GTZ
German Technical Cooperation
"Food for Work" - Project

Best Practices Report

FLOOD CONTROL MEASURES

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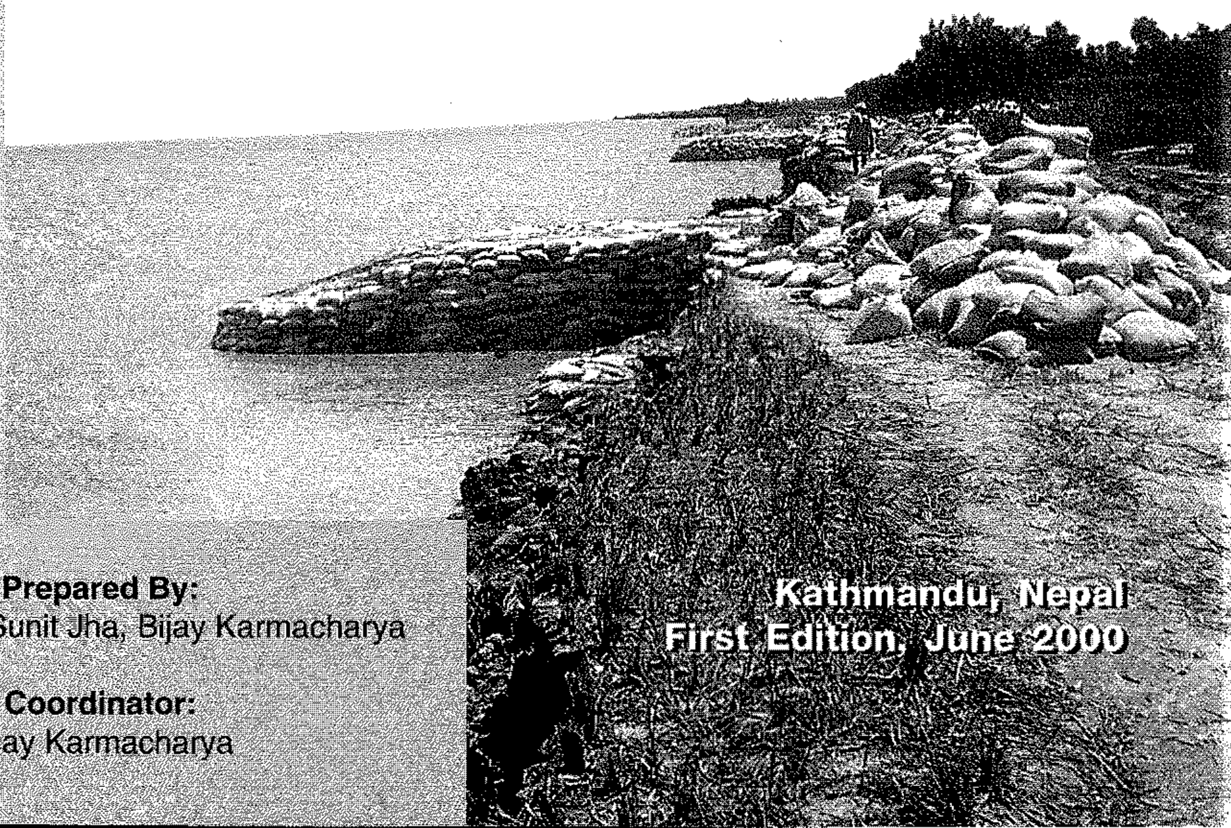
An approach for community based flood control measures in the terai rivers



Prepared By:
Hemant Jha, Sunit Jha, Bijay Karmacharya

Coordinator:
Bijay Karmacharya

Kathmandu, Nepal
First Edition, June 2000

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FOREWORD

Nepal has more than 200 rivers. Most of them originate from Mahabharat and Chure range and some from high up in the Himalayas and flow through the Hills into the lowland before they enter India and join the Ganges. These immense water resources hold out on one hand a promise of wealth and huge development potential for the nation and on the other hand, frequently loom over to people and environment as threat and menace. Every year during the monsoon Nepal has to bear with major flood problem caused mainly by heavy rainfall and compounded by degraded environment. Flooded rivers carry heavy load of sediments causing erosion, damaging crops, destroying private and communal properties and infrastructures and threatening the survival of many villages. Therefore flood control measures rank very high in the priority list of many communities and especially of the poorer section of the population which suffer the most from the floods than better off families. Unfortunately conventional flood control measures such as embankments and spurs provide only a partial protection and they are technically very demanding and costly. Putting up such structures often exceed the resources especially the financial capacity of the government. But flood control must be pursued in many fronts.

In order to meet the high aspiration and the relatively low resource base of the flood-affected communities in Nepal, a variety of new labor intensive, environmental friendly and self-help based flood control measures have been introduced and promoted by various private and public organizations over the past several years. Besides Department of Irrigation and JICA, especially GTZ within the context of the Churia Forest Development Project (ChFDP) and the Rural Community Infrastructure Works (RCIW) Program have been heavily engaged in the development and promotion of this new method. However without the support and assistance of the Ministry of Forest and Soil Conservation, the Ministry of Water Resources and the Ministry of Local Development we would not have succeeded in our efforts to develop more appropriate flood control methods. There are now evidences and indications that these new methods are technically sound, cost-effective, environmental friendly and an ideal spring board to promote community and self-help based flood control measures. These measures would become particularly effective if they are embedded in a holistic watershed management concept, combining preventive and curative and flood control measures in an intelligent and appropriate way as for instance in the case of ChFDP.

In order to compile a reference document and consolidate what has been done so far in this important field, the experienced and learned professionals have prepared this Best Practices Report. Those writing this report have been closely involved in the development and implementation of these new methods for several years. Without their serious efforts and dedication this report would not have materialized in this form. I therefore on behalf of GTZ would like to thank this very dedicated team for their highly appreciable work.

However, there are risks involved with the introduction of these new methods. To simply introduce them without considering specific technical, financial and management inputs as required might end in a failure. This in turn will jeopardize the large-scale application of this method and discredit the work done so far. To avoid this pitfall decision-makers and professionals should be made fully aware of the exact processes and procedures of this new method and for this appropriate training courses have to be organized.

It is hoped that this Best Practices Report would serve as an awareness creation and training tool and will be widely used by all people involved or interested in flood control in Nepal. I am confident that the application of the advice given in this document will not only benefit flood-affected communities but also promote rural development efforts in a sustainable way.

Dr. Dietrich Stotz
Team-Leader
GTZ-Food for Work -Project

ACKNOWLEDGEMENTS

The compilation of this Best Practices Report is only a logical next step towards documentation of information scattered in various places and in the minds of different professionals working in the field of flood control. We would like to record our sincere thanks and appreciation first of all to the Team Leader of GTZ- Food for Work, Dr. Dietrich Stotz without whose initiation and consistent urges this document would not have materialised.

A team of professionals has been principally responsible for the preparation of this document consisting of Er. Mr.Hemant Jha, Department of Irrigation and Mr. Sunit Jha, Professional Officer of GTZ-FfW and myself. Special thanks are due to Mr. Hemant Jha who collected various information required for several chapters and involved himself in analyzing them and writing parts of this report. This report leaves the testimony of longstanding experiences and interest of Mr. Sunit Jha who, over the last several years, has had a lot of practical and hands-on experiences in flood control.

We would like to extend our special thanks to Mr. Hrisieekesh Upadhyay for his editorial input in the final stages of this report. Thanks are also due to several other GTZ-Professionals and colleagues for their encouragement and support for the team in the form of feedback and necessary information during the entire period of this report preparation.

Special thanks are also due to Mr. Anil Shrestha of Format Graphic Studio and his colleagues for producing the drawings, designing the cover page and the page layout.

Finally this report is dedicated to all the poor families living along the riverside and constantly suffering and fighting back the recurrent floods. May this Best Practices Report be of some use to check the flood menace of the future.

Bijay Karmacharya
Senior Programme Officer
GTZ-Food for Work
May,2000

ABBERVIATIONS AND ACRONOYMS

DDC	District Development Committee
DoHM	Department of hydrology and Metrology
VDC	Village Development Committee
UC	Users Committee
UG	Users Group
FfW	Food for Work Programme of the WFP
FYN	Financial Year in Nepal (from Mid June to Mid June)
GTZ	Gesellschaft fuer Technische Zusammenarbeit, GmbH, Germany,
	German Agency for Technical Cooperation
HMG/N	His Majesty's Government of Nepal
INGO(s)	International Non-Governmental Organization(s)
LDO	Local Development Officer (MoLD)
LNGO	Local Non-Governmental Organization
m.	meter
km.	kilometer
MoF	Ministry of Forest of HMG/N
MoLD	Ministry of Local Development of HMG/N
NGO	Non- Governmental Organization
NPC	National Planning Commission of Nepal
NRs	Nepali Rupee(s)
RCIW	Rural Community Infrastructure Works Programme (MoLD/WFP/GTZ)
WFP	World Food Programme of United Nations
m/s	meter/sec
m^3/s	Cubic meter per second
cusec	Cubic feet per second
us	upstream
ds	downstream

CHAPTER I

The Context of Flood Problem

1.1 Background

Nepal is considered as one of the richest countries in the world in terms of available water resources. Its immense water resources can be the biggest sources of national wealth, if it is properly utilised for the production of hydroelectricity and for irrigation. Tremendous volume of water that flows in hundreds of big and small rivers also frequently creates serious threats because of their potential for adverse effects. Minimizing these adverse effects require large amount of technical and financial resources. Unfortunately, neither have rivers been properly harnessed to minimise their adverse effects nor have available water resources been fully utilized for beneficial purposes.

Topographically, Nepal is a mountainous country. Mountains and hills account for about 80% of the total national land. The only exception is the Terai plain, a low and flat land, stretching east to west in the southern part of the country along the Indian border. Nepal has unique topography with the altitude variation from 60 m at Jhapa in the south east to 8,848-m Mt. Everest in the north. Almost all of the rivers flow from northern mountains and hills to southern Terai plain.

Rivers originating from various high altitude topographic regions carry heavy sediment loads. On the one hand steep slope gradient, intense precipitation and sparse forest cover have made hills very vulnerable to erosion. On the other hand, these rivers cause heavy seasonal flood damaging agricultural land and properties in the hills and Terai every year.

Weak and fragile geology of Nepalese hills compounded with intense rainfall during the monsoon season and decreasing vegetative cover often result in a debris torrent, laden with boulders causing threats to lives and property.

Most of the rivers collect very high gradient before entering into Terai, forcing them to transport heavy sediment load. As they enter onto the Gangetic plain, the rivers spread out and their gradients decrease abruptly. This results in a decrease in sediment transportation capacity. Such obstruction produces deposition of bed load causing the rivers to spread out inundating vast areas of cultivated land. Thus the flood problems in Nepal have geological, topographical, hydrological as well as man made dimensions.

The main effort in the flood control measure in Terai should be to provide safer passage of flood water at minimum costs, minimizing damage with an approach and technology suitable for prevailing Nepalese conditions.

1.2 Flood Problem and Limitations of Flood Control

Flood in general is a relatively high flow above mean flow level that may overtop a natural bank in some reaches of a stream. International Commission on Irrigation and Drainage (ICID) defines flood as "A relatively high flow or stage in a river marked by higher than usual."

Flood is a natural phenomenon, often it is seasonal in nature. It is very difficult to control a river for a long period of time. When flood level exceeds the natural bank it inundates the agricultural land, villages or towns causing enormous threat to life and property.

Nepal experiences major flood problems during the monsoon (July to October) caused by incessant heavy rainfall. The problems caused by heavy rainfall are bank erosion, inundation and flooding of land and properties and sedimentation. During the incessant monsoon rain a considerable areas of paddy fields, houses, roads and channels are flooded. Heavy damage results due to bank erosion in the fields as well as sand deposits in the fields. Major damage occurs near the rivers by lateral erosion. Moreover, due to high sediment load, riverbeds rise up forcing rivers to change course, which in turn destroys vast areas of cultivated land.

Because of the aggressive lateral erosion of rivers and rivers changing their courses, farmers have, for a long time been desperate to devise means for flood control works. If the problem is discussed with local people, their demand will immediately be to construct spurs and embankment with boulder protection, that too, in gabion crates. Embanking of river is also not an ultimate solution to the flood problem. River training in the sense of channeling the whole of river length seems to be a solution to the recurrent flood problem. However river training for the entire stretch of the river is far too expensive and thus out of consideration. The costs will be so high that not a single river could be embanked within the resources available. Furthermore, aggradation of riverbed creates constant threat to the embankment, even if they were constructed.

Because of the desperate need for the additional farmland in recent decades, farmers have the tendency to encroach upon flood plains and reclaim riverbeds, thus narrowing the natural river widths. This has made the problem of flood control

even more difficult to tackle. They wish to embank the rivers within the natural riverbanks. Therefore the planning engineers often face serious problem of land acquisition, on top of the fund constraints.

Almost all of the rivers flowing in the Terai plain require some sort of flood controls measures. Although His Majesty's Government of Nepal (HMG/N) spends millions of rupees every year for this purpose, it is far too little for the need. The available financial resources from the government for one river may just be adequate for the protection of one village while several others remain endangered.

So it is beyond the capacity of government alone unless the affected people also contribute in one way or another to solve their own problem. They have to come out of this dependency syndrome and search for ways and means to protect themselves from recurrent flood. Instead of always looking for costly and hi-tech means, they should also embark on appropriate and locally affordable techniques with proven quality and success.

1.3 Flood Problem in the Terai

Nepal has an area around 147181 sq. km of which 20 % land is used for agriculture. Some 17% of the total agricultural land of the country lies in Terai plain. The Terai forms the part of the Indo-Gangetic plain, on the Nepal side of the border. It is approximately 30 km wide with a surface area of 29000 sq. km. This plain is not continuous from east to west but is divided into three parts by southern spurs of Churia hills. The soil of Terai is very fertile and the climate is ideal for agriculture. Therefore Terai is known as granary of Nepal.

Almost all of the rivers from the hills and mountains flow down into the Terai plain. Most of the rivers have a gradient high enough to enable them to transport their bed load. As they enter on to Gangetic plain, these rivers spread out and their gradient decreases abruptly resulting in sediment deposition. The rate of sediment deposition in Terai as estimated by different researchers is as much as 5 cm to 30 cm in a year. This is mainly the case in rivers originating from Churiya range. Because the Terai is flat, the main river channels often are not able to contain the large volumes of discharge that occur during the monsoon. This commonly results in flooding of the surrounding agricultural area. Recurrent flooding and sediment deposition, compounded by erosion of riverbank thereby increasing river width are becoming serious problems of concern in Terai.

1.4 Environment, Population Growth and Floods

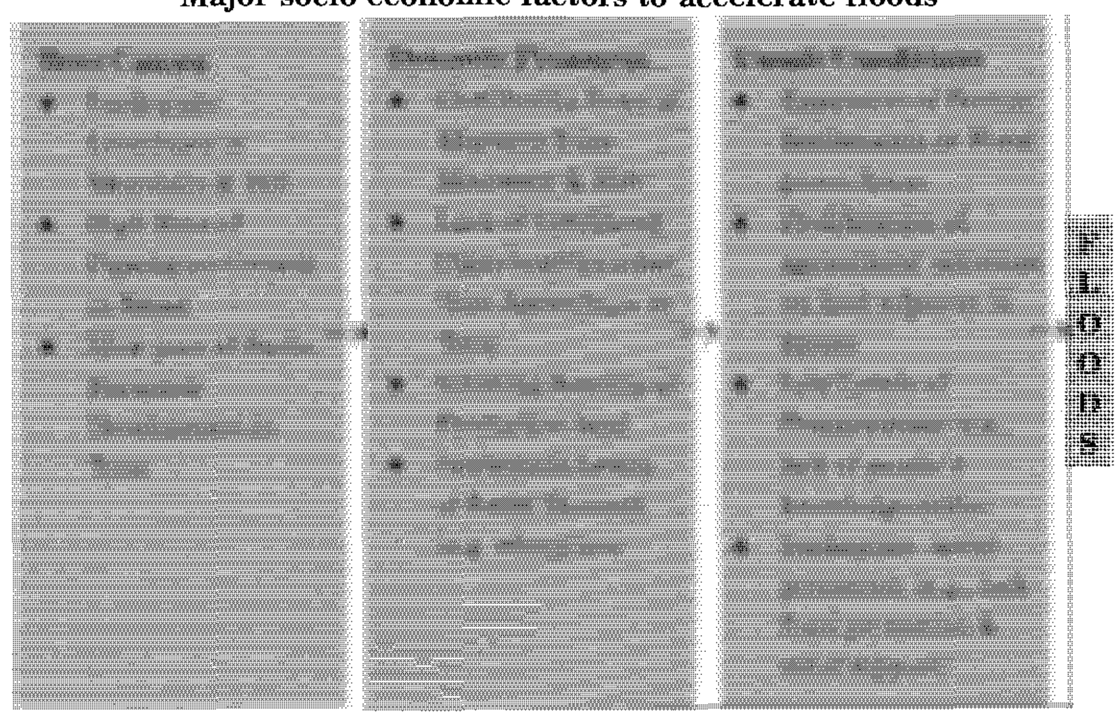
Most of the floods are primarily caused by heavy rainfall during relatively short monsoon season. However rainfall is only one of the several contributing causes of flood problem. It has deep interrelationship with natural environment as well as manmade causes.

Excessive soil erosion in the hills is one of the major causes of flood problem in Terai. Natural erosion rates are very high in Nepal because of the constant tectonic uplifting of the major mountain ranges and consequent downcutting of the river systems.

Over the last century, an increasing proportion of the top soil loss is attributable to accelerated erosion induced by an increased population pressure on a limited land resource. Forest clearing, overgrazing, poorly maintained marginal arable lands and summer forest fires have greatly altered the natural vegetation of Nepal, leaving the soil open to degradation.

On the other hand major pattern of population flow in Nepal is from mountain and hills to the Terai. The in-migration to the Terai has been accommodated by bringing new land into cultivation. When the southern plain was sparsely populated until three decades ago, the migrants were required simply to clear abundant forest. However as the free access to open land was exhausted people were increasingly bound to settle in the flood prone areas near the riverbank and on many occasions, literally in the riverbed itself.

Major socio-economic factors to accelerate floods



Source: The study on Flood Mitigation Plan for Selected Rivers in the Terai Plain in the Kingdom of Nepal, JICA/DOI. Feb 1999.

1.5 Interrelationship between Erosion, Flood and Poverty

The gradual uplift of the Himalayan region in general, by plate tectonics is widely acknowledged. The rate of uplift is about 1cm per year. Geologists consider Himalayan region as very active and one of the most fragile mountains on earth. In addition to the fragility of mountain, extraordinary nature of intense rainfall during monsoon results in enormous amounts of materials being moved by rivers towards the low lands of the Terai.

Fragile geology, steep slope gradient, intense precipitation and sparse forest covers– all contribute to massive soil erosion in the region. Very rapid erosion is occurring within the Churia range due to both side and down-cutting of the rivers, with many landslides of large and small magnitude. Recent observations have shown that sediment delivery from Churia range into the rivers suddenly increased about 10-15 years ago. Soil erosion in the adjacent Churia hill range and consequent sediment deposition in the Terai, as the rivers flow down, are major causes of the devastating floods.

Erosion includes all processes that result in the physical wearing down of the surface of the earth. Erosion in totality consists of "natural" (geological) erosion as well as "accelerated" (man-induced) erosion. Natural erosion rates are very high in Nepal because of the constant tectonic upliftment of the mountain ranges and consequent downcutting of the river systems. The net results of these unrelenting forces are unstable slopes. Natural erosion is characterized by different forms of mass wasting, particularly landslides, rock failures, slumps, riverbank cutting and gullying. Runoff and soil erosion from the surface alone are not seen as the primary cause of problem of sedimentation.

Accelerated erosion is characterized by the loss of topsoil by sheet and rill erosion. Surface erosion with rilling and gullying is occurring on overgrazed areas and farm land of non-leveled slopes. Whereas lateral erosion of riverside fields, where banks are not protected, is occurring as the rivers reach flat lands of the Terai.

Interrelation between erosion, flood and poverty is evident as erosion processes profoundly affect the economy of the Nepalese villagers in the following way:

- As topsoil is eroded from the cultivated and grazing land, soil fertility declines and the soil is less able to maintain its productive capacity.
- Mass movement of slopes including landslides, rock failure, slumps, and debris torrents cause tremendous destruction of productive land, irrigation systems, foot trails, road alignments as well as villages.
- Sedimentation, in conjunction with peak discharges results in abrupt river channel change, which causes tremendous hardships for farmers on the alluvial lands because of the damage they leave.

1.6 Flood and Watershed Management

The effects of environmental degradation are all too well known for the local inhabitants and outside observers. Activities of humans like deforestation, unsuitable or wrong farming techniques, livestock, over-grazing and faulty land use lead to the destruction of plant and tree cover exposing the earth to the natural forces like heavy rains, direct sunshine, high winds and drought. These lead to problems like soil erosion landslides and floods. Consequently, agricultural yield is lowered, which results in a decline in the income of the community and often to poverty and famine, leading eventually to migration from rural to urban areas and from mountain and hills to Terai.

Annual floods that bring so much damage in the Terai region are actually not rooted to the local causes, they are inherited from the environmental degradation taking place up-streams. Therefore, no matter how widespread and how effective the flood control works in the Terai may be, they cannot alter the sedimentation process and therefore check on the behavior of the river flow. Thus parallel to the flood control measures in the Terai, equal emphasis should also be given to the upstream watershed management.

Watershed development involves not only regeneration of the environment, but also the management of needs of the human community within that region in such a way that their demands are on balance with the availability of resources like land, water, and vegetation.

Such equilibrium between need and availability will lead to a better and increased resistance to drought, increase in the supply of food, agricultural produce, water, fuel, fodder, timber and as a result bring about an improved standard of living and reduced rate of poverty-induced migration.

1.7 The Approach

This handbook the Best Practices on Flood Control Works is designed to describe a set of basic approaches which have been developed over the decades by various organizations engaged in floor control works.

1. Participatory Planning of Flood Control Structures

   In order to coordinate the local, district, regional and national level efforts to mitigate the flood induced damages, the flood control plans and activities shall incorporate the views of the local communities through participatory planning process. Decisions shall be made in a bottom-up manner through consensus based on consultation.

2. Preservation of the fragile mountain environment as integral part of flood control measures

   Damage to the fragile mountain environment shall be minimized in order to reduce future risks by recurrent landslides or increased soil and water erosion through protection of the vegetation cover in the watershed area. Since local factors by themselves do not cause flooding of low lying area, linkages with watershed characteristics of the entire catchment area have to be studied and upstream management should form an integral part of flood control measure. Forest development, gulley control, catchment ponds and use of the vegetation cover to prevent excessive soil erosion should be included in overall flood control plan.

3. Promotion of appropriate labor-based technology

   Appropriate labor-based technologies (i.e. an optimum mix of manual and mechanized work), assisted by engineers who are familiar with low cost measures should be promoted. Use of suitable construction techniques using mainly local construction materials such as bamboo should be promoted. Emphasis is placed on field surveys that draw on indigenous knowledge and other self-help inputs.

4. Application of labor-intensive construction methods

   Employment opportunities for unskilled and landless are very limited in Terai because of high density of population and poverty. Application of labor-intensive construction methods using mainly manual work rather than mechanical works is used to generate local employment opportunities and to recycle financial resources at local level as an "anti-poverty" measure.

The major advantages of labor-intensive methods are:

- Additional income generating opportunities for local people which also contibutes to poverty alleviation.
- Protection of farm land, livestocks and village environment thereby boosting ownership feeling in the local community.
- Substantial boost to local economy as nearly 80% of expenditure on flood control structure construction can go to the local people in the form of labor payments and purchasing local material.
- Imparting of skills to the local people during construction which can be later utilized for maintenance activities and similar infrastructure works.
- Reducing the dependency on forest for firewood and fodder.

5. Performance- based work assignment methods

   Flood control structure measures should emphasize performance-based user group oriented approach of work assignment. Simplified small contract work assignments are acceptable for more complex structural works that require efficient construction management and specific professional expertise such as construction of spurs during flood.

6. Decentralization of implementation, decision-making and of ownership

   HMG/N's decentralization efforts are supported through the delegation of authority and responsibility from the center to the appropriate district level or village level. Both central and district level authorities could never look after the flood problems of numerous rivers, adequately. As long as the local people do not take the lead local flood problems can not be solved on timely basis.

   A local Users' Committee should be formed to take leading role at the local level and as an institutional medium for local conflict resolution. The land provided by the landowners for flood control measures, if any, is more than compensated indirectly in terms of higher land values following the completion of construction. Promotion of ownership feeling at the local level is essential for the development of a sustainable maintenance system.

7. Integration of local circumstances into implementation

Emphasis on local employment generation is essential for successful implementation of a flood control project. By harmonizing construction period to the local agricultural slack season, better participation of local people could be ensured. Applying appropriate gender concept for labor employment and introducing equal payment for male and female for equal work, improved gender equality could be achieved.

8. Self-help promotion and local capacity building

Self-help and local skill development are promoted through social mobilization support and local capacity building. Experience shows that trained local human resources often provide a most valuable resource for replication of the activities in the neighboring projects as well as for later maintenance and rehabilitation works.

9. High benefit cost

A high benefit to cost ratio is achieved by introducing low cost measure to the extent possible. The understanding is that the farmland protected by bank protection works, would otherwise be flooded every year or most of them would be destroyed by erosion.

Protection is to be provided by means of the cheapest alternatives available.The benefit of flood protection work is to maintain the value of the farmland which otherwise would be zero without flood protection.

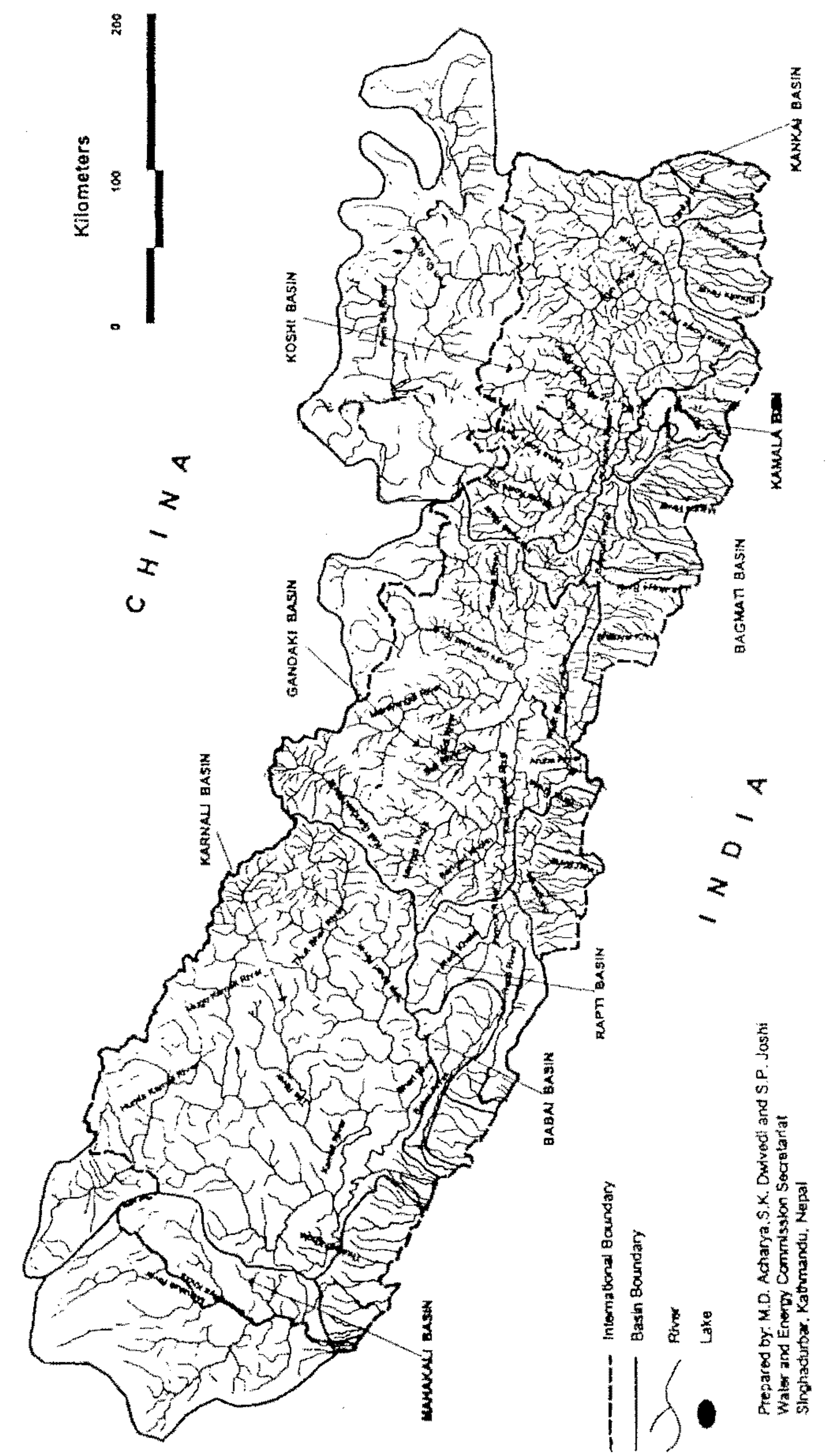
10. Collective financing and public audit

Resources of several stakeholders such as VDC,. DDC, line agencies are pooled. Public awareness on the utilization of funds is promoted via public audits and cost transparency, complementing the official audit. Project books having information about all matters related to the project are maintained at the users level and access to all is ensured.

11. Sustainable maintenance

Embankment maintenance shall be the responsibility of the local beneficiaries. Financial contribution needed for the regular maintenance of the structure is agreed among the contributing partners such as users, VDC and DDC, at the beginning of the project. If this regular financial contribution is missing, timely execution of functional maintenance would become difficult even for work that may involve a small cost.

RIVER SYSTEM OF NEPAL



CHAPTER II

River System and Rivers of Nepal

2.1 Rivers of Nepal

Rivers of Nepal can be classified in different ways based on their origin, age, topography and character. There are some very old rivers like the Kosi, Gandaki, Narayani and Karnali, which have deep cut and vertical gorges. They are in existence as early as the Himalayas.

According to the origin, the rivers of Nepal can be grouped in four categories.

(a) Rivers originating from Terai.

(b) Rivers originating from Churiya Hills (ephemeral river).

(c) Rivers originating from Mahabharat and inner Terai rivers (perennial streams).

(d) Rivers originating from Higher Himalayas (perennial streams).

Himalayan rivers are snow-fed rivers having very large discharge. River training of these rivers requires high level of technical and hydraulic analysis. These rivers are well known in the world for their huge discharge and extent of damage they frequently cause.

Rivers originating from the Mahabharat range such as Kankai, Kamala , Bagmati, Babai, Tinau etc. pass through the Churiya hill range. Discharge of these rivers reaches as high as 8000 to 10000 cumecs. While passing through in the hilly region, they can as high as transport large boulders.

There are large numbers of small, relatively very young rivers originating in the Churiya hills and Terai. These rivers form tributary to the larger rivers.

The Churia hill rivers originate from the southern face of the Churia range. Lengths of these rivers up to the Indian border range between 25-40 km. 30-50% of the total lengths fall in the steep collecting system in the Churia range. The remaining lengths fall on the low gradient part of the Bhabar and Terai zone. The catchment areas are between 30 km^2 to 200 km^2. About 90% of the run off occurs within 2-3 months of the monsoon season between July and September. During the dry period of the year the small and medium rivers completely dry up. Most of the runoff occurs during short and high flash flood of only 1-2 hours. The yearly floods range from 100-300 m^3/s. Hundred year flood in some rivers may reach 1000m^3/sec.

Rivers originating from the Mahabharat range have a much higher discharge. 50-year flood for Kamala is as high as 5500 m3/sec.

2.2 River Morphology

In the Churia range, rivers are excavating steep canyons. Because of the dramatic change in gradient upon leaving the Churia, these rivers assume a braided pattern. Near the Indian borders, rivers are partly meandering. Riverbeds in Bhabar and Terai zone are several hundred meters wide. Erosion in this region is lateral than vertical. In the Churia and Bhabar riverbeds consist of well-rounded boulders and coarse gravel. Further down to the south, in the Terai plain, riverbeds are formed by sand and silt.

Rivers on the Nepal side of the Terai zone are braided with several dynamic meanders. Those meanders are continuously changing their course. In many cases the rivers are even changing their main channels by finding a new riverbed through existing paddy fields. Since old fluvial deposits are found under the paddy fields, the new river has the same morphological characteristics in the new river bed.

2.3 Geology of Churia (Siwalik) Range

These are the East-West boundary ranges with the vast Indo-Gangetic planes in the South and MBT (Main Boundary Thrust fault) in the North. These are the youngest rocks in Himalayas formed about 40 to 2 million years ago (Neocene period) and are made up of mud-stones, sand-stones and conglomerate. They are further classified into three layers viz. lower, middle and upper Siwaliks.

The lower Siwaliks are represented by inter-bedded soft mud-stones and sand-stones. They are occasionally faulted and override the younger middle and upper Siwaliks. The depth of lower Siwalik is about 2–3 kms.

The middle Siwaliks, comprising of thick bedded sand-stone and mud-stones, are generally soft, but may constitute steep river gorges. The depth of middle Siwalik is about 2 to 2.5 km.

Gravels and conglomerates of the upper Siwaliks have also experienced tectonic movement and their beds are tilted. Most of the pebbles and boulders seen on the riverbed are derived from upper Siwaliks. The depth of upper Siwalik is about 1.2 to 1.5 km.

The topographic slope varies from 200-400 m per kilometer on the average. Most of Southern part of Nepal of around 22,797 km^2 is drained through numerous flashy rivers having catchment area less than 350 km^2.

2.4 Rainfall and Runoff Characteristics

The mean annual rainfall varies from 1 – 2.5m in most part of the country with exceptions at some places such as more than 3.5m in Pokhara and upper Arun valley. Of the total annual rainfall, 80% of the rainfall occurs during the monsoon. Although it can rain continuously for days at a time, the monsoon is often characterized by periods of rain lasting only for a few hours broken by dry spells of similar lengths. Rainfall intensities can also be extremely high; 24 hour rainfall totaling as high as 6m has been recorded.

Runoff of the rivers also concentrates in the monsoon, whereas in the dry months, it becomes very low because of the small size of the catchments and porous geological conditions. Factors such as short steep slopes, overgrazing, deforestation, and short time of concentration etc. acting together, rapidly produce high peak flood during and/or after rainstorms in the hills.

Flood hydrograph of the rivers therefore are very sharp with high peak discharge and short runoff duration of less than one day. The flood runoff is accompanied with heavy sediment load from the Churia hills.

The cultivated areas are along the main tributaries. The topographic slope of even more than 40° are also found to be cultivated and thus heavy soil erosion occurs during the rainy season. The annual sediment yield in the river Lakhandei for example, is estimated to be 178,000 m^3/year.

Rivers originating from the Churiya hills are short in length and have relatively low flood discharge. But due to steep bed slope in hilly region and loose geology; flash floods transport heavy sediment loads. Occasional landslides occur in Churia hills facing to the South.

Deforestation, overgrazing, poor land use pattern etc. are contributing to frequent flash floods with devastating effects year after year.

2.5 River Characteristics, River Reaches

For the purpose of effective flood control, the characteristic nature of the river that cause the problems most should be carefully identified. In this regard, some of the river characteristics to be considered are as follows:

i) Straight river with high velocity in a single channel

ii) Meandering river in a single channel

iii) Braided – interlaced river with high velocity

iv) Braided river

The same river may have different characteristic behavior at various segments and reaches.

River Reaches

River reaches could be classified as follows:

i) Mountain reach

ii) Boulder stage reach

iii) Alluvial reach

iv) Aggrading reach – rise of river bed due to sedimentation

v) Degrading reaches – lowering of river bed due to bed erosion

River channel can be divided into several reaches depending on the grain size distribution in relations to channel slope, river width and surrounding topography.

Report of 'The study on flood mitigation plan for selected rivers in the Terai plain' commissioned by JICA has suggested classifying river reaches based on some criteria. Details of the criteria for river segment are given in Annex.

(i) Segment M – mountain reach.

(ii) Segment 1 – alluvial fan

(iii) Segment 2 – natural levee zone

(iv) Segment 3 – delta reach (which does not exist in Terai plain of Nepal.)

This segment classification is based on grain size, bed slope and river width. River control measures should be based on channel characteristics of the respective segments.

River Meanders and Meander Shape

Causes of Meandering:

Warner (1951) suggested that local disturbance causes meander to form. The flow direction is deflected away from the line of steep down valley slope because of non-uniformity in flow. This local deflection causes concentration of flow on one side of the channel leading to curvilinear flow which in turn would result in development of meander. In the process of meander formation its tail end becomes skewed to the direction at valley slope and phenomenon of one-sided flow giving birth to a meander is repeated. The second, third and subsequent meanders thus automatically appear in the wake of the first meander.

Meander Shape:

Shape of the meander can be described as circular curve, sine curve, parabolic or sine generated curve. Figure 1 shows a shape of meander.

Meandering pattern can be divided into (i) tortuous (ii) irregular and (iii) regular meander. Meandering pattern of a river is defined by its sinuosity, which is the ratio of thalweg length LR to valley length LV. According to Schumn, sinuosity (LR/LV) for the tortuous, irregular, regular, transitional and straight channels are 2.3, 1.8, 1.7, 1.3 and 1.1 respectively. When curvature is extremely sharp and cut off is imminent across the neck, value of LR/LV would be nearly 5.5.

The following empirical formula give the relation between meander belt (MB), meander length (ML) and river width (W). In some cases meander can be very flat having low tortuosity whereas in other cases, meander can have acute tortuosity.

The meander relations given by different investigators are as follows.

i) For straight channel, width of the river $W = 3.3\ Q^{0.42}$

ii) For meandering channel, width of the river $W = 7.3\ Q^{0.42}$

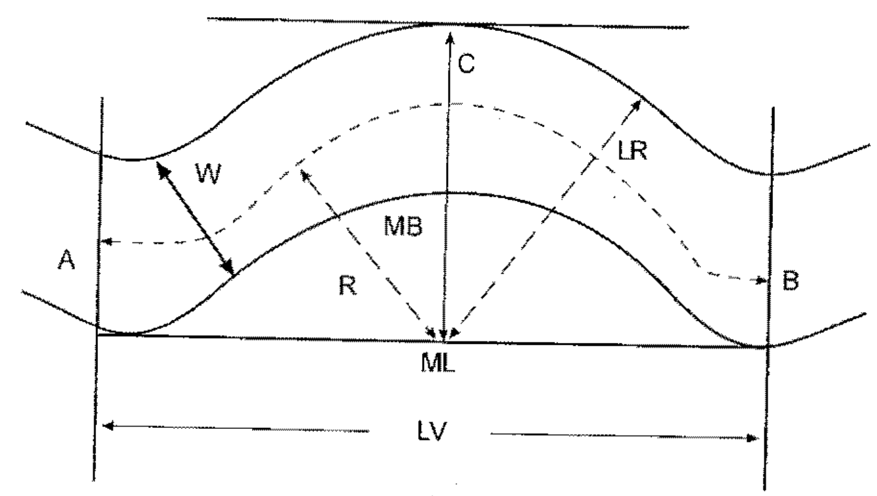
iii) Meander Belt $MB = 18.50\ Q^{0.505}$

iv) $ML/W = 4.47\ Q^{0.148}$

v) $MB/W = 2.17\ Q$

vi) $ML/MB = 2.06\ Q^{0.038}$

Fig: 1

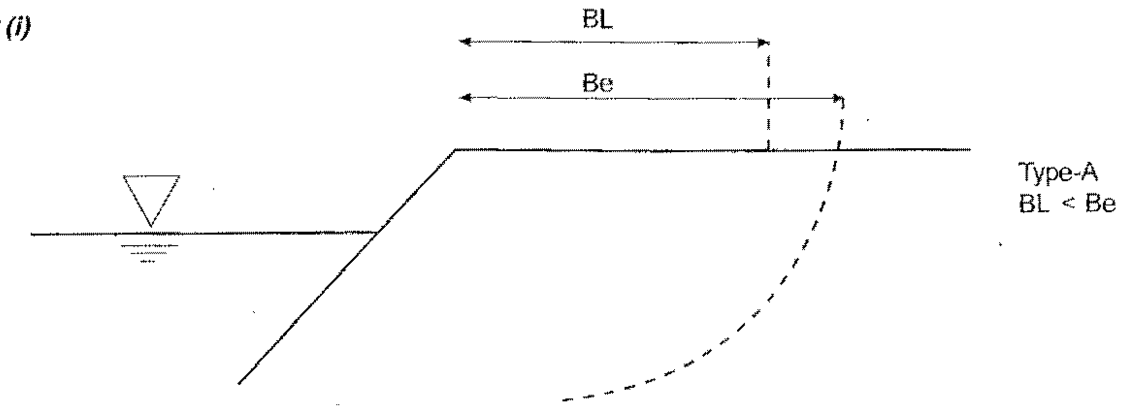


2.6 Classification of River Bank

In order to identify sites in critical conditions along the river bank and to prioritize the work sites for protection, river banks could be classified in the following types based on relationship between distance from riverbank to the river boundary line (BL) and design erosion width (Be).

i) Type -A Bank: BL < Be

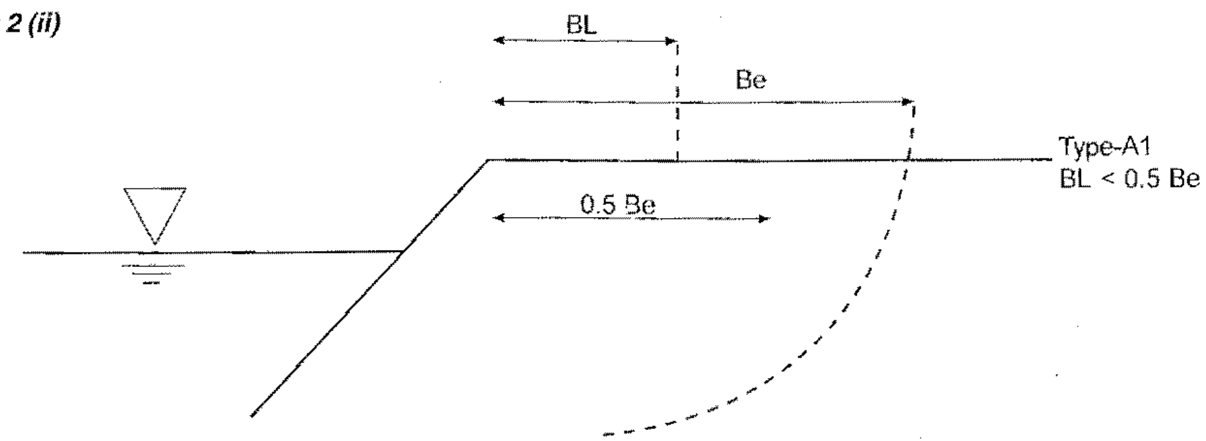
Fig: 2 (i)



Bank erosion is active. Bank protection works are desirable as far as the fund is available. Preventive measures for bank erosion are urgently needed.

ii) Type –A_1 Bank: BL < 0.5 Be

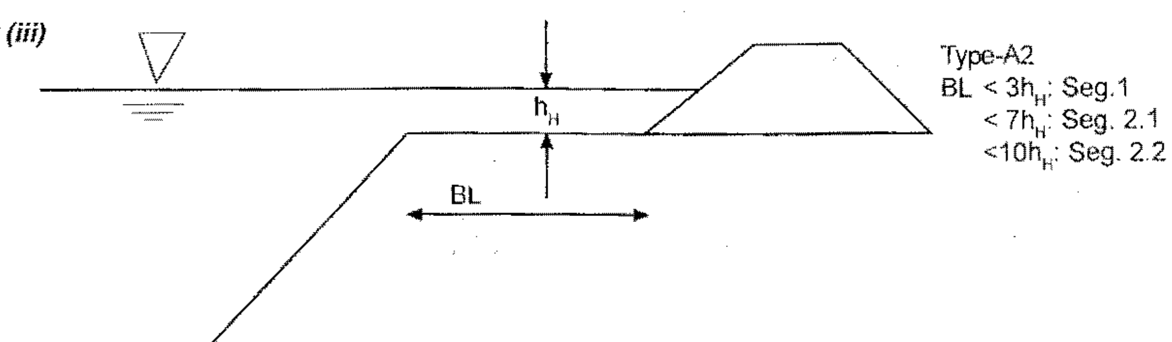
Fig: 2 (ii)



Bank erosion is active. Bank erosion is active. Bank protection works are urgently needed.

iii) Type- A_2 Bank: BL < 3 h_H, 7h_H and 10h_H for segment 1, segment 2-1 and segment 2-2, respectively. Where h_H is design water depth in high water level.

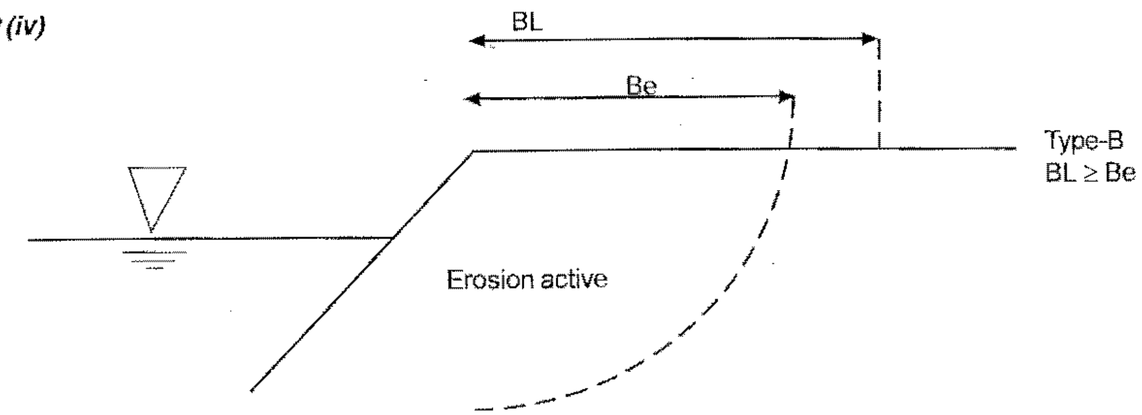
Fig: 2 (iii)



Protection works of dike slopes are needed.

iv) Type -B Bank: $B_L \geq$ Be

Fig: 2 (iv)

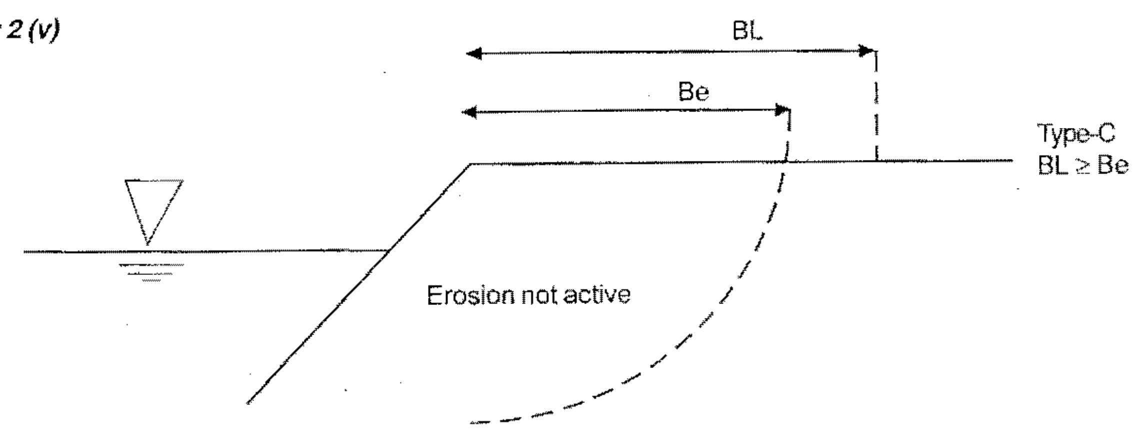


Bank erosion is active. Preventive measures for bank erosion are needed.

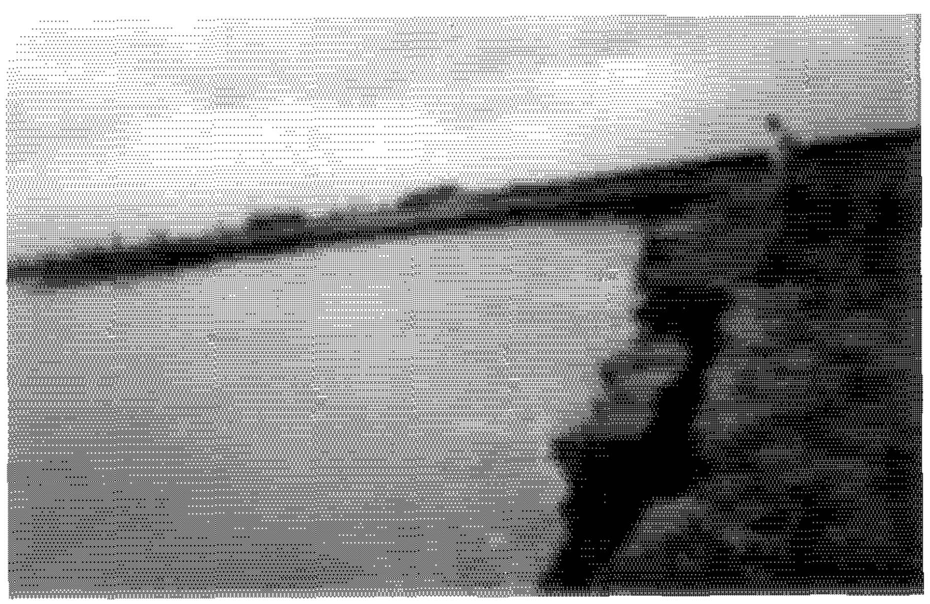
v) Type –C Bank: $B_L \geq$ Be

Bank erosion is not active due to topographical and geological reasons. No Bank protection works are needed.

Fig: 2 (v)



Active bank erosion in Charnath river, Dhanusha 1998.
a-deepest flow channel after flood
b-eroded bank in one night flood
c-easily erodable high bank
If a spur is provided it should be extended at least up to b.



Slumping of bank during high flood.

CHAPTER III

Flood Control Measures

3.1 Types of Flood Control Measures

Flood is a natural phenomenon and therefore attempts should be made only to minimize the damage likely to be caused by flooding. Flood control measures are required to protect life, land and property. In context of the Terai region major damage is caused by the Churia rivers. These rivers are small in size but large in numbers. Based on the types of interventions to control or minimize damage, flood control measures can be categorized as

- Structural measures
- Combination of structural and bioengineering (vegetative) measures.
- Watershed protection

Structural measures for flood control are the following. Detailed technicalities of these measures are dealt with in the later chapters. These structural measures supported by vegetative means form the best and affordable solution to flood problems in the Terai.

i) Flood embankment/dyke

ii) Spur and guide bund

iii) Revetment

iv) Channel improvement

Small-scale river control structures are best constructed through peoples' participation. Although sophisticated surveys and detailed designs which consume a lot of time and effort are not essential for labor intensive works, a careful consideration of a minimum of engineering aspects of flood control is essential.

The minimum technical information required are as follows:

- River site plan
- Cross–section of river at 50m intervals
- Bed slope and longitudinal profile of the river stretch
- Size of bed material and bank material should be known (obtain grain size distribution by sieve analysis)

The following details should be shown on site plan:

- Boundaries of various ground levels and flood plains
- Islands and bars
- Green vegetated area and plantation
- Location of structure (showing up to 500m u/s and 500m d/s for minor works and up to 2 km u/s and 2 km d/s from affected site or up to meander length for major works)
- Location of main flow channel
- Marking of the river segment (for precision works)

3.2 *Identification of the Problems and Their Solution*

Problems caused by rivers vary from one place to the other. The same river may be in aggrading condition at one location while after travelling some distance downstream it may be in degrading condition. In order to be able to address the problem properly, one must have the means to identify the real problem correctly. The problems at the given location may be one or the other of the following.

(a) Aggradation (i.e. rising of river bed) and inundation of neighboring land

(b) Aggradation and bank erosion.

(c) Bank erosion at one or many locations.

(d) Degradation (i.e. lowering of riverbed) and erosion.

(e) Shifting of river course.

(f) River retrogression and bank slumping.

3.3 *Decision Chart for Selection of Alternatives*

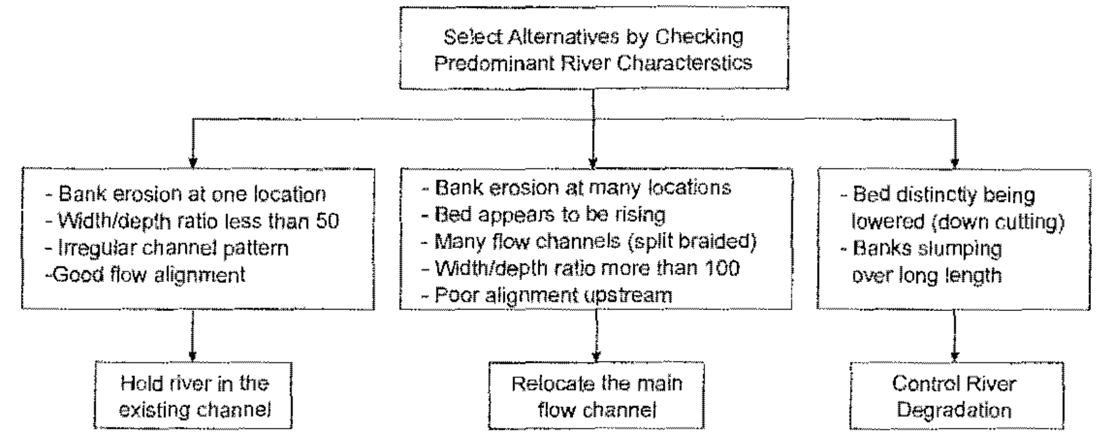
When the problem is properly identified, only then a proper intervention could be devised. Based on the nature of the problem, intervention needed may be one of the following

i. Keep the river channel in the existing position

ii. Control of river degradation

iii. Relocation of main flow channel

The following decision chart may be considered to identify the proper intervention measures.



Source: WECS

(i) Hold the River in the Existing Channel

There can be a number of problems in the riverbank. When the riverbank is high and lowering of riverbed is occurring near the bank, erosion takes place. Such riverbank can be protected in different ways. Through the construction of revetment, river bank can be held in existing position and thereby guide the river in the existing channel. The artificial surfacing of the bank by boulder pitching, cement concrete blocks paving or making the riverbank resistant to erosion by similar means is called revetment. Revetment requires apron of appropriate width and depth.

The following points should be considered for revetment construction:

- It should be well fixed to riverbank at both their upstream and downstream ends.
- It is generally placed at the outside of bend where local scour causes bank slumping.
- Its length should be established by the length of high velocity zone near the bank to be protected.
- When revetment is constructed of gabion boxes to protect the bank, launching apron of required length should be provided to protect against scour.

(ii) Control of River Degradation

Degrading river can be controlled by gradient control structures. If the degraded slope is steeper than stable slope of the river, then gradient control structure becomes necessary to flatten the slope to bring back to the stable slope.

Before designing a gradient control structure, the following observations should be made.

- Nature of degradation, u/s or d/s
- Profile of degradation reach
- Establish stable slope for the degradation reach.

The following points should be considered while designing and constructing degradation control structures.

- For upstream progressing degradation, control structure should be established at the knick point and work downstream.
- For downstream progressing degradation, control structure should be provided at downstream end and work upstream.
- For downstream progressing degradation, the following USBR formula can be used to assess the ultimate degradation.

  ds = 8/13 L.DS.

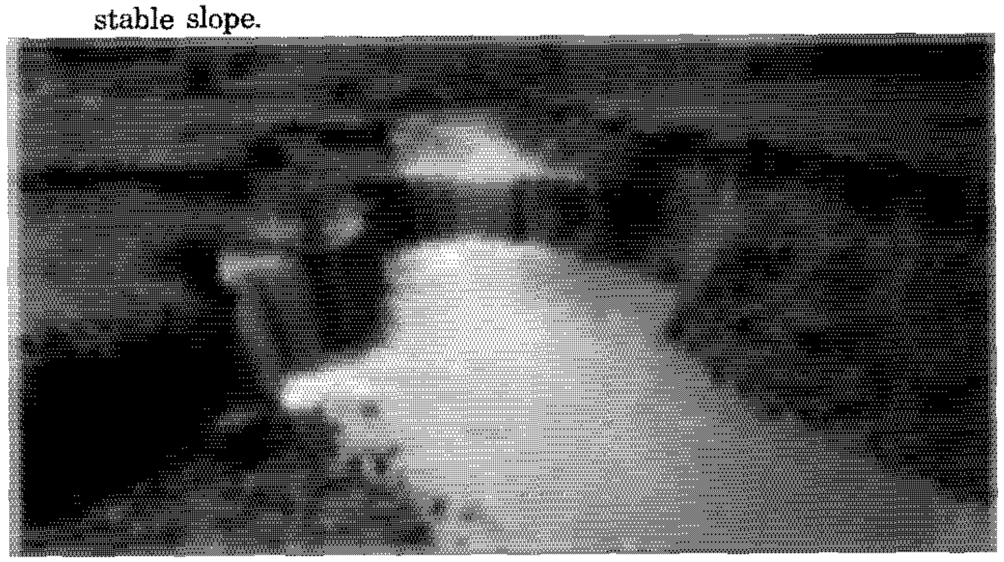
Where,

ds = ultimate depth of degradation below average bed level, m.

L = distance to downstream control point where degradation stops, m.

DS = change in slope from existing to future stable slope.

- The spacing should be set depending upon the height of the structures and stable slope.



Upstream progressing gulley:
A gulleying process on a tributory to Charnath river-1998; requires gradient control structure

(iii) Relocation of Main Flow Channel

If the main flow is diverted due to some reasons, the river will start cutting the bank on one side. Such deflected stretch of the river needs to be relocated to its initial flow channel, which can be done by the construction of spurs. Repelling or deflecting spur can deflect high velocity flow away from the bank. Similarly retard structures, generally permeable ones induce sedimentation in sediment-laden rivers.

Cut off is another measure to relocate river flow back to the main flow channel. Short-cuts across meander loop or new channels result in abandonment of the existing channels.

The following points should be considered for relocating the flow channel.

- Determine required water-way to pass flood flows.
- Trace out a smooth approach alignment.
- For braided river, determine the best flow channel into which the main flow could be relocated moving it away from the eroding bank.
- Locate the spur, retard and cut-off in such a way to ensure smooth flow along boundary of the relocated channel.

Embankment and Embankment Protection Works

4.1 Design Considerations

Flood embankment is constructed when floodwater overtops the natural riverbank and causes damage to crop, land, property or threatens human lives. Sometimes spill water is useful for agricultural purposes. If the volume of spill water is not very large or not damaging, in such cases embankments are not required.

Design flood discharge gives the real picture of spill water depth from which height of embankment needed can be determined.

The following considerations should guide the construction of embankment:

If flood plain is reduced by construction of embankment, the suspended load is carried downstream. Deposition of sediment occurs at un-embanked portion of the river, thereby flattening the river slope resulting in widening of river and formation of delta. This can further lead to develop a large submergence area. Hence only embanking of river may not be the final solution. The system of embankment confines flood water of the river within the embankment causing aggradation of the leveed reach upstream because of decrease in the water surface slope of stream above leveed portion.

4.2 Design of Embankment Section

Normally flood control embankments are trapezoidal in shape and are to be constructed from the bed material available nearby.

- It should be designed and protected to withstand erosion.
- It should be stable against undermining and piping.

- It should be stable against sliding of slope as a result of erosion and scour.
- It should be stable against sliding due to seepage.

Steps Involved in Design of Flood Embankment

- Determination of Design Discharge and Height of Embankment
- Determination of Spacing between Embankments
- Design of Embankment Section
- Design of Protection Works

4.3 Determination of Design Discharge and Height of Embankment

Determination of design discharge and high flood level is the first step in the design of an embankment because the discharge and the flood level determine the height of embankment required. Flood embankments can be designed to withstand floods that occur once in ten years, 25 years, 50 years or 100 years. The design flood is judged based on the normal flood of the river. For rivers having normal flood discharge of more than 300 cumecs a flood of 20 to 50 years return period should be considered. Rivers having normal flood discharge above 500 cumecs are damaging during flood and it is preferable to consider design discharge of 50 to 100 year return periods. Various methods of estimating design flood discharge are available which are included in the Annex.

Determination of Spacing between Embankments:

Wherever the proposed river control work can restrict the width of the river flow, it is necessary to establish the minimum width for the water way opening. Stable river-width, waterway and river boundary line give the same meaning.

As a preliminary estimate, Lacey's empirical formula for stable channel can be used.

$$p = k\sqrt{Q}$$

Where,

b = net water way opening in m

K = coefficient

Q = design discharge in m^3/s

For a given design discharge, net surface width of waterway opening can be determined from the graph given in Annex II. Otherwise, it can also be calculated as follows, which also gives the same result.

$$p = 4.75\ Q^{1/2}$$

For determining spacing between two embankments, designed waterway should be multiplied by 3 to 6 depending upon width, nature, river characteristics as well as level of protection that could be provided.

The following considerations should be followed while fixing the spacing:

Minimum Distance:

The minimum distance of an embankment should be at least 50^m from the existing riverbank. For smooth alignment, the minimum spacing between two embankments should be water way plus 100 m. This is the minimum cross sectional area needed through which flood water can pass. Additional widths may be provided at bends. Actual width of floodwater should always be more than the existing river section. Embankment should be constructed beyond meander belt (ref. Meander Belt). But before fixing the alignment, causes and shape of meander should be carefully analyzed.

Design of Embankment Section (Height, Side Slope and Top Width)

The height of the embankment is determined by the high flood level of the designed discharge. Clearance should be made for probable settlement, wave height and free board.

Therefore height of embankment is given by $= H + F_B + h_1 + S_L$

(i) High flood level	(H)
(ii) Free board	(F_B)
(iii) Wave height	(h_1)
(iv) Probable settlement after construction	(S_L)

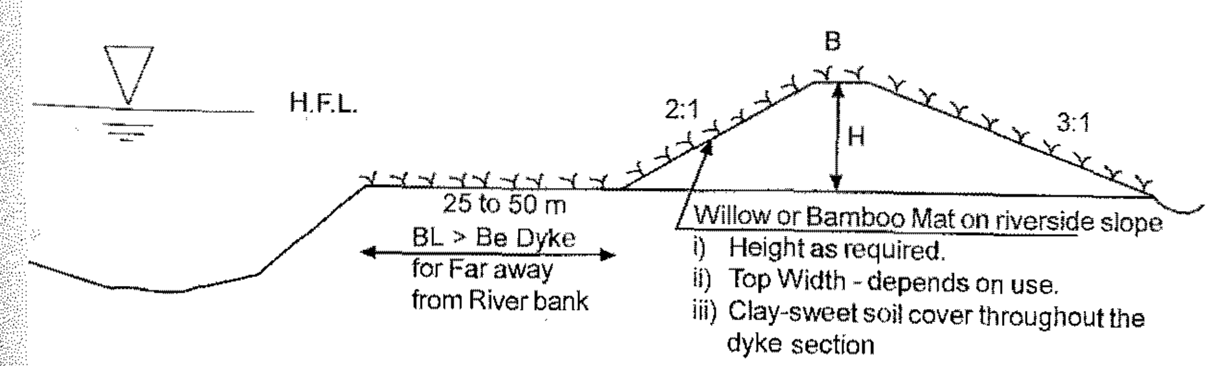
Wave height and probable settlement could be neglected, allowing adequate free board.

For small rivers free board of 1.0 m is provided whereas for larger rivers free board of 1.5-2.0 m is needed.

Generally, the upstream slope facing the river is provided at 2:1 to 3:1(H/V) and downstream slope is provided more gentler up to 5:1 depending upon the angle of repose of the material and stability analysis.

For small rivers top width of the embankment should be 2 m to 3 m. For larger rivers and longer embankments, they may also serve the dual purpose of road as well as flood control. In such cases top width should be 4m to 5m with intermediate bypasses of 6^m to 7^m wide at every 500 m .

Fig.3
General cross section of Embankment



Design of Protection Works for Embankments

Generally embankments are constructed on flood plain and are usually not subjected to strong current. If they are constructed very near to the main channel, they become the part of riverbank and are subjected to strong erosion. Heavy protection at toe and slope is required in such cases. Such protection can be classified as

(i) Direct protection

(ii) Indirect protection.

Direct Protection includes:

A. Slope protection of embankment.

B. Toe protection (Launching apron against scour).

Indirect Protection includes:

It is not a continuous work but intervention at certain intervals in order to protect the embankment indirectly.

- Construction of spur.

Based on the situation of site, time and resources available, protection works can be of temporary, semi-permanent or permanent nature. For example,

i) Temporary protection to check erosion at the time of emergency.

ii) Semi-permanent protection using brush wood, bamboo, wire mesh, sand bags until stabilization of vegetation.

iii) Permanent protection works using boulder, concrete blocks, G.I. crate, cement and sand mixture filled in jute bags.

Direct Protection Works:

A. Slope Protection of Embankment

I. Vegetative Cover on the Surface of the Embankment

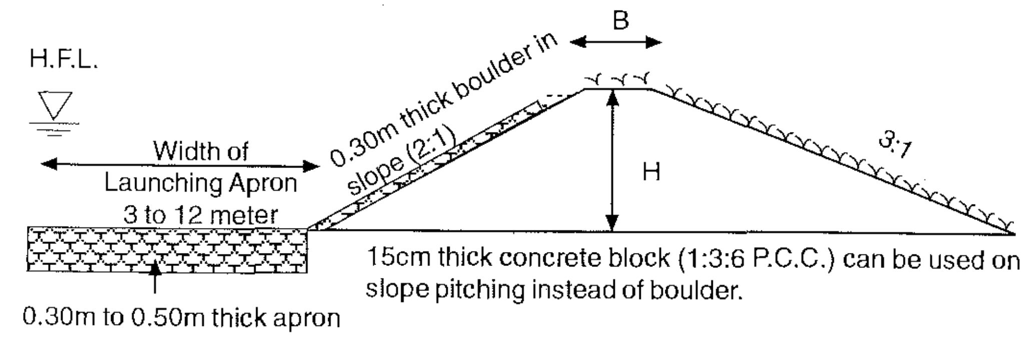
If the embankment is away from the main flow channel it is not subjected to strong current. Then vegetative cover like grass turfing, natural growth of bushes, shrubs and willows give most effective cover. Till the full growth of such vegetative cover, a temporary cover with mattresses of woven willow brushes is necessary for an initial period.

II. Boulder or Gabion Works for Slope Protection of Embankment

If the embankment is close to the main flow channel, it is highly vulnerable to erosion and scour. More solid protection work is needed on the side facing river as well as on the toe. These protections can be provided either by dry boulder pitching of adequate thickness or by flexible pavements of boulder in gabion. Lower portion of the bank is similar to the case of revetment, toe of which is constantly under water and liable to scour, whereas, upper portion of the bank faces low velocity current. In some locations such as caving portion of the

bank, upper portion remains in pressure of strong current and protection similar to the lower portion of the bank should be provided.

Fig.4
Example of Slope Protection



III. Revetment

Protection of the slope of an embankment simulates protection to the bank erosion. Revetments are constructed to maintain a riverbank in its existing position and to reduce the bank erosion.

As the embankment has to withstand strong current during high flood period, they have to be protected in the same way as the riverbank. If size of the stone is large enough to withstand local velocity, rip-rap loose boulder pitching is sufficient. If the available sizes of the boulders are small, use of gabion crate becomes necessary.

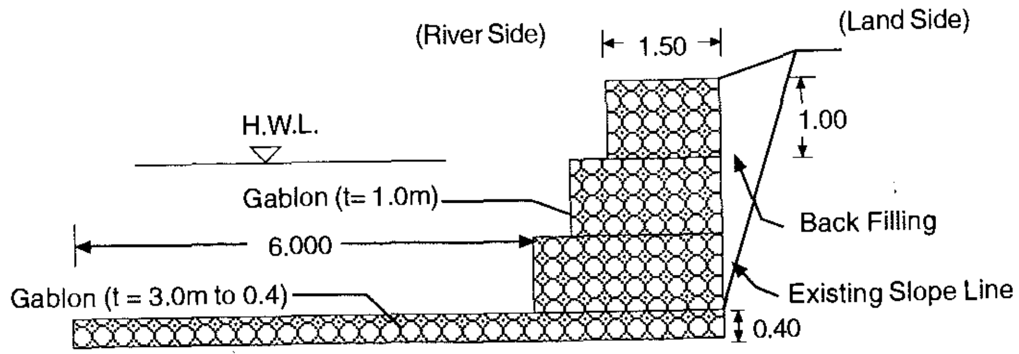
Revetment is provided to protect against bank slumping, erosion and scour. Construction of revetment at high bank where bank is slumping, requires strong protection works. Scour may increase in concave bank as bank slumping stops.

Revetment is a highly useful structure for river training works. Revetments used for bank protection works need launching apron too. The width of the launching apron at toe is based on scour magnitude and a launched slope of 1.5:1 to 2:1 as explained earlier.

Revetment can be combined with spur. If revetment is constructed on a single channel river, spur should be constructed on the opposite bank. Sometimes spur can be placed at the toe of revetment to secure protection against scour. Combination of spur on one bank and revetment on opposite bank may be more useful in split or braided channel. The following figure illustrates different types of revetment and their utility.

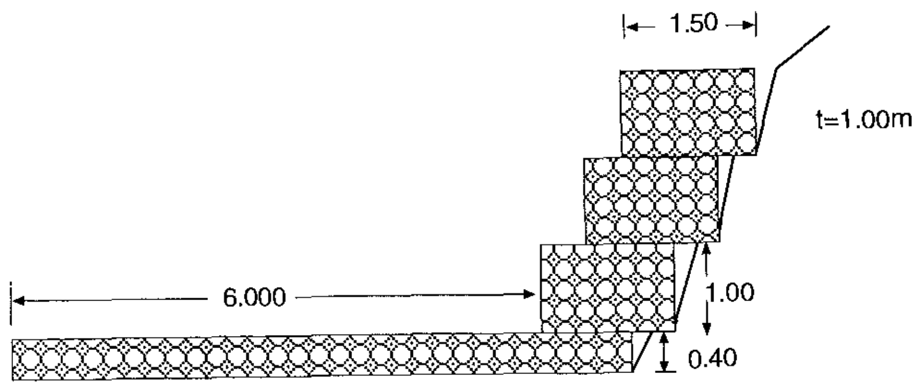
Typical Section of Revetments

Fig.5(i)
Boulder Crate



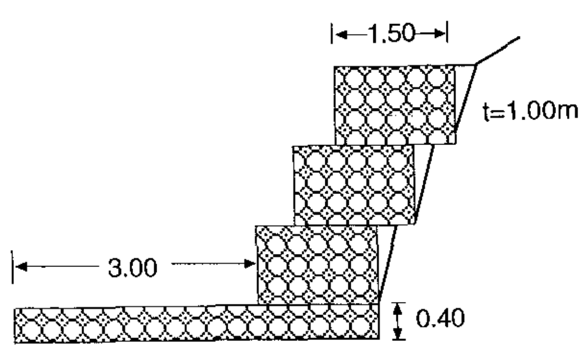
Lunching apron as per design (1.5 R to 2R)
R=Scour Depth

Fig.5(ii)



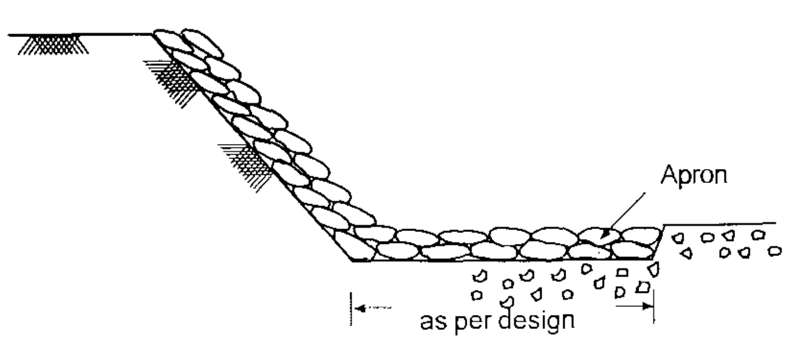
For Narrow, deep high veloucity River

Fig.5(iii)



For Small and Deep Rivers

Fig.5(iv)



Riprap revement with apron

B. Toe Protection; Launching Apron Against Scour

Scouring is the localized lowering of the riverbed during times of high flow around artificial structures that obstruct the natural river course. Embankments are to be protected against probable erosion and scour. Such protection against scour is given by providing launching apron. The launching apron assumes the launched slope as soon as scouring takes place thereby stopping further scouring to take place underneath the main structure. Size of such protection works depends upon the scouring capacity of the river. Therefore the first step towards design of toe protection is to determine potential scour magnitude.

Scour magnitude depends on the flow characteristics such as discharge, flow velocity, local obstruction to the flow as well as location. In order to allow for the site-specific variations, inflow characteristics design discharge is taken as 1.20Q. to 1.24Q for scour magnitude considerations.

The magnitude of scour can be calculated in two ways

a) Scour magnitude by Lacey's equation of normal scour depth

b) Scour magnitude from Z factor consideration

a) Scour Magnitude by Lacey's equation for normal scour depth.

$$\text{Scour depth, } R = 1.35\left(\frac{q^2}{f}\right)^{1/3}$$

$$\text{Where, } q = \text{discharge intensity} = \frac{Q_f}{(\textit{Water width})} \text{ in } m^3/s/m$$

Water width in the formula is flood water width.

Q_f = 1.2Q-1.24Q

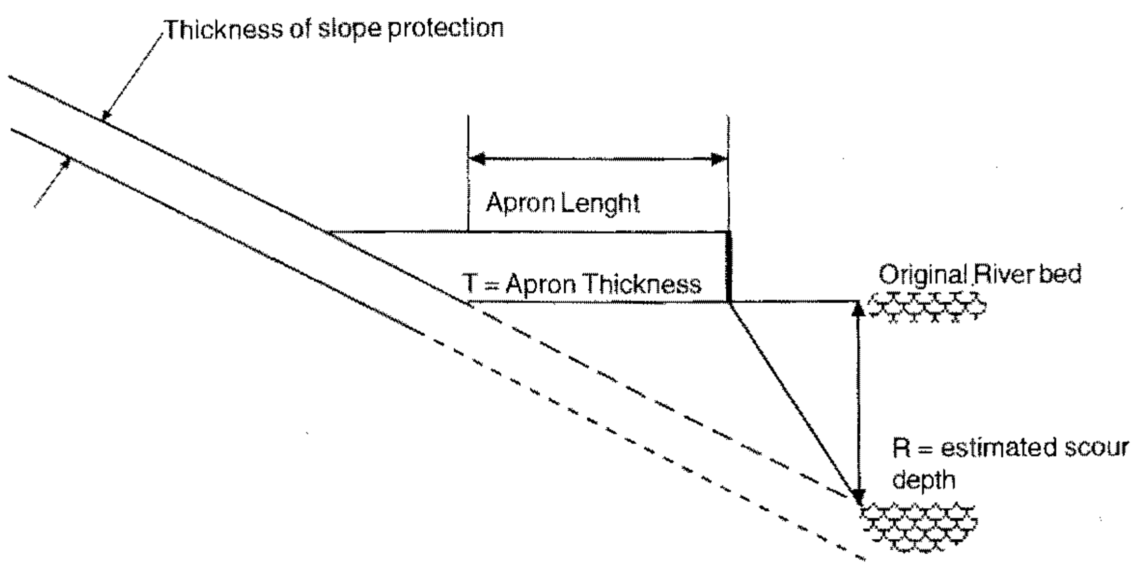
f = Lacey's silt factor which depends on grain size

Normally f is taken as, 0.90 to 1 for Terai whereas for Boulder river f >1.

[illegible]

- [illegible]
- [illegible]

Fig. 6(i)



Different investigators have different opinions about the thickness of protection work needed and thus volume of stone required per unit length. Thickness of stone required for the protection of sloping surface is given by the following equation.

$T = 0.06\ Q^{1/3}$

Where,

Q = Discharge is cusec (fps unit)

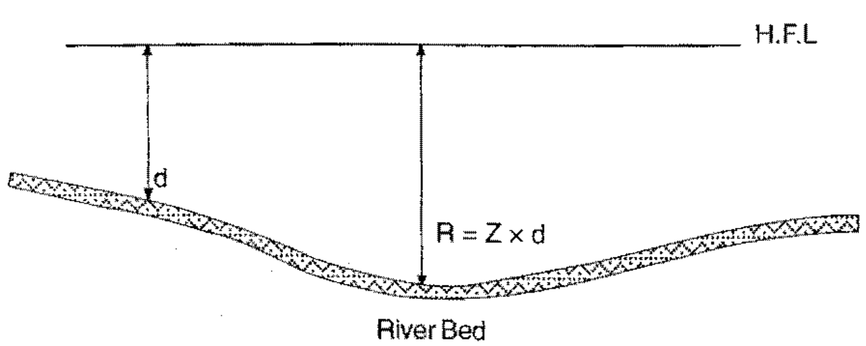
T = Thickness of stone in ft for slope protection work.

Thickness of launching apron = 1. 5. T

Thickness of launching apron in U/S of guide bund and at nose of spur = 2.25. T

b) Scour Magnitude from z-factor consideration:

Fig. 6(ii)



Scour depth varies at different locations of the river depending on local flow velocity at straight reach, concave reach, bends, confluences as well as at obstructions like spur head, bridge pier etc. At such places with marked differences in flow characteristics, scour depths can be estimated by Z factor consideration.

Mean hydraulic depth multiplied by Z-factor, a constant for a particular case, gives scour depth

R = Z x d

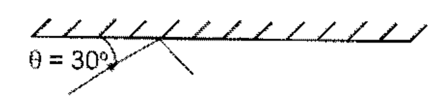
Where,

Z = factor for the given condition

d = Mean hydraulic depth (area/width)

a) Z - factor at abrupt change in flow direction

Fig. 6(iii)



For change in flow direction at 30° Z = 2

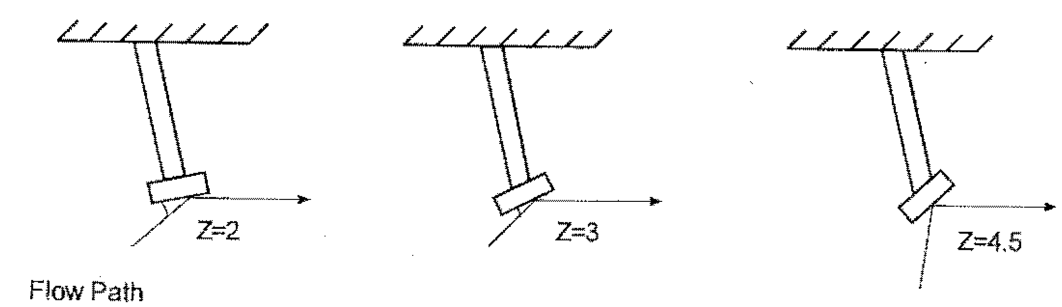
For change in flow direction at 45° Z = 3

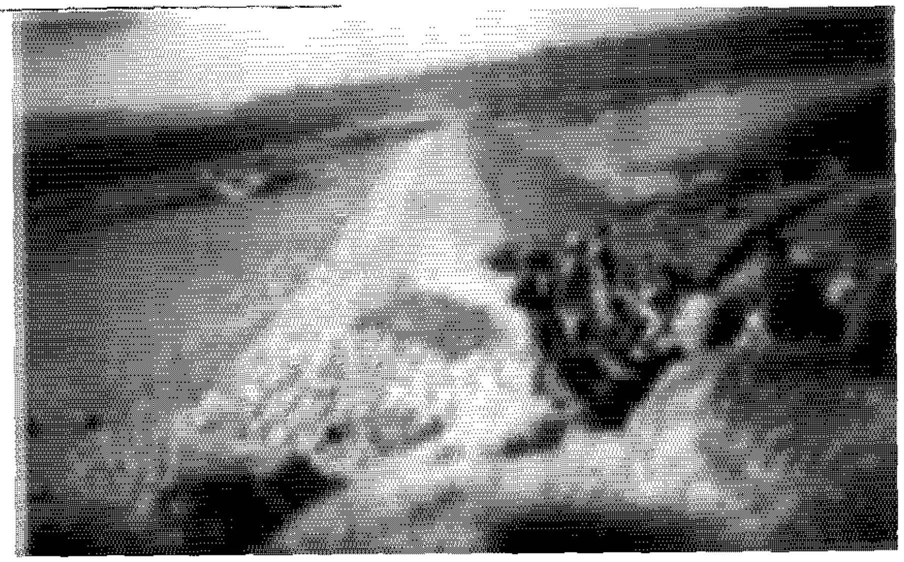
For change in flow direction at 90° Z = 4

For bridge pier, scour depth is directly estimated as R = 1.4 x width of pier.

(a) Z-factors at T- head of spur

Fig. 6(iv)





Toe and slope protection work of an earthen embankment by dry boulder pitching and plantation

Dry boulder packed with smaller stone: Proper stone protection can not be removed without using tools

Protected dyke through forest belt, Udayapur; when sizes of locally available stones are small, thickness of boulder work should be increased

CHAPTER V

Spur

5.1 Spur and Spur Classification

Spur is a structure constructed transverse to the river flow to deflect the main flow path of a river flow away from the eroding bank. It works as an obstruction to the flow at a specific location. Generally spurs are provided when bank erosion takes place. Spurs are constructed from high bank or from an embankment and extended towards main flow channel. Care should be taken that the spurs do not deflect the main flow too much and cause erosion of the valuable land on the opposite riverbank.

Spurs can be classified in several different ways. The most common and general practice of spur classification is according to its alignment and its function. They are also classified according to materials used and according to height as follows:

Classification according to alignment and function

i) Repelling spur

ii) Deflecting spur

iii) Attracting spur

Classification according to materials used

(i) Impermeable

(ii) Permeable

- Bamboo pile spurs
- Floating-Trees spur

Classification according to height of spur:

i) Non submerged – top of spur always remaining above high flood level

ii) Submerged spur – top level of spur below normal flood level

iii) Semi-submerged spur – a sloping spur which partially remains under water during a normal flood

5.2 *Design of Spur*

Length of Spur

There is no definite rule for specifying lengths of spur. It is entirely based on case by case basis. If the spur is too long, it may be harmful for the opposite bank. Therefore there is some limitation on allowable length of obstruction in main channel. As a rule, maximum length of a spur should not exceed $1/5^{th}$ of the river width. Similarly, the minimum length of spur should be more than 2.50 R. Short length of spur may cause bank erosion rather than bank protection. Sometimes long and strong spur is provided to change river course by repelling it towards opposite bank. Opposite bank should be protected in such case. While deciding the length of a spur, river width and width of the main flow channel which has to be deflected from the spur should be considered.

Furthermore, the total length of a number of spurs can be calculated depending on the length of bank to be protected and river segment type.

Total length of a series of spurs (L) for various river segments are as follows.

(i) $L = X/4$ for river segment 1

(ii) $L = X/3$ for river segment 2.1 and 2.2

Where X is bank length to be protected.

[illegible]

Dimensions of Spur

Height of Spur	Top Width and Side Slope	Spacing of Spur
• Height of spur should be above H.F.L with free board of 1.50 m to 2 m. • Height of submerged spur should be 1/2 of H.F.L. Such spur will work as bed bar or deflector.	• Minimum top width should be 3 m for general sand core filled spur. • For bar type spur constructed completely with boulder in crate, width can be reduced based on stability analysis. • Side slope of sand core filled spur should not be less than 2:1. Slopes of nose should be 3:1 to 5: 1 (H:V).	• Spacing can be decided based on total length of spur required as mentioned above. • Generally spacing between two spurs in concave bank should be 2 to 2.5 times its length. • In convex bank 2.50 to 3 times its length. • In the case of revetment with spurs, spacing can be increased without causing harm to the bank.

Thickness of the boulder at the nose of spur should not be less than 50 cm for rivers originating from the Churia rivers.

5.3 *Types of Spurs*

(I) Repelling Spur

Spur pointing upstream to the local flow direction is called repelling spur. It has the property of repelling the river away from its thrust. It remains under high pressure of water current. Repelling spurs are successful in achieving desired results if they are properly located in relation to meander length.

It should be aligned at a deflection angle of 60^0 to 80^0 with bank or prominent flow line. In other words, spur makes an angle 10^0 to 30^0 with the line perpendicular to bank or main flow line. A still water pocket is formed in the upstream of a repelling spur. It is very useful to divert the flow and its success depends on how quickly sediment deposition occurs. This can be accomplished only when the spurs are sufficiently long. Spurs are generally constructed in series.

Since the flow is obstructed by spur, the local velocity at the nose is high. Therefore, the nose of the spur is highly vulnerable to scouring, which thus requires strong protection at head. Scour magnitude diminishes from head towards the bank. Accordingly protection of slope and apron could also be reduced.

Fig:7
Plan and Layout of Repelling Spur

Fig: 7(i)

(i) Repelling spur plan and layout

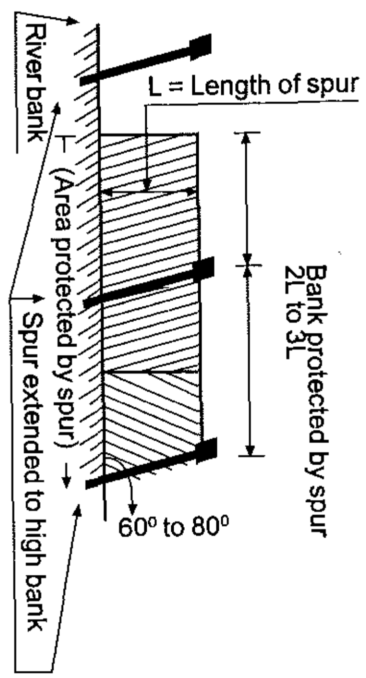
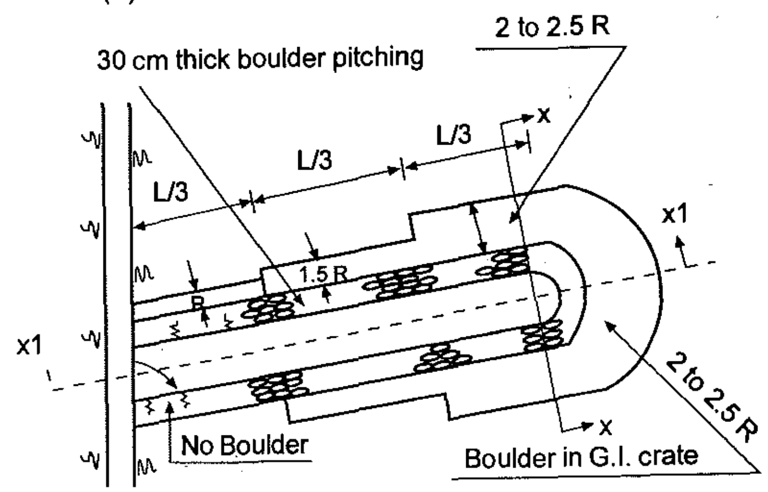


Fig: 7(ii)

It can be (i) Earthfilled (ii) Dumped boulder (iii) Boulder in G.I. crate



Plan

Fig: 7(iii)

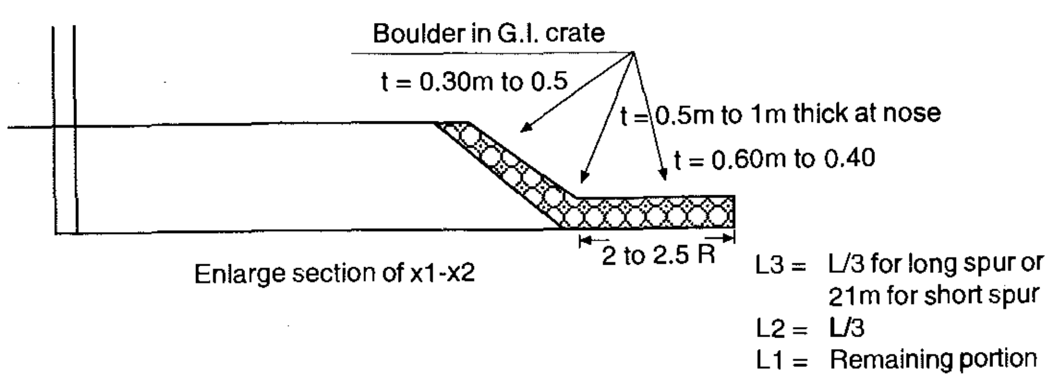
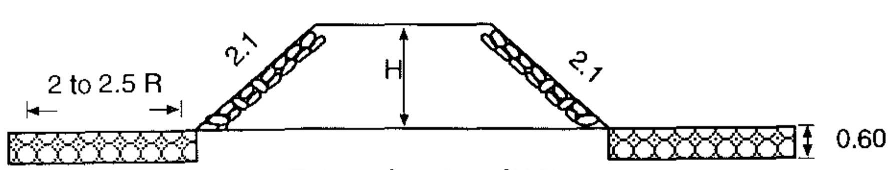


Fig: 7(iv)



Enlarged section of X-X
H = H.F.L. + 1.5m.
side slope-30cm to 40cm thick
Boulders in crate at nose

1. Width of launching apron of short length spur whose full length is in the main flow should not be less than 2 R.
2. Revetment should be provided in the U/S bank of 1st spur.
3. Launching apron should be below lowest bed level.
4. Spur remains in high presure, slope and apron should be well protected.

(ii) **Deflecting Spur:**

A spur structure perpendicular to the bank and having short lengths which only changes direction of flow without repelling it is known as deflecting spur. It provides only local protection by changing the direction of flow. A typical example of a deflecting spur is shown in the following figure.

Fig: 8
Plan and layout of Deflecting Spur

Fig: 8(i)

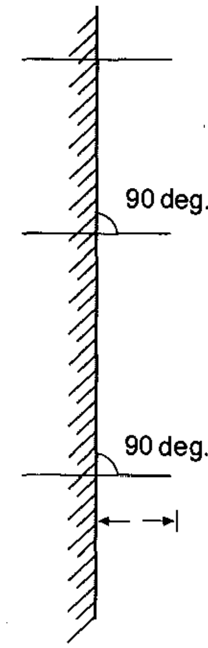
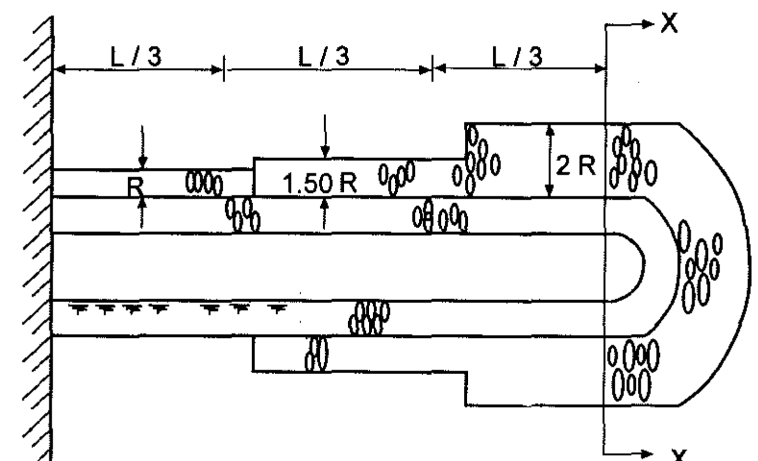


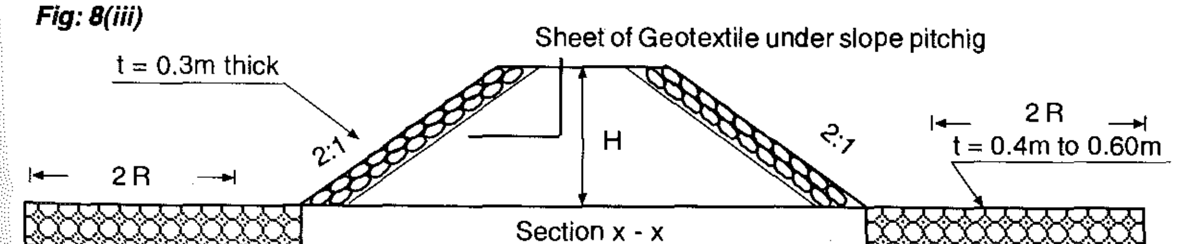
Fig: 8(ii)



Plan

Spur perpendicular to bank, width of apron is reduced towards bank or in slope

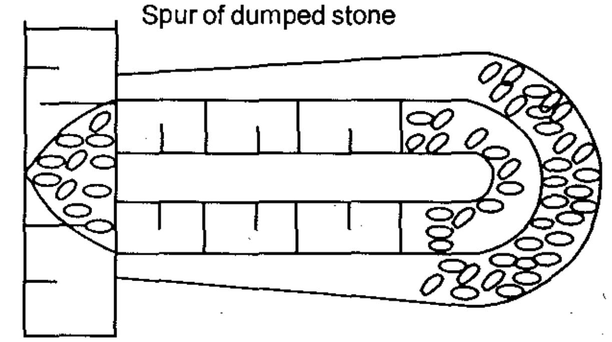
Fig: 8(iii)



Section x - x
H = H.F.L. + 1.5m
Launching apron-boulder in G.I. crate

Fig: 8(iv)

Spur of dumped stone



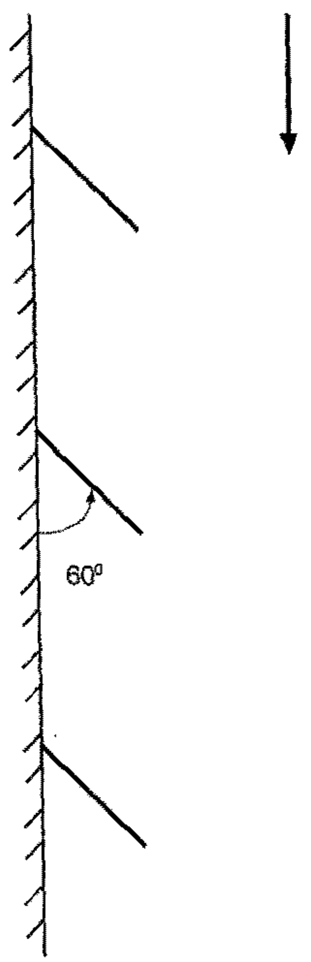
Plan

iii) **Attracting Spur:**

Spur pointing downstream towards the direction of flow is called attracting spur. It attracts the river flow towards its bank and therefore its named attracting spur. There will be no silting between successive spurs instead the bank gets eroded.

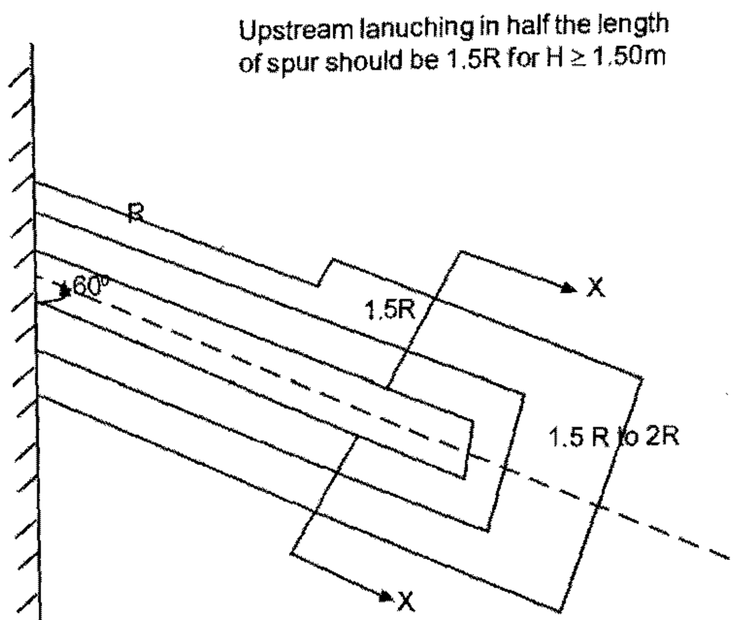
Fig. 9
Plan and Layout of Attracting Spur

Fig. 9(i)



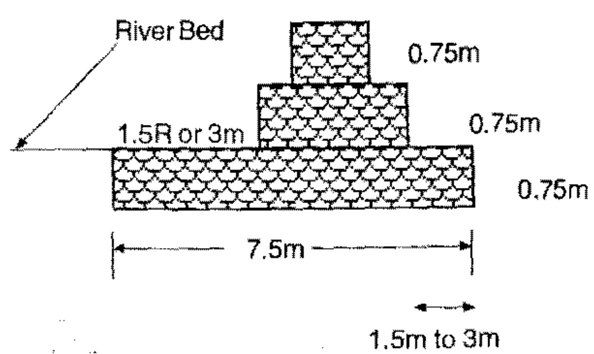
Line sketch

Fig. 9(ii)



Plan

Fig. 9(iii)



Section X - X

Comparision between Repelling, Deflecting and Attracting Spurs

Repelling Spur	Deflecting Spur	Attracting Spur
• Useful in narrow and deep rivers • It repels the flow and pressure develops on the opposite bank • There will be maximum pressure on the spur nose and therefore needs heavy protection work. • Number of spurs required to protect the given length of embankment is comparatively less • People living on the same bank are the beneficiaries of this type of spur. • It deposits sediments on the bank downstream of it. • Materials required are the same as that for an attracting spur.	• Useful in providing local protection. • They change direction of the flow. • Since they are short in length, materials required are less compared to both attracting and repelling spurs.	• Useful in wide shallow rivers. • It attracts flow and pressure develops on bank d/s of spur • There will be minimum pressure on spur and thus maintenance cost is low. • Number of spurs required to protect a given length of bank is more. • Sometimes long bar spur can divert main flow in wide and shallow rivers. • Users of opposite bank are beneficiaries of this type of spur. • It does not deposit sediment. • Materials required are the same as that for a repelling spur.

5.4 Protection Works for Spur

Design of protection work is similar as that for revetment and embankment. It is based on its location, scour magnitude and type of spur.

Thickness of stone required for protection work is given by

$T = 0.06\ Q^{1/3}$

Where,

Q = Discharge in cusec (fps unit)

T = Thickness of stone in ft for slope protection work.

Thickness of launching apron = 1. 5. T.

Thickness of launching apron in U/S of guide bund and at nose of spur = 2.25. T

Volume of stone for apron per unit length = $2.81\ D_{max}.\ T$

D_{max} = Scour depth below lowest water level.

For a normal case volume of stone for apron per unit length = 2.25 . Dmax . T.

Repelling and deflecting spur remains in high pressure of river current. Launching apron at nose should be strong enough to resist pressure and scour. Normally shank of the spur can be divided into 3 parts as shown in the figure.

The size and magnitude of the protection works at various part of the spur depend upon the scour magnitude. Maximum protection width of 2 to 3 times the scour depth is provided near the nose portion. Similarly, protection width of 1.5 times scour depth is provided beyond the nose and width equal to the scour magnitude (R) is provided near the bank. Downstream protection of spur is not a serious problem. At the downstream portion of the spur body lying in river channel, width of launching apron equal to R normal scour depth, can be provided.

5.5 *Other Types of Spurs*

(i) Submerged Spur/Bed Bar

Submerged spurs divide the flow horizontally. Its height should not exceed 1/2 of water depth nor should it be less than 1/3 of water depth. The flow up to the height of spur is diverted towards the nose, up to which it acts as a normal full height spur. If it is inclined to upstream, pressure gradient helps sediment deposition on the upstream side of the bar while the surface flow gets deflected away from the bank. It is highly successful for bank protection. Function of the bed bar is quite similar to spur depending on its alignment. Sometimes bed bar inclined to downstream is also provided at upstream of an off-take structure for sediment exclusion. Yearly maintenance associated with slow extension of the spur will push the main flow gradually away from the bank.

(ii) Sloping Spur (Semi Submerged Spur)

Spurs are generally constructed with horizontal top, shank and flat slope at the end. Whereas in sloping spur, entire length including shank and nose is given one continuous flat slope so that obstruction to the flow near the bank is the maximum, while at the river side end it is the minimum. In this type of spur scour at the riverside end is much less. Similarly, the return flow upstream and downstream of the spur is also much reduced.

(ii) Long Spurs

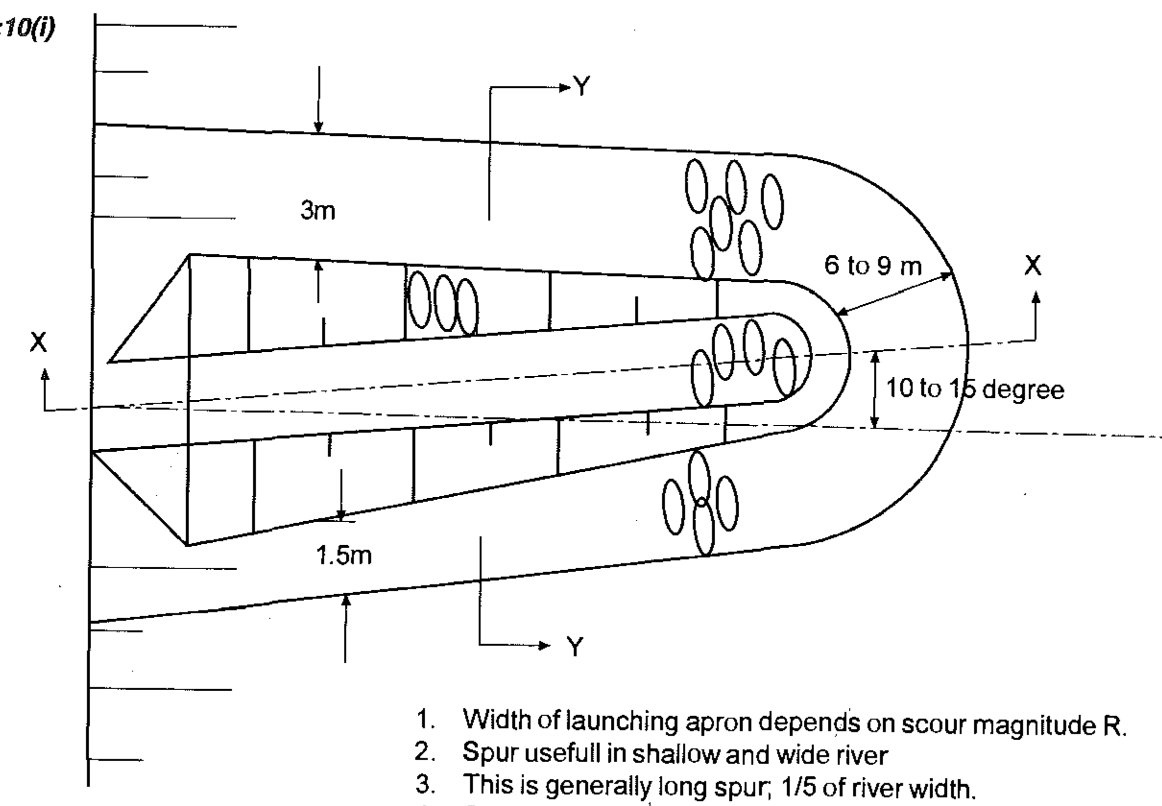
Spur in a very wide river should be long enough. Two thirds of its total length could be constructed from earth fill while the remaining should be constructed with boulder at slopes. Protection work is not required up to L/3 of the spur. Remaining length of the spur is given one continuous slope. Such long spur requires another small spur in its body at a place L/3 from the bank to relocate the main flow. Length of such a small spur called 'strong arm' should be one third of the length of the main spur. All the dimension and principle of the arm spur are the same as deflecting spur.

Sometimes the major portion of long spur lies on the natural ground. To reduce the costs of protection works, either revetment or a arm spur is provided along the river bank in the upstream or the upstream of the dyke itself is protected. Semi submerged portion of the spur is fully protected by boulder in Gabion crates. Lining of geotextile is provided below boulder layer on spur body and slope.

The figure below gives an example of long spur with slopes and long spur with revetment in the upstream.

Fig:10
Sloping spur
(Semi-submerged)

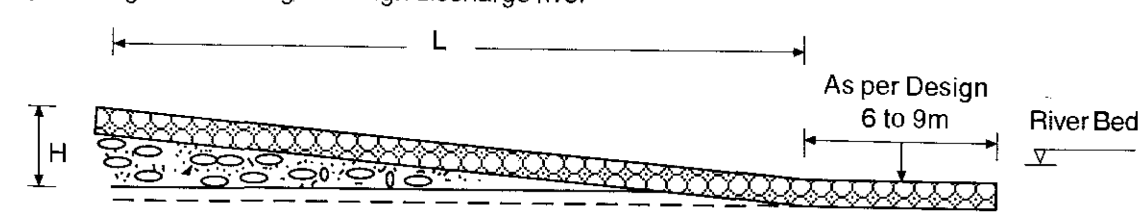
Fig:10(i)



1. Width of launching apron depends on scour magnitude R.
2. Spur usefull in shallow and wide river
3. This is generally long spur, 1/5 of river width.
4. Spur is fully covered by boulder in GI crate

Fig: 10(ii)

Slope through out the length for high discharge river



Section X-X

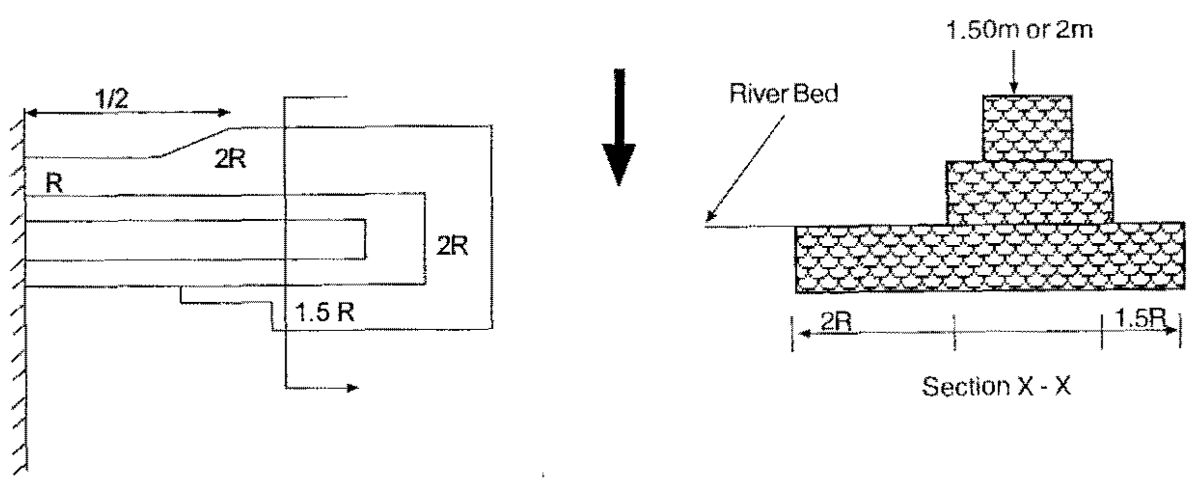
Bar spur

- Body of the spur constructed completely by boulders filled in gabion crates is called bar spur.
- It may be any of the above three types, repelling, deflecting or attracting.
- Instead of boulders, sandbags can also be used to fill in the crate.
- Construction of bar spur is easy.
- It is very useful in small rivers.
- It is easy to construct in emergency situation.

Materials Required

- Boulder and G.I crate or
- Sandbags & G.I. crate or nylon crate.
- Nylon thread and needle for sand bag.

Fig. 10(iii) Bar Spur



i) It can be of any height and length, with stable slope.
ii) Submerged spur and bars can be constructed in same way.
iii) Foundation should be excavate below River Bed.

CHAPTER VI

Implementation Arrangements

6.1 Users' Committee Approach of Implementation

Community based flood control infrastructures are best implemented through local users committee. This means that overall authority and responsibility for planning, construction and maintenance is given to the users' committee. Institutions like VDC, DDC, government and donors assist and support by providing resources or technical advice. Different local political interests are also accommodated in the planning, decision making and users' committee formation process.

The DDC and VDC Acts of HMG provide the legal basis for the formation of the users' committees. Under these acts both the DDCs and VDCs are empowered to form and approve the users' committees, and specify tasks for them to perform. Political balancing is to be attempted in forming the users' committees, and in the process, representatives of political parties having no standing in the DDC or VDC can also be nominated as UC members.

The users' committee can also be formed in different tiers, if necessary. For example a VDC can constitute a users' committee for implementation of flood control work in the respective community under the chairmanship of a person it considers the best. A users committee can further form sub-committees for specific tasks. The sub-committees will be answerable to the users' committee that in turn will be answerable to the VDC. Such arrangement works best for a project confined to a single VDC.

Similarly if the areas of intervention are scattered at several locations within a VDC, separate users' committees could be formed for each individual project.

Another method of forming a users' committee for a project spread over several VDCs; for example along embankment, is to form the main users' committee to coordinate works in all the related VDCs and sub-committees could be formed at each VDC level. To manage a "single basket" type of project using resources from several sources such as VDC, DDC, MLD, Donors etc., strong social mobilization support becomes crucial.

Users' Committee Approach	Conventional Contracts
Local people are directly involved in planning, construction and maintenance	Local people may be involved, but only as laborers
Policies are made by the representatives of local people in accordance with their need	Policies are made by outsiders, and may not be in accordance with the needs of local people
Investment made on infrastructure goes directly to the local people through off-farm employment generation	Major part of the investment goes to outsiders
Low-cost construction alternative	Construction can become expensive
Labor-intensive methods used	Capital-intensive methods including mechanized means of construction
Ownership feeling developed within the community	Ownership by government (or nobody) thus sustainable maintenance system compromised
Maintenance carried out locally as and when needed	Maintenance carried if funds are made available by government,
High emphasis on transparency	Local people generally not informed about costs and procedures
Construction synchronized with agricultural slack season to involve local people in off-farm employment Overheads are kept low	Construction dependent on budget release and appointment of contractors, factors that are not related to season or labor availability Contractors hire local contractors, who hire further sub-contractors, and each level keeps a margin of profit

Different Partners, their Roles and Responsibilities

The roles and responsibilities of the different partners involved in a project are well defined. The partners involved in a typical flood control project include:

1. labor groups
2. users' committee
3. District/Village Development Committee (DDC/VDC)
4. private engineering consultants or NGOs
5. donor(s)

Labor groups	Undertake construction and maintenance while developing a self-help culture. Once completed, it is maintained through local resources.
Users' committee	Users' committee has the overall responsibility for organizing construction and maintenance. It meets periodically, enacts necessary rules and regulations and enforces them. The UC identifies local supervisors, naikes, masons and labor group for training. Members coordinate with the DDC, line agencies, consultants, farmers' group, politicians, etc. It makes available the land necessary for embankment and monitors progress
DDC/VDC	Provide official approval for the project and users' committee. They carry out policy coordination, undertake monitoring, for the institutionalization of a maintenance system based on local resource generation. The DDC/VDC may provide resources and technical support. They may help solve site-specific problems, if requested, and arrange payment to the labor groups and suppliers on the basis of certification of the consultant or officer in-charge.
Consultant/NGOs	Provide the technical and social mobilization support
Donor(s)	Enters into contract agreement with local institutions and co-operating partners for the technical or financial support to the construction project. It selects, commissions and supervises local consultants and/or supplies technical support. It controls management of funds and may undertake independent evaluation and monitoring.

6.2 Construction Management

A community-based infrastructure should follow a process, rather than a fixed program. It should build the capacity of local people and institutions as much as possible, rather than using complex and sophisticated expertise. Flood control initiative should look for innovative alternatives rather than conventional, hard structural practices. Uses of "soft line", socially congenial technology should be promoted rather than hardline engineering practices. It should avoid unnecessary overheads and middlemen's profits which are the features of the conventional contracting system. The saving made on this should flow back to the local community. Workers on such programs are the farmers living adjacent to the river who work in the off–form–season for the protection of their own land and property.

- Performance Based Work Assignment

There are two main work assignment systems used in Nepal:

- labor payment without competitive bidding
- *assigning contractors (i.e.* with *competitive bidding)*

The first approach (labor payment without competitive bidding) can be further broken down into three methods, namely a muster-roll system, a lump-sum piece-work system, and payments based on work measurement and valuation. Valuation is based on approved unit rates.

Using the competitive bidding model, small contracts can be awarded either with or without a pre-qualification of contractors.

Work assignment methods emphasize performance-based compensation, in areas with a high level of self-help motivation. A muster-roll approach is appropriate when high levels of supervision are available, quality is particularly important, and in situations where time is not a constraint, such as in action research. Labor payment systems based upon work measurement and valuation is appropriate in larger projects where fast progress is required such as embanking long stretches of river. Labor payments based on work measurement and valuation are also preferred where an objective is to provide high incentives for local capacity and institution building.

The conventional contract systems are not preferred generally. Only in cases of more complex structural works requiring external construction materials or equipment that require specific professional experience and expertise, the conventional contract system becomes acceptable. For example construction of spurs in a limited time to protect an embankment needs to be done through an experienced contractor, because it could be very difficult to manage large volume of boulder transportation only by labor moblization and filling them into gabion boxes under pressing circumstances.

- Work Norms

  HMG/N work norms are heavily inflated in some cases and under-valued in others. For community based labor intensive approach, they are inappropriate given the participatory nature of the project. While analyzing unit rates for different work items, theoretically four different possibilities exist:

  a. HMG norms and official district wage rates

  b. HMG norms and adjusted district wage rates

  c. Adjusted HMG norms and official district wage rates

  d. Adjusted HMG norms and adjusted district wage rates

  HMG/N norms of rate analysis need to be adjusted to suit labor intensive approach. Specifically, HMG/N norms for gabion filling works need revision.

  Local norms for rate analysis based on years of practical experiences of local people have been successfully used in Food for Work program in four Terai districts, Siraha, Saptari, Dhanusha and Udayapur. Any such adjustment in government norms requires the prior agreement of either MoLD or DDC or of the users. The adjustment of HMG/N norms is recommended for some main items of work that are frequently encountered in flood control works, which influence the construction costs the most. For other items, HMG/N norms are acceptable. Recommended adjustments on the norms based on practical experiences which are being used successfully are given in Annex.

- Store Management

  In cases where the project is being carried out using only local resources (VDC/DDC), users' committee members also manage storekeeping with a view to minimizing costs.

  In order to ensure transparency, a record is kept of all materials, tools, stationery entering and leaving the store using a double entry system. All the tools and materials of the store are inventoried in the beginning and at the end of work season.

- Site Management System

  Each household is asked to provide an identical voluntary labor input.Work is assigned to labor groups composed of appropriate number of workers by the users' committee and are trained within the scope of the project. Local supervisors are trained and employed temporarily. These local supervisors provide day-to-day and hour-by-hour supervision, and ensure quality control.

  Work organization is coordinated by the users' committee which meets regularly at least once every month, and more frequently during the construction season. The entire users' group meets once per year, just prior to construction season, and as necessary to identify labor groups. All decisions are recorded and circulated. Labor attendance records are also kept in a transparent manner.

  Technicians and UC members identify what tools and materials are at hand with labor groups, and arrange additional supplies as necessary. One set of tools are provided to the labor groups soon after the work order is given. Broken or defective tools are replaced with the permission of supervisors. Tools loaned to laborers are collected before the labor wage payment. Naikes are responsible for the loss of tools. The cost of the lost tools is recovered from the responsible laborers.

  At least one UC member remains present constantly at the site during construction to help solve problems of social nature.

  A social mobilizer also remains present constantly at the site in support of the users' committee member. In addition, the social mobilizer's role is to maintain a communication linkage with the workers and to help solve the social problems.

  Naikes take daily attendance of the labor groups, which is verified by the site supervisors.

  Procedure for Measurement, Certification and Labor Payment

  A UC decides the number of labor groups to be deployed in a particular construction season. Required tools and construction materials are supplied. UC members inform local households of their responsibilities of voluntary contribution.

  The workers form their own group of appropriate size as per the instruction of the users' committee and get it registered. Labor groups keep daily attendance and submit this to the local supervisor. The site supervisor, the technician and the social mobilizer closely supervise work progress.

All the labors are paid equally for equal quantity of work they perform regardless of the sex. A Naike is the "first among equals" within the group, with a similar status to the other members of the group. The Naike does not receive any special benefits, and has to work equally as other members while leading the group at the same time.

In order not to disrupt agriculture work, the construction season is harmonized with off-farm season. Smaller groups may be deployed even during the agriculture season for preventive maintenance, re-vegetation and bio-engineering measures, or for completing special priority tasks.

An evaluation of the completed work is made, and the technician prepares the bill calculating the payable amounts to each individual group and then recommends to the responsible officer for payment. The concerned UC chairman or technician collects all the recommended bills. The LDO or the UC sends his accountant to the work site to pay to the labor groups. The users' committee, witnessed by social mobilizers and technicians makes payments. The labor group members sign a receipt.

A public audit is carried out in a mass meeting to verify randomly the payments made to the workers and to discuss other project related issues. At least three such public audits are conducted preferably after each running bill payment to the workers.

6.3 Technical Assisstance

For the success in implementing labor intensive flood control measures, local communities require outside support in technical areas and social mobilization. Social mobilization form an integral part of support needed to the community since a large number of people having diversified interests and opinion are involved in the process.

A. Technical Support

A good technical support in community based infrastructure consists of working with the local people on-site. The support term should work directly with the people building the structure together rather than preparing elaborate detailed drawings, designs and reports that few people use later. The nature of the technical and social mobilization support are as follows:

Types of support required for community based flood control structures

Technical Support	Social Mobilization Support
• surveys, designs and report • training materials • inputs to district decision making • training to naikes, labor groups, masons, supervisors, users' committee members etc. • arranging local supplies and services • construction supervision • site office and store management • work measurement, valuation and certification for labor payment • quality certification • progress monitoring and reporting • preventive maintenance follow-up	• initiating dialogues and meetings. • playing catalytic role in maintaining political balance and consensus in decision making • communication with politicians, the user committee and the general population • training • assistance to UC to mobilize local people • assistance to UC to ensure the social welfare of the laborers • assistance to make decisions and other aspects of the program transparent • witness labor payment work

Depending upon the size of infrastructure, technical support can be provided by a local engineering consulting firm that has engineers, overseers, sub-overseers, senior supervisors and social mobilizers experienced in community based infrastructure works. Alternatively, non-governmental organizations having adequate technical capability can also be recruited for this purpose. For the flood control works of smaller magnitude full-fledged technical and social mobilization support is not needed.

Technical assistance is provided during the construction period only, and ceases once the project is complete. Supervision of maintenance work, for example, is a local (UC, VDC, DDC) responsibility. Support may be extended to help institutionalize a proper maintenance system.

In cases where local leadership is active and capable, social mobilization support may not be necessary. Where local leadership is capable of managing most activities themselves (largely with their own resources), injecting outside social mobilization stifles local initiatives. In these cases only technical support is provided at the time of need.

B. Social Mobilization Support

Self-help Local Level Capacity Building

The focus of social mobilization support of social mobilization support should be on local capacity building. For this training efforts are integrated into the construction work. Experience has shown that trained people often provide invaluable human resources for the neighboring projects as well as for later maintenance, rehabilitation and upgrading works.

Gender Issues

There should be no discrimination against women in either work or wages, and instead they should be encouraged to participate in the committees. Policies that require a certain level of involvement of women workers (25-50%) have been experimented and found functional. Without provision calling mandatory women's involvement in the project policy guidance, women involvement does not increase. Sometimes separate women's groups, women naike, and women local supervisors make the women's involvement socially more acceptable.

There are also recognized areas of work where women perform better than men do. For example, women are better in collection and transportation of boulder, gravel and planting materials, whereas men are good in digging and stone filling etc.

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CHAPTER VII

Construction Methods

7.1 Construction of Earth Fill Embankment /Dyke

Flood Control Dyke or Embankment is constructed by earth fill materials available in the vicinity. Impermeable cohesive soils are best for construction of embankment. However, such soil is not always available in huge quantities to complete the work. Transportation of clay exceeds all limits of economic justifications.

In most cases of the Siwalik and Bhabhar zone, only sand, gravelly sand and slity sand and silt is available. Even in alluvial fan (segment 2-1, 2-2) silt with only a little clay exists on one bank and sand on opposite bank. Therefore construction of embankments has largely to be done with the material available nearby. Riverbed material is generally used for the filling of dyke section. If the bed material is highly permeable then clay cover as clay carpeting on the surface of the dyke becomes necessary.

- For very important embankments in high discharge rivers, 1m thick layer of clay carpet should be provided on the river side and at the top while on the downstream slope half meter thick clay carpeting should be provided with 2m deep clay cut off.
- In the upstream side of embankment of a minor river, clay cover of 30cm thickness is sufficient.

Since seepage will certainly occur through a river dyke made from dredged riverbed material, it is necessary to have gentler back slope. The back slope will be wetted during high flood stage due to seepage through river face of the dyke. In order to avoid sliding of the back slope angle, back slope should be less than or equal to half of its natural angle of repose. For example, if sandy gravel material is being used as fill material which has angle of repose of 36 degree, the side slope should at least be 18 degree which corresponds to 3:1.

Borrow Pit:

- Volume of earth required for the embankment should be obtained either from excavated material or from surrounding land.
- Borrow pit for the embankment should be placed on the riverside. Removal of material from the river side works as cut off channel.
- There should not be any continuous borrow pit in the back (D/s) of the embankment to avoid run off flow.
- Generally it will not be possible to obtain all the required material from the surrounding land. Therefore only the required clay or silty clay for surface dressing should be obtained from the surrounding land.

Compaction in Embankment

If the earth fill dykes were not properly compacted, there will be large voids between the soil lumps. Such dykes can settle down easily and can be eroded easily by rainwater. Un-compacted embankment can fail easily. Compaction is not seriously required in case of sand fill dyke, whereas in cohesive soils such as clay or loam compaction is very important.

Compaction of the earth fill material is done layer by layer. Each layer of compaction should not exceed 20 to 30 cm. If borrow pit earth is too wet it should be left excavated for a few days. Similarly if borrow pit is too dry, prewatering is useful, but generally it is not possible. Therefore each successive horizontal layer of the fill material is compacted by sprinkling optimum quantity of water and breaking the soil clods, if any.

Compaction gives the following advantages:

- Increase density and shear resistance.
- Reduce percolation through dyke body.
- Reduce future settlements.
- Increase safety and stability.

[illegible]

7.2 Construction of Spurs

Spur should be extended from high bank to the river channel. For earth filled spur (shank), as soon as filling work is completed, launching apron as well as slope pitching work should be completed at the earliest. Otherwise, unprotected shank will be in danger of washed away during the following monsoon.

The most important part of the spur is its nose and its junction with apron. Launching apron at nose should be at the deepest level of channel. At this location, riverbed consists of sand or silt and therefore extra cost is required for excavation. Layout of nose and boulder laying in G.I. crate should be done in the presence of a technician. Layout of spur alignment is a very important consideration, which must be as proposed in the detailed design.

In general, launching apron may stand at a slope of 1.5:1 to 2:1. Boulder needed for launching apron and slope protection should be stacked near middle portion of the spur body. When apron is constructed of gabion crates, there will be minimum wastage of stone. If deep scour hole occurs underneath gabion crates, it may fail. To resist such scour, width of apron should be sufficiently wide. Secondly, grading of stone fill in crate is important in order to fill in the voids between the stone properly. Stone should be packed by skilled labor.

[illegible]

CHAPTER VIII

Alternative Methods of Construction of Flood Control Structures

8.1 Some Alternatives Measures

The previous chapter dealt with engineering aspects of flood control measures and their construction. Interventions in the rivers through conventional means of purely hard structural measures have often proved beyond the affordable limits. Appropriate labor based technologies using locally available materials offer some cheaper alternatives. Local technologies are available in sufficient diversity with proven level of success. Technologies ranging from bioengineering measures, hard engineering structures and various combinations of the two could be applied to curb the flood problems at local levels. Most of the engineering structures mentioned in the previous chapter could also be constructed by combination of local material and some hard structures. This chapter deals with some of these appropriate measures of flood control.

- Flood Control Measures with the Use of Bamboo
- Low Cost Alternatives of Flood Control Measures
- Flood Control Measures with Bio-Engineering

8.2 Flood Control Measures with the Use of Bamboo

Bamboo Pile Spur/ Fences

Bamboo is one of the commonly available local materials, which can be used intensively for the flood control measures. Bamboo piles can be used to form the following structures.

a. Impermeable bamboo fences/ or spur – Non submerged or Submerged
b. Permeable spur /retard

c. Bamboo float / tree spur

A. Impermeable Bamboo Fence/ or Spur

This is one of the methods to deposit sediment load and stabilize a bank. Two or three rows of bamboo piling is fenced by pilling splintered bamboo. The space between the fenced piles is filled up either by pebbles, gravel or sand filled bags. Generally these spurs should be constructed in high sediment laden rivers where depth of floodwater is not more than 1.5m. For higher water depths piles of more than 3.5m should be used.

Bamboo pile spurs can be constructed as impermeable spurs as well as submerged spurs. Height of the piles and fill materials for an impermeable spur should be above high flood level. Height of submerged spur should be one third of depth of water. Submerged pile impermeable spur can be used as vanes with intermediate gap as slot and its length can be increased after each flood and subsequent deposition of sediments. Impermeable pile spurs are very cheap where pebbles and gravel are easily available in close vicinity.

B. Permeable Spur/Retards

Permeable spur can be constructed from bamboo pile. Wooden piles could also be used where wood is available as cheaper alternative. It is constructed transverse to flow to reduce velocities and induce sedimentation. It is found highly successful in rivers having high sediment load.

Bamboo pile fencing with bracing is filled in with bushes to form permeable spur. Part of the flow permeates through the spur with reduced velocity while the sediment load is deposited. Generally, permeable spur traps floating debris and slowly converts itself to impermeable spur. It behaves as a repelling or deflecting spur after deposition.

Bamboo/ round wooden piles with bracing is anchored to the high bank or fence. Piles can be driven to the same level or to the different level in the form of steps depending upon the height of the bank.

Permeable spurs or retards can be of various types:

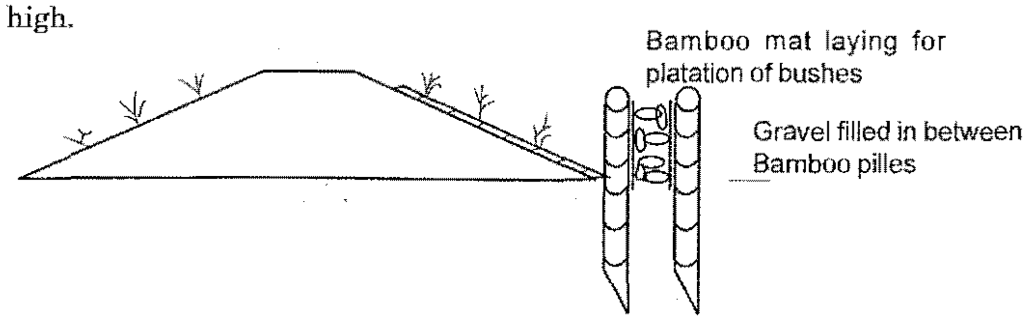
i) Submerged type

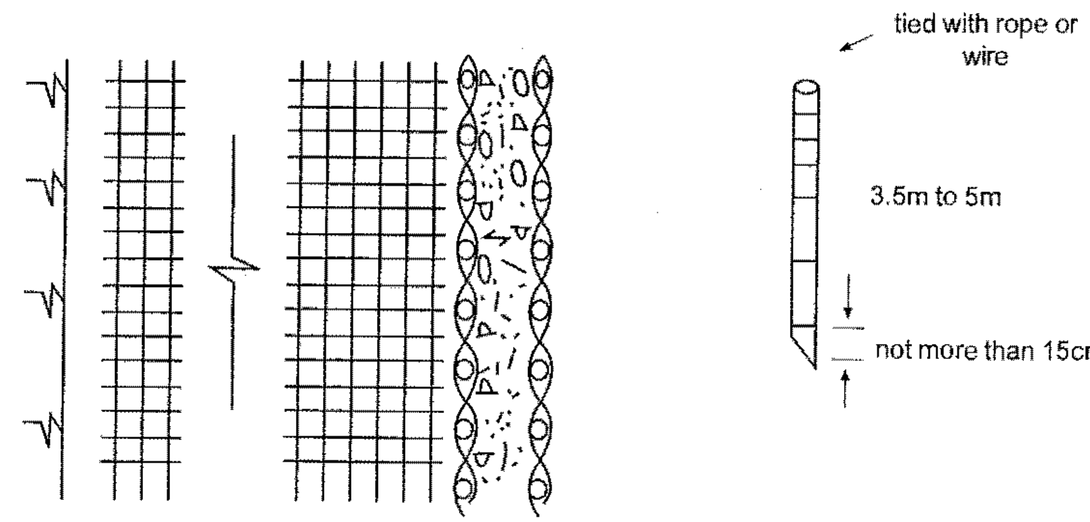
ii) Light type

iii) Heavy type–non submerged or submerged

These spurs are particularly successful in alluvial and Churiya rivers where sediment load is very high.

Fig: 11(i)





Bamboo rivement (mat surfacing and plantation)

Fig: 11(ii)

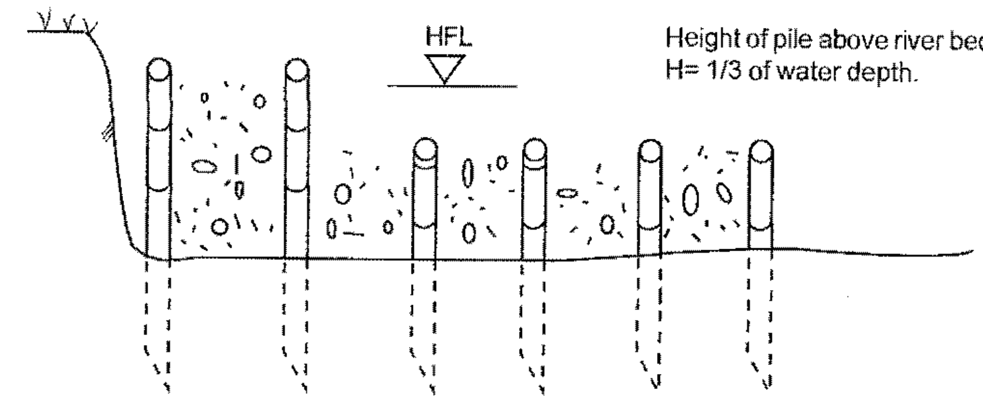
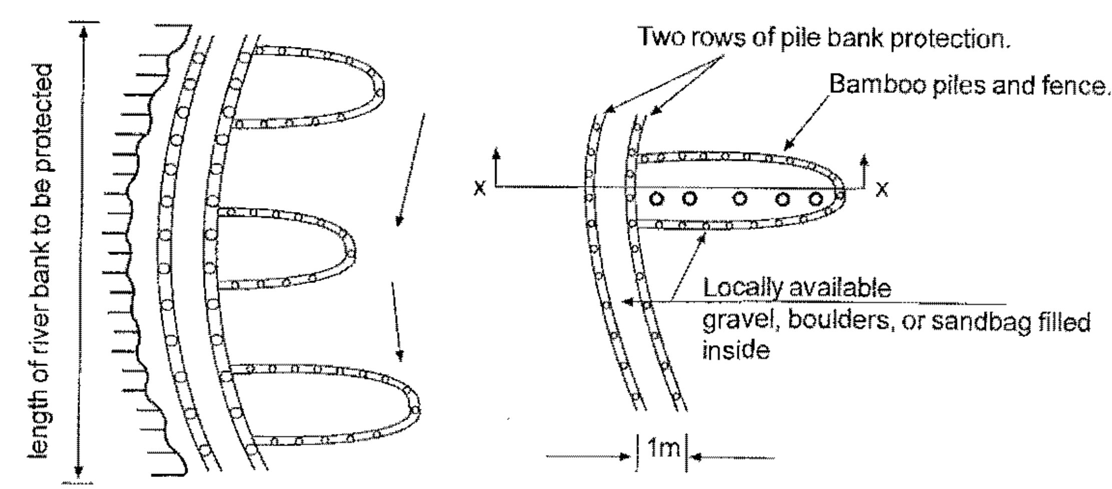


Fig: 11(iii)
Bamboo pile and fence filled of river bed pebbles



Useful Tips for Bamboo Pile Spur Construction

- Length of pile depends on scour depth.
- Length of bamboo spur should be between 5m to 10m. Spur longer than 4m requires 3 to 5 rows of piles.
- Total length of the spur depends on length of eroded bank that is to be recovered by deposition.
- Piles should be placed/driven in two rows perpendicular to bank for deflecting spur.
- Attracting and repelling spurs can be constructed with 4-5 rows of piles wrapped with bamboo fencing and filled in with sandbags or boulders.
- Spacing between rows of piles depends on pile's strength and bracing arrangements. It should be strong enough to withstand against strong current.
- Retard structures should be in slope or in steps instead of being horizontal.
- Horizontal retards can be constructed in small rivers.

C. Bamboo Float/ Tree Spur

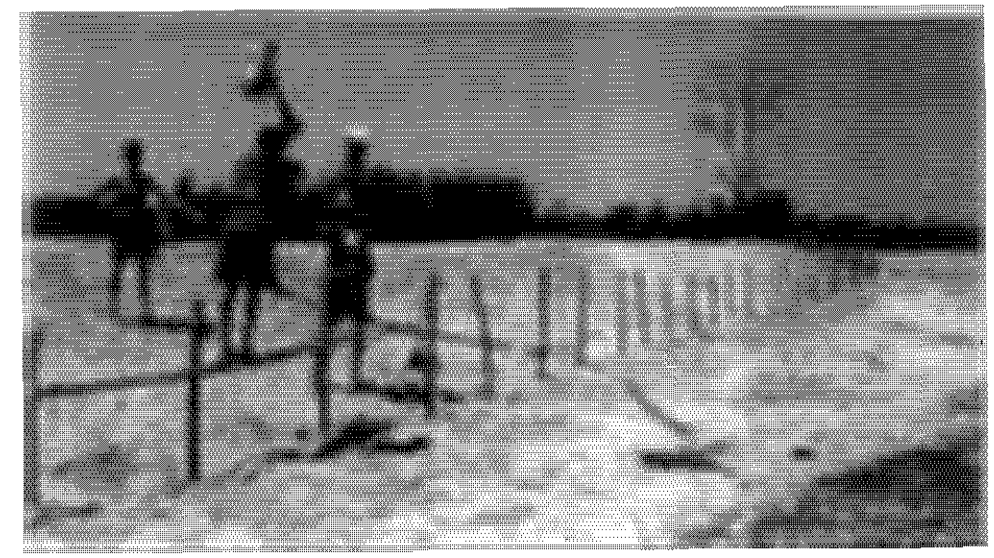
Entire trees with branches and roots can also be used as spur. It should be inclined to U/S or perpendicular to the bank. Tree spur consists of thick wire rope firmly anchored to the bank. Sandbags or concrete blocks are hanged on the other end of the rope near bushes so as to keep the crown submerged in water. Similarly bunch of full lengths of bamboo tied together could also be used as spur. Top end of bamboo along with their crown is emerged in the flowing water with the help of load while the other end is firmly fixed in the ground. They should be inclined upstream. The crown of the float traps floating debris. These spurs behave as repelling spurs after deposition converting themselves into impermeable spur. Bamboo float and tree spur are most useful under emergency situations.

Construction of Bamboo Structures

a. Bamboo Pile Driving

Piles should be erected and started in line and rows such that steps to stand and hammer the next pile can be prepared by interlaced bamboo. Before pile hammering, it should be strongly tightened either by rope or iron wire such that its face may not splinter. In case of splintering, one knot should be cutoff and removed. It should then be winded by rope and hammered either by wooden hammer or by 60cm long root piece of bamboo.

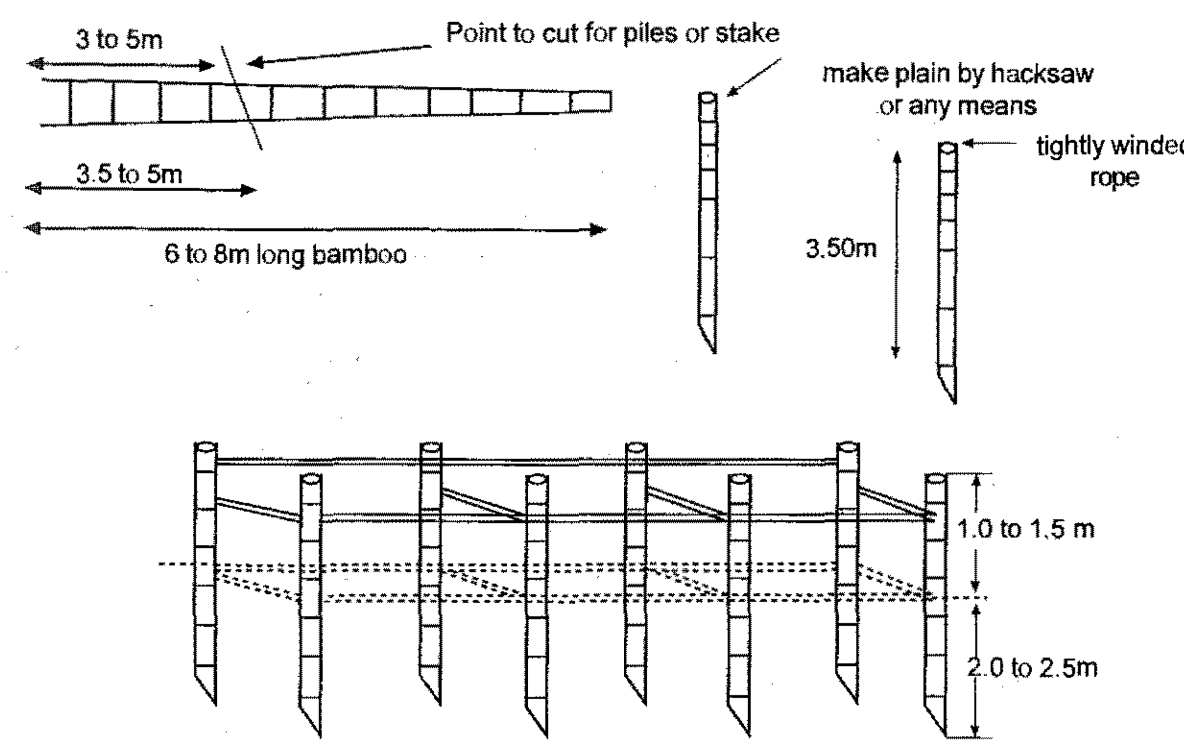
Piling in wet condition is very easy. Some times, piles can be driven 1m deep just by pressing and shaking. Piling in boulder stage river may not be possible but some times it can be done with little excavation and hammering. If piles are driven properly it will provide required protection adequately.



Bamboo protection under construction

The large number of perennial and seasonal rivers in Terai carry a high amount of sediment. It causes the riverbeds to rise and change their courses frequently. Especially in the monsoon and after heavy showers there is the danger of floods affecting vast areas.

Fig: 12



i) Double bracing for 5 m pile. Erected and braced for ready to pile hammer.

ii) Single bracing up to 3.5 m pile.

b. **Bamboo Fencing**

Bamboo fencing (Chachari or Tanti in Nepali) are used for various purposes in flood control measures.

Two rows of bamboo piling, both rows woven with bamboo fence and filled in with boulders, are used as toe protection measure for flood embankments. The purpose of bamboo fencing is to protect the dyke from erosion, movements of cattle and to protect grass turfing and plantation.

Similarly, bamboo spurs are curtained with bamboo fence to make it impermeable. The space between the rows is filled in with boulders or sandbags.

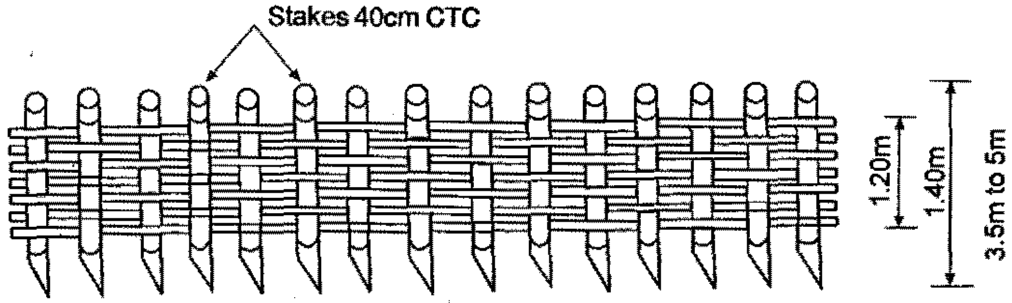
Bamboo stakes are used to keep the fence in desired position. It is a simple thin post of bamboo but strong enough to keep fence straight. It is prepared from the bottom portion of bamboo with length of 1.25m to 1.50 m, which depends upon the width of fencing. Three pieces of stakes are prepared from one small piece of bamboo.

C. **Bamboo Mattress**

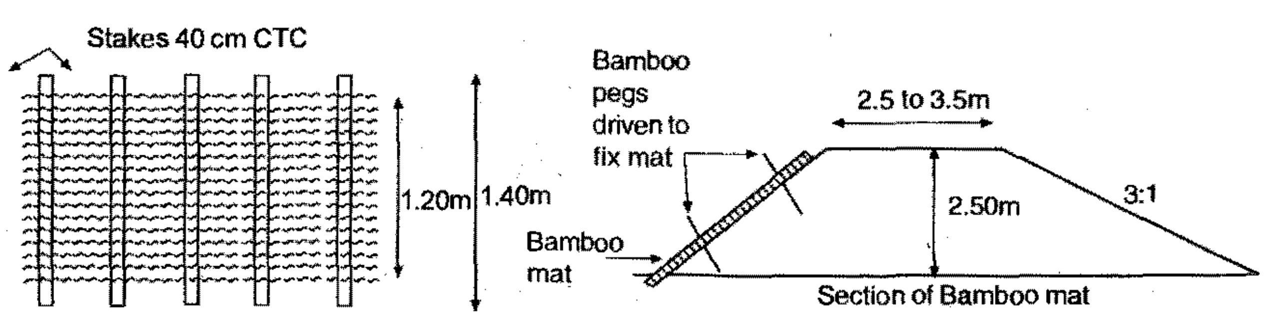
Sometimes grass turf is not available in adequate quantity at the place where it is needed and transportation of grass turf becomes very costly. In such cases, bamboo is used as mattress for temporary slope protection works. Width of mat depends on slope to be protected. Bamboo is divided longitudinally into 6 to 8 parts. Intermediate supports as stakes of little longer than width of mat is taken out from bottom portion of bamboo. These stakes can be erected vertically or laid on horizontal ground for weaving mattress. While it is laid on slope, it is nailed by bamboo pegs.

The same woven mat when fixed in driven or piles is called bamboo fencing. Fence can also be woven in erected piles.

Fig: 13 (i)

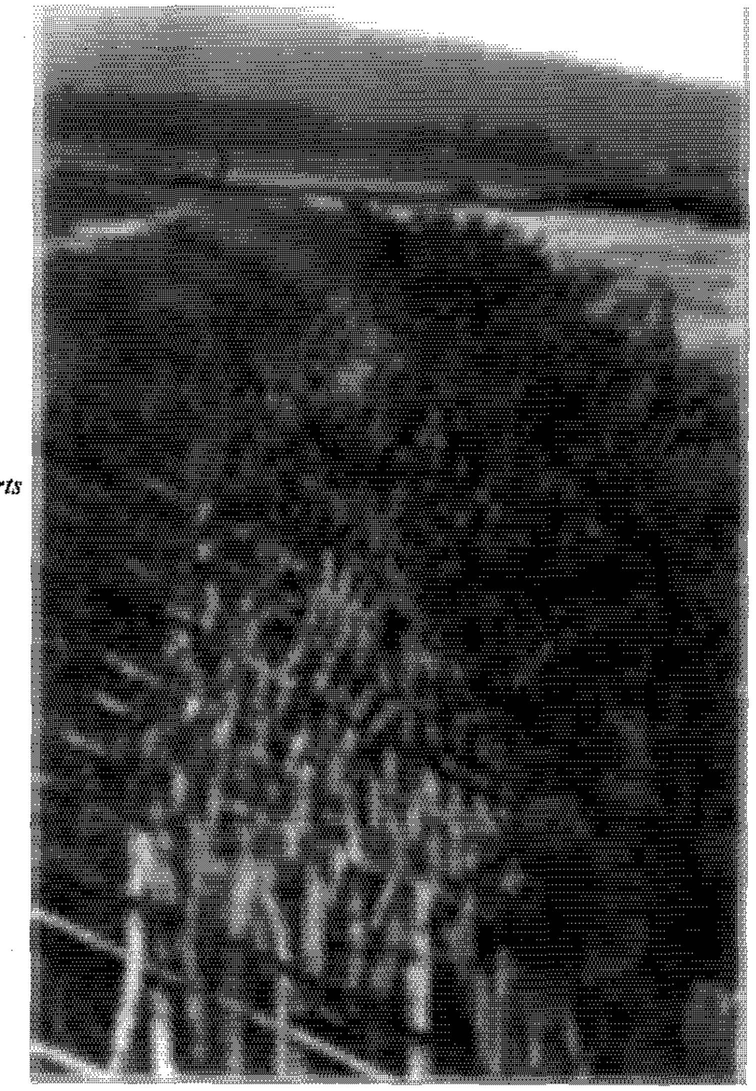


Section of bamboo mat or pile fencing (fig. not in scale)



Section of Bamboo mat

Brush Mattresses used for protection of embankment, Thalikhola, Udayapur.
Already one year after, vegetative growth starts stablizing the embankment.



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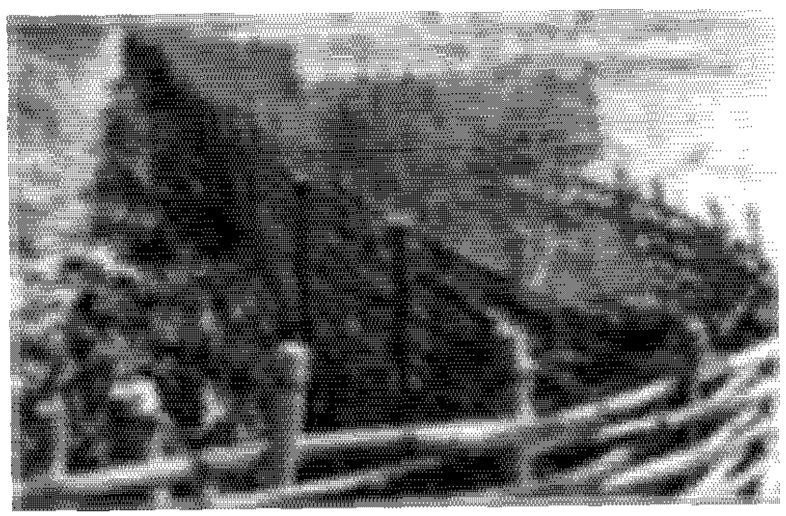
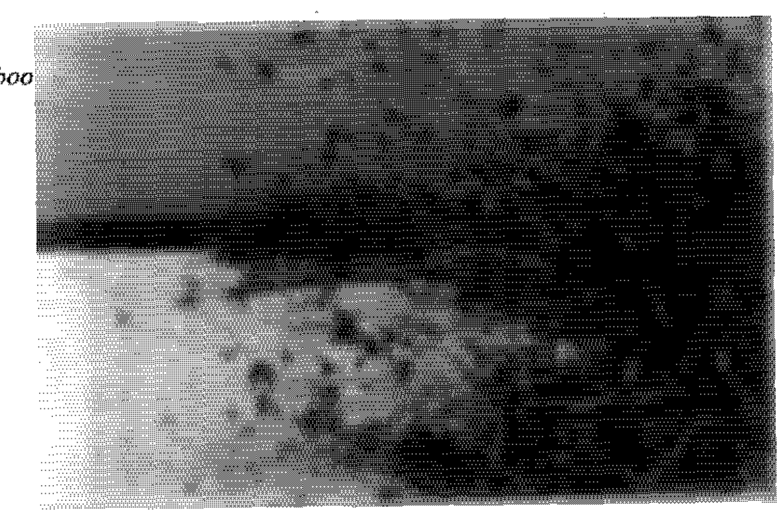
Rows of bamboo piles filled in with boulders and peebles for toe protection.



Protection of an earthen embankment by bamboo pilling and plantation.

Earthen embankment protected with bamboo structures, Hardiya Khola Udayapur.



8.3 Low Cost Alternatives to Flood Control Measures

A. **Use of Sand Bag in Nylon Crate for Construction of Spurs and Bank Protection**

Sometimes transportation of boulder becomes very costly or it may not be possible during the monsoon. In such emergency flood fight situations, use of polythene bags or jute bags in nylon rope crate is very effective for bank protection as well as for spur construction.

Used empty polythene bags are filled with locally available river sand and kept near the site. These bags are doublestitched and filled in crate as required. It lasts not more than two years. Nylon crate of different size is used. Nearly 35 to 40 pieces of polythene sandbags are required for one cubic meter. While filling sand in the bags 15 to 20 cm of the bag should be left unfilled in order to allow for stitching and flexibility to settle.

Sandbags filled structures should be combined with bio-engineering works. The main idea is to stabilize the structure by means of vegetative measures. Sandbags and nylon crate provide protection until the vegetative measures thrive and develop a permanent bank by itself.

Spur, revetment or slope pitching works could also be done using sandbags. Vegetative cover like bushes, Hehara (Behaya) Simali, Khar etc. should be incorporated in them so that they collectively form a permanent structure later on.

B. **Use of Cement Sand Blocks/ Cement Sand Bag/ Soil Cement**

At places where boulder is not locally available or is very costly to transport, cement sand mixture offers a cheaper substitute. In such cases slope pitching or revetment can be constructed by mixing cement in moist sand. It requires little curing if weather is completely dry. 3-5% cement is mixed with moist sand and packed in used cement bags. It sets, hardens and works as heavy stone.

Similarly, cement sand blocks can be used for the slope protection of dyke. Cement sand mixture of 1:10 proportion could be used to prepare blocks 0.4m x .4m size and 25cm thick. These blocks can be used successfully for slope protection.

Soil cement blocks can also be used for similar purposes. Only soils having nominal clay content and high sand content could be used for this purpose.

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C. Loose Boulder Works

If the boulder of larger size is locally available such as in boulder stage rivers, then protection work can be performed without using G.I. crate. Size of boulder required to withstand the flood depends on flow velocity. Required size of the boulder against a given flow velocity is already available and is given in the annex.

If large size boulders are used for protection works like launching apron, there will be big gap or cavity between boulders. These cavities between the boulders should be tightly packed by hammering smaller pieces of stones. Sometimes pebbles or gravel are filled in between cavity of larger boulders. It will reduce scour and velocity of flow at bed. In case of boulder stage rivers, scour is less as average grain size is large. Well compacted, interlocked boulders form a bond which is not easily damaged.

Generally aprons are launched in slope 1.5:1 to 2:1. Volume of stone required for an apron can be calculated accordingly and size can be decided from curve. If the required sizes of stone could be available in desired quantities, loose boulder can be used for apron.

D. Grass Turfing/ Sod Facing Work

All the naked land except agricultural land needs to be covered with grass, plants – trees, bushes to reduce sheet erosion, rill erosion by flash flood and to recharge ground water. Retardation of the flood velocity increases percolation.

Grass turf (sods) are used to cover the exposed portion of the embankment. Sods of 30cm by 30cm and 10 cm thickness with grown up grass is cut and laid on dyke surface. Before placing the sods, the slope has to be well smoothened and be properly watered. The work starts at the base of the slope. On steep slopes along riverbank, the sods are kept in place by short wooden pegs. After completion, turfing should not be stepped on for 3-4 weeks.

Generally turfing is done at the time of early monsoon or during monsoon rain. If turfing is done in between March to 15th of June, watering is required every alternate day for a month. If the riverside face is pitched with boulder or concrete blocks, only exposed part should be covered by grass turf.

E. Establishment of Forest and Grass Belt:

If the problem is not of bank erosion but of spill floodwater, forest development is the most desirable intervention in such areas. Basic idea behind the forest development is to reduce the velocity of spill water and to deposit sediments. Only if the depth of spill water is damaging, embankment or dyke should be constructed within the forest area providing sufficient waterway.

Forest development involves large areas belonging to various people who may not agree to convert their agricultural land into forest. If the land near the river belt is government land then forest development is fairly easier.

There are varieties of plants available for forest development, among them Bamboos, Sisam, Babul, Grasses, Khar, Napier are highly useful for river training work. Local people can show better understanding about the vegetation that thrive under local conditions. Certain trees/grass can be used to promote livestock farming. Bamboo is the most important and valuable plant for river training works.

Organizing the local community into the user's group has proved the most successful way of doing it. Such forest should be handed over to the community as the community forest. Forest and grass belt development serves both as flood mitigation work and income generation for maintenance activities.

Sometimes shifting of river course widens the river width. For example width of the Khando river in Saptari district between East West highway and Rajbiraj – Hanuman Nagar road bridge has widened as much as from 100 to 800m whereas width of the flood water in the river is only upto 300m. In such cases forest development is the most suitable intervention.

Fig: 14(i)
General River Cross-Section

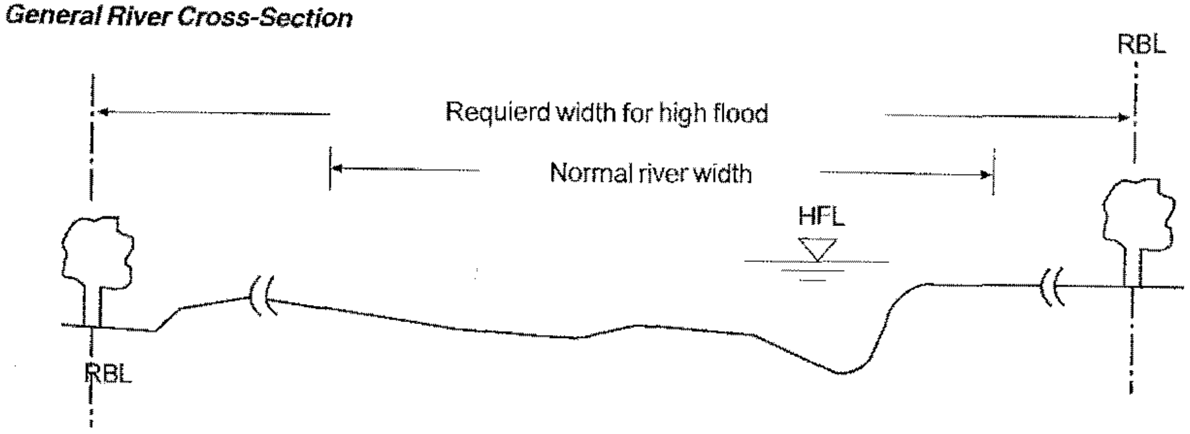
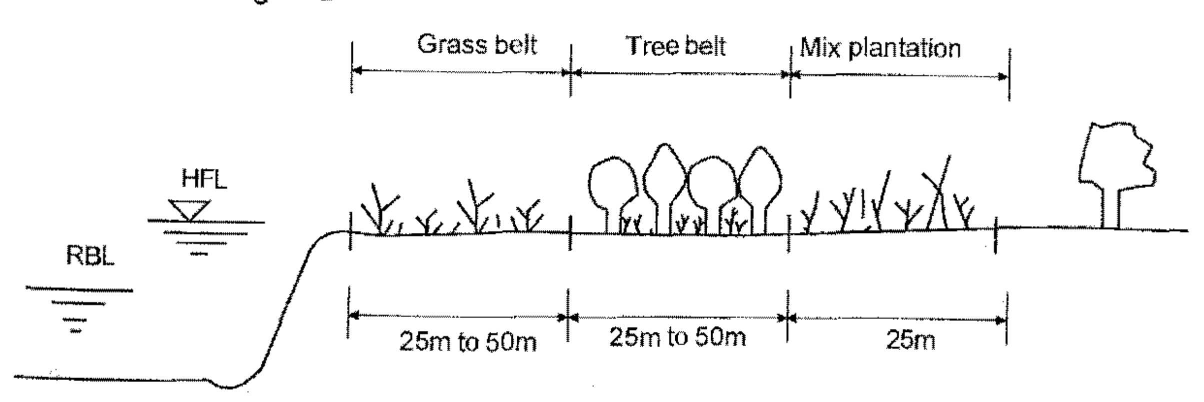


Fig: 14(ii)
Cross-Section of Right Bank



8.4 *Flood Control Structure by Means of Bio-Engineering & Local Materials*

Bio-Engineering

In fact bioengineering in river training is not an innovation. By nature, rivers and their embankments are good places for plants to grow. If we look to an untouched section of a stream we could normally find more or less dense vegetation. Rivers provide water and nutritive substances required to the vegetation. On the other hand, vegetation reduces the discharge and slows down the velocity and consequently, stabilizes the land next to plants and rivers.

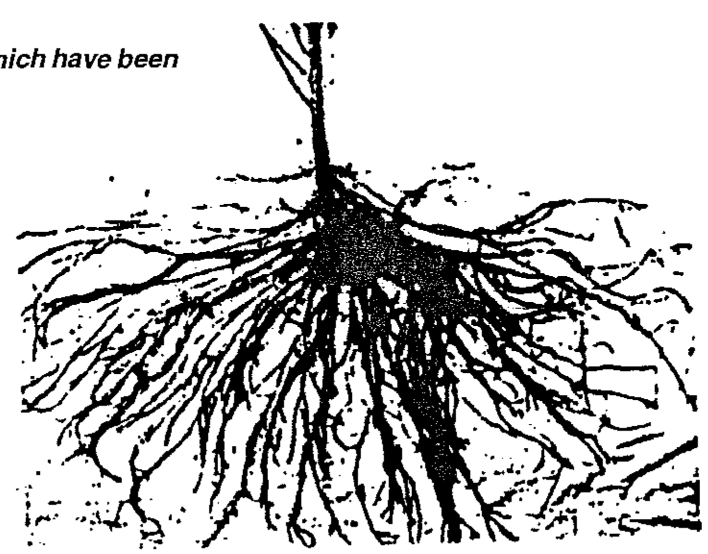
About 30 years ago a new attempt was made in the field of using vegetation for engineering purposes. Some engineers realized the economic benefit and the environmental value of using plants on the riverbanks. They collected information and old experiences and started with research works. Various protective constructions were designed and tested on trial. What had been done only by some institutions up to that time then became a technical concept, called bioengineering.

The field of engineering in which a combination of live and dead plants and plant parts are used as building materials for erosion control and land rehabilitation based on engineering principles and practices is Bio-engineering.

Rooting system is the main benefits of plants in river training. A dense and deep rooting system can resist erosive forces. Trees and bamboos can stabilize the soil horizon in slopes permanently within main roots. Bushes and shrubs reach a zone of about lm while grasses can conserve the top soil of 25cm depth.

It is very important to select appropriate plants for a given function. For the use of

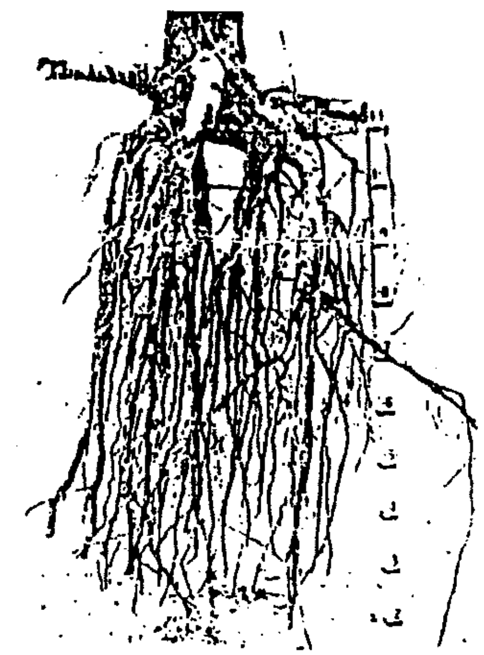
Fig: 15 (i)
Root formation of plants which have been propagated from cuttings



Solix matsudana, after one year.

Fig: 15 (ii)
Root formation of plants which have been propagated from cuttings

Populus maximowiczii, after four years



vegetative measures in river training works, it is necessary to look at the productive use of plants and acceptance by the local people. For example, if the vegetation can be used later for firewood or fodder they are readily accepted. In the first years of growth plants have to be protected against browsing by animals. Species which are not liked by grazing animals are therefore quite useful.

Bio-engineering systems have parallels with civil engineering system in that the engineering functions performed are common to both. There are differences in the strengths and the flexibility of the material and consequently the factor of safety that can be attained. Vegetation is dynamic, it takes some time for the material to reach their maximum strength, but they tend to become stronger overtime, not weaker.

The main engineering functions of vegetation compared to civil structures

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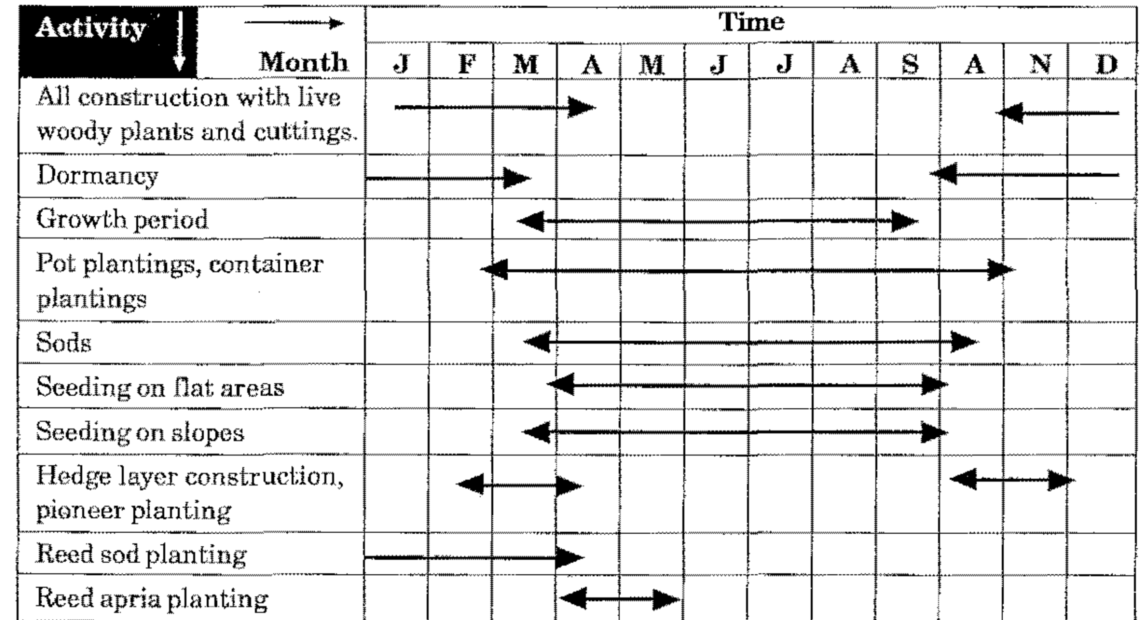
Advantages and Disadvantages of Bioengineering Measures:

Advantages	Disadvantages
▪ **Simple:** Higher technical know-how not required. ▪ **Low cost:** Roughly four-times cheaper than crated boulder structures. ▪ **Can be built by farmers:** Nominal skills required for construction. ▪ **Long life:** Tend to become stronger over time, not weaker. ▪ **Produce offsprings and by-products:** New plants will be growing naturally and can be used as fuel and fodder. ▪ **Self-maintaining:** Cheap and easy for maintenance and care not required after two years. ▪ **Income generating:** After a few years there can be income from vegetation. ▪ **No adverse ecological impact:** Environmentally sound ▪ **Labor oriented:** Short term employment for the poor people, most of the resources used by the poor people and retained in the community.	▪ **Weak:** For the first two years weaker than the crated boulder structures. ▪ **Special plants needed:** Plant selection is crucial and should be based on the purpose, natural environment and acceptance. Species which are deep rooted, fast growing and surviving under adverse conditions as well as not eaten by grazing animal, could only be used. ▪ **Local experience required:** Knowledge about the river characteristics, plants, local construction material and the community required. ▪ **No immediate protective effect:** In the first year there is no protective effect and close observation required to let the vegetation survive.

Schedule for Bio-Engineering Works

When using live plants as building materials it is of course necessary to pay regards to their vegetative rhythm. For example placing of pot plantings, sods and seeding is only possible during the period of growth when there is also enough water available. In contrast seed planting and the use of cuttings can only be done during the dormancy of the plants. The chart below gives a rough overview of the schedule for bioengineering works. Nevertheless for practical work it is important to obtain a more detailed schedule adapted to the particular site.



Schedule for Bioengineering works

Some varieties of Salix (Nepali: Bainsh) may serve as examples of good propagation and growth and their suitability in bioengineering works. One way of propagation is by transfer of 20 to 40cm. long shoot cuttings taken during the dormant season. They should be straight, well ripened and 0.8 to 1.5cm in diameter. Each cutting should have at least two and preferably four nodes. The cuttings are inserted vertically into prepared soil or joints of structures such as gaboin. During the growth period a dense rooting system and two or more shoots will develop from each cutting.

Selection of suitable species for flood control measures

In the use of vegetation for bio-engineering in flood control, as well as for forestry and agriculture, the choice of the correct species is of great importance. The two crucial considerations here are.

(i) Whether the plants do the job that is required

(ii) Whether it will grow satisfactorily on the site

The success of bio-engineering structures depend on the selection of suitable plants. The planting of vegetation has to be carried out at the correct time of the year. The spacing and pattern of planting, as well as the species, depends on the planting site and the technique that has been adopted.

Suitable grasses for flood control measures.

Local Nepali Plant Name	Botanical Plant Name	Growth	Rooting system	Productive Use		
				Firewood	Fodder	Grazing Protection
Dubo	Cynodon Dactyion	Me	Lo	–	x	–
Khar	Cymbopogon Microtheca	Fa	De	–	x	–
Musekharuki	Pogonath Erum Paniceum	Fa	De	–	x	–
Kansh	n.a.	Fa	De	–	x	–
Nepier	Pennisetum Purpurem	Fa	De	–	xxx	–
Babiyo (Sabai grass)	Eulaliopis Binata	Fa	De	–	x	–

Suitable bushes for flood control measures

Local Nepali Plant Name	Botanical Plant Name	Growth	Rooting system	Productive Use		
				Firewood	Fodder	Grazing Protection
Bihaja, Besaram, Karami, Saruwa	Ipomoea fistulata	Fa	Me	x	–	xx
Aak	Calatropha giganteum	Me	De	–	–	x
Assuro	Adhatoda vasica	Fa	Me	xx	–	xx
Simali	Vetex negundo	Me	De	xx	–	xx
Areri	Acacia Pennata	Fa	Me	x	x	–
Phulkanda	Lantana Camara	Me	De	x	n. a.	n.a.
Dhanyero	Wootfordia fruticasa	Me	De	x	n. a.	n. a.

Suitable bamboo for flood control measures

Local Nepali Plant Name	Botanical Plant Name	Growth	Rooting system	Productive Use		
				Firewood	Fodder	Grazing Protection
Dhanu bans Bhalu bans	Bambusa balcooa	Me	De	xx	x	x
Tharu bans	Bambusa tulda	Me	De	xx	x	–
Tama bans Choya bans	Dendrocalames hamiltonid	Me	De	xx	xx	–
Titeningalo bans	Drepanostachyum Khasnium	Me	De	–	xx	–
Lewas bans	Drepanostachyum khasnium	Me	De	xx	x	–

Suitable trees for flood control measures

Local Nepali Plant Name	Botanical Plant Name	Growth	Rooting system	Productive Use		
				Firewood	Fodder	Grazing Protection
Bainsh	Salin Certasperma	Fa	De/La	x	x	–
Lahare pipal	Populus euramericana	Fa	Sh/La	–	x	–
Utis	Alnus nepalensis	Fa	Me/La	x	–	–
Sissoo	Dalbergia sissoo	Fa	De	xxx	x	–
Seto siris	Albizia prooena	Fa/Me	n.a.	xx	x	–
Dabdabe	Gamiga pinnta	Fa/Me	n.a.	x	xx	–
Lankuri	Fraxinus floribunda	Sl	n.a.	x	x	–
Tooni	Toona oiliata	Fa/Me	Me/La	x	–	–
Bayer	Ziziphus mauritania	Fa	n.a.	xx	x	xx
Khayer	Acacia catechu	Me	Me	x	x	–

Growth: Sl (ow), Me (dium), Fa (st)
Rooting system: Sh (allow), De (ep), Me (dium), La (rge)
Firewood/ Fodder: X= normal value, XX= high value, XXX= excellent
Grazing Protection: X= resistant, XX= high resistant
n. a.: data not available

Grass turfing work established one year after placement.

Sediment deposition between the spurs establishing the embankment.

Bamboo pile spur for bank protection during flood situation.

Embankment after two years of establishment.

Use of sandbags in gabion crates for spurs.

Toe protection of flood control embankment constructed by using bamboo structure and hard wood plant cutting.

8.5 Some Bio Engineering Measures

Local people are generally familiar with the use of locally available resources. Optimum use of their skills and knowledge not only makes the construction of flood control embankment easy but also makes them more easily maintainable. Bioengineering concept thus envisages the use of locally available indigenous material to the extent possible. Some of the materials which are often used in bio-engineering structures are as follows.

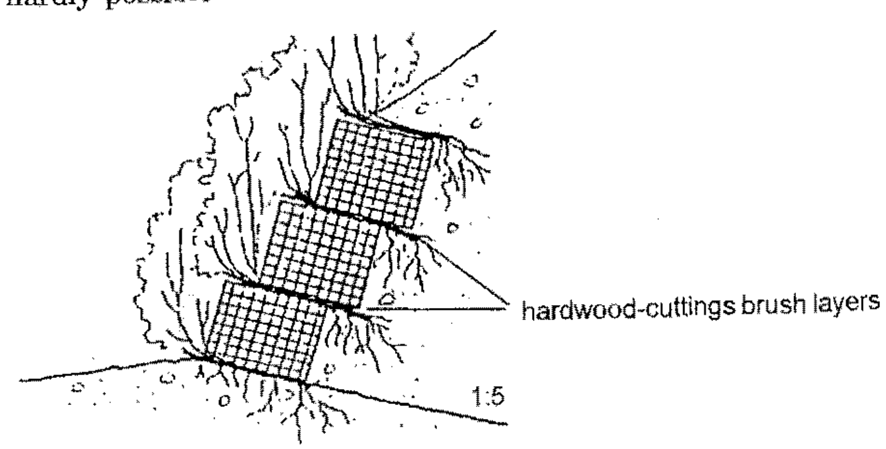
- River bed material: sand, soil, gravel, stone, boulder etc.
- Grass , grass sods.
- Bamboo
- Empty cement bags
- Nylon crates
- Cuttings of plants
- Stakes
- Seedling of plants
- Seeds
- G.I. wire and G.I. crates,
- Cement masonry

The following are some of the bio-engineering structures which are useful for flood control measures.

A. Vegetated Gabions

In combination with gabions that are leaning against the slope, cuttings or rooted plants have to be placed deep enough into the soil behind the gabions to ensure good root formation and growth. Vegetated gabions secure unstable slopes endangered by erosion. In unstable slopes they form solid protection remaining flexible and permeable. Live branches and rooted plants are required for this purpose.The best time is during the dormant season, since subsequent installation is hardly possible

Fig: 16

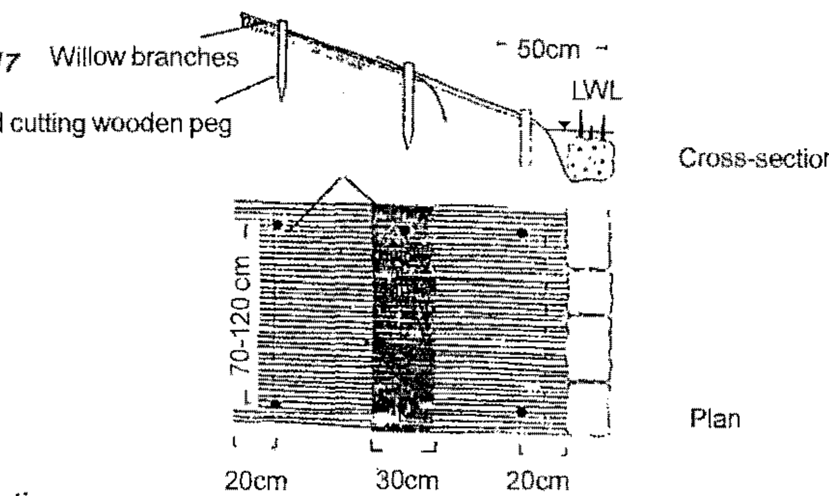


B. Brush Mattress

Mulch of hardwood brush is placed on the slope of the embankment. Stems having a thickness of about 2.5 cm or less should be cut and laid to form a light mattress. The brush mattress must be secured so that it will not float away. Stakes driven in at an angle and crossing each other in pairs may be all that is needed on small streams. On larger rivers the stakes should be driven straight and the mulch is held in place by lacing wire between the stakes. Hardwood brushes from Salix or Alnus are required for this purpose. Construction of brush mattress should be done during dormancy.

Brush mattresses form a dense vegetation on the slope with a protecting root system. Newly growing branches can reduce the water velocity and thereby reduce the traction force affecting the embankment.

Fig: 17



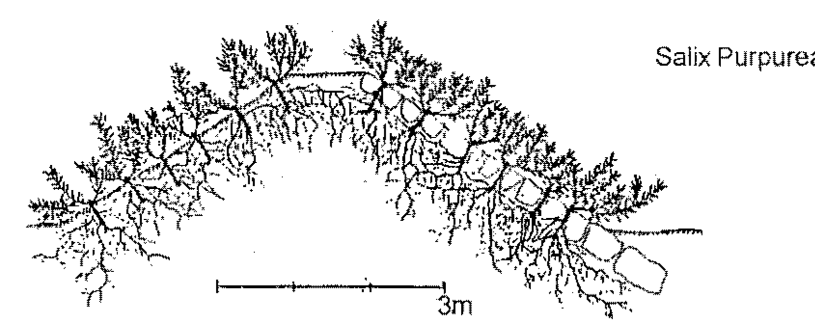
C. Joint Planting

Cuttings are driven into the joints of stone walls. They must be long enough to penetrate into the soil behind the stone walls. After the joints have been planted it is advisable to fill them with dry sand or topsoil.

It serves a wide range of purposes, for example it is especially fast and inexpensive method of planting on moist slopes for controlling erosion quickly and permanently. Joint planting reinforces boulder paving at guide walls and on toe of embankment. They should be planted during the dormant season.

Soil stabilization and drainage commences with root formation. The rock paving is so fortified by the root system that smaller rocks may be used than would be the case without joint planting.

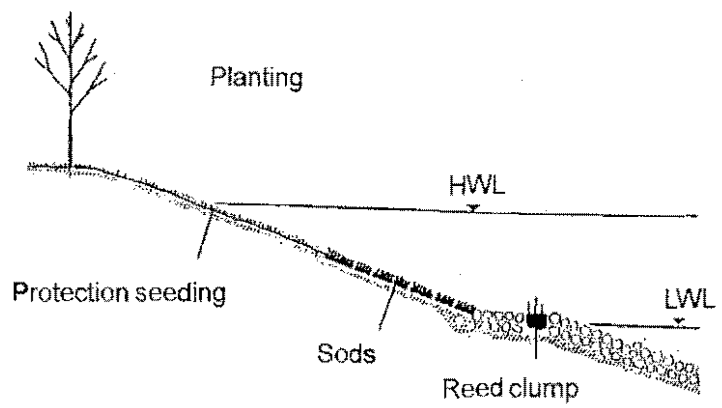
Fig: 18(i)



D. Seeding Unprotected Banks

Seeding must be done at a time when a fairly long flood free period can be expected to follow. The seeds must have time to grow and to develop enough roots to be sufficiently strong to survive water flow. If, in addition to this, protection against flooding is necessary, the water channel slope must be covered with a string fine meshed wire secured by the ground with pegs. The individual rolls have to be anchored together with wire. The wire is then placed into the soil and covered with rocks and gravel in order to prevent the wire mesh.

Fig: 19



E. Planting for Bank and Protection

Bank and shore protection plantings along waterways provide protection for the banks and the lowlands in the regions that lie above the normal water level. Such plantings have to be planned and carried out strictly in accordance with the zone of the natural shore vegetation (the shore is split up into different vegetation belts in relation to their height above the water level). To create shrub vegetation consisting of tree-willows and poplars, big cuttings (poles) from these plants can be used. The poles should be 150 to 250cm long, straight and preferably without branches. They are driven into the ground up to one-third of their lengths during the dormant season. These large poles are primarily used for the formation of shrub vegetation in flood plains. When river training work is to be done by bioengineering means, it is of course important, to choose the appropriate measures. As seen before there are quite big differences in what the single construction can contribute to bank protection. Often it is suitable to use a combination of two or more measures.

The resistance of bioengineering measures to the affecting forces on the embankment can be calculated. It is obvious that most of the measures need two or three growth periods to develop their full protection effect. If the riverbanks are regularly highly affected, supplementary temporary protection will be necessary during the first years. Therefore a combination of dead materials (stones, wire. etc.) and living plants will be required solution in these situations.

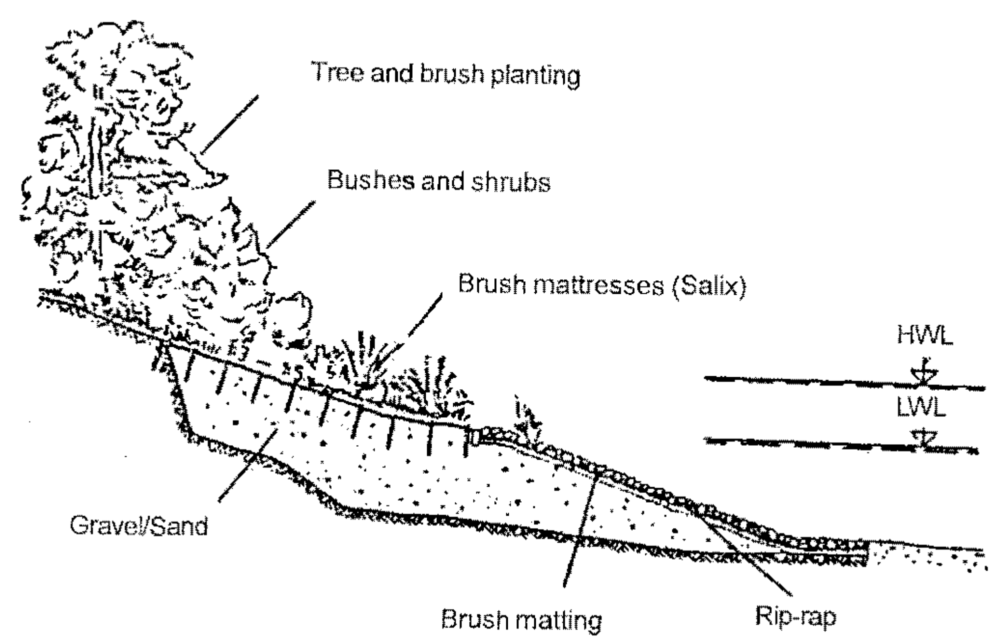
F. Planting of Cuttings in Soil

A hole is made on the ground and a cutting is put in it. The soil around the cutting has to be trodden down to make sure that the cutting is firmly in place. A hammer may be used to tamp these cuttings into the ground but the basal section of the cutting should be slanted, to ensure easy entry. No more than one quarter of the total length of the cutting should be above ground, otherwise there is too much danger of it drying out.

Preferably, the cuttings should be placed irregularly. At least two cuttings per square meter should be placed. In areas with considerable stress, five cuttings should be used per square meter. On dry sites, cuttings grow better in the joints of the rock paving system, where moisture is retained, than on unprotected soil.

Healthy one to two year old cuttings without branches that are 2 to 4cm in diameter and 20 to 40cm in length are used. If moisture availability and retention is poor, cuttings should be 40 to 60cm long.

Fig: 20



CHAPTER IX

Economics

9.1 Overall Economic Consideration

Normal smooth overflow of rain water for a short duration flooding paddy fields in itself is not harmful. Flooding of fields near to the riverbeds, however, are affected by high stream velocity, thus creating erosion in the fields, sedimentation of the field with sand and in most cases total loss of farmland transferring it into sandy riverbed. In some cases rivers change their riverbed abruptly by breaching the embankments and banks, destroying farmland in the wide area. Infrastructures such as roads, houses, irrigation and drainage channels are also affected by the flood and sometimes even totally destroyed. This is the reason why farmers' first priority in the flood prone area is often to set up flood protection measures.

River training in the sense of channeling the whole river would possibly be a sustainable measure for protection from recurrent flood. River training for the entire stretch of the river however, is far too expensive and thus out of reasonable economic and financial justification. It is therefore necessary to concentrate efforts only in the critical sections where heavy erosion of banks, major losses of farmland and threat to human life and infrastructures are eminent.

Benefits of Flood Control Measures

In an intervention like flood control, generally the benefits are the value of the losses or damage that would have occurred without control measures. The specific benefits as anticipated by the beneficiaries are often as follows

- Increase in crop yield
- Increase in area under crop

- Increase in price of land
- Saving in transportation expenses
- Other benefits

After a flood control measure is made operational, not only there will be an increase in the yield but the area under the different crops would also be changed. The denudated, valueless land and other marginalised land fetch better price after the flood control measures. A recent study for the Kamala River Training project has estimated that the price of land which is calculated about NRs. 20,000/Bigha is expected to reach more that NRs. 100,000/Bigha enhancing the price more than five times.

The floods will not only damage farmer's field but also the rural infrastructures such as roads, bridges, culverts etc. Such damage will create difficulties to farmers for transportation of farm produce to market. As they can not use wheel cart, they will have to use human labour.

Besides the benefit mentioned above, other gains for the local inhabitants would be increased employment opportunities, increased production from the reclaimed land, safety to human and animal life, better access to animal feed etc.

9.2 Economic Justifications

Economic justification for a project is generally assessed by three general indicators. The benefit cost ratio, the net present value and the internal rate of return.

The benefit cost ratio compares the present value of the benefit stream with the cost stream. Generally a project is considered as economically viable when the benefit cost ratio is greater than one.

During 1997, Churia Forest Development Project had initiated a considerable investment in the flood and bank protection work.

An analysis of data of the 32 subprojects of the Churia has revealed the following key data

Total lengths of the flood and bank protection	30506 m
Total protected farm land	2250 ha
Total protected households	3718 HH
Total cost of construction	NRs 17300000.00

The average cost of 1 ha of protected land was NRs.7689.00. However the specific costs range form 1100/ha to 8000/ha. The type of flood control measures adopted by Churia project was low cost measure with minimum of external material input.

Similarly, the average costs of 1m of flood and bank protection work was NRs. 567.00 and the specific costs ranged between NRs. 300.00 and NRs. 2500.00

The understanding is that the farmland protected by flood and bank protection work would otherwise be flooded every year and most of them would even disappear by

erosion. The benefit of flood control work is to keep the value of the farmland which otherwise would be zero without protection.

Even if one assumes that, only 25 % of the indicated protected land is really protected against total loss, the cost of protection of one hector of land would come to NRs. 31,000.00. Whereas, the value of the rain fed land in the region was reported to be in between NRs. 100,000.00-150,000.00/ ha.

These considerations are by no means a substitute for a professional benefit cost analysis based on more reliable data rather than on vague assumptions. However the figures above give an indication of the costs of bank protection works.

A more detailed and precise economic analysis conducted in the recently conducted study on flood control measures in the Kamala River showed the following results of Economic analysis.

EIRR	18%
NPV at 15% discount rate	106,906
B/C ratio at 15% discount rate	1.14

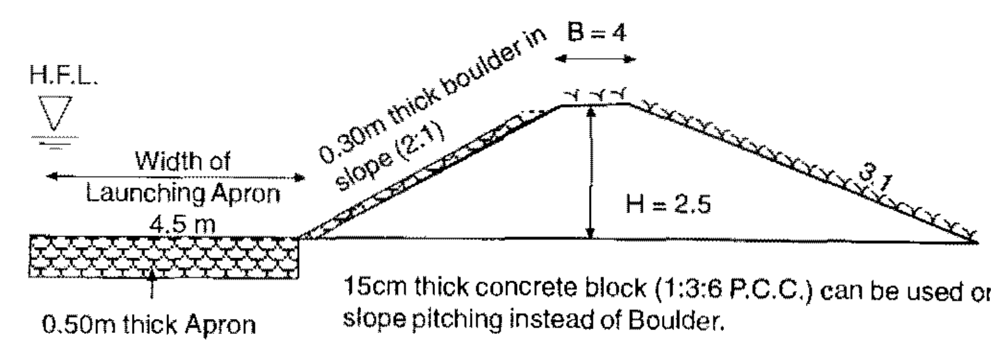
9.3 Costs of Construction of Some Flood Control Structures

In order to give an impression about the costs of various types and sizes of the embankments some estimations are provided here.

A. Embankment with Launching Apron and Slope Protection

Height of embankment	2.5 m
Top width (motorable track)	4.0 m
Depth of high flood level	1.0 m
River side slope	2:1
Back side slope	3:1
Width of the Launching Apron	4.5 m
Thickness of the Apron	0.5 m

Fig.21



Quantity and Cost per 100 m of the Above Mentioned Embankment

S. N.	Item	Unit	Rate	Quantity	Amount
1.	Earth work in filling	m^3	30	1958	58740
2.	Earthwork in excavation	m^3	40	180	7200
3.	Clay cover	m^3	50	605	30250
4.	Grass turfing	m^2	3	1414	4243
5.	Boulder at slope pitching	m^3	500	101	50500
6.	Boulder at apron in crate	m^3	600	225	135000
7.	G.I. Crate 3x1.5x.5 mesh size 15x15	kg	40	2579	103160
8.	Plantation	Nos.	3	500	1500
	Total Amount				**390593**

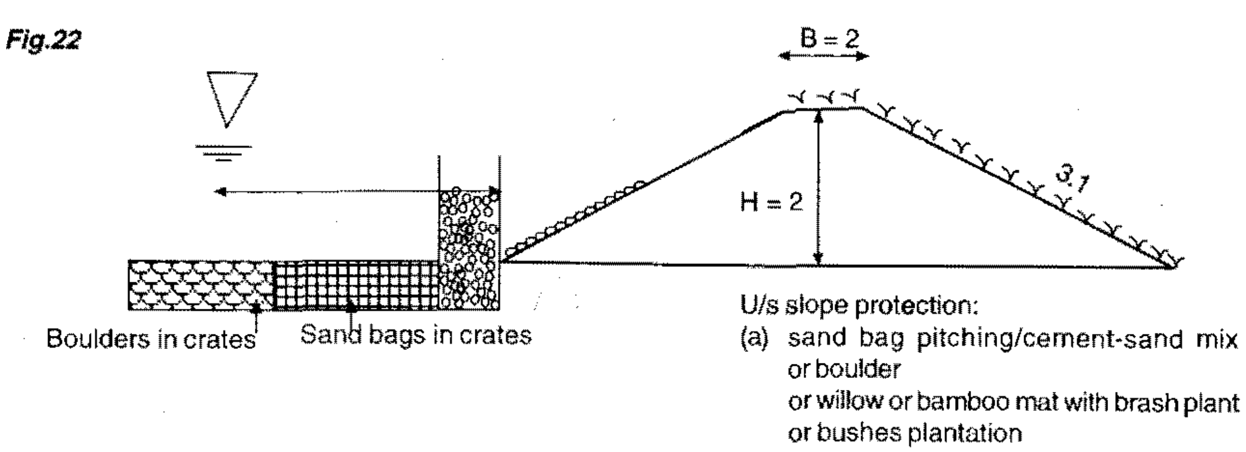
B. **Low Cost Embankment Works**

In case of the flood protection works at relatively smaller rivers, where flow velocity and discharge are relatively smaller, a relatively cheaper protection works could be provided. Dented apron with bamboo piling can be used as protection measures.

Given below is an example of toe protection with bamboo piling and dented apron made up of the combination of boulder in crate and sand bags in crate.

Height of the Embankment	2 m
Top width	2 m
River side slope	2:1
Back side slope	3:1
Width of the dented apron	1.5 m
Length of the projections (spur)	6 m
Width of the spur	3 m

Fig.22



Quantity and Cost per 100 m of the Above Mentioned Embankment

S.N.	Item	Unit	Rate	Quantity	Amount
1.	Earth work in filling	m^3	30	1200	36000
2.	Earthwork in excavation	m^3	40	126	5040
3.	Clay cover	m^3	50	-	-
4.	Grass turfing	m^2	3	759	2277
5.	Boulder at slope pitching	m^3	500	60	30000
6.	Boulder in crate at projection and apron	m^3	600	104	62400
7.	G. I. Crate	kg	40	1090	43600
8.	Bamboo pilling	Nos.	70	116	8120
9.	Bamboo fencing	m^2	15	125	1875
10.	Supply and filling of sandbags	Nos.	8	2195	17560
11.	Plantation	Nos.	3	500	1500
	Total Amount				**208372**

C. **Spur with Launching Apron and Slope Protection**

Length of the spur	45 m
Height of the spur	2.5 m
Top width	3 m
Side slope	2:1
Thickness of the Apron	0.6 m
Width of the Apron	3, 4.5,6 m

Quantity and Cost per 100 m of the Above Mentioned Embankment

S.N.	Item	Unit	Rate	Quantity	Amount
1.	Earth work in filling	m^3	30	987	29610
2.	Grass turfing	m^2	3	267	801
3.	Boulder at slope pitching	m^3	500	145	72500
4.	Boulder in crate at projection and apron	m^3	600	310	186000
5.	G. I. Crate	kg	40	3945	157800
6.	Gravel Filter	m^3	450	40	18000
	Total Amount				**464711**

All the above mentioned cost calculations are based on assumed rates of individual items which is just close approximation of the prevailing situation. These costs do not include overheads and any tax. Notice that the costs may be largely altered based on the availability of boulders.

9.4 Public Audit

The concept of " Public audit" implies an examination of accounts for the purposes of verifying financial transactions as well as in the sense of examining the quality and progress of work in a transparent manner.

The concept of public auditing is relatively new in Nepal. However some elements of public auditing have already been used in the Green Road projects in Palpa, Dhading, Gorkha and Lamjung on an experimental basis. Formal public auditing was first started in the Churiya Forest Development Project supported by GTZ in 1993 where Food for Work was used as a drought relief activity in Saptari. VDCs were involved in the process, monitored by the DDC. This experiment was a success. This concept of public audit has been further consolidated by GTZ in Rural Community Infrastructure Works Programme (RCIW).

In order to introduce process oriented approaches of improving transparency, RCIW has been using project books and project boards in each of its projects. These project books contain virtually all the information regarding the project. Anybody who wished to have some information about the project could have easy access to the project books.

Standard project boards are placed at each project sites. These project boards differ from the conventional construction site boards in its content as they are meant for improving the transparency of resources use.

The project boards contain information regarding the name of project, estimated cost, number of workers, name of the users committee responsible for work execution, as well as wage rates for the workers. For a mass based, labour intensive project wage rates are the key information for boosting transparency. In the project boards, rates are written in the way which are understood by a common worker

The conventional way of measurement is often confusing to the illiterate workers. They do not understand engineering way of measurement and payments. Therefore to make them understand, user friendly measurement system could be introduced. For example, the costs of all the item involved in the construction of dyke such as earth filling, turfing can be merged to form a cost per meter length of the dyke of a given section. This is much more easily understood by the workers than in terms of cubic meter of earth fill, square meter of turfing etc.

The experiences obtained from different agencies suggest that in publicly audited projects:

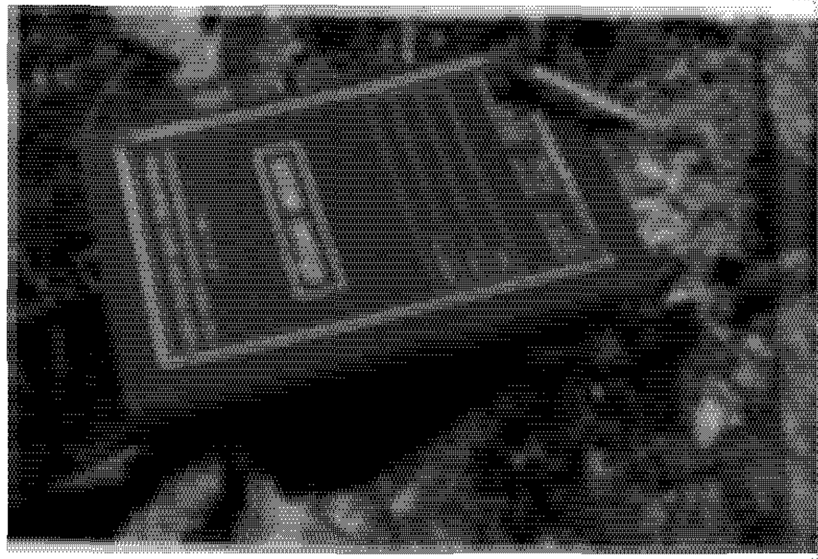
- funds are used more effectively;
- construction costs, as well as maintenance and rehabilitation values are reduced; and
- the distribution of benefits are more equitable.

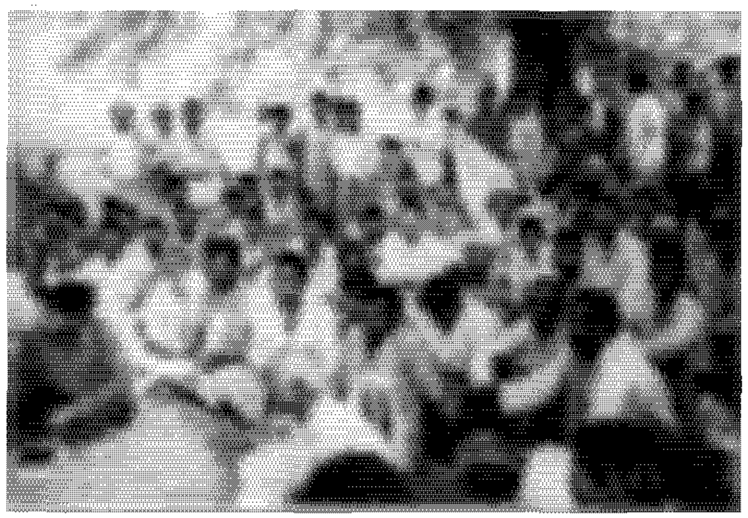
Public Audit Proposal

There must be norms and standards against which the performance of a project is assured in order for public auditing to be effective. The proposed public audit system shall consist of the following elements and principles:

- Local users' committees (UC) are the main responsible unit to conduct public auditing.
- Written records of all official decisions and transactions are maintained and are open to public inspection.
- All financial and procedural activities are carried out in a transparent manner, and any interested person may obtain expenditure information and have open access to the records in the project books.
- Work quality and financial transactions are subject to periodic random verification.
- Irregularity or deviation from the quality standards and misuse of resource will be identified. The person involved will be held accountable for compensating the loss.
- There will be one public hearing at the beginning of the project, and another upon the completion of the work. During the first public hearing, an introduction to the project will be made, a list of stakeholders will be developed, and the possible impacts of the project on the community will be discussed. The estimated cost of project will be discussed thoroughly. In the final hearing, final verification of the wage labor payment, resources use and quality of the work will be made. A description of the status of completed project, and role of community in the future with regard to the project operation and maintenance will be made.

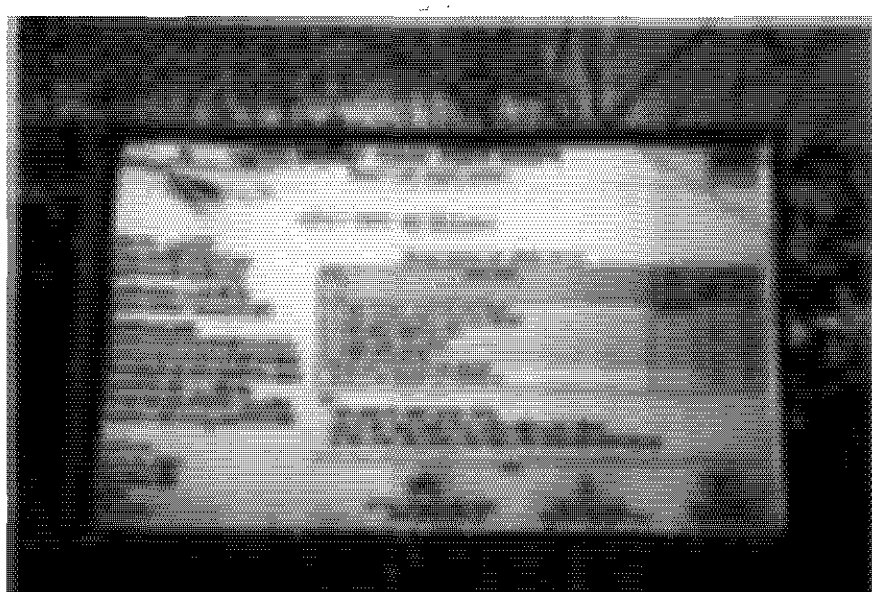
Rural Community Infrastructure Works (RCIW) project book kept with users in which all the information about the project are recorded and to which all interested have access.





Public Audit; Public Project review to ensure the transpararency of decision making process and resources use.

RCIW Model of Project Inform Local Population about the project.



CHAPTER X

Repair and Maintenance

10.1 Maintenance Issues

In the past, operation and maintenance were always viewed as separate issues that should begin only after the completion of a construction work. But often this assumption does not help because it proves difficult to introduce a separate and effective maintenance system once the project was completed. People often forget the old installations until they were damaged to unusable extent. Politicians, bureaucrats and even development workers prefer to go for new projects than to care and maintain the completed ones. Maintenance of infrastructures created with much expenses and efforts still remains a serious challenge throughout the developing world. Many well–intentioned efforts have not born out the intended results due to various reasons one of which is oversight of maintenance issues.

Operation and maintenance are not as simple as they look at the first glance. This is not only a technical issue of just getting things done physically. Maintenance is a process, which needs incorporating institutional, social as well as financial issues.

Today, it is widely accepted that operation and maintenance concept should be incorporated at the project perception stage itself. Right from the beginning of the project planning; sufficient thought has to be given for future maintenance. However, there are still many instances where maintenance is not given sufficient thought at the outset.

With increasing decentralization and bottom up approach of planning, laying more and more authority and responsibility to local levels, maintenance has also become more and more of a local issue. This requires an approach to engage local bodies in order to enable them to take up the maintenance work in timely and systematic manner.

Short-term maintenance is an issue of resources availability alone, while the sustainable maintenance for long terms benefits of a project requires placing a system for maintenance, which is functional and responsive. Preconditions for a sustainable maintenance system in place are:

- Clarity of ownership
- Generation of resources
- Institutionalization of users' committee

Preconditions for Sustainable Maintenance

A. Clarity of Ownership:

It will be difficult to establish a maintenance system without clearly specifying the ownership of the project. Owners of the project can then be held responsible for the maintenance by delegating authority to them. Defining owners of a public project is very important for the legal purpose as well, especially when it comes to resources generation.

Given the different sizes and nature of flood control projects, ownership cannot be laid off entirely on to the beneficiary community alone. There are some projects which are beyond the maintenance capability of communities or VDCs. Therefore the first concern should be to specify the ownership of the project. This will make the owners responsible and also give them a sense of authority for the regular maintenance.

B. Institutionalization of Maintenance Committee (Users' Committee):

The other important precondition for successful maintenance of public projects is a functional users committee. Usually, the attention of public projects thus far has been in planning and construction. UCs formed under a project function just as construction committees which cease to exist as soon as the construction work is completed.

There is no basis for them to remain intact after the completion of construction. A community based infrastructure can not be maintained when a functional UC does not exist. A project or program can not simply phase out of the project work just by asking the users' committee to maintain the project without making them capable of doing that or without sustaining them. Therefore sustaining the users' committee and empowering them to function adequately with required support base are the other preconditions.

Registration of users committee would be necessary in order to make its decisions authoritative and valid in connection to maintenance of the project. Furthermore, provisions should be made for changing the users' committee (maintenance committee) members at regular intervals.

C. Financial Resources Generation:

Financial resource is also a major constraint for smooth maintenance. The sources of income of VDCs and the DDCs are very limited. With the available limited resources, they have to fulfil unlimited needs. On top of that, each development project is asking for matching funds. Under these circumstances VDCs and DDCs may not be able to meet maintenance requirements. Furthermore their priority will mostly be on investing for the new projects than to maintain the old ones.

Therefore a certain arrangement should be made to share costs from contributing parties and beneficiaries to meet the regular maintenance need of the project.

On the other hand, financial resource may not always be a problem. Organized mass of peple could do a lot of maintenance work without a penny in hand. For generations in rural areas of Nepal, people have contributed voluntary labour for maintaining community infrastructures. For this purpose also the UC or maintenance committee can be made sustainable.

10.2 Maintenance of Flood Control Structures

River training and flood mitigation works take a few years of time to establish itself and require continuous effort from user's group as well as concerned agencies. Similarly, community development works take long time for their institutional development.

If embankments are subjected to scouring, settlement, raincut, slope erosion or damage by cattle, the local communities should undertake the timely repair before any major failure. Damage at nose of spur is the most serious case where immediate repair is required. If the riverbed is steadily lowered damaging the spur foundation, stone filling becomes necessary to stabilize the foundation.

Basically, local users' should be responsible for regular monitoring of the flood control measures. Important structures like spurs, sensitive locations like active bank erosion, caving etc., should be closely monitored by responsible persons, like engineers or experienced overseers after each major flood.

10.3 Repair of Breach

Monsoon rain causes soil erosion, landslides, torrents which are followed by floods.

The main factor that contributes to the damage of flood control measure is monsoon rainwater. On the top of the natural flood problems, the second factor, which increases the threat to the flood control infrastructure is ongoing deforestation within the watershed that accelerates soil erosion and increases the magnitude of flood. The destruction of vegetation from grazing of livestock is another problem in bio-engineering flood control structures.

Emphasis should be given to preventive measures for promoting sustainable operation and maintenance, rather than curative ones. Sustainable operation and maintenance begins from the planning stage of any construction

Maintenance requirements of a flood control infrastructure can be minimized and kept to affordable limits. This needs strong social mobilization support too. Organized people could maintain local infrastructure fairly easily. What is needed is to establish a system.

If users understand these issues properly and they are organized in a systematic way, various problems can be avoided. Problems such as grazing on embankments and failure to pay voluntary contribution for maintenance could be avoided by educating the users. Sometimes, however, mere education is not enough. Rules and regulations should also be framed and Users Committees empowered to enforce them. Fines can be imposed on those who violate the policies.

The main types of maintenance need in flood control infrastructures are

- In the first year of embankment construction when the plants are not self-sustaining, it should be regularly monitored and taken care of.
- Periodic maintenance must be carried out during the flood as well as following the flood. Issues here are repairing the damage caused by the flood.
- Carryout emergency maintenance of the breached portion of the embankment.

There are two distinct situations of breach repair requirement.

i) Repair of breach during monsoon.

ii) Repair of breach after monsoon

i) Repair of Breach During Monsoon

Emergency maintenance may be required at the time of monsoon because of the severe erosion of the embankment, which may lead to complete breach. If erosion of the riverbank is rapid, then following measures should be adopted.

- Extension of apron towards main flow by adding boulder crate
- Reconstruction of protection works that are being damaged
- Pile driving and fencing to lowest scour depth

When rate of bank erosion is too high and the flood is ongoing, construction of spur or revetment is very difficult. Under such situation the following measures should be adopted:

- Construct bar spur on natural ground and extend it to river bank and further down to the main flow by progressively increasing the length.
- Construct bamboo pile and fencing or pile spur

ii) Repair Breach after Monsoon

After the monsoon is over and flood subsides, repair and maintenance work is relatively easier.

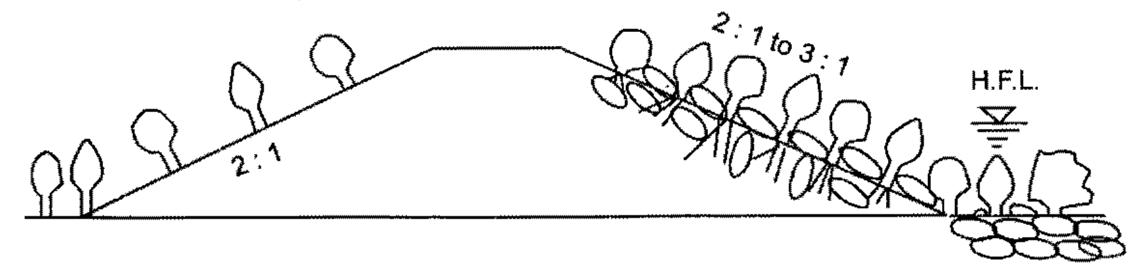
A careful assessment should be made on the alignment of the embankment itself and causes of the breach and its location. Causes of the damage may be overtopping, sliding, – piping or erosion due to lack of protection.

If failure is due to faulty alignment, lack of required width, sharp bend, in such cases alignment should be shifted to a proper location. Redesign of whole structure may also be required in some cases. Such repairs or reconstruction is possible only after monsoon. Construction will be easy but the required cost may be very high. In this case full protection measures can be adopted on the basis of revised design.

10.4 Emergency Maintenance of a Breached Embankment

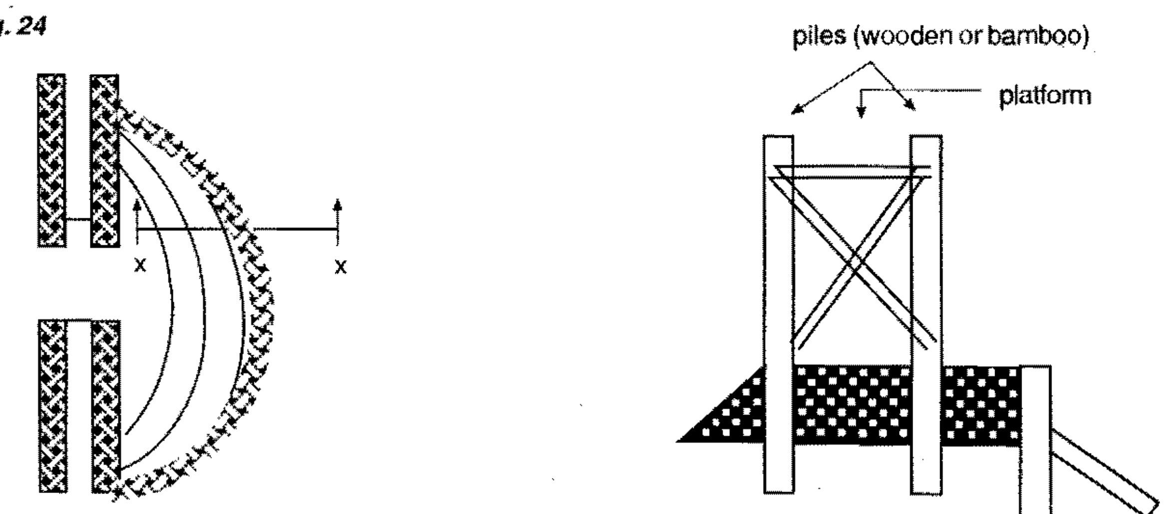
Sometimes embankment is breached in a location of low land area. In such cases, river can penetrate through the breached portion and shift its course causing widespread damage due to submergence of vast areas. These locations should be kept under intense vigilance and treated as hot spot. Stock of boulder, crate, sandbags should be kept ready as an emergency flood fighting measure. If the damage occurs in such location, repair of old embankment at the same place is not possible as the river flow causes to form the deepest channel at the breach. Such breached portion should be closed by a ring bund. This can be in the riverside or on natural ground. Length of such semi-circular ring bund will be much longer than breached portion. As shown in Fig. 24.

Fig: 23 Dyke with loose boulder protection
In boulder stage rivers or in forest area



This is a case of emergency flood fighting and transportation of boulder may not be possible or may prove very costly. In such a situation, bamboo piling or wooden piling combined with sand bag filling for protection work may prove very effective. Construction of such breach closure bund should be started from upstream. Earth filling and piling in continuous line should be done simultaneously. As the first step pilling should be done which will still allow free flow of water. This is followed by placing sand filled bags in the ring bund of plies and then by earth fill as the last step.

Fig. 24



u/s closure ring bund

Section X-X

Heightening of Old Embankment

Rise in riverbed is a common problem in Nepal. With the rise of riverbed flood height rises and therefore requires heightening of old embankment. The embankments which need heightening may be either earthen embankment with grass turfing, with or without plantation or it may also be one with slope and launching apron protected by boulder or concrete blocks.

Borrow pits for embankment heightening should be placed on the river side as it helps in

- removal of sediment from river bed
- development of channel
- reduces seepage gradient

If the embankment is well protected earth fill should be started from backside of the embankment.

Fig: 25
Heightening of Earth Fill Embankment

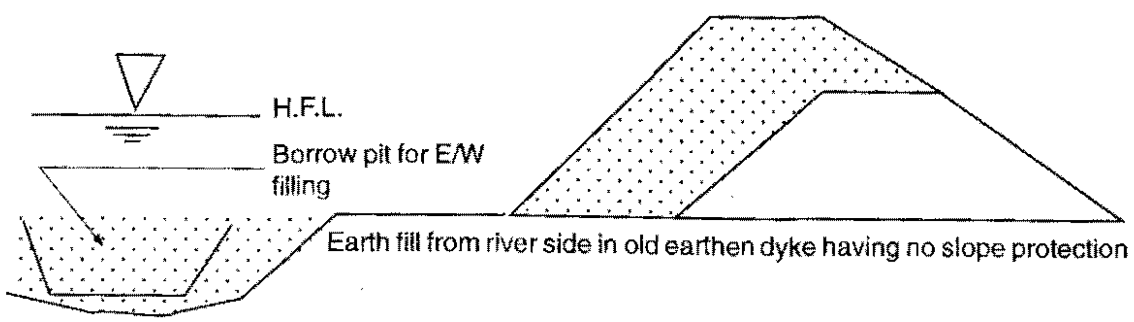
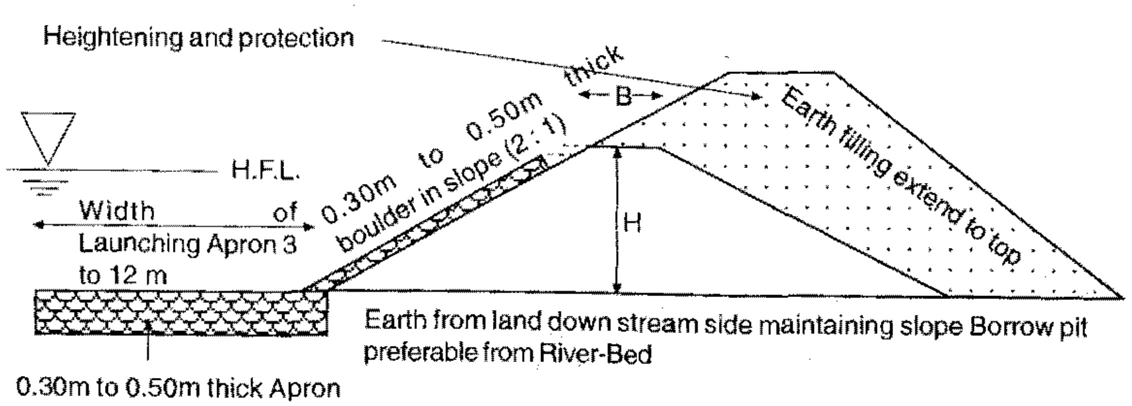


Fig: 26
Heightening of Protected Embankment



Annexes

Annex I

Design Discharge Determination

The first step in the design of any kind of flood control structure is to determine high flood level and high flood discharge. The life of river training/flood control work as well as the degree of protection works required depends on flood discharge. High flood discharge depends on rainfall intensity, duration and size, shape and conditions of the catchment area.

An experienced engineer is required to decide on the design of flood discharge. Some of the following methods can be helpful for the calculation of designing flood discharge.

Methods are :

i) Trash marks of past flood records.

ii) Empirical formula.

iii) Use of envelope curves.

iv) Statistical probability.

v) Unit hydrograph method and synthetic hydrograph.

Data required for the use of specific methods vary and each method has different limitations.

i) Flood estimation from trash marks:

Local old people can give very good information about the high flood level. The trash mark left over by the floods can be seen on and the in the riverbanks. The information given by an aged inhabitant about the high flood level would be

precise up to ± 50cm. The information from a 60-70 year old person about the high flood level corresponds to 50 years return period. If the flood information is relatively new, say flood that occurred 4 – 5 years earlier, the precision in that case would be ± 20cm.

After having decided about the high flood level, take river cross-sections at 3-4 different places and take the longitudinal profile of the river stretch.

Flood discharge can be calculated from

1.

i) Manning's Formula $V = \frac{1}{n} x \ R^{1/3} S^{1/2}$ and Q=A´V.

A = Area of cross-section corresponding to H.F.L.

n = 0.02 to 0.04 manning's roughness coefficient

R = A/P

P = Wetted Perimeter up to H.F.L.

S = Water Surface slope

ii) Chezy's Formula.

$Q = A.C\sqrt{RS}$

$C = 30 \text{ to } \frac{70m^{1/2}}{S}$

2. Use of Empirical Formula

The use of empirical formulae requires knowledge about the size of catchment area and geological conditions.

i) Dicken's formula $Q = CA^{3/4}$ m^3/sec

Where,

C = constant 14 to 19.5

A = catchment area in sq.km

ii) Ryve's Formula

$Q = C_1 A^{2/3}$ in cumecs.

for limited near hills $C_1 = 10.5$

A = Area in sq.km.

iii) Inglis formula

$$Q = \frac{123A}{\sqrt{A+10.4}} \text{ in cumes}$$

A = Area in sq.km.

3. Use of envelope curve

WECS has developed Regional Analysis to calculate peak flood discharge in 1989 for Nepal. It gives peak discharges for different return period.

Q_2 = A two year return period flood discharge

$Q_2 = 1.8767 \text{ (Area below 3000m)}^{0.8783}$

$Q_{100} = 14.630 \text{ (Area below 3000m)}^{0.7342}$

$Q_{50} = e^{(1_n x Q_2 + 1nSx2.054)}$

$$\text{Where } lnS = \frac{1n\left(\frac{Q^{100}}{Q^2}\right)}{2.326}$$

This method is useful for a catchment area of more than 100 sq.km. in size and lying below 3000m elevation.

4. Statistical probability analysis

If the discharge data of a river is available for 20 years i.e. if the river is gauged and recorded, then design flood discharge or high flood level can be calculated from statistical probability analysis. Data of different rivers are available in DOHM, HMG/N or DIO.

Example: Probability analysis of the Chepe Khola Garam Besi river having the following recorded data.

S.No.	Date	Guage Ht.	Discharge
1.	1 Sep 1964	3.00	218
2.	6 Aug 1965	3.01	220
3.	12 Jul 1966	4.50	508
4.	10 Jul 1976	4.70	556
5.	4 Oct 1968	2.30	118
6.	26 Jul 1969	3.20	250
7.	15 Jul 1970	3.50	300
8.	22 Sep 1970	3.25	266
9.	30 July 1972	3.85	370
10.	17 Jun 1993	3.02	223
11.	5 Aug 1974	4.10	420
12.	14 Sep 1975	3.50	300
13.	29 Jun 1976	4.12	424
14.	26 Aug 1977	3.13	240
15.	18 Aug 1978	3.19	249
16.	24 Jul 1979	3.09	234
17.	1 Sep 1980	2.50	145
18.	2 Aug 1981	2.53	149
19.	10 Jul 1982	2.73	179
20.	17 Jul 1983	3.14	242
21.	26 Jul 1984	2.60	159
22.	28 Jul 1985	2.42	133

From the above discharge data

X Mean = 268 m^3/s

SD = 120 m^3/s

NV = 22

SCALE = SD * 0.78 = 93 m^3/s

XMODE = XMEAN – SCALE * 0.5772 = 215 m^3/s

Xest = SCALE * REDVAR + XMODE

Gumble Reduced variables (REDVAR) for different return periods are given in the following table.

REDVAR for different Return Periods

Return Period	Gumble Reduced Variete (REDVAR)
2	0.37
5	1.50
10	2.25
20	2.97
50	3.90
100	4.60
200	5.30

Thus for 50 yr Return Period High Flood Discharge

Xest = 93 * 3.90 + 215 = 578m^3/s

5. Unit Hydrograph Method

Unit hydrograph is based on the hypothesis that if two identical volumes of rainfalls occur on a drainage basin having identical conditions prior to the two rain storms, the hydrograph of run off from these storms are expected to be the same.

A unit hydropraph is a hydrograph of run off produced by a rainfall of a specified duration and assumed to have the same shape but with ordinates of flow in proportion to the runoff volumes. This specified duration is called unit duration, and the storm of this specific duration is called unit storm.

It is common practice to ignore variations in rainfall distribution, and to assume that the effective rainfall is spread uniformly over the entire basin, throughout the unit duration.

The assumption of uniform distribution of effective rainfall is reasonable for small drainage basins, but for large drainage basins, this assumption is not valid because these variations, are usually too great to be ignored. The unit

hydropraphs cannot, therefore, give precise results, and should not be used for drainage areas larger than 8000 sq.km or so unless an approximate answer is acceptable.

It has been stated by some investigators, that the unit duration should not be more than the period of the rise, or time of concentration. It is a good rule to select a period of 12 hrs as unit duration for catchments over 2500 sq.km; 6, 8, or 12 hrs for catchments between 2500 to 250 sq.km. and 2 to 4 hrs for catchments of 250 to 50 sq.km. Where rainfall records for less than a day are not at all available, and the area is greater than 1250 sq.km. even 24 hrs may be adopted as a unit duration. It has been found that the best unit period for practical purpose is 1/4th of the basin lag.

References are available in books of hydrology for making use of unit hydrographs to determine the runoff volumes and hence the discharge.

6. Regional Flood Frequency Relationships

A detailed regional analysis was conducted by the Water and Energy Commission secretariat and the Water and Energy Resources Development Project (WECS/WERDP) in cooperation with DHM which developed regional relationships enabling estimations of flood discharges for any river in Nepal. The following procedure for estimating flood discharge is based on the study.

Calculate the mean annual flood peak (daily) by the following equation

$Q = b A^c$

Where,

Q = Mean annual flood peak discharge in m^3/sec

A = Watershed area below 3000m in square kilometers and

b and c = regional coefficients

Values of the coefficients b and c are given in the table and their values depend on which of four hydrological regions the river lies. These regions are

Karnali River

Gandaki River

Koshi River

Southern Rivers

Regional Coefficient For Mean Annual Flood Peak Estimates

Region	Coefficients	
	b	c
Karnali	1.27	0.864
Gandaki	2.39	0.826
Kosi	1.92	0.854
Southern	3.03	0.747

Region	Multiplier-k				
	Return period (t Years)				
	5	10	20	50	100
Karnali	1.3	1.6	1.9	2.2	2.5
Gandaki	1.2	1.4	1.6	1.9	2.1
Kosi	1.2	1.4	1.6	1.9	2.1
Southern	1.3	1.6	1.9	2.3	2.6

The estimates of the daily flood discharge of a particular return period is given by

$Q t = kQ$

Where,

$Q t$ = daily flood discharge in m3/s for return period t

Q = mean annual peak disharge in m/s and

K = multiplier shown in the table

Annex II

Width of stable rivers and structure openings

Wherever proposed river control works can restrict the width of river flow, it is necessary to establish the minimum width for the waterway opening. As a preliminary estimate, Lacey's empirical formula for stable regime channels can be used :

$b = k\ Q^{1/2}$

Where,

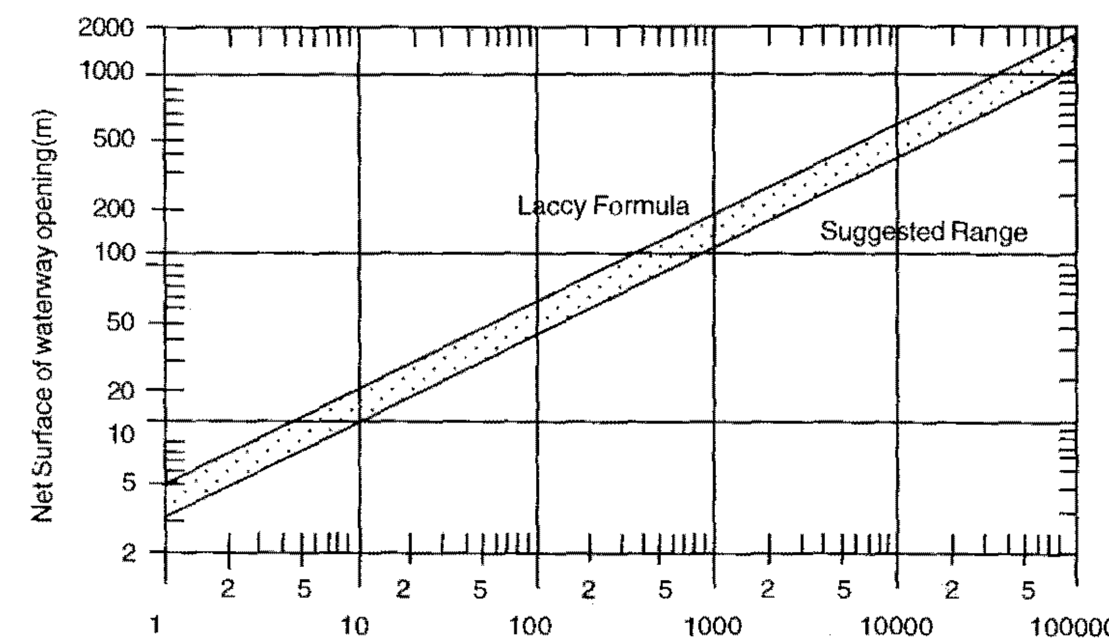
b = net waterway opening,m

K = coefficient

Q = design discharge, m^3/s

Relationship between required net surface width and design flow

Fig: 27



Annex III

Relationship Between Velocity of Flow and Size of Stones

Fig: 28 (i)
Size of Pitching Stone Vs Velocity

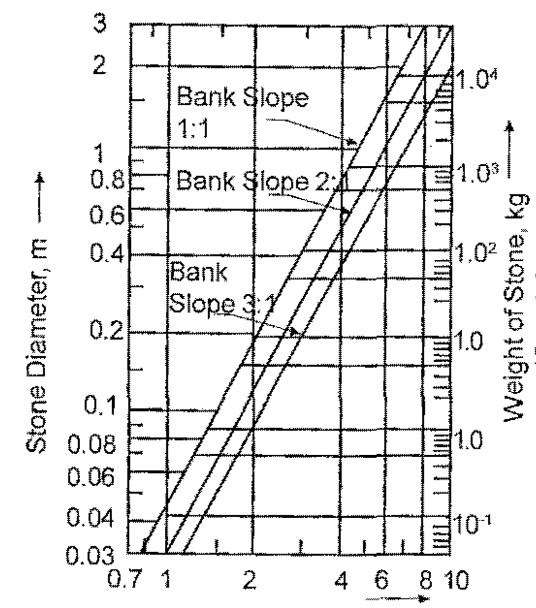
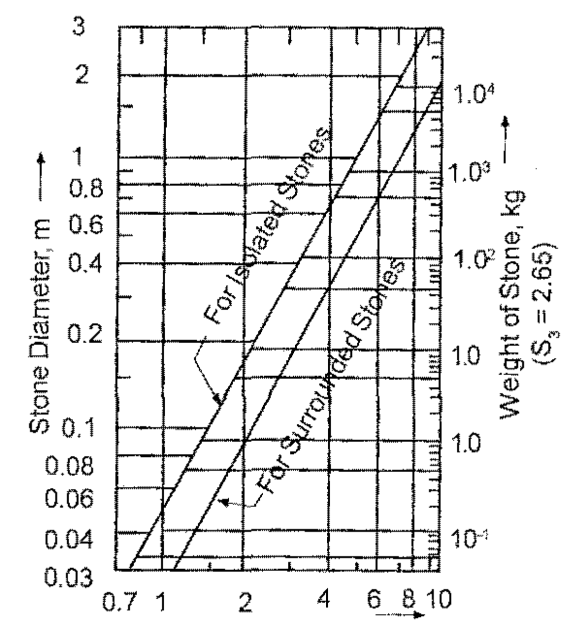


Fig: 28 (ii)
Size of Apron Stone Vs Velocity



Annex IV

Relevant Tables

Major Rivers in Nepal

Name of River	Catchment Area			Length of Main River		
	Total	Area in Nepal		Total	Length in Nepal	
	(Km^2)	(Km^2)	(%)	(Km^2)	(Km)	(%)
1 Koshi River	60,400	27,784	46	534	187	35
1-1 Tamar River	6,125	6,125	100	198	198	100
1-2 Arun River	34,000	5,100	15	481	135	28
1-3 Sunkoshi River	19,220	16,145	84	336	255	76
2 Narayani River	34,960	31,114	89	451	451	100
2-1 Trisuli River	19,700	15,366	78	270	159	59
2-1-1Budhi Gandaki River	4,960	3,621	73	154	100	65
2-1-2 Marshyangdi River	4,819	4,819	100	153	153	100
2-1-3 Seti River	2,843	2,843	100	125	125	100
2-2 East Rapti River	2,993	2,993	100	122	122	100
2-3 Kaligandaki River	11,600	11,600	100	316	316	100
3 Karnali River	44,000	41,360	94	550	435	79
3-1 Humla River Basin	8,500	5,525	65	243	129	53
3-2 Mugr Karnali River	6,155	6,155	100	195	195	100
3-3 Tila River	3,252	3,252	100	109	109	100
3-4 Seti River	7,103	7,103	100	202	202	100
3-5 Bheri River	13,867	13,867	100	264	264	100
4 Mahakali River	15,259	5,188	34	223	223	100
5 Kankai River	1,317	1,317	100	108	108	100
6 Kamala River	1,786	1,786	100	117	117	100
7 Bagmati River	3,681	3,681	100	163	163	100
8 Tinau River	550	550	100	100	100	100
9 West River	6,215	6,215	100	257	257	100
10 Babai River	3,252	3,252	100	190	190	100

Characteristics of River Channel

River stretch			River	Ground	Grain size		River width
	Form	To	Segment	Slope	d_{60}	d_R	Bm (min-max)
Reaches	(Km)	(Km)	Code	(1/1)	(mm)	(mm)	(m)
Ratuwa R.							
RA-1	0.0	13.0	2-2	1,180	0.30	0.30	356 (188-500)
RA-2	13.0	26.0	2-1	590	0.34	0.34	446 (275-638)
RA-3	26.0	36.2	1	320	0.43	0.43	516 (300-688)
RA-4	36.2	43.7	1	170	0.74	0.74	348 (225-425)
Lohandra R.							
LO-1	0.0	14	2-2	2,000	0.3	0.3	55 (25-100)
LO-2	14.0	33.1	2-2	970	0.27	0.27	89 (25-163)
LO-3	33.1	42	2-1	970	1.2	1.2	119 (75-238)
LO-4	42.0	49.6	2-1	320	2.4	2.4	200 (75-250)
LO-5	49.6	58.8	1	180	19	82	221 (138-350)
LO-6	58.8	67.5	1	80	23	81	178 (25-513)
Lakhandei R.							
LA-1	0.0	21.0	2-2	1,240	0.2	0.2	143 (38-375)
LA-2	21.0	37.0	2-1	520	0.31	0.31	326 (100-588)
LA-3	37.0	43.0	1	240	0.35	0.35	371 (200-588)
LA-4	43.0	51.4	1	240	4.3	4.3	547 (200-888)
Narayani R.							
NA-1	(Narrow reaches)		-	-			226 (150-350)
NA-2	18.4	44.9	2-1	1,560	39	60	1463 (400-2450)
NA-3	44.9	83	2-1	720	27	73	1394 (300-2500)
Tinau R.							
TI-1	0.0	12.7	2-2	3,180	0.18	0.18	163 (88-325)
TI-2	12.7	31.0	2-2	2,030	0.39	0.39	79 (50-150)
TI-3	31	41.0	2-1	1000	3.6	3.6	159 (63-325)
TI-4	41	53.0	1	430	17	42	557 (325-875)
TI-5	53	59.5	1	110	46	96	450 (88-925)
W .Rapti R.							
WR-1	0.0	23.0	2-2	1920	0.29	0.29	417 (225-750)
WR-2	23.0	53.0	2-1	1030	29	55	790 (238-1700)
WR-3	(Narrow reaches)		-	-	0.28	0.28	224 (75-950)
WR-4	115	132	2-2	1130	0.31	0.31	760 (350-1400)
WR-5	132	163.5	2-1	540	24	47	827 (125-1400)
Babai R.							
BA-1	0.0	30.0	2-2	2310	0.26	0.26	427 (88-724)
BA-2	30.0	38.0	2-1	890	43	63	592 (338-700)
BA-3	38.0	48.0	1	320	38	71	858 (325-1325)
Khutiya R.							
KH-1	0.0	11.5	2-2	-	0.58	0.58	346 (175-650)
KH-2	11.5	27.0	2-1	-	5.9	15	167 (50-350)
KH-3	27.0	5.0	1	-	84	124	355 (175-650)

Basin Area

River basin	Basin area (Km2)			
	Point	Km	Total	Remarks
Ratuwan R.	1	43.7	68	Upper end
	2	19.8	262	Mawa R.
	3	12.2	301	
	4	0.0	383	Border
Lohandra R.	1	67.5	109	Upper end (ChisanR.)
	2	49.6	197	Sukuna R.
	3	33.1	302	Kesaula R.
	4	0.0	419	Border
Lakhandei R.	1	51.4	65	Upper end
	2	39	155	Chapani R.
	3	0.0	300	Border
Narayani R.	1	-	16,481	Marsyandi R.
	2	-	19,560	Seti R.
	3	83.0	31,100	Upper end (Gandaki R.)
	4	44.9	34,089	East Rapti R.
	5	18.4	35,780	Narrow
Tinau R.	1	59.5	550	Upper end
	2	12.7	625	Dano R
	3	12.7	1,065	Dano R (aft. Jct.)
	4	0.0	1,081	Border
West Rapti R.	1	161.5	3,924	Rangsing R.
	2	132.0	4,647	Arjun R.
	3	53.0	5,464	Narrow
	4	23.0	6,125	Jhijhari R.
	5	0.0	6,418	Border
Babao R.	1	48.0	2,941	Barrage
	2	0.0	3,316	Border
Khutiya R.	1	35.0	119	Upper end
	2	11.5	209	Shiva Ganga R.
	3	11.5	309	Shiva Ganga R. (aft.Jct.)
	4	0.0	325	Border

Candidate Species For Bioengineering Works In Terai

	Naturally Grown Species	Nursery Species
Grasses	- Arundo clonax (Narkato) - Cymbopogon microtheca (Khar) - Cymbopogon pendulus (Dangre Khar) - Cynodon dactylon (Dhubo) - Eulaliopsis ninanta (Babiya, Sabai Grass) - Neyraudia arundinacea (Sito) - Neyraudia reynaudiana (Dhonde) - Pennisetum clandestinum (Kikuyu, Thulo Dhubo) - Pogonatherum paniceum (Musekharuki) - Saccharum spontaneus (Kans)	- Desmodium intortum - Pennisetum purpureum (Napier) - Setaria anceps - Thysanolaena maxima (Amliso) - also in forests - Stylo - Molasess grass
Shrubs & Non-Plantation Trees	- Adhatoda vasica (Assuro) - Butea minor (Bhjetro) - Calatorpha giganteum (Aak) - Colebrookea oppositifolia (Chusun) - Ipomoea fustulata (Saruwa---Beheu) - Lantana camara (Phul Kanda) - Phoenix humilis (Thakal) - Trema orientalis (Kunyelo) - Vitex negundo (Simali) - Wedlandia species (Tilka) - Woodfordia fruticosa (Dhanyero)	
Trees	- Acacia catechu (Khayer)--- also in nursery - Acacia auriculiformis - Albizia julibrissin - Ficus semicordata (Khasre Khayu, Khanayo) - Shorea robusta (Sal)-- also in nursery	- Bauhinia purpurea (Tanki) - Delonix regia (Gulmohar) - Leucaena species (Ipil Ipil) - Bamboo species

Source: "Vegetation Structures for Stabilizing Highway Slopes", Dept. of Roads, 1991.

Criteria of river segment

	Segment 1	Segment 1	Segment 2		Segment 3
			2-1	2-2	
Geomorphologic type	←Mountain→	←Alluvial fan→	← Natural Levee zone →	← Delta →	
Representative bed materials size(d_R)	Various	>2cm	3cm to 1cm	1cm to 0.3 mm	<0.3 mm
Riverbank materials	Exposed rocks are often seen	Same materials as those of river bed, occasionally covered with thin silt layer	Mixture of fine sand, silt and clay with same materials as those of river bed at the bottom		Silt and clay
Gradient of channel	Various	1/60 to 1/400	1/400 to 1/5,00		1/5,000 to level
Meandering	Various	Little meander	Severe meandering S-shaped meander and island are seen in the channel with large width-depth ratio		There are some large meanders and some others small meanders
Bank erosion	Very active	Very active	Medium; more active in the channel with larger bed materials		Not active and little river course change
Average channel depth	Various	0.5 to 3m	2 to 8m		3 to 8 m

Manning's roughness coefficient "n"

Major rivers (width more than 5o m)				
a. Straight, alluvial, sand	-	0.020	to	0.040
b. Straight, gravel	-	0.020	to	0.045
c. Irregular section	-	0.035	to	0.100
Minor Streams (width less than 30m)				
a. Straight, regular section	-	0.025	to	0.035
b. Winding, irregular	-	0.035	to	0.060
Floodplains				
a. Pasture, short grass	-	0.025	to	0.035
b. Pasture,high grass	-	0.030	to	0.050
c. Cultivated,no crop	-	0.020	to	0.040
d. Cultivated, field crops	-	0.030	to	0.050
e. Light,scattered brush	-	0.035	to	0.070
f. Medium to dense brush	-	0.070	to	0.160
g. Treed land, stumps	-	0.050	to	0.080
h. Heavy stand trees	-	0.080	to	0.120
Excavated channel				
a. Earth, recently completed	-	0.016	to	0.020
b. Earth with grass	-	0.018	to	0.033
c. Rock, smooth	-	0.025	to	0.040
d. Rock, jagged	-	0.035	to	0.050

Annex V

Local Norms

Rural Community Infrastructure Works programme has been using locally modified norms in Siraha, Saptari, Dhanusha, Udayapur. These local norms are duly endorsed by the respective District Development Committees and are in practice. Given below in the tables are the comparison of the government standard norms and the locally adopted norms for various work items, which are used in Dhanuhsa.

Labor Days required according to government norms.

Lift in meter	Lead in meter	0 - 10	11-20	21-30	31-40	41-50
	Type of Soil					
0 to 1.5	Ordinary	0.7	0.82	0.94	1.06	1.18
	Hard	0.8	0.92	1.04	1.16	1.28
	Soft rock	3.0	3.12	3.24	3.36	3.48
1.5 to 2.5	Ordinary	0.78	0.9	1.02	1.14	1.26
	Hard	0.88	1	1.12	1.24	1.36
	Soft rock	0.08	3.2	3.32	3.44	3.56
2.5 to 3.5	Ordinary	0.86	0.98	1.1	1.22	1.34
	Hard	0.96	1.08	1.2	1.32	1.44
	Soft rock	3.16	3.28	3.4	3.52	3.64
3.5 to 4.5	Ordinary	0.94	1.06	1.18	1.3	1.42
	Hard	1.04	1.16	1.28	1.4	1.52
	Soft rock	3.24	3.36	3.48	3.6	3.72

Unskilled Labor days requirement as per locally adopted norms

Lift in meter	Lead in meter	0 - 10	11-20	21-30	31-40	41-50
	Type of Soil					
0 to 1	Ordinary	0.41	0.47	0.53	0.59	0.65
	Hard	0.53	0.59	0.65	0.71	0.77
	Soft rock	0.65	0.71	0.77	0.83	0.89
1 to 2	Ordinary	0.47	0.53	0.59	0.65	0.71
	Hard	0.59	0.65	0.71	0.77	0.83
	Soft rock	0.71	0.77	0.83	0.89	0.95
2 to 3	Ordinary	0.53	0.59	0.65	0.71	0.77
	Hard	0.65	0.71	0.77	0.83	0.89
	Soft rock	0.77	0.83	0.89	0.95	1.01
3 to 4	Ordinary	0.59	0.65	0.71	0.77	0.83
	Hard	0.71	0.77	0.83	0.89	0.95
	Soft rock	0.83	0.89	0.95	1.01	1.07

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