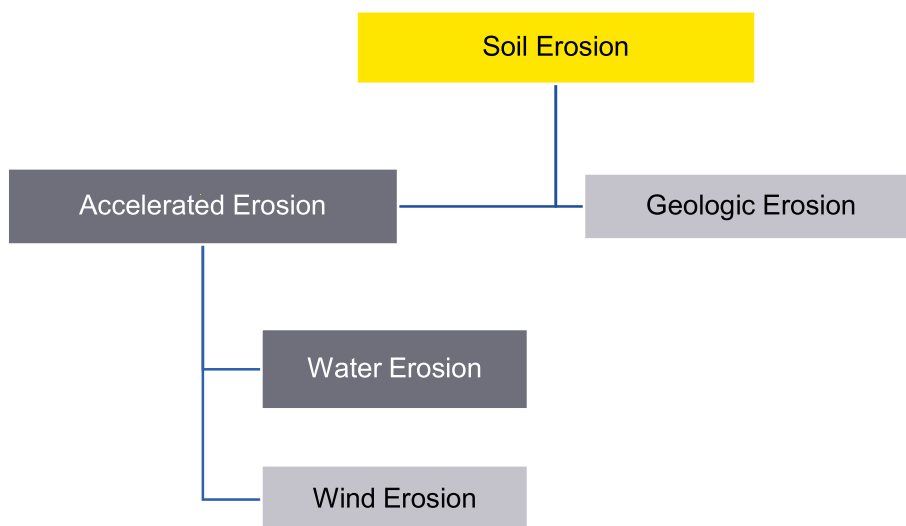


Table 3: Difference between erosion

Geologic Erosion	Accelerated Erosion
It is also known as natural erosion	This is not a natural process.
This takes place under the cover of vegetation due to the action of water and wind.	This takes places when the vegetation is removed and land is put under cultivation, the natural balance between soil building and soil removal is disturbed.
Rate of soil erosion is very slow, and it is compensated by formation of new soil by natural weathering process.	Removal of surface soil takes place much faster rate than the natural process.

Figure 13: Various factors influence soil erosion

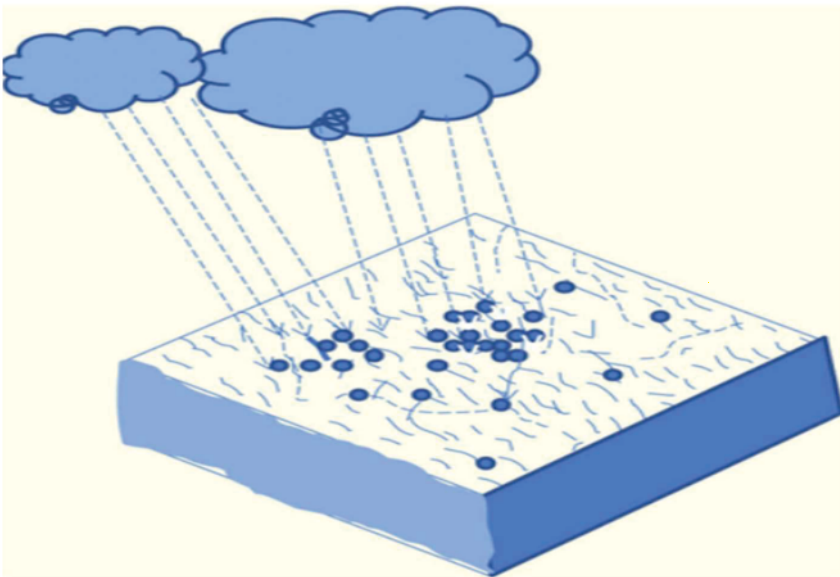
4.3 Stages of Soil Erosion

Rainfall and runoff produce four main forms of soil erosion. This would be classified as

1. Splash erosion.
2. Sheet erosion
3. Rill Erosion
4. Gully erosion

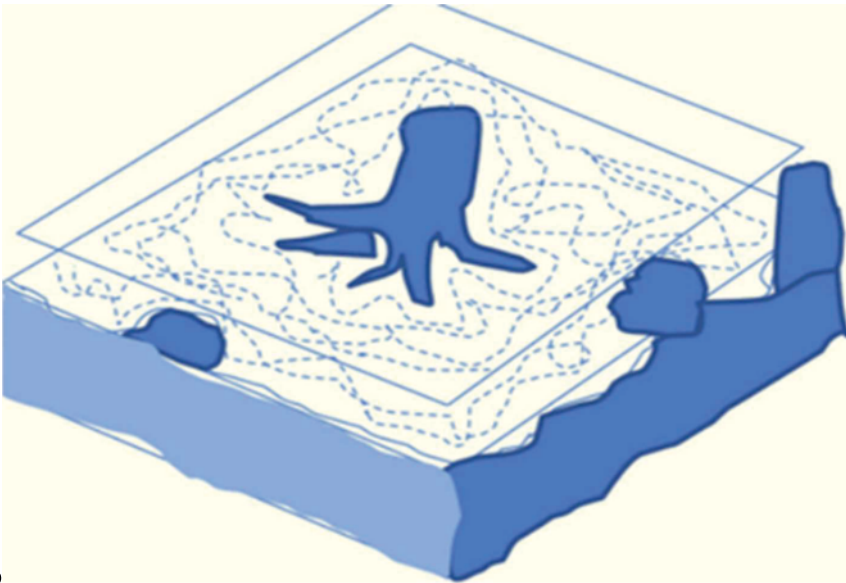
Splash Erosion

- ▶ First stage of erosion process.
- ▶ It occurs when raindrops fall on the soil.
- ▶ The soil begins to break into the individual particles, which can easily runoff when water is introduced.
- ▶ It mainly happens due to disposed/naked/bare/ uncover soil surface.



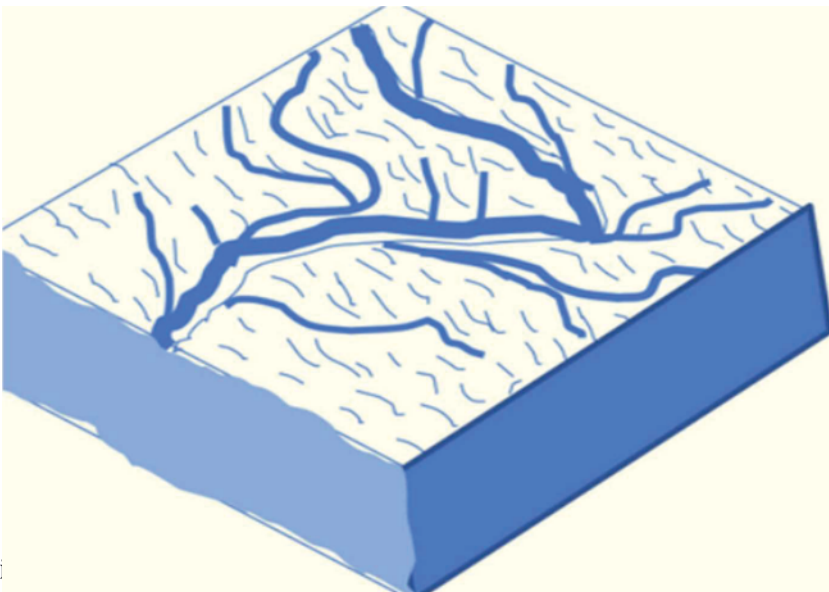
Sheet Erosion

- ▶ It occurs when heavy rains occur, or the shallow surface begins to runoff from water flow.
- ▶ It is removal of uniform layer of soil from the land surface by the beating action of rainfall.
- ▶ This erosion is extremely harmful to the land as the process is slow.



Rill Erosio

- ▶ This is an advanced stage of sheet erosion.
- ▶ Rills are shallow drainage lines and begin to erode the soil.
- ▶ This is removal of soil by running water with the formation of shallow channel.
- ▶ Rill developed due to concentration of runoff down the slope and if neglected.
- ▶ The rills are generally not more than 30 cm deep.



Gully Eros

- ▶ This is last and most advance stage of erosion.
- ▶ If the rills are not tended to, the erosion will continue to form gully erosion.
- ▶ This is removal of soil by running water, with the formation of channel.

- ▶ Cattle path, cart track, depression etc are potential sources of erosion.

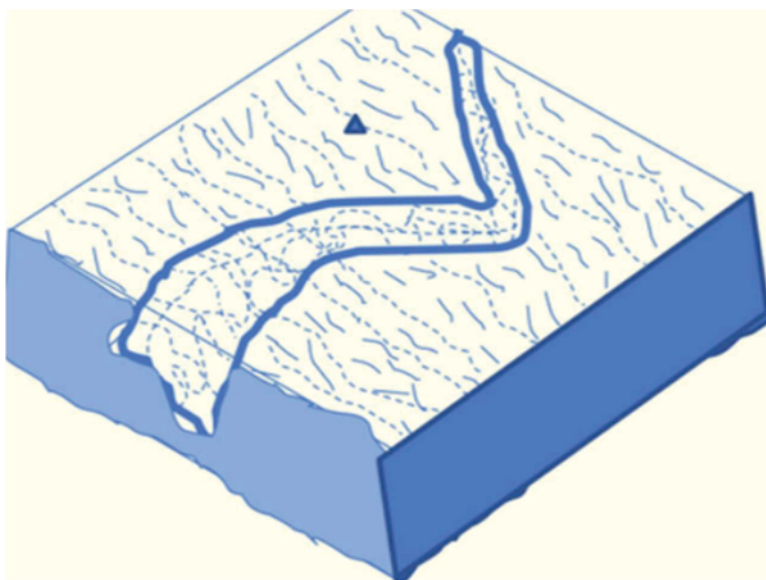
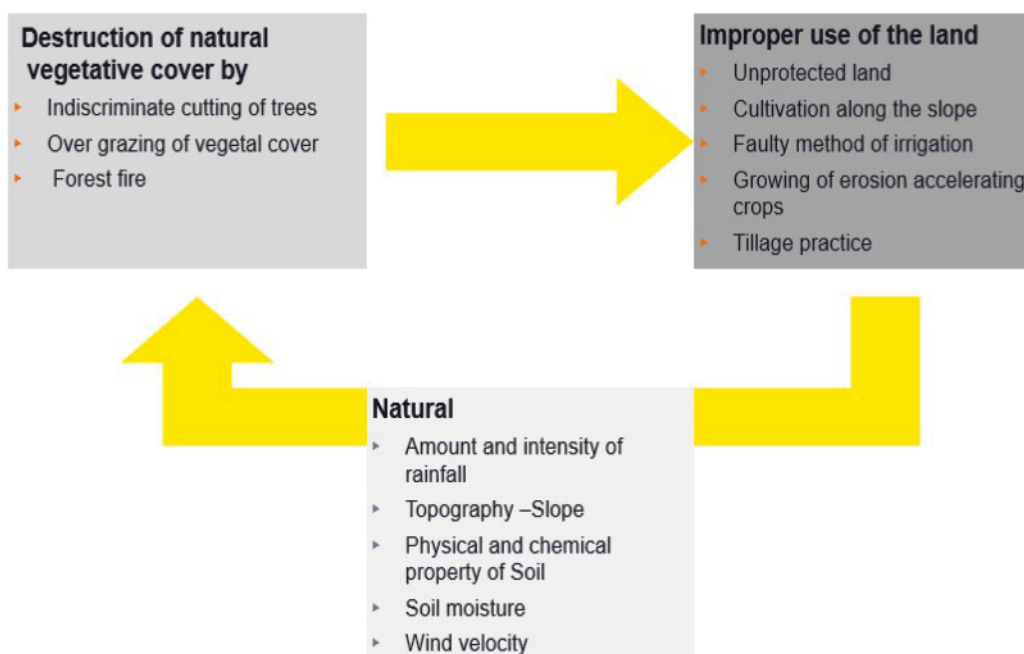


Figure 14: Images showing splash, sheet, rill and Gully erosion.

4.4 Effects and Losses Due to Soil Erosion

The image below shows about the natural and artificial factors contributing to soil erosion.



Loss of productive soil.

Formation of sand dunes.

Deposition of sand on productive fields.

Silting of water bodies and dams.

Silting of irrigation and drainage channels

Lowering of water table.

Fragmentation of land.

Chapter 5: Planning for Soil & Water Conservation Measures

This chapter outlines the mapping and surveying steps involved in the planning of any SWC measures. During the preparatory phase, the Project Facilitation Team (PFT) will engage in social mobilization and institutional development activities. The Village Forest Protection and Management Committee (VFMP) or Eco Development Committee (EDC) would be strengthened in the project area. The RFBDP has proposed a specific institution, namely the Community Users' Group (CUG), solely for SWC interventions in this project.

5.1 About Soil & Land Use Survey of India (SLUSI):

Previously known as All India Soil & Land Use Survey (AISLUS). It provides practitioner with access to resource material for use in watershed management planning.

Soil & Land Use Survey of India (SLUSI) is an apex organisation promoted by ministry of Agriculture & Farmers Welfare. SLUSI is primarily engaged in conducting soil survey of different intensities in order to provide scientific database for development programmes, encompassing soil & water conservation planning, watershed development & scientific land use planning. SLUSI well equipped with Remote Sensing techniques, Geographic Information System (GIS), Image Analysis along with modern facilities of soil analysis and cartography laboratories for acquisition of soil and land information and for the development and management of digital spatial database.		
Digital micro watershed atlas of India	Land degradation mapping	Soil resource mapping
Purpose : To identify and characterise each micro watershed in the country with specific spatial extent and unique national code. Scale : 1:50,000	Purpose : - To generate scientific information on degraded lands using Remote Sensing Techniques - Development of degraded land calls for their reclamation and proper management with specific information about their nature, extent, spatial distribution and magnitude of the problem. Scale : 1: 50,000 - Four components have been considered for legend construction for systematic mapping namely - Kind of Degradation - Severity of Degradation - Major Landform - Major Land Use	Purpose : - To prepare Soil map on 1:50000 scale using toposheets and satellite remote sensing data - To generate district-based information on nature, extent and potential of soil resources - To develop a methodology to reduce items and manpower required for ground surveys - To delineate soil mapping units using uniform legend.
Detailed soil survey		
Purpose : Is to generate detailed information on soil and land characteristics of the priority area using cadastral maps of various scales (1:4K/8K) or large-scale aerial photographs (1:15,000). Scale : 1:10000 .		

5.2 Mapping in Watershed Management

Mapping is a very important instrument for spatial display of information. Effective planning could be done through quality documents, including data and mapping. Here we will discuss on mapping in planning of Soil & water conservation measures.

What is a Map ?

- ▶ A map is a representation of the earth or its parts on paper or a plane surface and drawn to a scale. Direction, legend, and scale are three important attributes of a map.
- ▶ Let's understand scale by one example: 1:50,000 will be written in words as follows: "1 cm on map is equal to 50,000 cm or 500 m

Mapping

- ▶ Mapping is a key step in the planning of SWC measures. Practitioners use various types of maps. Some maps are readily available with the resources, while others need to be created by superimposing two or more maps through the digitization process. Below is a brief overview of mapping , types of map and steps provided.

Importance of mapping in watershed

To identify the location of the project area through the demarcation process on the map.

To measure the watershed /catchment area through calculation

To determine hydrological and geo morphological parameters

To assist in decision making by identifying the types of SWC interventions needed.

To illustrate the treatment plan on the map

To display the treated area on the map

To get know about topographical features of watershed area

5.3 Types of Maps

Sketch map	Cadastral map	Thematic map	Topographic	LULC map
Sketch maps are prepared to provide a quick overview of the important aspects of the area. These maps have legend and direction but may not always be drawn to scale. Social map and resource map made during participatory rural appraisal (PRA) are the examples of these maps.	A cadastral map comprehensively represents land parcels within a designated area. It's often referred to as a Bhu Naksha, or area map. It is released by revenue department. These maps are made by revenue department and maintained by Patwari. These are usually drawn to a very large scale, such as 1:4000. This map describe boundaries of plot, ownership and type of land.	A thematic map is a type of map that portrays the geographic pattern of a particular theme. Thematic map is also called special purpose, single topic map. A thematic map focuses on the specific topic or phenomenon such as vegetation, rainfall, topography, population density etc. Contour map, slope map, soil map, drainage map are some thematic maps use in mapping for planning of SWC structures.	These maps are prepared after the topographic survey. These maps provide information about the lay of land. Topo sheet is very important map use in planning. It provides information on relief of land using contour line, drainage, water harvesting structure, infrastructures, road, railway line, political boundary, settlement etc.	LULC map represent the current land use pattern of the watershed area. LULC refer to categorization of landscape, ownership of land and simply put what cover the surface of earth and how land is used.

Various types of maps are important in planning because they are valuable tools for understanding and managing our SWC assets.

They provide insights about the characteristics of the watershed area and identify the areas that are vulnerable to soil erosion and sedimentation, helping us to identify the types and locations of SWC measures.

Contour map: Contour map is a map showing curve line of same elevations. Contour map is very useful for the purpose of watershed planning

A drainage map: which displays the order of streams, helps to identify the types and locations of Soil and Water Conservation (SWC) interventions that can be selected.

A **slope map** indicates the gradient of the area and assists in identifying appropriate SWC interventions. A soil map reveals the types of soil groups, aiding in the identification of suitable locations for larger structures, particularly water harvesting structures.

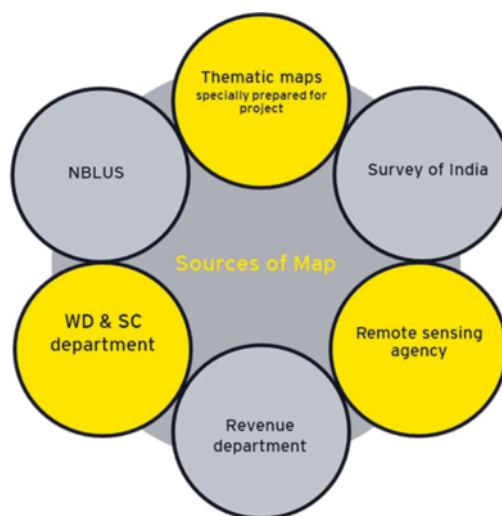
A **land use map** presents the status of land use, which is useful for determining the types of interventions needed, such as establishing pastureland on community land or constructing farm ponds on private land.

Soil map: This map shows the distribution of soil types in the area and its boundary. Soil types include sand, clay, sandy clay, sandy silt, silty clay etc.

Uses of Contour Map

- ▶ Facilitate the understanding of terrain characteristics within the watershed, such as whether it is flat or undulating, a ridge or valley, a hill, or a depression, etc.
- ▶ Facilitate in identification of proper SWC measures and their location, that are most economical and suitable such as Anicut, percolation tank, check dam etc.
- ▶ In computation of the storage capacity of a reservoir, fetch length of waterbody and volume of earthwork involved.

Figure 15 : Sources of maps



5.3.1 How to Prepare A Composite Map

The preparation of a composite map is a fundamental step in watershed area treatment planning. The following steps should be taken to create a composite map:

- ▶ Collect the necessary maps and data from the sources listed in the table below.
- ▶ Use GIS and remote sensing technologies to produce the required maps, tailored to the specific needs of the project.
- ▶ Carefully examine the scale and content of the maps and data to ensure they meet the information standards necessary for the final map.
- ▶ Update the map, refine the scale, and meticulously analyze all the maps.
- ▶ Construct thematic maps for specific project requirements by overlaying them on the base maps.
- ▶ Superimpose this composite map onto the village or micro-watershed map as needed

Table 4: Type of maps in planning of any SWC interventions

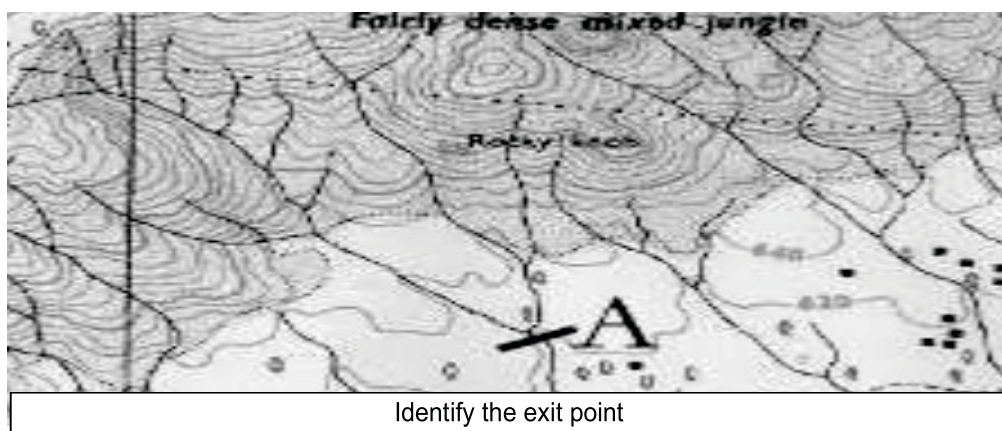
S. No	Name of Map	Scale	Source	Uses
1	Topographical (Topo) sheet	1: 25,000	Survey of India	Drainage, Type and order of stream, contour, land use, villages within watershed
2	Watershed Geo Coded map	1: 50000 scale	Watershed Atlas WD & SC Department	Milli & Micro watershed boundary
3	Remote sensed data	CartoSat 2.5 M	NRSA	Up to date drainage
4	Cadastral map (Khasra map)	1: 4000	Patwari Revenue department	Land records and ownership of land
5	Khasra girdavari		Patwari Revenue department	Land use and ownership of land

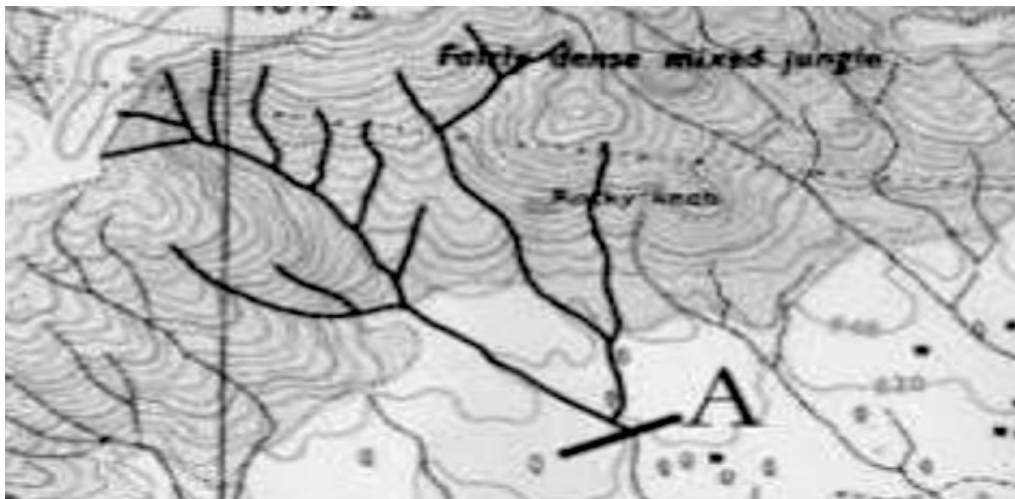
6	Soil Map		National Bureau of Land Use Survey and Planning	Type of soil,
7	Geology map	1:2,50,000	Geological survey of India	Geological information
8	Ground water map and data		Central ground water development board (CGWB)	Ground water strata and potential for development
9	Land use land cover map		Themes prepared at village level /micro watershed level	Help to identify the interventions
10	Present land use map			
11	Contour map			
12	Ground water well data			

5.4 How to Demarcate the Catchment Area

How to demarcate the Catchment for any SWC interventions	- Firstly, identify the point with respect to which the watershed is to be marked. - Secondly identify the exit point (point A) (outlet of watershed). - Mark out drainage lines of various orders, which drain into this common point. The simplest way to do this is to begin from the exit point and move along the drainage lines to its origin. - Beginning from the exit point, draw a line around the drainage system, enclosing all drainage lines which drain to point A, and leaving out other drainage lines which do not drain to point A. - This boundary line will terminate at the exit point. This line demarcating the watershed boundary is called a ridge line. In other words, a ridge line is an imaginary line joining all points of higher elevation in a selected watershed and separating the watershed from other watersheds. Since it never cuts across a drainage line, the defining feature of the ridge line is that water does not flow over it. - Ensure that the watershed boundary (the ridge line) never crosses any drainage line inside the watershed. If this has happened, be sure that it is a mistake and correct
--	---

Figure :16 Stages for demaraction of catchment area





Draw all drainage lines from exit point



Draw watershed boundary

5.5 Technical Surveying

Technical surveying is a process of determining positions on the Earth's surface and finding out the elevation of one location relative to another location whose elevation is already known. Surveying includes the determination of horizontal distances, differences in elevation, directions, angles, locations, areas, and volumes on or near the surface of the Earth.

5.5.1 Importance of Surveying in Soil & Water Conservation

Surveying assists practitioners with the following tasks and makes them simple and easier	
Creating a topographical map of the project area	Drawing contours
Design longitudinal (L) sections and cross sections of the area, which aids in decision-making for selecting the optimal site selection of SWC measure	Determining the precise length of structures
Calculating the distance, spacing between two structures, and measurement of size and shape of various structures	Internet of Things (IoT) specialists
Calculating the volume of earthwork required	Enhancing workmanship quality to maintain consistent elevation across different parts of a structure, which is crucial for large earthen dams and masonry structures to avoid level discrepancies.
Computing storage capacity, establishing the boundaries of a waterbody, and determining the fetch length of water harvesting structures	Optimizing the cost of construction.

5.5.2 Simple Survey Instruments

A frame, hand level, Abney level, and pipe level are small instruments used for surveying purposes to draw contours during the planning and implementation of SWC measures such as contour bunds, contour trenches, LSCD, etc.

GPS units (global positioning systems)	
	GPS is used to track the location in two dimensions (latitude and longitude) as well as altitude of the object. GPS is working by using satellite to triangulate the signals.

Hand Level



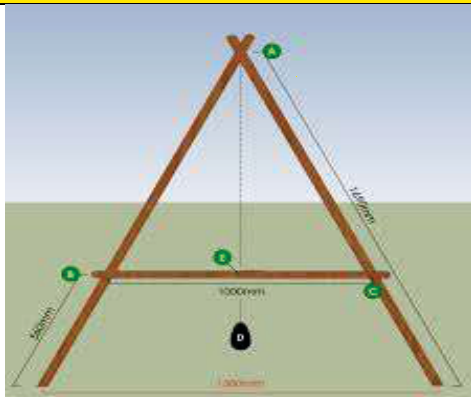
- It is a simple instrument having spirit level inside a telescope.
- It is used to compare multiple point level against the reference point.
- It is suited for rough levelling such as running of guidelines for contour farming or for approximate determination of land slope.
- It is not a very precise method.
- It is used by simply hold it and sighting through the eye piece like the pair of binoculars.

Abney level



- Abney level is same as Hand level with additional feature of Clinometer or equipped with a graduated arc.
- It can be used for measuring levelling as well as gradient or angle of slope.
- When it is used as a level the index of the vernier is set as zero.
- Common uses: In topographic surveying, to determine slope to horizontal distance calculation, contour tracing and relative heights. In forestry, for tree height measurement.

A -Frame



How to measure the slope

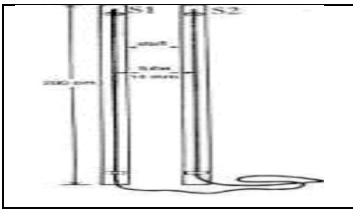
To calculate the slope, we need both the height and the horizontal interval. First, place the A-frame on a level surface and then on a tilted surface, measuring both dimensions. Calculate the slope by dividing the height by the horizontal interval and then multiplying by 100.

This is a simple levelling instrument can be used for marking contour lines. The simplest form of an A-frame is two similarly sized wooden or steel poles laid up against one another and arranged in a 45-degree or higher angle. A third pole is kept horizontal, connecting these two poles. These poles are then tied together with rope or welded together. In the cross bar a plumb with string is hung at A. A centre point is marked on the cross bar by standing the A frame in one position.

How to use A frame:

- Select a starting point and mark on the field.
- Hold one leg of the A frame at the marker and rotate the other leg until plumb is bubble is in the centre of the level tube.
- Stop and mark the point of the rotated leg.
- Repeat the same action by rotating the first leg 180° around the second until the plumb line is at the centre again and mark the new point again.
- Continue the process across the slope until the contour line completed.

Pipe level

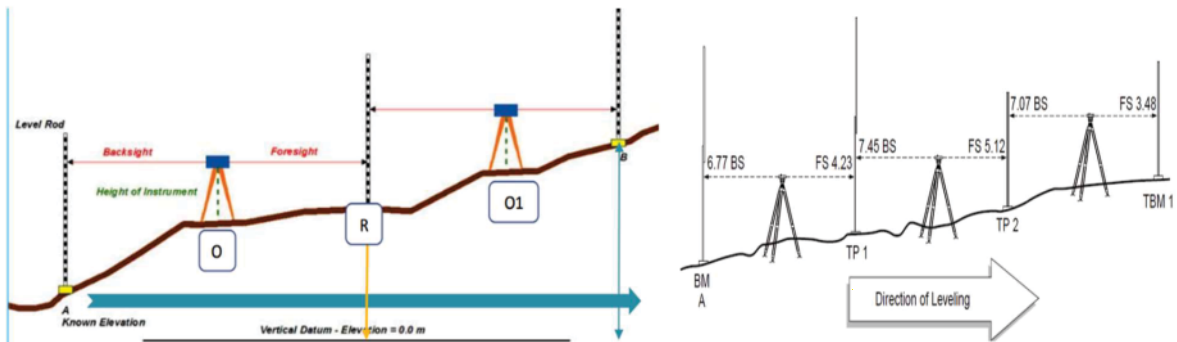


- Pipe level is a simple instrument made of a pipe fastened on two wooden staff. The scale is marked in each staff.
- Difference in level of both pipe shows the elevation.
- Same reading of water level in both the scale shows the land with same elevation, fixed the pegs on these points, and join to draw a contour line.

5.5.3 Levelling

It is a method of calculating the difference in elevations or levels between two points on the earth's surface. It involves measuring vertical distances using an optical or digital levelling instrument, such as a level or a theodolite, and a levelling rod.

Figure:17 Describing backsight, foresight, turning point and benchmark



Levelling : Basic terminology in surveying

Reduced level (RL)

It refers to equating elevations of survey points with reference to a commonly assumed datum. It is a vertical distance above or below the datum plane

Benchmark

Benchmarks is a fixed point of known elevation above datum

Backsight (BS):

First reading taken after the levelling instrument is setup and levelled. Backsight is taken on the point of known reduced level as on the benchmark or a change point.

Foresight (FS):

This is the last reading taken at every instrument station before moving the level.

Intermediate Sight (IS):

This is any reading taken at an instrument station between the backsight and the foresight.

Turning point (TP):

This point at which both a foresight and a back sight are taken before moving the staff.

Height of instrument

This is calculated by adding the back sight reading to the reduced level.

5.5.4 Surveying Instruments

Dumpy level and Auto level are levelling instruments and are used for measuring the height difference (elevation). Auto level is the advance version of dumpy level.

- An auto level, also known as an automatic level, is a surveying instrument that uses a suspended compensator to automatically level itself. This allows for quick and accurate measurements of height differences over a large area.
- A dumpy level, also known as a builder's level or a tilting level, requires manual levelling using foot screws.
- It is a simpler instrument compared to an auto level.
- For auto level, bubble can be adjusted from any angle with any 3 of the screws available. This is not in the case of dumpy level.
- Accuracy in case of auto level is higher than dumpy level.
- In the dumpy level survey, staff reading need to be adjusted as inverted level staff reading is seen in the eyepiece. In the auto level, no adjustment for staff reading is required as the actual reading is seen from the eyepiece.

Survey with dumpy level.

- Fix the dumpy level on the tripod.
- Level the dumpy by adjusting its 3 levelling screws so that the bubble is centered no matter in which direction you move the dumpy
- Adjust the focus of the telescope by rotating the focus screw.
- Place the staff at the spot whose reading you want to take.
- Take the reading of the elevation from the view finder.
- If it is not possible to take a reading then don't move the staff, this reading of the staff is known as "Foresight" or simply FS. At this point the position of the dumpy needs to be changed. Keep the dumpy level at new point and take the reading of the staff at same point. This reading is known as new B.S and find out the new height of instrument.



Tripod	
	Tripod is a portable device used to support and stabilize the surveying instrument. All tripods have three legs and mounting head to couple with surveying instrument. Tripods come in two types: metallic and wooden.
Measuring staff	
	A level staff, also called levelling rod, is a graduated wooden or aluminum rod. It is a kind of measuring rod of metal or wood used with a levelling instrument to determine the difference in height between points or heights of points above a vertical datum

Section B: Non-Arable Land Development Measures

Contents

- 6 Types of Soil & Water Conservation measures
- 7 Ridge area treatment : CCT, SGT, V-Ditch and Contour dyke
- 8 Contour bund
- 9 Plantation models

By delving into these chapters, practitioners will gain a thorough understanding about the SWC measures for treatment of non-arable land, enabling them to apply this knowledge in their conservation efforts.

Chapter 6: Types of Soil & Water Conservation Measures

6.1 Land Characteristics

Soil and water conservation involves protecting soil from degradation and loss by utilizing it within its capabilities and implementing necessary practices for its preservation and enhancement. Additionally, it aims to control soil erosion and maximize water retention.

The land use of the watershed is determined based on land use capability classification, purpose of land, erosion hazard, slope of land, soil type, and rainfall of the area.

Arable Land	Non-Arable Land
Land is suitable for agriculture purpose.	Lands which are not suitable for agriculture.
Agriculture lands under temporary crops, pasture, kitchen garden and temporary fallow.	Land suitable for forestry, pasture, afforestation, and wildlife
Land under capability class I to IV	Land under capability class V to VIII
Land with slopes less than 6 % and reside in lower reaches are often arable land.	Land with greater slopes and residing in upper and middle reaches are often non arable land.
Land with optimum soil depth	Stony, rocky, and very soil depth
Faces moderate and gentle soil erosion	Face severe and acute soil erosion

Drainage line is the line that passes from both arable and non-arable land. It usually starts in Hilly and non-arable areas from the ridge and end which is main drain at the valley of the watershed which is outlet.

6.2 Classification of SWC measures

Soil & water conservation measures (SWC) aim to reduce soil erosion and conserve water by utilizing the land within its best capabilities.

The SWC practices are based on the following principles.

- ▶ Reduction of raindrop impact
- ▶ Reduction in erosion
- ▶ Control of runoff and conserving measures
- ▶ Conserve in-situ moisture.
- ▶ Ground water recharges.

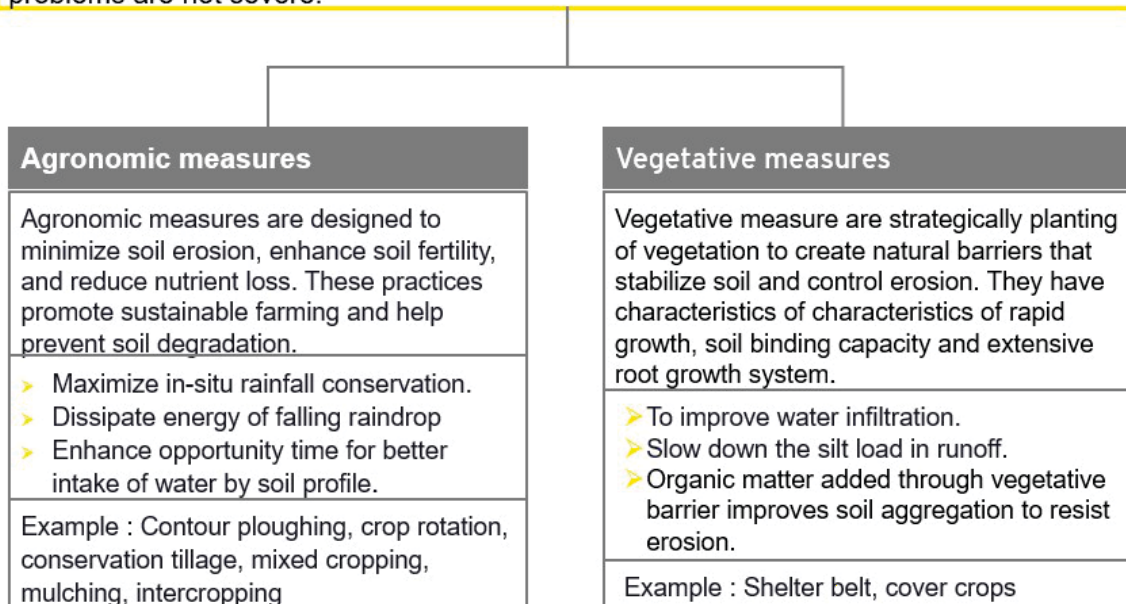
SWC measures are classified into two key categories based on characteristics.

1. **Agronomic and Vegetative measures:** These measures are adopted when the land slope is small (less than 2%) and erosion problems are not severe. Vegetative measures can also be adopted in combination with engineering measures.
2. **Engineering measures:** These measures are adopted when agronomic measures are not adequate to handle the runoff. These measures are adopted for more than 2 % of the slope.

In subsequent chapters, we will discuss engineering measures in detail and provide a brief description of agronomic and vegetative measures

Agronomic & Vegetative measures :

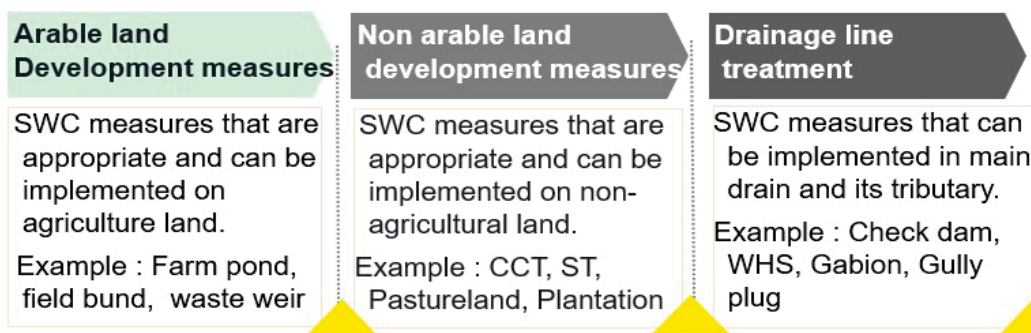
These measures are adopted when the land slope is less than 2 % and erosion problems are not severe:



The important principles to be kept while planning engineering measures are:

- Increase the time of concentration for allowing more runoff water to be absorbed and held by the soil.
- Break a long slope into several short ones for reducing the flow velocity below critical limits.
- Protection of drainage channels against damage owing to excessive runoff.
- Prevent excessive soil and water losses.

Figure 18: Types of SWC measures



Section B is focused on SWC measures for non-arable land development and plantation models only.

Chapter 7: Ridge Area Treatment

Watershed area can be divided into the three reaches. Upper reaches, middle reaches, and lower reaches. Watershed ridge area comes in upper reaches and these areas are generally hillocks or uplands with different slopes. These lands are with or without vegetation. Due to high slope speed of runoff is higher in the upper reaches compare to middle and lower reaches. Normally soil erosion is very high in upper reaches. In this chapter we will discuss about Continuous contour trench (CCT), Staggered trench (SGT), V-ditch and contour dyke as SWC measures for ridge area treatment.

7.1 Contour Trench (CCT & SGT)

Contour trench is a simple, low-cost method technique to check the velocity of runoff in ridge area of any watershed. In forestry development works, CCT and SGT are key interventions implemented in Assisted natural regeneration (ANR) and rehabilitation of degraded forest (RDF) models.

Although the model estimates of both interventions recommended fixed size and length, there is flexibility to adjust the dimensions according to specific requirement of the sites.

This is one of the important SWC measure to conserve moisture for plantation/grass seeding and check erosion.

What is It ?



- ▶ Contour trench is an excavated trench dug across the slope below the contour line so that its upper edge exactly coincides with the contour line.
- ▶ Types : Continuous contour trench (CCT) & Staggered trench (SGT)

Continuous Contour trench (CCT)



- ▶ When trench is continuous without any break in the length, it is called CCT.
- ▶ Slope : 3 to 10 %
- ▶ An equalizer is provided in the trench to prevent water from reaching an erosive velocity that is prone to causing soil erosion.

Staggered trench (SGT)



- ▶ These are the trenches dug in a staggered manner with interspace between them. These trenches are directly located below one another trenches following contour line.
- ▶ Slope : 10 to 30 %

Figure 19 : Images of CCT and SGT works constructed under MJSA-I in the Rajasthan





7.1.1 Location :

CCT	SGT
➤ Middle reach of watershed ➤ Degraded land/Hilly area /Hard strata ➤ Slope : 6 to 10 % ➤ Patches where old work trenches have filled with soil	➤ Upper reach of watershed ➤ Degraded land/Hilly area /Hard strata ➤ Slope : 10 to 25 % ➤ Patches where old work trenches have filled with soil

7.1.2 Functions:

- Contour trenches break the long slope into shorter one, reduce the velocity of runoff, and checking soil erosion.
- The rainwater retained in the trenches help in-situ moisture conservation.
- Water percolate into ground and benefits the better type of land for plantation and grass seeding .

7.1.3 How to design the contour trench?

It has become common practice to follow model design regardless of the specific design of the area. We should design the staggered trench according to our requirements to enhance the effectiveness and sustainability of the work.

Following are the steps for designing the contour trench.

Calculation of runoff: Calculate the runoff in the area considering rainfall data and intensity for at least the past 10 years.

Capture of runoff: Decide during designing how much runoff to capture; it should be 70% of the rainfall likely to be received in a day.

Decide the cross section of the trench:

- After deciding on the width and depth of the trench, we need to determine how long the trench should be.
- However, we must also consider that the trenches will fill up more than once during any period of rainfall. It depends on the type of soil.
- The more permeable the soil in which the trenches are dug, the more frequently the trenches will fill with water.
- Divide the amount of runoff (70%) by the cross-section and the number of refills to calculate the length of the trench.
$$\text{Length (L)} = \text{Runoff (Q)} / (\text{A}) \times \text{number of refills (f)}$$

Spacing between contour trench:

- Calculate the spacing between two consecutive trenches using the formula (area divided by the length of the trench).
- Usually for uniformly sloping areas, vertical intervals are kept constant, but for areas with undulating and uneven topography, the vertical interval would change because erosive velocity is higher in areas with steeper slopes compared to areas with lesser slope.

Distance between two successive rows: It is calculated by the formula (total area divided by total length).

Number of successive rows: It is calculated by dividing by the length of longest section of ridge area by the distance between successive rows (L_1 / d)

SGT

Top width : 0.45 m
 Bottom width : 1.05 m
 Depth : 0.6 m
 Cross section : 0.45 sq. meter
 per running meter
 Recommended size per
 hectare : 100 m

CCT

Top width : 0.5 m
 Bottom width : 1.70 m
 Depth : 0.6 m
 Cross section : 0.66 sq.
 meter per running meter
 Recommended size per
 hectare : 80 m

Note: These specifications pertain to older models for RDF I & II, which have been recently revised. Now, only one type of contour trench with a cross-section of 0.45 by 0.45 square meters is recommended.

7.1.4 Important tips

- ▶ The distance between two successive rows of trenches depends on the volume and velocity of trenches depends on the volume and velocity of runoff, which in turn depend on:
 - ▶ **The quantum of rainfall:** the greater the rainfall, the lesser the distance.
 - ▶ **The permeability of the soil:** the more permeable the soil, the greater the distance.
 - ▶ **The slope of the land:** the greater the slope, the lesser the distance.
 - ▶ **The vegetative cover:** the lesser the vegetative cover, the lesser the distance
 - ▶ Trenches should be closer to each other on steep slopes, but the distance should not be less than 10 meters in any case. Similarly, trenches should be farther apart on gentle slopes, but never more than 30 meters apart.
- ▶ If any mini percolation tank is designed downstream of the patch, then the cross-section should be designed in such a way that the available runoff is sufficient to fill it up to the designed storage capacity.

7.1.5 How to construct?

Following are the steps for construction of the staggered trench.

- **Design:** Determine the cross section, spacing and distance between the staggered trenches by prepare the designing as mentioned above.
- **Survey:** Mark the contour points and draw the contour lines using A frame.
- **Layout:** Apply the layout by using lime powder. Clearly mark the boundaries of burrow pit and a berm to leave the gap between bund and excavated pit.
- **Field training for construction personnel:** Provide brief field training to the construction workers on how to excavate, grade of trench and the place of bund among other things.
- **Excavation:** Dig the trench in such a way that it's upper edge exactly coincides with the contour line while leaving a berm of a minimum 0.30 m.
- **Construction of bund:** Bunds are formed in the downstream areas which is constructed from the soil taken from the trenches along the trenches.
- **Compaction:** Break the clods with the reverse spade or *durmut* (compactor) and compact it properly.

- **Final check:** Check the shape and cross section of the trench by the mould/frame and correct it if any discrepancy in the dimensions.
- **Sowing of seed:** In the rainy season, sowing of the local seed through dibbling process.

7.1.6 DO's & Don't in contour trench

Do's	Don't:
Determine the cross section and spacing, based on design computations of runoff only.	Do not plan the contour trench as the sole activity in the plot; include other activities as well.
Mark contour by using an A-frame and draw contour lines with lime powder. Clearly mark the boundaries of the borrow pit and berm	Do not construct pits above the contour line. Avoid using the same vertical interval for uneven slopes.
Ensure the edge of the trench aligns with the contour line on the downstream side and begin digging trenches from the ridge downward. Adopt a zig-zag layout for staggered trenches.	Avoid excavating trenches in areas with dense vegetation
Plant grass on the top and sides of the bund to strengthen it and prevent erosion. Undertake plantation in the available space between contour trenches	Do not excavate trenches if tree roots are encountered.
Align the edge of the staggered trench above with the centre point below, leaving a berm of at least 0.30 meters or equal to the depth of the trench.	Do not excavate trenches across streamlines
Maintain an even trench depth along its length, with a minimum grade of less than 0.5%.	Do not plant inside the trenches.
Install stone outlets or waste weirs where there are natural gully courses or waterways, determining the size and length based on the gully and rainfall only.	Refrain from stripping or removing grass in the trenches or on the bund.

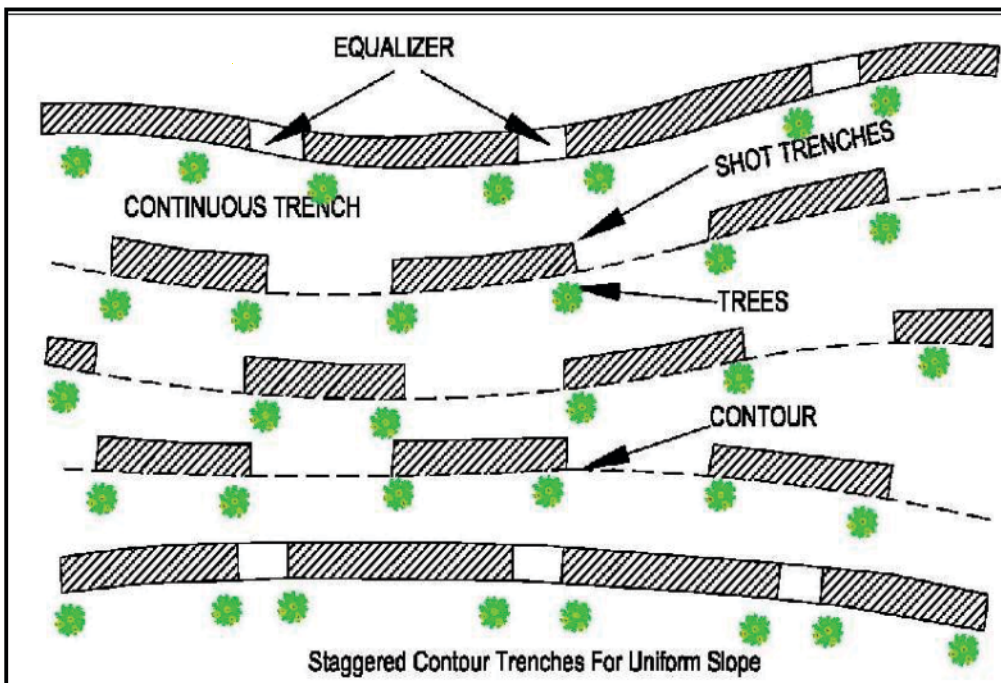
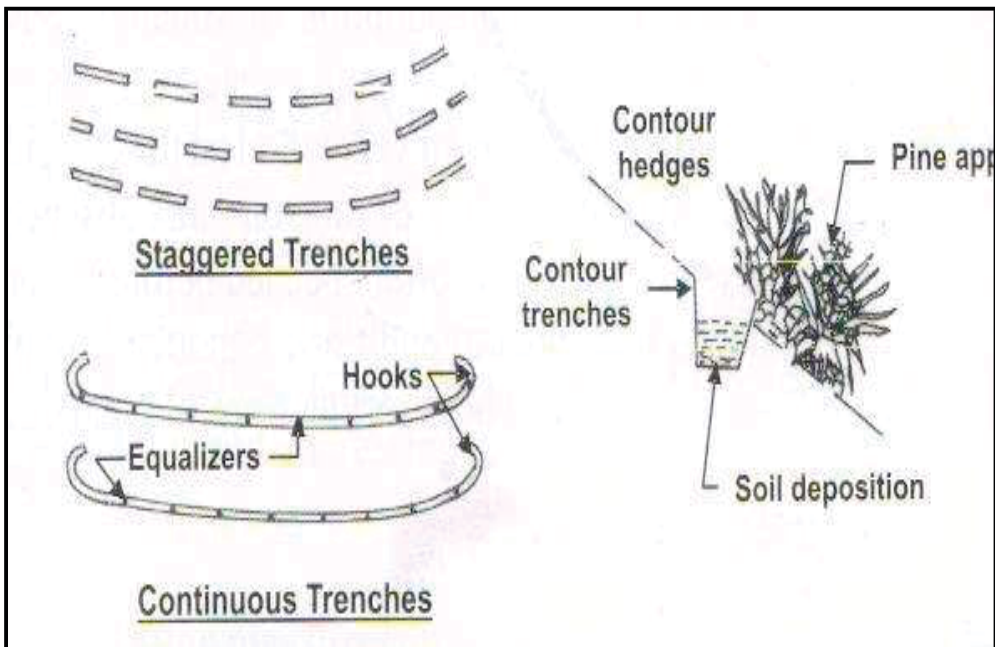
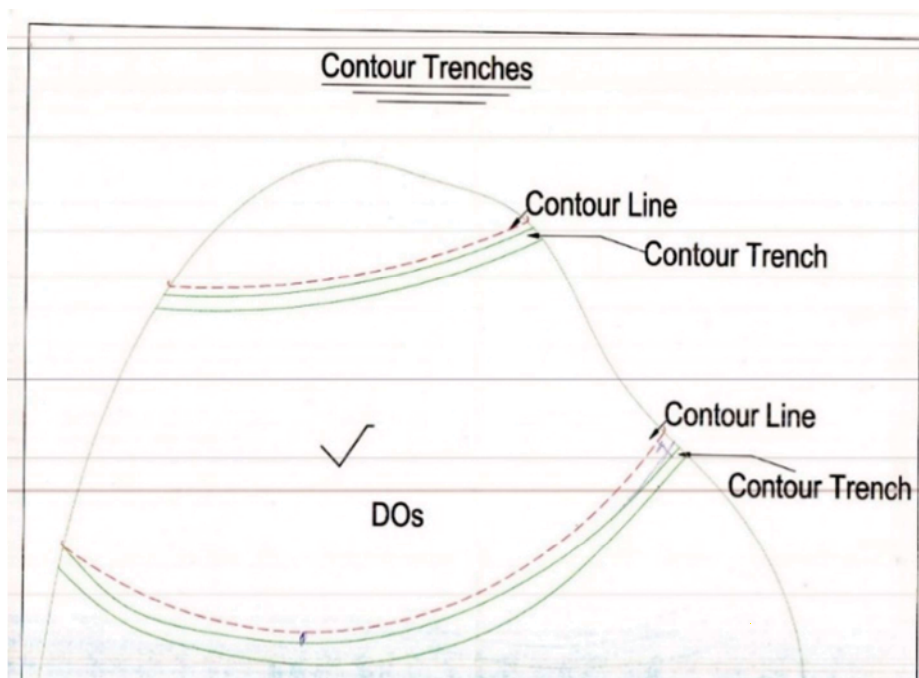


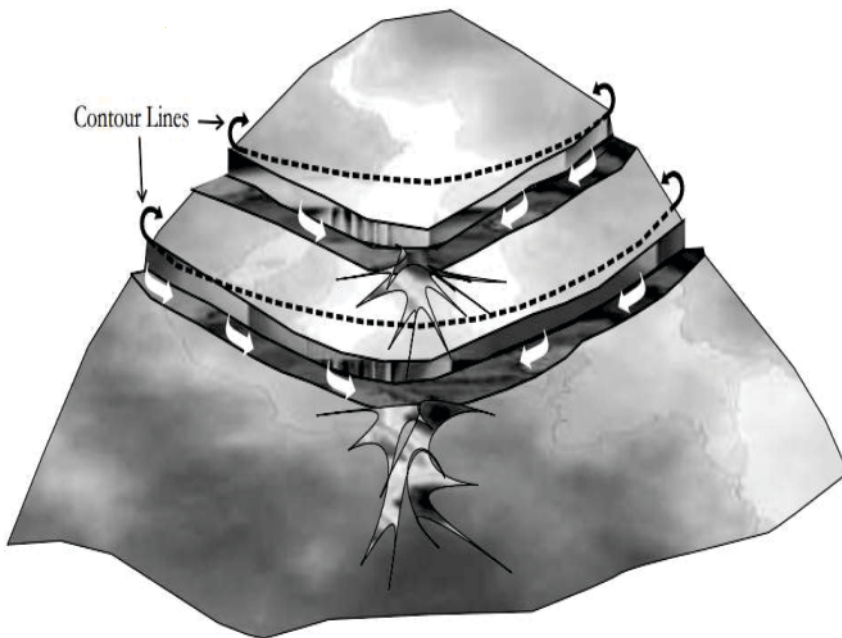
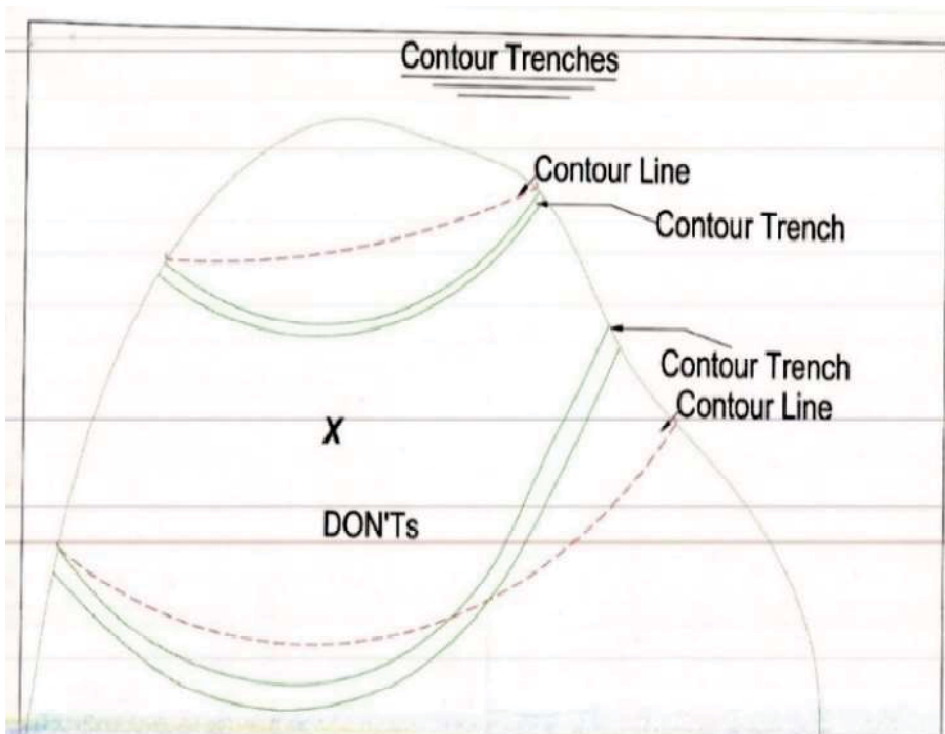
Figure 21: The figures illustrate that hooks should always be provided on both sides of the bund when constructing a contour trench, and an equalizer should be placed in the trench to prevent water from gaining the velocity that could cause surface erosion

Figure 22: Four Images of CCT and SGT reflect 'do' and 'don't' scenarios.

Images of CCT conveying the message that trenches should be dug along the contour only. In the 'don't' section, we can see that the trench is not aligned with the contour in the right image, which is incorrect and a common mistake practitioners make during implementation.



(The image shows a staggered trench arranged in a zigzag manner. This design increases the time of concentration of the runoff, which contributes to reducing velocity and allows more water to percolate into the ground.)



(The image shows that the contour trench has broken at the point where the runoff is maximum because the trench was not dug in alignment with the contour, which is demarcated in the figure. CCT is more likely to be damaged if not constructed in alignment with the contour compared to a staggered trench.)

7.2 V- Ditch and *Gradonie*

V -Ditch and *Gradonies* are important SWC measures for non-arable land development for treating ridge areas, especially for degraded lands, particularly for grassland and plantation purposes. The purpose of both measures is the same, but their shapes are just opposite to each other, which is why we are discussing both measures simultaneously.

Particular	V -Ditch	Gradonie
Definition	- It is V shape trench. - constructed on contours by excavating a trench and forming bund on the downstream side of the trench. - Constructed across the slope	- Gradonie is constructed on contours across the slope. - It is a steeply inward sloping and very narrow bench terrace. - Soil dug from the inner side is heaped on the outer edge to form a bund.
Location	Slope: between 6-10 % slope Reach: Middle Capability class: V to VIII Land type: Degraded land	Slope: between 10-20 % slope Reach: Upper and Middle Capability class: V to VIII Land type: Degraded land
Vertical interval	Range of 0.5 to 1.5 m	Range of 1 to 2 m
Soil depth	Comparatively low soil depth is required	Considerable soil depth is required
Usual size	Top =0.60 m, depth =0.30 m Shape = triangle	Width =1 to 1.5 m, depth =0.20 m
Suitability	It can construct on moderate and non-uniform slope	Gradonie is most suitable for uniform steep sloping area.
Key features	- The interval between the two adjacent V ditch should be designed that the quantity of water coming from the intervening area in V ditch is equal to per running meter capacity. - The excavated soil is heaped on the downstream side in such a way that a continuous ridge is formed having a designed base width and semi-circular height. - If required soil depth is available in the area it is recommended that the forest species suitable for the area must be planted in the pits so that proper moisture could be available for the growth of trees.	- They are suited for afforestation in uniformly sloping areas. Because they have enough capacity to retain water and at the same time plants grown in these and in the interspace of two gradonie will get more moisture. - Plantation Pits are excavated at the interspace between the two gradonie for afforestation purpose.

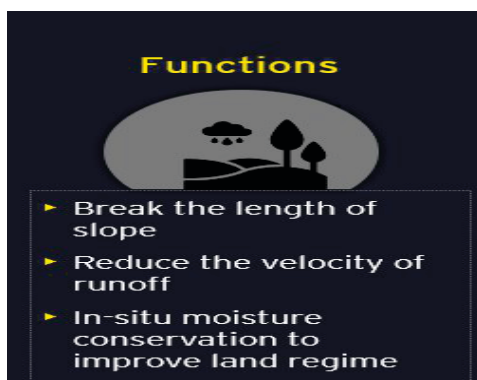
Grass land development

Top width : 0.3 m
 Bottom width : 0 m
 Depth : 1.2 m
 Cross section : 0.18 sq. meter per running meter
 Recommended size per hectare : 50 m
 Slope : Gentle slope

Afforestation model

➤ Top width : 0.3 m
 ➤ Bottom width : 0 m
 ➤ Depth : 1.2 m
 ➤ Cross section : 0.18 sq. meter per running meter
 ➤ Recommended size per hectare : 200 m
 ➤ Slope : Gentle slope

Figure: 23 Describe about forest department models' dimension



7.2.1 Do's & Don'ts in V ditch and Gradonie

- In gradonie vertical cut is upside of the slope which facilitates the reduction of the runoff velocity, and it is down sided to the slope in V ditch which facilitates the improvement in surface soil water.
- Decide the type of intervention based on purpose i.e plantation/ grass land etc.
- Considering the intervention basis on slope and soil depth

7.3 Deep CCT

Deep CCT is also known as a Water Absorption Trench (WAT), It is a complementary activity to CCT/ST. They are constructed on the upper side of a plot, with deep CCTs at the foothills, to effectively trap water and silt.

Where to construct?	Benefits	Do's and Don'ts:
➤ At the top surface of a hillock. ➤ On any degraded land with a slope between 3 to 10%. ➤ At places where a steep slope begins or there is a sharp fall. ➤ At the foothills. ➤ Where there is considerable soil depth available (minimum of 2.5 to 3 feet).	➤ Control of soil erosion. ➤ Prevention of further gully formation. ➤ Capture of the remaining runoff in the plot. ➤ Increase in vegetative cover. ➤ Protection of forest areas. ➤ Protection of downstream fields from erosive runoff during intense storms. ➤ Prevention of encroachment. ➤ Recharge of groundwater and conservation of wildlife. ➤ Reduction of cattle grazing on the hillocks. ➤ Increase in soil moisture.	➤ Provide a waste weir at suitable points. ➤ Implement waste weirs or stone pitching at depression points or gullies of low depth and low slope and construct a LSCD at large depression point. ➤ Use machinery for work in hard murum soil. ➤ Deep CCT or WAT also act as cattle-proof trenches, ensuring that water flows into the WAT, which serves as a barrier to cattle. ➤ Don't construct Deep CCT between two rows of CCT/ST ➤ Always construct on contour only

Deep CCT

Top width : 1.5 m

Bottom width : 0.50 m

Depth : 1 m

Cross section : 1 sq. meter per running meter

Recommended size per hectare : 20 m

Slope : 0 to 3 %

Figure 24: Dimension as per older RDF model

Note: The Forest Department recently ceased the construction of deep Continuous Contour Trenching (CCT). However, deep CCT was constructed by the department during the Mukhyamantri Jal Swavlamban Abhiyan (MJSA) and up until a few months ago. A brief description is provided for knowledge and understanding, as it is an important ridgeline treatment measure.

7.4 Contour Dykes

7.4.1 About Dykes

This is one of the simple and low-cost structure for hilly areas under ridge area treatment.

7.4.2 Key features of Contour dykes

What is it ?



- A contour dyke is a simple, small bund constructed along the contour lines in hilly areas. Its construction requires advanced skills, precise alignment of stones, and quality workmanship to create an effective dyke.

Location



- Hilly regions where stones are readily available.
- Suitable for upper and middle reaches.
- Moderate slope land
- Degraded land

Functions



- Reduces runoff velocity.
- Filters runoff water.
- Increases the rate of water infiltration.
- Captures sedimentation within the field.

Key features

Utilizes local resources, eliminating the need to purchase material

Does not require a spillway, which can concentrate potentially damaging runoff.

Low-cost and efficient solution

Requires minimal maintenance

Acts as a semi-permeable barrier, with its filtering effect providing better runoff distribution than earthen bunds.

Highly beneficial for the rehabilitation of barren and crusted soils, especially when combined with plantation efforts in the same area

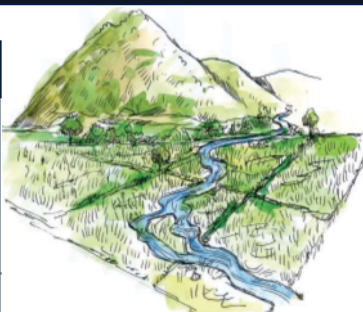
It promotes water retention, sediment deposition in soil cracks, and is conducive to seed sowing and the restoration of rocky terrains.

7.4.3 How to construct

The steps for construction are mentioned below.

- ▶ Mark the contour line on the terrain.
- ▶ Outline the contour.
- ▶ Identify the specific patch for construction.
- ▶ Determine the spacing between dykes based on stone availability, labor resources, and land slope.
- ▶ Typically, a spacing of 20 meters is suitable for slopes up to 1%, 15 meters for slopes of 2-3%, and 10 meters for slopes between 3-5%.
- ▶ Begin construction from the lowest point and work upslope, contrary to traditional methods.
- ▶ Excavate a trench to a depth of 10 cm to enhance stability.
- ▶ Build the stone bund with a base width of approximately 30-45 cm and a height of 25-45 cm.
- ▶ Ensure proper stone alignment and anchoring with skilled workmanship. Provide training to labourers if necessary.
- ▶ Use a mix of large and small stones for the dyke construction to prevent runoff from flowing freely through gaps.
- ▶ Arrange the stones so that smaller ones are placed upstream of larger ones to facilitate rapid siltation.

7.5 Diversion Drain

What is it?	Location	Functions
▶ It is a drain dug to divert and dispose the rainwater safely without damaging agriculture fields. ▶ Usually, it starts at the foot of the hill or from the place where it starts damaging the crops in the downstream ▶ It is a trapezoidal section drain constructed based on incoming runoff. ▶ Component: Drain, berm, Bund.	▶ Calculate the runoff available in the catchment. ▶ Determine the dimension of trench able to capture the available runoff without overflowing. ▶ Identify bottom width portion and top width portion to dig the trench place to deposit the earth, berm to leave. ▶ Side slope of the drain would be according to soil type between 0.6 :1 to 1.5 :1. ▶ Clear the unwanted bushes. ▶ Dig the bottom width portion till the depth. ▶ Then cut the earth from top width portion and maintain the slope as per design. ▶ Deposit the earth leaving the berm on the specified place with proper compaction. ▶ Do sectioning to the bund duly breaking the clods.	▶ Drain collects the excessive flow of rainwater and divert to a natural gully course and prevent soil erosion in the arable land. ▶ Diversion drains protect the downstream structures, divert the runoff away to protect the downstream field area. ▶ Diversion drain discharge the water safely.
How to Identify	Image of diversion	Do's & Don'ts
▶ Area where waterflow is damaging the crops. ▶ Area where the water flow can be diverted. ▶ Starting point from where the water is entering into the arable lands and end point where the drain or rainwater flow can be joined into the natural gully. ▶ Slope of the area ▶ Layout: Mark the trench, berm, and bund place ▶ Deposit the earth on the bank leaving the berm.		▶ Divert the drain with proper slope. The slope should be non-erosive, non-siltation grade. ▶ Alignment of the drain with common consent of community and forest department. ▶ Deposit the earth preferably on the downstream side. ▶ Leave the berm to prevent the sagging of the bund or siltation of the drain. ▶ Link the diversion drain to the natural gully course for safe disposal of water. ▶ Provide stone revetment in the drainage bed if velocity is high. ▶ Grow suitable grasses on the bund to prevent erosion.
Location		
▶ Between arable land and non-arable land. ▶ It starts from the bottom of the foothills in the ridge area and ends by joining into the natural drain.		

7.6 Eligibility Criteria for the Construction of CCT/SGT/Deep CCT/V- Ditch:

1. **Soil Depth:** The soil depth should be a minimum of 1.5 feet to 4 feet for contour trench interventions.
2. **Bed Slope:** CCT is suitable for slopes of 6 to 10%, SGT is suitable for slopes of 10 to 30%, Deep CCT is suitable for slopes up to 6%, and V-ditch is suitable for slopes up to 6%.
3. **Vegetation Cover:** Areas with minimal vegetative cover should be prioritized for treatment; the less cover present, the higher the priority.
4. **Existing Trees:** Areas with few trees should be prioritized for treatment; the fewer the number/patches of trees, the higher the priority.
5. **Permeability of Soil:** Areas with good soil permeability are best for contour trench interventions. However, permeability depends on soil type and land strata. In any case, the soil should allow water to drain within 2-6 hours to prevent trench collapse during heavy and continuous rain. The following types of land are not suitable for contour trenches due to low soil permeability:
 - Soils with high clay content that retain water for extended periods.
 - Plots of black soil or clay soil.
 - Land with hard rocky strata and low soil depth.
6. **Runoff Potential:** Any plot where the runoff potential is sufficient to fill all types of trenches, pits for plantation, and any planned water harvesting structures (WHS). The runoff should be at least 150% of the storage capacity of the demand created through soil and water conservation (SWC) measures.
7. **Quantum of Rainfall:** The amount of rainfall should be sufficient to fill the trenches and other soil moisture conservation (SMC) measures in the plot and capture the available runoff within 24 hours.
8. **Intensity of Rainfall:** The rainfall intensity of the area should match the soil permeability so that trenches can fill up multiple times in a day.
9. **Soil Moisture:** An area with low soil moisture content indicates degradation and reflects the health of the area, making it suitable for contour trench work.
10. **Erosion Intensity:** Any plot that is very highly, highly, or moderately prone to soil erosion.
11. **Shape of the Plot:** A uniformly shaped plot is best for contour trench interventions, or where the length and width are nearly identical.
12. **New or Rehabilitation (Old Work):** Areas that have not been treated previously should be given priority for treatment. Areas treated more than a decade ago may also be considered for rehabilitation.
13. **Drainage pattern:** Area with less drainage lines

Chapter 8: Contour Bund

Generally, practice of contour bund is found in farmers land to increase crop yield by conserving moisture in field. However, because of small and scattered land holding, farmers at places find it difficult to adopt bund strictly on contours. Contour bund in RFBDP project is proposed for non-arable land area treatment where the slope in the upstream is 6-10 percent.

These lands are typically covered with bushes, stones, steep gullies. they also have shallow soil depths and very hard soil/rocks. Bush clearance and boulder removal in non-arable land are not recommended under the watershed approach. In non-arable land, existing boulders conserve the soil mass and control the flow of runoff water. Contour bund is one of such activity to bring about the productive use of non-arable land. This could be pastureland or forest land as per the land use practice/category.

Contour trench and contour bund both are the activity for ridge area treatment but following points differentiate between both.

- ▶ Contour trenches are preferred for areas with steeper slopes, while bunds are better suited for areas with gentler slopes."
- ▶ Contour bunds create more storage because water is stored not only in the trench but also against the bund, resulting in a higher storage capacity.
- ▶ Bunds are comparatively less safe and require more maintenance. They are more susceptible to being breached by overtopping.

8.1 Introduction to Contour Bund

What is it?

- ▶ The bund lying on the contour is called a contour bund. This is one of the simplest techniques for treating non-arable land in areas with a gentle slope.

Component

- ▶ Trench, Berm and Bund

Purpose

- ▶ To check the erosive velocity of run off.
- ▶ To reduce soil erosion
- ▶ To conserve In-situ moisture conservation in land.

Location

- ▶ Lower and middle reach
- ▶ Non arable land: Forest/Pastureland
- ▶ Slope: 6 to 10 %
- ▶ Land covered with stone, steep gullies, dense vegetation is not preferred.

8.2 How to Construct a Contour Bund

Following are the suggested steps for the construction of a contour bund.

Measure the different parts of the slope area.

Mark out the area with less than a 10% slope for the layout of the contour bund.

Begin with the longest section within this area to adequately cover the ridge area.

Draw a straight line with wet lime from the top of the slope to the bottom and mark points at the decided interval between successive contour lines.

Maintain the shape of side slopes and top width using a frame. Ensure that the bund is in a trapezoidal shape

Do not mix this with the earth for the bund. Break clods with a reverse spade or wooden stick.

Dig the borrow pit for the trench following the contour line. scrape the trench portion and remove grass/weeds.

Starting from each mark, demarcate the contour line. Mark the trench (digging portion), berm (to leave a gap between the bund and trench), and bund.



Contour survey



Giving mark out/ layout



Digging trench and keeping soil on downstream side



Checking the section of the bund with a template



Breaking clods

8.3 Technical Consideration During Design

Determining the dimensions of any soil and water conservation (SWC) measure is important during the design phase. However, practitioners often follow model designs or determine the dimensions based on their field conditions and experience. Here, we describe how to determine the dimensions of a contour bund by following technical norms.

Height of bund

- ▶ The height of the bund depends upon the slope of the land, type of soil (water holding capacity), the rainfall expected in 24 hours period for 10 years frequency in each area and desired duration of water capture without overtopping or breach of the bund.
- ▶ Once the height is determined other dimensions of the bund viz: bottom width, top width and side slopes can be worked out depending upon the type of the soil.
- ▶ First method: With 30 cm depth of impounding which is a usual practice in many states, and the 30 cm is provided as depth of flow over the crest of the waste weir and 20 cm is provided as free board. This makes the overall height of the bund as 80 cm.
- ▶ Second method: To the theoretical height of bund so calculated 20% extra height or a minimum of 15 cm as free board (f.b) is added and another 15 to 20% extra height towards settlement due to consolidation.

Top width: A minimum of 0.3 m to 0.6 m width is kept facilitating plating of grasses on the top of the bund. But bunds with clay soil must have greater top width because they can crack when dry.

Side slope: Side slopes of the bund are dependent upon the angle of repose of the soil. Side slopes of bunds may vary from 1:1 (clayey soil) to 2:1 (sandy soil)

Base width: Preferred 2.5 m, however Base width of the bund depends upon the hydraulic gradient of water in the soil. A general value of 4:1 assumed for the hydraulic gradient. The base should be sufficiently wide so that the seepage line does not appear above the toe of the bund on the downstream side.

Berm: minimum 0.30 m

Size of the bund: The size of the bund is expressed in terms of its cross-section (C/S) area. Contour bunds are usually of trapezoidal shape and the cross-sectional area of the bund is worked out by the following formula:

$$\text{C/S area} = (\text{Top width} + \text{Bottom width})/2 \times \text{height of bund} = (T+B)/2 \times D$$

Where,

T = top width of bund m

B = Bottom width of bund m and

D = Height of bund, m

In general, the cross-section of bund depends on the soil type and rainfall, and it varies widely between 0.50 to 1.5 sq. m depending on the soil type and soil depth.

Settlement allowance: at least 20-25 %

How to design

- ▶ Calculate the runoff.
- ▶ Determine how much of runoff do we want to capture.
- ▶ Determine the size of bund and calculate cross section.
- ▶ Finding out the length of bund
- ▶ Calculate the number of rows.

Dos and Don'ts

- ▶ Always consider type of soil and slope during designing. Cross section must be decided accordingly.
- ▶ Always provide a berm during construction
- ▶ Always make the provision of settlement allowance during designing the height of bund
- ▶ Always provide the outlet in moderate slope and slopy land and area for more than 2 hectares in gentle slope
- ▶ In impermeable soil, increase the cross-section area of bund.
- ▶ Always begin the layout from larger section having uniform slope
- ▶ On high slopes do not make bunds closer than 30 m
- ▶ On low slopes do not make bunds further than 60 m
- ▶ Do not construct bunds where there is already dense vegetation.
- ▶ Do not excavate soil continuously in permeable soils.

8.4 Waste Weir

It has often been observed that there can be a casual approach to the provision of waste weirs, which can lead to the collapse of the entire work done small catchment during heavy rains. It is crucial to recognize that in the current climate scenario, where we experience significant rainfall within short durations, the importance of waste weirs has increased even more. Just as the heart is essential for a human being, a waste weir is equally important for any earthen work. Therefore, it is imperative that we give due attention to the construction of waste weirs.

Waste weir: It is like an exit. It is constructed to safely discharge of excess water from the area	Types of outlets ▶ Piped: using PVC/cemented pipe in the bund is named as piped outlet ▶ Dry masonry: A small outlet is constructed by skilled labour with a maximum height of 0.75 meters and a length of 3 meters." ▶ Pucca: This follows the same concept as dry-stone masonry but is constructed with mortar.
Purpose: 1. To hold the water for short time and then flow of the exit. 2. To protect the bund for breaching by heavy runoff. 3. To protect the area and bund at downstream side.	Important tips ▶ It should be constructed at depression with the crest of their head walls at the height above the depth of impounding. ▶ Successive outlets are not constructed in the straight line, but it should have to be constructed in a staggered manner. So that they will not cause gullying of the field in between the outlet. ▶ The length of outlet should be determined only through using of empirical formula. ▶ Determining the height of the waste weir is very important. It should be decided based on the height required to impound water in the field, the depth of flow, and the freeboard. Incorrect height and site selection can defeat the purpose of the contour bund.

8.5 Eligibility Criteria for Construction of Contour Bund

1. **Soil depth:** Good soil depth with minimum 2.5 feet
2. **Slope:** 3 to 6 %
3. **Vegetation cover:** Low vegetative cover land is suitable
4. **Trees:** Area with a smaller number of existing trees is suitable
5. **Permeability of soil:** Land with moderate to good rate of soil permeability
6. **Soil type:** Clay soil and black soil land is avoided
7. **Rainfall:** Area having 500-650 mm rainfall
8. **Erosion intensity:** Any plot where the land is very highly/highly/ moderately prone to soil erosion.
9. **Soil moisture:** area with low moisture content in the soil indicates degradation and reflects the health of the area and this is suitable for contour trench work

Chapter 9: Rehabilitation of Degradation Forest (RDF)

The lands belonging to capability class V to VIII are not suitable for cultivation. Their land is largely limited to pasture, silvi pasture, forest, recreation, and wildlife food. Such lands have one or more limitations of slope, shallow soils, stoniness, wetness, salinity problems, and erosion hazard.

9.1 Introduction to Rehabilitation of Degraded Forests (RDF)

RDF is an important activity implemented by the forest department. The degraded areas under forests require immediate attention for ecological restoration and to meet the socio-economic needs of the communities living in and around such areas. The forest department has developed two types of RDF models, RDF I and RDF II, based on the degradation status of the land. The RDF I model is implemented in areas where the land is severely degraded and devoid of trees. In such circumstances, they propose more plantations and the implementation of SWC interventions to maintain soil and moisture in the land. On the other hand, the RDF II model is proposed for lands that are in a comparatively better condition with existing plantations available, so a smaller number of plantations is proposed. The table below shows the differences between both models.

Parameter	RDF I	RDF II
Degradation	More degraded	Comparatively low degraded
Existing plantation	Less number of plants	Comparatively more plants
Size (unit)	50 Hectare	50 Hectare
Average Perimeter	3000 RM (500*100)	3000 RM (500*100)
Fencing	Stone wall fencing: Height =1.2 m 0.80 m base width, 0.6 top width Ditch cum bund: depth =1.2 m 1.5 m base width, 0.9 top width	
Contour trench	▶ 260 rm per hectare ▶ Cross section: 0.45*0.45 sq. m	
V Ditch	▶ 100 rm per hectare ▶ Cross section: Top width =0.30 m, bottom = zero, Depth =0.45 m	
Contour dyke	▶ 50 rm per hectare ▶ Height =0.30 m ▶ Width = 0.30 m	
Plantation	25000	10000

Note: The latest circular released by the Forest Department specifies new models with a labour rate of 259 per day. Previously, a rate of 200 per running meter (rm) per hectare was proposed, which included 100 meters of Continuous Contour Trench (CCT), 80 meters of Staggered Contour Trench (SGT), and 20 meters of deep CCT. However, the revised model now recommends only one type of contour trench with dimensions of 0.45 meters by 0.45 meters. The standard number for in situ moisture conservation structures, such as check dams, Nadis, and earthen dams, is not mentioned in the model. Nevertheless, these can be constructed according to site conditions within the sanctioned budget. Water Harvesting Structures (WHS), like mini percolation tanks, may also be constructed if required at the site.

9.2 Fencing

Fencing of RDF area is one of the important tasks for protection of RDF area so we would discuss fencing.

- ▶ Ditch cum bund fencing.
- ▶ Vegetative fencing
- ▶ Stone wall fencing
- ▶ Wire fencing
- ▶ Pucca *diwar* (Permanent wall)

9.2.1 Ditch-cum-bund (DCB): This is a common technique used in RFD in both forest and non-forest areas. The most appropriate cross-section for the ditch-cum-bund is typically trapezoidal. The standard dimensions are as per RDF model:

- ▶ Top width of 1.50 m,
- ▶ Bottom width of 0.90 m
- ▶ Depth of 1.20 m

Construction steps include:

1. First, conduct a transect walk along the periphery of the RFD model to identify the required types of fencing and their placement. Calculate the length of each fencing type.
2. Identify the area where ditch cum bund would be constructed. Draw a double line corresponding to the base width of the ditch-cum-bund. Avoid drawing the line at points of depression, gully, or stream where the ditch-cum-bund will not be constructed.
3. The soil excavated from the ditch should be piled on the inner side to form the bund, leaving a berm of 20-30 cm to prevent small ruminants from standing on it.
4. Compacting the bund is crucial to prevent soil disturbance and to keep it from filling back into the ditch.
5. Plant suitable vegetation on the bund to enhance its stability.

Dos and Don'ts

- ▶ The ditch cum bund should be constructed on contour and if does not, it would promote soil erosion and develop into a gully or ravine.
- ▶ This work should be completed by May-June month so that plantation/grass seed work could be done during the rainy season.
- ▶ The slope of the land should be perpendicular to the bund.
- ▶ Don't construct ditch cum bund at gully/drain and always construct a stone bund, pucca wall, or SWC structure at points of depression or gully.

9.2.2 Other types of fencing

Vegetative fencing	Wire fencing
▶ Also called live -hedge fencing ▶ This fencing is mainly use in farmers field and pastureland. ▶ One established this fencing does not require any maintenance. ▶ Two to three rows vegetative material are required for effective fencing. ▶ It becomes thinner and more effective as time passes. ▶ Agro climatic condition, soil type, soil depth must be considered during selection. ▶ This fencing requires skilled labor to come up with more effective ▶ Thore, Euphorbia spp Ram bans(agave), Jatropha are good examples in arid and semi-arid region. ▶ The species selected should be thorny. It should be able to come up by cuttings. It should also have good coppicing power.	▶ Three types: Plain wire, barbed wire, and woven wire and among this barbed wire is most effective but costly. ▶ Four to six strands of galvanized iron barbed wire are used horizontally, and crisscross knitted on angle iron or cement posts. U-nails are used for fixing the strands of barbed wire. This fencing is recommended in following conditions. ▶ Where ditch-cum-bund (DCB) cannot be constructed due to the nature of the surface strata. ▶ When stone fencing cannot be constructed due to the non-availability of stones in hilly regions. ▶ when a pucca wall or stone fencing is not feasible due to steep slopes ▶ If wire fencing cannot be completed due to challenging conditions, then the area should be left unfenced.

Stone fencing	Pucca wall
▶ Stone fencing is common activity for RDF model in the area where adequate stone are easily available. ▶ The 60 m per hectare is the average length proposed in the model estimate. ▶ The recommended size for stone fencing as per RDF model is: Height -1.20 m, top width=0.60 m, base width -0.80, ▶ A provision for a small hole should be made to drain runoff if constructed across the slope.	▶ Two types of Pucca wall are used in fencing i.e. Stone wall and brick wall. ▶ Model estimates suggest two types of models., first model recommend a height of 1.2 m, and the second model recommend 1.8 m height. Top width is 0.38 m and bottom width is 0.5 m ▶ An outlet should be constructed in the proper place with an appropriate size to accommodate runoff. ▶ A pipe should be buried in the wall with proper casing to prevent further erosion and ensure the stability of the wall. ▶ Community participation throughout the process is very important for the sustainability of the wall.

9.3 Pits for Plantation

Planting pits exist in variable size and spacing depending upon species and soil conditions. The planting pits are suitable for semi-arid area to enable crops to survive dry spells. They are used on a wide variety of soil types but most suitable are silt and clay soils, where runoff can be generated due to limited permeability.

Ordinary pits:

- They are suitable for plantation on gentle slope land.
- Three types of size: 0.30, 0.45 and 0.60 m in length, width and depth depend on type of plant and soil.
- In forestry plantation model – Recommended size is 0.45 * 0.45* 0.50 cubic metres

Ring pits:

- ▶ Firstly, pit is prepared and then a circular trench about 20 cm away from the centre of pit is dug.
- ▶ These pits are also dig combined with SWC measures with a central pit of 45 cm x 45 cm x 45 cm volume for planting purpose. Size may vary depending on type of soil, plant, and calculation of runoff to be captured.
- ▶ The circular trench accumulates maximum amount of rainwater for the benefits of root.
- ▶ They are beneficial for plant growth and biomass production in plantation forests as they prevent runoff losses and maintain higher soil moisture regime, facilitate root system, and improve water and nutrients use efficiencies thus give a good start to young plantations.
- ▶ Ring pits (trenches) are widely applied in forestry operation because they are beneficial in terms of protection from the domestic and wild animals.
- ▶ During the design we should provide the way to collect water from the adjacent area other than direct rainwater.
- ▶ The key point to note while digging pits (and trenches) are that the top fertile soil should be kept aside by scrapping and it is first to be filled in the pits while carrying out half filling operation in the pits.
- ▶ The pits are dug in the month of January/February i.e. nearly six months in advance of planting and the half filling (or refilling of pits) are done one or two months before the planting season so that soil gets nearly four to five months for natural weathering.

Saucer pits:

- ▶ Constructed on moderate and high slope land between 10-20 % slope.
- ▶ The pit is dug but the area around the pit is scraped to form a shallow saucer of 2-3 m diameter.
- ▶ The saucer helps in conserving the moisture.
- ▶ The soil obtained from scrapping is put along the edge of the saucer.
- ▶ Saucer pits may be suitable for prevent the runoff losses, maintain soil moisture regime, facilitate root system, and improve water and nutrients use (4-7 times) efficiencies thus give a good start to young plantations.
- ▶ They also act as water harvesting structures in arid and sandy areas.

How to dig the pits for plantation

Approximate 10 to 25 thousand saplings are planted in the RDF model according to the level of degradation of the land.

- ▶ Conduct a transect walk of the area to closely examine the current conditions, including topography, existing structures, vegetation, and slope.
- ▶ Clear the site by removing unwanted vegetation and debris.
- ▶ Determine the appropriate spacing for planting, taking into consideration the plant species and other physiographic factors.
- ▶ Decide on the size of the pits.
- ▶ Mark the demarcation of pits: First, draw a straight line, then mark the planting points perpendicularly across the line.
- ▶ Use a fixed-size frame to outline the four sides of each pit, ensuring the center aligns with the marked pit.
- ▶ Excavate to a uniform depth across the entire pit, ensuring all sides are excavated at the same level.
- ▶ Set aside the topsoil, which is fertile and would be used for refilling the pits.
- ▶ Place the subsoil on the other side.
- ▶ Construct a bund (*thawla*) on the downstream side of the pit in a semi-circular shape. The size, shape, and cross-section of the bund should be designed to capture runoff, withstand the velocity from the upstream side, fill the pit, and conserve in-situ moisture within the land regime.
- ▶ Place small-sized stones, if available from nearby areas, on the upstream side of the bund to reinforce it against high runoff.
- ▶ Sowing of suitable seed species will be carried out in the available areas nearby and between the pits.
- ▶ Allow the pits to remain exposed for a few days before proceeding with the actual planting.

9.4 Seeding

Subsoiling is a good method to enhance the regeneration of degraded land. Sub soiling by tractor drawn chisel plough at 2 m horizontal interval is the most effective in-situ soil and water conservation practice for early establishment and improving the quality of land. It will also increase the efficiency of work and a large area can be covered in few cost and limited time.

Part C: Drainage Line Treatment

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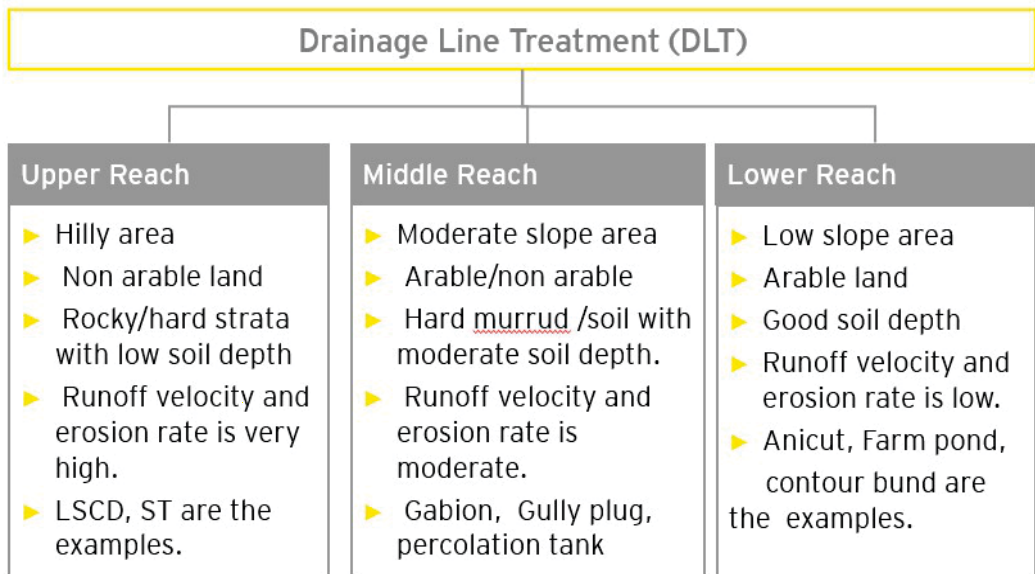
Silt detention dam

By delving into these chapters, practitioners will gain a thorough understanding about the SWC measures for drainage line treatment enabling them to apply this knowledge in their conservation efforts.

Chapter 10: Drainage Line Treatment – An Introduction

Drainage Line Treatment (DLT) refers to the treatment of drainage lines that pass through a watershed area. It typically begins in hilly and non-arable areas where the volume and volume of runoff are high and ends at the outlet of the watershed area.

Watershed areas can be classified into three categories for drainage line treatment: upper reaches, middle reaches, and lower reaches. Each reach has its own characteristics, and practitioners must design soil and water conservation (SWC) measures accordingly.



Important note

Generally, DLT measures are designed by considering the similar cross section from upper to lower reaches with the concept that the crest elevation of one will be same as the bottom elevation of the adjacent structure. But the design is not correct because the similar cross section cannot be adopted from upper reaches to lower reaches. In the upper reaches the quantity and erosive velocity of runoff will be much less due to lesser catchment area and it is much high due to sequential increase in catchment area in lower reaches. Under this condition the structure constructed in the upper reaches may be over designed and structures constructed in lower reaches may be under designed



Purpose and Principal of DLT works:

Purpose:

- ▶ To reduce and control the runoff velocity, thereby preventing the further enlargement of gullies.
- ▶ To conserve moisture and trap sediment, ensuring the eventual growth of vegetation.
- ▶ To impound water, increase the moisture regime, and recharge aquifers, thereby improving the water table of groundwater sources.

Principal

- ▶ To decrease the velocity of runoff that is moving at high speeds, preventing it from reaching erosive velocities that cause soil erosion.
- ▶ To halt the runoff at the surface, enabling the collection of surface water for harvesting and other purposes.
- ▶ To facilitate the percolation of water into the ground, thereby recharging the aquifers

Approach for DLT treatment

- ▶ The DLT works should start from upper reaches of the watershed and goes down following the ridge to valley approach
- ▶ The measures should be adopted after careful consideration of quantity of runoff, velocity of runoff and cross-sectional area of drains
- ▶ Approach for identification of location by following the thumb rule crest elevation of below point align with bottom elevation of top structure is not appropriate.
- ▶ Keeping this crucial factor each drainage lines should be divided into the following three reaches. Upper reaches, Middle reaches, Lower reaches
- ▶ The first structure in the stream from the ridge should be constructed at the point where velocity of flow tends to be erosive
- ▶ DLT works should be started after the treatment of the adjoining arable and non-arable areas so that maximum rainwater shall be conserved in the field itself, and the flow of velocity is likely to be reduce in the stream.
- ▶ Keeping the reduced amount of runoff and velocity of water in view, suitable structure with appropriate cross section shall have to be planned in the drainage line.

Chapter: 11 Loose Stone Check Dam (LSCD)

In a stream (drain) of high slope, where runoff velocity attains erosive velocity, it needs to be reduced to bring the runoff velocity within the permissible limit. Loose Stone Check Dam (LSCD) is one of the common and key structures in DLT treatment for upper reach and middle reaches treatment.

A series of LSCD must be constructed to transform the longitudinal gradient from a steep slope to a succession of flat steps with low drops. LSCD is a DLT structure construct from stone across the drainage with dry stone packing.

11.1 Objectives of LSCD

- To reduce the steep slope of the drain into a succession of flat steps with low drops
- To reduce the erosive velocity of water and control soil erosion.
- To trap the silt which reduce the rate of sedimentation loss in the WHS at downstream side.
- To increase the duration of flow of the runoff in the drainage line.
- Creating a hydraulic head which enhance infiltration of surface runoff into ground water.

11.2 Location:

Where to construct LSCD ?

- ▶ Upper /Middle reach
- ▶ Beginning of Gully/drain
- ▶ First/second order drain
- ▶ Drain with moderate slope (maximum slope 20 %)
- ▶ Independent catchment of each LSCD : Maximum 2-3 Hectare
- ▶ Total catchment : 5-10 Hectare
- ▶ In the hilly area where runoff velocity and sedimentation discharge are very high
- ▶ Where stones stones are adequately available

11.3 How to Design:

Technical survey:

- ▶ Carry out the L section of the drain. L section helps to find out the channel gradient (bed slope) and points of sudden drop.
- ▶ Cross section helps to find out the width of the drainage line and its depth for planning and designing treatment measures.
- ▶ Calculate the length and slope of the drain.

Number and Spacing of LSCD

- ▶ Calculate the horizontal interval by dividing V.I (which is 1 m) by the slope multiply by 100.
- ▶ Effective width of LSCD: H.I plus 5 m (base width of any LSCD)
- ▶ Determine the number of LSCDs by dividing total length of stream by effective width of one LSCD.

Calculation of runoff: Calculate the runoff to be passed from the independent catchment of the specific LSCD.

Cross section of LSCD

Length of LSCD: Length of any LSCD is equal to the width of gully. However, 2 to 6 m length is preferred.

Slope: This is one of the important parameters to be considered for the stability of the LSCD. Slope depends on the angle of repose volume and velocity of runoff. Usually, upstream side slope is fixed to 1:1 or maximum up to 1.5:1 and downstream slope is between 2:1 to 4:1.

Top width- usually the top width of LSCD is between 0.45 to 0.60 m. However, 0.6 H is the thumb rule for determine the top width.

Height: The preferred height of LSCD is maximum 1 m in any situation. We must consider height of the wall, height of free flow and free board.

Base width: Base width is calculated through a formula. It should be minimum 1 m and 2.8 maximum in any situation. Thumb rule is 1.2 H, where H is the height.

Free board:

- ▶ LSCD would be stable if the runoff overflows through the centre of the structure.
- ▶ Because there may be chances for erosion of the embankment on either side if free board is not provided.
- ▶ Free board should include the depth of flow and depth of free board.
- ▶ it should be calculated through a formula; however, it should be not less than 0.3 m in any situation. 0.3 to 0.6 m is the range of freeboard for LSCD up to 1 m height of LSCD.

11.4 How to Construct the LSCD

Cleaning: Firstly, clear and clean the site.

Marking the points of LSCD: The point of LSCD should be marked in such a way that the top of the downstream check dam should be at level with the bottom of the one upstream of it. (Dimensions from the design can be used for marking the points)

Layout: Mark the line for the main body wall and outer line from the central line at the D/S and U/S according to required slope.

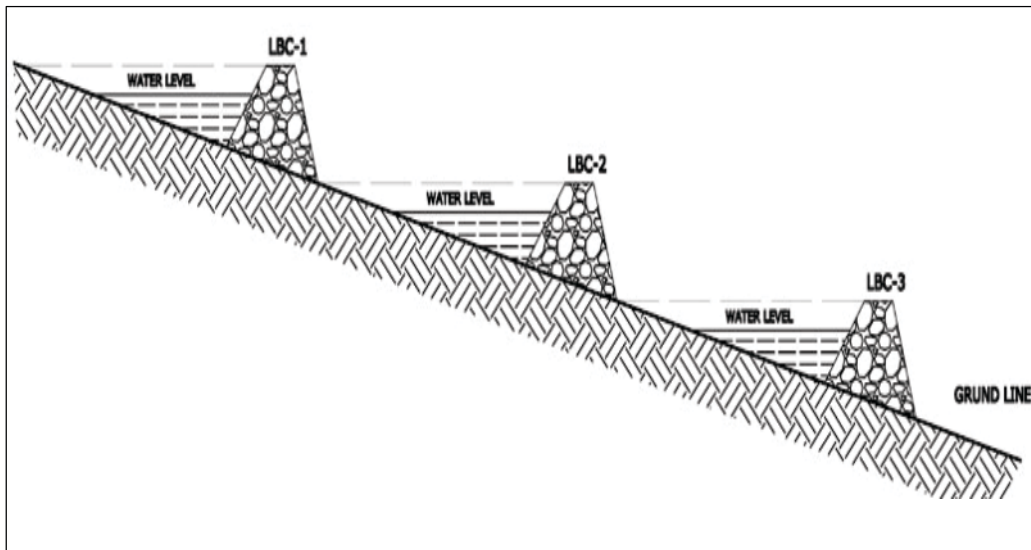


Figure 25: LSCD with thumb rule of crest elevation of below point align with top elevation of above structure

Foundation: The trench in a boulder check is not usually dug or hardly for 0.25 cm in the bed of the stream. Generally, digging the trench is only required for embedding the check into the embankment.

- ▶ The length of core wall is equal to the top width of the LSCD. This depth should be up to the foundation level.
- ▶ Cut both sides downstream to prevent sagging.

Dry stone masonry construction

- ▶ Put the dry stones in the foundation up to the bed level. All stones can be laid in such a way that all stones are keyed together.
- ▶ The check should be raised in horizontal layers.
- ▶ The larger boulders must be placed on the downstream face of the check. The outermost edge of the downstream side must be dug up to a depth of 0.25m and the largest boulders available must be placed at the lower most edge of the check on the downstream and anchored to the ground.
- ▶ Maintain the side slopes and top width as per specification by peg or frame.
- ▶ Provide adequate freeboard to safely passes the peak runoff.
- ▶ There should not be any gap between two stones joints. If any gap is there it should be filled by small pieces of stones
- ▶ A soil layer of 5-10 cm or wet mortar should be placed on the top of the structure to avoid its dismantling due to stray cattle and other human activity.

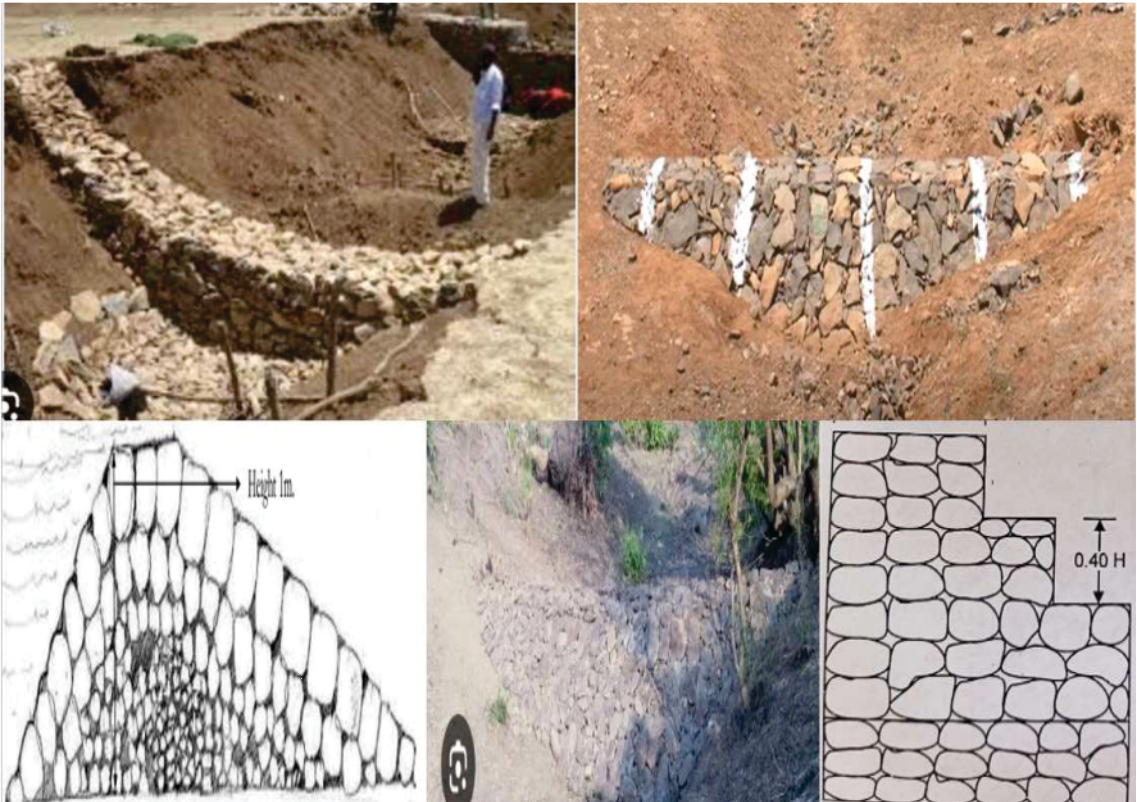
Figure 26: LSCD constructed in series in a drain



Tips to be considered during construction.

- ▶ Smaller stones can be used to fill up the interiors of the check.
- ▶ The use of boulders with a diameter of less than 15cm (or weight less than 1 kg) must be avoided.
- ▶ The use of angular stones gives greater stability to the check than the use of rounded boulders.
- ▶ Shale, limestone, mudstone, or any loosely cemented rock must not be used, because they disintegrate, when they come in touch with water.
- ▶ Large size stones should be placed at the centre of the stream, which can resist the velocity of runoff.

11.5 Shapes of Loose Stone Check Dam



11.6 Do's and Don'ts During Construction of LSCD

Do's	Don't
▶ The use of angular boulders should be preferred." ▶ Larger boulders should be placed on the outer portion of the check dam. ▶ The foundation should be dug to a minimum depth of 0.3 meters. ▶ Smaller stones should be used to fill the gaps." ▶ Training in dry stone masonry should be provided to masons and labourers before construction begins on the site. ▶ Locate the check dam only where the height of the stream embankment is greater than or equal to the sum of the peak depth of flow in the drainage line and the design height of the structure. ▶ The top of the check dam should be lowest in the middle of the stream and highest at either embankment. ▶ Upstream slope of the check dam should be 1:1 while the downstream slope can vary from 2:1 to 4:1	▶ No check dams should be constructed where the bed slope is above 25%. ▶ Check dams should not be constructed in areas where boulders are not adequately available within a 50-meter radius. ▶ Do not use boulders that have been dug up or picked if their removal would increase soil erosion in the area from which they are sourced. ▶ Avoid using flat stones or stones smaller than 15 cm in the construction.

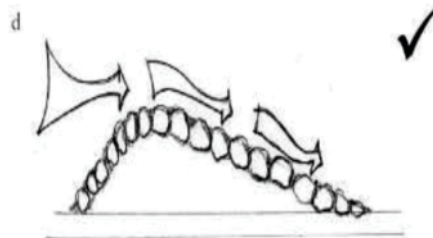
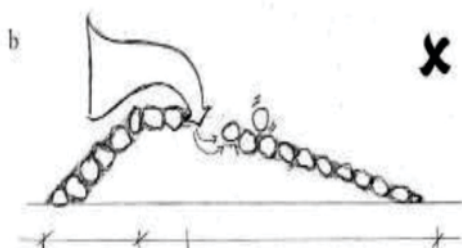
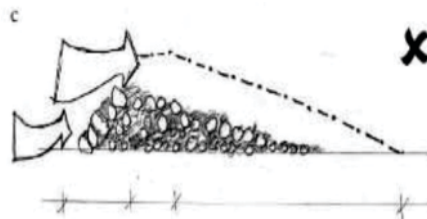
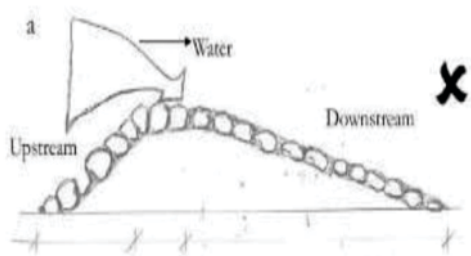


Figure 27: The largest boulders must be kept on the outer side as shown in the fig. above. Otherwise, smaller boulders will be displaced by the force of water and the boulder check will break.

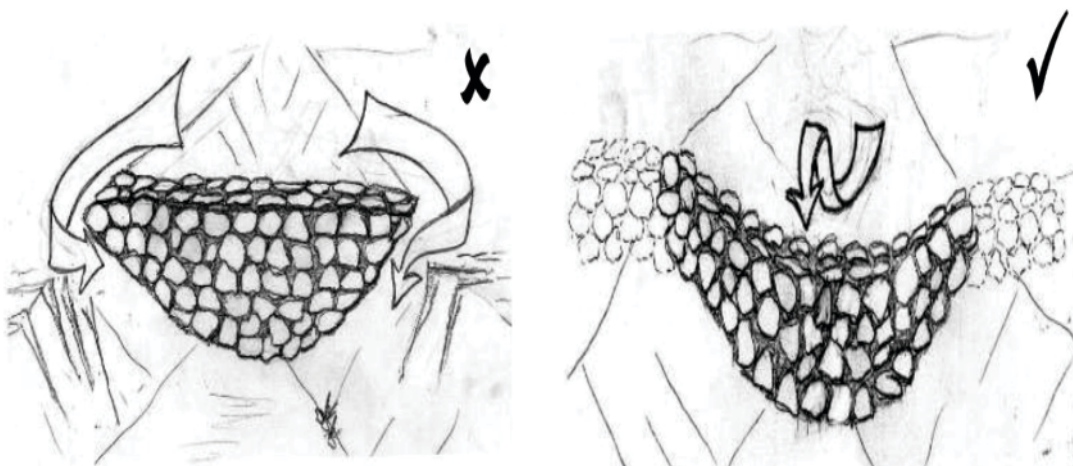


Figure 28: Reflect on the importance of freeboard or a minor tilt in the middle part of the structure to prevent erosion of the banks.

11.7 Eligibility Criteria for Construction of LSCD

Catchment Area:

- Independent catchment: up to 2 to 5 hectares
- Total catchment: up to 10 hectares

Bed Slope:

- A LSCD is suitable for slopes between 6% and 25%.

Stream Order:

- A LSCD is suitable for **first and second-order** drain

Erosion Intensity:

- Areas very highly prone to soil erosion.

Erosive Velocity:

- Drains that have a very high velocity of runoff (Erosive velocity)

Depth of Drain:

- The depth of the drain should be sufficient to accommodate both the height of the structure and the depth of flow, including freeboard. For an LSCD, the ideal depth is 1.5 meters, since the maximum height of the structure is typically up to 1 meter.

Location:

- The structure should not be located at any sharp curve; the water flow should be perpendicular to the structure.
- There should not be any sharp falls within the drain.
- The drain should have a uniform slope.

Availability of Material:

- Availability of high-quality, angular stones of the appropriate size.
- Skilled labour must also be accessible for dry stone pitching.

Banks:

- Stabilized banks to prevent erosion due to erosive velocity.

Chapter 12: Gabion

A dry-stone masonry structure that is encased in woven wire is called a Gabion structure. This type of structure is comparatively stronger than LSCD, so it falls under the semi-permanent structure category.



12.1 Introduction to Gabion:

Purpose of Gabion structure: -

- ▶ Control the erosive velocity of runoff
- ▶ Establishment of vegetation and reduce erosion
- ▶ Stabilisation of gully /Gully control structure
- ▶ Increase the duration of runoff in the drainage line
- ▶ Increase recharge of ground water
- ▶ Controlling landslides
- ▶ Act as a water harvesting structure with some minor addition in the lower reach

Location (where to construct Gabion)

- ❖ In the middle and lower reach areas of a watershed.
- ❖ In third or fourth-order streams.
- ❖ Gullies with moderate slopes (6 to 10% slope).
- ❖ The embankment should be stable enough to reduce the erodibility of the banks.
- ❖ Gabions are the best structures in gullies where the bed slope is flatter, in small catchments up to 50 hectares.
- ❖ Independent catchment area: 5 to 20 hectares; total catchment area: up to 50 hectares.
- ❖ In hilly areas where runoff velocity and sediment discharge are very high (erosive velocity and high rate of soil erosion).
- ❖ In gullies where the embankments of the drainage line are high (minimum 1.5 meters). However, it should exceed the sum of the designed height and depth of peak flow.
- ❖ Where irregular-sized stones are readily available.
- ❖ The soil should not be completely impermeable, allowing for temporary storage followed by groundwater recharge.
- ❖ Skilled labor is required for the construction of gabions.
- ❖ Location: Gabions should not be constructed at turns or where there are sharp falls.

Component of Gabion structure

1. Head wall (main body)
2. Head wall extension.
3. Foundation
4. Apron
5. Side wall
6. Retaining wall (if necessary)



Figure 29: Component of Gabion

12.2 Step by Step Process for Construction

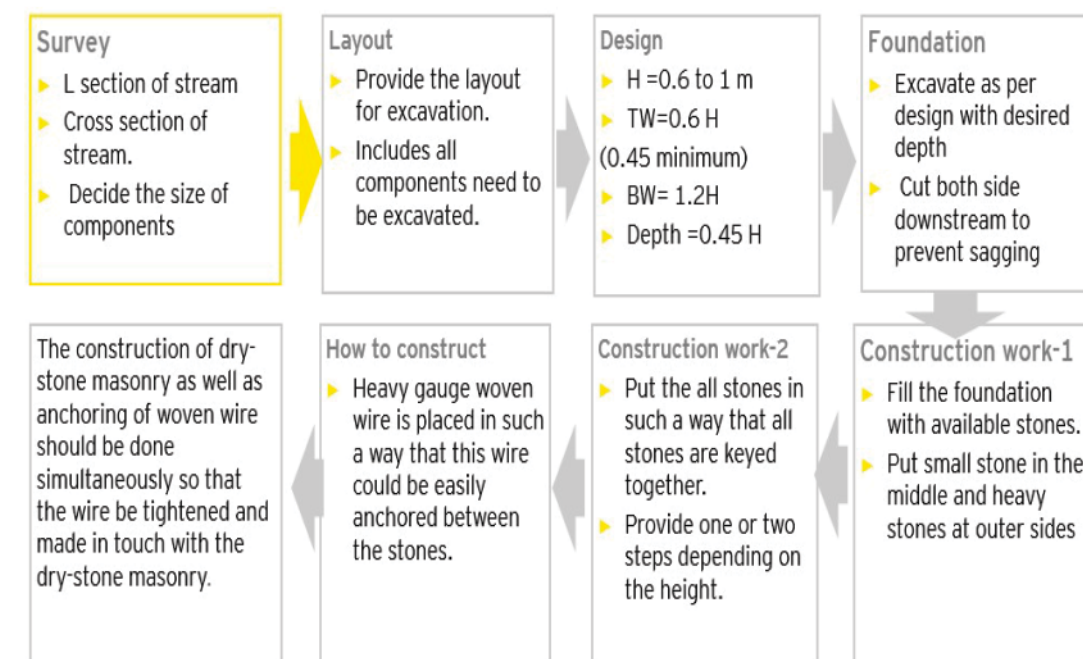
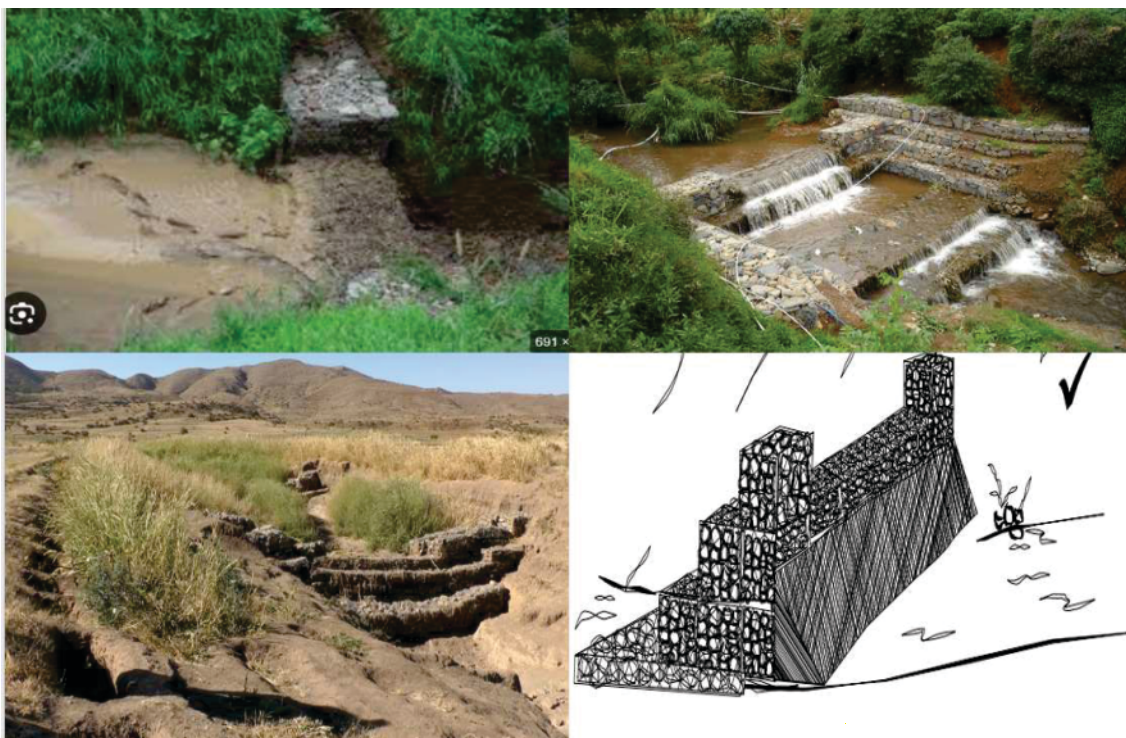


Table: 1 Material uses in Gabion

Wire mesh	Good quality galvanized wire of gauge 14-16 gauge. Gap in the wire should not be more than 7.5 *7.5 cm
Binding wire	The wire used for tying the wire mesh sections must be of the same strength as the wire used in the wire mesh. It could either be of the same gauge or of a thinner gauge plied and twisted together.
Boulder	The boulders should be hard and should not deteriorate under water. Size = 22.5 *22.5 cm
Plier	To tighten the wire

12.3 Images of Gabion Structure



12.4 Do's and Don't

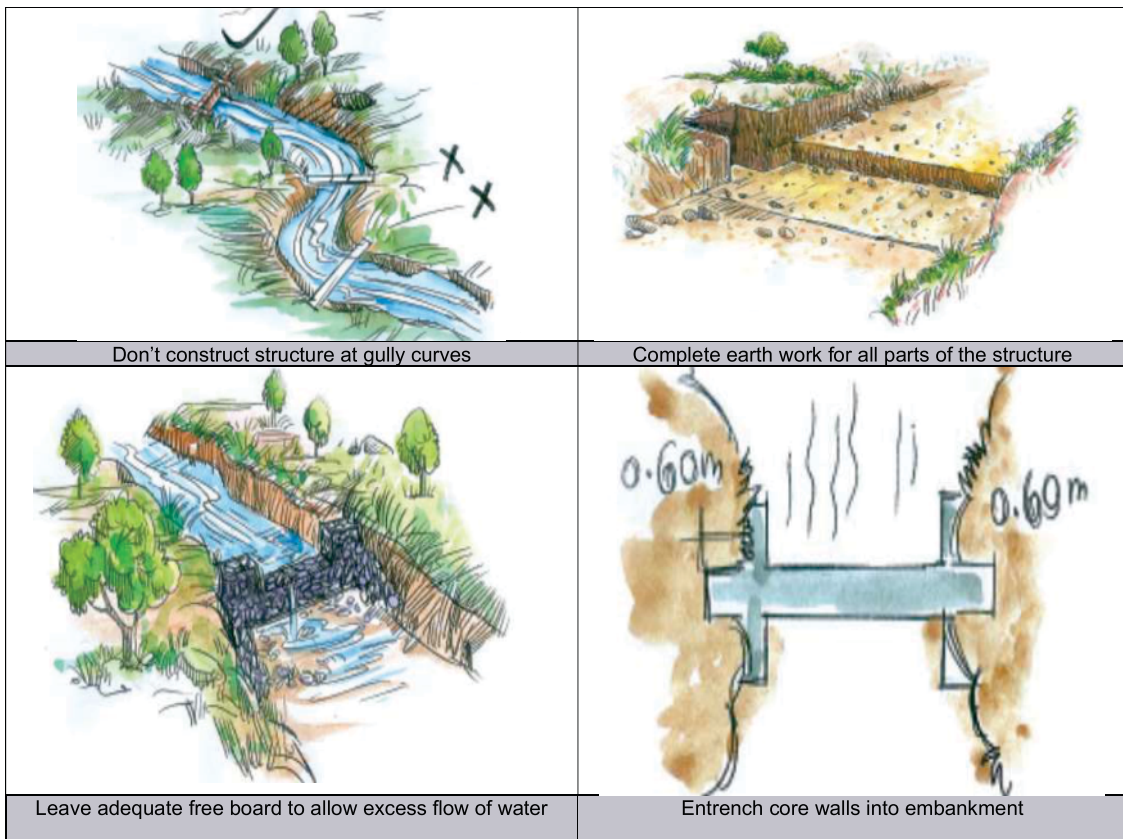
Do's

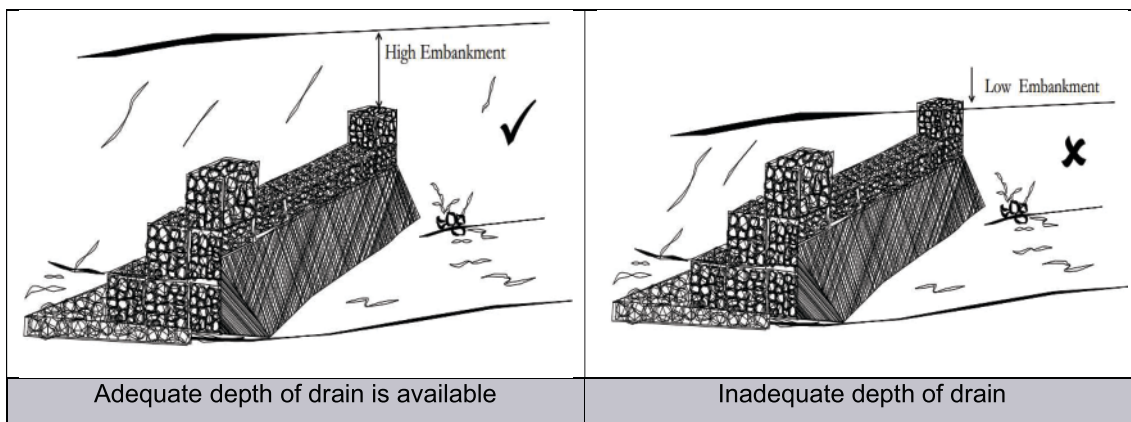
- ▶ Always clean and clear the site
- ▶ Always provide adequate proper freeboard to save the sides from scouring.
- ▶ Complete all the earth work at one time.
- ▶ Smaller boulders must be placed in the interior part of these boxes while the larger ones must be placed on the outside.
- ▶ The wire mesh must be stretched taut so that there is no bulging or sagging.
- ▶ Use skill and trained labour for construction of dry-stone masonry.
- ▶ Identify the point where scope for good amount of storage is available.
- ▶ Always provide the hands-on training to mason at site before construction.

Don't

- ▶ Don't construct without survey & design.
- ▶ Don't construct at curve
- ▶ Don't use round shaped stone
- ▶ Don't construct where the embankment is highly erodable or is of insufficient height
- ▶ Don't construct at points, below where is sharp drops
- ▶ Tighten the wire very well and bend it inward so that the joint does not open, as one open joint would cause the entire net to unravel.
- ▶ Don't construct if gully width is more.
- ▶ Don't construct the Gabion if catchment is more than 50 Hectare

Figure:30 Visual presentation of do's and don't





12.5 Eligibility Criteria for Construction of Gabion

Catchment Area:

- Independent catchment: up to 5 to 20 hectares
- Total catchment: up to 50 hectares

Bed Slope:

- A Gabion is suitable for slopes between 6 -10 %.

Stream Order:

- A Gabion is suitable for **third order** drain and in **fourth order**, if the catchment area is up to 50 hectares

Erosion Intensity:

- Areas very highly prone to soil erosion.

Erosive Velocity:

- Drains that have a very high velocity of runoff (Erosive velocity)

Depth of Drain:

- The depth of the drain should be sufficient to accommodate both the height of the structure and the depth of flow, including freeboard. For a Gabion, the ideal depth is 2 meters, since the maximum height of the structure is typically up to 1.25 meter.

Location:

- The structure should not be located at any sharp curve; the water flow should be perpendicular to the structure.
- There should not be any sharp falls within the drain.
- The drain should have a uniform slope.

Availability of Material:

- Availability of high-quality, angular stones of the appropriate size.
- Skilled labour must also be accessible for dry stone pitching and binding of box.

Banks:

- Stabilized banks to prevent erosion due to erosive velocity.

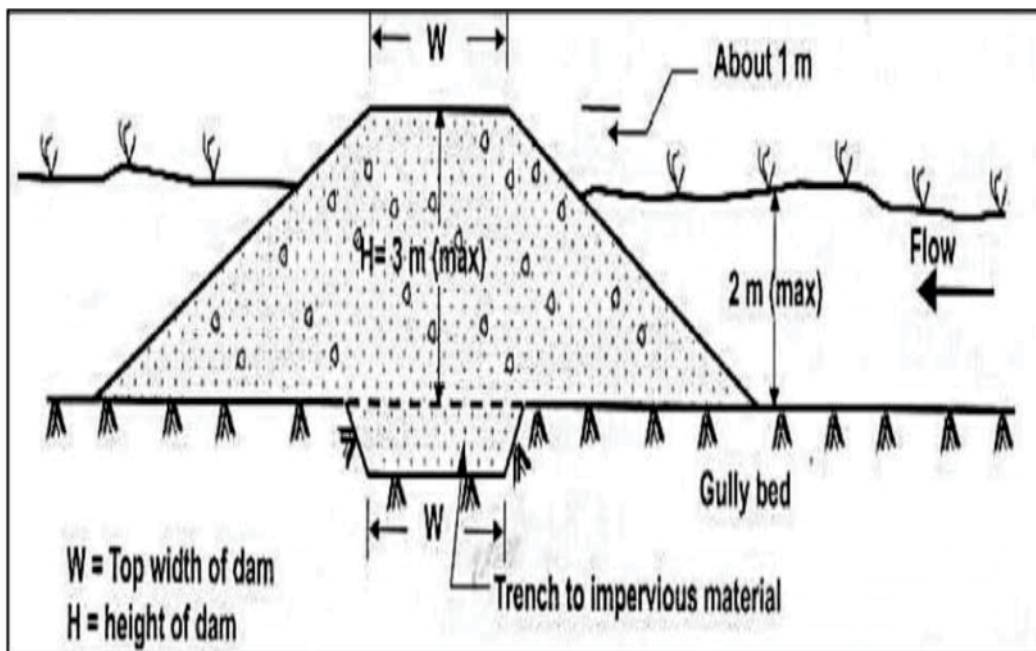
Chapter 13: Earthen Check Dam

13.1 Introduction

An earthen gully plug is a soil and water conservation structure built across small water channels or gullies. Its primary functions are to slow down water flow velocity, control soil erosion, and facilitate sediment deposition. These structures are commonly constructed using locally sourced materials such as soil, stones, and vegetation. While an earthen gully plug is similar to an earthen check dam, there are subtle differences in their purposes. An earthen gully plug is typically installed in drains to moderate water velocity where other resources are scarce, and it does not include a waste weir. It is suitable for very small catchments of up to 5 hectares. In contrast, an earthen check dam is a small but comparatively larger structure that also acts as a minor water harvesting structure. This type of dam requires a waste weir and can be constructed for catchments ranging from 20 to 25 hectares. Earthen check dams are primarily built in non-arable land treatment plots where there are appropriate sites for water storage and sediment capture.

The Forest Department typically constructs earthen check dams as part of the Rehabilitation of Forest Degradation (RDF) models. The design and construction of these structures can vary depending on the specific conditions of the gully, such as its size, slope, and the volume of water it carries.

Figure: 31 Check dam cross section and actual figure



13.2 Purpose of Earthen Check Dam

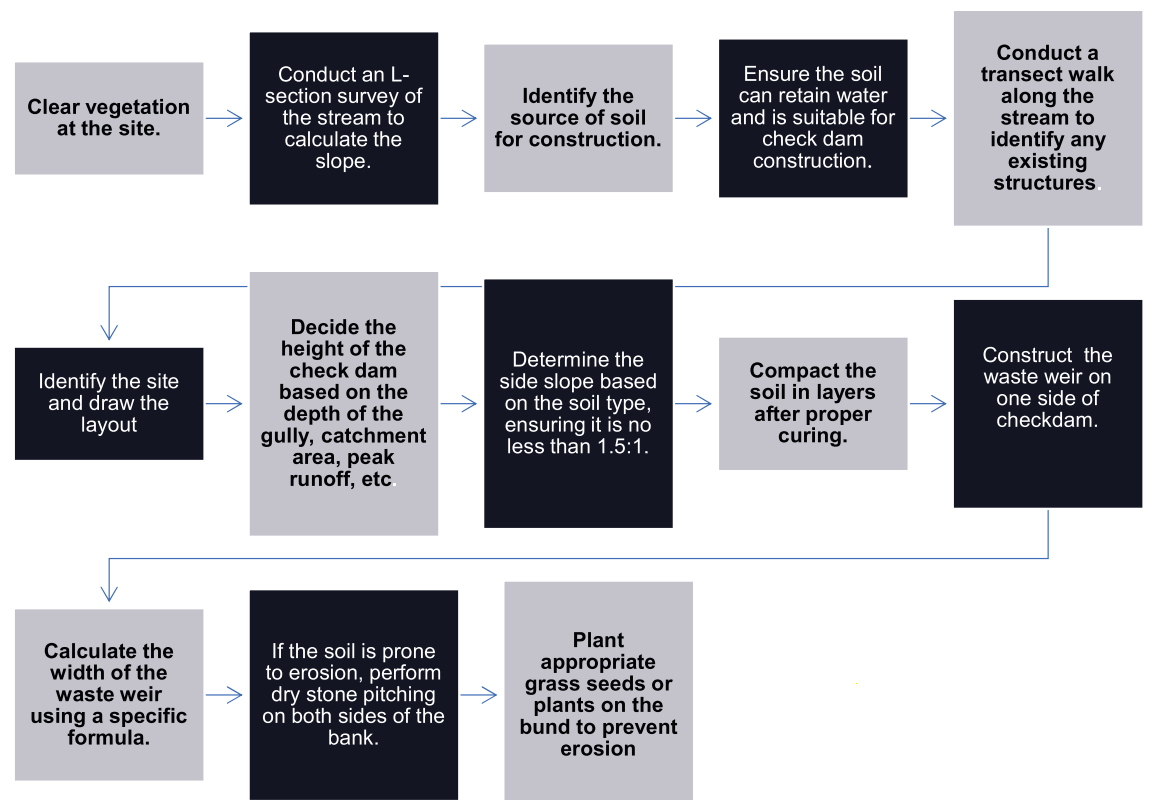
The primary purpose of an earthen gully plug is to:

1. Reducing the flow velocity of water in gullies to prevent further erosion and the formation of new gullies.
2. Trapping and accumulating sediment from runoff, contributing to the gradual buildup of the gully bed.
3. Enhancing soil water infiltration, which can improve groundwater recharge and decrease surface runoff.
4. Serving as an erosion control structure to stabilize gullies, ravines, and land.
5. Providing grade control to stabilize channels and waterways, maintaining a consistent elevation.
6. Offering protection to agricultural fields from encroachment and damage by gullies.

13.3 Location

- Small gullies or streams with a depth not exceeding 3 meters.
- In the upper or middle reaches of a catchment where there is potential for water augmentation.
- Earthen gully plugs are suitable for first or second-order streams.
- Areas with a low slope (less than 10 percent).
- Catchment areas up to 20 hectares with a waste weir, and up to 5 hectares when constructed in series to moderate the velocity of water without a waste weir.
- Slope: low to moderate (maximum 6 percent).
- Locations where stones are not available.
- Areas where suitable soil for embankment construction is available.
- Sites equipped with a facility for a spillway (waste weir).
- Locations without sharp turns, with a small suitable area available for storage, no sharp falls, and where no large water-harvesting structures (WHS) have been constructed upstream.

13.4 How to Construct.



13.5 Do's and Don't

Do's

- ▶ Perform an L-section survey of the stream.
- ▶ Maintain a minimum freeboard of 0.6 meters.
- ▶ Ensure a minimum top width of 1 meter.
- ▶ Maintain a minimum side slope of 1.5:1.

Don't

- ▶ Construct with sandy soil that has poor water-holding capacity.
- ▶ Construct without a waste weir.
- ▶ Construct to a height greater than 1.2 meters.
- ▶ Construct in a stream between two existing WHS.



Figure 32: These structures are constructed without compaction or a waste weir, and the soil is not suitable for an earthen check dam. The side slopes are also gentle, which may result in lower sustainability for these structures.

13.6 Eligibility Criteria for Construction of Earthen Gully Plug

- Depth of Gully: Gully with a depth not exceeding 3 meters.
- Reach: Upper and middle reach
- Stream order: first and second order
- Catchment area: Up to 5 Hectare without waste weir and 20 hectares with a waste weir
- Areas with a low slope (less than 10 percent).
- Slope: low to moderate (maximum 6 percent).
- Location:
 1. Where stones are not available.
 2. Areas where suitable soil for embankment construction is available
 3. Without sharp turns at point of construction
 4. No sharp falls
 5. Where no large water-harvesting structures (WHS) have been constructed upstream.

Chapter 14: Silt Detention Structure

14.1 What is It?

A silt detention structure is a type of dam built in the lower reaches of a catchment area to intercept the silt carried by runoff, while also serving to harvest water. This is particularly beneficial in areas where soil erosion is severe. For optimal results, a series of such dams can be strategically placed along the catchment's slope. These structures can be made from several types, including masonry, dam with a masonry spillway, or gabion structures with innovative designs.

14.2 Where to construct?

Location Criteria in forest areas.

- ▶ Lower reaches of the catchment.
- ▶ Third or fourth order streams with high erosion rates.
- ▶ Streams with an average slope of up to 6%.
- ▶ Locations with stabilized banks on both sides.
- ▶ Areas with low to moderate slopes in the submergence zone.
- ▶ Upper reaches that have undergone (SWC measures).

14.3 Purpose of silt detention structure

- ▶ Trap the sediment available in the catchment area.
- ▶ Control runoff velocity of the stream.
- ▶ Replenish groundwater in the water sources.

14.4 Do's and Don't

Do's	Don't
Design the structure with its specific purpose in mind. For instance, if the structure is intended solely for silt trapping, its dimensions should reflect that. However, if it is also meant for water harvesting, the design will differ.	Avoid overdesigning or under designing the structure.
Construct a silt trap upstream of the main structure to collect sediment, which can be cleaned out once the structure doesn't have water.	Do not build a silt detention structure if the upper reaches of the catchment have not been treated, as this will lead to rapid filling and reduced effectiveness.
Involve community institutions and establish mechanisms for removing deposited silt to maintain the structure's storage capacity.	
In cases where the catchment is low in the middle reaches, consider constructing a gabion structure to function as a silt detention facility	

Part D: Water Harvesting Structure

Contents

15

Masonry Check dam (Anicut)

16

Percolation Tank

By delving into this chapter, practitioners will gain a thorough understanding about the WHS, enabling them to apply this knowledge to design and construct a good quality WHS.

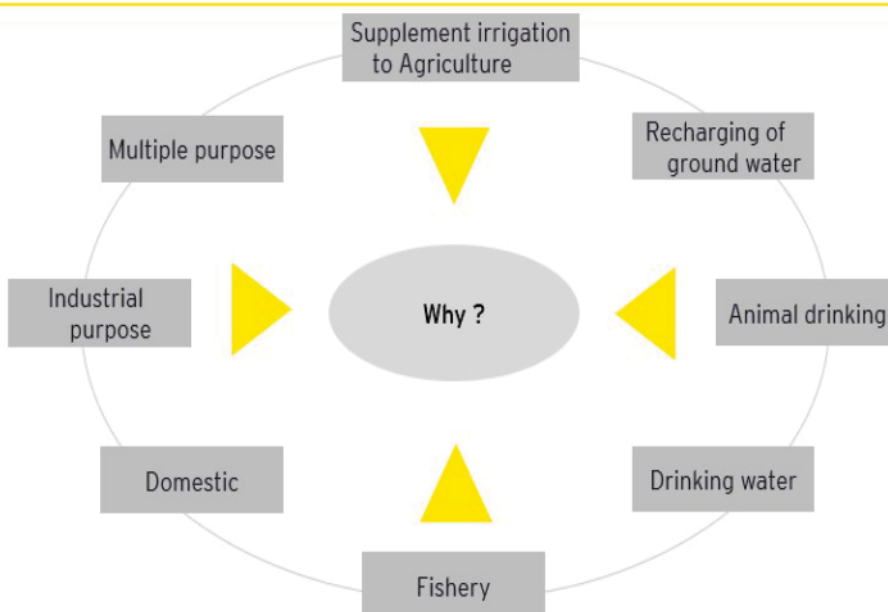
Chapter 15: Masonry Check dam (Anicut)

Rajasthan grapples with acute water scarcity, possessing a mere 1.16% of India's surface water while its groundwater reserves continue to decline. The state has classified over 80% of its blocks as 'overexploited' or 'critical.' This scarcity has taken a toll on agricultural yields and the socio-economic status of communities near forests. The construction of water conservation structures such as anicuts, earthen dams, percolation tanks, and ponds has been established as an effective method for enhancing groundwater reserves and water availability. These measures are set to boost agricultural output and alleviate the burdens faced by the local population, particularly women. Furthermore, they are expected to foster a positive change in the plantation of degraded lands, the introduction of superior plant species, and ensure year-round water availability in forested regions. Consequently, the moisture levels in the area will rise, the water table will elevate, and streams will flow for extended periods.

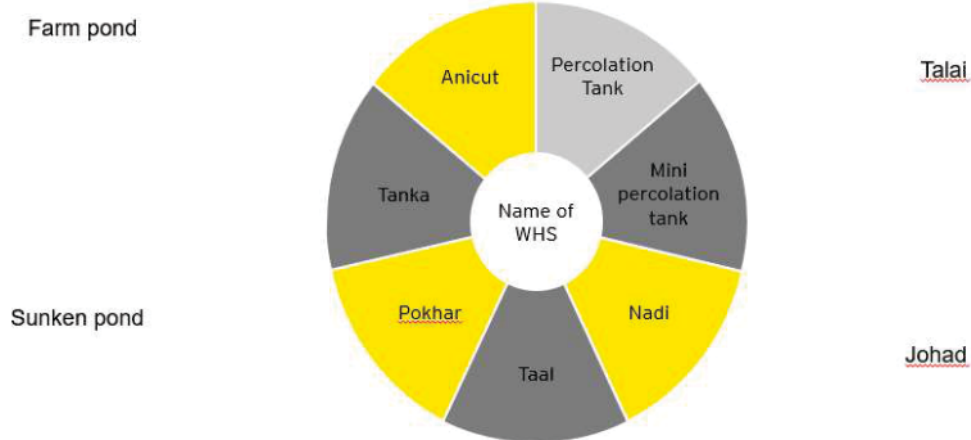
Before constructing any water harvesting structure, the Project Implementing Agency (PIA) should understand the purpose of the structure for the target group; otherwise, the structure will not serve its intended purpose. Consider that a structure will serve its purpose if we construct a Water Harvesting System (WHS) on land where the percolation rate is high, and the goal is either fisheries or providing drinking water to cattle during summer. However, it will not be effective if the water does not remain stored in the structure for a long time, as needed until summer, and thus the purpose will not be fulfilled.

The figure mentioned below indicates the various purposes that a WHS can serve

Why ?..... Decide the Purpose for construction of WHS



Most common types of WHS



(Figure 33: indicates various names of WHS according to region, purpose and land)

15.1 Introduction to WHS

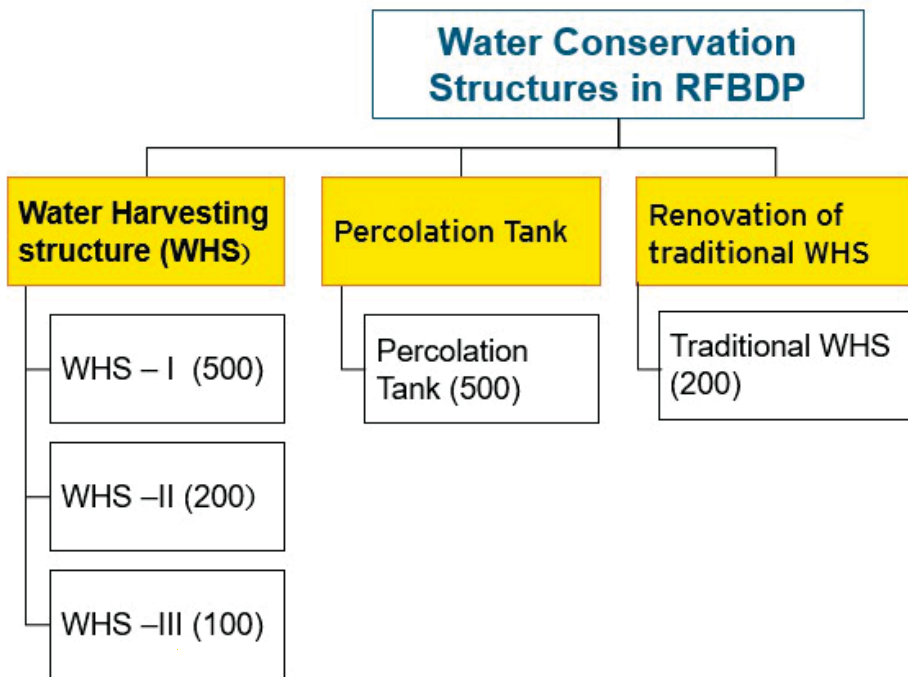
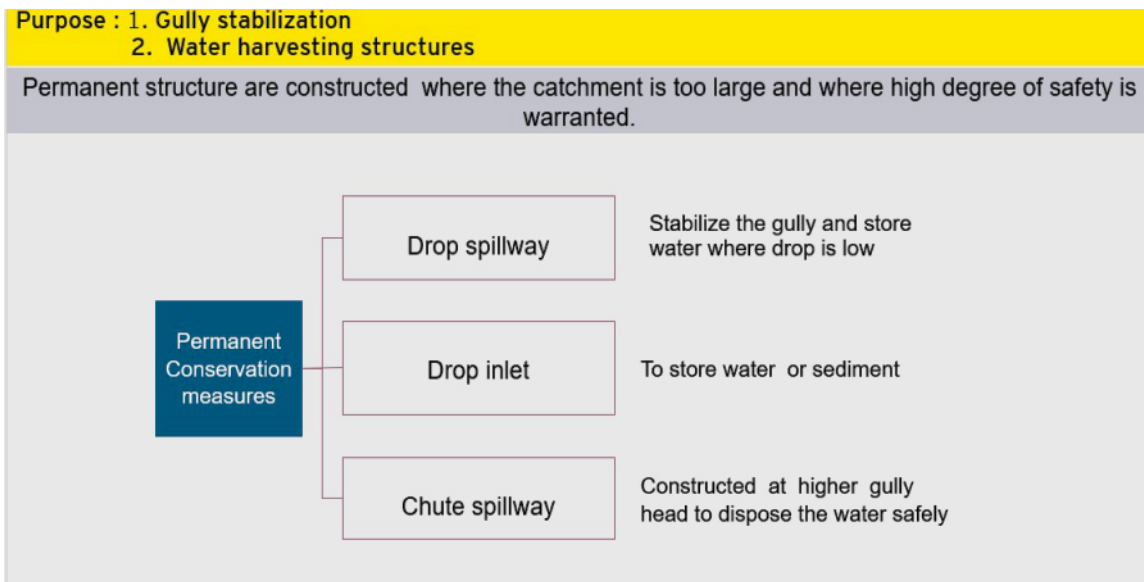


Figure:34 Describe water conservation structures in RDBDP

Water harvesting involves the collection and storage of rainwater using various methods to ensure water availability for future needs. A Water Harvesting Structure (WHS) is a specially designed water body that captures and stores surface water for beneficial uses, including drinking, groundwater recharge, and irrigation of agricultural crops. The figure mentioned below illustrates various water harvesting structures in the RFBDP project. The concept and design principles for any water harvesting structure are largely the same; thus, we will examine the masonry check dam (Anicut) in detail as a representative example of a WHS. Additionally, we will address important considerations concerning the earthen dam as a WHS in the chapter on percolation tanks.

Permanent soil conservation measures (masonry structure) could be classified into three categories based on purpose.

Figure 35: Types of permanent structures for gully stabilization and erosion control.



15.2 Masonry Check Dam (Anicut)

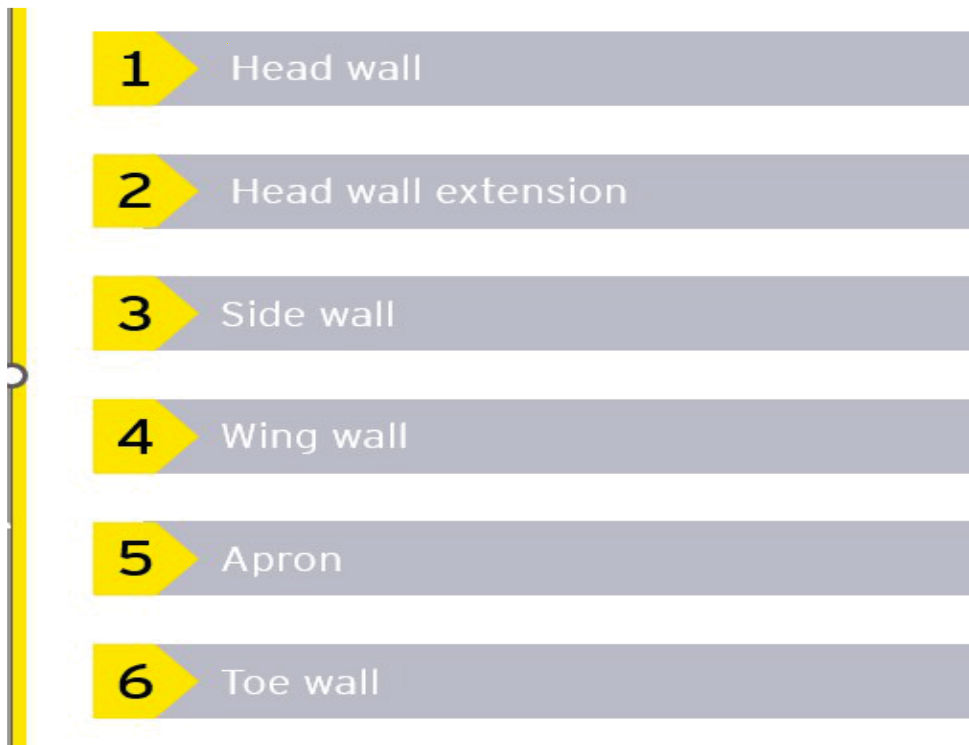
What is it? It is a weir structure constructed in the natural drain or nalla to impound water. It is a masonry structure that intercepts water from the local catchment and stores it for optimum utilization.

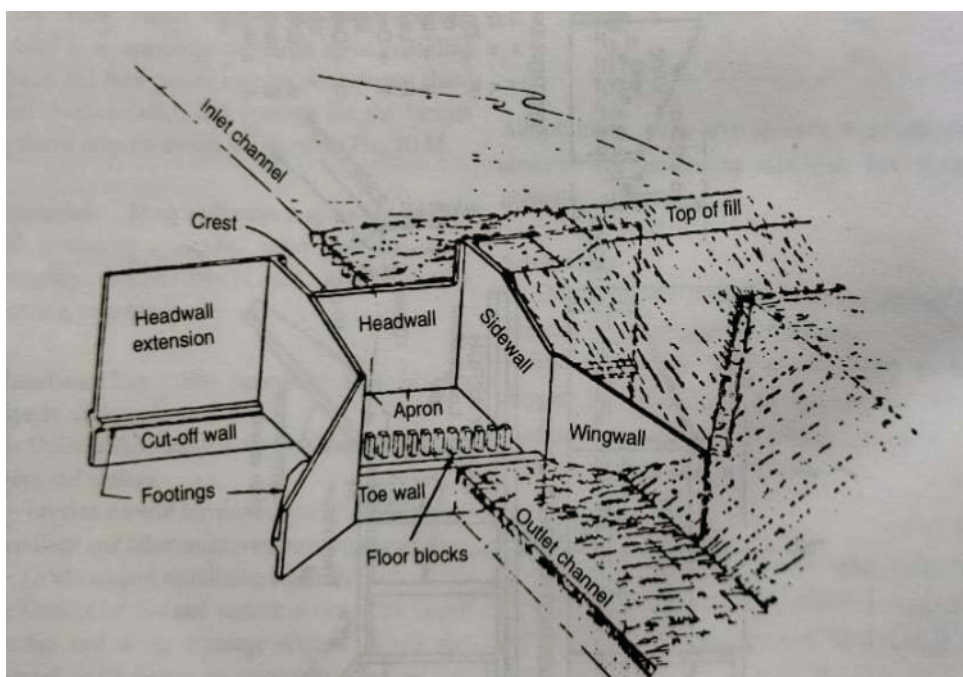


Figure 36 : Images of various masonry check dam

Functions:

- ▶ Providing drinking water for wildlife, animals, and cattle.
- ▶ Supplemental irrigations for agriculture.
- ▶ Recharging ground water resources
- ▶ Supplying drinking water to the community.
- ▶ Serving domestic purpose for the community
- ▶ Positively impacting biodiversity
- ▶ Work as erosion control structures in upper and middle reaches
- ▶ Stabilization of gully

15.3 Components (Parts) of Anicut:**Figure:37 Components of Anicut**



Headwall (HW): It acts as a front wall against runoff in the check dam. The headwall is provided with a weir to allow flow to pass through. A rectangular weir is most constructed with an ogee shape or with steps. The size of the weir should be sufficient to safely pass the design discharge.

- ▶ The top width of the headwall should be no less than 0.45 m in any case and may be up to 1 m, depending on the runoff and the height of the structure.
- ▶ The bottom width should be determined based on a formula; however, it should not be less than 1.8 m in any case.
- ▶ Both the top width and bottom width should be determined by a formula.
- ▶ The maximum height could be 2 m (as per the Rajasthan water policy), although it is 1.5 m for forest areas.

Headwall Extension (HWE): It is the extended portion of the headwall into the sides of the nalla. Its main function is to provide structural strength against the sliding of the structure. The length of the HWE depends on the site conditions. If the length is more than that of an earthen embankment, stone pitching can be constructed. The headwall extension of different base widths, as per site conditions, can also be decided to save on expenditure.

- ▶ The top width of the headwall should be no less than 0.45 m in any case and up to 0.6 m in the case of an anicut constructed in a forest area.
- ▶ The bottom width can range from 0.9 to 1.2 m.
- ▶ The height of the HWE should be determined after adding the freeboard to the height of the structure.

Sidewall: These are constructed along the sides of the gully walls. The two sidewalls define the apron section. Their function is to prevent water from splashing over the nalla banks and

to confine the water flow within the apron. Sidewalls are usually constructed downstream of the structure; however, they are constructed on both sides if the banks are susceptible to erosion.

Wingwall: These are constructed at the rear end of the structure, with some inclination, usually at 45° from the vertical. These walls extend up to the nalla sides and serve to prevent the flow from moving backward into the space between the gully wall and the sidewall of the structure.

Apron: This is one of the main downstream components of the check dam. It receives the runoff flow at high velocity and dissipates the kinetic energy of the flow to protect the downstream channel from erosion.

Toe Wall: Toe walls are constructed at the bottom of the structure to prevent slippage or spreading of soil.

Freeboard: This is the elevation difference between the surface of the headwall and the top of the headwall extension. It represents the height of the weir and should not be less than 0.6 m in any case.

15.4 Designing of Masonry Check Dam (Anicut)

Types of design:

Masonry check dam in water conservation is normally designed for a recurrence interval (RI) of frequency of 10-30 years which means that they are supposed to discharge the maximum runoff expected during the design frequency or recurrence interval (RI) safely. The structure should be strong enough to withstand the forces exerted by water/earth. A structure should, therefore, be designed with the following considerations



Hydrologic design

- It involves computation of the peak discharge at the point of watershed where the structure is to be constructed. Generally, Rational method is employed for this purpose.



Hydraulic design

- It involves calculation of the dimensions of the spillway which can carry the above peak discharge safely.



Structural design

- It involves calculation of the dimensions of each component of the structure which ensures its safety against water/earth forces, the structure is likely to withstand

Investigation to be done during planning

- ▶ Total catchment area that contributes runoff to the WHS site
- ▶ If any structure has already been constructed on the upper catchment area, then 30 % of the previous structure should be included in the next one.
- ▶ The catchment area can be determined from the GT sheet.
- ▶ Intensity of the rainfall for a 25-year recurrence interval.
- ▶ Detailed contour plan of the proposed submergence area.
- ▶ L section of the natural drain and cross section of the drain.
- ▶ The details for the soil profile and strata for the section
- ▶ Map showing the position of wells/tubewells which would be recharged and area under proposed irrigation.
- ▶ Availability of the total volume of runoff from the catchment area
- ▶ Presence of existing WHS at u/s and d/s side in one km distance

How to decide the dimension of the Anicut

1. Technically the length and height of anicut can be determined by the cross-section survey of the Nalla. This survey helps to decide the crest height, depth of flow, free board and length of flow and non-overflow section.
2. Estimation of peak rate of runoff of maximum flood discharge can be calculated either by rational formula or Dicken formula.
3. **Height: It depends on the following**
 - ▶ Volume of runoff from the catchment area
 - ▶ Volume of water required to be stored. A need assessment should be done to calculate the water requirement.
 - ▶ The expected runoff volume should be more than designed storage capacity.
 - ▶ Refer to Rajasthan water policy, maximum permissible height is 2 m.
4. **Depth of foundation**
 - ▶ Depth of foundation can be determined by the formula.
 - ▶ However, under field conditions, formula is not exactly applicable, and it depends on the site conditions so depth of foundation should be taken up to hard rock.
 - ▶ A trial pit should be dug before initiate the work to avoid over expenditure.

15.5 Steps for Construction of Anicut:

Figure 38: Steps to be followed for construction of Anicut.

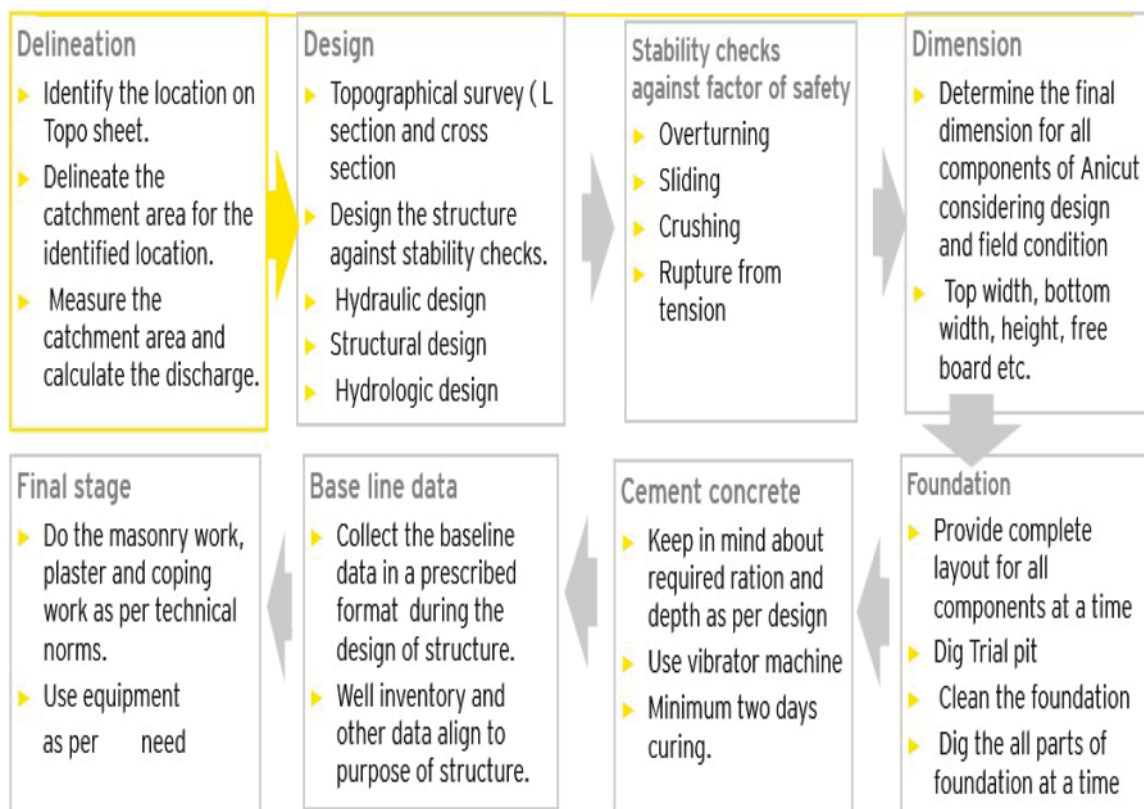
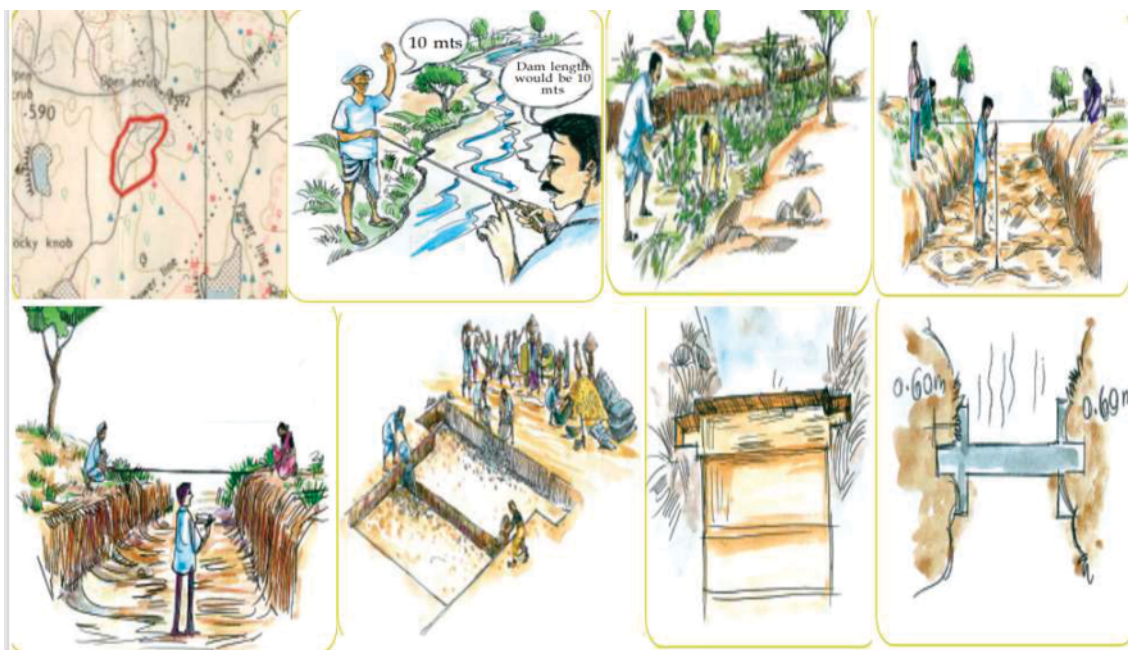


Figure 39: Steps to be followed for construction of Anicut described by images



15.6 Dos and Don'ts during construction of Anicut

Do's	Don'ts
▶ Entrench core walls into the sides as much as possible. ▶ Perform proper filling, pitching, and pointing work on both sides of the banks. ▶ Ensure a 0.6 : 1 slope in the u/s side of head wall for stability of structure. ▶ Ensure the foundation is of adequate depth in all parts of structure. ▶ Ensure curing for 21 days. ▶ Extend the gully, and ensure the foundation is parallel to the ground ▶ Maintain a minimum gap of 3 days between construction of body wall and concrete bed. ▶ Cure the Concrete bed thoroughly and, use vibrator. ▶ Ensure the size of stone aggregate in the cement concrete is 40mm (60% of total aggregate) and 20mm (40% of total aggregate). ▶ Ensure pitching is parallel to the apron and toe wall. ▶ Pack the apron with smaller stones between the 0.225m size stones to increase the bond.	▶ Do not construct the check dam without treating the upper reaches with appropriate structures. ▶ Do not widen the gully for constructing the check dam. ▶ Do not construct the dam where the gully has sharp curves. ▶ Do not construct the dam if the flanks are not strong. ▶ Do not pour concrete without completing the earthwork for all parts of the structure. ▶ Do not leave the earth excavated for foundations in the gully. Instead, transport it

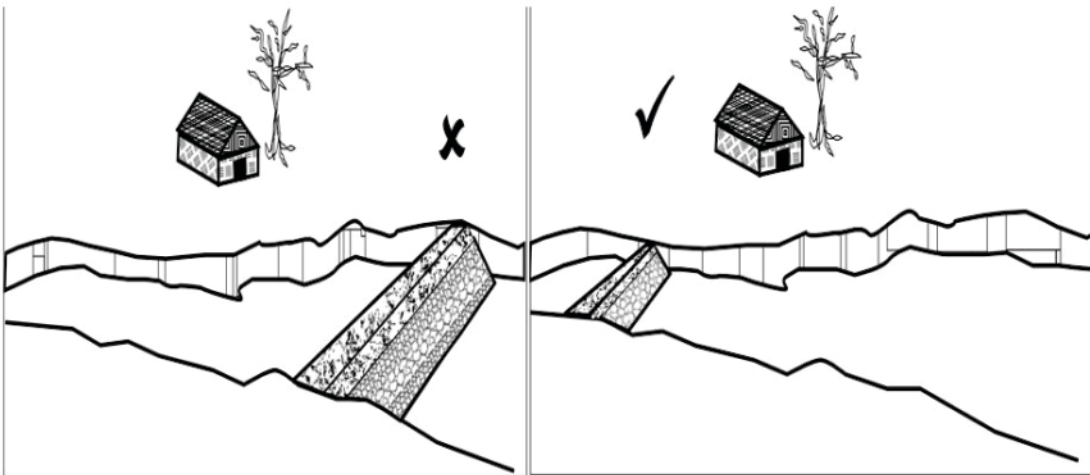


Figure 40: The image shows that the first structure is incorrectly placed in a wide area, while the second image depicts the correct placement in a narrower location

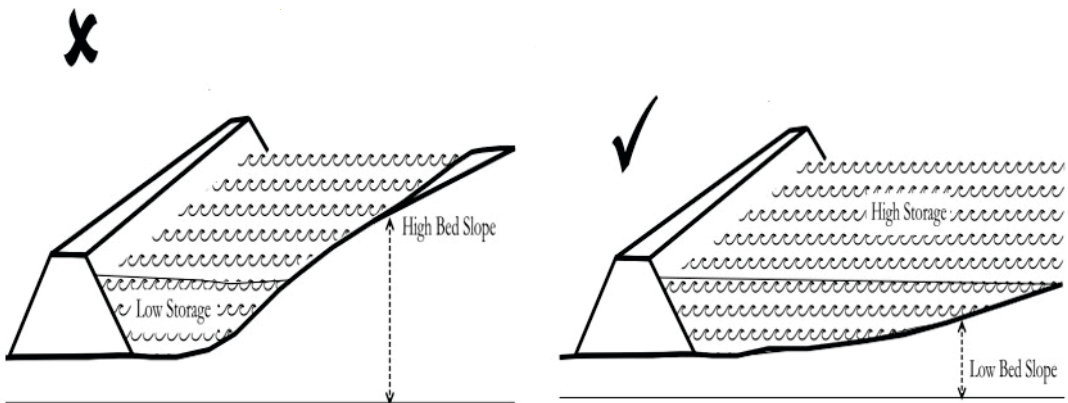


Figure 41: The image illustrates that the first structure is not ideal because it is situated on overly sloped land, resulting in low storage capacity and a shorter fetch length, whereas the second structure benefits from a longer fetch length due to its placement on land with a gentler slope

15.7 Eligibility Criteria for Construction of Anicut

An anicut can be constructed if the site fulfils the following criteria:

1. **Stream/stream order:** Main drain/Nalla of the drainage pattern or Fourth order or higher order stream.
2. **Slope:** in the main drain: 3% or less, or a maximum of 5% in exceptional situations.
3. **Catchment area:** 250 to 1000 hectares.
4. **Banks: Stabilized banks** are available on both sides of the drain.
5. **Runoff potential:** Adequate to fill the structure with a 70% probability of rainfall.
6. **Location:**
 - A **narrow length** is available in the drain (minimum crest length) with a **wide area for submergence**.
 - Without turns or curves, where efficient utilization of the stored water is possible.
 - Proximity to farmers' fields for water conveyance through proper channels
7. **Depth of drain:** Minimum of 2 meters or the height of the anicut plus 0.75 meters.
8. **Water holding capacity** of soil: Slow or moderately slow.
9. Sites where maximum storage can be achieved: Deep and narrow sections of valleys with steep side slopes.
10. **Strata of surface:** Location has hard rock or stabilized strata at a shallow depth.
11. **Accessibility:** Accessible location for easy transportation of construction materials.
12. Hard strata to provide water for wild animals over extended periods.
13. Areas without alternative water sources in grasslands or plantation plots.
14. Forest areas with acute water scarcity for wildlife drinking water.
15. No structure in the submergence at upstream or downstream, or no structure on both sides within a minimum half kilometre.
16. **Good fetch length:** Minimum of 500 meters.
17. **Submergence:** Nothing, including habitats, plantations, trees, or wildlife, should be submerged by the structure

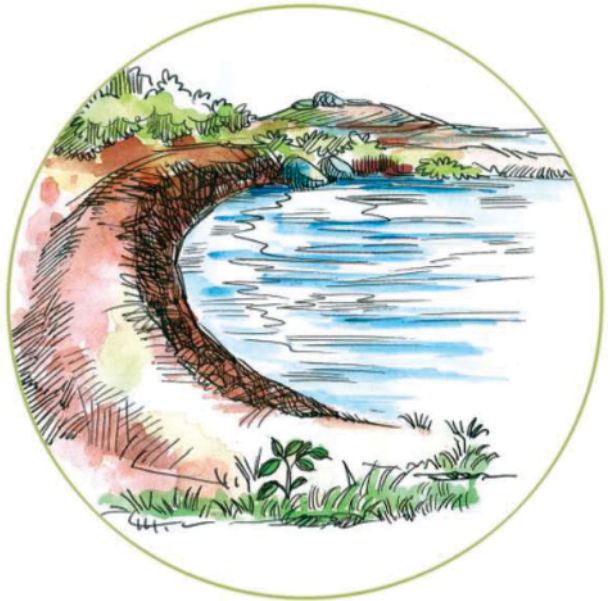
Chapter 16: Percolation Tank

Percolation tanks are small water storage structures constructed across natural streams and nalla to collect and impound the surface runoff from the catchment during monsoon rains and store it for a longer time to facilitate infiltration and percolation of water into the strata to raise the ground water level in the zone of influence of the tank. They are mostly earthen dams.

Component: Earthen embankment (bund), core wall, waste weir, cut off trench.

Objectives

- To conserve water during rainy season to be used for irrigation in post monsoon season.
- To recharge ground water resources such as wells, tubewells.
- To serve as a source for drinking water and domestic usage for the nearby communities.
- Drinking water for wildlife.



Every practitioner needs to understand three important soil properties - Texture, infiltration capacity and natural angle of repose- before designing the percolation tank or any earthen structure. These properties are discussed below in the figure.

Figure 42: Properties of soil

Texture :

Soil texture refers to the proportion of sand, silt and clay sized particles that make up the mineral fraction of the soil. Such as light soil refers to a soil high in sand relative to clay, while heavy soils are made up largely of clay.

Infiltration capacity

This is the property of soil about the ability to allow water to pass through. Water easily passes through gravels and sands; however, it takes time or does not pass through clay at all.

natural angle of repose

The natural incline that the sides of the heap form with the ground is called angle of repose. In general, the slope of any SWC intervention must always be less than the natural angle of repose of the material used in its construction. The more squat the structure is, the safer it is.



Figure 43: Images of percolation tank

16.1 Suitable Location for Construction of Percolation Tank

- **Independent catchment area:** between 50 to 500 hectares.
- **Order of stream:** Third or fourth order stream/main drain.
- **Permeability (water holding capacity) of soil:** The soil should have moderately low permeability to help store water for an extended period, allowing for the recharge of groundwater sources downstream. Clay soil, with its fine texture, exhibits very slow permeability. Loamy soil, with moderately fine to coarse texture, has moderate to rapid permeability, while sandy soil has a rapid rate of permeability.
- **Narrow place with wide submergence:** To create more storage, select a narrow location that allows for wide submergence.
- **Demand and supply:** Aim to match the storage capacity of the dam with the catchment area as closely as possible.
- **Runoff potential:** The runoff from the catchment should be at least 25% more than the water requirement to ensure that the structures fill during the monsoon season.
- **Well-defined embankment:** Stabilized banks on both sides are an important technical condition for an anicut and percolation tank.
- **Depth of drain:** It should exceed the sum of the designed height, depth of flow, and freeboard. A minimum depth of 3 meters, with 3 to 5 meters being optimal.
- **Slope of drainage line:** It should be less than 5%.

- **Geology:** The natural embankments should be impermeable, while the water spread area should consist of relatively more permeable material.
- **Availability of material:** Quality soil should be easily and readily available nearby, eliminating the need for long-distance transportation.
- **Proper location of the outlet:** The outlet should be situated on either side of the structure where minimal excavation is required, where the bed strata are neither rocky nor prone to erosion, and where it can merge into the natural stream without damaging the farms.
- **Submergence:** Farms should not be located in the submergence zone of the percolation tank.
- **Socially acceptable:** The project should have the free, prior, and informed consent of the farmers.
- **Scope of recharging groundwater resources:** A significant number of tube wells/open wells should be available downstream.
- **Low evaporation loss:** The topography of the proposed site should favour the formation of a deep pond to minimize evaporation losses.

16.2 Design of Percolation Tank

During designing any earthen embankment, we must consider the structure against three stability checks: sloughing, scouring and overtopping.

Stability checks

Sloughing	Scouring	Overtopping
While controlled seepage in earthen dams is normal and typically harmless, uncontrolled seepage through the foundation can result in sloughing. This is particularly likely when the downstream portion remains saturated under a full reservoir, softening the soil mass. Sloughing occurs when seepage saturates the dam's external base, leading to soil removal from the wet downstream face. Internal erosion due to seepage through the embankment and abutments can also cause dam collapse.	Rainwater falling on the bund acquires scouring velocity as it flows on the downstream face of the embankment. It, therefore, cuts channels on the downstream side and weakens the structure. Pitching and vegetative measures on the downstream side help keep the velocity of flow within the non-scouring limit	All causes of earthen dam failure ultimately led to overtopping. Water washing over the top of the bund gradually erodes the top and downstream slopes, thus cutting a channel through the bund to a depth below the Full Reservoir Level (FRL) which speedily results in a breach. To prevent this, the top of a bund is raised to a certain height called the 'freeboard' above the FRL

Figure 44: Three types of stability for percolation tanks

Practitioners must understand the following terminology before undertaking the designing of any earthen structure.

Basic terminology

Top Bund Level (TBL): $MFL + \text{freeboard} = TBL$. The TBL refers to the top level of the dam. If water flows over the top of the bund in an earthen dam, the dam will break. Therefore, the TBL in all earthen structures must be kept higher than the FRL/MFL.

Full Reservoir Level (FRL): The FRL indicates the maximum level up to which water will rise when the structure is full. FRL is decided considering total runoff in relation to the effective storage potential of the site.

Maximum Flood Level (MFL): The MFL is the maximum level up to which water is allowed to rise in a structure after an intense spell of rain. This provision takes care of extraordinarily high floods, which might damage the structure because it takes time for flood water to move out of the surplus weir.

Top Width: Top width of dams varies with the height and purpose of the dam. For earthen dams in the range of 3 to 6 meters height, top width is kept in the range of 1 to 2 meters. If the top is to serve as a road, the top width will need to be more than 2m. The top width may be determined by the empirical formula,

$W = 0.4 \times h + 1$ where, W = top width of bund

h = maximum height of bund

Freeboard: Over and above the MFL, we provide an extra height to the dam, which is called the freeboard. Freeboard is the difference in height between the top of the bund and the maximum level up to which floodwater rises in a dam. Normally, the freeboard should be at least double the difference between FRL and MFL. It has been found through years of experience that for earthen structures with height less than 5m, a freeboard of 1m would be adequate.

Hydraulic gradient: also called seepage line or line of saturation. It is a line inside an embankment marking the boundary between wet earth and damp ordinary earth. The hydraulic gradient is between 3:1 to 10:1 for different types of soil.

Upstream and Downstream slope:

The upstream slope of the dam is subject to erosion by the sloughing action of waves and by receding water. The downstream slope of the bund is subject to erosion by intense rainfall and the scouring action of flowing water.

The precise upstream and downstream slopes of the bund depend on the angle of repose and erodibility of the materials used in the outermost face.

However, it is necessary to provide a lower slope on the upstream side than the downstream side to counter the sloughing action. Through experience it has been found that for a stable earthen structure, the upstream slope should range from 2.5:1 to 4:1. The downstream slope should range from 2:1 to 3:1.

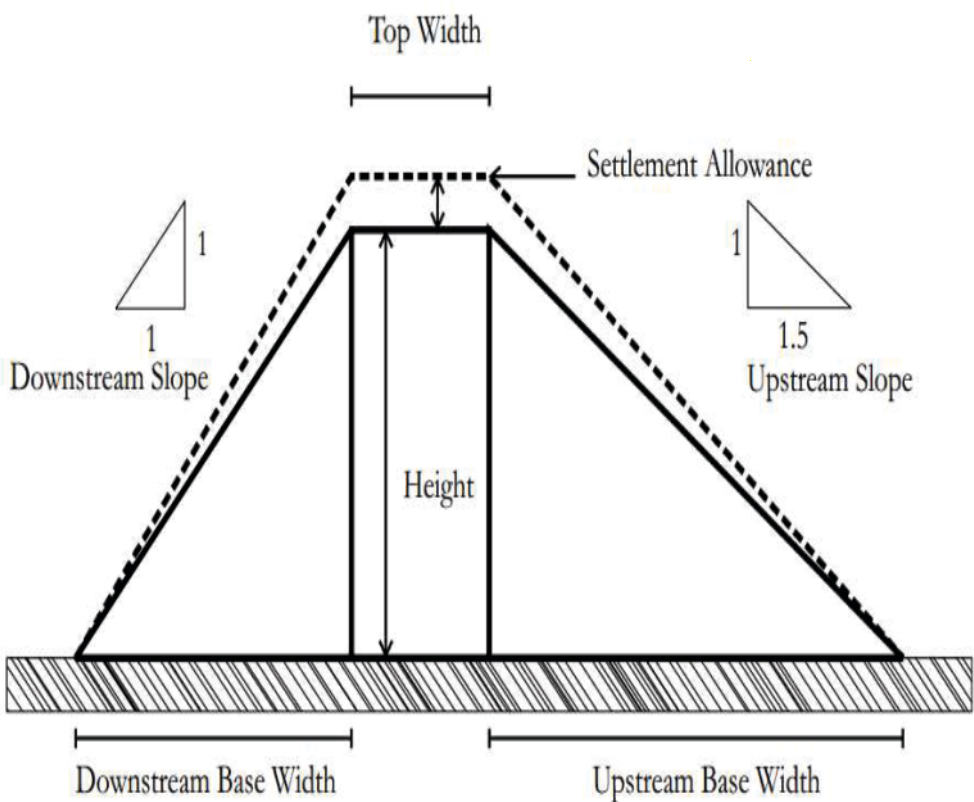
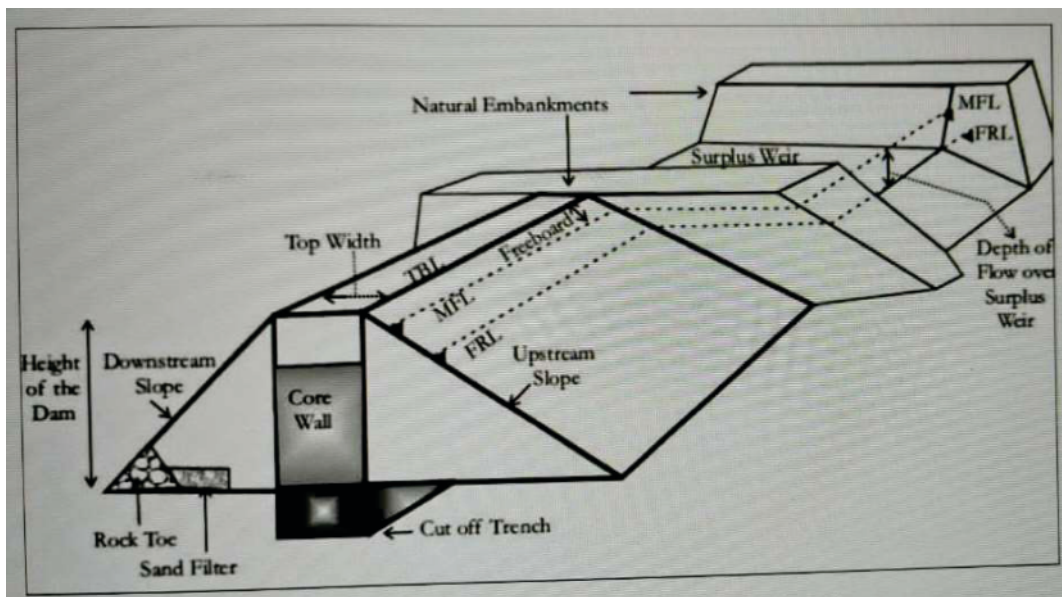
Settlement allowances

The soil used on an earthen dam is usually compacted to a certain degree. Even the, this artificial compaction can never match the state of natural compaction in which the materials are found on earth's surface. Hence, a certain allowance must be made for natural process of compaction due to the weight of the dam, movement of its materials towards their natural angle of repose, the increased moisture caused by water storage and the direct impact of rainfall. This allowance to be provided for this settlement depends on the type of fill material and the method of compaction used. Thus, the earthen dam must be made convex shaped with the middle portion being higher than the sides.

Waste Weir.

Water in excess in percolation tank above the FRL is drained out by the waste weir. There may be great variation in the rains in terms of intensity. There may be sudden storms and very high runoff of water is available so a waste weir is required so that extra runoff may be drained after filling the dam up to FRL. The dimensions of the surplus weir are determined by taking into consideration the peak runoff from the catchment.

Figure 45: Top and cross section view of percolation tank



16.3 Step by step procedure for construction of percolation tank

Trial pit:

1. Experimental pits measuring 1m x 1m should be dug at three or four locations on the proposed dam site.
2. Water should be filled into these pits to gauge the percolation rate of the site. If the percolation rate is excessively high, the site should be discarded.
3. Trial pits also assist in determining the depth of the cut-off trench at the base of the dam.
4. Another purpose of the trial pit is to evaluate the strength of the strata beneath the dam.



Calculation of catchment area

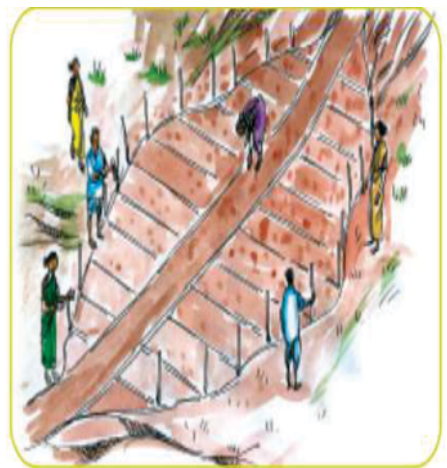
1. Identify the location on the Topo-sheet.
2. Measure the catchment area.

Site clearance

1. Remove all vegetation at the proposed site and scrape the area to a depth of 10-20 cm, ensuring that all tree roots, sand, stones, and other debris are cleared away.
2. Create "toothing" at the site by making the base of the dam uneven to enhance the grip of the structure on the ground.
3. This preparation will help ensure better adhesion of the dam to the site.

Layout

1. Draw a line along the centre of the proposed bund from embankment to embankment (centre line). Determine the FRL and TBL of the structure.
2. At 4-meter intervals along the centre line, use a dumpy level to mark points where the dam will be raised to the TBL, adding a settlement allowance to the height at each point. Based on the decided slope parameters, indicate the distances on the upstream and downstream sides at each point and draw lines through these points.
3. Ensure that the required top width is precisely in the middle of the bund. For example, if the maximum dam height is 5m, the top width is 2m, and the upstream and downstream slopes are 2.5:1 and 2:1 respectively, mark the upstream edge of the dam at $(5 \times 2.5) + 1 = 13.5\text{m}$ and the downstream edge at $(5 \times 2) + 1 = 11\text{m}$.



Cutoff trench

1. To prevent water leakage and seepage in an earthen dam, we need to dig a cut-off trench and fill it with puddled clay. The purpose of the cut-off trench is to control excessive seepage below the dam wall, not to provide a foundation.
2. Dig a 1m wide trench to the required depth along the centre line of the proposed dam. In earthen dams, the depth of the cut-off trench is typically 25% of the TBL or until impervious strata is reached, whichever comes first.
3. After excavation, thoroughly ram the base of the cut-off trench by watering. Fill the trench with 30-35 cm thick layers of puddled clay, ensuring each layer is properly watered and rammed into the layer below. Ramming inside the trench is usually done by labourers walking on the puddled clay.

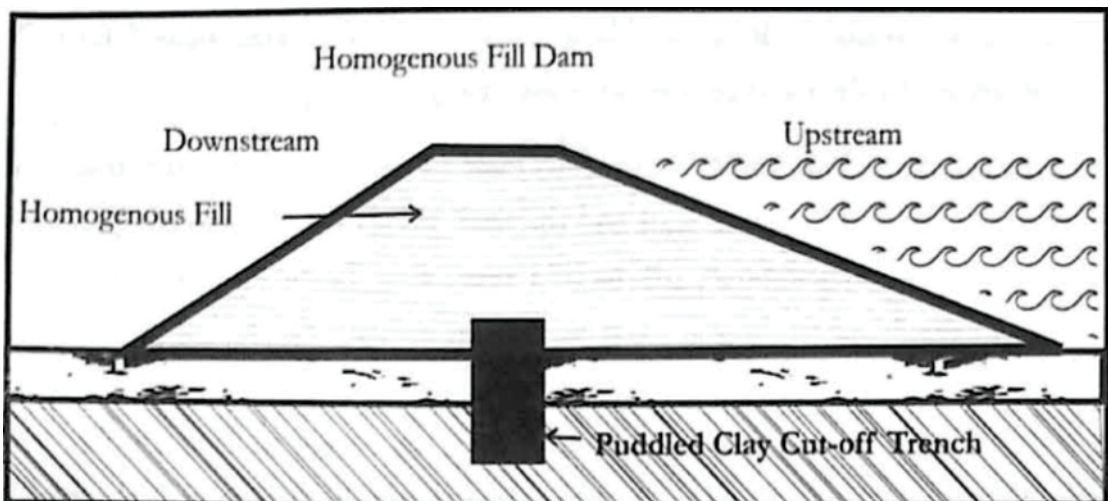


Embankment and Core wall

Depending on the construction materials used, earthen dams can be classified into three types

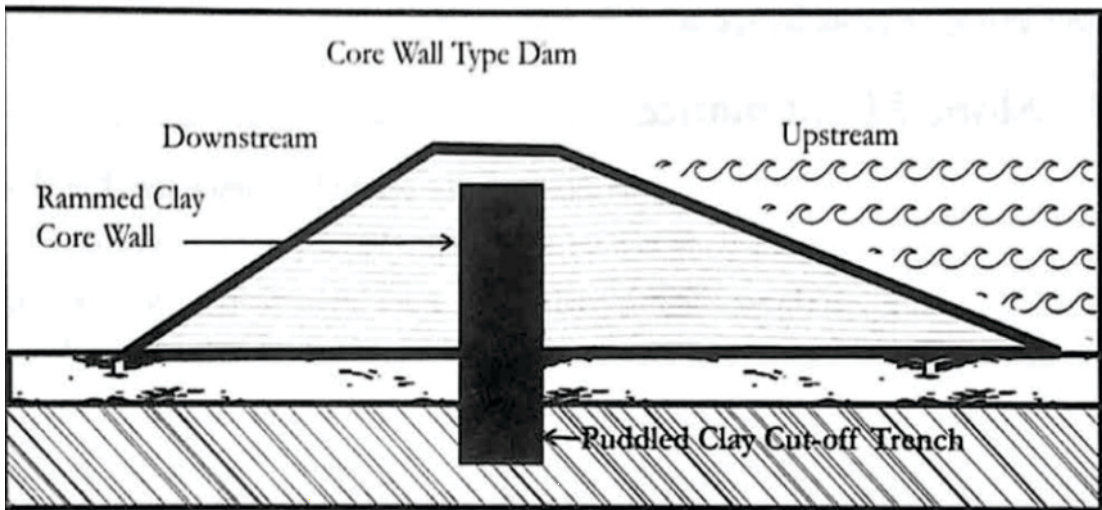
1. Dams of Homogeneous Material:

- ▶ Used where impervious foundation is present and clay is scarce.
- ▶ Constructed from pervious material by increasing the dam's cross-sectional area.
- ▶ Requires careful watering and ramming.
- ▶ The dam cross-section should be broader with lower slopes upstream and downstream and increased top width.



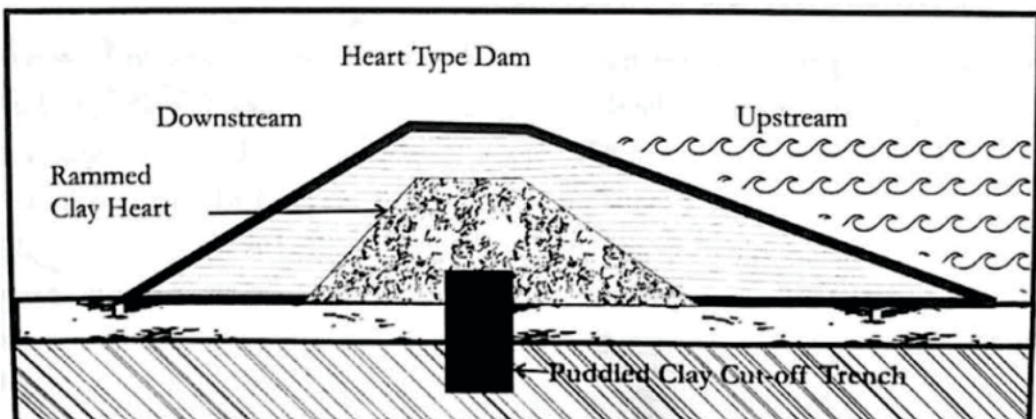
2. Core Wall Type Dam:

- ▶ Constructed where both pervious and impervious materials are available.
- ▶ A narrow, impermeable, puddled clay barrier (core wall) is created by soaking, kneading, and ramming clay.
- ▶ The cut-off trench is filled with puddled clay up to ground level.
- ▶ Outer flanks consist of rammed coarser soils with finer particles inside, protected by stone pitching on the upstream face.



3. Hearting and Casing Type Dam:

- ▶ Built where clay is plentiful.
- ▶ The core of the dam is made with wetted and rammed clay, with a casing of coarser soils for protection.
- ▶ The dam wall is raised in horizontal layers with inner clay having side slopes.
- ▶ Even when pure clay isn't available, finer soils can be used for the core and coarser soils for the casing.
- ▶ Ensure simultaneous raising of core and casing, with layers of 6 to 8 inches laid, wetted, and rammed, graduating from finer soils inside to coarser soils outside.

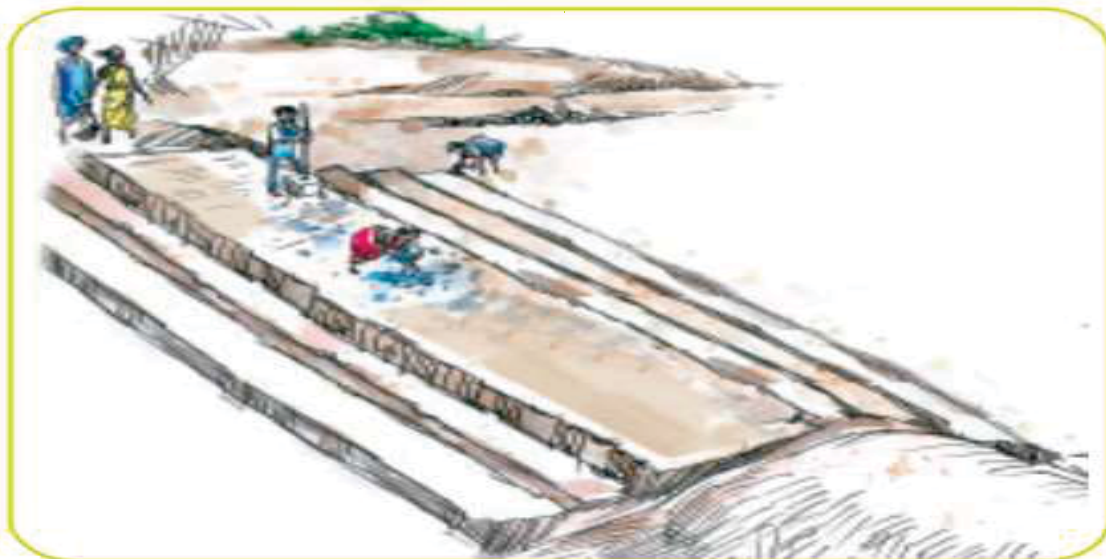


Slope maintenance

- ▶ The upstream and downstream slopes of the dam must be carefully maintained.
- ▶ Construct the side slopes as a series of steps.
 - ▶ Steps allow labourers to walk and place material effectively.
 - ▶ Steps facilitate mid-term corrections if the slopes deviate.
- ▶ At the end of construction, break the steps and create a continuous slope.

Stone Pitching and Grass Turfing for Embankment Protection:

- ▶ The outer parts of the dams are highly susceptible to erosion caused by water. To safeguard the upstream face from the erosive effects of waves, stone pitching should be employed using boulders ranging from 15-30 cm in size. For effective protection, select stones that are flat on one side and angular on the other. The amount of stone pitching required is determined by the Full Reservoir Level (FRL) of the dam and the gradient of its upstream slope.
- ▶ In areas where boulders are not readily available, an alternative method is to use grass turfing to protect both the freeboard zone on the upstream face and the entire downstream face. Planting grass helps by forming a network of roots that binds the soil together, while the grass blades absorb the impact of raindrops, thereby reducing erosion. Ensure that grass turfing is completed before the onset of the monsoon season, with particular attention given to the downstream side of the dam.



Surplus waste weir

When constructing a surplus weir after the completion of the main dam, several important factors should be considered to ensure effectiveness and durability:

Site Selection for waste weir:

- ▶ Choose a location for the surplus weir that minimizes excavation and avoids disrupting the existing terrain.
- ▶ Ideally, the weir should be connected to a natural drainage channel nearby. This connection helps manage excess runoff and reduces the risk of additional erosion.

Emergency Measures:

- ▶ If the monsoon season is approaching rapidly and completing the main dam on time is not feasible, prioritize constructing the surplus weir first. This measure helps protect the ongoing dam construction from potential damage due to excess runoff.

Topography and Geology:

- ▶ In cases where the topography or geology makes it difficult to place the surplus weir on the side of the dam, an alternative solution is to incorporate a stone or cement masonry weir directly into the main body of the dam. This ensures that excess water is still managed effectively.

Protection and Design:

- ▶ Ensure that all types of surplus weirs are adequately protected. Use stone pitching or stone/cement masonry to reinforce the sides and bed of the weir.
- ▶ Avoid designing the weir with very steep slopes or sharp curves. Steep inclines and sharp bends can increase soil erosion risks. Instead, opt for gradual slopes and smooth curves to promote stability and reduce erosion.
- ▶ By following these guidelines, you can enhance the functionality and longevity of the surplus weir, effectively managing excess water and protecting the dam infrastructure.

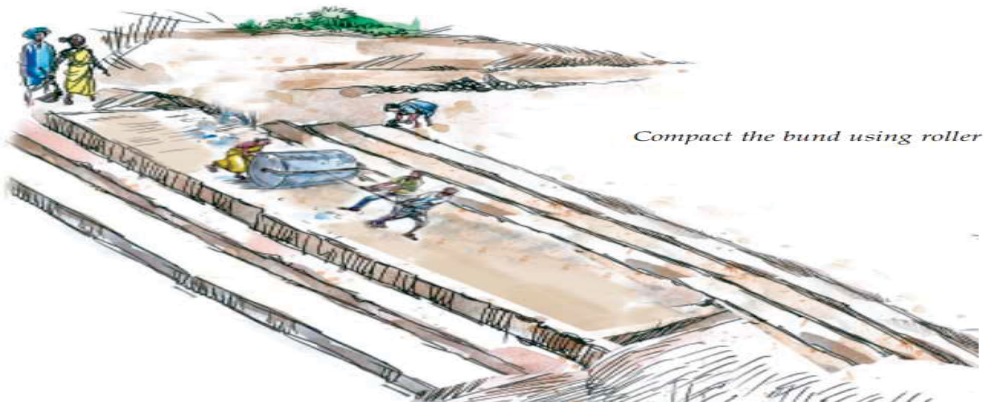


Figure 46: Describes step for construction of a percolation tank

The following key points also should be kept in mind while constructing waste weirs:

- ▶ It might be difficult to provide a waste weir on the side of the dam due to adverse topography. In such cases, a pucca weir must be provided in the main body of the structure.

- ▶ Waste weirs should have adequate protection of their sides and bed through stone pitching.
- ▶ The surplus weir should not be very steep or have sharp curves.

16.4 Do's and Don'ts for Percolation Tank

Do's	Don't
1. Select a percolation tank where narrow banks are available for dam construction and a wide area is available for water storage. 2. Ensure a top width of 3 meters for the dam if mechanical roller compaction is required. 3. Check the soil's percolation rate at the location before beginning construction. 4. Verify the soil's density and ensure proper compaction during the construction of the earthen dam. 5. Determine the location of the outlet before starting construction. 6. Confirm the availability of soil and water before commencing construction.	1. Avoid constructing the structure at sharp curves 2. Do not construct the structure without a cutoff trench and core wall if the soil does not support the intended purpose of the structure. 3. Do not construct the structure without maintaining proper side slopes on both sides as per the design. 4. Do not build the structure with insufficient freeboard, as it may cause the structure to collapse. 5. Do not proceed with construction without adequate watering; curing is essential for each layer of soil. 6. Do not construct the structure without proper provisions for an outlet to ensure safe runoff disposal.

16.5 Eligibility Criteria for Construction of Percolation Tank

A Percolation tank can be constructed if the site fulfils the following criteria:

1. **Stream/stream order:** Second/third order for mini percolation tank and fourth order or higher order stream for percolation tank
2. **Slope:** For the main drain, the best location is where the slope is 3% or less, with an average of up to 6%, or a maximum of 10% in exceptional situations.
3. **Catchment area:** For MPT: 5 to 25 Hectare and PT: 20 to 50 Hectare
4. **Banks: Stabilized banks** are available on both sides of the drain.
5. **Runoff potential:** Adequate to fill the structure with a 70% probability of rainfall.
6. **Location:**
 - A **narrow length** is available in the drain (minimum crest length) with a **wide area for submergence**.
 - Without turns or curves, where efficient utilization of the stored water is possible.
 - Proximity to farmers' fields for water conveyance through proper channels
7. **Depth of drain:** Minimum of 3 meters or the height of the structure plus 1 meter.
8. **Permeability of soil:** Soil with having low rate of permeability (*Clay soil having fine texture is very slow in permeability. Loamy soil with moderately fine/coarse have moderate slow and rapid permeability and sandy soil has rapid rate of permeability*)
9. Sites where maximum storage can be achieved: Deep and narrow sections of valleys with steep side slopes.
10. **Accessibility:** Accessible location for easy transportation of construction materials/soil/water.
11. Areas without alternative water sources in grasslands or plantation plots.
12. Forest areas with acute water scarcity for wildlife drinking water.
13. No structure in the submergence at upstream or downstream, or no structure on both sides within a minimum half kilometre.
14. **Good fetch length:** Minimum of 750 meters.
15. **Submergence:** Nothing, including habitats, plantations, trees, or wildlife, should be submerged by the structure

References

This technical manual has been prepared for the Forest department functionaries engaged in implementation of Soil & Moisture component measures in RFBDP project. The technical manual has been prepared after mainly referring the documents available on open-source platforms on Soil & water conservation. The information available in these documents mainly used to enhance the knowledge of the forest functionaries only.

1. Samarthya Technical Training Manual for MGNREGA developed by MoRD, Government of India.
2. A resource booklet for MGNREGS functionaries designed and developed by WASSAN as part of GIS for Government of India.
3. Watershed works manual for MGNREGS act developed by Baba Amte centre for people empowerment, SPS for Ministry of Rural development, Government of India
4. A handbook on Soil & water conservation by ICFRE, Dehradun
5. A textbook on Watershed management by Dr P.K. Singh

