WATERSHED MANAGEMENT PLANNING USING WATERSHED MODELLING SYSTEM (W.M.S.) : A CASE STUDY

A DISSERTATION

Submitted in partial fulfillment of the requirements for the award of the degree
of
MASTER OF TECHNOLOGY
in
IRRIGATION WATER MANAGEMENT

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CANDIDATE DECLARATION

I hereby certify that the work, which is being presented in this dissertation, entitled "WATERSHED MANAGEMENT PLANNING USING WATERSHED MODELLING SYSTEM (WMS)' : A CASE STUDY," in my partial fulfillment of the requirement for the award of the degree of Master of Technology in IRRIGATION WATER MANAGEMENT(IWM) submitted in the DEPARTMENT OF WATER RESOURCES DEVELOPMENT AND MANAGEMENT , Indian Institute of Technology, Roorkee is an authentic record of my own work carried out during the period from June 2004 to June 2005 under the supervision of Dr. Deepak Khare,Associate Professor in the Department of Water Resources Development and Management, Indian Institute of Technology, Roorkee and Dr. Sanjay Kumar Jain,Scientist "E", National Institute of Hydrology , Roorkee .

I have not submitted the matter embodied in this dissertation for the award of any other degree.

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Place: Roorkee.

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ABSTRACT

Watershed is made-up of components like soil, water and vegetative cover including trees, crops, grasses and legumes. The integrated development of a watershed incorporates harnessing of these vital resources of nature. The comprehension includes various types of data collection i.e. rainfall, runoff, land use, drainage soil type agricultural and socio-economic and geological .The procedure of spatial and non spatial data collection, storage, analysis and slides view needs a collective, memorizable and effective system.

Watershed Modeling System (WMS) is computer oriented, and well designed system for such data 'feedback. Basic data structures used in Watershed Modeling Systems (GIS vector data or feature objects, DEMs, and TINs) helps in how watersheds can be delineated to set up hydrologic models from them. Under basics it covers supporting hydrologic calculations such as curve number generation from land use and soil data layers and time of concentration (or lag time) computations from computed geometric values

Many watersheds become barren due to poor conservation and management of water resources and over exploitation of soil. Recharging of ground water and renewable of surface water resources are commonly used for integrated planning and management of watersheds .The thesis includes conservation, utilization and management of water resources in Churachandpur district of Manipur state in India to make hilly land cultivable fertile and useful to meet the food shortage and control of erosion ,land slides, and other natural land degraded phenomenon .

The western part of the district area of Churachandpur district covers river Barak and its tributaries and the study of it comes under Barak Watershed Management Project .In its eastern part the river Manipur flow all along its boundary and area is bounded by its tributaries Leimatak, Khuga, Tuicha etc and its study comes under Manipur Watershed Management Project .The catchment area of the district is 4.570 sqkm which is entirely hilly and rain fed area. The average elevation of the district is 650m and minimum average elevation is 150m. The non-agricultural land is above 800m elevation. The highest average elevation of the district is

2,200m.The non-agricultural land includes reserved forests, population land and pastures. The agricultural and horticulture land in the district covers only 20% of the adjust area and this can be improved to 30% without affecting environment and ecology of the district. Proper land use ,erosion control measures and following topographical measures to agricultural crops ,control of soil fertility and timely rainfall further improve the food productivity of the district .The underlying strata consists of sandy loam to silty loam brownish soil structure rich in organic content.

The soil status shows soil group ranges from Andisol to Alfisol, which are hydro logically grouped in C&D. These also ranges from group 2-to 7 , agro-climatic zones vary from zone II to zone III and agro-ecozones varies from zone I to zone4.Here rainy season starts from June and end in the month of September. The highest average rainfall 2810mm is recorded at Tipaimukh and it decreases linearly towards state capital Imphal .The average rainfall of the valley is 2100mm and the mean monthly temperature is $27^{\circ}C$.

Among the major source of water in the district are groundwater, streams, rivers, springs, rainwater harvesting structures and boreholes. The water available from shallow well abstraction is 460 Mcm/year. There are 480 nos. of boreholes in the district with total yield of 18.00Mcm/year. There is no running canal in the district and water is either lifted by pumping on higher elevations or by pipe through gravity for lower elevations. The total amount of available water in the district is 902 Mcm/year.

Average annual evaporation in the district is 628mm.By 2003 the annual population growth rate was recorded 17.39 and the population was 2,06. 856 persons .The future population calculated by extrapolation of population graph is recorded as 2,17,648 in 2004, 2,42,830 in 2011, 2,85,083 in 2021, 3,34,648 in 2031, 3,92,922 in 2041, and 4.61.291 in 2051.

The runoff is measured in the district by SCS conventional, SCS modified and soil trapped Tank models.USLE model is used to estimate soil erosion without its proper place of deposition. Other characteristics of these models are to estimate curve numbers and soil water retention factor during a storm (S).

In the thesis the proposed developed plan with irrigation and water supplies for all five watersheds namely Barak, Tuijang, Tuicha, Leimatak and Khuga are suggested. A comprehensive watershed management plan is prepared in the light of fact the people remain intact with settled agriculture, proper irrigation planning. The engineering measures suggested are favorable to control excess runoff and soil erosion.

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CHAPTER –1

INTRODUCTION

1.1 General

The water resources development and management involves collection of data, storage, processing and its presentation. This requires lot of precision in handling, keeping and storing data. Computer aided Watershed Modelling System (WMS) is an effective tool for spatial data analysis particularly for rainfall-runoff models and use of MUSLE and other rational methods.

WMS is suitable in storing, decision-making, handling, spatial; and non-spatial data analysis due to reasons as stated below.

- The geographical factors are easily evaluated for spatial and non-spatial data of watersheds.
- Any type of data can be easily feed in geographical factor.
- The interpretation of data is much simpler.
- Comparative study of the data, geographical parameters are easier.

WMS is a simple tool to predict the expected amount of runoff-by-runoff modelling using Rational Method. It is helpful in generating soil type maps, prediction of soil erosion.

The WMS Consultants / Managers / Advisors / Engineers must have knowledge of,

- Reporting of data source and its locality, contact media and way of collection.
- Interlinking and engagement of departments /agencies under WMS Cell for data collection.

1.2 Watershed management

1.2.1 General

An area connected with streams in such a way forming a common outlet point and is separated by two-ridge lines delineating the area topographically from other areas. This area is formed by tank, lake, stream or river. The identity take part in naturally acting hydrologic cycle and maintains all regime conditions on the other a watershed management is referred to all operational activities implemented through rational planning formulated for its socio-economic, physical, biological, institutional

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1.2.2 Requirements

The existing resources lands, water, live stocks, milk providing animals are to be protected in the watershed. The watershed management gives an opportunity to use landscape topography to our best advantage. In order to maximize production or minimizing losses, increase in income and employment generating activities activities these resources along with skilled strength, capital other input and related technologies utilized optimally.

1.2.3 Country background and information

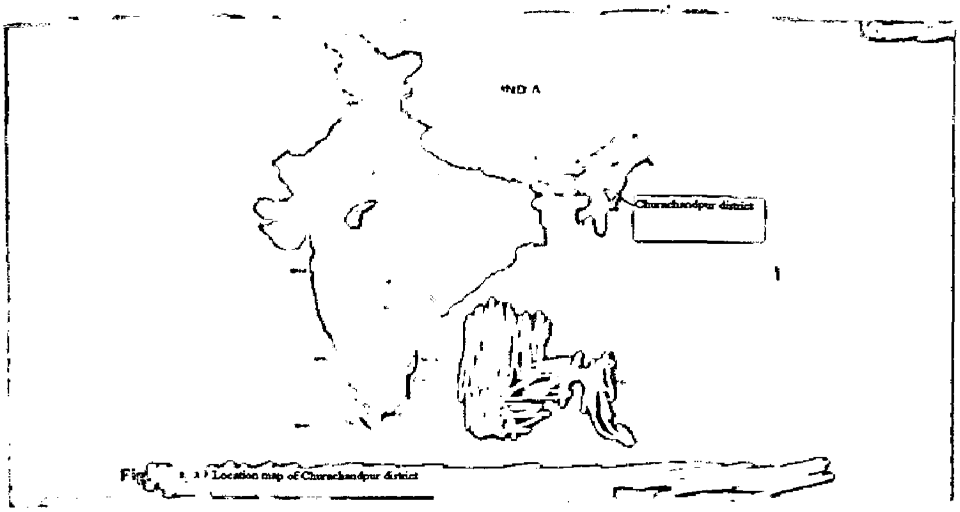
India covers an area of approximately 3.29 Mha.The area is further divided into arid, semi arid and humid zones. The average rainfall in India is 1,170mm.Increased irrigation facilities alone has contributed to about 52% increase in food grain production. improved management, agricultural practices and high yielding varieties have contributed to 48% increase in food production. The larger part of northeastern region is rain fed and humid: the net area sown in the country is 145ha.

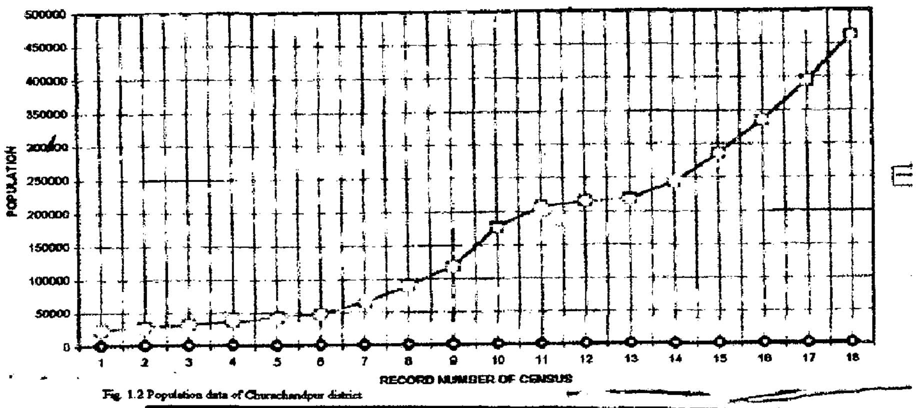
1.2.4 District background and information

The Churachandpur district area lies between Latitude-24 ^{0} *N to* 24 ^{0}18' *N* 93 ^{0}9' E-to 94 ^{0} E.The district HQ is 60 Km away from state capital Imphal.The river Barak flows through western part of the district from north to south up to Tipaimukh and then it traverse along the western boundary. The Manipur river tributary flows in the eastern part of the district. The total area of the district is 4,570 Sqkm.The average elevation of the district is 1,170m The average slope of the 60% of the area is greater than 50% and the minimum slope is 10% and maximum slope is 200%.

1.2.5 Geology

The Churachandpur district area is located on the top range running in north-south direction almost parallel to the adjacent Brail range and Chine hills in Burma.





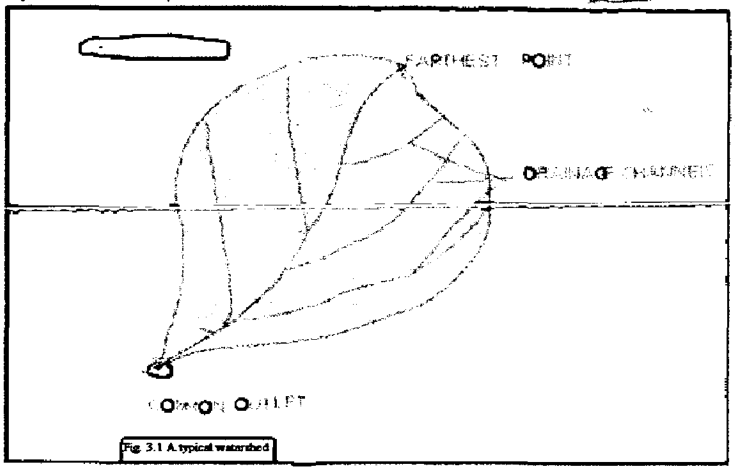


Fig. 1: Showing location , population trend, typical watershed.

These areas are prone to land slides. The present soil formed by sandstone rocks, since these rocks came up and deposited on hillside. Shale and mild stone below it formed due to erosion of surface layer.

1.2.6 Land and soil

The soil of the region is sandy silt loam with tracts of clay. These are brown in colour and covers land capability class II to VII. It is poor in lime, low in phosphorus content and with 1 to 3% organic matter. In SCS grouping these falls under C&D classes. These are acidic and suitable for paddy cultivation and plantation crops after terracing.

The Fig. 1.1 shows the location , Fig. 1.2 shows rate of change of population and Fig. 1.3 shows a typical watershed on page I-3.

1.3 Watershed Modelling System (WMS)

WMS is a easy tool used with microcomputers for storing, manipulating and analysing geographical parameters for specied locations. It is excellent tool for generating, information on spatial and temporal data inputs.

Here problems are solved using a digital terrain model and the rational method. composite curve numbers, time of concentration, runoff, soil profiles, TIN contours etc, are calculated in land use grid and soil ype grid and selecting SCS curve numbers and runoff coefficients. TIN contours are directly read by digitising the selected polygons of watersheds.

For the assessment of soil pattern, soil classification, runoff coefficient C, rainfall intensity (i) soil type, SCS / Monglen / Tank model methods are commonly used. These parameters have geographical values WMS reference manual contain tables of typical values or the available field data can be modelled into WMS interface to any of the methods. The coordinate conversion is possible at three different occasions.

1. The watershed has spans zones within a given coordinate system.
2. The data is available for entire watershed model, but the data is in different coordinate systems. For example, the elevation data in one coordinate system and land use data in another coordinate system.

3. The data is in one coordinate system, but the job assigned is in another coordinate system. For example, all the data in the watershed 'GIS database may be in one coordinate system, but available data is in another coordinate system. Other methods are time consuming and costly. The present feedback is able to register large amount of data, its storing, analysis and presentation.

1.4 Objectives

WMS becoming popularise day by day due to its lesser handling problems, simple parameters, ease in views, simple attributes and varieties of approaches in storing, analysing, manipulating spatial and attribute data. The approach is rational and need accuracy in collection, storing, handling and manipulating watershed data.In the present study five sub- watersheds namely Barak sub-watershed Tipaimukh, Tuijang Sub watershed Thanlon, Leimatak Sub-watershed Churachandpur North, Khuga sub watershed Churachandpur and Tuicha sub-watershed Thing hat are considered for planning of watershed management . The main **objectives** of the study are ,

- To demonstrate the ability of WMS to resolve the watershed management problems .
- To determine various parameters for rainfall-runoff models showing the procedure for framing runoff models and soil loss models.
- To assess runoff for different watersheds under different land use / land cover .
- To estimate soil erosion by Universal Soil Loss Equation.
- Prepare strategies for watershed management and study the impact of the plan on soil erosion and runoff

1.5 Organization of thesis

The present study relates to rainfall-runoff analysis, calculation and analysis of soil type, soil erosion and their showing on TINS / DEMS of different watersheds under Churachandpur district .

Chapter –1 includes the introduction part of the descriptive study of watersheds by WMS ,objectives ,organization of thesis.

Chapter –2 contains literature review (theory & methodologies) on rainfall –runoff model by SCS methods ,Monglen method and Tank model to generate runoff model, soil conditions,soil erosion ,USLE model parameters and engineering measures .

Chapter –3 add the description of study area of five watersheds namely Barak watershed Tipaimukh, Tuijang watershed Thanlon, Leimatak watershed Churachandpur North,Khuga watershed Churachandpur and Tuicha watershed.

Chapter –4 show the contents of Watershed Modelling System (WMS) concept.

Chapter –5 relates to the applications of WMS in watershed management.

Chapter –6 covers results and discussions of rainfall-runoff model, drainage,soiltype ,soil erosion ,water availability etc.

Chapter-7 focusses on watershed management plan by various measures and improvements afterwards .

Chapter-8 draw the basis of choosing a particular watershed under conclusions and recommendations.

Images are provided for help wherever necessary.

LITERATURE REVIEW (THEORY & METHODOLOGY)

The present chapter deals with related papers on watershed planning and watershed management including parameters like runoff, soil erosion and latest engineering methods for measurements of these components.

2.1 Recent research contributions in watershed management

Reddy et al.,(1999) stressed for sustainable development of agriculture by unifying the multiplicity of watershed programmes within the framework of an overreaching national initiative which is desirable in national interest . It is added that watershed approach has been identified as a major route and a promising area for development of agriculture.

In his study in two micro watersheds i.e. Danta (Saraswati) under Banaskantha district and Dayapur (Lakhpat) of Kutch district in Gujarat state, India under National Watershed Development Project (NWDPRA) for Rain fed Areas proved that the Danta watershed was more effective in generating positive impact in moderate to high rainfall situations compare to Dayapur with very low rainfall conditions .As per guidelines the cropping pattern change to more profitable commercial crops allowing increase use of fertilizer, high yielding variety and improved seeds . This increases the production and allows increase in cropping intensity by reducing growing time of crops. The soil erosion is also controlled by check dams, vegetative contour bunds and embankments to harvest rainwater, planting trees, shrubs, grasses thus proving it economically viable and feasible programme.

Singhal, (1999) studied on Nada watershed development project in Shivalik hills of Haryana,India stated that people's participation in watershed management decreases the perpetual dependence of the people on the government thereby making the programme self-sustaining and gaining access to control of the resources. The paper attributes the contribution of hill villagers in protection of hill resources through Hill Resource Management Societies (HRMS). The informations are collected from marginal farmers, members of HRMS, Panchayat and Government Officials of Forest Department under Participatory Rural Appraisal Method. Under the programme women were also allowed to express their ideas.

Chess et al., (2000) discussed the stakeholder involvement and government as well as scientific community participation in U.S.A. and adaptive approaches to participation.

In its report of Badakhera watershed in Bundy district of Rajas than (TDET, IWDP project) Central Soil and Water Conservation Research & Training Institute (CSWCRTI) (2000-2001) depicted effect of biological and mechanical measures and showed that under improved technology the yield of mustard, wheat, greengram,soyabean and Pigeon pea is increased by 76.98 ,65 and 39 in comparison to comparatively untreated watersheds similarly runoff and soil loss were reported 76.09 and 47.32% less respectively .In Antisar Kgeda district of Gujarat (IWDPT Tech, DET project) the conservation and agronomical measures the increase in crop yield to by 18-155% .

From the Kokriguda watershed in Orissa it is found that land holding, education and age of family head had highest, second highest and third highest impact of its development. Normally younger head shows more participation. Similarly intercropping system of ragi-pigeon peas (2:1) provided highest income. The women participation was highest at Kattery watershed in TamilNadu community contribution to CPR's was 40% in terms of cash. It provides training and knowledge to 56% of participated population. Under it water conservation measures followed 40%.

Under 29 shivalik foothill villages of Haryana there were only seven village programmed successful because agencies able to govern, maintain and manage the system properly. The expenditure in other cases increased due to sedimentation of schemes. By study of central plateau and hill region of Uttar Pradesh, Hazra et al., (2000) noted seven deforestation, land degradation and erosion in seven micro watersheds of Kharaiya Nala spreading in 5,395 ha under agro forestry projects. . The popular holistic management strategy put forth to conserve soil and water (with construction of contour trenches, dams, planting of trees, grasses, legumes and other measures) to improve crop production generating series of land under proper management plan. These plans not only reduce losses but directed for increased production of crop, fodder, milk etc. An economic survey shows that all expenditure incurred has been recovered in these years. Crop productivity, addition of land and employment were supplement benefits.

Kishore,(2000) discussed on problem and prospect of watershed development in India including topics such as land and water ,watershed management and rural development programme and progress , people's participation and watershed development ,funding of these programmes including NABARD ,IGWDP approaches.

In his paper on Huangjiaercha small watershed in Ningxia Hui Autonomous region of China Qui-Shi et, al.,(2000) discussed problems in different control stages. In his model,comprehensive control stage, strengthening, promoting, stablising stage and sustainable development stage are incorporated with stress on population, scientific technology, market and long term policies

In his paper presented on land degradation under Wasteland Development Programme (WLDP) in India Ramanathan (2000) discussed on soil erosion by wind and water, waterlogging, salinity, deforestation, grazing, misuse of fertilizer and biocides etc.

In his paper on Drought Prone Areas Programme in India Rao (2000) discussed on watershed development strategy ;prospects for agriculture in 2020; social ; economical and environmental impact and factors affecting good performance on issues like institution building and leadership formation, capacity building ,expert and independent evaluation ,watershed development is agricultural development ,rain fed farming.

Reddy, (2000) stressed on collective action (CA) to achieve the theoretical ground for detailed and rigorous empirical work. He also improved that Rural Development Trust (RDT) is a voluntary organization working in Anantpur District of Andhra Pradesh,India and it is based and spirited on government funded new guidelines .In his paper on a case study on the World Overview of Conservation Approaches and Technology (WOCAT) programme of the World Association of Soil and Water Conservation (WASWC) Schreier et al., (2000) stressed to achieve sustainable use of soil and water conservation.

Estrada et al., (2001) discussed about stages such as estimation of soil loss and stream flow; construction of a farm model, characterizing the externalities of upper catchment management; testing new scenarios and evaluating the impact of land use.

Gardi (2001) added adoption of European Union (EU) agricultural policy of significant changes of crop rotation for marginal areas.

Kerr et, al., stressed on improved agricultural productivity and natural resource management.

While studied on watershed management programmes of Taiwan Lu-Shiang Yue et al., (2001) recognized the problem due to weak geological formations in 74% mountainous region. It now manage 58% forest cover with density of 590 people per sqkm.

Shah et al., (2001) study on dry region of Gujrat India with respect to benefit and sustainability its best perspective.

With study to Little Miami River watershed, Ohio, U.S.A using biological water chemistry and habitat indicators Wang (2001) discussed spatial relationships between land uses and river water quality.

N.Ranjan, (2002) developed drainage maps of various watersheds of Manipur State.

Anand Kumar ,(2002) suggests multiple databases for design of barrages.

Yonjan etal., 1991 suggests that "spatial data base is required to understand existing resources, their status, spatial distribution and associate with other socio-economic situation of the watershed .

C . Mongkol sawat et al.,(2002) calculated the soil loss in Huai Sua Ten watersheds located in Northeast of Thailand. They estimated erosion range of 59-153 tons /ha /yr. while Wichaidet et al., 1992 reported it 31-125 tons /ha /yr.

DR Francisco,(2004) ' project was a collaborative initiative of the United Nations Environment Programme (UNEP) ; the Resources , Environment and Economy Centre for Studies (REECS) ; UPLB; and EEPSEA . She and her colleagues aimed to design market –based instruments (MBIs) for the Makiling Forest Reserve (MFR) , an important watershed and nature reserve 100 km south of Manila.

Pandey et al.(2002) calculated runoff for Dikrong river basin by SCS Curve number method. The lowest runoff calculated by him is 410.75mm and highest runoff is 1611mm.

Pathak et al., (1985) conducted studies between 1976-2000on small agricultural watersheds at ICRISAT Centre near Hyderabad, India. Various storms are considered which produces 75-91% of seasonal runoff and 65-90% of seasonal soil loss.

2.2 Components of Watershed Management

1. Human resource development (skills, upgrading, organization development etc.)
2. Soil and water conservation measures.
    - Land treatment (bunding, trenching, vegetative barriers, bench terracing etc.)
    - Drainage lines treatment (gully control works)
    - Water harvesting structure
3. Agricultural development (seed production, cropping pattern, organic farming etc.)
4. Alternate land use systems (afforestation, agro forestry, dry land horticulture fodder production, non timber productions etc.)
5. Live stock development.
6. Watershed plus activities (empowerment, improved conditions of living, etc).

2.3. Runoff

Runoff is the drainage of precipitation from catchments, which flows out through its natural drainage system, after the occurrence of infiltration and other losses from the precipitation (rainfall). The excess rainfall flow out through the small natural channel on the land surface to the main drainage channel (Ghansyam Das 2002).

The surface runoff process, when rain falls, the leaves and stems of the vegetation intercept the first drops of water. This is usually referred to as interception storage as the rain continues, water reaching the ground surface infiltrates into the soil until it reaches a stage where the rate of rainfall (intensity) exceeds the infiltration capacity of the soil. Thereafter, surface puddles, ditches, and other depressions are filled (depression storage), after which runoff is generated.

The infiltration capacity of the soil depends on its texture and structure, as well as on the antecedent soil moisture content (previous rainfall or dry season). The initial capacity (of a dry soil) is high but, as the storm continues, it decreases until it reaches a steady value termed as final infiltration rate (Fig.2.1).

The process of runoff generation continues as long as the rainfall intensity exceeds the actual infiltration capacity of the soil but it stops as soon as the rate of rainfall drops below the actual rate of infiltration.

2.3.1 Types of runoff

Runoff is broadly classified into following three types,

2.3.1.1. Surface runoff

It is the portion of rainfall which enters the streams, channels etc. immediately after occurring the rainfall. The process may be described as when all losses are satisfied and if rain is still continued with the rate greater than infiltration rate, then excess water makes a head over to soil surface, which tends to move due to land slope, known as overland flow. The overland flow joining the stream, channel or ocean etc., is called as surface runoff.

2.3.1.2. Sub-surface runoff

It is the amount of rainfall ,which first leaches into the soil and then starts flowing laterally without joining the water-table to the streams, rivers etc., called as sub-surface runoff. Sometimes, sub-surface runoff is also treated as surface runoff due to the fact that, it takes very little time to reach the rivers, like the surface flow.

2.3.1.3 Base flow

It is delayed flow ,defined as that part of rainfall ,which after falling over the ground surface ,percolates into the soil and meets to the water table, and finally joins to the streams ,oceans etc . In other words, flow of ground water towards streams, channels etc,is known as base flow.

2.3.2 Factors affecting runoff

Apart from watershed characteristics such as land use and vegetation cover, topography and terrain profile, soil type and soil depth, which have a direct bearing on the occurrence, and volume of runoff. These are mainly of two types.

2.3.2.1 Climatic factors

2.3.2.1.1 Types of precipitation

The types of precipitation have great effect on the runoff. For example: a precipitation ,which occurs in the form of rainfall , starts moving immediately in the form of runoff over the land surface ,depending upon its intensity and magnitude .While another precipitation, which takes place in the form of snow or hails, the flow of water on the ground surface will not take place immediately, but after melting of the same. During this time interval, a large amount of melted water is absorbed by the soil, resulting into very less runoff generation.

2.3.2.1.2 Rainfall intensity

Intensity of rainfall has dominating effect on the runoff yield . If rainfall intensity is greater than the infiltration rate of the soil , then surface runoff is generated very rapidly , while in case of low intensity rainfall, there is a reverse trend is found .Thus, a high intensity rainfall causes higher runoff and vice versa.

2.3.2.1.3 Forms of precipitation

- **Rain**

  It is the principal form of precipitation in India. The term rainfall used to describe precipitation in the form of water drops of size larger than 0.5mm. The maximum size of drop is about 6mm. On the basis of intensity, rainfall is classified as

-Light Rain	Intensity up to 2.5mm/h
-Moderate Rain	Intensity 2.5mm/h to 7.5mm/h
-Heavy Rain	Intensity >7.5 mm/h

- **Snow**

  Snow consists of ice crystals which usually combine to form flakes .When new snow has an initial density varying from 0.06 to 0.15g/cm 3 .

- **Drizzle**

  A fine sprinkle of numerous water droplets of size less than 0.5mm and intensity less than 1mm/h is known as drizzle .in this the drop are so small that they appear to float in the air .

- **Glaze**

  When rain or drizzle come in contact with cold ground at around zero degree celcious ,the water drops freeze to form an ice coating called glaze or freezing rain.

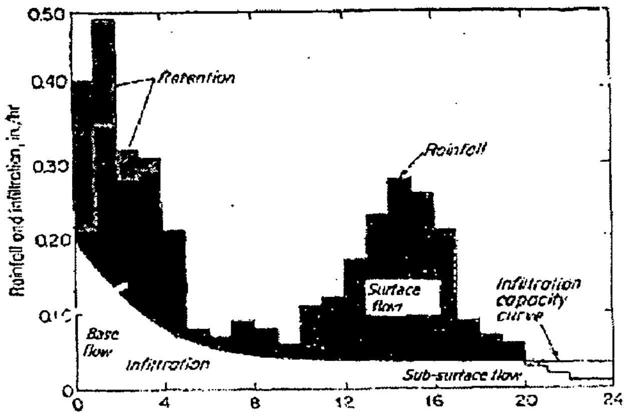


Fig 2.1: Rainfall -- runoff -- infiltration relationship

- **Sleet**

  It is frozen raindrop of transparent grains which form when rain falls through air at subfreezing temperature .

- **Hail**

  It is showery precipitation in the form of irregular pellets or lumps of ice or size more than 8mm.Hails occur in violent thunderstorms in which vertical currents are very strong .

2.3.2.1.4 Duration of rainfall

Rainfall duration is directly related to the runoff volume due to the fact that, infiltration capacity of the soil goes on decreasing with the advancement of time, till it attains a constant value. As a result a mild rainfall occurring for longer duration may produce considerable runoff from the catchment.

2.3.2.1.5 Rainfall distribution

Runoff from a catchment ,depends very much on the rainfall distribution pattern. The effect of rainfall distribution on runoff,can be presented by a term known as " distribution coefficient ". The distribution coefficient can be defined as,the ratio of maximum rainfall at a point to the mean rainfall of the concern catchment, i.e.

$$Cd = \frac{Maximum\ rainfall\ amount}{Mean\ rainfall}$$

For a given total rainfall ,if all conditions are the same ,greater the coefficient of distribution higher will be the peak runoff and vice-versa. However, for the same distribution coefficient, the peak runoff would be resulted very shortly from, for the storm falling on the lower part of the basin i.e. near to the outlet than the storm occurring on upper part of the brain .

2.3.2.1.6 Direction of prevailing wind

The direction of prevailing wind affects the runoff flow greatly. If the direction of wind is same as the runoff flow direction in the drainage system of the catchment,it makes a great effect on resulting the peak runoff as well as duration of surface runoff. That is why a storm moving in the stream flow direction , results higher peak very shortly ,compared to the storm, moving in opposite direction .

2.3.2.1.7 Evapotranspiration

Evaporation and transpiration commonly called evapotranspiration (ET) is the conversion of water to vapour and the transport of that vapour away from watershed surface into the atmosphere. The ET varies both in space and time and mainly depends on available water and solar radiation. Water is available at plant surfaces,streams and ponds or snow packs .The bulk of evaporation and transpiration takes place during the time between runoff events ,which is usually long .hence the abstractions are most important during this time interval. Estimation of ET require to consider three sets of variable in a vertical water budget within a system as (i) determination of potential ET (ii) plant –water related characteristics and (iii) soil-water –related characteristics.

2.3.2.1.8 Other climatic factors

It includes temperature,wind velocity,relative humidity,annual rainfall etc. All these factors also affect the runoff producing characteristics of watershed to some extent Actually these factors affect the initial losses of precipitation water. Thus ,if the losses are more, the runoff will be less and vice –versa.

2.3.2.2 Physiographic factors

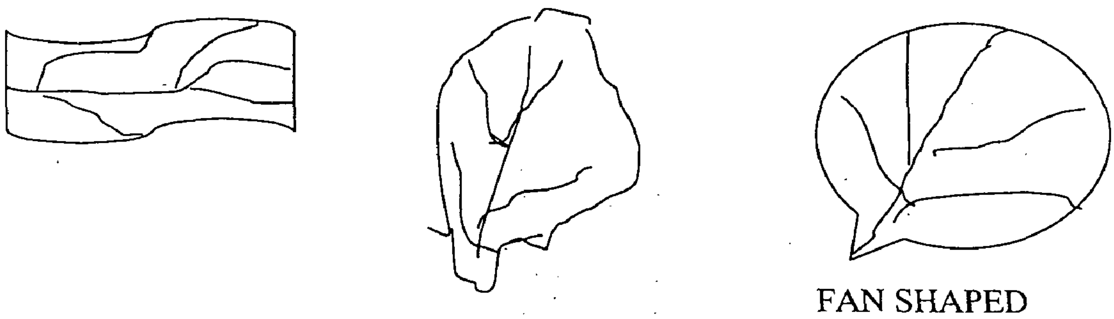
2.3.2.2.1 Size of watershed

Regarding the size of watershed,if all other factors such as depth and intensity of rainfall being same ,the two watersheds irrespective of their size, will produce the same runoff .However, large watershed area, takes longer time for passing the runoff to the outlet and hence the peak flow expressed as depth will be smaller and vice-versa. But larger watershed produces greater runoff per unit area to that of smaller watershed.

2.3.2.2.2 Shape of watershed

The shape of watershed is divided in two types, given as under

- Fan shape and
- Fern shape
- Dumble shape



FAN SHAPED

DUMBLE SHAPED FERN SHAPED

Fig. 2.2: Shapes of watershed

The fan shape watershed produces higher peak rate of runoff in shorter duration than the fern shape watershed ,due to the reason that, in former one all parts of the watershed contribute the runoff to the outlet simultaneously ,comparatively in little time period .

Generally, the shape of watershed is expressed by form factor and compactness factor ,described as under.

Form factor. It is defined as ,the ratio of average width to the axial length of watershed ,expressed as:

$$Formfactor = \frac{Average\ watershed\ width}{Axial\ watershed\ length}$$

$$Ff = \frac{B}{L} = \frac{A/L}{L} = A/L^2 \qquad \ldots \ldots \ldots (2.1)$$

Compactness factor. It is the ratio of perimeter of watershed to the circumference of circle whose area is equal to the watershed area, i.e

$$Compactness\ coefficioent = \frac{Perimeter\ of\ watershed}{Circumference\ of\ circle\ whose\ area\ is\ equal\ to\ the\ watershed\ area}$$

$$= \frac{P}{2\Pi A} \quad \dots\ \dots\ \dots\ (2.2)$$

Where, P = Perimeter of watershed (m)

A = Area of the watershed (m)

2.3.2.2.3 Slope of watershed

The watershed slope has an important role on runoff producing characteristics of the watershed .but its effect is complex on the causes responsible for making the initial losses. The watershed slope decreases the time of concentration and thus, peak runoff occurs relatively at shorter duration. For example: incase of sloppy land, the runoff velocity is more, and infiltration loss is less resulting into higher peak runoff and vice –versa.

2.3.2.2.4 Orientation of Watershed

This factor affects the evaporation and transpiration loss by making influence on the amount of heat received from the sun. The north and south orientation of the watershed affects the melting time of collected snow and accordingly to the runoff, too. Similarly in the mountainous watershed the windward side of the mountain receives comparatively higher intense rainfall than the leeward side of the same due to orientation effect.

2.3.2.2.5 Land use

The land use pattern or land management practices used have great effect on the runoff. For example –an area that is under forest on which a thick layer of mulch of leaves and grasses have been accumulated,the surface runoff becomes too less ,as huge rainfall amount is absorbed by the soil due to increase in infiltration rate and formation of resistance in the flow path of the water over the ground surface ,while in barren lands just reverse trend is found.

2.3.2.2.6 Soil moisture

amount of runoff produced from the catchment area is mainly dependent upon the amount of moisture present in the soil at the time rainfall .If rain occurs over the land

, which has more soil moisture, the water absorbing capacity of the soil becomes too less and thus ,resulted more runoff yield. Similarly, if the rain occurs after a long dry spell, the soil becomes to dry and total rain water is absorbed by the soil causing no extra water to make runoff. In this way runoff amount approaches to zero. In this condition even intense storm becomes unable to produce the runoff in appreciable amount. But on the other hand, if rain occurs at close time interval, a reverse effect on runoff yield is obtained.

2.3.2.2.7 Soil types

The yield of surface runoff is also dependent upon the types of soil of the catchment area, acts as important parameter, because absorption of rain water varies from soil to soil. For example –a light texture soil (sandy soil) consists of coarse soil particles and has large pore spaces ,results rapid absorption of water and thus it has less runoff potential .but in heavy texture soil(Clay soil), the soil particles are fine and size of pore spaces are too small. which results little absorption of rain water, causing formation of huge runoff volume.

2.3.2.2.8 Topographical characteristics

It includes topographical features such as undulating nature of the watershed. Undulate land yields greater runoff than the flat land because of the reason that runoff water gets additional power to flow to the outlet due to slope of the area.

2.3.2.2.9 Channel characteristics

Regarding channel characteristics, the cross-section, roughness, storage, channel densities are considered for study of their effect on runoff.

$$Drainage\ density = \frac{Total\ \ channel\ length}{Drainage\ \ area}$$

Or, $$D.D. = \frac{L}{A} \qquad \dots\ \dots\ \dots\ (2.3)$$

If value of drainage density is more then runoff yield is relatively more, as rain water enters the drains, immediately and reaches to the outlet.

2.3.3 Land use or vegetation cover

Vegetation is another important parameter that affects the surface runoff. From the studies in West Africa (Tauer & Humborg,1992) and Syria (Prinz et al., 1999) proved that an increase in the vegetation density results in a corresponding increase in interception losses ,retention and infiltration rates which consequently decrease the volume of runoff. Vegetation density can be characterized by the size of the area covered under vegetation. There is a high degree of congruence between density of vegetation and suitability of the soil used for cropping.

2.3.4 Topography and terrain profile

The land form along with slope gradient and relief intensity is other parameters, which are important in computing runoff. The terrain analysis can be used for determination of the length of slope, a parameter regarded of very high importance for the suitability of an area for macro-catchments water harvesting. With a given inclination, the runoff volume increases with the length of slope. The slope length can be used to determine the suitability for macro or micro- or mixed water harvesting systems decision making (Prinz et al.1998).

2.3.5 Soil type & soil depth

The suitability of a certain area either as catchments or as cropping area in water harvesting depend strongly on its soils characteristics viz. the infiltration and percolation rate ; which determine water movement into the soil and within the soil matrix ,and the soil depth including soil texture ; which determines the quantity of water which can be stored in the soil.

2.3.6 Prediction of design peak runoff using hydrologic soil cover complex number method

There are number of methods used for estimation of runoff. Methods suitable for small watershed are Rational Method ,Cook's Method, Table method and Hydrologic Soil Cover Complex Number Method.

The Hydrologic Soil Cover Complex Number Method which is commonly called the Cover Number Method was developed by The US Department of Agricultural and Natural Resources Conservation Service (NRSC), formerly known as the Soil Conservation Service(SCS). As compared to other methods, it is relatively simple both in term of the input and the conceptual framework.

The major factors that determine the Curve Number are the hydrologic Soil Group(HSG),Cover Type treatment and hydrologic condition of watershed.

2.3.6.1 Hydrologic soil group

SCS developed soil classification system that consists of four groups ,which are identified by the letters A,B,C and D. Soil characteristics that are associated with each groups are:

Group A. Under this category soils have a low runoff potential due to high infiltration rates even when saturated (7.6 mm/hr to 11.4 mm/hr).These soils primarily consist of deep sands, deep loess, and aggregated silts.

Group B. Such soils have moderately low runoff potential due to moderate infiltration rates when saturated (3.8 mm/hr to 7.6mm/hr). These spoils primarily consists of moderately deep to deep ,moderately well to well drained soils with moderately fine to moderately coarse textures (shallow loess, sandy loam).

Group C. Soil of this category has a moderately high runoff potential due to slow infiltration rates (1.3mm/hr to 3.8 mm/hr if saturated). These soils primarily consists of soils in which a layer near the surface impedes the downward movement of water or soils with moderately fine to fine texture such as clay loams, shallow sandy loams, soils low in organic content, and soils usually high in clay.

Group D. Such soils have a high runoff potential due to very slow infiltration rates (less than 1.3mm/hr if saturated). These soils primarily consists of clays with high swelling potential ,soils with permanently high water tables ,soils with a clay , pan or clay layer at or near the surface ,shallow soils over nearly impervious parent material such as soils that swell significantly when wet or heavy plastic clays or certain saline soils.

2.3.6.2 Cover type

The most cover type s are vegetation, bare soil and impervious surface. There are a number of methods for determining cover type. The most common are field reconnaissance, aerial photograph and land use map.

2.3.6.3 Treatment

Treatment is a cover type modifier to describe the management of cultivated agricultural lands .It includes mechanical practices, such as contouring and terracing, and management practices, such as crop rotations and reduced.

2.3.6.4 Hydrologic condition

Hydrologic condition indicates the effects of cover type and treatment on infiltration and runoff and is generally estimated from density of plant and residue cover on sample areas. *Good hydrologic* condition indicates that the soil usually has a low runoff potential for that specific hydrologic soil group, cover type, and treatment. Some factors to consider in estimating the effect of cover on infiltration and runoff are(a) canopy or density of lawns,crops,or other vegetative areas; (b) cover;(c) amount of grass or close-seeded legumes in rotations; (d) percent of residue cover; and (e) degree of surface roughness.

2.3.6.5 Antecedent Moisture Condition (AMC)

The amount of rainfall in a period of 5 to 30 days preceding a particular storm referred to as antecedent rainfall and the resulting condition of the condition in regard to potential runoff is referred to as an antecedent condition. This condition, which is most often, called antecedent moisture condition influences the direct runoff that occurs from a given storm, the effect of antecedent rainfall may also be influenced by infiltration and evapotranspiration during the antecedent period, which in turn affects direct runoff.

To determine the antecedent moisture storm conditions from data normally available, SCS developed three conditions, which were labeled II, III, and I. The soil condition for each is as follows:

- AMC I: A condition of watershed soils where the soils are dry but not to the wilting point ,and when satisfactory plowing or cultivation takes place.
- AMC II: The average cases for annual floods ,that is ,an average of the conditions ,which have preceded the occurrence of the maximum annual flood on numerous watersheds.
- AMCIII: When heavy rain fall or light rainfall and low temperatures have occurred during the 5 days previous to the given storm. and the soil is nearly saturated.

2.3.6.6 Curve number

A curve number is an index that represents the combination of hydrological soil group and land use and land treatment classes. Empirical analysis suggests that the CN was a function of three factors: soil group, the curve complex, and antecedent moisture conditions . Appendix A shows the CN values for different land uses, treatment ,and hydrologic conditions , Basic SCS Direct Runoff Equation.

In developing the SCS rainfall -runoff relationship the total rainfall was separated into three components; direct runoff (Q), actual retention (F), and the initial abstraction(la) . Conceptually, the following relationship between P, Q.la and F are assumed:-

F/S = Q/(P-Ia) ... ... (2. 4)

The actual retention is given by

F = (P-Ia) -Q ... ...(2.5)

From Eq.2.4 and Eq 2.5 the following equation was derived for runoff;-

$$Q = \frac{(P - I_a)^2}{(P - I_a) + S} \qquad \text{... ... ... (2.6)}$$

Where ,S= potential maximum retention.

To simplify Eq. 2.6, empirical relation between the available S and Ia, was developed from data collected from various watersheds in U.S.A. This empirical evidence resulted in the following equatioin :

Ia.=0.2 S for AMC II ... ... (2.7)

Ia = 0.3S for AMC I ... ... (2.8)

Ia = 0.1S for AMC III ... ... (2.9)

The final basic equation developed for computing the direct runoff depth is:

$$Q = \frac{(P - 0.2S)^2}{(P + 0.8S)} \qquad \text{... ... ... (2.10)}$$

Where , Q = direct runoff (mm)

P= rainfall (mm)

S = maximum potential retention (mm)

Runoff for other antecedent moisture conditions can similarly be obtained using the relations given in Eq.2.7 and Eq.2.8 in Eq.2.9. The variable S in Eq.2.10 is the function of the curve number . The relation between S and CN, which was developed from empirical analysis and is given by:

$$S = \frac{25400}{CN} - 254 \qquad \text{... ... ... (2.11)}$$

Effect of orientation of spatially distributed curve number

The averaging procedure used to determine runoff necessarily has an effect on the derived result .Traditionally ,an average curve number is determined first and the watershed being analysed and this value is then propagated through Eqs.2.6,2.7.2.8,2.9and 2.10 . An alternative (weighted runoff) procedure is to postpone the averaging step until after the spatially varied curve numbers have been converted to spatially varied runoff. The consequences of the use of the weighted runoff procedure were recently examined by Grove et al., (1998) in Moglen, (2000) . These two procedures can be summarized as follows:

Traditional procedure : Determine a lumped (weighted average) curve number (representative of n sub-areas with different curve numbers) . Perform one calculation for Eqs. 2.6 ,2.7,2.8,2.9, and 2.10. The result from Eq.2.10 is the lumped runoff ,QL from the watershed.

Weighted runoff procedure : Determine runoff values (representative of n sub-areas or pixels with different curve numbers) by performing n calculations each for Eqs. 2.6, 2.7, 2.8, 2.9, 2.10, and 2.11. Determine a weighted average runoff from these n values . The result of the average is distributed runoff, QD.

Because of the non-linearity in Equations 2.6, 2.7, 2.8, 2.9, and2.10 a bias is observed such that

QL . QD

Where the equality only applies if there is no variation in curve number within the basin.

New procedure (allow for infiltration infinitely downstream) proposes to continue along the spirit of the analysis undertaken by Grove et al., (1998) to account not only for spatial variability ,but also the spatial organization of the varied curve number values. The runoff produced from Eq. 2.10 for an arbitrarily chosen pixel will naturally proceed downhill ,eventually finding its way to a location of concentrated flow (termed a swale or channel in NRCS method). From the perspective of the downhill pixel,runoff and rainfall are the same : they are both sources of an input volume of water .Eq2.10 can be modified to reflect this perspective,

$$Rd = \frac{\lfloor (ERu + P)^2 - Ia}{(ERu + P + Sd - Ia)} = \frac{\lfloor (ERu + P)^2 - 0.2Sd}{(REu + P) + 0.8Sd} \quad \dots \dots \dots \quad (2.12)$$

where

Rd: the runoff leaving the downstream pixel (in units of pixel –mm or pixel inc hes);

Ru: the summation of the runoff from all immediately upstream pixels(in pixel Mm or pixel inches);

Sd: the storage of the downstream pixel (in pixel-mm or pixel inches).

This new unit of measure ,the "pixel mm" or "pixel inch" is necessitated by the flow accumulation nature of Eq.2.12 . Pixel –inches are converted back to inches after the runoff of all pixels within the watershed has been determined. The runoff. Rd (in pixel mm or pixel inches), is divided by the number of pixels draining respectively to each pixel within the watershed.

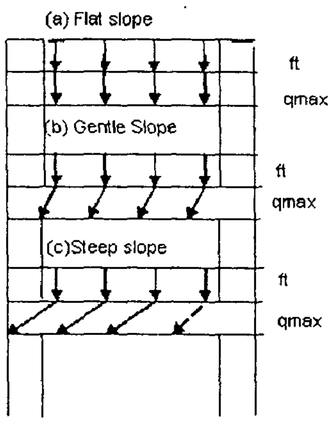


Fig.2.3 : Infiltration capacity f_t and the maximum infiltration rate q_{max} in flat land, a gentle slope, and a steep slope, respectively.

2.3.7 Infiltration capacity and Horton overland flow on a slope

Infiltration capacity was defined by Horton (12) as the maximum infiltration rate of falling rain (or melting snow) in a given soil. Since the infiltration rate is the flux of water across a land surface into soil, the maximum flux of water across a land surface into soil is equal to the infiltration capacity in flat land. However, the infiltration capacity in a slope f_t is not necessarily equal to the infiltration capacity in a flat land f_c,but generally exceeds it, especially in the early stage of infiltration. Since the flux of water in the early stage of infiltration is induced mainly by matric head gradients, the contribution of gravity is assumed to be negligible. On the flat land,fc is equal to qmax according to the definition of infiltration capacity. On a gentle slope ,the same influx refracts at the land surface due to refraction law, and the refracted flux is slightly less than qmax.On a steep slope ,the same influx refracts more at the land surface ,resulting in less flux than qmaxin the soil.

The quantitative relation between ft and the flux q (z=0) at the soil surface is given as

$$ft = \frac{Cos\beta}{Cos\alpha} q(z = 0) \qquad \ldots\ldots\ldots(2.13)$$

Where α the incidence angle of rain is flux and β is the refraction angle of soil water flux at the surface.

Apart from watershed characteristics such as land use and vegetation cover, topography and terrain profile, soil type and soil depth, which have a direct bearing the occurrence , and volume of runoff.

2.3.8 Soil erosion

Topsoil is the most vital part of soil (made-up of top soils plus layer beneath). The minimum depth is 17 cm to 20cm .this upper layer of top soil is the principal feeding zone of the plants ,which provide food for human or livestock consumption fibre for clothing ,and timber for shelter .soil constitutes the physical basis of our agricultural enterprise ,it is a sine qua non in the production of practically all food(except fish) of all fibre(without exception),and of all wood (without exception)

Water or wind ,in moving across the ground surface exerts an abrasive force which picks up soil particles and carries them away in suspension .The removal of top soil is known as normal erosion, sometimes referred to as geological erosion or the geologic norm of erosion.

It is a normal process ,proceeding with tediousness of centuries .It abrades at one place and builds (aggrades) at another . In slowly sculpturing the high lands of the world ,it contributes material for the development of alluvial plains,valleyfills,and aeolian deposits.

Where the land surface is bared of protective vegetation –as it must be under cultivation the soil is exposed directly to the abrasive action of the elements. Transportation processes of an extremely rapid order are setin motion. Stripped of the protective cover that normally anchors soil to the landscape, this indispensable material frequently isc moved a thousand times faster than under natural conditions .the accelerated phenomenon of soil removal is known as **soil erosion**.

2.3.8.1 Rain drop splash erosion: As soon as the rain drop touches the soil it deflects the soil by its velocity and weight .These deflected particles move towards channels with runoff. This phenomenon is more common in loose sandy soils.

2.3.8.2 Rill erosion: When water takes the path of least resistance to flow over the soil in forms minute channels . Rill erosion is the removal of soil by water from small well advanced channels in which the overland flow concentrates .Detachability transportability of soil particles are both greater during rill erosion than during erosion because of higher 'velocities . Rill erosion is most serious in regions where stone are of high intensity and the top soils are loose and shallow .

2.3.8.3 Gully erosion: If the channel formed in the land are so deepened and widened by erosion that their size is greater than those of common rills,then the land is no longer readily useable. The effect is then termed as gully erosion. These channels carry, huge sand and silt during the immediately after rains . Gullies care usually formed by (i) water fall eroded the gully head, (ii) channel erosion caused by water flowing through the gully~ alternate freezing and thawing of exposed soil banks and (iii) slides and mass moved of soil in the gully . Gullies are also referred to as ravines .

2.3.8.4 Stream erosion: is the scouring of materials which form the water channel and the cutting of banks by running water.

2.3.8.5 Land slide erosion: This form of erosion caused by land slide, is common on steep hill slopes, which are subject to heavy rainfall because the soil gets saturated with water and its weight increases . Also the water weakens the cohesion between the soil particles. Under this condition the soil yields to gravity and slide down.

2.3.9 The Universal Soil Loss Equation USLE

Wischmeier and Smith (1960 and 1978) developed the Universal Soil Loss equation (USLE) for prediction of gross soil erosion. The USLE is an empirical model most widely used for estimation of soil loss from sheet and rill erosion. The equation states that :

$$A = R\,K\,L\,S\,C\,P \qquad \text{(2.14)}$$

Where : A = Average annual soil loss in tons per hectare year

R = Rainfall / runoff erosivity

K= Soil erodibility

LS = Hill slope length and steepness

C = Cover – management

P = Support practice

The R factor is an expression of the erosivity of rainfall and runoff at a particular location . The value of "R" increases as the amount and intensity of rainfall increases.

The K factor is an expression of the inherent erodibility of the soil or surface material at a particular site under standard experimental conditions. The value of "K" is a function of the particle -size distribution, organic -matter content, structure, and permeability of the soil or surface material.

The LS factor is an expression of the effect of topography ,specifically hill slope length and steepness ,on rates of soil loss at a particular site . The value of "LS" increases as hill slope length and steepness increase ,under the assumption that runoff accumulates and accelerates in the down slope direction . This assumption is usually valid for lands experiencing overland flow but may not be for forest and other densely –vegetate.

The C factor is an expression of the effects of surface covers and roughness, soil biomass, and soil-disturbing activities on rates of soil loss at a particular site. The value of "C" decreases as surface cover and soil biomass increase, thus protecting the soil from rain splash and runoff.

The P factor is an expression of the effects of supporting conservation practices, such as contouring ,buffer strips of close–growing vegetation ,and terracing ,on soil loss at a particular site . The value of "P" decreases with the installation of these practices because they reduce runoff volume and velocity and encourage the deposition of sediment on the hill slope surface. The effectiveness of certain erosion – control practices varies substantially due to local conditions. For example, contouring is far more effective in low-rainfall areas than in high-rainfall areas.

2.3.9.1 Rainfall/runoff erosivity factor

The erosivity factor of rainfall ® is a function of the falling raindrop and rainfall intensity (Wischmeier and Smith1958) in G Das(2002) found that the product of the kinetic energy of the raindrop and the maximum intensity of rainfall over a duration of 30 minutes,in a storm as the EI value. It has been established that this value gives a very good correlation for estimation of soil loss , and is the most reliable single estimate of potential of rainfall intensity.

The EI values are determined from the recording rain gauge data of each storm. The rainfall mass curve is divided into small increments, and for each increment the values for intensity of rainfall and their raindrop –kinetic energy E) are calculated.

From these calculated values ,the maximum intensity of rainfall during 30 minutes duration(I_{30}) is then determined . The multiple of this value with E, gives the EI_{30} value. The erosivity of rain is calculated for each storm ,and these value are summed up for the desired periods, namely weeks,months,years,etc.The kinetic energy is calculated by the following formula(Wischmeier and Smith,1978) in G Das, (2002)

Kinetic energy of Rainfall (E) = $.E_i$ ……… (2.15)

Where :

$$.E_i = \sum_{i}^{n} (210.3 + 89 \log_{10} I_i) \qquad \text{……… (2.16)}$$

Where:

E = total kinetic energy of rainfall

E_i = rainfall kinetic energy of the ith increment (per storm) m-t/ha-cm.

I_i = average intensity of rainfall during the ith increment (each storm) , cm/ha

N = total number of discrete increment.

The kinetic energy of rainfall can also be calculated as follows:

$$E_i = (200 + 87 \log_{10} I_i) P_i$$

$$E = \sum E_i = \text{kinetic energy of rainfall ,J/m}^2$$

Rainfall Factor ® = $\sum$ Erosion Index ………(2.17)

Or

$$\text{Rainfall Factor ®} = \sum_{i=1}^{N} \frac{E_i I_{30}}{100} \quad \text{……… (2.18)}$$

Where

E_i = rainfall kinetic energy ,kg-m/m ^{2} -mm

I = maximum intensity of rainfall during a continuous periods of 30 minutes . mm/h

n = number of rainstorm per year

For meteorological stations that did not have automatic recording rain gauges ,the following relation can be used to approximate EI_{30} values.

a. Feasibility Study Report, Identification Study and Detail design of Small Pond in East Java Province of Churachandpur used approximate:

$$EI_{30} = ExI_{30} x10^{-2} \quad \text{……… (2.19)}$$

$$E = 14.374 R \quad \text{……… (2.20)}$$

$$I_{30} = R/(77.178+1.010R) \quad \text{……… (2.21)}$$

b. Bolds,(1978) developed formula for Java ,for estimation of rainfall factor:

$$E I_{30} \text{ monthly} = 8.119 \, Rm^{1.21} x N^{-.44} x R_{max}^{0.53} \quad \text{……… (2.22)}$$

Where,

Rm =average monthly rainfall in cm

Rmax = average maximum daily rainfall in cm

N = average number of rainy days per month

2.3.9.2 Soil erodibility factor, K

The soil –erodibility factor represents, susceptibility of soil or surface material to erosion , transportability of the sediment ,and the amount and rate of runoff given a particular rainfall input ,as measured under a standard condition .

Fine –textured soils that are high in clay have low K values(about0.05 to 0.15) because the particles are resistant to detachment . Coarse -textured soils ,such as sandy soils ,also have low K values (about 0.05 to 0.2) because of high infiltration resulting in low runoff even though these particles are easily detachable . Silt loam the medium textured soil have moderate K values(about0.25 to 0.45) since they are moderate to particle detachment and have moderate runoff .High silt ccntent soils are erosion prone and have high K value ranging from 0.45 to 0.65 since particles are highly detachable producing high rate of runoff .

The presence of organic matter reduces erodibility and surface runoff help biological activity thereby increase infiltration rates . The value of K is dependant of permeability it changes runoff.Soil structure also changes infiltration rate .mineralogy also changes K even in subsoil strata.

Valadimir et al., (1981) give a table of magnitude of soil erodibility as under

Table 2.1: Magnitude of soil erodibility factor (K) , (after Novotny and Olem 1994)

Textural class	K for organic matter content (%)		
	<0.5	2.0	4.0
Sand	0.05	0.03	0.02
Fine sand	0.16	0.14	0.10
Very fine sand	0.42	0.36	0.28
Loamy sand	0.12	0.10	0.08
Loamy fine sand	0.24	0.20	0.16
Loamyveryfine sand	0.44	0.38	0.30
Sandy loam	0.27	0.24	0.19
Fine sandy loam	0.35	0.30	0.24
Very fine sandy loam	0.47	0.41	0.33
Loam	0.38	0.34	0.25
Silt loam	0.48	0.42	0.29
Silt	0.60	0.52	0.42
Sandy clay loam	0.27	0.25	0.21
Clay loam	0.28	0.25	0.21
Silty clay loam	0.37	0.32	0.26
Sandy clay	0.14	0.13	0.12
Silty clay	0.25	0.23	0.19
Clay		0.13-0.20	

2.3.9.3 Hill slope length and gradient factor (LS)

The effect of topography on erosion is accounted for by the LS factor in USLE ,which combines the effect of a hill slope-length factor ,L, and a hills slope gradient factor ,S. generally speaking ,as hill slope length and/or hill slope gradient increase ,soil loss increases . As hills slope length increases ,total soil loss and soil loss per unit area increase due to the progressive accumulation of runoff in the down slope direction . As the hill slope gradient increases, the velocity and erosivity of runoff increases . The following sections of this chapter describe the effects of L and S on soil loss rates ,the interactions between L and S, and their combined effects on soil loss, and the ability of USLE to estimate soil loss from non-uniform ,complex ,hill slopes.

Hill slope –length factor (L)

Inter rill erosion is the main cause of soil loss distributing uniformly all along hill and the value of L will increase with length and increases in down slope direction since runoff accumulates . Both inter rill and rill erosion causes soil loss. When interrill erosion predominates the value of L remains constant with the increase of hill slope length however if rill erosion predominates the value of it increases linearly .

Wischmeier and Smith (1965) ,derived the following relation between soil loss and slope length.,

$$L = (\lambda / 22.13)^{m} \qquad \text{......... (2.23)}$$

Where:

= slope length measured from the water divide of the slope(m)

m = exponent dependent upon slope gradient and may also be influenced by soil properties ,type of vegetationetc.

Recommended exponent values (Wischmeier and smith, 1978) are given in the following table below.

Table 2.1: Recommended value of m

Slope gradient(%)	m
S<1.0	0.2
1.0< S<3.5	0.3
3.5 < S<4.5	0.4
4.5 < S <5.5	0.5

2.3.9.4 Hill slope –gradient factor (S)

This factor shows the effect of soil loss on hill slope profile gradient . In case of (% gradient in a unit plot the value of S is equal to 1. These values of S varies above to below 1 if gradient is greater than or less than of the unit plot.If gradient increases more than soil length soil loss increases . Rill erosion changes rapidly with change of hill slope gradient rather then inter rill erosion.

Gradient of a hill slope profile is defined by the change in elevation with change in horizontal distance and is expressed in percentage . In the field the gradient of hill slope can be measured by rod and Abney or hand level, electronic survey level,& GPS unit along with length of slope . Digital aerial survey and specific site maps are also used to measure hill slope gradient however their accuracy is directly proportional to scale .

By field measurements and experiments on soil monoliths Masgrave,(1947) ,Zingg,(1940) ,Neal; (1938) et al., derived the following empirical relation between soil loss and slope gradient.

$$S = f \mid (S_w)^n \qquad \text{.........(2.24)}$$

Where:

S = Soil Loss

S_w = Slope gradient

n = power value whose value range from 0.8 to 1.5 (n in Masgrave expression = 1.35 ,Zingg=1.4 , and Neal =0.8)

Wischmeier and Smith (1962) processed a large number of data received from experimental stations on intensity of erosion and by using USLE the following expression was developed:-

$$S = f\frac{[0.43+0.30*S_w+0.043*(S_w)]}{6.613} \qquad \text{.........(2.25)}$$

Where:

S = Slope gradient factor

S_w = Slope gradient (%)

The combination effect of the slope gradient and slope length can be calculated from the following equation:-

$$LS = (\lambda / 22.13)^{m} * \frac{[0.43 + 0.30 * S_w + 0.043 * (S_w)]}{6.613} \quad \ldots\ldots\ldots (2.26)$$

2.3.9.5 Cover –management factor C

Cover –management factor© represents the effect of vegetation, management and erosion- control practices on soil loss . As with other USLE factors ,the C value is a ratio comparing the existing surface conditions at a site to the standard conditions of the unit plot as mentioned earlier.

The effect of plant,soilcovers,soil biomass (roots and incorporated residue)and soil disturbing activities on soil loss are represented by C-factor. The sub-factor method to compute soil-loss ratios (SLR) used in USLE as ratio of soil loss at any given time in the cover-management sequence to soil loss under standard conditions. The land use, canopy cover, surface cover, surface roughness ,and soil moisture are important sub-factors for computation of soil-loss ratio. Average soil – loss ratio is used for computation of C by distribution of rainfall EI(energy intensity) in a year .

2.3.9.5.1 Canopy cover

It is the vegetative cover above soil surface that intercepts raindrop.USLE use following characteristics of canopy

(1) The percent of surface covered by the canopy.

(2) The height within the canopy from which intercepted raindrops re-form into water droplets and fall to the ground; this fall distance is known as the " effective fall height"

Open spaces in a canopy are not used in planners estimating.

Effective Fall Height

This is measured from the ground up to level from which majority of water droplets fall and varies with the vegetation type, the density of the canopy ,and the architecture of the plants.

2.3.9.5.2 Surface cover

The soil that intercepts raindrops and slows surface runoff is termed as surface cover e.g. mulches and rock fragments, live vegetation in contact with soil surface ,cryptogrammic crusts(which are formed by mosses or fungi in the soil), plant litter. If small size it must be anchored to the surface and in case of big size it should be such

2.3.9.5.2 Surface cover

The soil that intercepts raindrops and slows surface runoff is termed as.surface cover e.g. mulches and rock fragments, live vegetation in contact with soil surface ,cryptogrammic crusts(which are formed by mosses or fungi in the soil), plant litter. If small size it must be anchored to the surface and in case of big size it should be such that wind or water have no effect on it. Surface cover and rock overlapping is commonly used in USLE.The percent rock cover is transferred through K factor screen to C factor computations.

Mulch is commonly used in dominant type of soil erosion occurring on the slope, the slope gradient, the extent of contact between the surface cover and the soil. In general, surface cover does a better job of reducing rill erosion rates than it does in reducing inter rill erosion rates(Foster ,1982).For soil erosion due to riling a given cover material will reduce erosion more than if the same amount of cover material were placed on a soil that is eroded by in Terrill erosion.

In steep hill slopes(greater than 10% gradient) the share of rill erosion is more than in Terrill erosion. On the other hand in Terrill erosion on hill slopes (less than 3% gradient) is more than rill erosion The cover material help in reduction of steep hill slopes soil erosion rather than flat hill slopes.

Surface cover becomes more useful if soil and surface cover are in good contact so that cover remaining in place. Otherwise severe rill erosion may occur. Hence, mulch must be placed to in such a way to keep maximum contact with the soil.

Meyer et al., (1971, 1972) proved that mulch on construction sites is less effective than nonagricultural land. Normally low b value is used while programming with mulchsincecontact and bonding between mulch and subsoil is assumed to be less effective in comparison to bonding between the mulch and the top soil. If contact is fair not good between mulch and the soil the smallest value of b is used since effective and vulnerable soil remains beneath the cover. In order to prevent runoff or wind guided soil erosion mulch should always be anchored to the soil.

2.3.9.5.3 Surface roughness

The disturbance of soil shows two types of surface roughnesses i.e.

(1) Oriented

(2) Random

Oriented roughness

It is recognizable e.g. ridges and furrows made by "cattracking" or a chisel plow used in preparation of seedbed .It redirects surface runoff and take sediment if ridges and furrows are nearer to the contour ,runoff move along the slope rather than directly downslope therby reducing erosivity of the runoff.It is inherited in P factor.

Random roughness

Soon after oriented roughness considered it is usually the standard deviation of the elevation from a plane across a tilled . Normally no recognizable pattern is available though it is the result of soil disturbing activities such as clods and aggregates .The erosion rate can be reduced by ponding water between clods which slows down runoff,increases infiltration and stores sediment.Random roughness normally varies with the initial condition of the site,the tillage implement and its use,soil texture and soil moisture at the time of disturbance .

2.3.9.5.4 Cover –management systems

The cover management system includes plant types, surface covers, and operations combinedly with planting or implementation dates for calculation of C values.

2.3.9.6Support –practice factor,P

In construction –site reclamation planning and mined land's USLE soil loss estimates cover- management © and support-practice (P) factors have due design considerations to control erosion. In USLE p is the ratio of soil loss with a specific support practice to the corresponding soil loss with straight –row upslope and down slope tillage factor P influence the drainage patterns, runoff concentration ,runoff velocity and hydraulic forces exerted by runoff on soil by controlling and reducing it. It is further supported by mechanical measures i.e. tillage (furrowing, soil replacement, seeding, etc.), strips of close growing vegetation, deep ripping, terraces, diversions,and other soil-management practices oriented or on near the contour help in reduction of runoff(AH-703,Renard et al., 1997).

2.3.10 Engineering measures for catchment protection

These measures are adopted to prevent raindrop splash erosion, sheet erosion, gully erosion and to make usable severely eroded agricultural and non agricultural

Table 2.3: Cover and management factor © Hamer et al.,

No.	Crop management	C value
1.	Finely tilled ridge surface	1.50
2.	Bare cultivable soil	1.00
3.	Irrigated sawah	0.01
4.	Rainfed sawah	0.05
5.	Upland crop(tegalan),not specified	0.70
6.	Cassava	0.80
7.	Interplanted cassava and soybean	0.20
8.	Maize	0.70
9.	Beans	0.60
10.	Potato	0.40
11.	Groundnut	0.20
12.	Rice	0.50
13.	Sugarcane	0.20
14.	Serai Wangi(Cymopophagon)	0.40
15.	Tales(yam)	0.85
16.	Spices (chilli,ginger)	0.90
17.	Brachiaria grass for stock feed at establishment stage Subsequent years	0.30 0.02
18.	Shrub /grassland	0.30
19.	Multistory mixed garden high density ground cover medium-density ground cover low-density ground cover	0.10
20.	Estate crops (poor ground cover) Rubber Tea Oil palm Coconut	 0.80 0.50 0.50 0.80
21.	Natural forest ,primary,well-generated High litter Low litter	 0.001 0.005
22.	Surface mullah Litter or straw, 6MT/ha/yr Litter or straw ,3MT/ha/yr Litter or straw, 1MT /ha/yr	 0.30 0.50 0.80
23.	Very well protected soil	0.00

Table 2.4:Conservation support practice factor(P) Hamer et al.,1980

No.	Conservation practice	P value
1.	Bench terraces High standard design/construction Medium standard design/construction Low standard design /construction	 0.04 0.15 0.35
2.	Traditional terrace	0.40
3.	Hillside trenches (silt pit)	0.30
4.	Contour cropping 0-8% slope 0-20% slope higher than 20% slope	 0.50 0.75 0.90

ultural lands. These are followed by afforestation measures to minimize further land degradation .

Principles to be Followed:

- Increase time of concentration help to reduce runoff and allow more water to be absorbed by the soil.
- Dividing the slope into small segments keeping velocity of flow below critical limits.
- Control of water and soil loss.

2.3.10.1Measures on agricultural land

2.3.10.1.1Terraces

An embankment constructed to control runoff and soil erosion across the slope on sloppy land .These divide the slope into small strips thereby reducing runoff velocity . The soil loss is proportional to the square root of the length of slope hence by reducing the length the soil loss is reduced . Raindrop splash eroded soil flowing with runoff is stopped by terraces. Due to limiting length between the terraces the runoff velocity always remain below the critical velocity .

Terraces are of following two types:

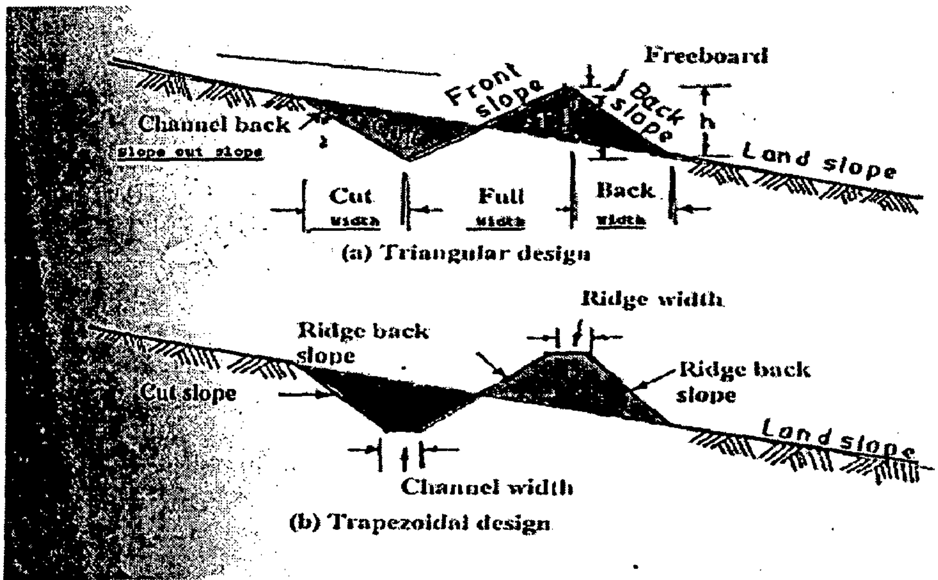


Fig.2.4 Cross-sectional view of a broad base terrace

2.3.10.1.1.1 Broad –base terraces

It consists of ridge with broad base so that farm machinery can move to and fro over it . All sloppy land with broad-base terraces can be cultivated
These are also following two types

- **Level terraces:**

These are also termed as ridge types of terraces .These are further classified as narrow –based and wide based decided by width of the channel and ridge .
The width of narrow based terraced varies from 1.2 to 2.5m. No farm machinery can be installed over it.

- **Graded terraces**

The design of graded terraces involve its spacing, capacity and cross-sections.

2.3.10.1.1.2 Bench terraces

The slope gradients are controlled and erosion is reduced by these terraces though they are costly on hills frequently used being environmentally sound in use.These are frequently used on slopes is greater than 35% . These are constructed in medium to high degree of hazards of soil erosion .Their design is dependent of gradient of slope,soil depth,type of earthwork in fill or cutting ,crops and cropping pattern as shown in figure 3.5. The construction of bench terrace helps in dividing the steep land surface into a series of leveled segments of non-risky farm lands .

2.3.10.1.1.3 Contour bunding

It is commonly known as narrow base terracing These are low height earthen embankment either along contours or with a permissible deviation from watershed contours.Contour bunding are used in rolling (slope less than about6%) and in plain lands with little rainfall (annual rainfall less than 100cm). These are useful in permeable soils (except clay and black cotton soils)and used where runoff flowing down on slope to check soil erosion.

2.3.10.1.1.4 Vegetative barriers

Vegetative barriers consists of closely spaced plants ,grass hedges . These are grown in one or more rows along contour or in one or more rows along contour or on small grades to check erosion in agricultural fields .It is of sufficient proof that grasses like Vertiver hedge rows ,Leucaena,Lemongrass ,and Cenchrus are most feasible solution to control runoff and erosion for nearly flat topography .They are much popular between successive terraces to check high velocity of overflowing water.

Objectives:

- It act as a barrier to moderate the velocity of overland flow and as a trap for silt ,in that top soil cover is kept unharmed.
- It reduces the cost on terracing since these are far cheaper.
- It augment productions of food ,fuel,fodder or fibre from farm lands growing for vegetative barriers of largely growing species.
- It enhance income to concerned farmers.

Preferable site conditions

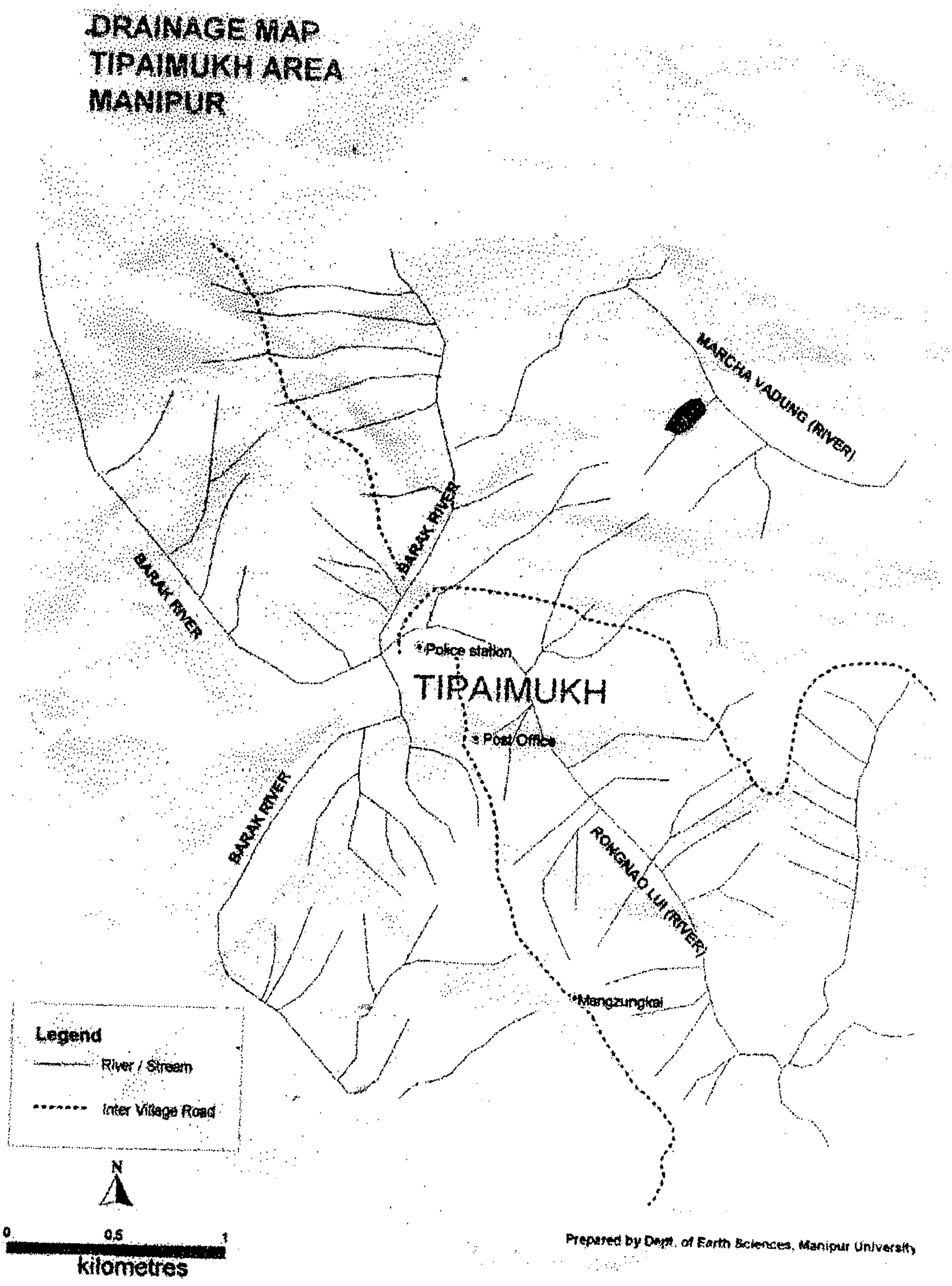
These are used when there is large uncovered masses of soils of thin to very thin grass cover. These are not much suitable to class II to classVII lands of North Eastern Region of India and other desert areas.Here local grasses are preferred.They are site based and depends on soil and climatic variables and only whenthere is no cattle grazing .

Functioning

It should act as a filter to help silt and cut down the velocity of flow.

Concluding remarks

The chapter relates to the watershed,watershed management, rainfall ~runoff characteristics , soil erosion ,curve number ,engineering measures well adopted in the study.


DRAINAGE MAP
TIPAIMUKH AREA
MANIPUR
MARCHA VADUNG (RIVER)
BARAK RIVER
BARAK RIVER
BARAK RIVER
Police station
TIPAIMUKH
Post Office
RONGNAO LUI (RIVER)
Mangzungkai
Legend
River / Stream
Inter Village Road
N
0
0.5
1
kilometres
Prepared by Dept. of Earth Sciences, Manipur University

STUDY AREA

3.1 General

In the present study five watersheds namely Tuijang, Barak, Tuicha, Leimatak and Khuga watershed of Churachandpur District of Manipur State of India are chosen. These watersheds are located in between latitude 24 ^{0} N to 24 .3 ^{0} N and between longitude 93.15^0 E to 94 ^{0} E . The area is surrounded in the North by Tamenglong district, in the west river Barak flowing from south to north, in the east by Manipur River and Loktak Lake, Mizoram and Burma in the south. The 70 % of the area is hilly with deep forests and the rest is sloppy plain with altitude ranging between 300m to 1100m, which consist of farmland, housing area etc.

The total area of the district is 4,570 sq km while area of these five watersheds is 35,329 ha. .The area consists of 1 municipality, 502 small towns,6 subdivisions. As per 2001 census the total population of the district was 2,06,848. The density of population per sq.km is 45 and its growth of population is 17% .Figure 3.1 represent the study area.

Development of Barak basin was started in early fifties . The survey and investigation of Tipaimukh dam project was completed in 1979-80 by CWC . The soil survey and socio-economic survey of Tuijang sub-watershed was also completed in the year 1981. In later stage a series of projects are completed in the basin .Large numbers of master plans, project reports, and drainage reports are prepared to overcome the floods and to reduce the salinity in the basin. Basic concept of this development was comprehensive and integrated development that was "one river, one plan, and one coordinated management" because water is a dynamic resource that flow from upstream down to the estuary as an unity. Even though the river was flowing across the boundary of the districts, prefectures or countries, it has to be managed as an unity to avoid conflict of interest. This is essential when water is to be shared among States. The water of the river Barak is to be shared by three States namely Manipur, Mizoram and Assam. Up to the year 2001 , benefits of the Barak river basin development were flood control (protection of about 1,40,000 ha of land) namely Manipur, Mizoram and Assam. Up to the year 2001 . benefits of the Barak river basin development were flood control (protection of about 1,40,000 ha of land) , embankment & drainage (construction of 270 km of embankment) ,irrigation (supply of water for about 1,25,000 ha of paddy field) , electricity (upcoming approximately 3,000 MW),drinking water (supply raw water about 500 million m^3 /year),industrial water (supply raw water of about 150 million m^3/year) , fishery, recreation etc. The Barak basin has supported about 5% of National Stock of rice. Development of Barak river basin has raised up social life prosperity in economy, social and culture within the river basin. Field survey results, most of people take water from both dug-well and hand pump and the rest from river and spring

Agricultural sector is of the main livelihood of the people of the study areas. Average percentage of farming household is 70%. Types of crops those are common in the project area consists of Paddy, Maize, Coffee, Soya bean, Groundnut, sugarcane. Average paddy production is 1.64 ton/ha in rain fed conditions. Maize production is 2.5 t/ha in rain fed conditions. Free intake, ponds and pumps are traditional irrigation systems coming up in the area with water resources supplied from river spring and ground water.

Climate data for all the watersheds collected from local T.E. The Tipaimukh Damsite data ia available from beginning of 70's. The period of data collected is from 1970 to 2004.

The agro-ecological zones of the project area, which are at most spreading within the Barak river basin and Manipur river basin, are classified in accordance within the following components

3.2 Soil order

The soil is brown and covers capability classes II to VII. It is poor in lime and low in phosphorus content and with 1 to 3% organic matter. The first survey was conducted in 1981.

Following ten series are found in the five watersheds and their properties are recorded as following

STUDY AREA

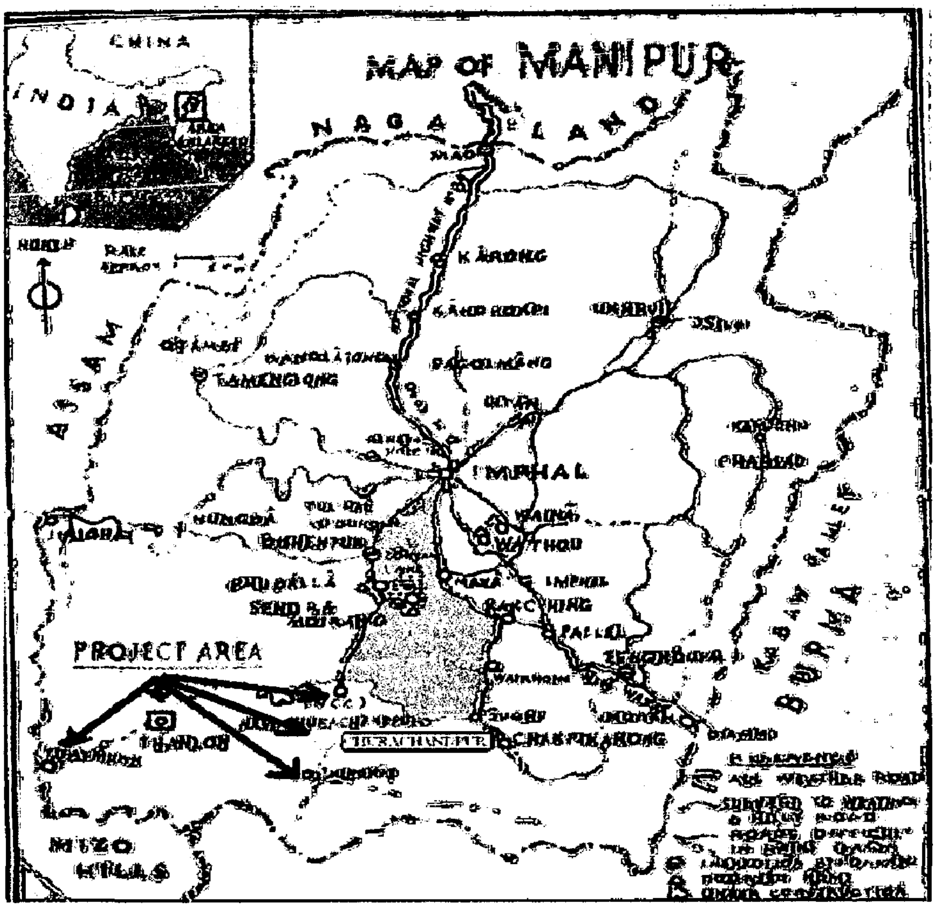


Figure 3.1 Study Area

1. Akui series

Slope varies 5-20% .Depth is 0-90cm..It is of high infiltration and medium erosion soil.

2. Dialong series:

Slope varies 10-35% .Depth. is 0-55cm. of medium infiltration and high erosion soil.

3.Gumta series

Slope varies 20-35%.Depth is 0-105cm .It is of low infiltration and high erosion soil.

4. Nonet series

Slope varies 15 -40%.Depth is 0-90cm. It is of low infiltration and severe erosion soil.

5.Thinkew series

Slope is greater than 50% . Depth is 0-67.5cm . It is of medium infiltration and high erosion soil.

6. Leimatak series

Slope is greater than 60% .Depth is 0-90cm .it is of low infiltration and severe erosion soil.

7. Ukramei series

Slope varies 10-35%. Depth is 0-45cm. It is of high infiltration and high erosion soil.

8. Tuijang series

Slope is less than 20 %.Depth is 0-90cm .It is of high infiltration and high erosion soil.

9. Khuga series

Slope is less than 20% .Depth is 0-90cm .It is of high infiltration and high erosion soil.

10. Barak series

Slope is less than 20% .Depth is 0-90cm .It is of high infiltration and high erosion soil.

3.3 Acidic regime

The soils are acidic and suitable for paddy cultivation and plantation crops after terracing

3.4 Temperature regime

The area lies in sub-tropical zones and its mean monthly maximum temperature varies from from 20^0C to 28^0C and minimum temperature is nearly 4^0 C.As per international standard the area is isothermic.

3.5 Physiography

The region is hilly, the average elevation varies 1300m .The slope of these watersheds varies from 10% to 200% .The average slope of 60% of the area is greater than 50% , greater the slope greater the soil erosion. The region is classified into three groups

- **Flat to gently sloping:** The area with less the 3% slope degree and difference in height of less than 5m.
- **Undulating to rolling:** The area with less than 3 to 15% slope degree and difference in height 5-50m .
- **Hilly to mountainously:** The area with more than 15% slope in degree and difference in height of 50

Climatic data of the various stations are collected from I.M.D.Imphal.State Irrigation Department. Flood Control Department for Churandpur. Than Lon, Khuga Dam Project Churachandpur ,Local T.E. Other departments like CWC for other stations. Rainfall data of Tipaimukh is collected from Tipaimukh dam Project for the year 1970 to 2004. The water harvesting structures are available at Tipaimukh Dam Project and Khuga Dam Project.

3.6 Data Acquisition

3.6.1 Tuijang watershed

3.6.1.1 General information

(i) Name of watershed		: Tuijang
(ii) Name of river/ river basin		: Tuijang
(iii) Land use		
	- Settlement /residential	: 90 ha
	- Paddy field	: 47 ha
	- Rainfed and secondary crop	: 198 ha
	- Bush/ pasture lands	: 4,857 ha
	- Forest / plantation trees	: 1,576 ha
(iv) Geography		
	- Coordinate	: $24^0 9'$ N to $24^0 12'$ N
		$93^0 9'$ E to $93^0 12'$ E

- -Map : GSI Landuse map 1:2,50,000
- - Elevation :679m
- -Land form : Steeply undulated ridge
- - Average slope :42%
- - Geological formation :Alluvial, sandstone loam
- - Soil type :Oxisol
- - Soil Texture :Moderate

(v) Hydrology and climatology

Description	Rainfall (mm)	Temperature (°C)	Humidity (%)	Sunshine (%)	Wind velocity(Km/hr)
Yearly average	2,700.60	25.93	82.45	62.22	1.33
Name of station	Thanlon	Songpekmun			
Observation period	1970-2004	1970-2004			

3.6.1.2 Benefited village profile

(i)Population and main occupation

No	Description	Town/ village
1	Nos of population(year 2001)	2,807
2	Population density (person/km2)	123
3	Average population growth	17%
4	Nos of household	326
5	Main occupation a. Farming (household Nos) b. Other main occupation - Animal husbandary - Gardener - Construction labour - Trader /industry - Government official / soldier	 186 53 13 15 40 19
6	Average income / year (rupees)	3,30,000

*District data

(ii) Land & farm land ratio

No	Description	Area (ha)
1.	Settlement	52
2.	Paddy field -Technical irrigation - Semi technical irrigation - Simple irrigation	 10 45 60
3.	Farm land per household (ha/house)	0.42
4.	Irrigation farm land per household ha/house)	0.10

(iii) Agricultural food crop production (ton / ha)

Crop	Paddy field			Rain fed	Upland
	Technical	Semi technical	Simple irrigation		
Ws paddy	5	4	3.5	2.50	2.50
Ds I paddy	5	3	2.5	2.0	2.00
Ds II paddy	5	3	2.5	2.0	2.00
Maize	1.25	1.2	1.1	1.0	0.80
Soyabean	1.25	1	0.8	0.75	0.70

(iv) Water resources and allocation

(a) Irrigation

Resources	Water tapping	Area served		Availability/ year (month)	Name of scheme
		(ha)	(%)		
Spring/river	Free intake weir	492	94	8	Thanlon
Rain		26	5	5	
Deep well	By hand	3	0.6	12	
Shallow well	By hand	2	0.4	10	

(b)Water supply

Resources	Water tapping	Water supply	Distance of take (km)	Served	
				Household	Persons
Spring	Bucket	By foot	1.0	34	293
River	Bucket	By foot	1.0	237	2032
Deep well	Hand pump/bucket	By foot	0.1	34	293
Shallow well	Hand pump / bucket	By foot	0.1	22	189

3.6.1.3 Present condition of beneficiary area

(i)Irrigation

Description	Irrigation paddy field			Rain fed			Upland		
	Crop area (ha)	Intensity (%)	Product (t/ha)	Crop area (ha)	Intensity (%)	Product (t/ha)	Crop area(ha)	Intensity %)	Product (t/ha)
Paddy Ws	60	100	2.25						
Paddy Ds	30	50	2.25	17.5	25	1.75	5	25	1.75
Paddy Ds -I	32.5	50	2.25	17.5	25	2	5	25	1.25
Maize	13	50	1.25	6.5	25	1.00	6.5	25	1.00
Total	145.5	250	8.00	41.5	75	4.75	16.5	75	4.00

3.6.1.4 Proposed development plan

(i)Small pond

- Name of pond : :Thanlon
-Location : District :Churachandpur
Village :Thanlon
- Distance : 2.5km
District : 150Km
-Type : Homogeneous fill
- Dam body, height/length : 10.5m/43.5m
-Catchment area : 1,050ha

- Impounding area	: 0.22 ha
- Storage volume	: 6900 m3

(ii) Irrigation development plan

- Area	: 115ha
-Proposed cropping pattern	: Paddy –Maize- Groundnut
- Crop intensity	: 300%
- Storage volume	: 50,000 m^3
- Unit diversion requirement	: 2.00 l/sec
-Discharge diversion requirement	: 0.82m3/sec
- Intake	: Left
- Method of irrigation	: Gravity

(iii) Water supply development plan

-Nos of beneficiary	
-Supply design Requirement	: 60 l/day/capita
- Intake	: Left
-Method of water supply	: Gravity
. Pipe Line Requirement	: 2,000 m

(iv) Access road development plan

- Existing	: Footpath (upland)-4nos.
- Length	: 1km
- Wide	: 5m
- Proposed	: 2km ,zeepable road 6m wide.

3.6.2 Barak watershed

3.6.2.1General information

(i) Name of watershed	: Barak
(ii) Name of river/ river basin	: Barak
(iii) Land use	
- Settlement /residential	: 96 ha
- Paddy field	: 50 ha
- Rainfed and secondary crop	: 211 ha

- Bush/ pasture lands :5,17 8ha
- Forest / plantation trees : 1,680 ha

(iv) Geography

- Coordinate : $24^0 14'$ N to $24^0 18'$ N
  : $93^0 2'$ E to $93^0 5'$ E
- Map :GSI Landuse map 1:2, 50,000
- Elevation : 600m
- Land form :Steeply Undulated Ridge
- Average slope : 40%
- Geological formation :Alluvial, sandstone loam ,shale
- Soil type : Oxisol
- Soil texture :Moderate

(v) Hydrology and climatology

Description	Rainfall (mm)	Temperature (°C)	Humidity (%)	Sunshine (%)	Wind velocity(Km/hr)
Yearly average	2,810.00	28.50	58.33	64.00	1.33
Name of station	Taithu	Sartuinek	Tipaimukh		
Observation period	1970-2004	1970-2004	1970-2004		

3.6.2.2. Benefited village profile

(i)Population and main occupation

No	Description	Town/ village
1	Nos of population(year 2001)	4,065
2	Population density (person/km2)	123
3	Average population growth	17%
4	Nos of household	472
5	Average income / year (rupees)	3,50,000

*District data

(ii) Land & farm land ratio

No	Description	Area (ha)
1.	Settlement	55
2.	Paddy field -Technical irrigation - Semi technical irrigation - Simple irrigation	 11 48 64
3.	Rainfed	41.5
4.	Upland	16.5
5.	Bush	4
6.	Estate	330
7.	Forest	768
8.	Others	27
9.	Farm land per household (ha/house)	0.44
10.	Irrigation farm land per household ha/house)	0.10

(iii) Agricultural food crop production(ton/ha)

Crop	Paddy field			Rainfed	Upland
	Technical	Semi technical	Simple irrigation		
Ws paddy	5	4	3.5	2.50	2.50
Ds I paddy	5	3	2.5	2.0	2.0
Ds II paddy	5	3	2.5	2.0	2.0
Maize	1.25	1.2	1.1	1.0	0.8
Soyabean	1.25	1	0.8	0.75	0.70

(iv) Water resources and allocation

(a) Irrigation

Resources	Water tapping	Area served		Availability/ year (month)	Name of scheme
		(Ha)	(%)		
Spring/river	Free intake weir	525	94	8	Tipaimukh
Rain		28	5	5	
Deepwell	By hand	3	0.6	12	
Shallow well	By hand	2	0.4	10	

3.6.2.3 Present condition of beneficiary area

(i)Irrigation

Description	Irrigation paddy field			Rainfed			Upland		
	Crop area (ha)	Intensity (%)	Product (t/ha)	Crop area (ha)	Intensit(%)	Product (t/ha)	Crop area(ha)	Intensity (%)	Product (t/ha)
Paddy Ws	75	100	2.25						
Paddy Ds	38	50	2.25	22	25	1.75	6.35	25	1.75
Paddy Ds-I	41	50	2.25	22	25	2	6.35	25	1.25
Maize	16	50	1.25	8	25	1.00	8.30	25	1.00
Total	170	250	8.00	52	75	4.75	21	75	4.00

3.6.2.4 Proposed development plan

(i) Small pond

- Name of pond : : Sartuinek

-Location : District : Churachandpur

Village :Sartuinek

- Distance : 2km

District : 120Km

-Type : Homogeneous fill

- Dam body ,height/length : 10.5m/43.5m
- Catchment area : 1,115ha
- Impounding area : 0.23 ha
- Storage volume : 7,000 m3

(ii) Irrigation development plan

- Area : 125ha
- Proposed cropping pattern : Paddy –Maize- Groundnut
- Crop intensity : 300%
- Storage volume : 50,000 m^3
- Unit diversion requirement : 2.00 l/sec
- Discharge diversion requirement : 0.82m3/sec
- Intake : Left
- Method of Irrigation : Gravity

(iii) Water supply development plan

- Nos of beneficiary
- Supply design : 60 l/day/capita

Requirement

- Intake : Left
- Method of water supply : Gravity
- Pipe line requirement : 2,000 m

(iv) Access road development plan

- Existing : Footpath(upland)-4nos
- Length : 1km
- Wide : 5m
- Proposed : 2km ,zeepable road 6m wide.

3.6.3 Tuicha watershed

3.6.3.1 General information

(i) Name of watershed : Tuicha

(ii) Name of river/ river basin : Tuicha

(iii) Land use

- Settlement /residential : 39 ha
- Paddy field : 21 ha

- Rainfed and secondary crop : 87 ha
- Bush/ pasture lands : 2,123 ha
- Forest / plantation trees : 689 ha

(iv) Geography

- Coordinate : $24^0 7'12''$ N to $24^0 12'$ N
  $93^0 35'48''$ E to 93^0 $40'12''$ E
- Map :GSI land use map 1:2,50,000
- Elevation :975m
- Land form : Steeply Undulated Ridge
- Average slope :39%
- Geological formation :Alluvial, sandstone loam ,clay
- Soil type :Oxisol
- Soil Texture :Moderate

(v) Hydrology and climatology

Description	Rainfall (mm)	Temperature (°C)	Humidity (%)	Sunshine (%)	Wind velocity(Km/hr)
Yearly average	2,347.50	29.17	84.00	61.50	1.33
Name of station	Thing hat	Khozong	Mualtam		
Observation period	1970-2004	1970-2004	1970-2004		

3.6.3.2 Benefited village profile

(i)Population and main occupation

No	Description	Town/ village
1	Nos of population(year 2001)	5,625
2	Population density (person/km2)	123
3	Average population growth	17%
4	No of household	300
6	Average income /year (rupees)	3,40,000

*District data

(ii) Land & farm land ratio

No	Description	Area (ha)
1.	Settlement	23
2.	Paddy field -Technical irrigation - Semi technical irrigation - Simple irrigation	 5 20 26
3.	Rainfed	17
4.	Upland	7
5.	Bush	1
6.	Estate	136
7.	Forest	315
8.	Others	11
9.	Farm land per household (ha/house)	1.23
10.	Irrigation farm land per household ha/house)	0.30

(iii) Agricultural food crop production(ton/ha)

Crop	Paddy field			Rain fed	Upland
	Technical	Semi technical	Simple irrigation		
Ws paddy	5	4	3.5	2.50	2.50
Ds I paddy	5	3	2.5	2.0	2.00
Ds II paddy	5	3	2.5	2.0	2.00
Maize	1.25	1.2	1.1	1.0	0.80
Soyabean	1.25	1	0.8	0.75	0.70

(iv) Water resources and allocation

(a) Irrigation

Resources	Water tapping	Area served (Ha)	Area served (%)	Availability/ year (month)	Name of scheme
Spring/river	Free intake weir	296	94	8	Mualtam
Rain		16	5	5	
Deep well	By hand	2	0.6	12	
Shallow well	By hand	1	0.4	10	

(b) Water supply

Resources	Water tapping	Water supply	Distance of take (km)	Served Household	Served Persons
Spring	Bucket	By foot	1.0	31	
River	Bucket	By foot	1.0	218	5,625
Deep well	Hand pump/bucket	By foot	0.1	31	
Shallow well	Hand pump /bucket	By foot	0.1	20	

3.6.3.3 Present condition of beneficiary area

(i) Irrigation

Description	Irrigation paddy field			Rain fed			Upland		
	Crop area (ha)	Intensity (%)	Product (t/ha)	Crop area (ha)	Intensity (%)	Product (t/ha)	Crop area(ha)	Intensity (%)	Productbn (t/ha)
Paddy Ws	25	100	2.25						
Paddy Ds	13	50	2.25	8.5	25	1.75	3.5	25	1.75
Paddy Ds -I	14	50	2.25	8.5	25	2	3.5	25	1.25
Maize	5	50	1.25	3	25	1.00	3	25	1.00
Total	57	250	8.00	20	75	4.75	10	75	4.00

3.6.3.4 Proposed development plan

(i)Small pond

- Name of pond:	: Khozong
-Location: District	: Churachandpur
Village	: Khozong
- Distance	: 2km
District	: 120Km
-Type	: Homogeneous fill
- Dam body, height/length	: 10.5m/43.5m
-Catchment area	: 500ha
- Impounding area	: 0.13 ha
- Storage volume	: 3,500 m3

(ii) Irrigation development plan

- Area	: 70ha
-Proposed cropping pattern	: Paddy –Maize- Groundnut
- Crop intensity	: 300%
- Storage volume	: 25,000 m^3
- Unit diversion requirement	: 2.00 l/sec
-Discharge diversion requirement	: 0.82m3/sec
- Intake	: Left
- Method of irrigation	: Gravity

(iii) Water supply development plan

-Nos of beneficiary	
-Supply design	: 60 l/day/capita
Requirement	
- Intake	: Left
-Method of water supply	: Gravity
. Pipe line requirement	: 2,000 m

(iv) Access road development plan

- Existing	: Footpath(upland)-3nos
- Length	: 1km
- Wide	: 5m
- Proposed	: 2km ,zeepable road 6m wide.

3.6.4 Leimatak watershed

3.6.4.1 General information

(i) Name of watershed : Leimatak

(ii) Name of river/ river basin : Leimatak

(iii) Land use

- Settlement /residential : 12 ha
- Paddy field : 65 ha
- Rainfed and secondary crop : 273 ha
- Bush/ pasture lands : 6,693 ha
- Forest / plantation trees : 2,172 ha

(iv) Geography

- Coordinate : $24^0 24'$ N to $24^0 36'$ N
  $93^0 33'$ E to $93^0 39'$ E
- Map : GSI Landuse map 1:2,50,000
- Elevation : 1,300m
- Land form : Steeply Undulated Ridge
- Average slope : 45%
- Geological formation : Alluvial, sandy loam, silty loam
- Soil type : Oxisol
- Soil texture : Moderate

(v) Hydrology and Climatology

Description	Rainfall (mm)	Temperature (^{0}C)	Humidity (%)	Sunshine (%)	Wind velocity(Km/hr)
Yearly average	1,574.20	28.10	91.70	66.00	1.36
Name of station	Churachandpur North	Gallenshof			
Observation period	1970-2004	1970-2004			

3.6.4.2 Benefited village profile

(i)Population and main occupation

No	Description	Town/ village
1	Nos of population(year 2001)	7,298
2	Population density (person/km2)	123
3	Average population growth	17%
4	Nos of household	848
6	Average income /year (rupees)	3,40,000

*District data

(ii) Land & farm land ratio

No	Description	Area (ha)
1.	Settlement	96
2.	Paddy field -Technical irrigation - Semi technical irrigation - Simple irrigation	 19 86 114
3.	Rain fed	75
4.	Upland	29
5.	Bush	5
6.	Estate	588
7.	Forest	1367
8.	Others	48
9.	Farm land per household (ha/house)	1.38
10.	Irrigation farm land per household ha/house)	0.33

(iii) Agricultural food crop production(ton/ha)

Crop	Paddy field			Rainfed	Upland
	Technical	Semi technical	Simple irrigation		
Ws paddy	5	4	3.5	2.50	2.50
Ds I paddy	5	3	2.5	2.00	2.00
Ds II paddy	5	3	2.5	2.00	2.00
Maize	1.25	1.2	1.1	1.00	0.80
Soyabean	1.25	1	0.8	0.75	0.70

3.2.6.4.3 Present condition of beneficiary area

(i)Irrigation

Description	Irrigation paddy field			Rain fed			Upland		
	Crop area (ha)	Intensity (%)	Product (t/ha)	Crop area (ha)	Intensity (%)	Product (t/ha)	Crop area(ha)	Intensity (%)	Product (t/ha)
Paddy WS	107	100	2.25						
Paddy DS	54	50	2.25	37.5	25	1.75	14.5	25	1.75
Paddy DS -I	58	50	2.25	37.5	25	2	14.5	25	1.25
Maize	22	50	1.25	14	25	1.00	19.5	25	1.00
Total	241	250	8.00	89	75	4.75	48.5	75	4.00

(ii) Water supply

Resources	Water tapping	Water supply	Q(lit/sec)	Hh(nos)	Water price rs/month
River	Pump,handpump,bucket	Pipe,by foot	32	1,295	150
Ground water					
-Deep well	Pump,handpump,bucket	Pipe ,byfoot	32	2,330	200
-Shallow well	Pump,handpump,bucket	Pipe,byfoot	32	1,940	180

3.6.4.4 Proposed development plan

(i)Small pond

- Name of pond:	: Gallenshof
-Location: District	: Churachandpur
Village	: Gallenshof
- Distance	: 2 km
District	:15Km
-Type	: Homogeneous fill
- Dam body, height/length	: 10.5m/43.5m
-Catchment area	: 1,220ha
- Impounding area	: 0.25 ha
- Storage volume	: 7,500 m3

(ii) Irrigation development plan

- Area	: 160ha
-Proposed cropping pattern	: Paddy –Maize- Groundnut
- Crop intensity	: 300%
- Storage volume	: 60,000 m^3
- Unit diversion requirement	: 2.00 l/sec
-Discharge diversion requirement	: 0.82m3/sec
- Intake	: Left
- Method of irrigation	: Gravity

(iii) Water supply development plan

-Nos of beneficiary	
-Supply design	: 60 l/day/capita
Requirement	
- Intake	: Left
-Method of water supply	: Gravity
. Pipe line requirement	: 2,200 m

(iv) Access road development plan

- Existing	: Footpath(upland)-5nos
- Length	: 1km
- Wide	: 5m
- Proposed	: 2km ,zeepable road 6m wide.

3.6.5 Khuga watershed

3.6.5.1 General information

(i) Name of watershed : Khuga

(ii) Name of river/ river basin : Khuga

(iii) Land use

- Settlement /residential : 120 ha
- Paddy field : 63 ha
- Rain fed and secondary crop : 265 ha
- Bush/ pasture lands : 6,503 ha
- Forest / plantation trees : 2,110 ha

(iv) Geography

- Coordinate : $24^0 18'$ N to $24^0 30'$ N
  $93^0 36'$ E to $93^0 42'$ E
- Map : GSI land use map 1:2,50,000
- Elevation : 875m
- Land form : Steeply undulated ridge
- Average slope : 43%
- Geological Formation : Alluvial, sandstone loam
- Soil type : Oxisol, Entisol
- Soil texture : Moderate

(v) Hydrology and climatology

Description	Rainfall (mm)	Temperature (^{0}C)	Humidity (%)	Sunshine (%)	Wind velocity(Km/hr)
Yearly average	1,624.8.60	28.50	83.45	63.22	1.5
Name of station	Mata	Kupu	Hosphar	Churachandpur	Bijang
Observation period	1970-2004	1970-2004	1970-2004	1970-2004	1970-2004

3.6.5.2Benefited village profile

(i)Population and main occupation

No	Description	Village
1	Nos of population(year 2001)	12,245
2	Population density (person/km2)	123
3	Average population growth	17%
4	Nos of household	1,422
5	Average income /year (rupees)	3,60,000

*District data

(ii) Land & farm land ratio

No	Description	Area (ha)
1.	Settlement	70
2.	Paddy field -Technical irrigation - Semi technical irrigation - Simple irrigation	 14 60 80
3.	Rain fed	52
4.	Upland	21
5.	Bush	4
6.	Estate	415
7.	Forest	964
8.	Others	34
9.	Farm land per household (ha/house)	0.42
10.	Irrigation farm land per household ha/house)	0.10

(iii) Agricultural food crop production(ton/ha)

Crop	Paddy field			Rainfed	Upland
	Technical	Semi technical	Simple irrigation		
Ws paddy	5	4	3.5	2.50	2.50
Ds I paddy	5	3	2.5	2.0	2.0
Ds II paddy	5	3	2.5	2.0	2.0
Maize	1.25	1.2	1.1	1.0	0.8
Soyabean	1.25	1	0.8	0.75	0.70

(iv) Water resources and allocation

(a) Irrigation

Resources	Water tapping	Area served		Availability/ year (month)	Name of scheme
		(Ha)	(%)		
Spring/River	Free intake weir	906	94	8	Hosphar
Rain		48	5	5	
Deep well	By hand	6	0.6	12	
Shallow well	By hand	4	0.4	10	

(b) Water supply

Resources	Water tapping	Water supply	Distance of take (km)	Served	
				Household	Persons
Spring	Bucket	By foot	1.0	150	1271
River	Bucket	By foot	1.0	1050	8,898
Deep well	Hand pump/bucket	By foot	0.1	150	1271
Shallow well	Hand pump /bucket	By foot	0.1	95	805

3.6.5.3 Present condition of beneficiary area

(i)Irrigation

Description	Irrigation paddy field			Rainfed			Upland		
	Crop area (ha)	Intensity (%)	Product (t/ha)	Crop area (ha)	Intensity (%)	Product (t/ha)	Crop area(ha)	Intensity (%)	Product (t/ha)
Paddy WS	75	100	2.25						
Paddy DS	38	50	2.25	26	25	1.75	11	25	1.75
Paddy DS -I	41	50	2.25	26	25	2	11	25	1.25
Maize	17	50	1.25	10	25	1.00	14	25	1.00
Total	171	250	8.00	62	75	4.75	36	75	4.00

(ii) Water supply

Resources	Water tapping	Water supply	Q(lit/sec)	Hh(nos)	Water price rs/month
River	Pump,handpump,bucket	Pipe,By foot	31	1,255	150
Ground water					
-Deep well	Pump,handpump,bucket	Pipe ,byfoot	31	2,257	200
-Shallow well	Pump,handpump.bucket	Pipe,byfoot	31	1,879	180

3.6.5.4 Proposed development plan

(i)Small pond

- Name of pond : :Hosphar

-Location : District : Churachandpur

Village	: Hosphar
- Distance	: 2km
District	: 60Km
-Type	: Homogeneous fill
- Dam body ,height/length	: 10.5m/43.5m
-Catchment area	: 1,250ha
- Impounding area	: 0.25 ha
- Storage volume	: 7,500 m3

(ii) Irrigation development plan

- Area	: 130ha
-Proposed cropping pattern	: Paddy –Maize- Groundnut
- Crop intensity	: 300%
- Storage volume	: 60,000 m^3
- Unit diversion requirement	: 2.00 l/sec
-Discharge diversion requirement	: 0.82m3/sec
- Intake	: Left
- Method of irrigation	: Gravity

***(iii)* Water supply development plan**

-Nos of beneficiary	
-Supply design Requirement	: 60 l/day/capita
- Intake	: Left
-Method of water supply	: Gravity
. Pipe line requirement	: 2,200 m

(iv) Access road development plan

- Existing	: Footpath(upland)-4nos
- Length	: 1km
- Wide	: 5m
- Proposed	: 2km ,zeepable road 6m wide.

CHAPTER-IV

WATERSHED MODELLING SYSTEM (WMS) CONCEPT

WMS is suitable in storing, decision-making, handling. spatial; and non-spatial data analysis due to its functioning in various modes of actions reasons as stated below.

4.1 WMS and decision making

Basic data structures used in Watershed Modeling Systems (GIS vector data or feature objects, DEMs, and TINs) helps in how watersheds can be delineated to set up hydrologic models from them. Under basics it covers supporting hydrologic calculations such as curve number generation from land use and soil data layers and time of concentration (or lag time) computations from computed geometric values and related topics.

4.2 DEMO vs. normal mode

The interface for WMS is divided into six separate modules . Some of the modules contain interfaces to models such as HEC-I. Such interfaces are typically contained within a single menu. Since some users may not require all of the modules or model interfaces provided in WMS, modules and model interfaces can be licensed individually. The modules and interfaces that have been licensed are enabled using the register commanding the file menu. The icons for the unlicensed modules or the menus for model interfaces are dimmed and cannot be accessed.

4.3 Basic feature object manipulation

The map module is at the heart of most operations in WMS, so it is important to gain a good understanding of how to create, edit, and apply feature objects. Within WMS, feature object data can be used for drainage characterization, land use, soil types, time of travel calculations, and many other applications.

4.4 Advanced feature object manipulation

Under it one will learn about tools for cleaning and editing feature objects. Then it help to learn how to import and use data in arc view shape file and DFX format as feature objects in WMS.

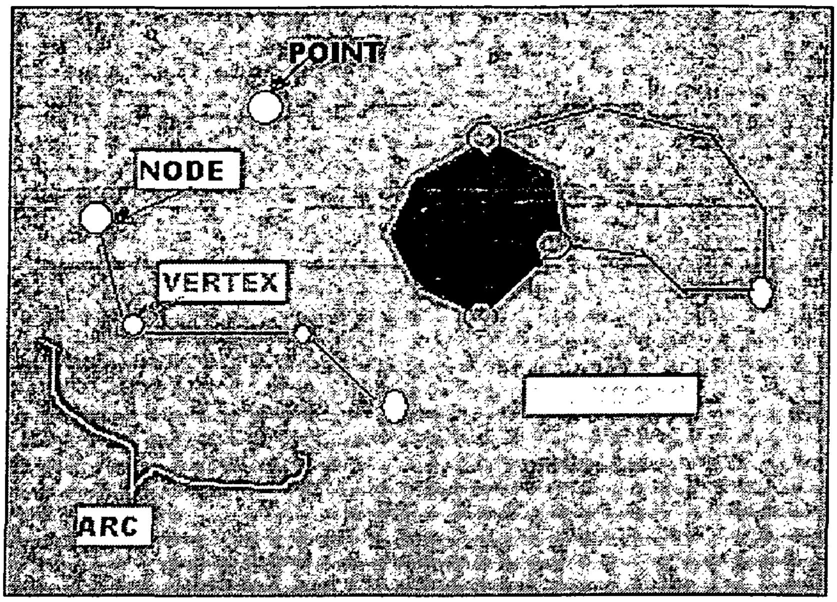


Fig.4.1 :Feature objects

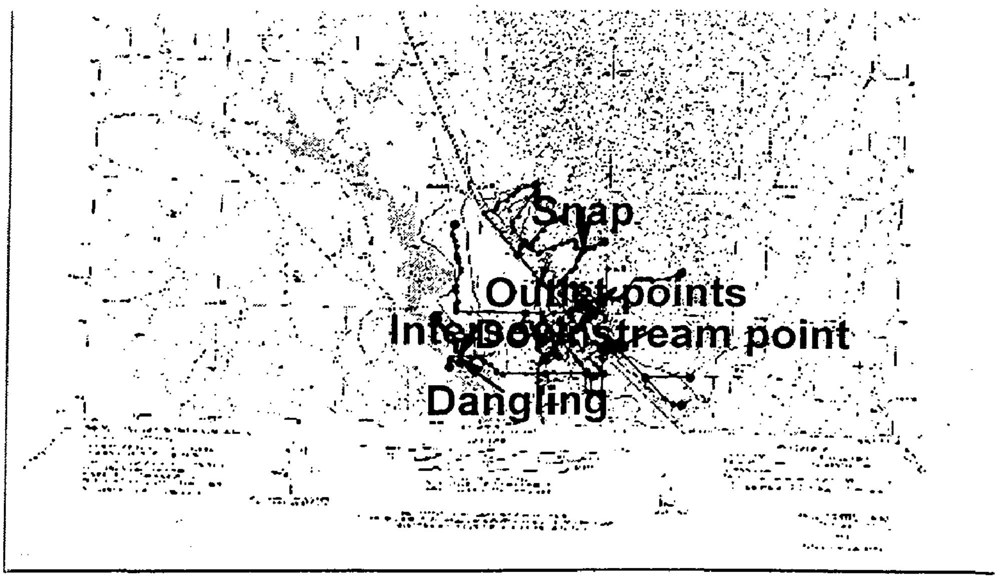


Fig.4.2:Importing and cleaning feature object data

4. 5 Hydrologic models from feature objects

Feature objects may be digitized on-screen using a registered image, or imported as a shape file from an arc / info or arc view layer. Using the drainage coverage type, features can be converted to streams, outlets,and basins to represent the watershed being modeled.If GIS layers are imported as shape files, their corresponding attributes (i.e.area,curve number, time of concentration,etc.)are also imported and assigned to the appropriate basins.

4.6 DEM basics

A DEM (Digital Elevation Model) is a file containing x,y,and elevation data (in UTM coordinates) for a portion of the earth's surface.While DEM data can be obtained from the USGS, it is often supplied by state, country or other local agencies involved in GIS work.For a listing of web sites where DEMs can be obtained see www.emrl.byu.edu/gishydrodata/dem.htm.WMS can use DEMs to directly delineate watersheds, or as background elevation maps when constructing TINs.

4.7 Watershed delineation from DEMS

DEMs can be used to develop watershed boundaries and important geometric parameters, or as a background elevation source for defining elevations at TIN vertices.

4.8 TIN basics

WMS can also use TIN (Triangulated Irregular Networks) for surface representation. Each TIN is constructed from a scattered set of x y z vertices. From the TIN generated by WMS, drainage basins can be delineated.

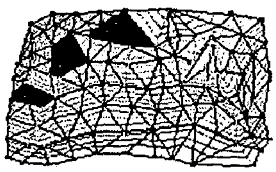


Fig.4.3 After swaping

The vertices used to create a TIN can be imported from an ASC II file, from another TIN can be imported from an ASC II file, from another TIN file (such as in roads),or by interpolation from a DEM.

4.9 Watershed delineation from TINS

Under it feature objects, DEMs and TINs combine together to create a TIN that can be used for watershed delineation parameter computation.

4.10 HEC-1 interface

Once a watershed has been appropriately subdivided into smaller basins, you can use WMS to enter parameters for defining a complete HEC-1 input file. Geometric attributes such as areas, lengths, and slopes are computed automatically from TIN geometry. Parameters such as loss rates, base flow, unit hydrograph method, and routing data are entered through a series of interactive dialog boxes. Once the parameters needed to define an HEC-1 can be written automatically .There is no need to use an editor or even look at the file.

4.11 Time of concentration calculations

Travel times (time of concentration, lag time, and travel time along a routing reach) are critical to performing analysis with any of the hydrologic models. By learning two different ways WMS can be used to compute time of concentration for a TR-55 simulation (lag times are computed in the same way):

- Runoff distances and slopes for each basin are automatically computed whenever you create watershed models from TINs or DEMs and compute basin data. These values can then be used in one of several available equations in WMS to compute lag time or time of concentration.
- If you want to have a little more control (and documentation) over the lag time or time of concentration ,you will use a time computation coverage to define critical flow paths . Time computation coverages contain flow path arc(s) for each sub-basin . An equation to estimate

travel time is assigned to each arc and the time of concentration (or lag time) is the sum of the travel times of all arcs within a basin . Lengths are taken from the length of the arc and slopes derived if a TIN or DEM are present.

4.12 National Flood Frequency (NFF) program interface

The National Flood Frequency program developed by the USGS provides a quick and easy way of estimating peak flow values and hydrographs at ungaged sites. This data can be used in the design of bridges and culverts, flood-control structures, and flood–plain management . It utilizes regression equations that have been developed for each state. Besides an interface to the NFF program, WMS can be used to calculate many of the variables used by the regression equations .

4.13 Rational method interface

The Rational Method is one of the simplest and best known methods routinely applied in urban hydrology. Peak flows are computed from the simple equation:

$$Q = k\,C\,iA \quad \text{(i)}$$

where:-

Q = Peak flow(cumec)

K = conversion factor

C = Runoff coefficient

i...= Rainfall intensity (mm/hr)

A = Area (m^2)

Here problems are solved using a digital terrain model and the rational method.

4.14 Drainage calculation tools

Several drainage calculation tools are included in WMS to aid in analysis and design of hydraulic structures. These tools include a channel calculator, a weir calculator a detention basin calculator ,a curb and gutter calculator ,and an interface to, HY8,a culvert analysis program

4.15 Flood plain delineation

In addition to drainage basin analysis, WMS also contains flood plain delineation features that can be used to define flood plain boundaries on any TIN. Flood plains are delineated from stage values that are entered at various locations on a TIN .Stage values are defined as the difference between the flood water surface elevation and the normal TIN elevation.

4.16 Computing curve numbers

One of the most important parameters to compute when running a hydrologic simulation is the curve number or runoff coefficient for basin. Besides being one of the most sensitive parameters, the curve number is also one of the most difficult parameters to compute. Fortunately, WMS has tools that make computing curve numbers for a basin a simple task.

4.17 Scattered data and 2D grids

The scattered data module and grid module can be used in combination to visualize any set of scalar values that can be assigned to unique x-y positions. The sc-clar value used under it is rainfall intensity generated from NEXRAD radar files, but they could just as easily represent rain gages or other locations for which rain fall intensity generated from NEXRAD radar files ,but they could just as easily represent rain gages or other locations for which rainfall intensities or accumulations are known.

4.18 TIN editing

In order to define a stream network and delineate basins ,you must first have flow defined everywhere on the TIN .Triangulating a set of raw data points rarely produces such a TIN .Often ,flat triangles and edges, artificial pits, and discontinuities in channel segments exist. For this reason, a set of tools is provided in WMS which allows you to alter the initial triangulation, using your own knowledge about the site being modeled ,so that drainage is properly defined and channel edges are accurately represented. Data points used for the initial triangulation generally come from one of two different sources: digitized data from an existing contour map or gridded data such as is provided by the USGS . Different types of problems arise with each of these types of data ,and therefore the editing approach is generally different .

Fig .4.4 :Importing the land use and segmenting the watershed(HSPF model for HEC-1)

4.19 Creating topological models from HEC-1

Here one understand how WMS compares to and how it differs from traditional HEC-1 modeling. It is useful for new users of HEC-1 as well, since it will help become familiar with what types of structure

4.20 Universal Traverse Mercator (UTM)

U.S. army designed international plane (rectangular). coordinate system by dividing the world into 60 zones each results 6 degree of longitude.The latitude shows 84^{0}N to 80^{0}S (Figure).Central meridian and equator intersect to form each zone . This is very accurate and comprehensive.The UTM is read in meters. It is notified that negative values of coordinates must be avoided.The central meridian read false easting while equator show false northing.Northern hemisphere can be read by assigning false easting of 500000 meters and a false northing 0.Southern hemisphere can be read by assuming origin a false easting of 500000 meters and a false northing of 10,000,000 meters(10,000km)

To read the distorted model the central meridian is reduced by multiplying scale factor 0.9996 . These twin lines are of zero distortion nearly 180km on either side of

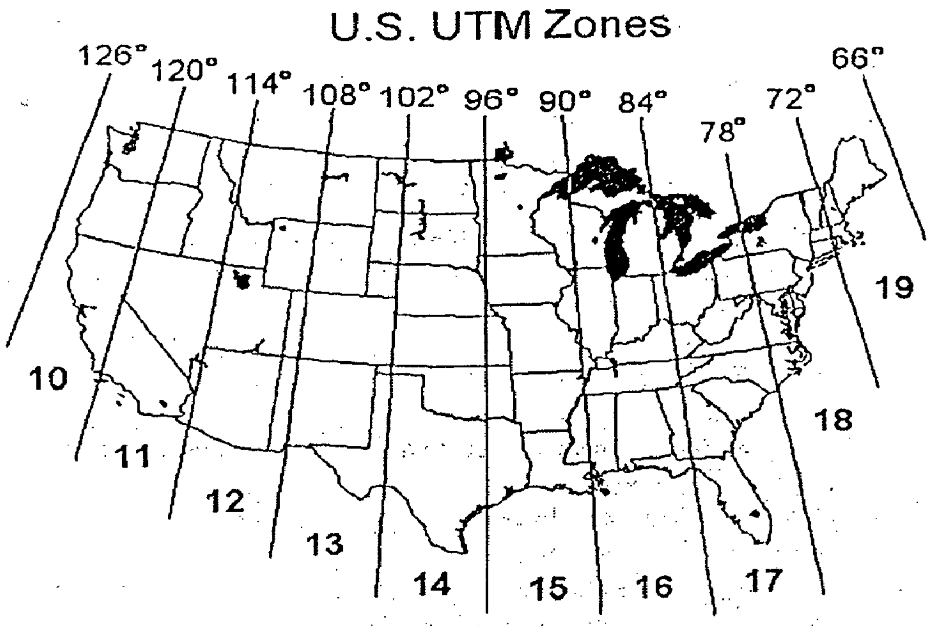


Fig.4.5:UTM coordinate system

central meridian. .Geo-references of conformal areas can be accurately located by UTM .

For example ,the kingdom of Nepal has been divided into three vertical zones (zone 43,44 and zone 45). Hence all the zones need to be geo-referenced. This is very useful in providing input storage and exchange for digitized maps and correct output.

For better results the areas should be small spheroid and datum are used in coordinate conversion.

The most commonly used, spheroids are "Southeast Asia" (semi major axis 63781 55km , semi minor axis 6356773.3205) and "Modified Everest" (semi –major axis 63777304.063,semi minor axis 6356103.039) .

4.21 Data ,dataset and data base

Data is information represented in the format of digit, letter and symbol used to describe status, behavior and their consequence of geographical object. There are some inner relations and different between data and information ,as defined above, data indicates those value recorded and stored in computer ,the meaning of the value represented is information.

Dataset is the minimum body of data used for data transform, storage, manipulation, copying, and other activities . Usually, there is one type of spatial data feature as point ,line or polygon employed to represent one kind of geographical object such as river or topography or building . In most cases ,data layer have the same meaning with dataset ,but a few data layer can be organized into one dataset in some special occasions.

Database, as the word per se means data and base, is the combination of dataset according to the defined logical principles. Usually, the dataset in one database share the same data structure, data storage method, data format and similar data management interface. Except the dataset contained, database itself has some functions as data updating, data manipulation (extracting,clipping,overlaying, statistics) and user propriety definition.

4.21.1 Primary data and secondary data

Data and information representing the real world can be stored in simplified forms and processed to facilitate decision –making or it can also be presented later in simplified forms to suit specific needs . Geographical data come in many different - different forms. A basic distinction can be made between primary and secondary data .

Primary data refers to the sorts of information that can be collected first hand by fieldwork and questionnaire survey. The primary geo-spatial data can be collected from the sources, such as Geodetic Surveying and Geodetic Control Networks ; Surveying, Photogrammetry; Remote Sensing and Watershed Modeling

Secondary data are those found in published sources, such as official statistics, maps and aerial photographs, or are gathered by some agency other than you. Secondary data acquisition refers to the process of converting existing maps or other documents into a suitable digital form. There exists lot of secondary data but sometimes not all of them are available for use. Sometimes no convenient secondary data source exists and one has collect the necessary data conducting field survey which can be time consuming and expensive.

There are number of important points relating to why we collect data in the first instance and this should considered on the ground of sound scientific approach of the problem before the real data collection process start. Depending upon the objectives, there may be two approaches. The Inductive approach, also called as classical method, involves observation and collection of data in the first stage followed by statement of theory and verification ,where as the deductive approach ,also called as critical rational method ,involves setting up the problem at the first stage followed by collection of necessary data and statement or theory at later stages .

4.21.2 Watershed modeling data

The data are also called as geographical data, geographic data, geographic information, GIS data, earth-sciences data or geo-scientific data ,and spatial data. Geographical data are information that identifies the geographic location and characteristics of natural or constructed features and boundaries on the earth. The main difference between geographical data and other data is that the later helps answer question like, what? Or where? As the former answers both what? And where? It is because that it contains Geometric or Spatial data for spatial elements and attribute data . Spatial data is used to describe the location of geographical object, and attribute data describe the fundamental characteristics of the phenomena involved. For instance, the objects classified as buildings may have a number stores attributes with legitimate value of 1to10, etc.Attribute data can in turn be sub-divided into qualitative and quantitative data.

Historically several terms have been used to describe the data in a WMS database, among them features, objects, or entities. The term feature derives from cartography and is commonly used to identify "features shown on a map". While entity and object are terms from computer science used to identify the elements in a database. The normal dictionary definitions of these terms are:

Object: a thing that can be seen or touched; material thing that occupies space characterized by type, attribute, geometry, relation and quality.

Entity: a thing that has definite, individual existence in reality (e. g. house number)

Features: the make, shape, form or appearance of a person or thing(e. g.circle,linear)

4.21.3 Spatial elements:

Spatial objects in the real world can be thought of as occurring as four easily identifiable types: points, lines, areas, and surfaces (Fig. 4.6). Collectively, they can represent most of the tangible natural and human phenomena that we encounter on an everyday basis. In general, points, lines, and areas are used to explicitly represent real

– world object, where as surfaces are mostly used for volumetric representation, such as to represent hills, valleys. Thus, all data can be considered to be explicitly spatial.

Point features are spatial phenomena each of which occurs at one location in space. Each feature is said to be discrete in that it can occupy only a given point in space at any time and considered to have no spatial dimension – no width or length. Example of such feature would be a house or a village. But a village can be represented by point feature or area feature as well depending upon the resolution of data .

Line features are conceptualized as occupying only a single dimension in coordinate space . They are represented as the series of single coordinates connected to each other. Roads, rivers, are the examples of linear features . The resolution or scale of given dataset once again places a fundamental limitation to conceive them as having any width. Linear features, unlike point features, allow us to measure their spatial extent/length.

Area features have two dimensions both length and width dimensions . Area is composed of series of lines that begin and end at the same location. We can describe their shapes and orientations, and the amount of territory occupied as well. In database, the term polygon is often used instead of area. Again, physical size in relation to the scale determines whether an object is represented by an area or by a point.

It is often that area is divided into regular squares or rectangles so that all objects are described in terms of areas. This entire data structure is called a grid. Each square or rectangular is known as a cell and represents a uniform value. Adding the dimension of height to area features allows us to observe and record the existence of Surfaces. Surfaces have three dimensions- length, width and height. For instance , hills, valleys, and ridges can be described by citing their locations, amount of area they occupy, how they are oriented , and by noting their heights.

4.21.4. Basic data models

Spatial elements can be represented in two models: vector and raster / grid (Fig. 4.6) . In the vector model ,the spatial locations of features are defined on the basis of coordinate pairs. These can be discrete, taking the form of points (point or node data) ; linked together to form discrete sections of line (arc or line data); linked together to form closed boundaries encompassing an area (area or polygon data). Attribute data pertaining to the individual spatial features is maintained in an external database. The data model used by the software, like arc/info, arc view is vector model.

In raster model, one or group of cell/grid/pixel depending upon the grid resolution represents spatial elements . Most of raster models adhere strictly to a

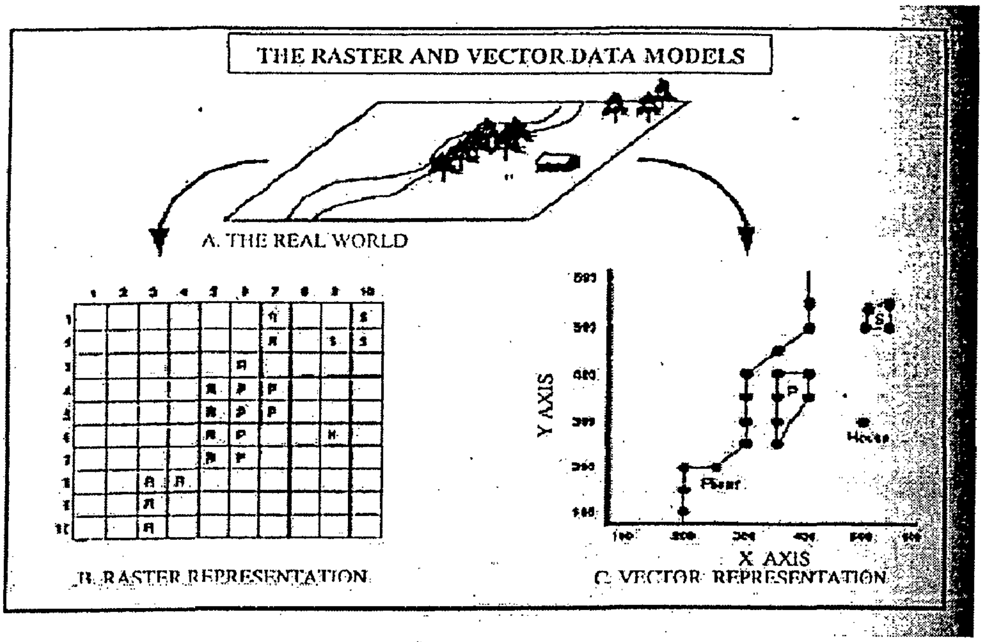


Fig.4.6:Comparison of raster & vector models.

single attribute per cell structure although some raster models support the assignment of values to multiple attributes per discrete cell.

Table 4.1 presents the advantages and disadvantages of vector and raster model. Vector data sets can have topology,i.e. in addition to the position of every feature; the spatial relationships of adjacency and connectivity between features are also maintained . Topological relationships are stored in a series of relational databases. Each database stores information about a feature. For example, a database would store the information about each individual arc, such as number of the arc, beginning node number, ending node number, polygon to its left, and polygon to its right.

Within this model spatial data is not continuous but is divided into discrete units. In terms of recording where individual cells are located in space, each is referenced according to its row and column position within the overall grid. To fix the relative spatial position of the overall grid, i.e. to o geo-reference it , the four corners are assigned planar coordinates . An important concept concerns the size of the component grid cells and is referred to as grid resolution. The finer the resolution the more detailed and potentially closer to ground truth a raster representation becomes. Unlike the vector model there are no implicit topological relationships in the data. The following information should always be recorded when assembling, compiling and utilizing raster data:

. Grid size (number of rows and columns)

. Grid resolution

.Watershed-referencing models, e. g. UTM coordinate, source projection

Table 4.1:Vector vs raster data model

Vector	Raster
Advantages	
Compact data structure(less data volume)	Simple data structure
Efficient topology encoding, good for	Easier and efficient overlay operation
Operations, such as network analysis	High spatial variability is efficiently
Better graphics for precise expression	Represented efficient in manipulation
	and enhancement of digital images
Disadvantages	Less aesthetic graphic output
Inefficient representation of high spatial	Not good for some operations ,such as
Variability	Network analysis
Not effective for manipulation and	
enhancement of digital images	

4.21.5. Data analysis and modeling

The most significant characteristics of WMS are the provision of the capabilities for data analysis and spatial modeling. These functions use the spatial and non-spatial attribute data of the watershed.

WMS database to answer questions about the real world. The database in WMS is the model of the real world that can be used to simulate certain aspects of reality. A model may be represented in words ,in mathematical equations or as a set of spatial relationships displayed on a map.The general problem in data analysis is: user's query.* database link.* output.

The user has particular specification, constraints or query.The database contains information in the form of maps that can be used to answer the users query. All that is necessary is to establish a link between database and output that will provide the answer the form of a map, table, or figure. The link is any function that can be used to convert data from one or more input maps, into an output.

4.21.5.1 Analysis; functions

The power of WMS lies in its ability to analyze spatial and attribute data together. A large range of analysis procedure/ functions have been divided in to four categories; retrieval, classification and measurement overlay; Distance and conn-ectivity; and neighborhood.

4.21.5.2 Retrieval, reclassification and measurement operations

In these functions retrieval of both spatial and attribute data are made and only attribute data are modified. Creation of new spatial elements is not made.

Retrieval operations: This involves the selective search and manipulation and output of data . Retrieval operation includes the retrieval of data using:

- geometric classification,
- symbolic specifications,
- a name of code of an attribute,
- conditional and logical statement.

Reclassification procedures: This procedure involves the operation that reassign thematic values to the categories of a existing map as a function of the initial value ,the position size or shape of the spatial configuration associated with each category (for instance a soil map reclassified into erodibility map) . In raster based WMS, numerical values are often used for indication of classes, decimal points are avoided in all calculations. A cell might be assigned the value to indicate classes. Classification is done using simple data layers as well as with multiple data layers as part of an overlay operation.

Measurement operations: Spatial data measurement includes: calculation of distance ,length of lines, areas and perimeter of polygons ,and volumes .Measurements involving points are: distance from a point to a point , a line, a polygon, enumeration of the total number as well as the enumeration of points falling within the polygon.

4.21.5.3 Overlay operation

Overlay operation creates a new data set containing new polygons formed from intersection of the boundaries of the two or more sets of separate polygonal layers. There are two common overlay operations: arithmetic and logical. .Arithmetic overlay includes operation such as addition, subtraction, division and multiplication of each value in a data layer by the value in the corresponding location in the second data layer. Logical overlay involves the selection of an area where a set of conditions are satisfied. The logical overlay operation is done using the rules of Boolean logic. Boolean algebra uses the operations of AND .OR.XOR, NOT to see whether a particular condition is true or false.

4.21.5.4 Neighborhood operation

This involves the creation of new data based on the consideration of roving window of neighboring points about selected target locations. They evaluate characteristics of an area surrounding spatial location. In all neighborhood operations, it is necessary to indicate one or more target locations, the neighborhood considering each target and the type of function to be executed. The typical neighborhood operation in most WMSs are ; search topographic functions and interpolation.

Search functions: This constitutes one of the most commonly use neighborhood function. Value assignment to each target feature is made on the basis of some characteristics of its neighborhood. The basic parameters required to be defined in a neighbor search are targets, the neighborhood, and the functions to be applied to the neighborhood to generate neighborhood value . The search area is usually square , rectangular or circular whose size is determine by the analyst.

Topographic functions: Slope, relief and form of the area the surface characteristics inherit in topography. Digital Elevation Model (DEM) help in representation, identification and comparison of these characteristics. By Valenzuela ,(1990), DEM represents a topographic surface terms of a set of elevation values measured at a finite number ,on points, and contains terrain features of geo morphological importance such as valleys and ridges ,peaks and pits. The functions of a DEM help in measuring topographic values of the watershed. Elevation data with slope and aspect- slope face direction is used for transformation.

Interpolation: By using the known values from neighboring locations unknown values are predicted for sampled sites. By Burrough,1986;Valenzuela,1990,Point and aerial interpolation involve variety of methods such as polynomial regression ,kriging,splines,trend surface analysis ,Fourier-series and moving averages .The optimality of results by interpolation is based on precision ,accuracy ,no of points their distribution, mathematical model function reality. Mathematical model function help in estimation of unknown values.

4.21.5.5 Connectivity functions

These operations were performed on large data to estimate values (qualitative or quantitative) on watersheds.The information furnished includes Interconnection of spatial elements, rules controlling movement along spatial elements, unit of measurement with specifications.Contiguity, proximity, network and spread operation used for grouping connectivity functions.

CHAPTER V

APPLICATIONS OF WMS IN WATERSHED MANAGEMENT

5.1 Introduction

Composite curve numbers, time of concentration, runoff, soil profiles, TIN contours etc, are calculated in land use grid and soil type grid by selecting SCS curve numbers and runoff coefficients. TIN contours are directly read by digitizing the selected polygons of watersheds.

Digital terrain model and the rational method are commonly used in urban hydrology for computing the peak flows.

For the assessment of soil pattern, soil classification, runoff coefficient, rainfall intensity ,soil type, SCS / Mônglen / Tank model methods are commonly used.

These parameters have geographical values WMS reference manual contain tables of typical values or the available field data can be modelled into WMS interface to any of the method.

The Coordinate conversion is possible at three different occasions,

1.The watershed has spans zones within a given coordinate system.

2.The data is available for entire watershed model, but the data is in different Coordinate systems. For example, the elevation data in one coordinate system and land use data in another coordinate system.

3.The data may be in one coordinate system, but job assigned is in another coordinate system. For example, all the data in a watershed 'GIS data base may be in one coordinate system, but available data is in another coordinate system.

5.2 Software use

The WMS software is a product of the Environmental Modelling Research Laboratory of Brigham Young University. The key of recent use is made in Philippines. Feature objects menu is used for creating basin boundaries creating stream network, building polygons and updating geometric parameters. TIN basics is used for reading VERTEX data files into WMS .WMS is an easy tool used with microcomputers for storing, manipulating and analyzing geographical parameters for a specified locations. It is excellent tool for generating informations on spatial and temporal data inputs.

5.3 Computations

5.3.1 Rainfall –erosivity index

Both geographical and spatial data sets are used for these studies. Geographical data set consists of drainage map, landuse map, soilmap, and contour map. Rainfall data and its analysis fall under spatial data set. Rainfall data is used for predicting rainfall erosivity index. It is also used in SCS, Monglen and Tank Runoff Models. Table 5.1 give average monthly rainfall data in mm for more than 30 years for five sub-water sheds namely Barak sub-watershed Tipaimukh, Tuijang sub-watershed Thanlon, Leimatak sub-watershed Chura-chandpurNorth, Khuga sub-watershed Churachandpur and Tuicha sub-watershed Thing hat

Table: 5.1 Monthly rainfall data of Churachandpur district in mm

Month	Tipaimukh	Thanlon	Churachandpur North	Churachandpur	Thing hat
January.	14.0	8.2	5.0	5.0	9.0
February	40.0	38.0	20.0	25.0	37.0
March	62.0	42.7	2 5.0	28.0	40.0
April	190.0	183.6	120.0	124.0	180.0
May	302.0	290.8	235.0	230.0	260.0
June	530.0	525.8	365.0	395.0	410.0
July	570.0	550.6	315.0	300.8	500.0
August	426.0	414.3	229.0	220.8	380.0
September	361.0	359.0	107.0	146.6	310.0
October	204.0	195.0	90.2	88.6	155.0
November	95.0	86.0	56.0	55.0	60.0
December.	16.0	6.6	7.0	6.0	6.5

Source: Feasibility study reports, Tipaimukh dam project, Khuga dam project, and Tuijang watershed management project

5.3.2 Calculations of rainfall erosivity index

5.3.2.1 Barak sub-watershed Tipaimukh

Month: July

Average monthly rainfall = 570mm

Rainfall kinetic energy (E) = 14.374x570= 8193.18(ton m/ha cm)

Maximum rain intensity I^{30} = 570 / (77.178+ 1.01 x650) = 0.87 mm/hr

Rain erosivity index EI^{30} = 71.53 (toncm /ha-hr)

Table :5.2 Rainfall erosivity index (ton/ha yr) for Barak sub-watershed Tipaimukh

Month	R (mm)	E (ton-m/ha-cm)	I^{30} (mm/hr)	EI^{30} (ton-cm/ha-hr)
January	14.0	201.24	0.15	0.31
February	40.0	574.96	0.34	1.96
March	62.0	891..19	0.44	3.95
April	190.0	2,731.06	0.71	19.28
May	302.0	4,340.95	0.79	34.30
June	530.0	7,618.22	0.87	65.92
July	570.0	8193.18	0.87	71.53
August	426.0	6123.32	0.84	51 .41
September	361.0	5,189.01	0.82	42.40
October	204.0	2,932.30	0.72	21.12
November	95.0	1365.53	0.55	7.49
December	16.0	229.98	0.20	0.47
Total EI^{30}				320.35

Source : Feasibility satudy report small pond Tipaimukh

5.3.2.2 Tuijang sub –watershed Thanlon

Month: July

Average monthly rainfall = 550.60mm

Rainfall kinetic energy (E) = 14.374x550.60 = 7914.3 (ton m/ha-cm)

Maximum rain intensity I^{30} = 550.60/ (77.178+ 1.01x550.60) = 0.87 mm/hr.

Rain erosivity index EI^{30} = 7,914 .30 x0.87x10^{-2}

= 68.85 (ton cm /ha-hr)

Table :5.3 Rainfall erosivity index (ton/ha/yr) for Tuijang sub-watershed Thanlon

Month	R (mm)	E (ton-m/ha-cm)	I_{30} (mm/hr)	EI_{30} (ton-cm/ha-hr)
January	8.2	117.87	0.10	0.11
February	38.0	546.21	0.33	1.80
March	42.7	613.77	0.36	2.21
April	183.6	2639.10	0.70	18.45
May	290.8	4179.96	0.78	32.77
June	525.8	7557.85	0.86	65.34
July	550.6	7914.30	0.87	68.85
August	414.3	5955.15	0.84	49.78
September	359.0	5160.27	0.82	42.31
October	195.0	2802.93	0.71	19.94
November	86.0	1236.16	0.52	6.48
December	6.6	94.87	0.09	0.10
Total EI_{30}				308.14

5.3.2.3 Leimatak sub-watershed Churachandpur North

Month : June

Average monthly rainfall = 365.00mm

Rainfall kinetic energy (E) = 14.374x365.0 0 = 5,246.5 (ton-m/ha-cm)

Maximum rain intensity I_{30} = 365.00/(77.178+1.01x365.00) =0.82mm/hr

Rain erosivity index EI_{30} = 5,246.51 x 0.82x10^{-2} = 43.02 (toncm/ha-hr)

Table 5.4 :Rainfall erosivity index (ton.cm/ha.hr) for Leimatak sub-watershed Churachandpur North.

Month	R (mm)	E (ton-m/ha-cm)	I_{30} (mm/hr)	EI_{30} (ton-cm/ha-hr)
January	5.0	71.87	0.06	0.04
February	20.0	287.48	0.21	0.59
March	25.0	359.35	0.24	0.88
April	120.0	1724.90	0.61	10.43

May	235.0	3377.89	0.75	25.24
June	365.0	5246.51	0.82	43.02
July	315.0	4527.81	0.80	36.08
August	229.0	3291.65	0.74	24.44
September	107.0	1538.02	0.58	8.88
October	90.2	1296.54	0.54	6.95
November	56.0	804.94	0.42	3.37
December	7.0	100.62	0.08	0.08
Total EI_{30}				160.00

5.3.2.4Khuga sub-watershed Churachandpur

Month : June

Average monthly rainfall = 395.00mm

Rainfall kinetic energy (E) = 14.374x395.0 0 = 5,677.3 (ton-m/ha-cm)

Maximum rain intensity I_{30} = 395.00/(77.178+1.01x395.00) =0.83mm/hr

Rain erosivity index EI_{30} = 5,677.3 x 0.83x10^{-2} = 47.10 (toncm/ha-hr)

Table 5.5: Rainfall erosivity index (toncm/ha.hr) for Khuga sub-watershed Churachandpur .

Month	R (mm)	E (ton-m/ha-cm)	I_{30} (mm/hr)	EI_{30} (ton-cm/ha-hr)
January	5.00	71.87	0.06	0.04
February	25.00	359.35	0.24	0.88
March	28.00	402.47	0.27	1.07
April	124.00	1782.38	0.61	10.87
May	130.00	1868.75	0.62	11.65
June	395.00	5677.30	0.83	47.10
July	300. 80	4323.70	0.79	34.14
August	220.80	3173.78	0.74	23.34
September	146.60	2107.23	0.65	13.72
October	88.60	1273.54	0.53	6.75
November	55.00	790.57	0.41	3.28
December	6.00	86.24	0.07	0.06

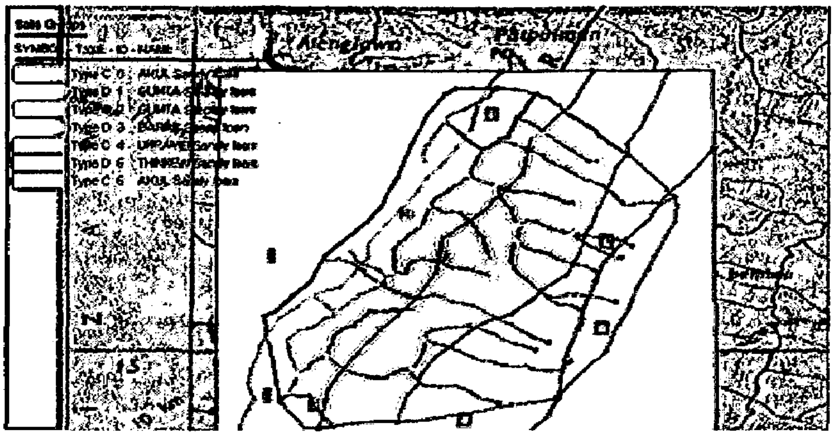


Fig. 5.1 Soil map of Barak watershed

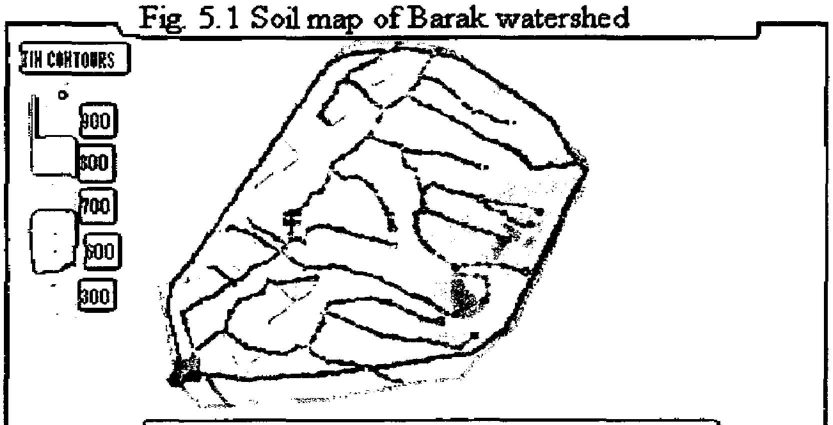


Fig 5.2 : TIN contours of Barak watershed

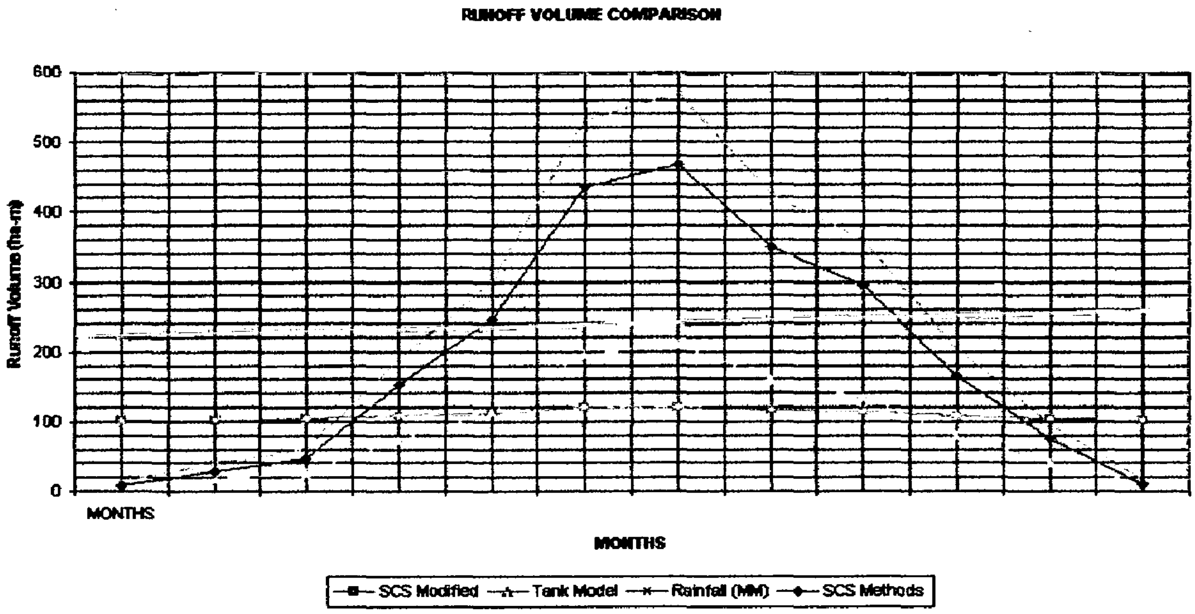


Fig. 5.3 Runoff volume of Barak watershed

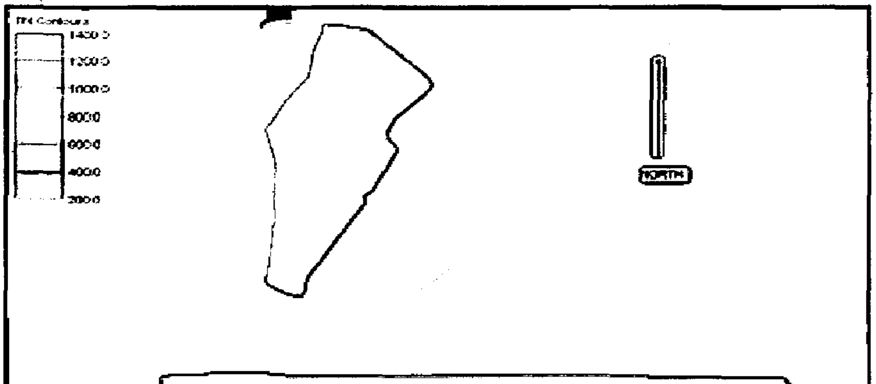


Fig 5.4 : Tin contours of Tuijang watershed

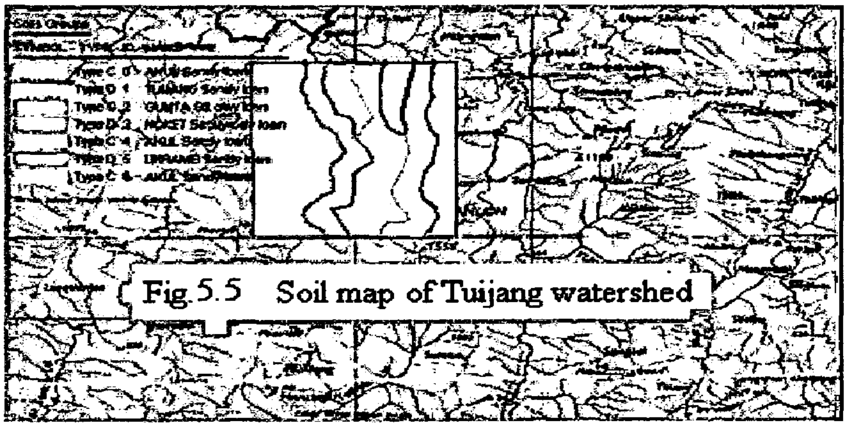


Fig.5.5 Soil map of Tuijang watershed

SCALE 1cm= 2.5 km

2.5 0 2.5

FIG 5.6 TIN CONTOURS OF KHUGA WATERSHED

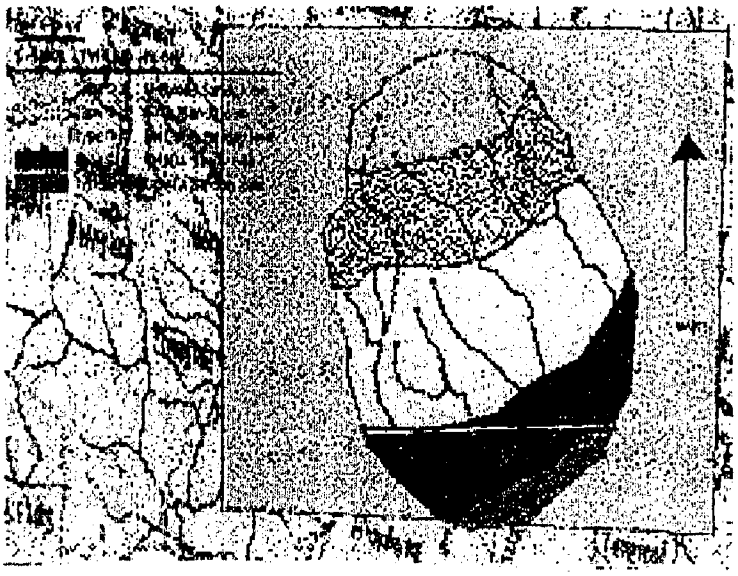


FIG 5.7 SOIL MAP OF KHUGA WATERSHED

SCALE 1cm ==2.5km

2.5 0 2.5

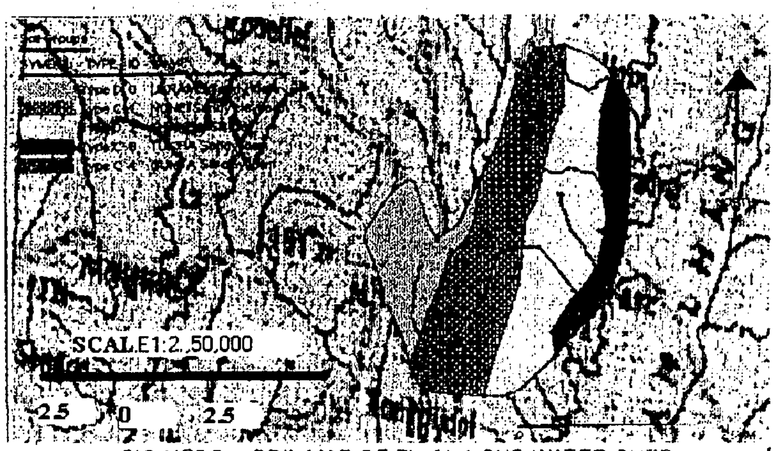


FIG NO5.8 SOIL MAP OF TUICHA SUB WATER SHED

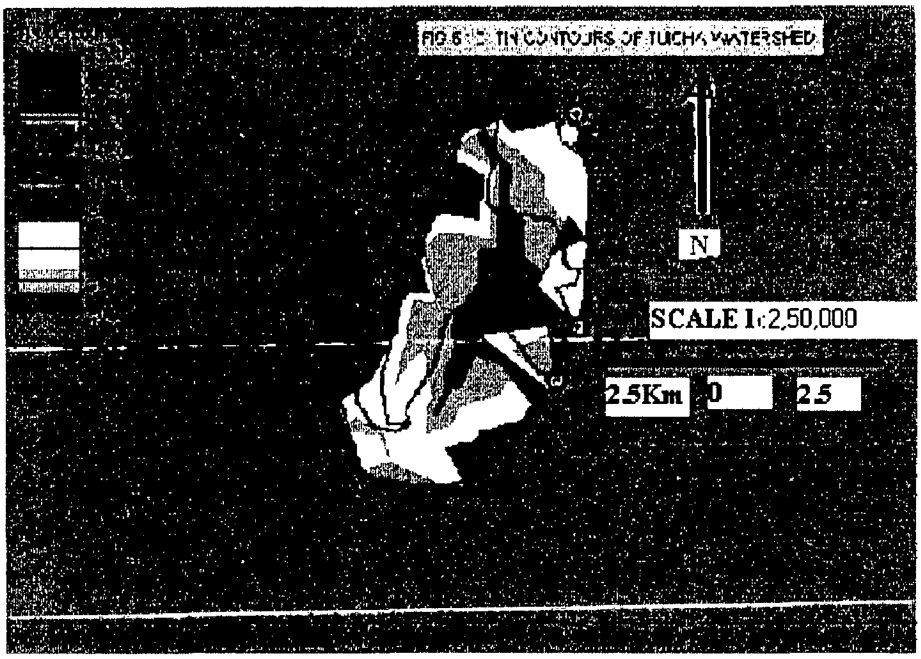
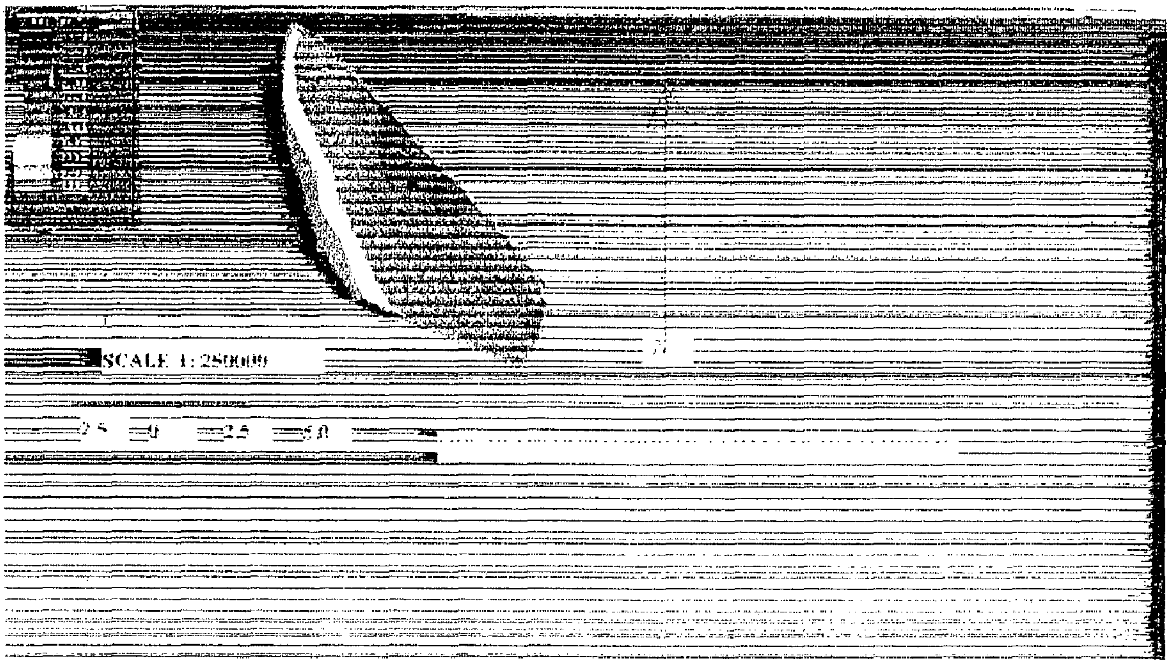
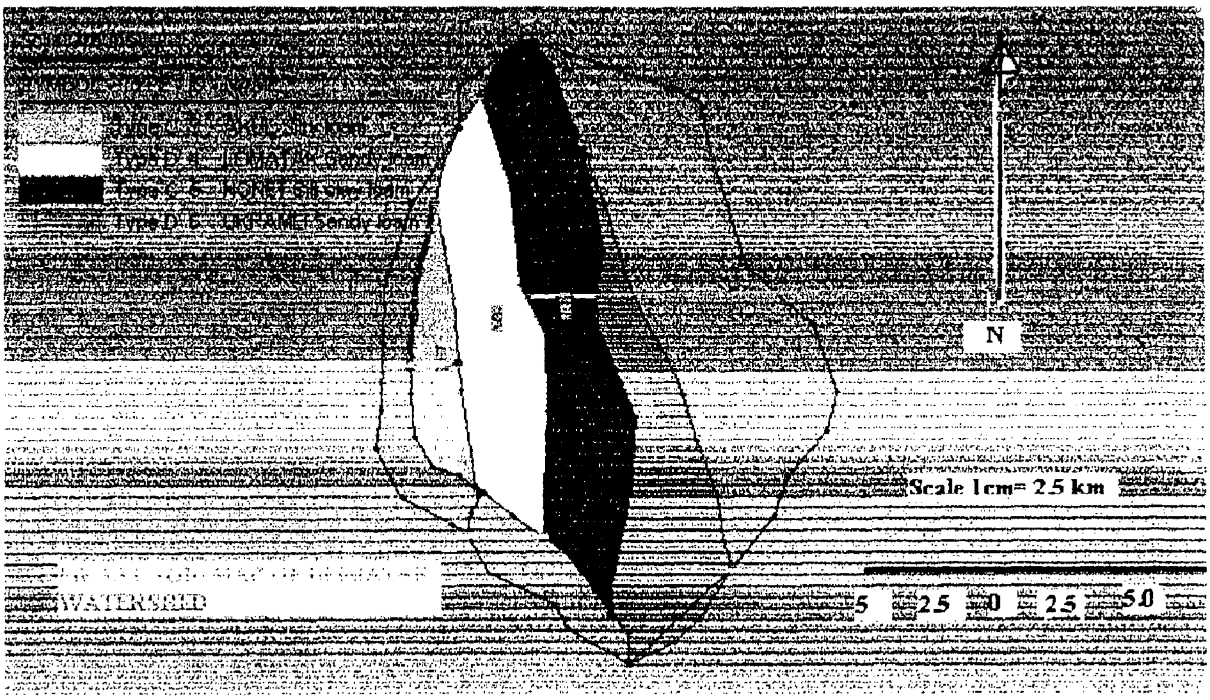


FIG 5.9 TIN CONTOURS OF TUICHA WATERSHED


SCALE 1: 280000
2.5
0
2.5
5.0


N
Scale 1cm= 2.5 km
WATERSHED
5
2.5
0
2.5
5.0

Total EI_{30}	152.90

5.3.2.5 Tuicha sub-watershed Thing hat

Month: June

Average monthly rainfall = 410.00mm

Rainfall kinetic energy (E) = 14.374x410.00 = 5,893.34 (ton-m/ha-cm)

Maximum rain intensity I_{30} = 410.00/(77.178+1.01x410.00) =0.83mm/hr

Rain erosivity index EI_{30} = 5,893.34 x 0.83×10^{-2} = 49.18 (ton cm/ha-hr)

Table:5.6 Rainfall erosivity index (toncm/ha.hr) for Tuicha sub-watershed Thinghat

Month	R (mm)	E (ton-m/ha-cm)	I_{30} (mm/hr)	EI_{30} (ton-cm/ha-hr)
January	9.0	129.37	0.10	0.14
February	37.0	531.84	0.32	1.67
March	40.0	574.96	0.34	1.79
April	180.0	2587.32	0.70	17.98
May	260.0	3737.24	0.77	28.60
June	410.0	5893.34	0.83	49.18
July	500. 0	7187.00	0.86	61.73
August	380.0	5462.12	0.82	45.03
September	310.0	4455.94	0.79	35.39
October	155.0	2227.97	0.66	14.78
November	60.0	869.44	0.44	3.76
December	6.5	93.43	0.08	0.07
Total EI_{30}				260.12

Source : Feasibility Study Report

5.3.3 Soil –erosion

5.3.3.1 Soil loss factor model

The rainfall –runoff erosivity index obtained from Tables 5.1, 5.2, 5.3, 5.4, 5.5 and 5.6 are used to calculate USLE for calculation of soil loss in these watersheds on annual basis.

Soil erodibility factor

For sandy loam to silty loam soil the soil erodibility factor is assumed 0.25. The soil erodibility factor maps are prepared for the watersheds in the present study by digitizing TINS/DEMS of these watersheds

Topographical factor

The slope and length factors of these watersheds are calculated from WMS given in Table 5.7.In soil map/drainage map legend pixel size is kept as slope length and L factor values are obtained. The recommended value of m are to be used as pixel size and S factor can be calculated..

Table 5.7 : Watershed parameters

Sl .no.	Name of watershed	Slopex10^3	Length (mm)
1	Tuijang	9.21	10.90
2	Barak	9.33	12.15
3	Leimatak	8.42	11.27
4	Khuga	9.22	12.07
5	Tuicha	8.52	8.40

Overlay operation

Slope length (L) = $(\lambda / 22.13)^m$

Length 1 map iff slope > = 35 {PIX SIZE (TIN /DEM iff) /22.13) 0.5}, ?}
Length 2 map iff (15 <= Slope and 35 > Slope , POW ({ PIX SIZE (TIN/DEM) iff}/22.13) , 0.4 } , ?)

Length 3 map , iff (5<=Slope and 15 > Slope ,POW ({ PIX SIZE (TIN /DEM iff) / 22.13 } , 0.3 } ,?)

Lmap = Map Glue (length 1, Length 2, Length 3, replace)

Smap = {0.43 + 0.3 Slope / 100 ^ SQ (Slope)} /6.613

LS map = Lmap * Smap.

Thus LS factor map was generated for these watersheds.

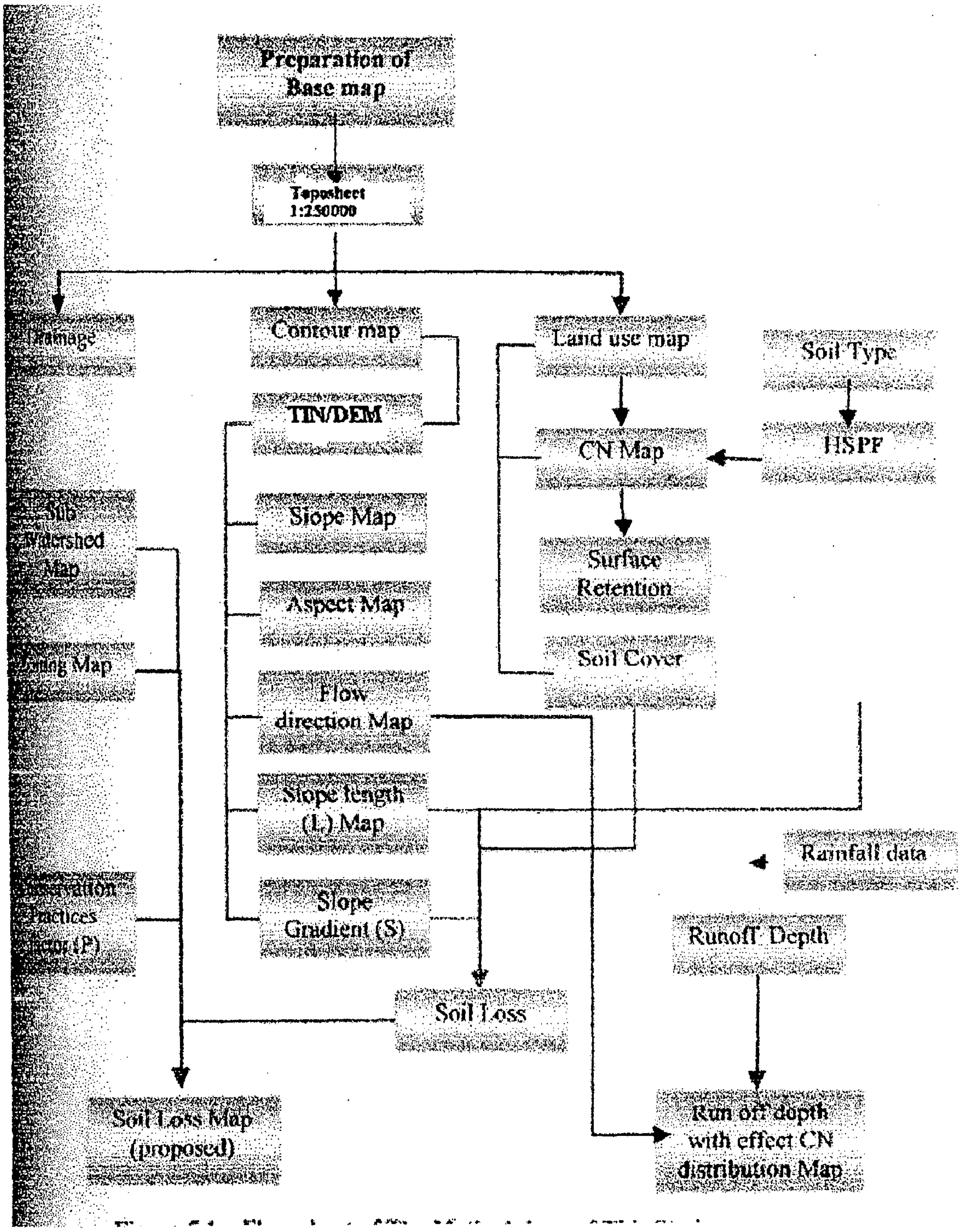


Figure 5.12Flow Chart of the Methodology of this Study

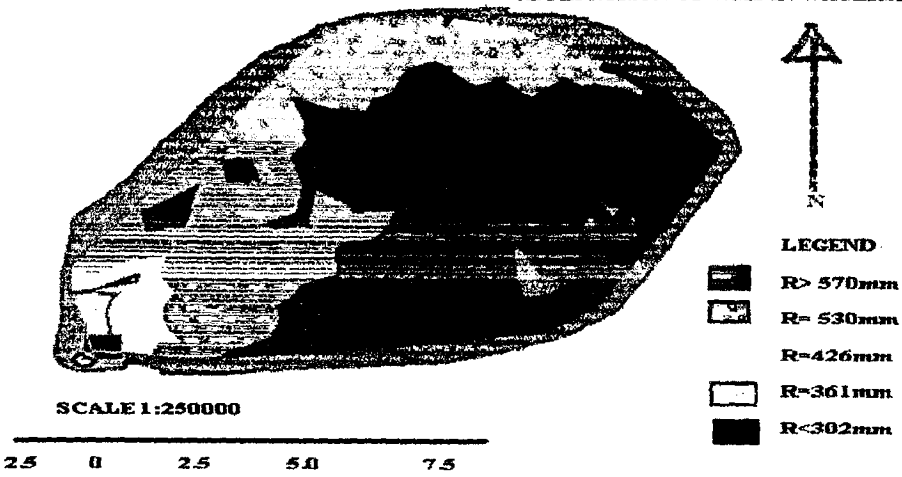


FIG5.13 RUNOFF DEPTH MAP OF BARAK WATERSHED

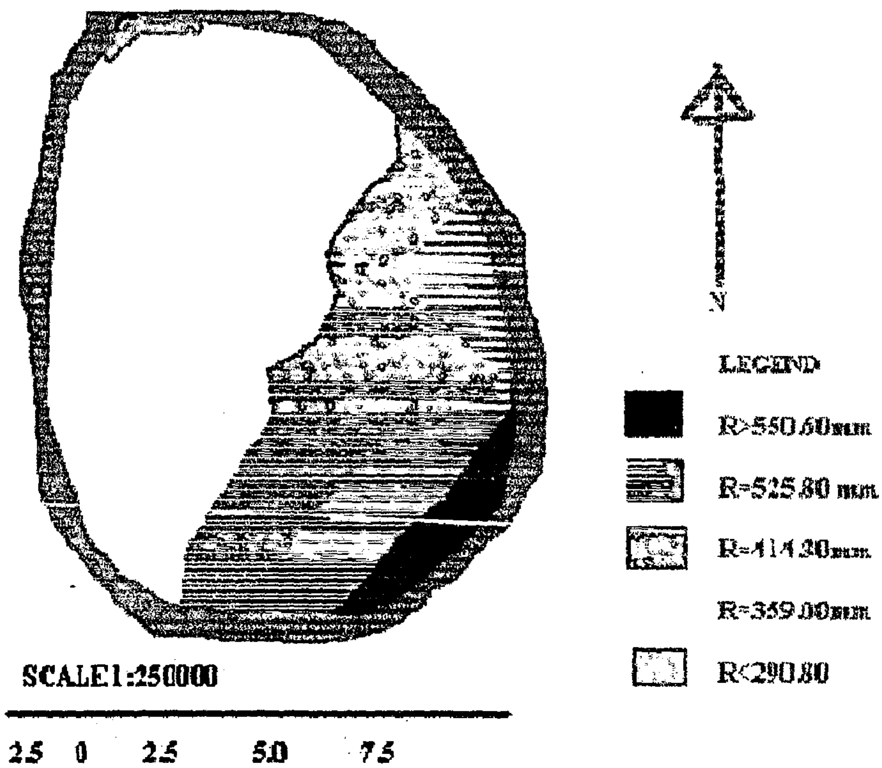


FIG 5.14 RUNOFF DEPTH OF TUIJANG WATERSHED

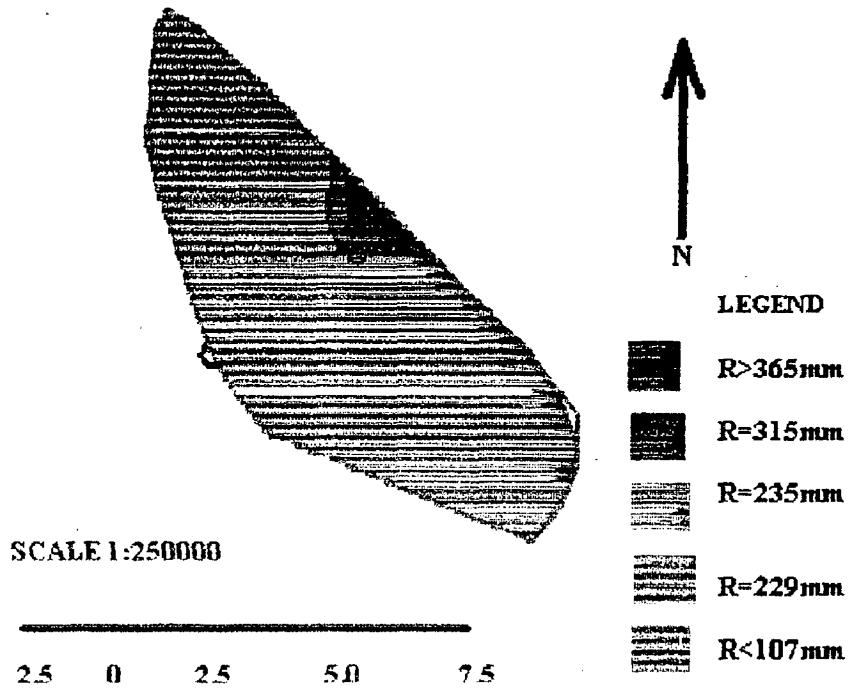
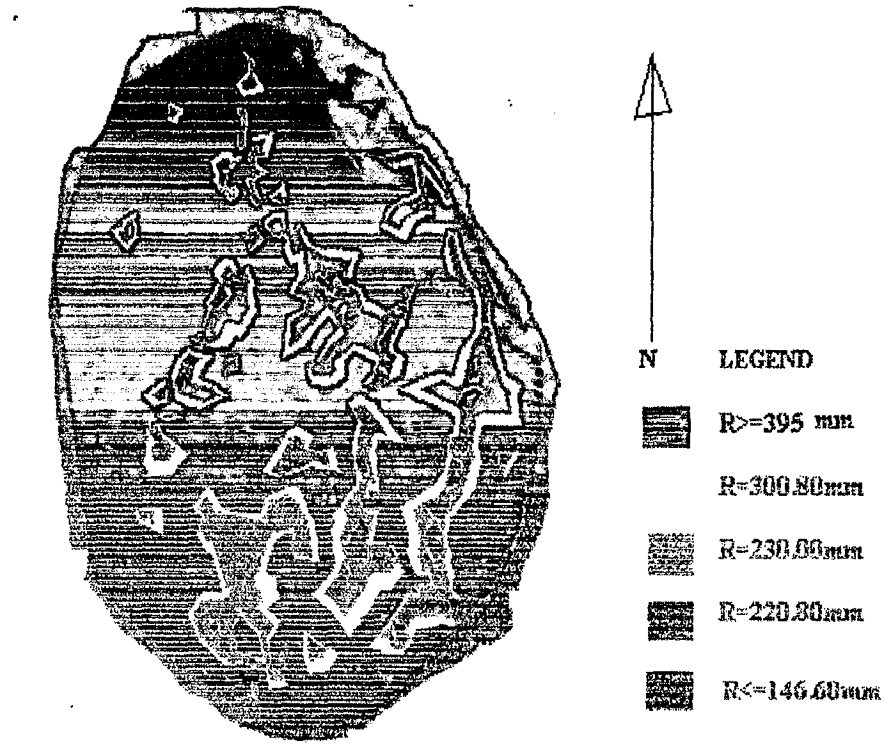


FIG: 5.15 RUNOFF DEPTH OF LEIMATAK WATERSHED



SCALE 1:250000

2.5 0 2.5 5.0 7.5

FIG5.16 RUNOFF DEPTH MAP OF KHUGA WATERSHED

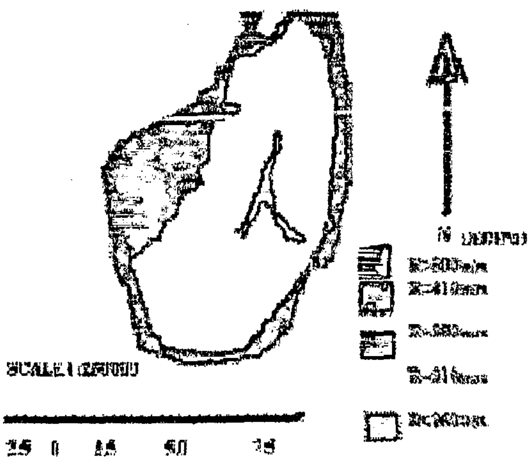


FIG5.17 RUNOFF DEPTH OF TUICHA WATERSHED

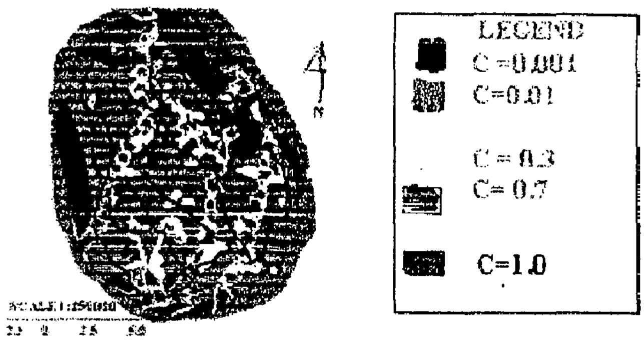


FIG 5.18 SOIL COVER MANAGEMENT C KHUGA WATERSHED

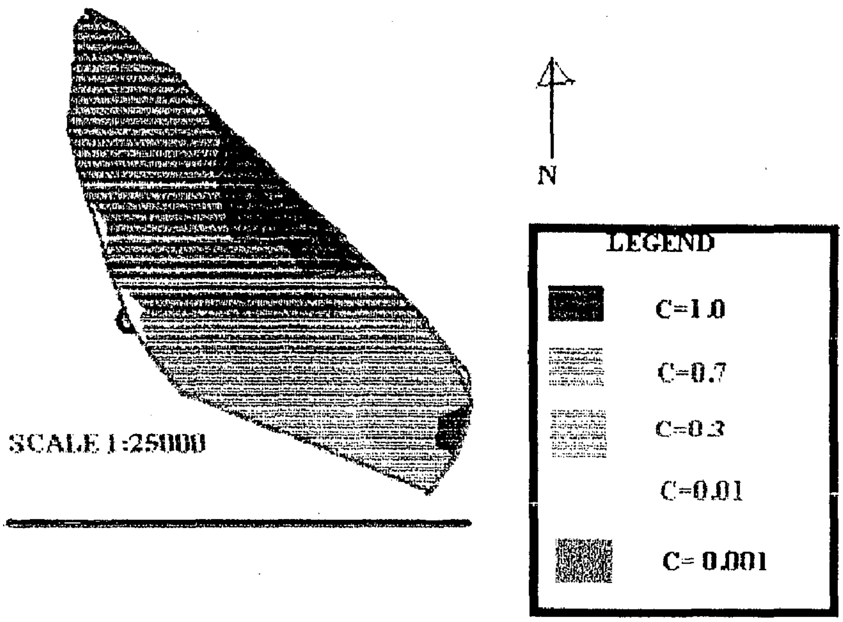


FIG:5.19 SOIL COVER MANAGEMENT C LEIMATAK WATERSHED

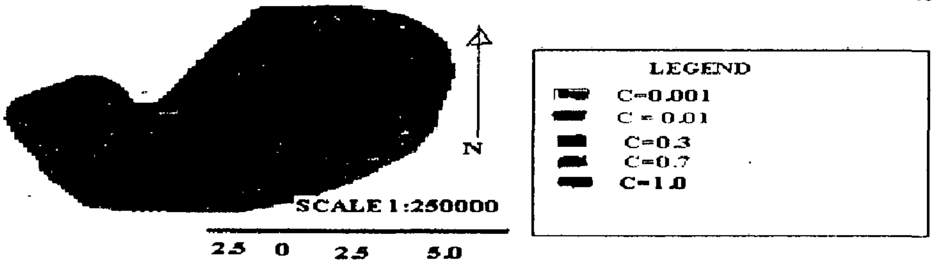


FIG : 5.20 SOIL COVER MANAGEMENT C TUICHA WATERSHED

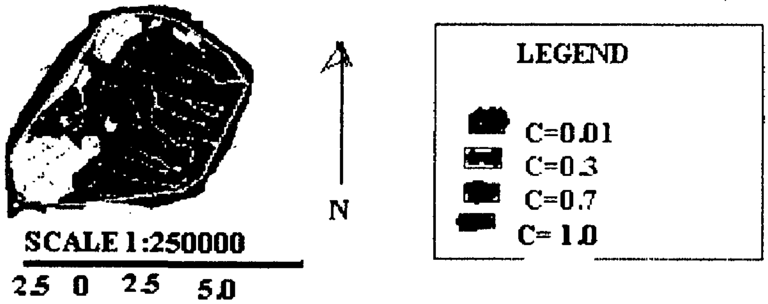


FIG 5.21 SOIL COVER MANAGEMENT C BARAK WATERSHED

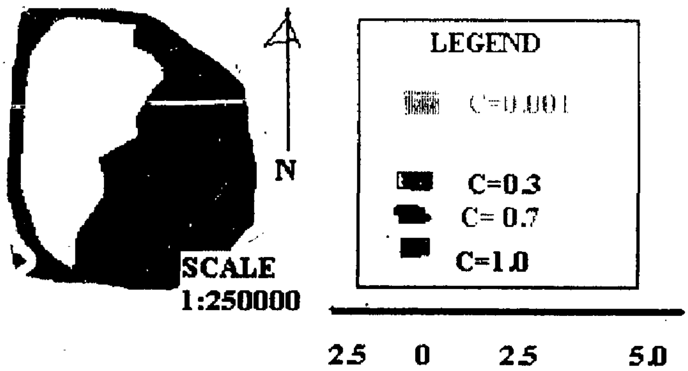


FIG :5.22 SOIL COVER MANAGEMENT C TUIJANG WATERSHED

5.4 Layers

5.4.1 Preparing soil type layers

5.4.1.1 Building polygons

Polygons must be build to assign soil types to areas in the soil coverage.

1 Select the Build Polygon command from the Feature Object menu.

2 When prompted if you want to use all arcs to build the polygons, select OK to build the polygons. If you build the soils arcs correctly, polygons will be generated from your soil arcs.

3 Select the Select Polygon tool. This tool must be selected to access the polygon attributes for the land use coverage

4 Notice that the type of each soil is written on the background image .Use SHIFT –select to select all the soil type A polygons and select the Attributes...command from the Features Objects menu.

5 Note the soil type mapping dialog that SCS soil type A is the default soil type when a soil polygon is created. Select the Apply button to assign this default

6 value to all the selected polygons .

7 Perform steps 4 and 5 for soil types B,and C.For soil type B,you will need to select "Add soil ID to list ". Select the Soil Type soil property, and change the SCS soil ID to Type B . For soil type C, you will need to select " Add soil ID to list ". Select the Soil Type soil property, and change the SCS soil ID to Type C.

8 Select the Display Options ... command from the Display menu.

9 Toggle the Colour fill polygons option on and select the OK button.

10 Select the New command from the File menu.

11 Select OK to confirm that you want to delete all data.

5.4.1.2 Creating basin boundaries

1 Select the Create Arcs tool

2 Select the Attributes ... command from the Feature Objects menu.

3 Make sure that the arc type is Generic and select OK.

4 Beginning at the outlet point (lower right) trace out the entire watershed boundary. We do not need to follow every detail, take as much time as we want .End by double-clicking near the same point where you began.

5.4.1.3 Soil map

Take the GSI map of scale 2:50,000. Select the watershed and build polygons and streams by Feature Objects menu with Attribute Command. Select the Coverage... command from the Feature objects menu.

Select the new button in the Coverages window

Change the name of the coverage to Soil type and change the Attribute set to Soil Type .

Select the Drainage coverage and select the Delete button.

Select OK when prompted for confirmation.

Select the open button in the Coverage window

Select the Import. Command from the File menu.

Select Feature object polygons Shape file (*.shp).

Select and Open "aspenso.shp".

In the polygon attributes text window, notice that HYDGRP database field is automatically mapped to the SCS soil type attribute in WMS.

The soil maps of Tuijang, Barak, Leimatak Khuga and Tuicha are enclosed in Figures 5.2, 5.3, 5.7, 5.8.5.11 respectively

5.4.2 Importing a USGS DEM

1 Switch to the DEM module by selecting the DEM module icon from the top of the Toolbox.
2 Select Import ... command from the File menu.
3 Select USGS DEM File (*.dem ;*.dbf) from the Files of type field .
4 Find and Open the file "aspen.dem". This file should be found in the tutorial directory. This will add the Dem contained in the file to the list in the Import USGS DEMs dialog.

The window at the top of the dialog shows a list of the DEM files that will be imported.

1 Select the OK button in the Import USGS DEMs window.

5.4.3 Displaying contours on a TIN

WMS has several options for displaying contours on a TIN .WMS can display lined contours, colour filled contours, and contour elevation labels. The interpolation is done soon after correction is completed for TIN . The TIN contours of Tuijang watershed,Barak watershed, Leimatak watershed, Khuga watershed and Tuicha watershed are enclosed in Figure 5.1,5.4 ,5.6,5.9, 5.10 respectively . For creating Slope map and slope direction (aspect map) from TIN the slope angle or slope percentage can be calculated in x,y direction using TIN.

5.4.4 Converting data from one coordinate system to another

In this first example, you have data in UTM Coordinates. But you want to work in State Plane coordinates.

1 Select the Open command from the File menu.
2 Find and Open the file named utm.map.
3 Select the Import command from the File menu.
4 Find and Open the file named aspen.dem.
5 Set the Import file type to USGS DEM and select OK.
6 Select OK to import the DEM.
7 Select the DEM module.
8 Select the Contour Options from the Display menu.
9 Toggle on the option for the Display Legend.
10 Select OK.

5.4.5 Computing C N using land use coverage / soil type grid

For computing curve numbers using a land use coverage and a soil type grid anew land use is coverage is created and read in a land use shape file:

1 Select the Map module icon.
2 Select the Coverages... command from the Feature Objects menu.
3 Select the New button in the Coverages window.
4 Change the name of the coverage to Land Use and change the coverage's Attribute set to Land Use .
5 Select the OK button in the Coverages window.

6 Select the Import ... command from the File menu.

7 Select Feature objects polygons Shape file (* . shp) from the Files of type field.

5.4.6 SCS Ruunoff model parameter

Antecedent moisture condition of the soil and Hydrologic Soil Cover Complex help in generating SCS Runoff Model Parameters

The soil consists of mainly C&D group .all the five sub-watersheds have sandy loam to silty loam on countryside and sandy clay to clay on the riverside area.

The land use /land cover are also developed for determining Hydrologic Soil Cover Complexes. The main cover include rain fed paddy field with Straight Row (SR) treatment and dry fields for another cropping under contoured and terraced treatment. These covers cover only poor conditions.

The largest part of the land use cover is pastures of fair conditions and forest with poor conditions.

Editing the land use map polygons with respective Curve Numbers or Soil maps generates curve Number Maps.

Table 5.8: Hydrologic soil group in the study area.

No	Land use	Condition	Curve Number (CN)	Code
1	Residential	-	74	1
2	Rained paddy field	Poor	83	2
3	Dry field with secondary crop	Poor	82	3
4.	Commercial Crops	Poor	77	4
5.	Forest land	Fair	82	5
6.	Pasture land	Poor	86	6

The maximum soil moisture retention (S) can be calculated by use of Curve Number Map. The image map for soil moisture retention can be calculated from CN Map

Smap = (25400/CN map) – 254

These values are calculated for these watersheds and shown on maps.

The runoff is calculated in terms of depth by S map and input of average monthly rainfall.

Rmap $(P-0.2 * Smap)^2$ / (P + 0.8 * Smap)

For Tipaimukh watershed for the month of July:

Rmap = $(570 - 0.2*Smap)^2$ / (570+ 0.8*Smap)

Similarly maps for other watersheds are digitized.

The runoff from upper pixel is flow accumulation in a DEM /TIN and model can be read

fdir = (Map flow accumulation mpr .TIN)

Monglen model

Monglen = (flow accumulation +P) $-0.2* Smap)^2$ / (flow accumulation + P + 0.8*S)

For Tipaimukh watershed for the month of July:

Monglen = $\{(Flow acc mpr+570) - 0.2*Smap\}^2$ / {(Flow Acc mpr 570) + 0.8*Smap}

The runoff depth and runoff accumulation map for the five watersheds can be generated.

CHAPTER VI

RESULT AND DISCUSSION

6.1General

The previous chapters includes SCS runoff model, Universal Soil Loss Equation their parameters for Barak, Tuijang, Leimatak, Khuga and Tuicha Sub-watersheds.

The maps were digitized using TIN; DEM or HEC-1 and HSPF modules.The runoff parameters were generated using Conventional SCS, modified SCS (Monglen) and Tank models. The study is related to watersheds of Manipur State of India.

The water balance is determined and soil cover; soil losses were calculated under different conservation practices.

The Figures 6.1,6.4,6.7,6.10,6.13 and Tables 6.2,.6.8,6.12.,6.16,6.21 show that in Conventional SCS method runoff is directly proportional to rainfall while in modified (Monglen) the runoff is almost constant and in tank model the runoff is almost equal to rainfall.

The water balance study shows that runoff and losses are to be determined first. The water losses are measured with domestic supply and irrigation water requirement since water demands are ever increasing the constant yield of runoff is significant to meet the requirements, hence Modified SCS (Monglen) method is given significance in the present study since it provide a relation between ETO, irrigation water requirement and domestic supply without any other major constraint .The detailed feasibility reports of Tipaimukh Dam Project and Khuga Dam Project are used for rate of flow analysis.

The surplus runoff is used to determine the additional uses .The study also suitable for water balance at outlet point. The Tank Models help in study of the weighted soil loss due to runoff reaching to these ponds.

The evapotranspiration and other losses are assumed in calculating the water balance in all the five watersheds. The surplus runoff is further utilized for more significant beneficiary areas while the deficit runoff has to other runoff storage, ground water and canal water and hence accounted in measures.

The soil losses are measured as weighted soil loss. The soil is transported by water completely and no deposition takes place. The model is significant in depicting

erosion pattern of watershed. storage Tank model / pond method can calculate the complete erosion.

6.2 Barak watershed

The Table 6.2 and Figure 6.1 read the runoff in Barak sub-watershed. From the Figure and table it can be seen that by SCS conventional method, the maximum runoff volume is 468.63 ha-m and by SCS modified, it is 131.48 ha-m produced by 570mm of rainfall which occur in the month of July. The minimum runoff volume is 8.08ha-m and 74.29 ha-m by these methods respectively by 14mm of rainfall in the month of January while Tank model gives 209.35 ha-m and 10.14 ha-m runoff for these months.

For SCS conventional method the runoff is calculated directly from the available graph. For SCS the runoff is calculated considering expected flow accumulation from drainage and rainfall or excess flow due to time lag from nearby source or watershed above. In tank model flows accumulation if any is considered along with losses due to flow of water from an area to the tank. These losses are nearly 12 to 60% depending on the type of watershed. Infiltration losses are more pronounced in sandy loam to silty loam soil.

The watershed is divided into three sub-watersheds namely Marcha Vadung River, Barak part of Sartuinek, and Barak part of Taithu villages. The available water deficit is visible in the month of November, December, January, February and March. Tables 6.3to 6.5 and Figure6.12

The results of USLE are shown in Figures and Tables 6.6,6.7 for existing and proposed conditions .The erosion by rainwater is shown by Figures 6.2.,6.3.The location of deposition of soil is unable to locate. Actual soil loss is calculated and shown by digitized TIN. The watershed is divided into five zones depending upon the elevation ranges . Zone I is upper hilly portion of watershed. Zone II is middle. Zone III is middle lower. Zone IV is lower and Zone V is critical inhabited/deeply cultivated zone where soil loss is more than 400 ton/ha/year.

Where there is more loss of soil the slope of the watershed is above 35%. Abrupt slopes without land treatments and conservation measures show more soil loss. The soil loss seems to be under control after suitable conservation measures.

Table 6. 1 :Soil erosion and conservation measures

Soil loss (ton/ha-yr)	Conservation measures	Construction
> 400	Bench terraces	High standard
50-400	Bench terraces/ graded bunds	Medium standard

The following table shows the values of rainfall –runoff models.

Table 6. 1 :Soil erosion and conservation measures

Soil loss (ton/ha-yr)	Conservation measures	Construction
> 400	Bench terraces	High standard
50-400	Bench terraces/ graded bunds	Medium standard

The following table shows the values of rainfall –runoff models.

Table 6.2 :Runoff volume of Barak sub-watershed Tipaimukh

Month	Rainfall (mm)	SCS(mm)	Monglen(mm)	Tank(mm)
January	14.00	8.08	74.29	10.14
February	40.00	29.05	82.85	19.21
March	62.00	47.19	103.19	27.06
April	190.20	153.25	107.70	72.93
May	302.00	246.08	117.82	113.09
June	530.00	435.34	120.10	194.50
July	570.00	468.63	131.48	209.35
August	426.00	349.12	115.86	157.99
September	361.10	295.18	113.40	134.81
October	204.30	164.90	107.93	78.82
November	95.00	74.53	79.46	39.99
December	16.00	9.64	74.97	12.10

Table 6.3 : Water balance of Barak sub-watershed part Tipaimukh (Area=2,425ha)

Month	Runoff (mm)	Evapotranspiration loss (mm)	Irrigation. water requirement (mm)	Water supply (mm)	Surplus /deficit (mm)
January	25.70	16.00	12.65	0.05	-3.00
February	29.00	17.90	14.70	0.05	-3.65
March	36.12	28.25	12.13	0.05	-4.31
April	37.70	23.21	12.50	0.05	1.94
May	41.60	29.43	9.85	0.05	2.27
June	41.86	26.53	8.46	0.05	6.82
July	46.02	30.63	7.93	0.05	7.41
August	40.50	25.66	8.00	0.05	6.79
September	39.69	24.04	12.40	0.05	3.20
October	37.77	23.72	12.00	0.05	2.00
November	27.81	17.05	12.81	0.05	-2.10
December	26.24	15.46	13.23	0.05	-2.50

Table 6.4:Water balance of Barak sub –watershed part Sartuinek (Area=2,620 ha)

Month	Runoff (mm)	Evapotranspiration loss(mm)	Irrigation water requirement (mm)	Water supply (mm)	Surplus/ deficit (mm)
January	29.37	17.44	12.87	0.07	-1.01
February	33.14	20.28	14.08	0.07	-1.29
March	41.28	32.28	14.50	0.07	-5.57
April	43.08	26.52	13.80	0.07	2.69
May	47.54	36.10	8.42	0.07	2.95
June	47.84	29.81	7.20	0.07	10.37
July	52.59	34.87	7.59	0.07	10.74
August	46.28	28.64	7.50	0.07	10.07
September	45.36	27.48	13.20	0.07	4.61
October	43.16	25.87	14.20	0.07	3.02
November	31.78	19.60	13.11	0.07	-1.00
December	29.99	17.50	13.47	0.07	-1.05

Table 6.5 :Water balance of Barak sub-watershed part Taithu (Area= 2,170 ha)

Month	Runoff (mm)	Evapotranspiration loss(mm)	Irrigation water requirement (mm)	Water supply (mm)	Surplus/deficit (mm)
January	18.38	11.35	8.20	0.03	-1.20
February	20.71	14.02	7.86	0.03	-1.20
March	25.80	20.18	6.50	0.03	-0.91
April	26.93	16.58	6.50	0.03	3.82
May	29.71	18.01	6.47	0.03	5.20
June	29.90	18.95	5.11	0.03	5.81
July	32.87	16.18	6.36	0.03	10.30
August	28.93	17.10	6.20	0.03	5.60
September	28.35	17.18	6.60	0.03	4.54
October	26.98	17.50	6.80	0.03	2.65
November	19.87	14.50	6.61	0.03	-1.27
December	18.74	11.36	9.62	0.03	-2.27

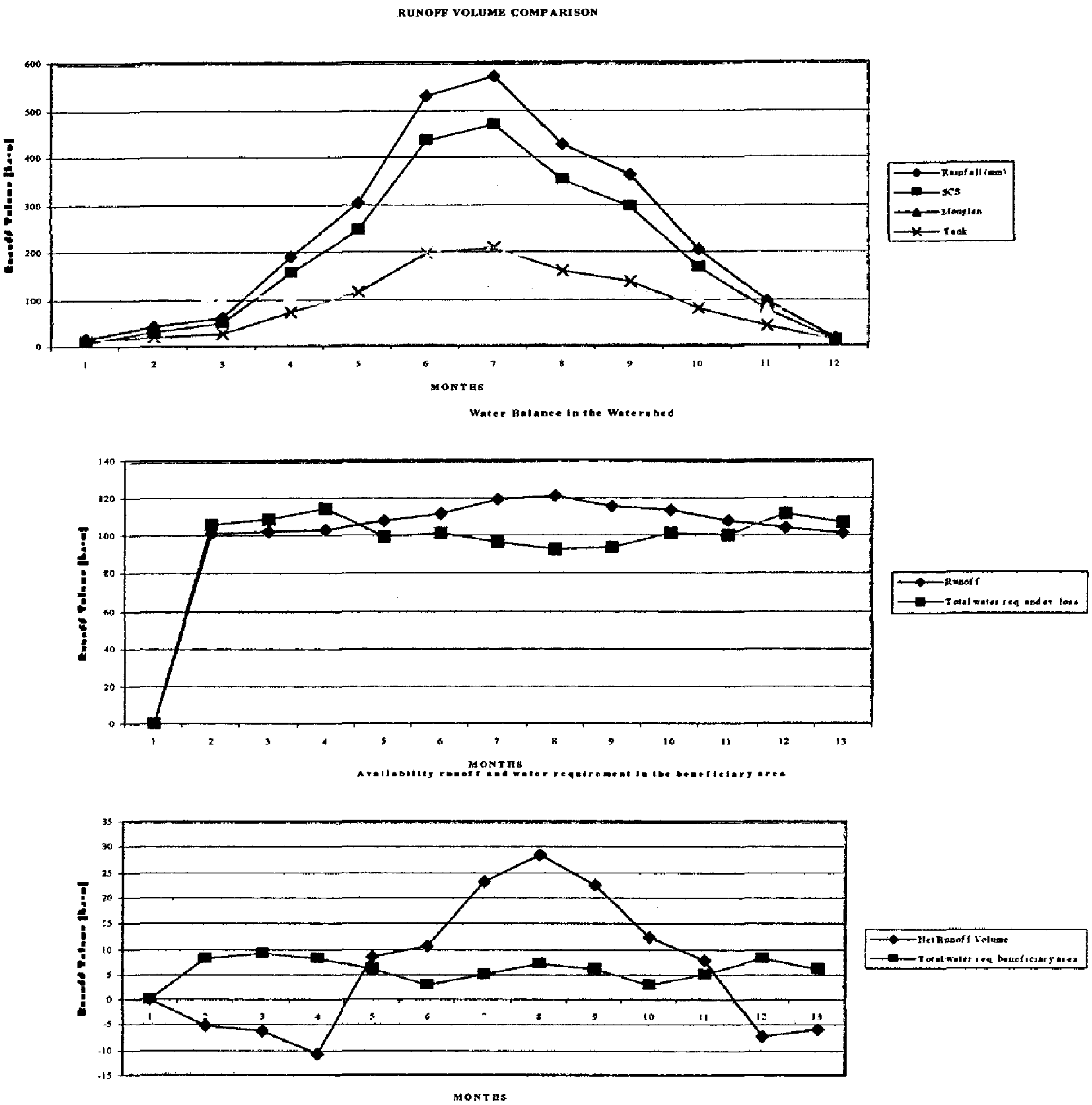


Fig. 6.1 Runoff volume of Barak watershed

Table 6.6 :Soil loss, existing condition for Barak watershed (without conservation practices) ton/ha/yr

Sub catchments		Zone (Elevation range m)					
		I >1000	II (750-1000)	III (500-750)	IV (250-500)	V <250	Total
A*	Area(ha)	505	-	1,900	20	-	2425
	Soil loss (tonnes/yr)	908752.6	-	11072535	-	-	11981288
	Rate of soil loss (ton/ha/yr	1799.51	-	5827.65	-	-	4940.74
B**	Area(ha)	1955	-	100		115	2170
	Soil loss (tonnes/yr)	12346998	-	822348		1071248	14240594
	Rate of soil loss (ton/ha/yr)	6315.60	-	8223.48		9315.20	6562.49
C***	Area(ha)	300	-	520		1,800	2620
	Soil loss (tonnes/yr)	2565030	-	4519892		16040664	23125586
	Rate of soil loss (ton/ha/yr)	8550.10	-	8692.10		8911.48	8826.56
Total	Area(ha)	2760	-	2520	20	1915	7215
	Soil loss (tonnes/yr)	15820781		16414775	-	17111912	49347468
	Rate of soil loss (ton/ha/yr)	5731.17		6513.80	-	8935.72	6839.57

A*=Slope range <5% , B**= Slope range 5-15% C***= Slope range >15%.

Table 6.7 : Soil loss ,proposed condition for Barak watershed (with conservation practices) ton/ha/yr

Sub catchments		Zone(Elevation range m)					
		I >1,000	II (750.1000)	III (500-750)	IV (250-500)	V <250	Total
A*	Area(ha)	505	-	1,900	20	-	2425
	Soil loss (tonnes/yr)	273003.0	-	1121000	-	-	13940030
	Rate of soil loss (ton/ha/yr)	5 40.60		590			574.480
B**	Area(ha)	1955	-	100		115	2170
	Soil loss (tonnes/yr)	1173977.5		88800		102373	1365150.5
	Rate of soil loss (ton/ha/yr)	600.50		888		890.20	629.10
C***	Area(ha)	300	-	520		1,800	2620
	Soil loss (tonnes/yr)	266400		462280		1602000	2330680
	Rate of soil loss (ton/ha/yr)	888		889		890	889.57
Total	Area(ha)	2760	-	2520	20	1915	7215
	Soil loss (tonnes/yr)	1713380.5	-	1672080		1704373	5089833.5
	Rate of soil loss (ton/ha/yr)	620.79	-	663.52		890.01	705.45

A*= Slope range <5%. B**=Slope range 5-15% ,C***=Slope range >15%

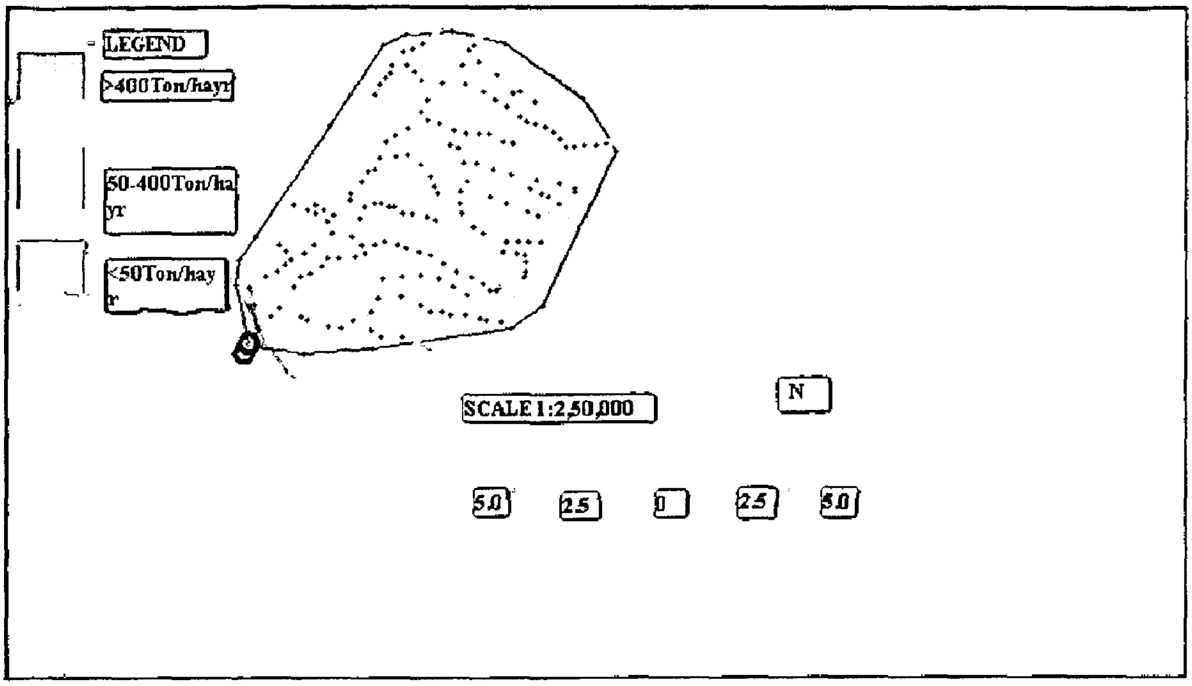


Fig. 6.2 Soil loss map of Barak watershed (existing condition)

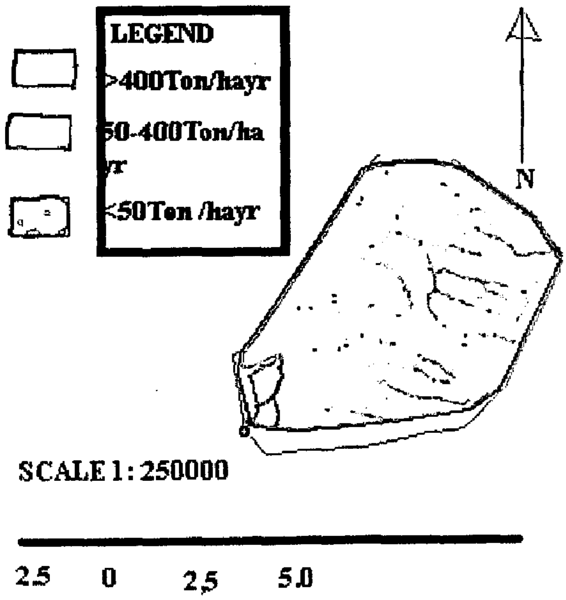


Fig. 6.3 Soil loss map of Barak watershed (proposed condition)

6.3 Tuijang watershed

The Table 6.8 and Figure 6.4 read the runoff in Barak sub-watershed. From the Figure and Table it can be seen that by SCS conventional method, the maximum runoff volume is 452.68 ha-m and by SCS modified, it is 116.32 ha-m produced by 550.60mm of rainfall which occur in the month of July. The minimum runoff volume is 3.98ha-m and 59.58 ha-m by these methods respectively by 6.60mm of rainfall in the month of December while Tank model gives 204.84 ha-m and 5.00 ha-m runoff for these months.

The watershed is divided into five sub-watersheds namely part of Tolba Lui, Chinba Lui, Vatb Lui, Vako lui and Ngatum Lui. The available water deficit is visible in the month of November, December, January, February and March. Table and Figure show the details.

The results of USLE are shown in Figures 6.5, 6.6 and Tables 6.10, 6.11. for existing and proposed conditions .The erosion by rainwater is shown by Figures 6.5,6.6.The location of deposition of soil is unable to locate. Actual soil loss is calculated and shown by digitized TIN. The watershed is divided into five zones depending upon the elevation ranges. Zone I is upper hilly portion of watershed. Zone II is middle. Zone III is middle lower. Zone IV is lower and Zone V is critical inhabited/deeply cultivated zone where soil loss is more than 400 ton/ha/year Where there is more loss of soil the slope of the watershed is above 35%. Abrupt slopes without land treatments and conservation measures show more soil loss. The soil loss seems to be under control after suitable conservation measures.

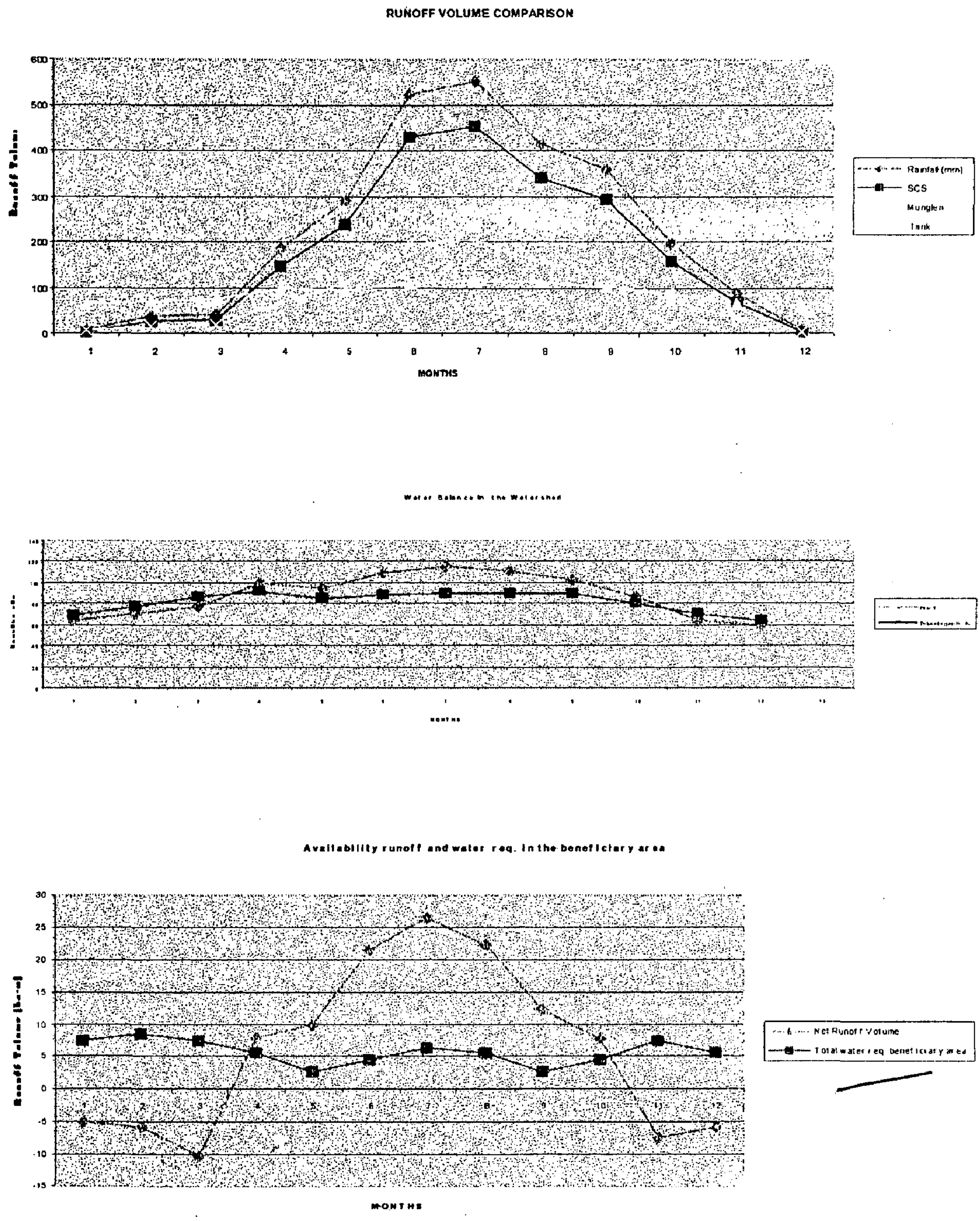


FIG: 6.4 Runoff Volumes, Water Balance Condition Tuijang Watershed

Table 6.8 :Runoff volume of Tuijang sub-watershed (Area=6,768 ha)

Month	Rainfall (mm)	SCS(mm)	Monglen(mm)	Tank(mm)
January	8.20	4.73	63.87	5.94
February	38.00	27.60	71.18	16.09
March	42.70	31.01	77.22	17.61
April	183.60	148.09	99.74	69.58
May	290.80	236.95	95.24	109.05
June	525.80	431.89	110.07	195.60
July	550.60	452.68	116.32	204.84
August	414.30	339.53	111.42	154.45
September	359.00	293.55	102.40	133.96
October	195.00	157.63	87.44	73.43
November	86.00	67.47	64.36	33.28
December	6.60	3.98	59.58	5.00

Table 6.9: Water balance of Tuijang sub-watershed (Area= 6,768 ha)

Month	Runoff (mm)	Evapotranspiration loss (mm)	Irrigation water requirement (mm)	Water supply (mm)	Surplus/ deficit (mm)
January	63.87	36.43	32.17	0.15	-4.88
February	71.18	42.42	34.37	0.15	-5.76
March	77.22	56.11	31.08	0.15	-10.12
April	99.74	60.90	30.77	0.15	7.92
May	95.24	63.09	22.23	0.15	9.77
June	110.07	67.05	21.30	0.15	21.57
July	116.32	69.60	19.88	0.15	26.69
August	111.42	69.91	20.35	0.15	21.01
September	102.40	60.45	30.21	0.15	11.59
October	87.44	49.14	30.96	0.15	7.19
November	64.36	37.80	33.33	0.15	-6.92
December	59.58	33.64	31.20	0.15	-5.41

Table 6.10 :Soil loss, existing condition Tuijang watershed (without conservation practices) ton/ha/yr

Sub catchments		Zone(Elevation range m)					
		I >1,000	II (750-1000)	III (500-750)	IV (250-500)	V <250	Total
A*	Area(ha)		670.80			406.08	1076.88
	Soil loss (ton/yr)		2227867.20		-	797558.74	3025425.9
	Rate of soil loss (ton/ha/yr)		3291.74		-	1960.76	2809.44
B**	Area(ha)	338.90	-	203.04		421.32	963.26
	Soil loss (ton/yr)	842046.66	-	663136.70		688007.4	2193190.8
	Rate of soil loss (ton/ha/yr)	5443.40	-	3266.04		1633.00	2276.84
C***	Area(ha)	338.40		203.04	179.39		720.83
	Soil loss (ton/yr)	1770004.60		649931.04	235558.8		2655494.4
	Rate of soil loss (ton/ha/yr)	5230.51		3201.00	1313.11		3683.94
D****	Area(ha)	685.25	571.05	456.84	421.32	179.39	2313.85
	Soil loss (ton/yr)	6106591.70	3327879.50	822076.38	688007.4	235558.8	11180114
	Rate of soil loss (ton/ha/yr)	8911.48	5827.65	1799.50	1633.00	1313.11	4831.82
E*****	Area(ha)	532.98		355.32	-	888.295	1776.59
	Soil loss (ton/yr)	8171382.90		593516.18	-	15567636	29674180
	Rate of soil loss (ton/hayr)	15331.50		16703.80	-	17025.30	16702.89
Total	Area(ha)	2118.45	842.63	1354.10	270.71	2536.23	6768.00
	Rate of soil loss (ton/yr)	17169028	1376014.8	3211981.30		21920941	43677965
	Rate of soil loss (ton/hayr)	8104.52	1633.00	1488.90		8643.12	6453.60

A* - Slope -<5% , B** -Slope 5-15% ,C***-Slope 15-35%, D**** Slope 35-60%,E-slope >60%

Table 6.11 :Soil loss ,proposed condition for Tuijang watershed(with conservation practices) ton/ha/yr

Sub catchments		Zone(Elevation range m)					
		I .1,000	II (750-1000)	III (500-750)	IV (250-500)	V <250	Total
A*	Area (ha)	358.78	842.63	456.84	270.71	406.08	2235.04
	Soil loss (ton/yr)	182762.5	446762.4	246967.7	-	223425.2	1099917.8
	Rate of soil loss (ton/hayr)	509.40	5 30.20	540.60	-	550.20	492.12
B**	Area (ha)	203.04	-	203.04	-	670.80	1076.88
	Soil loss (ton/yr)	112687.2		113296.3		374977.2	600960.7
	Rate of soil loss (ton/hayr)	555		558		559	558.06
C***	Area (ha)	338.40		338.90	-	571.05	1248.35
	Soil loss (ton/yr)	189504		190631.3		322643.3	702778.6
	Rate of soil loss (ton/hayr)	560		562.5		565	562.97
D****	Area (ha)	685.25			-		685.25
	Soil loss (ton/yr)	609872.5					609872.5
	Rate of soil loss (ton/hayr)	890					890
E*****	Area (ha)	532.98		888.295		355.32	1776.59
	Soil loss (ton/yr)	817218.2		1484163.3		604363.8	2905745.3
	Rate of soil loss (ton/ha.yr)	1533.30		1670.80		1700.90	1635.6
Total	Area (ha)	1915.41	842.63	1887.08	270.71	2003.25	6768.00
	Soil loss (ton/yr)	1912044.4	446762.4	2035058.6		1525409.5	5919274.9
	Rate of soil loss (ton/hayr)	998.24	5 30.20	1078.42		761.47	874.60

A*- Slope <5% , B** - Slope 5-15% , C-Slope 15-35% ,D –Slope 35- 60% ,E –Slope >60%

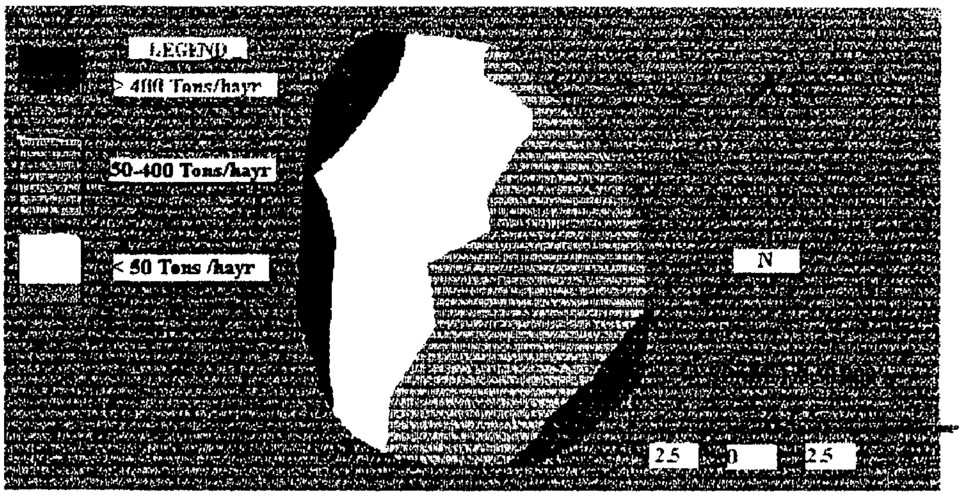


FIG: 6.5SOIL LOSS MAP TUIJANG WATERSHED (EXISTING CONDITION)

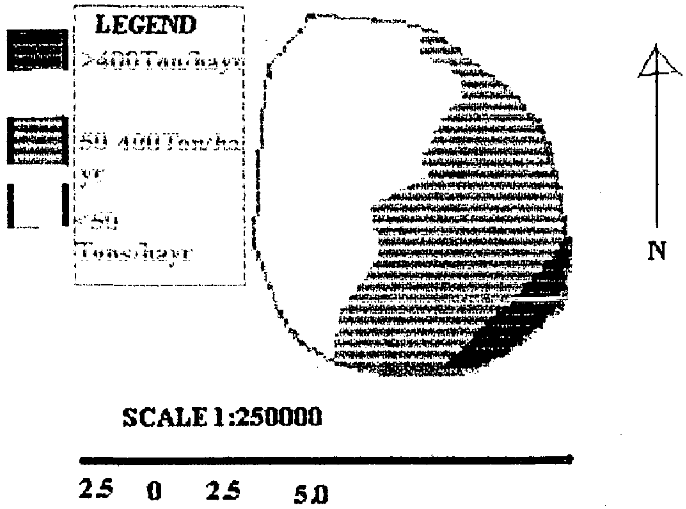


FIG6.6 SOIL LOSS MAP TUIJANG WATERSHED (AFTER CONSERVATION MEASURES)

6.4 Leimatak watershed

The Table 6.12 and Figure 6.7 read the runoff in Leimatak sub-watershed. From the Figure and Table it can be seen that by SCS conventional method, the maximum runoff volume is 299.81 ha-m and by SCS modified, it is 132.48 ha-m produced by 365mm of rainfall which occur in the month of June. The minimum runoff volume is 2.88ha-m and 71.52 ha-m by these methods respectively by 14mm of rainfall in the month of January while Tank Model gives135.55 ha-m and 3.61 ha-m runoff for these months.

The watershed is divided into two sub-watersheds namely Leimatak part of Churachandpur North town, and Gallenshof village. The available water deficit is visible in the month of November, December, January, February and March. Table 6.3and Figure 6.7 shows the details.

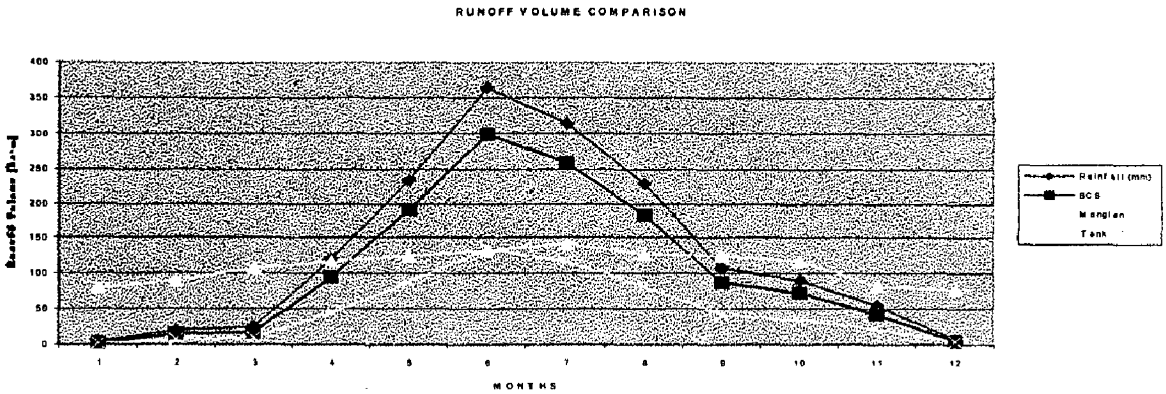
The results of USLE are shown in Figures 6.8,6.9 and Tables 6.14,6.15. for existing and proposed conditions .The erosion by rainwater is shown by Figures 6.8,6.9.The location of deposition of soil is unable to locate. Actual soil loss is calculated and shown by digitized TIN. The watershed is divided five zones depending upon the elevation ranges. Zone I is upper hilly portion of watershed. Zone II is middle. Zone III is middle lower. Zone IV is lower and Zone V is critical inhabited/deeply cultivated zone where soil loss is more than 400 ton/ha/year
Where there is more loss of soil the slope of the watershed is above 35%. Abrupt slopes without land treatments and conservation measures show more soil loss. The soil loss seems to be under control after suitable conservation measures.

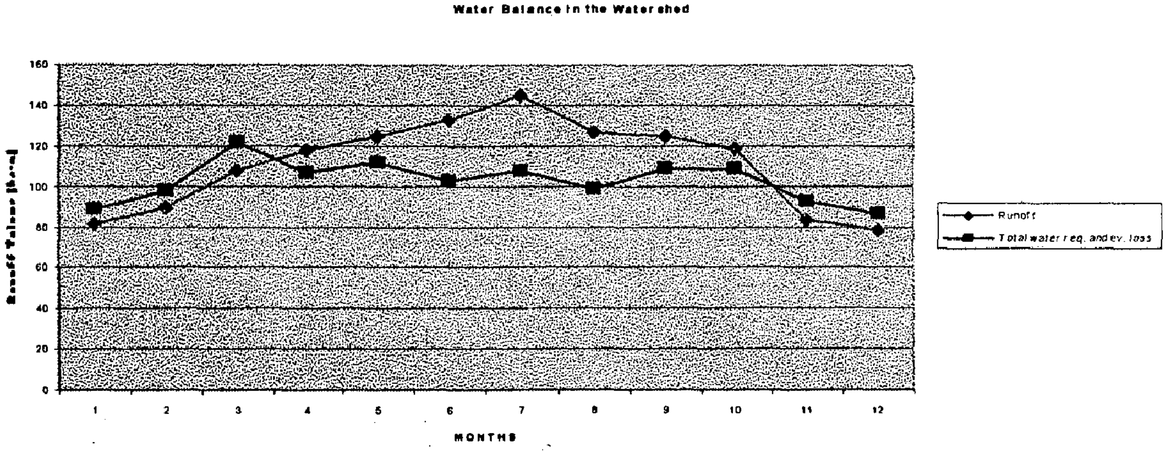
Table 6.12:Runoff volume of Leimatak sub-watershed Churachandpur North (A=9,327 ha)

Month	Rainfall (mm)	SCS(mm)	Monglen(mm)	Tank(mm)
January	5.00	2.88	71.52	3.61
February	20.00	14.53	90.02	8.79
March	25.00	18.16	108.13	10.40
April	120.00	96.79	118.02	45.34
May	235.00	191.48	124.90	87.41
June	365.00	299.81	132.48	135.55
July	315.00	258.98	130.67	117.56
August	229.00	183.25	127.27	84.19
September	107.00	87.49	125.00	41.99
October	90.20	72.91	118.34	35.57
November	56.00	43.93	83.25	22.80
December	7.00	4.22	78.64	5.30

Table 6.13 :Water balance of Leimatak sub-watershed part (A= 9,327 ha)

Month	Runoff (mm)	Evapotranspiration loss(mm)	Irrigation water requirement (mm)	Water supply (mm)	Surplus/deficit (mm)
January	81.52	43.71	44.34	0.20	-6.73
February	90.02	50.40	47.36	0.20	-7.94
March	108.13	79.05	42.83	0.20	-13.95
April	118.02	64.50	42.40	0.20	10.92
May	124.90	80.60	30.63	0.20	13.47
June	132.48	73.20	29.35	0.20	29.73
July	144.52	80.14	27.40	0.20	36.78
August	127.27	70.06	28.05	0.20	28.96
September	125.00	67.20	41.63	0.20	15.97
October	118.34	65.57	42.66	0.20	9.91
November	83.25	46.65	45.93	0.20	-9.53
December	78.64	42.90	43.00	0.20	-7.46





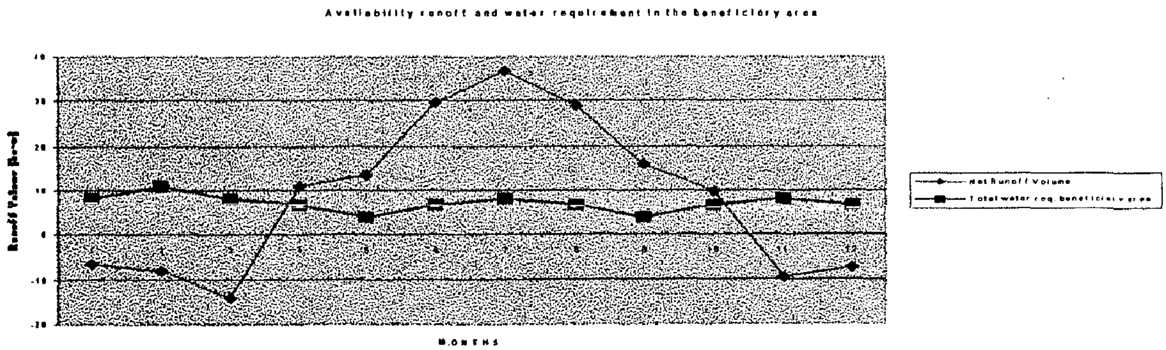


FIG: 6.7 Runoff Volumes, Water Balance Condition Leimatak Watershed

Table 6.14 :Soil loss, existing condition for Leimatak sub-watershed (without conservation practices) ton/ha/yr

Sub catchment		Zone (Elevation range m)					
		I >1,000	II (750-1000)	III (500-750)	IV (250-500)	V <250	Total
A*	Area (ha)	1212.51		1,818.77		3,031.28	6062.55
	Soil loss (ton/ha)	181018040		274692470		463882230	919592740
	Rate of soil loss (ton/hayr)	149292.00		151032.00		153031.18	151684.15
B**	Area (ha)	1632.22			1632.22		3264.43
	Soil loss (ton/yr)	179498150			299163580		478661730
	Rate of soil loss (ton/hayr)	109971.79			183286.31		146629.50
Total	Area (ha)	2844.73		1,818.77	1632.22		9327
	Soil loss (ton/yr)	360516190		274692470	299163580	463882230	1398254500
	Rate of soil loss (ton/hayr)	126731.25		151032.00	183286.31	153031.18	149914.71

A*.-Slope <60% , B** Slope >60%.

Table 6.15 :Soil loss, proposed condition for Leimatak sub-watershed (with conservation practices) ton/ha/yr

Sub catch ment		Zone(Elevation range m)					
		I >1,000	II (750-1000)	III (500-750)	IV (250-500)	V <250	Total
A*	Area (ha)	1212.51		1,818.77		1632.22	6062.55
	Soil loss (ton/yr)	7268694.3		11120324		11808606	37168199
	Rate of soil loss (ton/hayr)	5994.75		6114.20		7234.69	6130.79
B**	Area(ha)	1632.22			1632.22		3264.43
	Soil loss (ton/yr)	5297647.5			11808606		12338371
	Rate of soil loss (ton/hayr)	3245.67			7234.69		3779.64
Total	Area(ha)	2844.73		1,818.77	1632.22	1632.22	9327
	Soil loss (ton/yr)	12566342		11120324	11808606	11808606	49506570
	Rate of soil loss (ton/hayr)	4417.41		6114.20	7234.69	7234.69	5307.88

A*-Slope<60% , B-Slope >60%.

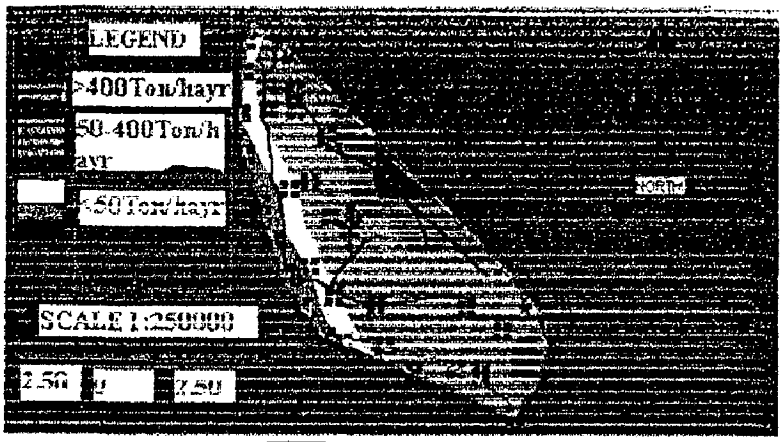


FIG 6.8 SOIL MAP OF LEIMATAK WATERSHED
(EXISTING CONDITION)

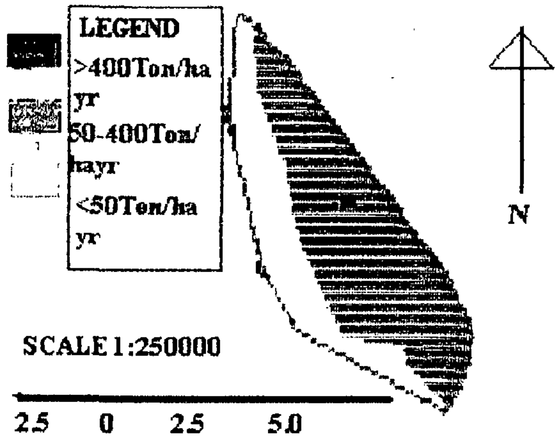


FIG6.9 SOIL LOSS MAP LEIMATAK WATERSHED (AFTER CONSERVATION MEASURES)

6.5 Khuga watershed

The Table 6.16 and Figure 6.10 read the runoff in Khuga sub-watershed. From the Figure and Table it can be seen that by SCS conventional method, the maximum runoff volume is 324.45 ha-m and by SCS modified, it is 142.48 ha-m produced by 395mm of rainfall which occur in the month of June. The minimum runoff volume is 2.88ha-m and 71.94 ha-m by these methods respectively by 5 mm of rainfall in the month of January while Tank model gives 146.85 ha-m and 3.61 ha-m runoff for these months.

The watershed is divided into five sub-watersheds namely part of Mata village, Kupu village, part of Hosphar, Part of Churachandpur Town and Khuga part of Bijang village and its tributaries. The available water deficit is visible in the month of November, December, January, February and March. Table 6.17and Figure 6.10 shows the details.

The results of USLE are shown in Figures 6.11,6.12 and Tables 6.18,6.19 for existing and proposed conditions .The erosion by rainwater is shown by Figures 6.11,6.12.The location of deposition of soil is unable to locate. Actual soil loss is calculated and shown by digitized TIN. The watershed is divided into five zones depending upon the elevation range. Zone I is upper hilly portion of watershed. Zone II is middle. Zone III is middle lower. Zone IV is lower and Zone V is critical inhabited/deeply cultivated zone where soil loss is more than 400 ton/ha/year

Where there is more loss of soil the slope of the watershed is above 35%. Abrupt slopes.

Runoff Volume of Khuga Sub-Watershed Churachandpur without land treatments and conservation measures show more soil loss. The soil loss seems to be under control after suitable conservation measures

Table 6.16 :Runoff volume of Khuga sub-watershed Churachandpur (A=9,061 ha)

Month	Rainfall (mm)	SCS(mm)	Monglen(mm)	Tank(mm)
January	5.00	2.88	71.94	3.61
February	25.00	18.16	89.03	10.42
March	28.00	20.33	98.31	11.38
April	124.00	100.02	98.19	46.88
May	230.00	187.41	121.01	85.81
June	395.00	324.45	142.48	146.85
July	300.80	247.31	140.87	112.63
August	220.80	176.69	139.74	81.31
September	146.60	104.88	126.49	49.46
October	88.60	71.62	119.00	34.70
November	55.00	43.15	84.30	22.07
December	6.00	3.62	80.28	4.54

Table 6.17 :Water balance of Khuga sub-watershed part (A= 9,061ha)

Month	Runoff (mm)	Evapotranspiration loss(mm)	Irrigation water requirement (mm)	Water supply (mm)	Surplus/deficit (mm)
January	84.94	48.21	43.08	0.19	-6.54
February	89.03	50.54	46.01	0.19	-7.71
March	98.31	70.06	41.61	0.19	-13.55
April	98.19	46.20	41.19	0.19	10.61
May	121.01	77.97	29.76	0.19	13.09
June	142.48	84.90	28.51	0.19	28.88
July	153.37	90.83	26.62	0.19	35.73
August	139.74	84.17	27.25	0.19	28.13
September	126.49	70.35	40.44	0.19	15.51
October	119.00	67.74	41.44	0.19	9.63
November	84.30	48.75	44.62	0.19	-9.26
December	80.28	45.57	41.77	0.19	-7.25

Table 6.18 :Soil loss, existing condition for Khuga sub watershed (without conservation practices) ton/ha/yr

Sub catchments		Zone (Elevation range m)					
		I >1,000	II 750-1000	III 500-750	IV 250-500	V <250	Total
A*	Area(ha)	898.07	90.61	543.66	279.52		1811.9
	Soil loss (ton/yr)	2956212.9		1065986.8	-		4022199.70
	Rate of soil loss (ton/hayr)	3291.74		1960.76	-		2219.93
B**	Area(ha)		453.72	271.83	180.73		906.10
	Soil loss (ton/yr)		2469779.4	887807.65	295932.3		3653519.30
	Rate of soil loss (ton/hayr)		5443.40	3266.04	1633		4032.14
C***	Area(ha)		453.05	271.83		181.22	906.10
	Soil loss (ton/ha)		2369682.6	870127.8		237941.9	3468987.5
	Rate of soil loss (ton/hayr)		5230.51	3201.00		1313	3828.48
D****	Area(ha)	917.41	764.52	611.62	459.20	299.12	3058.06
	Soil Loss (ton/yr)	8175480.9	4455355	1100610.2	749873.6	392744.6	14882357
	Rate of soil loss (ton/hayr)	8911.48	5827.65	1799.50	1633	1313	4866.60
E*****	Area(ha)			1189.25	713.55	475.70	2378.50
	Soil loss (ton/yr)			20247338	10939792	7945997.7	39133128
	Rate of soil loss (ton/hayr)			17025.30	15331.50	16703.80	16452.86
Total	Area(ha)	1815.48	1761.90	2888.17	1633.00	956.04	9061.00
	Soil loss (ton/yr)	11158160	6650450.1	4300196.3	12855201	1424662.1	65818174
	Rate of soil loss (ton/hayr)	6119.056	3774.59	1488.90	7902.68	1490.17	7263.89

A*-Slope range <5%, B** -Slope range 5-15%, C*** -Slope range 15-35%, D****-Slope range 35-60% , E***** -Slope range >60%,

Table 6.19 :Soil loss, proposed condition for Khuga sub watershed (with conservation practices) ton/ha/yr

Sub catchments		Zone(Elevation range m)					
		I >1,000	II 750-1000	III 500-750	IV 250-500	V <250	Total
A*	Area(ha)	898.07	90.61	543.66	279.52		1811.9
	Soil loss (ton/yr)	457476.9		153059.43			786317.29
	Rate of soil loss (ton/hayr)	509.40		565.40			580.91
B**	Area(ha)	-	453.72	271.83	180.73		906.10
	Soil loss (ton/yr)		204085.58	114758.21	71849.09	-	390692.9
	Rate of soil loss (ton/hayr)		602.20	565.20	530.80		577.26
C***	Area(ha)		453.05	271.83		181.22	906.10
	Soil loss (ton/ha)			201574.73	114798.82	69182.05	385555.60
	Rate of soil loss (ton/hayr)			595.67	565.40	530.70	569.67
D****	Area (ha)	1815.48	764.52	611.62	459.20	299.12	3058.06
	Soil Loss (ton/yr)	630635.58	348112.08	274332.4	201946.1	121222.49	157624.41
	Rate of soil loss (ton/hayr)	920.30	609.60	600.50	589.40	530.70	690.07
E*****	Area(ha)			1189.25	713.55	475.70	2378.50
	Soil loss (ton/yr)			1164465.9	666384.89	453317.26	2284161.8
	Rate of soil loss (ton/hayr)			1310.90	1250.30	1275.80	1285.70
Total	Area(ha)	1362.05	1316.03	2157.28	1214.00	714.10	6768.00
	Soil loss (ton/yr)	1028279.6	440687.9	1908178.9	1054978.1	643689.7	5422995.4
	Rate of soil loss (ton/hayr)	754.95	334.10	884.53	869.01	901.44	801.27

A*-Slope range <5%, B** -Slope range 5-15%, C*** -Slope range 15-35%, D****-Slope range 35-60% , E***** -Slope range >60%,

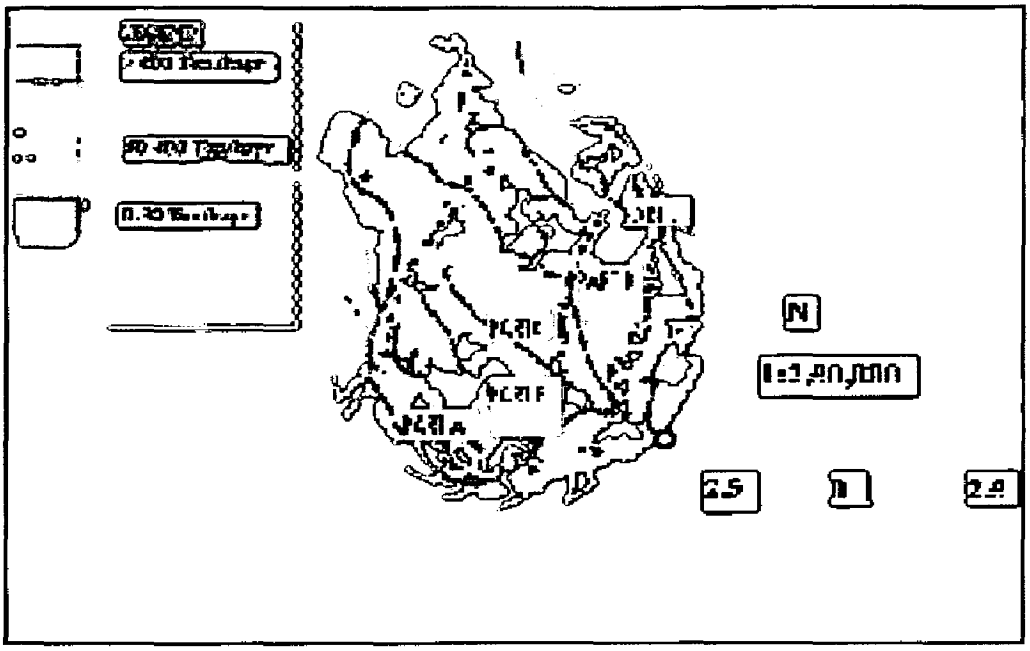


Fig 6.11: Soil loss map of khuga watershed(existing condition)

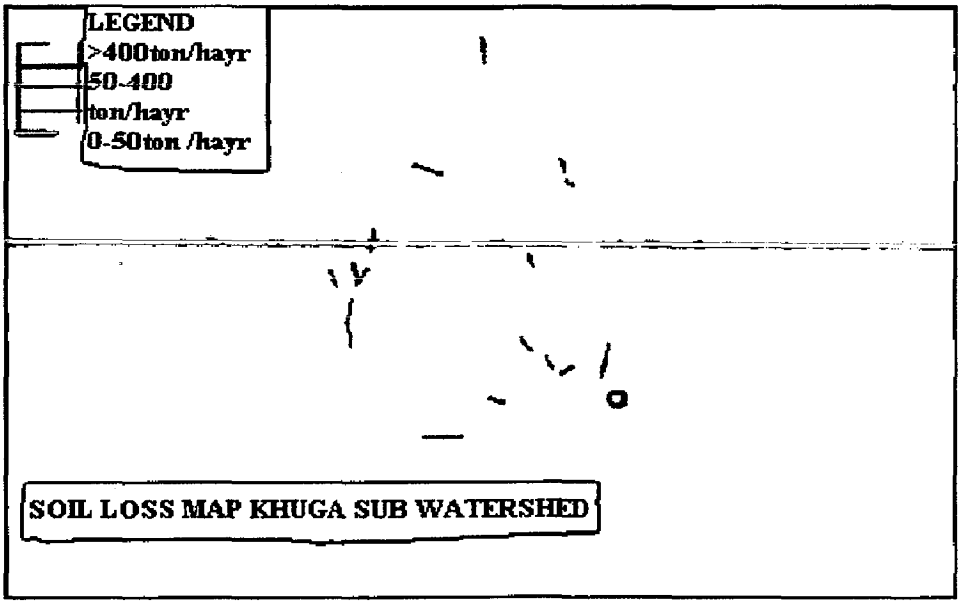


Fig 6.12 Soil loss map of Khuga watershed (proposed condition)

6.6 Tuicha watershed

The Table 6.20 and Figure 6.13 read the runoff in Khuga sub-watershed. From the Figure and Table it can be seen that by SCS conventional method, the maximum runoff volume is 411.08 ha-m and by SCS modified, it is 103.83 ha-m produced by 500mm of rainfall which occur in the month of July. The minimum runoff volume is 3.92ha-m and 41.47 ha-m by these methods respectively by 6.5 mm of rainfall in the month of January while Tank model gives 185.82 ha-m and 4.92 ha-m runoff for these months.

The watershed is divided into five sub-watersheds namely part of Mata village, Kupu village, part of Hosphar, Part of Churachandpur Town and Khuga part of Bijang village and its tributaries. The available water deficit is visible in the month of November, December, January, February and March. Table 6.21and Figure 6.13 shows the details.

The results of USLE are shown in Figures 6.14,15 and Tables 6.22,6.23. for existing and proposed conditions .The erosion by rainwater is shown by Figures 6.14,6.15.The location of deposition of soil is unable to locate. Actual soil loss is calculated and shown by digitized TIN. The watershed is divided into five zones depending upon the elevation ranges. Zone I is upper hilly portion of watershed. Zone II is middle. Zone III is middle lower. Zone IV is lower and Zone V is critical inhabited/deeply cultivated zone where soil loss is more than 400 ton/ha/year

Where there is more loss of soil the slope of the watershed is above 35%. Abrupt slopes.

Runoff Volume of Khuga sub-watershed Churachandpur without land treatments and conservation measures show more soil loss. The soil loss seems to be under control after suitable conservation measures

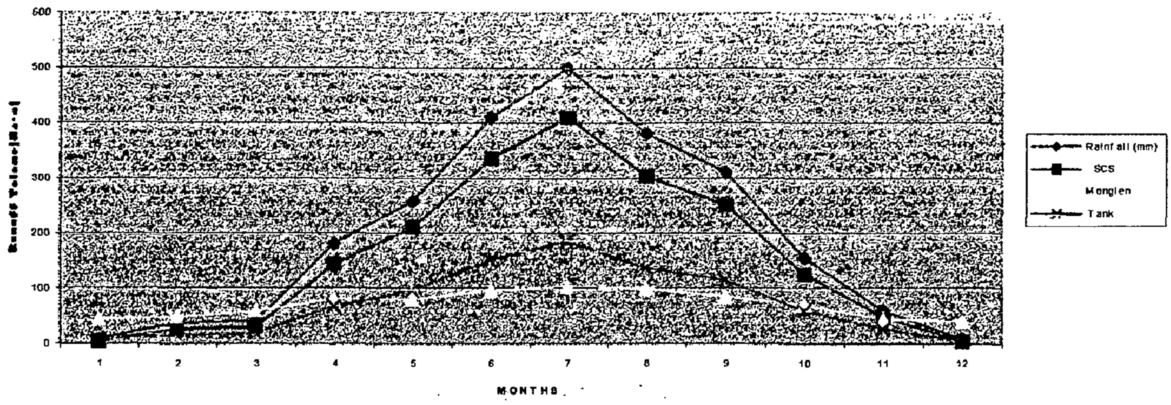
Table 6.20 :Runoff volume of Tuicha sub-watershed Thing hat

Month	Rainfall (mm)	SCS(mm)	Monglen(mm)	Tank(mm)
Jauary	9.00	5.19	44.08	6.51
February	37.00	26.87	49.85	16.09
March	40.00	29.05	58.78	17.05
April	180.00	145.19	81.99	68.36
May	260.00	211.85	80.46	97.81
June	410.00	336.77	96.90	152.99
July	500.00	411.08	103.83	185.82
August	380.00	304.08	98.40	138.28
September	310.00	253.48	84.78	115.80
October	155.00	125.30	70.12	58.85
November	60.00	47.07	44.02	24.09
December	6.50	3.92	41.47	4.92

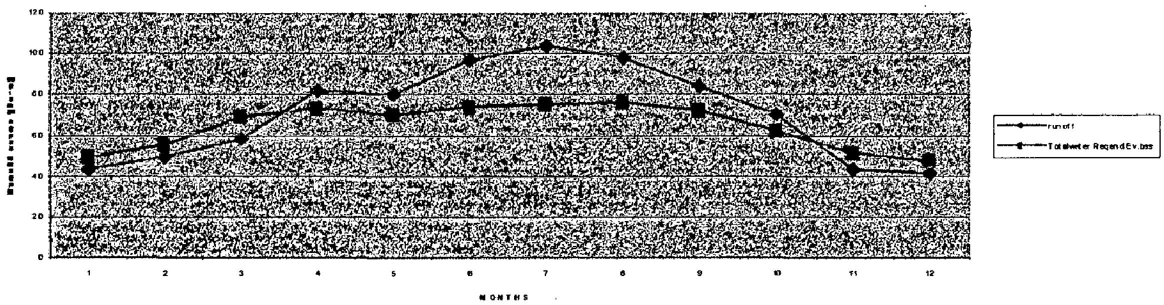
Table 6.21:Water balance of Tuicha sub-watershed part (A= 2,958ha)

Month	Runoff (mm)	Evapotra nspiration loss (mm)	Irrigation water requirement (mm)	Water supply (mm)	Surplus/deficit (mm)
January	44.08	35.7	13.50	0.07	-5.19
February	49.85	41.6	14.30	0.07	-6.12
March	58.78	55.00	14.50	0.07	-10.79
April	81.99	59.7	13.80	0.07	8.42
May	80.46	61.8	8.20	0.07	10.39
June	96.90	65.7	8.20	0.07	22.93
July	103.83	68.2	7.20	0.07	28.36
August	98.40	68.5	7.50	0.07	22.33
September	84.78	59.2	13.20	0.07	12.31
October	70.12	48.2	14.20	0.07	7.65
November	44.02	37	14.30	0.07	-7.35
December	41.47	33	14.15	0.07	-5.75

RUNOFF VOLUME COMPARISON



Water Balance in the Watershed



Availability runoff and water requirement in the beneficiary area

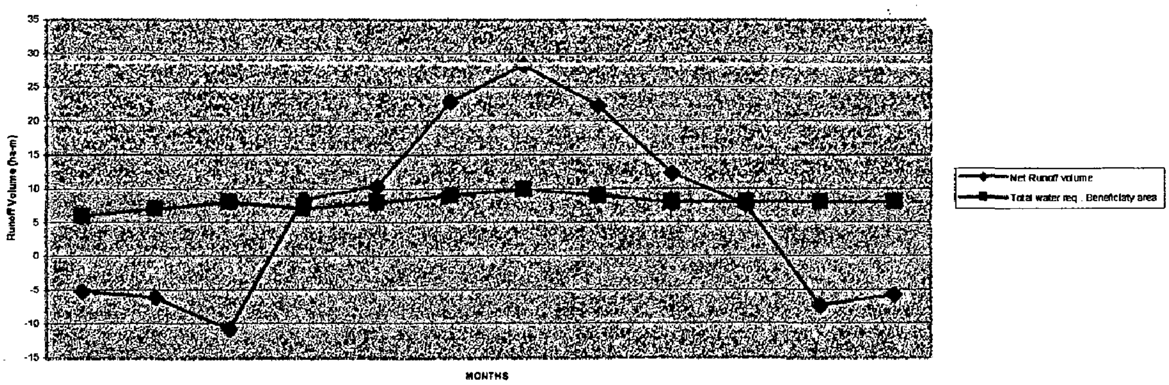


Table 6.22 :Soil loss, existing condition for Tuicha sub-watershed (without conservation practices) ton/ha/yr

Sub catchments		Zone(Elevation range m)					
		I >1,000	II 750-1000	III 500-750	IV 250-500	V <250	Total
A*	Area(ha)	156.81	177.48	297.64	293.18	218.87	1143.98
	Soil loss (ton/yr)	168049.4	284012.4	777569.1	787629.4		2017260.3
	Rate of soil loss (ton/hayr)	1071.68	1600.25	2612.45	2686.50		1763.37
B**	Area(ha)	397.70		436.30	302.1		1136.10
	Soil loss (ton/yr)	1225144.8		1862478.6	1508680.2		4596303.6
	Rate of soil loss (ton/hayr)	3080.58		4268.8	4993.98		4045.69
C***	Area (ha)	271.93		116.00		289.99	677.92
	Soil loss (ton/yr)	3402544.5		1581381.6		4029396.	9013322.7
	Rate of soil loss (ton/hayr)	12512.58		13632.6		13894.95	13295.55
Total	Area(ha)	826.44	177.48	849.94	595.28	508.86	2958.00
	Soil loss (ton/yr)	4795738.7	284012.4	4221429.3	2296309.6	4029396.	33234594
	Rate of soil loss (ton/hayr)	5802.89	1600.25	4966.74	3857.53	7918.48.95	11,235.50

A*-Slope range <5% , B-Slope range 5-15% , C-Slope range >15%

Table 6.23 :Soil loss, proposed condition for Tuicha sub -watershed(with conservation practices) ton/ha/yr

Sub catchments		Zone(Elevation range m)					
		I >1,000	II 750-1000	III 500-750	IV 250-500	V <250	Total
A*	Area (ha)	156.81	177.48	297.64	293.18	218.87	1143.98
	Soil loss (ton/yr)	67917.55	81896.37	140938.49	141840.48		432592.89
	Rate of soil loss (ton/hayr)	433.12	461.44	473.52	483.80		378.15
B**	Area(ha)	397.70		436.30	302.1		1136.10
	Soil loss (ton/yr)	193341.86		215968.50	155823.18		565133.54
	Rate of soil loss (ton/hayr)	486.15		495	515.8		464.93
C***	Area(ha)	271.93		116.00		289.99	677.92
	Soil loss (ton/yr)	277480.09		120782.68		310251.6	711341.46
	Rate of soil loss (ton/hayr)	1020.41		1041.23		1069.87	1049.30
Total	Area(ha)	826.44	177.48	849.94	595.28	508.86	2958.00
	Soil loss (ton/yr)	538739.50	81896.37	477689.67	297663.66	310251.6	1706240.8
	Rate of soil loss (ton/hayr)	616.14	461.44	562.03	709.22	609.70	576.82

A*-Slope range <5% , B-Slope range 5-15% , C-Slope range >15%

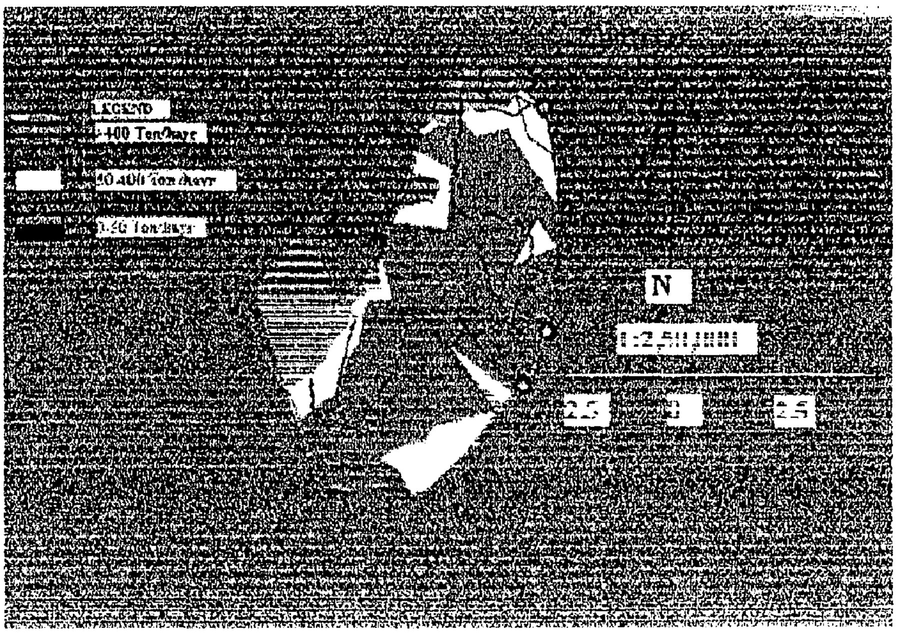


FIG6.14 SOIL LOSS MAP TUICHA WATERSHED (EXISTING CONDITION)

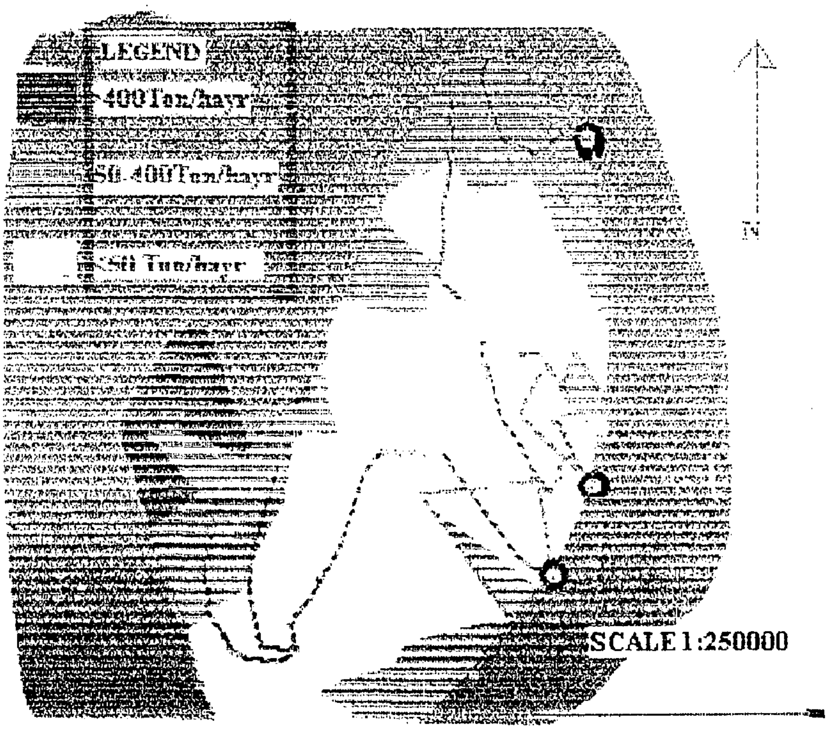


Fig. 6.15 soil loss map Tuicha watershed (proposed condition)

CHAPTER VII

WATERSHED MANAGEMENT PLAN

7.1 General

Watershed management plan is essential for maximization of benefits from the watershed for a plan period.It includes infrastructure development from construction to full functioning of the various structures. This is essential for comparative study of the watersheds and further improvement under watershed management programmes. The main consideration includes the saving of the top soil cover from rain splash erosion, keeping optimum soil moisture content, reducing decay of nutrient content, reducing the soil loss to a permissible limit and growing crops under recommended cropping pattern

7.2 Watershed management plan

The watershed management plan includes following

- Survey of the area to locate pockets, tracts for development of settled agriculture.
- Proposal for watershed management measures.
- Irrigation facilities.

The first survey was conducted for Tuijang watershed in the year 1981 .The watershed management of these areas is also included in the ix th plan. Now in 10^{th} plan few watersheds are also to be developed .The following tables shows the land available for settled agriculture and horticulture.

7.2.1Proposals

- Where there is thick soil of 1m-bench terracing is suitably constructed. The vertical interval is kept 1m and depth of cut 0.50m.riser slope would be 1:1. Minimum width is 2.3m and maximum width is 5.7m..Shoulder bunds are kept 0.30m high and its top width is kept 0.15cm.They are kept at 1in 15 inward slope. Bamboo pipes are provided for excess runoff.
- The Graded bunds and diversion bunds are provided to control soil erosion and silt deposition. These are protected by bamboo plantation

Table 7.1 :Settled agriculture / horticulture land in Barak watershed

Sl no	Particulars	Total area (ha)	Tipaimukh	Sartuinek	Taithu	Slope range
1.	Forests	5922.67	3086.45	1486.21	1350	Above 35%
2.	Land suitable for bench terracing for agriculture	157.60	88.72	43.67	27.61	Below 35%
3.	Horticulture	504.35	327.72	94.63	82	Below 35%
4.	Jhum land (present)	630.41	409.63	118.28	102.50	Varying
	Total	7215	3912.52	1742.79	1562.11	

Table 7.2 Settled agriculture / horticulture land in Tuijang watershed

Sl no	Particulars	Total area (ha)	Thanlon	SongpeKmun	Slope range
1.	Forests	5555.73	3645.67	1910.06	Above 35%
2.	Land suitable for bench terracing for agriculture	147.84	112.36	35.48	Below 35%
3.	Horticulture	473.08	363.68	109.40	Below 35%
4.	Jhum land (present)	591.35	487.86	103.49	Varying
	Total	6768	4609.57	2158.43	

Table 7.3 :Settled agriculture / horticulture land in Leimatak watershed

Sl No	Particulars	Total area (ha)	Churachand pur North	Gallenshof	Slope range
1.	Forests	7656.37	5024.11	2632.26	Above 35%
2.	Land suitable for bench terracing for	203.74	148.84	48.90	Below 35%
3.	Horticulture	651.95	501.19	150.76	Below 35%
4.	Jhum land(present)	814.94	672.33	142.61	Varying
	Total	9327	6352.46	2974.53	

Table 7.4 :Settled agriculture / horticulture land in Khuga watershed

Sl no	Particulars	Total area (ha)	Mata	Kupu	Hosphar	Churach andpur	Bijang	Slope range
1.	Forests	7438.02	540	560	580	5,200	558.02	Above 35%
2.	Land suitable for bench terracing for agriculture	197.92	14.37	14.90	15.43	138.37	14.85	Below 35%
3.	Horticulture	633.35	45.98	47.68	49.39	442.78	47.51	Below 35%
4.	Jhum land (present)	791.70	57.48	59.61	61.73	553.49	59.40	Varying
	Total	9061	657.83	682.19	706.55	6334.64	679.78	

Table 7.5: Settled agriculture / horticulture land in Tuicha watershed

Sl no	Particulars	Total area (ha)	Thing hat	Khozong	Mualtam	Slope range
1.	Forests	2428.17	1318.17	560	550	Above 35%
2.	Land suitable for bench terracing for	64.61	35.07	14.90	14.63	Below 35%
3.	Horticulture	206.76	112.24	47.68	46.83	Below 35%
4.	Jhum land (present)	258.45	140.30	59.61	58.54	Varying
	Total	2958	1605.80	682.19	670.01	

- The 2.4 m long 1.2 to 1.5 m high check dams are provided for control of gully erosion. The vertical interval is kept 5m for agricultural land and 20 m for horticultural land.
- For excessive runoffs rock fill dams are provided. These are 1m high 1.4 m wide at bottom and 0.9m at top. Sahikuhi wooden posts .20m dia and 2.2m long are provided at 1.5m interval. Rock and boulder stacked around it and messed with 3mmGI wire net 10 cm square diagonal mesh with overlapping 0.6m.

There are 66 U/S rock fill dams and 42D/S rock fill dams on river Tuijang (Table 7.6)

Table 7.6 Number of rockfill dams on rivers of watersheds

Name of river	U/S Rock fill dams	D/S Rock fill dams
Barak	70	45
Tuijang	66	42
Leimatak	91	58
Khuga	88	56
Tuicha	29	18
Total	344	219

7.2.2Irrigation facilities

The diversion structures are allowed to be constructed across tributaries of river Barak, Tuijang, Leimatak, Khuga and Tuicha for providing irrigation facilities to these areas for Kharif and Rabi season.

The water, from the streams would be diverted by rock fill dam structure and is carried through unlined channels and rubble stone lined channels. Drop structures across each channel are also provided. . Drainage crossings are also provided. Each 1to 2 hectare of land is provided outlet. Flooding method is most common method used for irrigation.

7.3 Measures

7.3.1Introduction

Water and soil are two basic natural resources in a watershed. Their management is essential to achieve significant inputs in crop production, industrialization, rehabilitation and mass business activities. The soil of the watersheds is prone to erosion and need erosion control measures also termed as soil conservation practices /measures /structures and are grouped as

- Biological or cultural measures
- Engineering or mechanical measures.

7.3.2Biological measures:

Biological measures are normally adapted without any disturbance /movement of surface soil or modification of land surface. However, the vegetation canopy dissipates the kinetic energy associated with the falling rain the cultivated land allow more soil to move along with runoff. The optimal solution is to reduce the value of crop management factor C in Universal Soil Loss Equation and quantity of runoff.

7.3.2.1 Farm management

The common biological measures come under Farm Management.

Farm Management advised

- High percentage of clay in soil.
- Clods and large pores.
- High percentage of organic matter

- High fertility.
- Divalent ions.

Among all above requirements except clay content other conditions can be achieved. Some of the important measures include

7.3.2.2 Crops early planting

Planting crops can reduce the erosion and runoff in the soil before rainy season. It is oblivious that the empty fields are more prone to erosion.

7.3.2.3 Companion crops

The companion crops have proved to be very useful in reducing soil erosion and runoff. The common companion crops include cereals and vegetable oil.

Table7.7: Effect of companion crops on soil loss

Treatments	Annual runoff in % of rainfall	Annual soil loss in tons/acre
Bare soil, not worked	32	11.5
Maize, not fertilized	10	3.6
Maize+ mineral fertilizer	9	3.1
Maize+ mineral fertilizer +companion crop	6	2.1

Source C G Wenner, 1981

7.3.2.4 Mulching

7.3.2.4.1Normal mulching or stubble mulching

The dead plant residues are used to cover the crops thus reducing Cover Management Factor . Banana –leaf and grasses mulch are more useful because

- It control raindrop erosion, induce infiltration without clogging the soil pores.
- The earthworms, other insects are attracted by mulches that increase the permeability of the soil.

7.3.2.4.2 Trash farming

The trashes of crops left in the fields are ploughed to reduce the soil erosion.

7.3.2.5 Contour farming

The farming has its significance in making furrows and planting along the contours .This allow medium slopes to come across .Hence extra cost involved can be saved in overall agricultural activities .These are also suitable in paddy cultivation and other commercial crops need more depth of water. Since runoff formation is very less which results in less damage to nutrient content. The method is commonly used on terraced land.

7.3.2.6 Strip cropping

To reduce soil erosion between contours contour strip cropping are preferred over contour farming. The grass strips as well as crop strips save from rain splash erosion. These are not suitable for humid reason due to large forest cover over soft soil cover.

Table 7.8 :Recommended maximum widths of crop strips

Slope	Recommendation
50%	8m for Churachandpur District
30-20%	10 m or closer if experience demands
20-12%	According to observations made in
	Churachandpur district 20m
Less than 12%	168-(7x% slope) in feet for an average 10% slope 168-(7x10) = 98feet or33m for lower slopes

7.3.2.7 Pitting

These are suitable for low rainfall areas, usually prone to drought .These are recommended at the Katumani Research Center of Machakos district of Kenya. These are semicircular pits of 30cm dia and 20cm deep with seeds planted in the middle.

7.3.2.8 Tied ridging or listing

This includes the cutting along contours on ridging lands in nearly plain area. The method is unsuitable in low permeable zones with high rainfall. This can be used with Pitting up to 0.75m deep pits.

7.3.3 Engineering or mechanical measures

These are measures adopted across the overland flow. These are physical since these are used after identification of direction of overland flow.

7.3.3.1Cutoff drains/cutoff trenches

Cutoff drains/cutoff trenches on higher slopes to check rill and gully erosion control the greater flows of intensive rainfall. This is the most common method used in the district.

7.3.3.2Terraces

These are also preferably used on slopes (Fig.7.6). Some of the recommended values are as below

Table 7.9 Recommended terraces

Type of terrace	Slope	Comments	Adaptability in the district
Excavated			
Ordinary	12(20)-35%	Expensive &not	Not recommended for use
Modified	35-55%	Suitable for shallow soils	
Developed			
Grass strip	2-35(55)%	Cheap and easy to construct	Highly recommended
Fanya juu	2-55%		Commonly used in foreign countries

7.3.3.2.1 Design of developed terraces

The vertical interval VI= {% slope (above the terrace line/a} +b)

The value of a for Churachandpur district is 4 and the value of b can be taken as 2 .

The Horizontal Interval HI= (Vix100) / % slope

7.3.3.3 Check dams

These are constructed across gully to check high flow velocity and induce infiltration(Fig. 7.7). Thus constructed small check dams control erosive velocity of current across gully. These are made compacted and vegetations are grown to reduce further erosion.

VI between checks dams = Height of check dams

For stone check dams VI=1m

They are limited to 2m deep and 5m wide gullies.

As per Heede and Mufich (1973), the spacing between two check dams are

$X = H_E / K \tan S \cos S$

Where

X = Spacing in meters,

H_E = Effective dam height (m) as a measure from gully bottom to spillway crest,

S = Slope of the gully floor,

K = Constant, 0.3 when tanS is less than or equal to 0.2 and 0.5 when tanS is greater than,0.2

Table 7.10 :Spacing in meters between check dams

Gradient %	Height of check dams			
	0.3m	0.6m	0.9m	1.2m
2	15	30	45	60
4	15	30	45	60
6	7.5	15	23	30
8	5.2	10.3	15	20
10	4.0	7.7	11.5	15
12	3.2	6.3	9.3	12
14	2.7	5.3	7.8	10
16	2.3	4.6	(a)6.7,(b)7.4	(a)8.9,(b) 10.0
20	1.8	(a)3.7,(b)4.5	(a) 5.4,(b)6.7	(a)7.1,(b)8.5
24	1.7	(a) 3.1,(b) 3.9	(a) 4.5,(b) 6.1	(a)5.9 ,(b) 8.0
28	(a)1.4,(b)1.7	(a) 2.7,(b)3.4	(a) 3.7 ,(b) 4.5	(a) 3.7,(b) 4.5
32	(a) 1.2,(b) 1.6	(a) 2.3 ,(b) 3.2	(a) 3.3,(b) 4.6	(a) 4.3,(b) 6.0
36	(a) 1.1,(b) 1.5	(a) 2.1,(b) 2.9	(a) 3.0,(b) 4.4	(a) 3.9, (b) 5.7
40	(a) 1.0(b)1.3	(a) 1.9,(b)2.9	(a) 2.7,(b) 4.2	(a) 3.5,(b) 5.5
44	(a)0.9,(b)1.2	(a) 1.7, (b) 2.8	(a) 2.4, (b) 4.0	(a) 3.1,(b) 5.2

7.3.3.4 Contouring and terracing

If contouring is ineffective measure, a combination of contouring and terracing is preferred.

Table 7.11: Runoff curve number values with watershed management in Manipur

Land use	Area (ha)	Treatment /practices	Hydrologic condition	Curve number
Rice	30,330	Contoured+ terraced	Good	81
Maize	3120	Contoured+ terraced	Good	80
Millet/Sorghum	700	Contoured+ terraced	Good	79.5
Root /tuber crops	900	Contoured+ terraced	Good	77
Pulses	9,500	Contoured+ terraced	Good	77
Coffee/fruit Trees	1,200	Contoured+ terraced	Good	70
Grazing land	65,130	-	Good	70
Forest land	3,10,180	-	Good	70
Pasture land	8,35,860	-	Good	70
Scrub	75,000	-	Good	70
Total	13,31,920	-		

Hence after acquiring watershed management the weighted Curve number will be ,

CN={30,330x81+3,120x80+700x79.5+900x77+9500x77+1,200x70+65,130x70+3,10 ,180X7+ 8,35.860x70 +75,000x70}/13,31,920

={24,56,730+2,49,600+55,650+69,300+7,31,500+84,000+45,59,100+2,17,12,600+5, 85,10,200+52,50,000}/13,31,920

=70.33

Or, 70.33=25400/(254+S)

S=107.15mm (10.72cm)

$Q= (P-0.2S)^2/(P+0.8S)$

$=(42.9-0.2x10.72)^2/(42.9+8x10.72)$

=1661.05/128.66

=12.91cm (129.10mm)

Water savings = 183.78-129.10 =54.68mm

Water saving (volumetric) = Depth xarea {54.68/1000} x13, 31,920 x10^4 =728Mcm of the entire Manipur State.

Water savings for Barak sub-watershed for the proposed area = 0.32Mcm

Water savings for Tuijang sub-watershed for the proposed area = 0.31Mcm

Water savings for Leimataksub-watershed for the proposed area = 0.42Mcm

Water savings for Khuga sub-watershed for the proposed area = 0.41Mcm

Water savings for Tuicha sub-watershed for the proposed area = 0.14Mcm

7.3.3.5 Bunding

These are earthen structures constructed in numbers on agricultural lands for breaking the speed of runoff on 1 to 6% moderate slopes and rainfall less than 600mm(Fig.7.5). Rill and Gully erosion are controlled by these structures. These are of two type's namely contour bunds and graded bunds. Contour bunds are constructed along the contours for storing rainwater during a day and suitably at a recurrence interval of 10 years. Graded bunds are constructed along the predetermined longitudinal grades.

7.3.3.6 Dug –out ponds /farm ponds

If the watershed slope to a suitable distance is nearly flat or small slope the idea of construction of embankment is costly. Due to storage of water at a place the evaporation losses are very less .In fact low land areas are further suitable.

Estimation of volume of pond

Using primordial formula

$$V= (A + 4B + C) \times D/6$$

Where:

V = Volume of excavation $(m)^3$,

A = Area of excavation at the ground surface $(m)^3$,

B = area of excavation at the mid depth point (0.5D) $(m)^2$

C= Area of excavation at the bottom of pond $(m)^2$

D= Average depth of the pond (m).

(e) For **Khuga watershed** the analysis does making **5 sub-divisions**, which were made in light of drainage map. Main features are ,

(i) The slope range of watershed varies **15% to 200%** from TIN/DEM.

(ii) Runoff depth under existing conditions varies from **423.00 mm**

(iii) Surplus runoff volume generated from the watershed is 130 ha-m

(iv) After the use of this surplus runoff volume from the area**8 ha-m** always remains surplus.

(v) Rate of soil loss with existing condition is**7263.89 ton/hayr** and after applied soil conservation measures is **801.27ton/ha.yr**.

8.3 Recommendations

Evaluation of these watersheds shows that the excess runoff is generated more in Barak, Leimatak watershed. The soil loss is high in all the watersheds. The excess soil losses will harm Tipaimukh and Khuga reservoirs. The soil conditions are not favorable even for selection of a project without watershed management measures. The conditions in Tuijang and Tuicha are serious but under control. High and medium standard bench terraces and graded bunds are advised to be constructed at all the places having soil loss greater than **400 ton/hayr**.. The National Watershed Development Programme for Rainfed Areas(WDPRA), other govt organization or local NGO's may be approach for implementation of watershed management programmes successfully.

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These are earthen structures constructed in numbers on agricultural lands for breaking the speed of runoff on 1 to 6% moderate slopes and rainfall less than 600mm(Fig.7.5). Rill and Gully erosion are controlled by these structures. These are of two type's namely contour bunds and graded bunds. Contour bunds are constructed along the contours for storing rainwater during a day and suitably at a recurrence interval of 10 years. Graded bunds are constructed along the predetermined longitudinal grades.

7.3.3.6 Dug –out ponds /farm ponds

If the watershed slope to a suitable distance is nearly flat or small slope the idea of construction of embankment is costly. Due to storage of water at a place the evaporation losses are very less .In fact low land areas are further suitable.

Estimation of volume of pond

Using primordial formula

$$V= (A + 4B + C) \times D/6$$

Where:

V = Volume of excavation $(m)^3$.

A = Area of excavation at the ground surface $(m)^3$,

B = area of excavation at the mid depth point (0.5D) $(m)^2$

C= Area of excavation at the bottom of pond $(m)^2$

D= Average depth of the pond (m).

Pond capacity

Max. Pond Capacity = (AxPx0.3)/1,000,

Where ,

A= Calculated area (ha),

P= Annual total rainfall (mm) and 0.3 factor is considered for general technical

Assumption runoff accumulation is 30 % of rainfall.

Assuming that one pond is to be constructed per 5 ha of land ,therefore maximum capacity of pond is

V = (AxP x0.3)/1,000

= (5x2100 x 0.3)/1,000

$=3.15m^3$

Total proposed area under crop in the district under comprehensive watershed management is 3733 ha ,

Volume of water stored V = 3733/5x3.15 = 2351.79 m^3

For pasture land 1 pond is to be dug per 100ha. Therefore capacity of pond

= 100 x 2100 x0.3 /1,000=63m^3

Total area under pasture under comprehensive watershed management is 286795 ha

Hence volume of water stored

= (286795/100) x63 = 180680.9 m^3

Total water stored in pond = 180680.9+ 2351.79 = 183032.7 m^3

Total water in terms of depth = 183032.7/457000x1, 000 = 400.5 mm

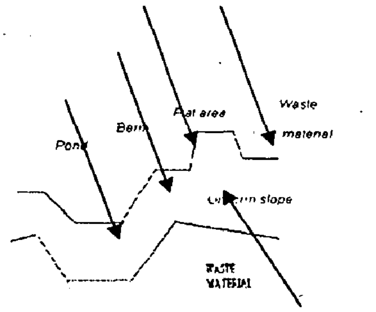

Fig 7.1 disposal of excavated material (dug out pond)

7.3.3.7 Formation of bench terraces

Bench terraces alone may not be a complete solution to check soil loss(Fig.7.2). In sandy silt to sandy loam to silty loam. On steep slopes the soil losses for sand and loam(Fig.7.3) are greater than 5Tons/acre yr(Fig.7.4) .The percentage of slopes can be reduced till condition for acceptable soil losses are not achieved. By fixation of slope the VI and HI can be calculated for terraces.

Benefits The additional moisture can be retained all along the bench terraced land that is suitable to grow maize and beans in drought prone areas.

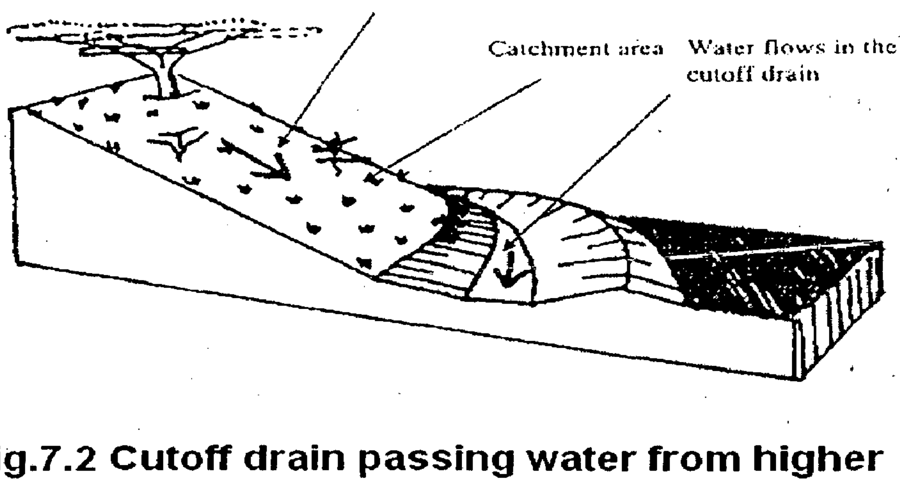

Fig.7.2 Cutoff drain passing water from higher slopes

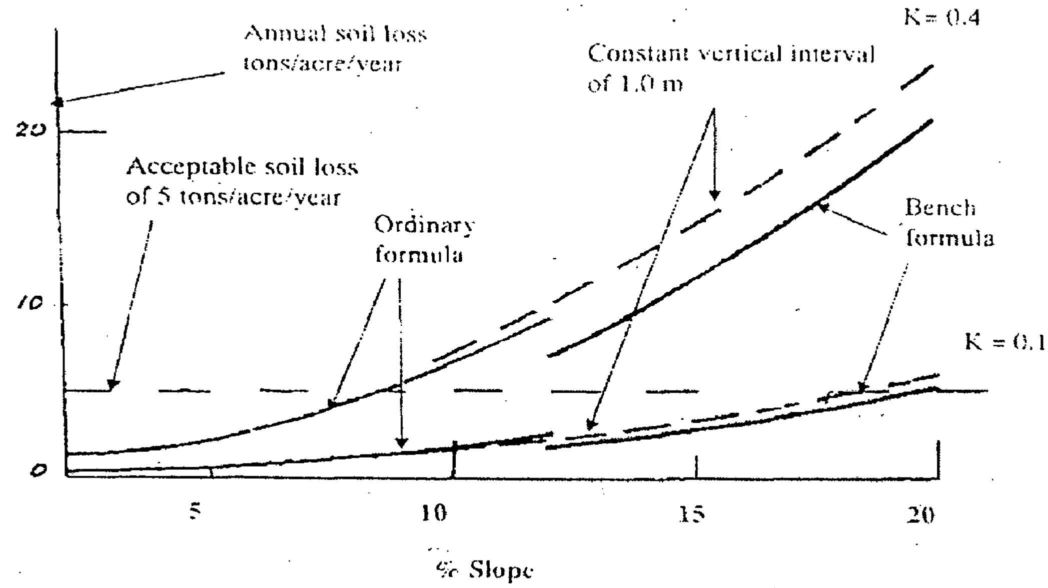

Fig **7.3 Soil** *loss from sand and loam for various slopes*

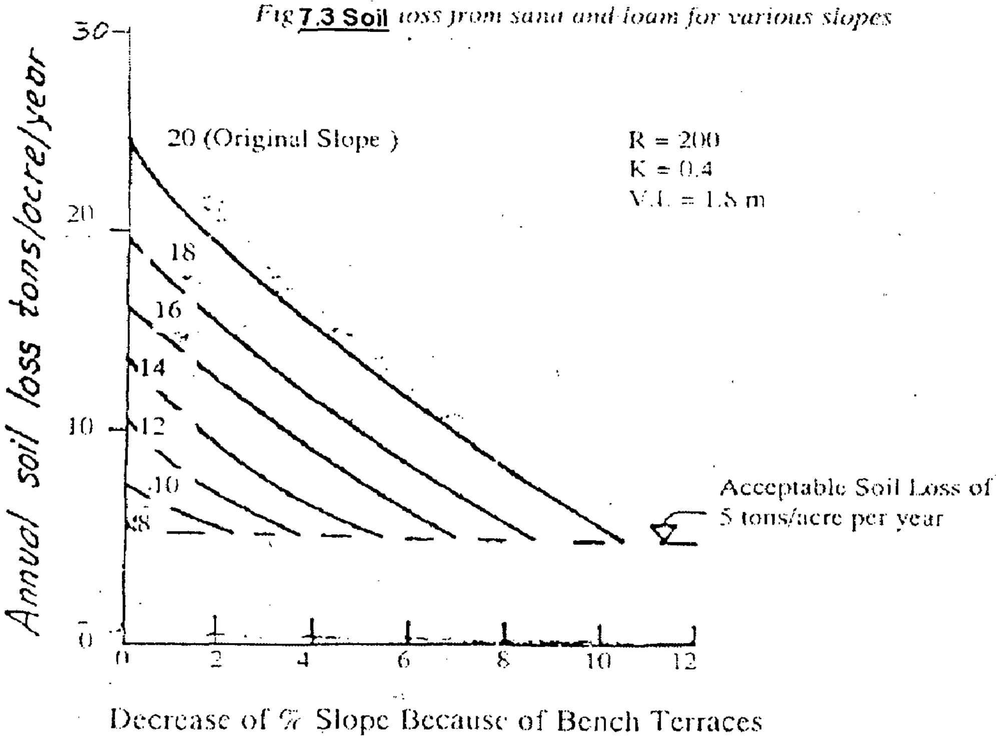

Fig **7.4 S** *lope reduction to acceptable loss of 5 tons/Acre/Year*

7.3.3.8 Field channels: When the slopes are not much and soil is clayey loam the field channels are provided to irrigate agricultural land (Fig.7.8) .Suitable cross drainage works (Fig.7.9) and diversion structures (Fig.7.10) are provided on bigger channels when slopes are more .

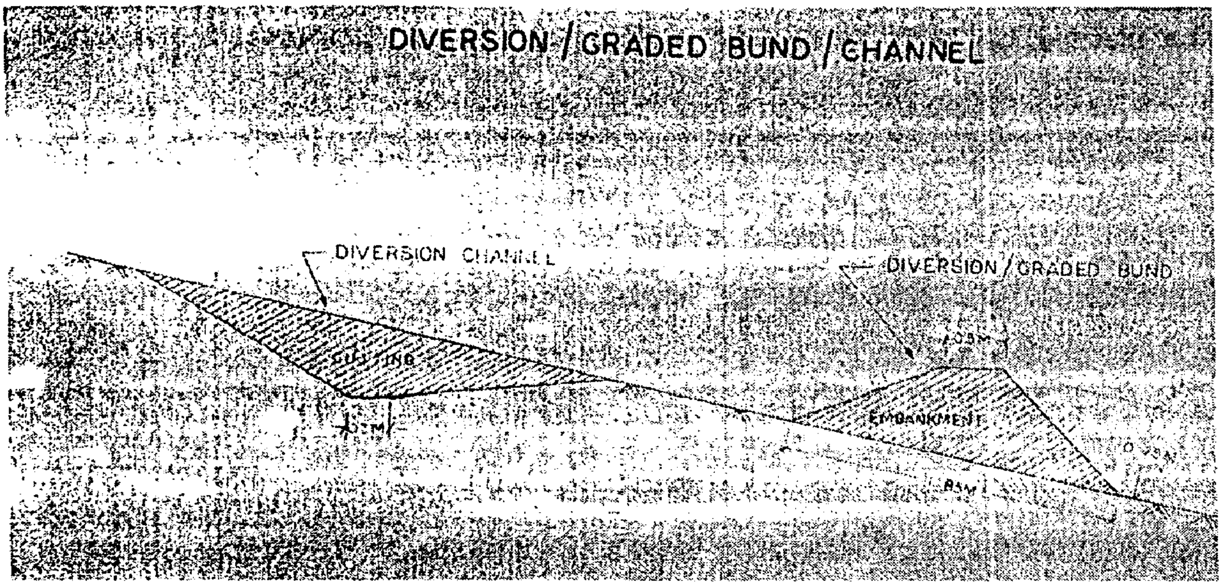

Fig. 7.5 :Diversions / graded bund / channel

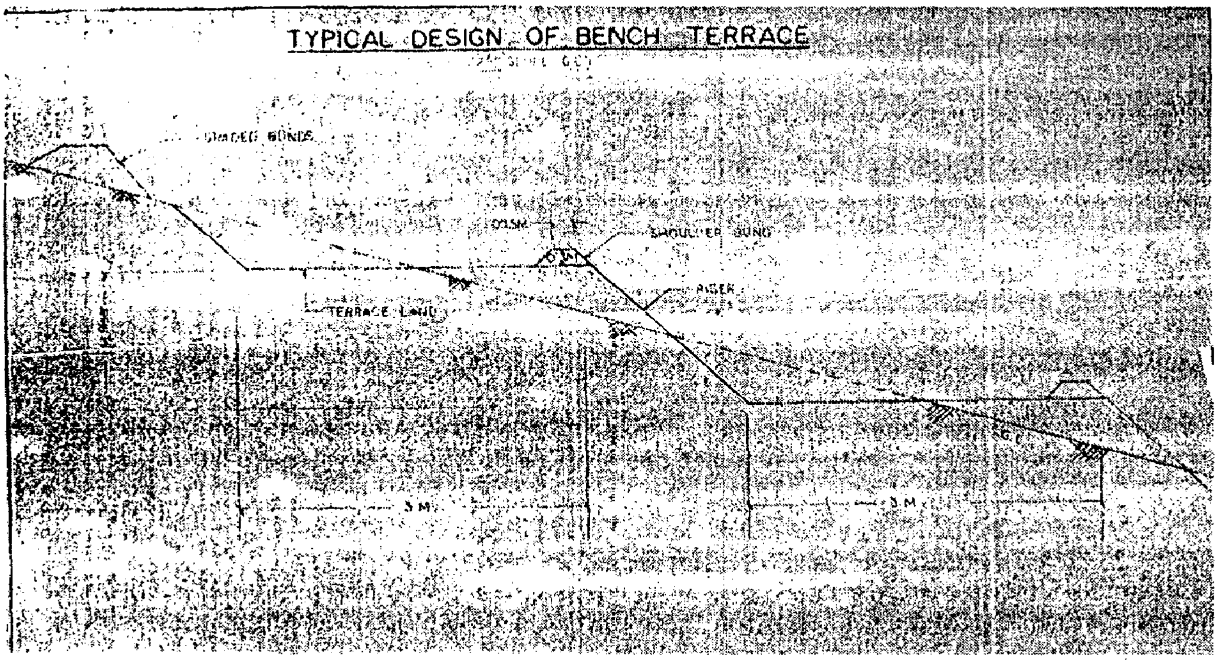

Fig.7.6 :Bench terraces

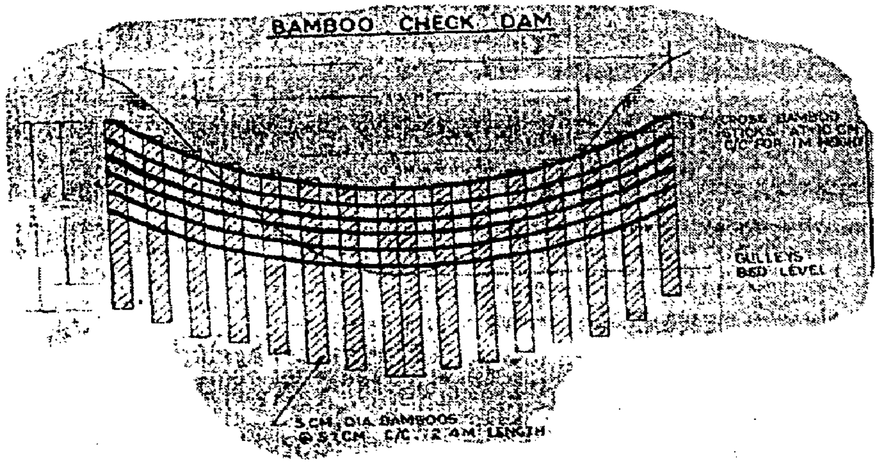

Fig.7.7:Bamboo check dam

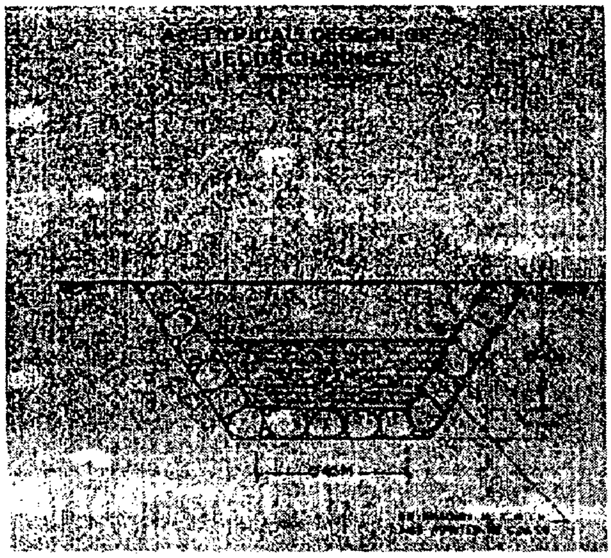

Fig .7.8 :A typical design of field channel

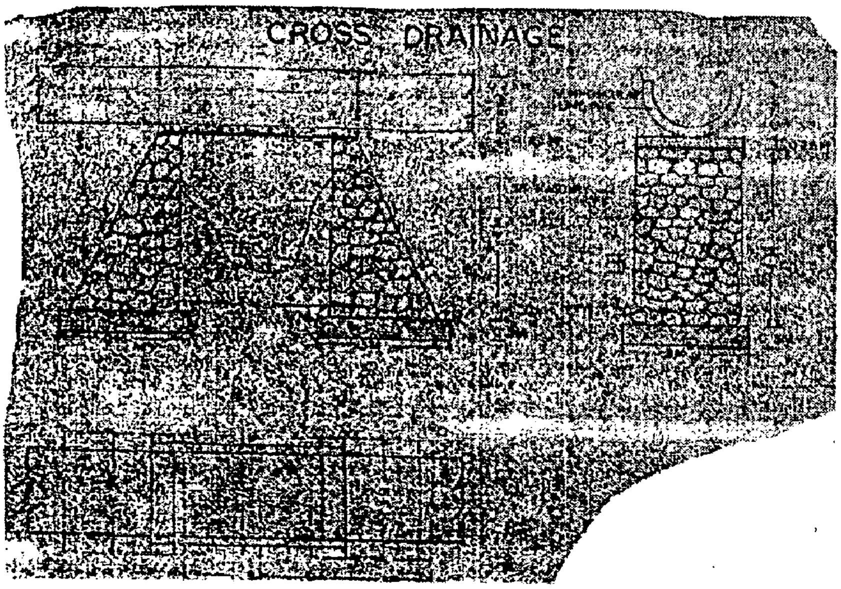

Fig. 7.9Cross drainage

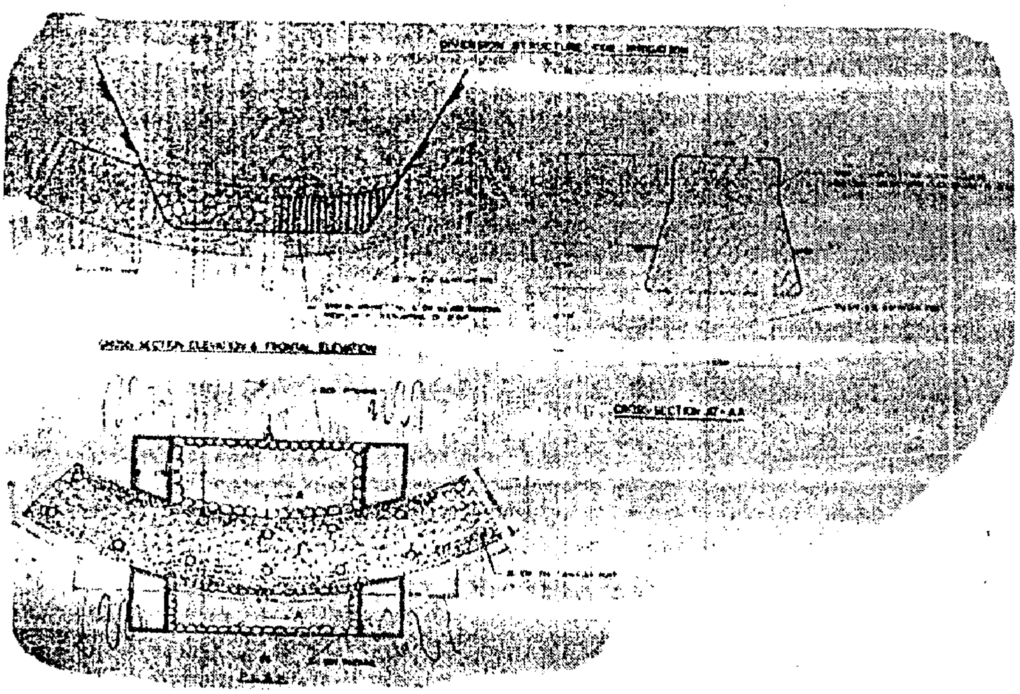

Fig. 7.10 :Diversion structure

CHAPTER -VIII

CONCLUSIONS AND RECOMMENDATIONS

8.1 General

The computer aided Watershed Modelling System (WMS) is simple comparatively to other approaches of spatial data analysis particularly of rational method, soil type and SCS rainfall-runoff models. This recent approach to watershed management is applies to Churachandpur district of Manipur state of India, where nearly twelve sub-watersheds are under study in the **10th plan**.The water shortage problem is increasing in the district. The data were collected for the district and popular scientific methods were used to analyze it.

The analog forms of data are digitized to vector structures, afterwards rasterized to common transformation scale forming common digital database. Water balance and soil classification for Barak sub-watershed Tipaimukh, Tuijang, sub-watershed Thanlon, Leimatak sub-watershed Churachandpur North, Khuga sub-watershed Churachandpur and Tuicha sub-watershed Thinghat were determined by creating rainfall-runoff and model.

8.2 Salient features

Based on the analysis and in light of the conditions and possibilities of watershed management in Manipur following are the **salient features**,

- The average rainfall ranges from **2100mm** annually within a topographic range of **800m** above sea level.
- The mean annual temperature ranges from **23°C**.The average annual evapotranspiration is **730mm.**
- The total water demand by **2003** is **260Mcm/year** and the amount available is **200 Mcm/year** giving a deficit of **60Mcm/year**.
- The water deficit is expected to grow to **118Mcm** / year by the year **2025** in case of unavailability of suitable measures. The total average runoff in the catchments is **183.78 mm** using the hydrological soil cover complex method.
- The soil loss in the district is between **8.43 tons**/ha for agricultural land. These are to be brought nearly **7.2 tons/ha** by conservation measures to increase food production.

- Soil loss on the high lands is higher than the tolerable limit and therefore soil conservation measures need to be applied.
- The total amount of water saved by watershed management may be as high as **260 Mcm** in the district.
- The land treatments are to be taken up according to local requirements. These are also discussed with the level of acceptance.
- The yield of major crops increased when grown with trees therefore agro forestry are to be encouraged to check topsoil cover erosion. These planted trees produce firewood and timber **13times** more than available from local forests of national savanna and woodland.
- Tree grown on the contour has **10-15%** of the area which seizes the overland flow and **40-50%** covered by forest can absorb it completely. Hence afforestation is not needed in these areas.
- The participatory approach includes people's participation, gender and equity, the people involved the project approach, demonstration, training and extension, implementation approach, subsides and incentives, monitoring and evaluation.
- Level of public satisfaction and proper documentation of specified projects for using the experience of the ground realities during implementation of similar projects.
- Runoff is calculated by SCS model.
- Soil maps are generated by soil type models under following assumptions,
    - Soils are basically of C&D classes carrying nearly thirteen popular names.
    - Rainfall erosivity- index generated for calculation of soil loss by rainfall data have inputs for R factor in Universal Soil Loss Equation..
    - The soil covers are very common and widely used.
    - Management soil practices factor are also commonly used all over Manipur state of India.

Based on the study followings conclusions and main features are outlined ;

(a) Barak watershed consists of three sub-divisions. The division is made according to drainage map . Main features are,

(i) The slope range of watershed varies **15% to 200%** from TIN/DEM.

(ii) Runoff depth under existing conditions is recorded **459.65mm.**

(iii) Surplus runoff volume generated from the watershed is **140ha-m**

(iv) After the use of this surplus runoff volume from the area **10 ha-m** always remains surplus.

(v) Rate of soil loss with existing condition is **6839.57 ton/hayr** and after applied soil conservation measures is **705.45ton/ha.yr.**

(b) For **Tuijang watershed** the analysis is done in **5 sub-divisions**, which were made in the light of drainage map.The main features are;

(i) The slope range of watershed varies **15% to 200%** from TIN/DEM..

(ii) Runoff depth under existing conditions varies from **442.39mm.**

(iii) Surplus runoff volume generated from the watershed is **140ha-m**

(iv) After the use of this surplus runoff volume from the area **9 ha-m** always remains surplus.

(v) Rate of soil loss with existing condition is **6453.60 ton/hayr** and after applied soil conservation measures is **874.60 ton/ha.yr.**

(c) For**Tuicha watershed** the analysis is done in three sub-divisions, which were made in light of drainage map. Main features are

(i) The slope range of watershed varies **15% to 200%** from TIN/DEM.

(ii) Runoff depth under existing conditions is recorded **397.1mm.**

(iii) Surplus runoff volume generated from the watershed is **135ha-m**

(iv)After the use of this surplus runoff volume from the area **9ha-m** always remains surplus.

(v) Rate of soil loss with existing condition is **11,235.50 ton/ha yr** and after applied soil conservation measures is **576.20 ton/ha.yr.**

(d) For **Leimatak watershed** making two sub-divisions, which were made in light of drainage map, does the analysis.Main features are,

(i) The slope range of watershed varies **15% to 200%** from TIN/DEM..

(ii) Runoff depth under existing conditions is recorded **430.00mm.**

(iii) Surplus runoff volume generated from the watershed is **150ha-m**

(iv) After the use of this surplus runoff volume from the area**10 ha-m** always remains surplus.

(v) Rate of soil loss with existing condition is **149914.71ton/hayr** and after applied soil conservation measures is **5307.88 ton/ha.yr.**

(e) For **Khuga watershed** the analysis does making **5 sub-divisions,** which were made in light of drainage map. Main features are ,

(i) The slope range of watershed varies **15% to 200%** from TIN/DEM.

(ii) Runoff depth under existing conditions varies from **423.00 mm**

(iii) Surplus runoff volume generated from the watershed is 130 ha-m

(iv) After the use of this surplus runoff volume from the area**8 ha-m** always remains surplus.

(v) Rate of soil loss with existing condition is**7263.89 ton/hayr** and after applied soil conservation measures is **801.27ton/ha.yr**.

8.3 Recommendations

Evaluation of these watersheds shows that the excess runoff is generated more in Barak, Leimatak watershed. The soil loss is high in all the watersheds. The excess soil losses will harm Tipaimukh and Khuga reservoirs. The soil conditions are not favorable even for selection of a project without watershed management measures. The conditions in Tuijang and Tuicha are serious but under control. High and medium standard bench terraces and graded bunds are advised to be constructed at all the places having soil loss greater than **400 ton/hayr**.. The National Watershed Development Programme for Rainfed Areas(WDPRA), other govt organization or local NGO's may be approach for implementation of watershed management programmes successfully.

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Runoff Curve Numbers for Urban Areas Churachandpur District

Cover Type and hydrologic Condition	Average Percent Impervious Area	A	B	C	D
Open space (lawns ,park,golfcourses,cemeteries ,etc)					
* Poor condition (grass cover < 50%		68	79	86	89
*Fair condition(grass cover 50% to 75%)		49	69	79	84
* Good condition (grass cover >75%)		39	61	74	80
Paved parking lots ,roofs,driveways,etc(excluding ,right of way)		98	98	98	98
Streets and roads :					
* Paved: curbs and storm drains (excluding right –of-way)		98	98	98	98
* Paved : open ditches (including right- of –way)		83	89	92	93
* Gravel (including right – of- way		76	85	89	91
* Dirt (including right of way)		72	82	87	89
Western desert urban areas :					
*Natural desert landscaping (pervious areas only)		63	77	85	88
* Artificial desert		96	96	96	96

landscaping (impervious weed barrier ,desert shrub with 1 to 2 inch sand or gravel mulch and basin border					
Urban districts :					
* Commercial and business	85	89	92	94	95
* Industrial	72	81	88	91	93
Residential districts by average lot size :					
* 1/8 acre or less (town houses)	65	77	85	90	92
*1/4 acre	38	61	75	83	87
* 1/3 acre	30	57	72	81	86
* ½ acre	25	54	70	80	85
* 1 acre	20	51	68	79	84
* 2 acre	12	46	65	77	82
Developing urban areas:					
Newly graded areas (pervious area only ,no vegetation)		77	86	91	94

Notes : Values are for average runoff condition, Ia = 0.2S

The average percent impervious area shown was used to develop the composite RCNs

Other assumptions are: impervious area are directly connected to the drainage system, impervious areas are considered equivalent to open space in goodhydrologiccondition.

Runoff Curve Numbers for Cultivated Agricultural Land Churachandpur District

Cover Type	Treatment	Hydrologic Condition3	A	B	C	D
Fallow	Baresoil		77	86	91	94
	Crop residue	Poor	76	85	90	93
	Cover (CR)	Good	74	83	88	90
Row Crops	Straight row (SR)	Poor	72	81	88	91
		Good	67	78	85	89
	SR+CR	Poor	71	80	87	90
		Good	64	75	82	85
	Contoured	Poor	70	79	84	88
		Good	65	75	82	86
	C+CR	Poor	69	78	83	87
		Good	64	74	81	85
	Contoured & Terraced (C&T)	Poor	66	74	80	82
		Good	62	71	78	81
	C&T +CR	Poor	65	73	79	81
		Good	61	70	77	80
Small grain	SR	Poor	65	76	84	88
		Good	63	75	83	87
	SR+CR	Poor	64	75	83	86
		Good	60	72	80	84
	C	Poor	63	74	82	85
		Good	61	73	81	84
	C+CR	Poor	62	73	81	84
		Good	60	72	80	83

	C&T	Poor	61	72	79	82
		Good	59	70	78	81
	C&T +CR	Poor	60	71	78	81
		Good	58	69	77	80
Close seeded or	SR	Poor	66	77	85	89
		Good	58	72	81	85
Legumes	C	Poor	64	75	83	85
Rotation		Good	55	69	78	83
Meadow	C&T	Poor	63	73	80	83
		Good	51	67	76	80

Notes : 1. Values are average runoff condition , and Ia =0.2S

2. Crop residue cover applies only if residue is on at least 5 percent of the surface throughout the year.

3. Hydrologic condition is based on a combination of factors affecting infiltration and runoff : density and canopy of vegetative areas ,amount of year-round cover ,amount of grass or closes-seeded legumes in rotations , percent of residue cover on land surface (good > 20%) ,and degree of roughness .

Poor : factor impair infiltration and tend to increase runoff.

Good : Factor encourage average and better infiltration and tend to decrease runoff.

Runoff Curve Numbers for Other Agricultural Lands of Churachandpur District

Cover Type	Hydrologic Condition3	A	B	C	D
Pasture,grassland ,or range – continuous forage for grazing	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Meadow – continuous grass ,protected from grazing and generally mowed for hay		30	58	71	78
Brush –weed – grass mixture ,with brush the major element	Poor	78	67	77	83
	Fair	35	56	70	77
	Good	30	48	65	73
Wood-grass combination (orchard or tree farm)	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
Woods	Poor	45	66	77	83

	Fair	36	60	73	79
	Good	30	55	70	77
Farmsteads – building ,lane driveways ,and surrounding lots		59	74	82	86

Notes : 1. Values are average runoff condition , and Ia =0.2S

Pasture: Poor is <50% ground cover or heavily grazed with no mulch ,Fair is 50% to 75% ground cover and not heavily grazed ,and Good>75% ground cover and lightly or only occasionally grazed.

Meadow : poor is 50% ground cover ,fair is 50 to 755 ground cover ,good is >75% ground cover .

Woods/grass : RCNs shown were computed for areas with 50% grass (pasture) cover .Other combination of condition may be computed from RCNs for woods and pasture

.

Woods :Poor is forest litter ,small trees and brush destroyed by heavy grazing or regular burning . Fair is woods grazed but not burned and with some forest litter covering the soil . Good is woods protected from grazing and with litter and brush adequately covering soil.

Runoff Curve Numbers for Arid and Semi Arid Rangelands of Churachandpur District

Cover Type	Hydrologic Condition3	A	B	C	D
Herba ceous –mixture of grass ,weeds , and low growing brush ,with brush the minor element	Poor		80	87	91
	Fáir		71	81	89
	Good		62	74	85
Oak –aspen –mountain brush	Poor		66	74	79
Mixture of oak brush ,aspen	Fair		48	57	63
Mountain mahogany ,bitter brush , Maple and other brush	Good		30	41	48
Pinyon – juniper –pinyon,juniper , or both ; grass undersory	Poor		75	85	89
	Fair		58	73	80
	Good		41	61	71
Sagebrush with grassunderstory	Poor		67	80	85
	Fair		51	63	70
	Good		35	47	55
Saltbush, greasewood,ereosote Bush ,blackbrush,bursage,palo,Verde,mesquite,and cactus	Poor	63	77	85	88
	Fair	55	72	81	86
	Good	49	68	79	84

Notes: Values are average runoff condition, and Ia=0.2S

Hydrologic Condition: poor is <30% ground cover (litter, grass, and brush over story), fair is 30% to 70% ground cover ,Good is >70% ground cover ,

Curve numbers for group A have been developed only for desert shrub.

Water Requirement

1. Domestic Water supply

Normal domestic water demand is 60l / person /day .The source of supply are pond /hand pump / streams/rivers. The ponds are constructed for taking 15 years of population growth by relationship as stated below.

$$Pn = Po\ (1+r)^n$$

Where

Pn= total population in last plan year (head)

P = Total population in beginning plan year (head)

r = population growth ratio (%)

h = total year

Total domestic water demand may be evaluated as below.

$$Q = n x\ q$$

Where,

Q= total water demand (m^3/day)

n= total population (head)

q = total water demand per person (60l /day /head)

2. Irrigation Water Requirement

Irrigation water demand is evaluated for per hectare of land and is assessed by a sum of effective crop requirement and influent irrigation demand excluding losses.

2.1 Land Preparation

The inheritance of optimum soil moisture for plant growth and easy ploughing of land for amount of water needed is termed as water requirement for land preparation.Vide Van de Goore et,al., 1968 the depth of water needed is 292.50 mm (9.7mm/day) according to planning without (Pusa 33) . The average value for Churachandpur District is given by

$IR = Me^K / (e^K - 1)$

Where

IR = Water requirement (mm/day)

M = EO+P or 1.1 EO +P (mm/day)

= Peak water requirement

Eo = Evaporation, P =Percolation

K= MT/S

T= Time of land preparation (days)

S = Saturation requirement

= 25400 /CN – 254

2.2 Consumptive Use

It is defined as water requirement of a crop to meet the evapotranspiratory demand. This is infect to meet the demand of evaporation from plant surface, transpiration by the plant and other respiratory demands .it is calculated as below,

Etc = Kc X ETO

Where,

ETc = Consumptive use (mm/day)

ETo = potential evapotranspiration (mm/day), calculated by Pennman's Method.

Kc = Crop coefficient, depend on kind, sort and crop age.

Percolation

It is the process where water infiltrates in to soil from unsaturated zone to saturated zone. It is taken as 1.5 to 2.0mm/day for estimation of water requirement to crop fields.

2.3 Change of Water Layer

For the use of fertilizers and antibiotics to control weed growth water surface is to be lowered for a crop thus change in water layer occur.

The change is observed 37.5 mm to 50mm for each half of second month and fourth month after transplanting.

2.4Irrigation Efficiency

The conveyance losses and farm water losses are measured in terms of irrigation efficiency. The design of water conveyance these efficiencies are taken 70 to 75% (for Pusa 33).

The design efficiency is taken 72%.

2.5 Effective Rainfall

The effective rainfall (Pe) is measured as

1. 0.8P –25 for rainfall > 75mm.
2. 0.6P – 10 for rainfall < 75mm.

By Gumbel Distribution Statistic (80% probability of return period, R80) effective rainfall is 70% to 80% probability for paddy crop.

Paddy effective rainfall =0.7xR80/15.

APPENDIX A-6

ESTIMATION OF SEDIMENT PRODUCTION RATE

1. Barak Watershed

Name of watershed	Drainage area km2	Length of mainstream km	Circularity ratioRc	Compactness Coefficient Cc	Form factor Rf	Relief m	Mainstream Channel slopes* 10^-3	Watershed perimeter Lp, km
1.Tipaimukh Watershed	72.15	16.045	.65	1.10	.49	150	9.33	33.05

Rate of sedimentation = 1.1 ha-m /100km^2 /year

2. Tuicha Watershed

Name of watershed	Drainage area km2	Length of mainstream km	Circularity ratioRc	Compactness Coefficient Cc	Form factor Rf	Relief m	Mainstream Channel slopes* 10^-3	Watershed perimeter Lp,km
1.Tuicha sub-Watershed	29.58	9.0	.605	1.28	.42	77	8.52	24.77

Rate of sedimentation = 2.45 ha-m /100km^2 /year

3. Khuga Watershed

Name of watershed	Drainage area km2	Length of mainstream km	Circularity ratioRc	Compactness Coefficient Cc	Form factor Rf	Relief m	Mainstream Channel slopes* 10^-3	Watershed perimeter Lp,km
1. Churachandpur Watershed	22.00	9.00	.82	.82	.40	70	7.07	18.72

Rate of sedimentation = 1.6 ha-m /100km^2 /year

4. Leimatak Watershed

Name of watershed	Drainage area km2	Length of mainstream km	Circularity ratioRc	Compactness Coefficient Cc	Form factor Rf	Relief m	Mainstream Channel slopes* 10^-3	Watershed perimeter Lp,km
1. Churachandpur North, Watershed	93.27	20.78	.58	1.03	.73	175	8.42	44.86

Rate of sedimentation = 69.82 ha-m /100km^2 /year

5. Tuijang Watershed

Name of watershed	Drainage area km2	Length of mainstream km	Circularit y ratioRc	Compactness Coefficient Cc	Form factor Rf	Relief m	Mainstream Channel slopes* 10^-3	Waters perime Lp,km
1. Thanlon Watershed	67.68	17.026	.93	1.038	.57	75	9.2	30.27

2

Rate of sedimentation = 1.0 ha-m /100km /year

1. Rainfall data Tipaimukh

Average Annual Rainfall

Year	Rainfall in (cm)	Year	Rainfall in (cm)	Year	Rainfall (cm)	Year	Rainfall (cm)	Year	Rainfall (cm)
1970	258.00	1978	257.00	1986	256.00	1994	302.00	2002	280.00
1971	289.00	1979	267.00	1987	321.00	1995	254.00	2003	270.00
1972	195.00	1980	249.00	1988	316.00	1996	258.00	2004	315.00
1973	277.00	1981	289.00	1989	321.00	1997	306.00		
1974	282.00	1982	271.00	1990	258.00	1998	330.00		
1975	337.00	1983	296.00	1991	282.00	1999	287.00		
1976	295.00	1984	250.00	1992	286.00	2000	306.00		
1977	341.00	1985	342.00	1993	267.00	2001	273.00		

Meteorological Data Tipaimukh

SlNo.	Month	Average rainfall (mm) 1970-2004	Av. No of rainy days 1970-2004	Average temperature (1970-2004)		Average humidity (1970-2004)	
				Max.	Min.	Max.	Min.
1	January	14.0	2.0	26.0	5.00	94.00	54.00
2	February	49.0	7.0	29.0	9.00	86.00	54.00
3	March	62.0	9.0	33.0	11.00	90.00	59.00
4	April	190.0	11.0	30.0	13.00	94.00	56.00
5	May	302.0	21.0	32.0	16.00	94.00	46.00
6	June	530.0	17.0	33.0	18.00	94.00	65.00
7	July	570.0	16.0	33.0	20.00	90.00	62.00
8	August	426.0	10.0	31.0	17.00	94.00	63.00
9	September	361.0	20.0	30.0	19.00	100.00	72.00
10	October	204 .0	20.0	31.0	17.00	95.00	59.00
11	November	95.0	7.0	28.0	14.00	93.00	54.00
12	December	16.0	2.0	26.0	11.00	93.00	56.00
Total		2810.0	142.00				

2. Rainfall data Churachandpur North

Average Annual Rainfall

Year	Rainfall in (cm)	Year	Rainfall in (cm)	Year	Rainfall in (cm)	Year	Rainfall in (cm)	Year	Rainfall in (cm)
1970	146.7	1978	149.2	1986	147.0	1994	149.2	2002	160.0
1971	163.9	1979	151.0	1987	182.0	1995	152.0	2003	154.0
1972	113.0	1980	143.8	1988	180.0	1996	146.7	2004	186.7
1973	159.7	1981	165.0	1989	183.0	1997	179.0		
1974	162.1	1982	162.1	1990	146.7	1998	187.0		
1975	190.2	1983	177.4	1991	162.1	1999	166.0		
1976	202.5	1984	142.8	1992	165.0	2000	180.9		
1977	184.5	1985	165.0	1993	152.2	2001	155.9		

Meteorological Data Of Churachandpur North

SlNo.	Month	Average rainfall (mm) 1970-2004	Av. No of rainy days 1970-2004	Average temperature (1970-2004)		Average humidity (1970-2004)	
				Max.	Min.	Max.	Min.
1	January	5.00	1.00	25.00	0.00	93.00	53.00
2	February	20.00	3.00	28.00	0.00	86.00	54.00
3	March	25.00	4.00	32.00	5.00	89.00	59.00
4	April	120.00	12.50	15.00	10.00	94.00	56.00
5	May	235.00	12.70	31.00	10.00	93.00	44.00
6	June	365.00	16.30	32.00	18.00	94.00	65.00
7	July	315.00	17.20	32.00	19.00	89.00	62.00
8	August	229.00	15.00	30.00	19.00	94.00	60.00
9	September	107.00	13.20	29.00	16.00	100.00	72.00
10	October	90.20	12.80	30.00	11.00	94.00	57.00
11	November	56.00	8.00	27.00	4.00	93.00	54.00
12	December	7.00	0.60	25.00	1.00	92.00	54.00
Total		1574.20	116.40				

3. Rainfall data of Churachandpur

Average Annual Rainfall

Year	Rainfall in (cm)	Year	Rainfall in (cm)	Year	Rainfall in (cm)	Year	Rainfall in (cm)	Year	Rainfall in (cm)
1970	140.78	1978	133.75	1986	202.60	1994	161.00	2002	154.29
1971	150.06	1979	90.67	1987	211.31	1995	134.16	2003	104.66
1972	101.27	1980	181.57	1988	174.41	1996	203.26	2004	117.39
1973	176.33	1981	224.04	1989	160..99	1997	154.29		
1974	159.28	1982	202.07	1990	114.04	1998	205.27		
1975	160.85	1983	295.55	1991	124.10	1999	150.93		
1976	136.96	1984	142.86	1992	144.23	2000	154.29		
1977	192.97	1985	150.94	1993	228.08	2001	147.57		

Meteorological Data Churachandpur

SlNo.	Month	Average rainfall (mm) 1970-2004	Av. No of rainy days 1970-2004	Average temperature (1970-2004)		Average humidity (1970-2004)	
				Max.	Min.	Max.	Min.
1	January	5.00	1.0	25.00	0.00	93.00	53.00
2	February	25.00	3.00	28.00	0.00	86.00	54.00
3	March	28.00	5.0	32.00	5.00	89.00	59.00
4	April	124.00	12.50	15.00	10.00	94.00	56.00
5	May	230.00	12.70	31.00	10.00	93.00	44.00
6	June	395.00	16.30	32.00	18.00	94.00	65.00
7	July	300.80	17.20	32.00	19.00	89.00	62.00
8	August	220.80	15.00	30.00	19.00	94.00	60.00
9	September	146.60	13.20	29.00	16.00	100.00	72.00
10	October	88.60	12.80	30.00	11.00	94.00	57.00
11	November	55.00	8.0	27.00	4.00	93.00	54.00
12	December	6.00	0.60	25.00	1.00	92.00	54.00
Total		1624.80	117.40				

4. Rainfall data of Thing hat

Average Annual Rainfall

Year	Rainf-all in (cm)	Year	Rainfall in (cm)	Year	Rainf-all in (cm)	Year	Rainf-all in (cm)	Year	Rainf-all in (cm)
1970	215.5	1978	214.0	1986	268.2	1994	252.3	2002	234.5
1971	241.4	1979	223.0	1987	264.0	1995	212.2	2003	225.6
1972	162.9	1980	208.0	1988	213.9	1996	215.5	2004	263.2
1973	231.4	1981	241.0	1989	268.0	1997	245.6		
1974	235.6	1982	226.4	1990	215.8	1998	275.7		
1975	246.4	1983	247.3	1991	235.6	1999	239.8		
1976	281.0	1984	208.9	1992	238.9	2000	255.9		
1977	275.0	1985	246.4	1993	223.1	2001	228.3		

Meteorological Data Of Thing hat

SlNo.	Month	Average rainfall (mm) 1970-2004	Av. No of rainy days 1970-2004	Average temperature ! Max. / Min. (1970-2004)		Average humidity Max. ! Min. (1970-2004)	
1	January	9.0	2.00	26.00	0.00	87.00	53.00
2	February	37.0	7.00	29.00	0.00	85.00	54.00
3	March	40.0	8.00	33.00	5.00	88.00	59.00
4	April	180.0	12.50	16.00	10.00	93.00	56.00
5	May	260.0	14.70	32.00	10.00	92.00	44.00
6	June	410.0	16.30	33.00	18.00	93.00	65.00
7	July	500.0	17.20	33.00	19.00	88.00	62.00
8	August	380.0	15.00	33.00	19.00	93.00	60.00
9	September	310.0	13.20	30.00	16.00	100.00	72.00
10	October	155.0	12.00	31.00	11.00	93.00	57.00
11	November	60.0	5.00	28.00	4.00	92.00	54.00
12	December	6.5	1.00	26.00	1.00	91.00	54.00
Total		2347.50	123.90				

5. Rainfall data of Thanlon
Average Annual Rainfall

Year	Rainfall in (cm)	Year	Rainfall in (cm)	Year	Rainfall in (cm)	Year	Rainfall in (cm)
1970	250.00	1979	258.00	1988	303.70	1997	294.09
1971	280.00	1980	245.70	1989	308.50	1998	317.15
1972	193.00	1981	283.000	1990	247.96	1999	275.83
1973	273.00	1982	268.04	1991	271.02	2000	294.08
1974	277.00	1983	286.02	1992	274.87	2001	262.37
1975	325.00	1984	243.93	1993	256.60	2002	269.10
1976	305.00	1985	300.20	1994	290.24	2003	258.00
1977	315.00	1986	245.70	1995	244.11	2004	302.74
1978	255.00	1987	308.50	1996	247.95		

Meteorological Data of Thanlon

SlNo.	Month	Average rainfall (mm) 1970-2004	Av. No of rainy days 1970-2004	Average temperature (1970-2004)		Average humidity (1970-2004)	
				Max	Min.	Max.	Min.
1	January	8.20	0.90	20.50	8.50	100.00	74.50
2	February	38.00	2.80	24.40	11.00	99.40	73.30
3	March	42.70	4.50	27.00	12.40	98.70	78.00
4	April	183.60	12.50	27.70	15.40	100.00	75.40
5	May	290.80	16.90	27.00	16.40	100.00	82.70
6	June	525.80	21.70	27.00	17.70	100.00	87.70
7	July	550.60	22.90	27.40	20.70	100.00	89.40
8	August	414.30	20.00	28.40	16.60	100.00	89.40
9	September	359.00	17.60	27.00	19.00	100.00	85.70
10	October	195.00	11.50	26.70	17.00	99.40	88.00
11	November	86.00	5.60	26.40	14.00	99.40	83.40
12	December	6.60	0.80	22.00	11.00	99.40	82.40
Total		2700.60	137.70				