DEVELOPMENT OF LAND AND WATER MANAGEMENT PLAN USING REMOTE SENSING TECHNIQUE - A CASE STUDY

By

Bimalendu Mohanty

A THESIS SUBMITTED TO THE
ORISSA UNIVERSITY OF AGRICULTURE AND TECHNOLOGY, BHUBANESWAR
IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE DEGREE OF

MASTER OF TECHNOLOGY

(AGRICULTURAL ENGINEERING)

IN

SOIL AND WATER CONSERVATION ENGINEERING

Department of Soil and Water Conservation Engineering
COLLEGE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY
ORISSA UNIVERSITY OF AGRICULTURE AND TECHNOLOGY
BHUBANESWAR, ORISSA

SEPTEMBER, 2001

DEVELOPMENT OF LAND AND WATER MANAGEMENT PLAN USING REMOTE SENSING TECHNIQUE – A CASE STUDY

By

Bimalendu Mohanty

A THESIS SUBMITTED TO
THE ORISSA UNIVERSITY OF AGRICULTURE AND TECHNOLOGY
BHUBANESWAR

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF

MASTER OF TECHNOLOGY

(AGRICULTURAL ENGINEERING)

IN

SOIL AND WATER CONSERVATION ENGINEERING

2001

Approved by the Advisory Committee

Chairman :

29.9.01

(Dr. N. N. Sahu)

(Dr. S. Swain) 29/9/01
Dean, CAET

Member :

1. 29-09-01
(Sri. A. P. Sahu)

2. (Dr. J. C. Muduli) 29.9.01

External Examiner

DEDICATED
TO MY
BELOVED PARENTS

Dr. N. N. Sahu
Associate Professor and Head,
Department of Soil and Water Conservation Engineering
College of Agricultural Engineering and Technology
Orissa University of Agriculture and Technology
Bhubaneswar - 751 003

CERTIFICATE

This is to certify that the thesis entitled "DEVELOPMENT OF LAND AND WATER MANAGEMENT PLANS USING REMOTE SENSING TECHNIQUE - A CASE STUDY" submitted in partial fulfilment of degree of MASTER OF TECHNOLOGY (AGRICULTURAL ENGINEERING) in Soil and Water Conservation Engineering of the Orissa University of Agriculture and Technology, Bhubaneswar is a faithful record of bonafide research work carried out by SHRI BIMALENDU MOHANTY under my guidance and supervision. No part of the thesis has been submitted for any other degree or diploma.

The help and information availed during this investigation have been duly acknowledged by him.

Bhubaneswar.

Date : 3rd September, 2001

3/9/2001
(Dr. N. N. Sahu)

ACKNOWLEDGEMENTS

I express my profound sense of gratitude and indebtedness to my Chairman, Advisory Committee, Dr. N. N. Sahu, Associate Professor and Head, Department of Soil and Water Conservation Engineering, C.A.E.T., O.U.A.T, Bhubaneswar for his scholastic guidance, constant supervision and persistent endeavour throughout the period of research.

I would like to express my sincere obligation to Sri A. P. Sahu, Asst. Professor, Department of Soil and Water Conservation Engineering, C.A.E.T. and member of my advisory committee for his valuable suggestions, encouragement and support to carryout the work.

I extend my deep sense of gratitude to Dr. J. C. Muduli, Director, College of Basic Science and Humanities for his valuable advice and whole hearted co-operation.

I feel greatly indebted and record my gratitude to Dr. S. Swain, Dean, College of Agricultural Engineering and Technology for his constant encouragement and help to complete the work.

I express my sincere obligation and gratitude to Dr. S. D. Sharma, Dean PGF-cum-DRI, O. U. A. T., Bhubaneswar for his valuable advice and inspiration.

I express my heartfelt gratitude to Er. G. Behera, Chief Executive, ORSAC, Bhubaneswar for providing me necessary laboratory facilities and help to carryout the work.

I avail the opportunity to express my indebtedness and sincere obligation to Sri P. Mishra, Scientist, ORSAC for his able guidance and constant inspirations during the research work.

I do acknowledge the help and co-operation received from the scientific staff, ORSAC namely Mr. A. K. Mohapatra, Mr. S. Das, Mr. K. S. Pattnaik and Ms. S. Jena during my research work.

I do express my profound sense of reverence and indebtedness to my esteemed teachers like Dr. K. N. Sharma, Sri S. C. Nayak and Sri J. C. Paul.

I duly acknowledge the advice, valuable suggestions and co-operation received from Er. B. Naik, Ex-Additional Director of Agriculture (Engg.), Govt. of Orissa, Er. S. K. Khatua, Asst. Project Director (Water Management), Western Orissa Rural Livelihoods Project, Bolangir, Er. Santosh Kumar Panda, Asst. Project Director (Tech.), DRDA, Bolangir and Mr. D. Patang, Junior Agriculture Officer, Bolangir during my research work.

My heartiest appreciation goes to my seniors, friends, classmates and juniors especially Kamakshi, Sanjay, Surjit, Nirakar, Padma and Kshanaprabha for their encouragement and help during the entire period of research.

My heartfelt thanks goes to Sri Santosh Kumar Mishra for his special interest and care in preparing the report.

Last but not the least I bow down my head before my parents whose blessing and love made me so today.

Bhubaneswar

Date : 3rd September, 2001

Bimalendu Mohanty

(BIMALENDU MOHANTY)

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS AND SYMBOLS

AIS & LUS	All India Soil and Land Use Survey
CCT	Computer Compatible Tape
ERLAS	Earth Resources Laboratory Application Software
FCC	False Colour Composite
GEC	Groundwater Estimation Committee
GIS	Geographic Information System
Gph	Gallons Per Hour
GT	Ground Truth
ha.m	Hectare metre
IRS	Indian Remote Sensing Satellite
ISRO	Indian Space Research Organisation
LISS	Linear Imaging Self Scanner
MSS	Multi-Spectral Scanner
NASA	National Aeronautics and Space Administration
NNRMS	National Natural Resources Management System
NTFP	Non Timber Forest Produce
ORSAC	Orissa Remote Sensing Application Centre
SOI	Survey of India
Sq.km	Square kilometre
SYI	Sediment Yield Index
TM	Thematic Mapper
%	Percentage

CHAPTER - I
INTRODUCTION

INTRODUCTION

Population growth and poverty on one hand and the pressure of rising demand from affluence and consumerism on the other, have been exerting powerful pressure on the ecosystems. The macro-economic policies which provide inducement to the over-exploitation of natural resources, that is, at a higher rate than the rate of regeneration, are also responsible for denudation of environment. There is no doubt that lands subjected to erosion constitute the biggest single threat to our country's economy. For not only do such lands suffer an increasing loss of productivity because of the progressive loss of the fertile topsoil but they also contribute to the loss of a great deal of water by way of excessive runoff along denuded slopes. Soil erosion has threatened the survival of small and marginal farmers in India. Every year about 12 billion tons of soil is eroded from wastelands and agricultural lands in India. The runoff causes a great deal of damage contributing to the causation of floods and premature siltation of river-beds, tanks and reservoirs. So, suitable land and water management programme with active participation of the people of the locality is of utmost importance. It has tremendous potential to render socio-economic justice, attain self-reliance and to usher a balanced development. Everything in nature is linked with everything else and is mutually complementary. Suitable land and water management programme can cater to this relationship between nature and mankind.

Watershed is a geohydrological unit draining at a common point by a system of streams. It is a topographically delineated area draining into a single channel. It is a land mass bound vertically by the area influenced by the human activities and horizontally by the water that drains into a point in the channel. Essentially it is a managable hydrologic unit that makes a harmonious use of the prevailing climate, soil, water, locally available materials and human resources towards sustainable development of the region.

Management of a watershed thus entails the rational utilization of land and water resources for optimum production with minimum hazard to natural and human resources. Embedded in this concept is the recognition of the inter relationships among land use, soil and water and the linkages between upstream and downstream areas.

Thus, watershed management can be defined as an integration of technologies within the natural boundaries of a drainage area for optimum development of land, water and plant resources to meet the basic minimum needs of the people in a sustainable manner.

To achieve the goal of sustainable development and to minimise the environmental and ecological degradation, watershed management is highly required through planned development of land and water resources. The need for watershed management assured urgency because of the following factors.

- Deforestation or degradation of forest cover.
- Soil erosion and siltation of rivers/reservoir.
- Waterlogging and salinity.
- Erosion of locations/surfaces thus increasing sediment yield and high runoff.
- Low agricultural productivity yield.
- Slope cultivation/shifting cultivation.
- Non-availability of soil moisture in pre-monsoon and post-monsoon period.
- Ground water table fluctuations.
- Changes in the wildlife habitat.
- High maintenance cost and investment for reclamation and conservation due to above factors.

The necessity of watershed management arises from the problems mentioned above. Therefore, there is a great need for highly specialized knowledge or expertise to deal the great majority of issues, large volumes of spatial data and systems to handle such data for information extraction, scenario development and decision making.

Remote sensing is the art or science of collecting and interpreting information about an object, area or phenomenon through the analysis of data acquired by a device that is not in direct contact with the object, area or phenomenon under investigation. Remote sensing is currently used more commonly to denote identification of earth features by detecting the characteristic electromagnetic radiation that is reflected, emitted or scattered by the earth surface. Electromagnetic radiation extending from the ultraviolet to the far infra-red and microwave regions provides the greatest potential in the context of earth resources survey. The underlying principle is that depending on its physical features and chemical properties different objects on earth's surface reflect, radiate or emit different amounts of electromagnetic energy in various wavelengths.

Remote sensing through the space-based systems offer unique possibilities for systematic and timely acquisition of information on the earth's resources, and also environmental and meteorological data with a very short turn-around time for use by resource managers, planners and environmental scientists. The remarkable features of the space based remote sensing techniques are their ability to obtain synoptic view and frequent repetitive coverages of large and even inaccessible areas. Remote sensing lends itself beautifully as a powerful, common input media representing the faithful, unbiased reproduction of the natural features in the form of photographs/imagery and thereby economising the process of multi-disciplinary approach for planning of natural resources for integrated development.

Spatial data for development of land and water management plans can be obtained from topographic data, from archive data/maps, from ground survey and by remote sensing technique. However, remote sensing plays a significant role and is an efficient and useful tool in this context. From interpretation of the satellite imagery vital informations can be obtained which are prerequisite for development of such a plan. The advantages of remote sensing data for watershed management are as follows.

- It provides a reliable, near real time base line information.
- Topographic and thematic map preparation instead of ground survey.
- Characteristic of the object or land features (rock type, vegetation condition, land use and environmental quality etc.) and three-dimensional view of the terrain.
- Accurate discrimination of spatial units and its study on the spatial distribution covering large area because of advantage in synoptic coverage.
- Photomaps generation (orthophoto) for topographic / resource / morphometric / environmental data generation as a map alternative.
- Capable of operating in portions of electro-magnetic spectrum which are beyond the photographic emulsion sensitivity.
- Detectors having wider dynamic range than photographic emulsions for identifying subtle change in scene radiance (feature discrimination).
- Relatively fast and economical for gross estimates as compared to any other method of surveying.
- Terrain data is available in both analog and digital form (Digital terrain model)

- Amenable to computer processing and compatibility to GIS packages makes the data easy to handle.

Information on existing land use / land cover and pattern of their spatial distribution are the essential prerequisite to land and water resources planning and development. The land use / land cover maps are helpful in finding out the spatial distribution of various land use / land cover categories and their percentage area coverage to act as the basic information needed for efficient utilisation and management. The current land use has to be assessed for its suitability in the light of land potential before suggesting alternate land use practices.

Remotely sensed data helps in mapping the hydrogeomorphological units which are important inputs for land management, soil mapping, geological information like lithology / rock type and identification of potential zones of ground water occurance.

Satellite imagery is a useful tool for preparation of soil association maps. One image covers so large an area that regional relationship becomes apparent. This aids in assessing the effect of soil forming factors as well as providing a means of checking the pattern of soil association over most or all their areas of extent. Once the soil composition of each land unit is established, the interpretation of the imagery can be done for entire area by extrapolation. Thus, a physiographic soil map is prepared, though it can not directly depict soil depth.

Besides, slope maps, drainage maps are also prepared taking the help of both satellite imagery and SOI topographical maps. Intergrating all the informations / maps suitable management plan can be generated for sustainable development.

The study area is Bagjore micro-watershed which comes under "West Central Table Land" agro-climatic zone (code-083) of Deogaon block of

Bolangir district and drains through Bagjore → Songard river → Tel river → Mahanadi → Bay of Bengal drainage system. Maximum area of the watershed comes under pediment zone with population dominated by the Schedule Castes and Schedule Tribes.

Considering the need of the hour and the vast scope of remote sensing for land and water resources management, the present study has been undertaken with the following objectives.

1. To delineate the watershed boundary.
2. To prepare the land use / land cover, hydrogeomorphology, soil resource, slope and drainage map of the watershed.
3. To study the land use pattern, groundwater prospect, morphometry, soil type and slope category of the watershed.
4. To develop a land and water management plan for the watershed.
5. To analyse the rainfall record of the watershed for desired probability levels and return periods.
6. To design the different proposed soil and water conservation structures.

CHAPTER - II
REVIEW OF LITERATURE

REVIEW OF LITERATURE

2.1 Introduction

Exploration of natural resources, particularly earth resources, is vital for socio-economic development of any country. The state-of-the-art technology of space-based earth observation systems offer timely and accurate information on various land and water resources. It, can be noted, though the potential of orbiting space platforms were realised at the time of lunching of very first satellite, the Russian "Sputnik" in 1957, the remote sensing application especially for earth resources came into its own from 1972 with the launch of "Earth Resources Technology Satellite" later named as Landsat by National Aeronautics and Space Administration (NASA). Recognising the potential opportunities and benefits of satellite based remote sensing, Indian Space Research Organisation (ISRO) has conducted a variety of extensive and intensive nature of activities, including aerial flights and experimental satellite missions like BHASKARA-I and II. Then, India's first indigenously developed operational Remote Sensing Satellite, IRS-IA was successfully launched on March 17, 1988. The series of Indian Remote Sensing Satellites (IRS) are an important element of NNRMS (National Natural Resources Management System). Out of the seven satellites launched so far by ISRO, six satellites (IRS-IA, IB, IC, ID, P2, P3) carried multispectral cameras and two (IRS-IC/ID) carried PAN-Chromatic camera and they were meant mainly for land, agriculture, water resources and cartographic applications. IRS-P4 which was recently launched during May 1999, is meant for oceanographic applications, though this can also be used for limitted land applications.

The vast potential of remote sensing led the study of available natural resources for optimal use by various investigators. This chapter deals with the works carried out in the past in areas related to land and water resource management.

2.2 Remote Sensing for Land Use / Land Cover Mapping

Roy *et al.* (1981) proposed a computerised spatial analysis system for assessing wild life habitat from vegetation maps. The study concluded that if the degree of interspersion of cover types and relative value of each edge type and importance of spatial diversity are given, an index of spatial habitat can be computed for each parcel of land relative to each wild life species or groups. This was accomplished by defining a grid which was either placed on a land cover map or on an aerial photograph. Each cell was then coded on the basis of its predominant cover type. A computer programme subsequently analysed the arrangement of these coded cells and produced maps of interspersion, juxtaposition and spatial diversity.

Hamaza *et al.* (1981) made an attempt to generate useful land use / land cover classification maps of central Tunisia from landsat imagery. An important consideration included the use of multi-temporal data for monitoring changes over time. After geometric correction to a lumbext conformal map projection and spectral contrast enhancement, a false colour image was produced for both data sets at the scale of 1 : 2,00,000. Two manual interpretation maps were obtained with forty different land use / land cover classes.

Sahai *et al.* (1983) selected Panchamahals one of the most economically backward districts in Gujarat for making an up-to-date resources survey using remote sensing techniques. Multiband and multitude landsat data and multiband air craft data were used for these studies. The detailed land use maps were prepared in 1 : 12,500 scale. Colour infrared imagery was also used for mapping forests.

Sharma *et al.*(1984) carried out study in Deharadun-Roorkee region for preparation of land use and land cover maps and monitoring changes, if any, over a period of 5 years from landsat images using visual interpretation techniques. They found that remote sensing is potentially an effective and economic means to collect the data and to monitor changes occuring in land use categories.

Sahai and Baldev (1985) utilised remote sensing techniques for the land use survey of Idukki district in Kerala. An integrated resources survey aimed at making a comprehensive survey of land and water resources was carried out jointly by Space Applications Centre, Ahmedabad and Kerala State Land use Board.

Dutt *et al.* (1986) did the identification and mapping of wastelands at micro-level using remote sensing techniques. Landsat thematic mapper (TM) FCC was used for visual interpretation of an area of about 2000 sq.km. covering parts of Bangalore district in Karnataka. Their study showed that integrating remotely sensed information with that available from revenue records can yield sufficiently accurate information to meet the requirements of National Wasteland Development Board for planning wasteland reclamation measures.

Nagaraja *et al.* (1986) used remote sensing techniques for monitoring land use changes for planning and environmental conservation. They studied the capability of remotely sensed data to delineate and understand the present land use / land cover and pattern of change over a large area of Belgaum district of Karnataka. The spatial distribution of various land use / cover categories and their prercentage area coverage for the periods 1980 and 1982 were calculated to understand the pattern of changes in the land use.

Shih (1988) used landsat MSS data in conjunction with unsupervised classification technique of Earth Resources Laboratory Applications Software (ERLAS) to determine land use / cover classification. He analysed the landsat computer compatible tapes (CCTs) to spectrally classify unique land use / cover conditions within the Econ lockatche river basin, Florida. The results showed that the of band 4, band 6 and the traditional band 5 and band 7 scatter diagrams can be utilized for classifying land use / land cover.

Subudhi *et al.* (1989) used landsat thematic mapper (TM) for urban land use / cover mapping. Lucknow city and its environs through visual interpretation of TM data had been studied to evaluate the usefulness and potentiality of satellite data for urban area studies.

Palaniyandi and Nagarathinam (1997) mapped the land use / land cover classes in Thiruvallur area of Chengai MGR district of Tamilnadu during the years 1986-1990 through visual interpretation of LANDSAT-5 TM and IRS IA LISS-II images, over space and time. It was observed that the built-up area and the agricultural land use extensions were on the upward trend, whereas the area under forest and wasteland showed a declining trend, caused by both increasing population and related trends in other parameters. The system devised through the study has thus been able to detect the changes in the land uses and cover classes during the selected time periods.

Gupta and Ahmed (1998) mapped the degraded lands in Palamau districts of Bihar using remotely sensed data IRS-IA FCC of 1 : 50,000 scale and observed that the water erosion is the main cause of land degradation affecting 6.27 percent area of the district of which 5.22 percent is subjected to severe to very severe erosion and remaining 1.05 percent is moderate to severe gully erosion. Degraded lands are mostly confined to agricultural areas followed by forest land and open scrub and pastures respectively.

Chaurasia *et al.* (1999) prepared the land use map of Dehlon block of Ludhiana district, Punjab from the analysis of the IRS-IB LISS-II data in 1993 and survey of India toposheets of 1964 and revealed that a large change in the area of different land use categories from period 1964 to 1997. A significant change in the cropping pattern have been observed despite the excessive increase in population.

Jaiswal *et al.* (1999) studied land use / land cover changes over a period of 30 years using remote sensing technology in a part of Gohparu block, Shahdol district of Madhya Pradesh. The loss of vegetation cover was estimated to be 22 percent and 14 percent of the land was found to have been transformed into wasteland between 1967 and 1996. Overall rate of change was found to be 1.8 percent per year during this period.

2.3 Remote Sensing Application in Hydrogeomorphological Mapping and Groundwater Studies

Agarwal (1989) made a study on Hydrogeomorphological and structural analysis using photo interpretation and remote sensing technique pertinent to ground water prospects in Jhansi and Lalitpur area of U.P. Their study dealt with visual interpretation of landsat imageries and aerial photograph and the structural variation of the area and subsequently identifying the zones of ground water recharge.

Chandel and Asthana (1990) carried out a comparative study of different remote sensing techniques for geological studies in the Eastern part of Doon valley. Aerial photographs, standard landsat T.M. (F.C.C.) and computer compatible tape were used to delineate lithologic units and geological structures which affect the occurrence of ground water. Aerial photo interpretation was found to be the best for large scale mapping, digital analysis was found to be very good for lithological and for structures like faults, lineaments etc. landsat T.M. (FCC) was found to be superior for small scale mapping.

Sinha *et al.* (1990) observed that satellite remote sensing techniques were very much helpful for identifying fractures, joints etc. which could serve as an ideal site for setting up a well. Their study emphasised on an integrated approach for locating well sites through satellite data analysis and resistivity tests along with vertical electrical sounding. With the combined effort of collecting superficial features like drainage, lithology, lineaments etc. and taking into account the geophysical survey aspects like depth and thickness of fractured zone, its lateral extent etc. a fairly accurate result for localising well sites can be decided.

Agarwal *et al.* (1992) delineated the different hydrogeomorphological units in and around the immediate environs of Jhansi city with a view to attempt a correlation between the well yields and hydrogeomorphological units using satellite remote sensing technique and concluded that the pediment residual hill complex provide wells with discharges ranging from 100 gallons per hour to 5,000 gph while the wells drilled in shallow weathered buried pediplain has yields in the range of 2,000 to 10,000 gph, moderately weathered buried pediplain has discharges in the range of 8,000 to 12,000 gph and deeply weathered buried pediplain has discharges in excess of 12,000 gph.

Panigrahi *et al.* (1995) used survey of India toposheet and satellite imagery of bands 2, 3 and 4 for delineating the ground water potential zone map on a survey of India toposheet for Athagarh block of Cuttack district of Orissa. The validity of demarcation of the study area into different zones, as decided by remote sensing technology was justified by analysing the georesistivity sounding data of a number of places in this area. The net potential of the study area was estimated by GEC norm. It was observed that only 11.8% of annual utilisable ground water is now used and there is vast scope of further exploitation of this resource.

Dutta (1996) conducted ground water study in the peidmont zone of Mechi Mahananda interfluve in Darjeeling district, West Bengal and concluded that steeply sloping area with high relief show poor ground water potential whereas peidmont zone has good ground water potential.

Tiwari and Rai (1996) used Landsat-5 MSS data of band 2, 4 and false colour composite of band 2, 3, 4 to interprete visually different hydrogeomorphological units and to delineate the major trends of lineaments. The non different geomorphic features identified are linear ridges, residual hills, pediplain, buried pediment and dissected pediplain, besides lineaments. The study shows that the pediplain and buried pediments are promising zones for ground water prospecting.

Behera and Das (1997) prepared the hydrogeomorphological map for ground water exploration in Keonjhar district, Orissa and studied the effect of different geomorphic units and lineaments in controlling ground water potential of the area.

Ravindran and Jayaram (1997) prepared the hydrogeomorphological map and evaluated the ground water prospect of each hydrogeomorphological unit on the basis of lithology, structure, land form and available aquifer data in the Shahbad tehsil, Baran district, Eastern Rajasthan and concluded that there is a vast potential for ground water exploitation in the Vindhyan sand stones in which ground water occurs in confined to unconfined conditions along bedding planes, fractures and joints. Deep tubewells and dug-cum-bore wells have been suggested in this region for ground water development.

Kumar and Tomar (1998) carried out ground water assessment through hydrogeomorphological and geophysical survey in Godavari sub-watershed, Giridih, Bihar. The hydrogeomorphological units were categorised based on depth of weathering, local geomorphological association, recharge characteristics etc. The top layer resistivity of the units was analysed by electrical resistivity method. Resistivity zonation map prepared on the basis of field data could be modified / corrected with the help of the informations derived from remotely sensed data to obtain more realistic picture through interpolation / extrapolation.

Murthy *et al.* (1999) prepared the hydrogeomorphological map of Varha river basin which originates in the Eastern Ghats and inferred that there is a close relationship between ground water condition and geomorphology of the area. Area covered by buried channels have shallow aquifers of very good quality water with excellent yield. Lineaments and fractures may prove to be potential zones for ground water development

2.4 Remote Sensing Application in Soil Resource Mapping

Bleeaker (1978) employed visual interpretation of landsat data for preparation of national level soil degradation maps in Sierra Leone at 1 : 10,00,000 and 1 : 50,00,000 scale for world soil degradation maps.

Karale and Sinha (1990) used IRS-IA LISS II digital data of parts of Wagpur district for preparing the soil map of parts of Parseoni and Ramtek tehsils. The results of the study affirmed that IRS-IA LISS II data based on remote sensing technique in conjunction with fieldwork in prudently chosen sample strips facilitate speedier and dependable soil mapping at reconnaissance level.

Ahuja *et al.* (1992) used the remotely sensed data for soil resource mapping and its interpretation for land use planning of Bhiwani district, Haryana. They carried out visual interpretation of IRS IA LISS II FCC at 1 : 50,000 scale and divided the area into 34 sub-units. The soil of each unit were classified and are found as coarse loamy, fine loamy etc.

Sen *et al.* (1992) employed the remote sensing techniques to identify and delineate soils in a part of Dibrugarh district of Assam. Landsat – 4 MSS data in the form of FCC were interpreted visually and four major physiographic units were delineated and they concluded that satellite remote sensing techniques coupled with survey of India topographical maps and ground data could be employed successfully to prepare physiographic soil resource map depicting association of soil families.

Kaur and Bhadra (1998) gave a numerical technique for transformation of ground based soil spectral information into soil mapping unit formation. In terms of the total information content they carried out of 14 surface soil samples and concluded that the numerical index can prove to be an efficient tool for delineating boundaries for soil mapping units.

2.5 Morphometric Studies

Profali and Singh (1983) conducted photogeomorphic analysis for evaluation and management of the Narmada river basin. They found that Narmada river basin forms a large natural entity consisting of hills, plateaus and plains as the major land form units. These units were further sub-divided into sub-units for a systematic assessment of problems and potential associated with them. They suggested that problems of erosion, sedimentation, water logging and salinity in different land form units may be analysed from the imageries by developing legend with limited ground truth and conformed by random check.

Agarwala and Sinha (1983) conducted quantitative geomorphic analysis of watershed with the aid of aerial photographs. They studied drainage pattern, order analysis, bifurcation ratio and drainage density which provide suitable means for measuring size and form properties of drainage basins and stream number which gives the permeability of soil mantle.

Mishra *et al.* (1984) studied the effect of topo elements on the sediment production rate from sub watershed in upper Damodar valley by conventional methods. They analysed the effect of watershed area, drainage density, stream grade, watershed slope, shape index and time of concentration and concluded that drainage density and average watershed slope are the most important parameters that increase the sediment production rate.

Singh *et al.* (1984) used aerial photographs to obtain the drainage pattern of Kalighai river basin in West Bengal for calculating the gemorphological parameters. Stream morphology like stream order, bifurcation ratio, stream length, drainage density, stream frequency etc. was studied using aerial remote sensing technique.

Nautiyal (1994) made the morphometric analysis of Khairkuli drainage basin, Deradun district using aerial photographs. The morphometric parameters worked out include bifurcation ratio, stream length, form factor, circularity ratio, elongation ratio, drainage density, constant of channel maintenance and stream frequency.

Agarwal (1998) mapped the drainage pattern of Nuagarh Block of Varanashi district. The basin characteristics have been analysed in terms of basin morphology and related parameters. He concluded that surface water resources could be enhanced in the region by constructing check dams and creating artificial recharge through effective planning and management.

Nag (1998) carried out morphometric analysis using remote sensing techniques in Chaka river sub-basin of Manbazar block, Purulia district, West bengal which is one of the most drought affected area in West Bengal. The morhometric analysis suggested that the area is covered by fractured, permeable rocks, the drainage network not so affected by tectonic disturbances.

Biswas *et al.* (1999) used remote sensing and geographic information system techniques to conduct the morphometric analysis of nine sub-watersheds of the major part of Nayagram block of Midnapore district, West Bengal. The morphometric parameters in terms of stream length, bifurcation ratio, drainage density, stream frequency, texture ratio, form factor, circularity ratio and elongation ratio were studied and they prioritised all the sub-watersheds under study. They also prioritised the same sub-watersheds using Sediment Yield Index (SYI) model and found that both the methods tally in most of the cases with the present approach. So, it was concluded that morphometric analysis could be used for prioritisation of watersheds even without the availability of reliable soil maps of the area under study.

2.6 Watershed Management

Phadnawis *et al.* (1993) carried out work in Podalsingi watershed, Beed district of Maharashtra for resource management in rainfed watershed and concluded that productivity of the traditionally grown crops like bajra, redgram etc. have increased due to resource management in watershed basis. The area under irrigation increased. Due to construction of cement plugs, nala bunds and percolation tanks the groundwater level was increased and per capita income of the farmers increased by large extent.

Agninhotri *et al.* (1996) carried out a watershed management programme in a typical hilly watershed in Hoshiarpur Shiwalliks, Punjab to demonstrate the minimization of soil erosion from the hills and flood problem in the plain while boosting hill economy, through development of hill resources with community participation. The benefit cost ratio of 1.27 indicated economic viability of the programme.

Khatik *et al.* (1997) studied the impact of operational research project on agricultural production through integrated watershed management in Rabni watershed situated in Panchamal, a backward district of Gujarat. Under the integrated watershed management programme the area was treated with different soil and water conservation measures like land leveling, contour bunding, gully plug, check dam etc. The study revealed that integrated watershed management programme increased the ground water recharge due to different soil conservation measures. The cropping intensity also increased, positive imapct of operational research project on food grain productivity, fodder availability and animal population etc. in watershed is conspicuous and apparent.

Nyonand *et al.* (1997) conducted watershed management work in Bagor-Ganigor watershed in Mohindergarh district of Haryana to demonstrate the efficient management of soil and water resources for rehabilitation of degraded ecosystems. Regular monitoring of changes in the watershed indicated that a number of wells and irrigated area increased. The demand of fertilizers, seeds, plant protection measures and agricultural implements increased with time which resulted in an increase in crop production by 20 to 25 percent. The watershed management programme provided about 22 percent higher employment opportunity in various sectors. Income of the village panchayat increased three fold during the period.

Prasad *et al.* (1997) studied the impact of watershed management on runoff, water resource development and productivity of arable lands in Chhajawa watershed of Baran district in Eastern Rajasthan and the results indicate that integrated watershed development treatments such as graded bunds, gully control structures etc. halted the process of land degradation and improved the ground water recharge which could be successfully exploited for increasing the productivity of arable lands. The investments made recovered in 4 years indicating that the programme is economically viable.

Pande *et al.* (1998) conducted the watershed management programme in Semi-Arid tropics of Gujarat to examine the sustainability and equity issues. The results revealed that net returns were not only increased by 2.3 to 2.4 times but also had fair distribution across the community. Watershed management further resulted in higher investment on farm assets ranging from two to five times with better distribution in post project period as compared to project period.

Singh (1999) conducted the study in Chhajawa watershed and adjacent villages in Baran district of Rajasthan to assess the impact of watershed management efforts on the farmers income and the study highlighted that the average family income of farmers living inside the watershed were significantly more in comparison with the farmers of outside the watershed.

Chhotaray (2000) used remote sensing technique for development of watershed plan of Shikharagochha micro-watershed, Nayagarh district, Orissa. He used visual interpretation techniques to develop watershed management plan from IRS ID LISS false colour composites. He generated the thematic maps like land use / land cover map, hydrogeormorphological map, drainage and surface water body map, soil and slope map for the watershed and integrated all the informations to develop the watershed management plan. He found that false colour composites can be effectively used for preparing watershed management plans.

CHAPTER - III
MATERIALS AND METHODS

MATERIALS AND METHODS

This chapter deals with location, physiography and socio-ecnomic status of the study area, the different types of data used, the methods as well as materials used for carrying out the project work.

3.1 Location and Extent of the Study Area

Bagjore micro-watershed lies geographically between $20^0 36'45''$N to $20^0 38'45''$N lattitude and $83^0 11'10''$E to $83^0 13'25''$E longitude at a distance of about 30 kms. from the block headquarter Deogaon and 40 kms from the district headquarter Bolangir in the state of Orissa as shown in fig. 3.1. The watershed area is approximately 732.5 ha. and is included in Survey of India toposheet number 64 P/2 in 1: 50,000 scale. The watershed spreads mainly over two villages namely Luhakhan and Ramchandrapur. The micro-watershed belongs to Mahanadi catchment and river Tel sub-catchment.

The natural drainage system of the watershed is Bagjore a tributory of river Songarh. The unique code assigned to this watershed is 1-03-02-01-01 or 04-07-01-06-03-02-01-01.

3.2 Physiography of the study area

The Bagjore micro-watershed comes under the west central table land zone. The area consists of pediments, shallow weathered buried pediments and valley fills, pediments being the predominant feature. Rock of this area is mostly granitic gneiss type. The highest and lowest relief is at a height of 260 metres and 238 metres respectively above mean sea level. The watershed is fan shaped with undulating and folded topography. The entire area has a sedentary land-scape with distinct phases namely erosional phase and depositional phase. The erosional phase includes pediments, where as the depositional phases includes shallow weathered buried pediments and valley fills. The area is highly eroded and excessively drained due to the present stage of topography and drainage pattern. Soils of the pediment are generally sandy loam to gravelly sandy loam with moderate to shallow depth and slope varies from 3 to 5%. The soil of shallow weather buried pediments are sandy clay loam type with moderate depth whereas the valley fill soil texture is silt clay loam type with very deep soil depth, slope being 0 to 1%.

The climate of the study area is sub-tropical monsoon type, major rainfall being received by the South West monsoon. The rainfall is erratic and distribution is uneven. Mean annual rainfall is 1169.22 mm and the mean annual temperature is 29.45^{0}C.

3.3 Socio-economic status

As the total area of the village Luhakhan comes under the watershed boundary and parts of other villages are lying in this, the socio-economic status of the village Luhakhan is presented here in the following tables.

Table 3.1 : Population

Category	Male	Female	Total
ST	53	46	99
SC	43	52	95
OBC	156	147	303
General	15	11	26
Total	**267**	**256**	**523**

Table 3.2 : Category of the farmers

Mariginal farmers	Small farmers	Big farmers	Landless	Total
62	23	15	32	132

Fig. 3.1 LOCATION MAP
BAGJORE MICRO-WATERSHED
(04-07-01-06-03-02-01-01)

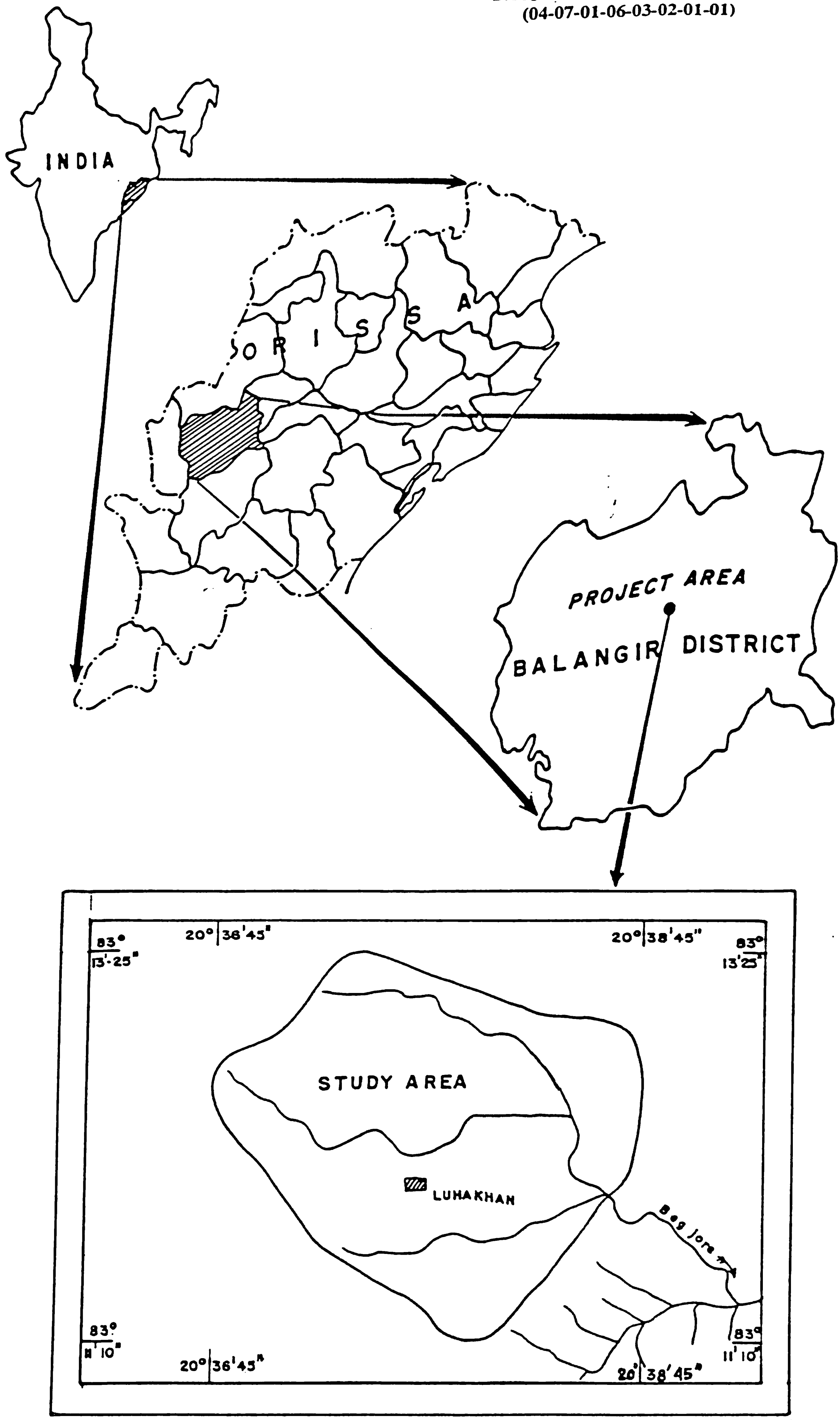


Table 3.3 : Present Agriculture Production

Sl No.	Type land	Crop grown	Area covered in hect.	Yield in Qntl/ha.	Total yield in Qntl.
1.	Upland	1. Paddy, Gurji, Kudo	33.30	3.50	116.55
		2. Pulse, Biri, Mung, Kulthi, Arhar	28.45	1.20	34.14
		3. Oilseed, Mustard Groundnut, Til	23.45	0.90	21.105
	Total		**85.20**		
2.	Medium land	1. Paddy	26.00	6.70	174.20
		2. Sugar cane	-	-	-
	Total		**26.00**		
3.	Low land	1. Paddy	19.10	10.00	191.00
		2. Sugar cane	0.50	90.00	45.00
	Total		**19.60**		
	G. Total		**130.80**		

Table 3.4 : Livestock

Cow	Ox	She Buffalo	He Buffalo	Goat	Sheep	Pig	Hen	Duck	Total
72	109	29	14	111	23	4	46	21	429

3.4 Data Used

3.4.1 False colour composite

False colour composite refers to the composite image generated by remote sensing observations, by assigning colours complementary to observation bands i.e. blue, green and red colour to observations in green (0.52-

0.59μm) red (0.62-0.68μm) and near infrared (0.77-0.86μm) spectral bands respectively of Indian Remote Sensing Satellite-ID LISS sensor.

IRS ID LISS III FCC of 2nd February, 1998 and 28th November, 1998 were used for the preparation of thematic maps like land use / land cover map, hydrogeomorphology map, soil resource map and drainage map of the watershed. The FCC are available in 1: 50,000 scale.

3.4.2 Toposheets

The Survey of India topographical sheet numbering 64 P/2 on a scale of 1: 50,000 with 20 metre contour interval was used to prepare the base map and to finalise the transport network, land use / land cover classes, hydrogeomorphological units, slope classes and drainage pattern of the watershed.

The toposheet covers an area within 15 minutes × 15 minutes of latitudes by 15 minutes × 15 minutes of longitudes.

3.4.3 Village boundary map

The village boundary map of the watershed was brought from Orissa Remote Sensing Application Centre, Bhubaneswar. The map has been prepared with the use of database collected from Census department and Revenue Department of Govt. of Orissa.

3.4.4 Rainfall data

The monthly rainfall data of Deogaon Block for last 30 years (1970-1999) was collected from the office of the Collector, Bolangir. Then monthly rainfall analysis was done with the help of a computer programme (SMADA). Out of the different probability distributions, the distribution which best fitted to the data was found out from chi-square test and the expected or predicted values of rainfall within desired probability levels and return periods were found out. Similar process was followed for each month. Annual and monsoon rainfall analysis was done likewise. The results of the analysis have been used for design of different soil and water conservation structures in the watershed.

3.4.5 Ground truth

Selective ground truth has been carried out in the areas which seemed to be doubtful during the interpretation of satellite imageries. The thematic maps related to natural resources of the watershed were checked on the ground. Soil samples have been collected from the sites to finalise the soil maps.

3.4.6 Cadestral maps

Cadestral maps of the concerned villages were collected from the office of the Collector, Bolangir. The maps were combined to generate the complete village maps. These maps served as important guides for preparation of different thematic maps.

3.5 Concept and Methods

3.5.1 Delineation of watershed

First of all the watershed boundary was delineated from the SOI topographical sheet no. 64 p/2. Then it was further modified and corrected using the multidata geocoded satellite imagery. Which was used for the study.

3.5.2 Codification of watershed

The codification of watershed provides a uniformity and fix the identity to each and every watershed. The codification of watersheds for the state of Orissa has been done by ORSAC following AIS & LUS guideline upto watershed level. The method adopted by AIS & LUS is given in table 3.5.

Table 3.5 : Nomenclature adopted for codification of watershed

Hydrologic unit	Nomenclature
Regions	Arabic number (1-6)
Basins	Alphabets (A-H)
Catchments.	Arabic number (1-9)
Sub-catchments	Alphabets (A-open)
Watershed	Arbaic numbers (1-9)
Sub-watersheds	Alphabets
Mini-watersheds	Alphabets
Micro-watersheds	Alphabets

A unique numbering system has been adopted by ORSAC to codify each micro-watershed of the state considering the following objectives in mind.

- The micro-watershed should have a unique code.
- The coding to follow numeric system for computerisation and GIS database generation.
- The coding should be on a common logic for the entire state and to follow AIS & LUS guideline upto watershed level.

The coding is done by using following steps.

1. Orissa state is coming in the region 4 as per AIS & LUS watershed classification system.

2. All the basins under region 04 again systematically coded from alphabetic to numeric codes like A stands for 01, B for 02 so on.

3. The catchments coming under each basin having number code in AIS & LUS Atlas are assigned number codes systematically from 01, 02, 03 etc.

4. The sub-catchment under each catchment having alphabetic codes in AIS & LUS Atlas are again coded on numeric values assigning 01 for A, 02 for B and so on.

5. The watersheds under each of the sub-catchment are given systematic number codes from 01, 02 .... etc.

6. Each of the sub-watershed under particular watershed, mini-watersheds under sub-watershed and micro-watersheds under mini-watershed are assigned systematic numbers from 01, 02, 03 .... etc. respectively.

7. Finally each micro-watershed has a code with 16 digit number.

04	00	00	00	00	00	00	00
↑	↑	↑	↑	↑	↑	↑	↑
Region	Basin	Catchment	Sub-catchment	Watershed	Sub-watershed	Mini-watershed	Micro-watershed

The area which has been selected for the present study is coming under region 4, basin 7 (Mahanadi Basin), catchment 1, sub-catchment 6, watershed 3, sub-watershed 2, mini-watershed 1 and micro-watershed 1.

So, the code for Bagjore micro-watershed is 04-07-01-06-03-02-01-01.

As each micro-watershed have a 16 digits code, in case of areas having common number up to first 8 digits, the same are again assigned single digit number of 1, 2, 3 .... systematically for all the districts without repetition of same number in the district.

In this case 1 is substituted for 04 07 01 06.

So, the code can be written as

1 - 03 - 02 - 01 - 01

3.5.3 Preparation of settlement and transport network map

The transport network and settlement map of the watershed is prepared from SOI toposheets of 1: 50,000 scale and the village map. The transparent tracing film was placed over the toposheet and all the roads were drawn. Village and forest boundaries have been collected from ORSAC and incorporated in the base map.

3.5.4 Preparation of land use / land cover map

Land use refers to men's activities and the various use which are carried on land. Land cover refers to natural vegetation, water bodies, artificial cover and other resulting due to land transformations.

The land use map of the Bagjore watershed was prepared using visual interpretation techniques. An initial base map of the study area clearly indicating the watershed boundary and a few control points was prepared from SOI toposheets. This base map was superimposed on the satellite FCC which was illuminated using a light table. Boundaries of various land use / land cover classes were demarcated. Keeping in mind the fundamentals of visual interpretation, different features were classified. The interpretation was based on size, shape, shadow, tone, texture, pattern and association characteristics of the images.

After preliminary image interpretation, the findings were compared with limited ground truth on the field. Corrections and modifications were made wherever found necessary. After the modification, final land use / land cover map for Bagjore micro-watershed was drawn. A digtal planimeter (PLACOM make) was used to obtain the spatial distribution of different land use and cover classes as depicted on the land use / land cover map.

3.5.5 Preparation of hydrogeomorphological map

Information on land forms is an important input for land management, soil mapping and identification of potential zones of ground water occurrence. Apart from the land form characteristics, the geological information like lithology / rock types also plays an important role in identifying the ground water potential zones. Hydrogeomorphological map contains the above mentioned aspects.

The hydrogeomorphological map is prepared by demarcating the geomorphic units and forms. First the base map of the study area was prepared from SOI toposheets indicating the boundaries and few control points. This base map was superimposed on the satellite F.C.C.. The geomorphic units are delineated based on image interpretation elements like shape, size, colour, texture, pattern and associations. The structural information like folds, fractures, lineaments have also been incorporated.

Ground data was collected to supplement and confirm the interpreted features. After modifications, details were transferred to the base map and a final hydrogeomorphological map of the area was prepared. The area under different units were then calculated by using a digital planimeter.

3.5.6 Preparation of drainage and surface water body map

The drainage map of the watershed is prepared by using SOI toposheets and satellite images. The transparent film with minimum base details was superimposed on the toposheet of 1 : 50,000 scale. The major rivers, streams, streamlets, were drawn carefully. It was placed over the post monsoon image and the extent of waterspread of the tanks, reservoirs and ponds was delineated. Standard photo interpretation technique was adopted for identifying and mapping drainage pattern and other surface water features.

Morphometric analysis

After preparing the drainage map of the watershed, the morphometric parameters like basin length (L_b), basin width (B), basin perimeter (P), basin area (A), bifurcation ratio (R_b), stream length, form factor (R_f), circularity ratio(R_c), circularity index (I_c), compactness coefficient, elongation ratio (R_e), texture ratio(R_t), drainage density (D_d) and stream frequency (F_u) were computed.

Basin length (L_b)

It is defined as the maximum length of the basin measured from the outlet.

Average basin width (B)

It is calculated as :

$$B = \frac{A}{L_b}$$

Where, A = Basin area, Km^2

L_b = Basin length, Km

Bifurcation ratio (R_b)

The term bifurcation ratio (R_b) is used to express the ratio of the number of streams of any given order to the number of streams in the next higher order, draining the watershed

$$\text{Bifurcation ratio, } R_b = \frac{N_u}{N_{u+1}}$$

Where, N_u = Number of stream segments of order 'u'.

N_u+1 = Number of stream segments of next higher order than the order 'u'.

The stream order is a measure of the position of a stream in the hierarchy of the tributaries (Horton, 1945). The first order streams are those which have no tributaries. The second order streams are those which have only first order streams as tributaries. Similarly, the third order streams receive first and second order streams as tributaries and so on.

The lower bifurcation ratio values are characteristic of the watersheds which have suffered less structural disturbances and the drainage pattern has not been distorted because of the structural disturbances. The R_b values range between 3 to 5 in such areas (Strahlar, 1964).

The bifurcation ratio is indicative of shape of the basin also. An elongated basin is likely to have a high R_b, whereas a circular basin is likely to have a low R_b.

Stream length

Length of the stream is indicative of the contributing area of the basin of that order. Generally, cumulative length of streams of a particular order is measured and the mean length (L_u) of that order stream (u) is obtained by dividing cumulative stream length by number of segments of that order (N_u).

Basin shape

The shape of basin affects stream flow hydrographs and peak flow. The important parameters describing the shape of the basin are form factor (R_f), circularity ratio (R_c), circularity index(I_c), compactness coefficient, elongation ratio (R_e), texture ratio(R_t) etc.

Form factor (R_f)

It is defined as the ratio of average width of the basin to the basin length.

$$\text{Form factor, } R_f = \frac{B}{L_b} = \frac{(A/L_b)}{L_b} = \frac{A}{(L_b)^2}$$

Where, A = Area of the basin, Km^2

L_b = Length of the basin, Km

The value of form factor should always be less than 0.7854 (for a perfectly circular basin). Smaller the value of form factor more elongated is the basin. The basin with high form factor has high peak flows for shorter duration, whereas elongated basin with low form factor will have a flatter peak flow for longer duration. Flood flows of elongated basins are easier to manage than that of the circular basins.

Circularity ratio (R_c)

It is the ratio of circumference of a circle with same area as that of the basin to the basin perimeter.

$$\text{Circularity ratio, } R_c = \frac{P_c}{P} = \frac{2\sqrt{\pi A}}{P}$$

Where A = Area of the basin, Km^2

P = Basin perimeter, Km

P_c = Perimeter of the circle having equal area as that of the drainage basin, Km

When the circularity ratio is closer to 1, the basin is more like a circle in shape.

Circularity index (I_c)

It is the ratio of the drainage basin area (A) to the area of a circle having same perimeter.

$$\text{Circularity index, } I_c = \frac{A}{A_c} = \frac{4\pi A}{P^2}$$

Where A = Basin area, Km^2

A_c = Area of the circle having equal perimeter as that of the drainage basin, Km^2

When I_c is closer to 1, the basin is almost circular in shape.

Compactness coefficient

It is defined as the ratio of the perimeter of the basin to the circumference of a circle whose area is equal to the area of the basin.

It is the inverse of circularity index.

Elongation ratio (R_e)

It is defined as the ratio of diameter of a circle which has same area as the basin to the basin length, expressed as

$$\text{Elongation ratio, } R_e = \frac{D_c}{L_b} = \frac{2}{L_b} \times \sqrt{A/\pi}$$

Where D_c = Diameter of the circle having same area as that of the basin, Km

L_b = Basin length, Km

A = Basin area, Km^2

When R_e value approaches 1, the shape of the basin is nearly circular.

Texture ratio (R_t)

It is defined as the number of first order streams per unit perimeter of the drainage basin.

$$\text{Texture ratio, } T = \frac{N_1}{P}$$

Where N_1 = Number of first order streams

P = Basin perimeter, Km

Higher value of texture ratio implies a well-drained basin.

Drainage density (D_d)

Horton (1932) defined drainage density (D_d) as the ratio of total length of all stream segments within a specified basin to the basin area.

$$\text{Drainage density, } D_d = \frac{L}{A}$$

Where, L = Length of all stream segments, Km

A = Area of the basin, Km^2

The factors controlling drainage density are resistance to weathering and permeability of rock formations apart from the climatic and other factors like vegetation. Low drainage density is observed in regions of highly resistant or permeable soil material under dense vegetation cover and low relief. High drainage density is observed in the regions of weak and impermeable subsurface material and sparse vegetation and mountainous relief.

Table 3.6 : Drainage density classes.

Value of D_d	Class
Below 1 km/sq.km	Extremely low density
1-2 km/sq.km	Low density
More than 2 km/sq.km	Medium density

Stream frequency (F_u)

Stream frequency is defined as the number of stream segments per unit basin area, given as :

$F_u = N/A$

Where, F_u = Stream frequency, Km^{-2}

N = Total number of stream segments of all orders.

A = Basin area, km^2

Higher the value of stream frequency, higher is the runoff.

Table 3.7 : Stream frequency classes.

Value of F_u	Class
Below 10	Poor drainage frequency
10-20	Medium drainage frequency
Above 20	High drainage frequency

3.5.7 Preparation of slope map

Information on slope is an important parameter in preparing action plans for management of land and water resources of a micro-watershed.

Survey of India topo maps on 1: 50,000 scale were used for preparing the slope map. The vertical drop is estimated / measured from the contour intervals and the horizontal distance in between the contours was measured from maps by multiplying the map distance with the scale factor. Close spaced contours on the map indicate higher percentage slope and were compared to sparse contours in the same space. The density of contours on the map was used for preparing the slope map that gives various groups / categories of slopes.

Slope is calculated by the formula :

$$\text{Slope in percentage} = \frac{\text{Vertical drop}}{\text{Horizontal distance}} \times 100$$

The categories of slopes and corresponding contour spacings are given below in table 3.9.

Table 3.8 : Land slope classes

Sl No.	Slope category	Slope %	Lower and upper limit of contour spacing
1.	Nearly level	0-1	More than 4 cm
2.	Very gently sloping	1-3 (more than 1% upto 3%	More than 1.33 cm and upto 4 cm
3.	Gently sloping	3-5	More than 0.8 cm and upto 1.33 cm
4.	Moderately sloping	5-10	More than 0.4 cm and upto 0.8 cm
5.	Strongly sloping	10-15	More than 0.26 cm and upto 0.4 cm
6.	Moderately steep to steep sloping	15-35	More than 0.11 cm and upto 0.26 cm
7.	Very steep sloping	> 35	0.11 cm and less

3.5.8 Preparation of soil resource map

Soil is a three dimensional body and can not be directly interpreted from satellite image. For extracting information on soils, study of pedons in ground condition followed by physico-chemical analysis of pedons in the chemical laboratory is a must in conjuction with the satellite image analysis. Genesis of soils is directly influenced by climate, relief, organic matter, parent material and time. Physiographic analysis carried out through the use of satellite image indicate the spatial distribution of variety of soils occurring in a micro-region.

For preparing the soil resource map of the Bagjore micro-watershed, the satellite image has been visually interpreted using standard interpretation elements. Pedons have been studied in selective physiographic locations. Parameters like soil depth, soil permeability, erosion condition, etc. were studied for individual soils. Sample pedons were collected from variety of physiographic locations for further analysis in the chemical laboratory.

Incorporating the laboratory analysis data, the field findings of soil and terrain parameters with the physiographic details as derived from satellite image, the final soil resource map for the watershed has been prepared.

The soil resource map thus prepared indicate the variety of soils occurring over different landforms. The soils corresponding to each land form have been discussed in terms of soil depth (Table 3.9), soil erosion (Table 3.10) and drainage (Table 3.11) and particle size (Table 3.12) etc.

Table 3.9 : **Soil depth classes**

Sl No.	Name	Depth range
1.	Very deep	More than 90 cm.
2.	Deep	45-90 cm.
3.	Moderately deep	22.5-45 cm.
4.	Shallow	7.5-22.5 cm.
5.	Very shallow	Less than 7.5 cm.

Table 3.10 : Soil erosion phases

Sl No.	Erosion	Characteristics
1.	Slight erosion	No or mild sheet erosion where 0-25% top soil is removed.
2.	Moderate erosion	With sheet and rill erosion where 25-75% of top soil is removed.
3.	Severe erosion	Top soil is removed and sub-soil is exposed.
4.	Very severe erosion	From 25% to 75% of sub-soil is removed and may include a few shallow gullies and occasional deep gully.

Table 3.11 : Soil drainage classes

Sl No.	Symbol	Drainage classes
1.	D_1	Poorly drained.
2.	D_2	Imperfectly drained.
3.	D_3	Moderately well drained.
4.	D_4	Well drained.
5.	D_5	Excessively drained.

Table 3.12 : Soil particle size classes

Sl No.	Soil class	Characteristics
1.	Fragmental	A fine earth component of less than 10 percent (including associated medium and fine pores) of the total volume.
2.	Sandy or sandy skeletal	A texture of sand or loamy sand, including less than 50 percent (by weight) very fine sand in the fine earth fraction.
3.	Loamy skeletal	Less than 35 percent clay in the fine earth fraction and a rock fragment content of 35 percent or more of the total volume.
4.	Clayey skeletal	A rock fragment content of 35 percent or more of the total volume.
5.	Clayey	A clay content of 35 percent or more in the fine earth fraction.
6.	Loamy	All other sub-groups of histosols.

3.5.9 Generation of action plan

3.5.9.1 Land resources development plan

The action plan for the land resources management of the watershed is generated by integrating the thematic information like land use / land cover, hydrogeomorphology, slope, drainage, soil, ground water potential etc. Manual overlaying of thematic maps using light table is adopted for generating the action plan. A thematic map with maximum number of polygons was used as a base. Accordingly, land use / land cover map was used as the base and other thematic maps i.e. slope, hydrogeomorphology, soil, drainage etc. were overlaid for finding the intersection and comparing the composite characteristics from which different action items are suggested.

While generating the action plan, a short deliberation is made on the optimality of the present land use especially keeping in view the sustainable production and quality of ecosystem. If the present land use is considered sub-optimal, then a few possible options for such a site are discussed with an aim to achieve optimality within the overall framework of sustainability of production. Unless and otherwise the present land use is beyond the threshold limit of some land parameters, a drastically different option is not recommended since such a change will not meet with high level of acceptability. For example a land unit, which is ideally suitable for horticulture or fodder or fuel-wood plantation, if presently under agricultural practice, then a modest change such as agro-horticulture or agro-forestry is recommended. However for a similar site if the slope is very steep then it becomes the limiting factor. Hence agriculture practice is ruled out and an altogether new land use practice like silvipasture or fodder and fuel-wood plantation is recommended.

Further while making alternate recommendations for land use practice, futuristic considerations such as exploitation of ground water, if presently not exploited and possibility of adopting more efficient system of irrigation and water management and other site improvements through soil and water conservation are also kept in view. Availability of improved varieties of crops, trees, shrubs and grasses and advantages of interdependency of agriculture, livestock and other practices as in case of integrated farming system that have been made available through contemporary research are also considered.

Thus with these considerations, finally an alternate land use practice is recommended for the site suitable for its recorded parameters.

To suggest a piece of land area to a certain activity, the procedure followed is explained below with the following example.

Example

If the land use = single cropped area

Hydrogeomorphology = pediment

Ground water potential = poor

Slope = 5-8%

Soil = Coarse textured with fine gravel, moderately deep to deep and well-drained soils.

Then recommended action = Agro-horticulture with appropriate soil conservation measure.

3.5.9.2 Water resources development plan

The water resources development plan is generated by recognising precipitation and its hydrological cycle along with nature of terrain to enhance productivity and mitigation of drought. The terrain parameters like slope, drainage pattern, soil cover and thickness and hydrological conditions like rock types, thickness of weathered strata, fracture, depth to bed rock etc. are analysed and integrated for the preparation of water resources development plan of the watershed. The surface water resources within the micro-watershed such as drainage network, tank, pond, water harvesting structures, reservoirs etc. are mapped for potential use. Suitable sites for engineering structures such as check dam, nala bunding, water harvesting structure, percolation tank etc. are identified. The areas suitable for ground-water development are also proposed.

Following points are considered for suggesting suitable actions for drainage line treatment.

- Where the local bed slope is above 20% and where thinning operation yields adequate raw material, brushwood checks are preferred.
- Where the local bed slopes are between 5-20%.
    - If boulders are freely available go for dry boulder checks.

- ♦ If boulders are not freely available go for boulder cum earth checks.

❑ Where local bed slopes are less than 5%

- ♦ Nala bunds which serve as percolation reservoirs in the upper catchment.
- ♦ Sand filled bag structures in order to check the velocity of stream flow where sand is locally available.
- ♦ Gabion structures where velocity and volume of peak runoff is too high for loose boulder checks.

CHAPTER - IV
RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

The present chapter deals with the results obtained through analysis of satellite imagery with ground truthing, analysis of rainfall data, integration of the informations for development of land and water resources management plan for the watershed and design of different soil conservation structures proposed in the management plan.

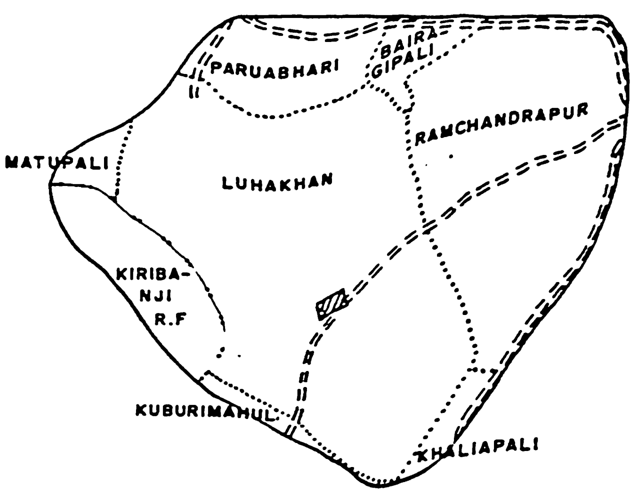
4.1 Settlement and Transport Network of the Watershed

The settlement and transport network map of the watershed was prepared to a scale of 1 : 50,000 and is presented in Fig. 4.1. The watershed spreads over seven villages namely Luhakhan, Ramchandrapur, Paruabhari, Matupali, Khaliapali, Bairagipali and Kuburimahul. Total area of village Luhakhan comes under the watershed whereas all other villages come partially under it. The settlements are mostly rural which depict the poor economic condition of the people. Transport network is not well developed and includes few unmetalled roads and cart tracks.

4.2 Land Use / Land Cover Pattern of the Watershed

Land use / land cover map of Bagjore micro-watershed was prepared in a scale of 1 : 50,000 through visual interpretation of IRS ID False Colour Composites (FCC) of date of pass October 2, 1998 and November, 28 1999. Different land use / land cover types were classified and are presented in Table 4.1. Figure 4.2 shows the information on land use / land cover status of the watershed.

Fig. 4.1 SETTLEMENT AND TRANSPORT NETWORK MAP
BAGJORE MICRO-WATERSHED
(04-07-01-06-03-02-01-01)
Scale – 1 : 50,000



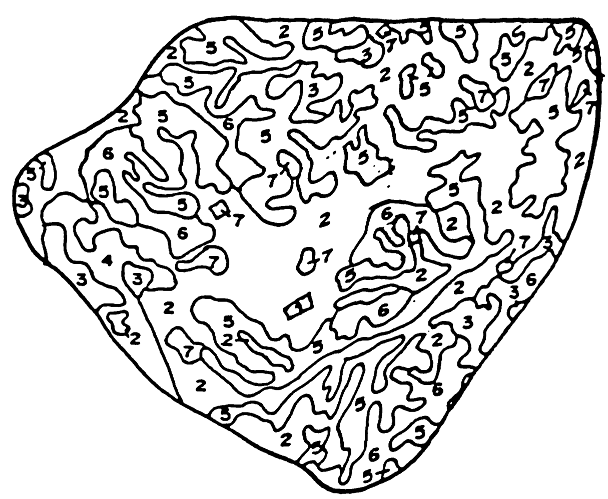
LEGEND

Settlement
Roads
Village boundary
Forest boundary

Table 4.1 : Land use / land cover classification of Bagjore micro-watershed

Map Unit		Land use classes	Area (ha.)	% of the total geographical area
I.		**Builtup land**		
	1.	Settlement	1.5	0.21
II.		**Agricultural land**		
	2.	Single cropped land	333.5	45.53
III.		**Forest**		
	3.	Open forest	43.75	5.97
	4.	Degraded forest	32.0	4.37
IV.		**Wasteland**		
	5.	Land with scrub	220.0	30.03
	6.	Land without scrub	88.0	12.01
V.		**Water bodies**		
	7.	Reservoirs / tanks	13.75	1.88
		Total	**732.5**	**100**

Fig. 4.2 LAND USE / LAND COVER MAP
BAGJORE MICRO-WATERSHED
(04-07-01-06-03-02-01-01)
Scale – 1 : 50,000



LEGEND

1. Built-up land
2. Single cropped land
3. Open forest
4. Degraded forest
5. Land with scrub
6. Land without scrub
7. Reservoirs / tanks

1. **Built-up land**

It refers to the area of human habitation developed due to non-agricultural use and which has a cover of settlements.

The built-up lands in Bagjore micro-watershed is constituted of mostly the rural settlements. The total area occupied by this land category is 0.21 ha. which is 0.21 per cent of the total area of the watershed.

2. **Agricultural land**

It refers to the land primarily used for farming and for production of food, fibre and other commercial and horticultural crops. It includes land under crops, fallow land and plantations.

Agriculture occupies an area of 333.5 ha. which is 45.53 per cent of the total area of the watershed. Almost all the agricultural land is under single crop.

3. **Forest**

It is an area bearing an association predominantly of trees and other vegetation types capable of producing timber and other forest products.

The area under the forest is 75.75 ha. which is 10.4 per cent of the total area of the watershed. Open forests include 4.75 ha. and degraded forest includes 32.0 ha. of land. A part of Kiribanji reserve forest comes under this category.

4. **Wastelands**

Wastelands refer to degraded land which include land with scrub and land without scrub. It covers 308.0 ha. which is 42.04 per cent of the total area. Land with scrub covers 220.0 ha. which is 30.03 per cent of the area. Similarly land without scrub covers 88.0 ha. which is 12.01 per cent of the total geographical area.

5. Water bodies

This unit constitutes the reservoirs, village ponds and tanks etc. and covers an area of 13.75 ha. which is 1.88 per cent of the total geographical area.

The results indicate that Bagjore micro-watershed is one of the potential micro region for agricultural development. Agriculture alone occupies about 45.53 per cent of total watershed area but almost all the agricultural lands are single cropped. So, with suitable management practices these lands can be turned to double cropped areas. Forest area constitutes only 10.34 per cent of the total area. Wastelands which constitute 42.04 per cent of the total area are to be planned for productive use.

4.3 Hydrogeomorphological Characteristics of the Watershed

The hydrogeomorphological units were identified and mapped through visual interpretation in 1 : 50,000 scale. The hydrogeomorphological units are presented in Table 4.2. Fig. 4.3 shows the hydrogeomorphological map of the watershed.

Table 4.2 : Hydrogeomorphological characteristics of Bagjore micro-watershed.

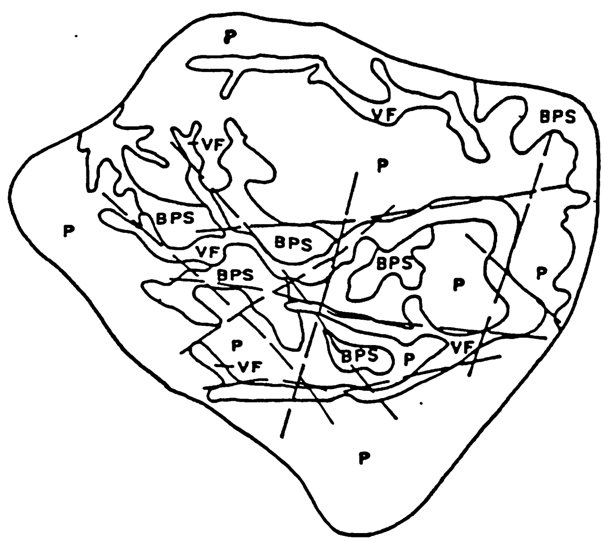
Map unit	Geomorphic unit	Groundwater prospect	Area (ha.)	% of the total geographical area
P	Pediment	Poor to moderate	544.15	74.29
BPS	Shallow weathered buried pediment	Moderate to good	86.55	11.81
VF	Valley Fill	Good	101.80	13.9
Total			**732.5**	**100**

Fig. 4.3 **HYDROGEOMORPHOLOGICAL MAP**

BAGJORE MICRO-WATERSHED

(04-07-01-06-03-02-01-01)

Scale – 1 : 50,000



LEGEND

P Pediment

BPS Shallow weathered buried pediment

VF Valley fill

— — Lineament

1. Pediment

This hydrogeomorphic unit acts mostly as a runoff zone. The weathered thickness is very small and the groundwater potential is moderate to poor. This is the major hydrologic unit in the study area covering an area of 544.15 ha. which is about 74.29 per cent of the total area of watershed.

2. Shallow weathered buried pediment

This hydrogeomorphic unit consists of a shallow over burden of weather materials (0.5m thickness). Infiltration is moderate and groundwater potential is moderate to good. If covers an area of 86.55 ha. which is about 11.81 per cent of the total area of the watershed.

3. Valley Fill

This hydrogeomorphic unit consists of unconsolidated alluvial materials consisting of sand, silt and gravels etc. deposited along a valley. This unit acts as both recharging and discharging zones for groundwater. Groundwater occurs at shallow depths in this zone. The groundwater potential is good due to its topographical location and geological composition consisting of highly porous materials. Depending upon the thickness of the fill, the prospect varies. It covers an area of 101.8 ha. which is about 13.9 per cent of the total area of the watershed.

4. Lineaments

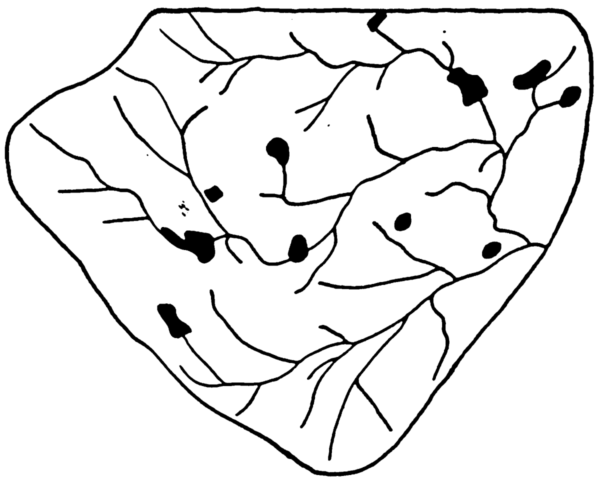
Lineaments are the surface manifestations of some structural features in the bedrock as fractures and joints developed due to tectonic stress and strain. The fracture zones formed on interlaced network of high transmissivity and serve as groundwater conduits in massive rocks in interfracture areas. The lineament intersection areas are considered as good potential zones for groundwater.

The above results indicate that pediment is the major hydrogeomorphic unit of the watershed which accounts for 74.29 per cent of the total area of the watershed. Shallow weathered buried pediment accounts for 11.81 per cent and valley fill accounts for 13.9 per cent of the total watershed area. Features like moderately weathered buried pediment, residual hill, structural hill, denudational hill are absent in the area.

4.4 Morphometric Analysis of the Watershed

The drainage map of the watershed was prepared by using Survey of India topographical sheets and recent false colour composites derived from satellite remote sensing to a scale of 1 : 50,000. Fig. 4.4 represents the drainage and surface water body map of the watershed. The morphometric parameters like bifurcation ratio (R_b), stream length, form factor (R_f), circularity ratio (R_c), circularity index (I_c), compactness coefficient, elongation ratio (R_e), texture ratio (R_t), drainage density (D_d) and stream frequency (F_u) are computed and presented in Table 4.3.

Fig. 4.4 DRAINAGE AND SURFACE WATER BODY MAP
BAGJORE MICRO-WATERSHED
(04-07-01-06-03-02-01-01)
Scale – 1 : 50,000



LEGEND

River / Nala

Tank / Pond

Table 4.3 : Morphometric parameters for Bagjore micro-watershed

Sl No.	Morphometric parameters	Value
1.	No. of 1st order stream segments	37
2.	No. of 2nd order stream segments	10
3.	No. of 3rd order stream segments	3
4.	No. of 4th order stream segments	1
5.	Length of the basin, Km	3.55
6.	Average basin width, Km	2.0634
7.	Perimeter of the basin, Km	10.6
8.	Bifurcation ratio, R_b (1st/2nd order)	3.7
9.	Bifurcation ratio, R_b (2nd/3rd order)	3.3333
10.	Bifurcation ratio, R_b (3rd/4th order)	3.0
11.	Bifurcation ratio, R_b (Average)	3.3444
12.	Stream length, Km	18.55
13.	Form factor (R_f)	0.5812
14.	Circularity ratio (R_c)	0.9051
15.	Circularity index (I_c)	0.8192
16.	Compactness coefficient	1.2207
17.	Elongation ratio (R_e)	0.8603
18.	Texture ratio (R_t)	3.4906
19.	Drainage density (D_d), Km/km^2	2.5324
20.	Stream frequency (F_u), Km^{-2}	6.9625

4.5 Slope Attributes of the Watershed

The slope map of the watershed was to be prepared using SOI topographical sheet. But all the areas come under a single category i.e. nearly level with slope ranging from 0 to 1%. So, the slope map could not be prepared for the watershed.

4.6 Soil characteristics of the Watershed

Information generation on soil resources for Bagjore micro-watershed is based on the multistage approach of remote sensing based spatial information, field base observation of soil, terrain parameters and analysis of pedons in the chemical laboratory.

In total, three different categories of soils have been recognised in the scale of 1 : 50,000, Fig. 4.5 represents the soil resource map of the watershed. The details of individual soil category is discussed in Table 4.4.

Table 4.4 : Soil resource characteristics of Bagjore micro-watershed

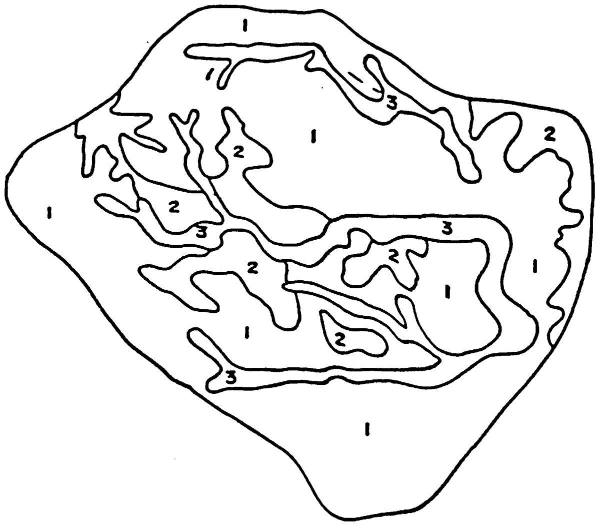
Map unit	Geomorphic unit	Soil Characteristics	Area (ha.)	% of the total geographical area
1.	Pediment	Moderately deep, coarse loamy textured, well drained soil under moderate erosion	5.44.15	74.29
2.	Shallow weathered buried pediment	Deep to very deep, coarse loamy textured, moderately well drained soil	86.55	11.81
3.	Valley fill	Very deep, fine loamy textured, imperfectly drained soil	101.80	13.9
Total			**732.5**	**100**

Fig. 4.5 **SOIL RESOURCE MAP**

BAGJORE MICRO-WATERSHED

(04-07-01-06-03-02-01-01)

Scale – 1 : 50,000



LEGEND

1. Moderately deep, loamy skeletal textured well drained soil under moderate erosion on pediments
2. Deep to very deep, coarse loamy textured, moderately well drained soil on shallow weathered buried pediment
3. Very deep, fine loamy textured, imperfectly drained soil in valley fills

The results indicate that the general texture of the study area range from loamy skeletal to fine loamy. The depth of soil is more than 90 cm. in the valley fills which constitute 13.9 per cent of the total geographical area.

4.7 Land Resources Development

The land resources utilization plan reflects the approach of use of the physical environmental condition in a judicious manner for sustainable development of the watershed. For this area, 10 action items have been suggested. Fig. 4.6 shows the land resources development plan of the watershed. Table 4.5 represents areas under different action items suggested for the watershed.

Table 4.5 : Recommended action items for land resources development of the watershed

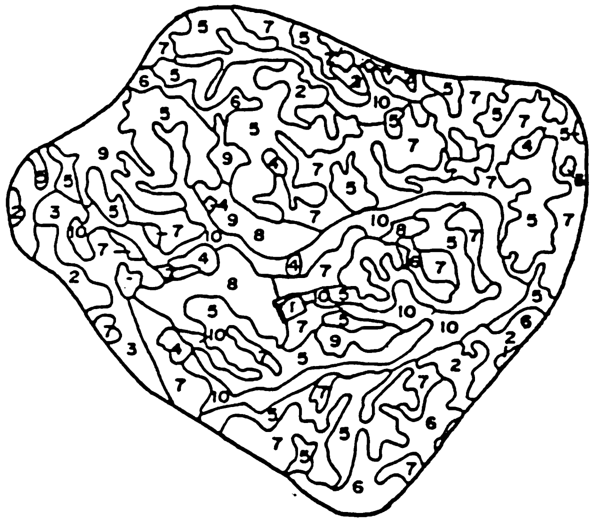
Map unit	Action items	Area (ha.)
1.	Optimally used land	1.5
2.	Gap plantation	46.5
3.	Afforestation with cattle protection trenches	25.75
4.	Pisciculture with plantation on bunds	17.0
5.	Silvipasture	234.5
6.	Pasture land development	36.5
7.	Agroforestry with vegetative contour bunding	155.5
8.	Agrohorticulture with groundwater exploration	44.0
9.	Horticulture	42.5
10.	Intensive Agriculture	128.75
	Total	**732.5**

Fig. 4.6 LAND RESOURCES DEVELOPMENT PLAN

BAGJORE MICRO-WATERSHED

(04-07-01-06-03-02-01-01)

Scale – 1 : 50,000



LEGEND

1. Optimally used land
2. Gap plantation
3. Afforestation with cattle protection trenches
4. Pisciculture with plantation on bunds
5. Silvipasture
6. Pasture land development
7. Agro-forestry with vegetative contour bunding
8. Agro-horticulture with groundwater exploration
9. Horticulture
10. Intensive agriculture

1. Optimally used land

In the present context, optimally used land refers to the settlements in the watershed area. These lands need no modification or treatment in the action plan.

2. Gap plantation

Gap plantation is suggested in an area of 46.5 ha. in the open forest. Since there is a shortage of fuel-wood for domestic use of the people in the project area, it is necessary to take up plantation of fuel-wood species by way of gap filling. The different fuel-wood species to be planted are Chakunda, Accacia, Gambhari etc. This will not only help to meet the fuel-wood requirement of the area, but also largely available for ecological balance and better environment.

3. Afforestation with cattle protection trenches

The lands under degraded forests inside reserve forest must be brought back to vegetation cover through afforestation. Varieties like teak, accacia, eucalyptus, sal, sishal etc. may be planted following the proper package of practice. Social fencing may be advisable to restrict the cattle grazing inside this area without any cost involvement or artificial fencing is to be provided. An area of 25.75 ha. is suggested for afforestation in the watershed.

4. Pisciculture with plantation on bunds

The existing tanks, ponds and reservoirs located inside the watershed can be used for pisciculture. Water bodies suggested for renovation and the suggested water harvesting structures may also be used for pisciculture. The earthen bunds surrounding the tanks/ponds can be used with plantation of horticultural species. This will add to the net return from the same piece of land. An area of 17.0 ha. is suggested for pisciculture in the watershed.

5. Silvipasture

In this system, grass lands grow in forest and livestock are allowed to enter in the forest areas for pastoral purposes. Before planting the trees, protection of the trees by the community is to be ensured. After 2 to 3 years of growth of the trees, livestock are to be allowed to graze and the people given the right over fodder, fuel-wood and other NTFP. The lands with scrub which come under pediment have been planned for silvipasture. An area of 234.5 ha. is suggested for silvipasture in the watershed. The lands are to be covered with fodder crops along with silviculture.

6. Pasture land development

In the plan, it is suggested to go for pasture land development or fodder cultivation in the land without scrub which comes under the pediment. The people of the watershed area are to be motivated to adopt cut and carry system for the above purpose. Open grazing is to be restricted and stall-feeding is to be encouraged. An area of 36.5 ha. is suggested for pasture land development.

7. Agro-forestry with vegetative contour bunding

Trees valued for fuel, timber and other NTFP can be grown with crops in the field scattered in different locations or as inter crops or alley farming on field bunds. Alley farming is defined as an agro-forestry system in which food crop are grown in alleys between rows of hedges. The trees provide green manure and mulch to the soil which recycles soil nutrients. Plantation on field boundaries is a common and acceptable practice without encroaching or affecting field crops. Due to the relative robustness of trees to climatic extremes, trees make a valuable source of income at times of drought or flooding when annual crops have failed. Productivity and sustainability should be the main criteria for accepting a particular type of agro-forestry system. The lands with single cropped area which are under pediment are planned for agro-forestry. An area of 155.5 ha. is suggested for this item.

8. Agro-horticulture

It is the practice of growing field crops along with horticulture plantation in the left out interspaces. Rainy and winter season vegetables are generally grown with horticultural trees. Some fruit plants like banana, papaya, pineapple etc. may be cultivated as field crops and they are grown as intercrops among trees. Citrus trees can be intercropped with vegetables, grams etc. Intercropping of leguminous crops is profitable and remunerative with mango and litchi plantations. So, some recommended crops with fruit plantation can be taken so as to have a higher rate of income from the same unit of land.

The lands with single cropped area which come under shallow weathered buried pediment are planned for agro-horticulture. The soil on these lands are coarse loamy in texture with fine gravels moderately deep to deep and well drained. Keeping the sentiment of the people a total transformation of present land use practice can not be taken. However, an improvement in the present practice will be beneficial to the users. An area of 44.0 ha. has been suggested under this action item.

9. Horticulture

Horticulture, a suitable strategy to attract rural poor in afforestation as a viable economic activity has to be evolved. Horticulture serves as a sustained source of regular income over very long periods and in addition to fruits, these trees provide fuel, fodder and small timber. Selection of proper tree species should be ascertained based upon the need and the potential. There should be an intermix of early fruiting and late fruiting trees such that the economic returns should be immediate as well as late. The shallow weathered buried pediments which are without scrub are planned for horticulture. These lands are unproductive in the present situation. This action item has been recommended in an area of 42.5 ha. The main constraint for horticulture in the locality is water. So, suitable irrigation facilities through dugwells and water harvesting structures are to be created for this purpose.

10. Intensive agriculture

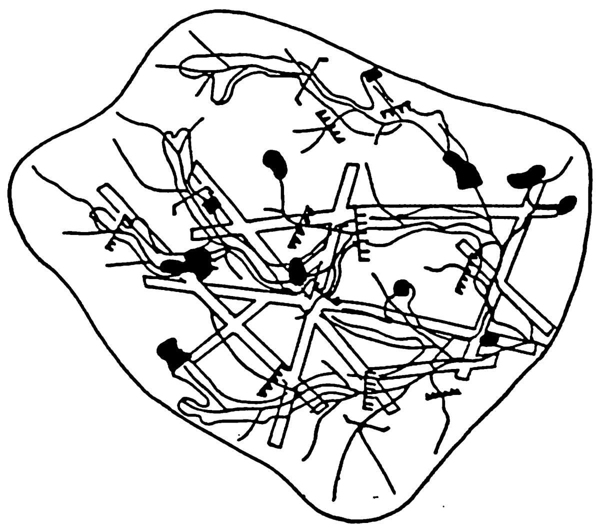
Despite high risk of failure, farmers of the locality use to grow low yielding paddy under primitive technology. Due to erratic rainfall and practice of growing a single crop the annual production gets reduced. So, intensive agriculture is planned in the valley fills which are at present under single crop. Suitable crop rotation with the use inputs like high yielding variety seed, recommended fertiliser and pesticide dose is to be followed for getting a high return from the same land. Here the farmers are in a habbit of growing only paddy which is to be restricted and minimum two crops (non paddy crops) are to be taken for increasing the cropping intensity and net return from the same area of land. An area of 128.75 ha. is recommended for this item in the action plan.

4.8 Water resources development

The water resources management plan is generated to make the judicious and effective use of water resources of the watershed to enhance the productivity and mitigate drought. The plan indicates sites for surface water development and sites for groundwater exploitation. Different engineering structures proposed for the water resources development are shown in Fig. 4.7.

The water bodies to be renovated are also indicated in the map. The number, type, location of proposed engineering measures / structures are given in Table. 4.6.

Fig. 4.7 WATER RESOURCES DEVELOPMENT PLAN
BAGJORE MICRO-WATERSHED
(04-07-01-06-03-02-01-01)
Scale – 1 : 50,000



LEGEND

Surface water development

Renovation of water bodies

Nala bund

Check dam

Water harvesting structure

Ground water development

Exploitation through shallow dug well

Exploitation through deep bore well

Table 4.6 : **Number / location of proposed structures for water resources development in the watershed.**

Sl No.	Engineering structures	Number	Location
1.	Renovation of water bodies	11	Luhakhan (5) Ramchandrapur (5) Bairagipali (1)
2.	Nala bunds	8	Luhakhan (5) Ramchandrapur (2) Bairagipali (1)
3.	Check dams	4	Luhakhan (2) Ramchandrapur (1) Paruabharai (1)
4.	Water Harvesting Structures (WHS)	2	Luhakhan (2)

1. Renovation of water bodies

This includes all the existing water bodies which need renovation because of siltation, development of weeds and structural failure.

2. Nala bunds

Nala bund is an earthen dam constructed to impound water flowing in a nali or nala for the primary purpose of increasing water percolation and improving soil moisture regime.

Site conditions

The feasibility of site for locating nala bund depends upon technical and economic considerations such as :

(a) The sites should be selected in relatively flatter nala reach and the slope of the nala should not be more than 2 per cent.

(b) As far as possible, the catchment area of the nala bund should not be less than 40 ha.

(c) There should be proper site for construction of emergency spillway by the side of the nala bund.

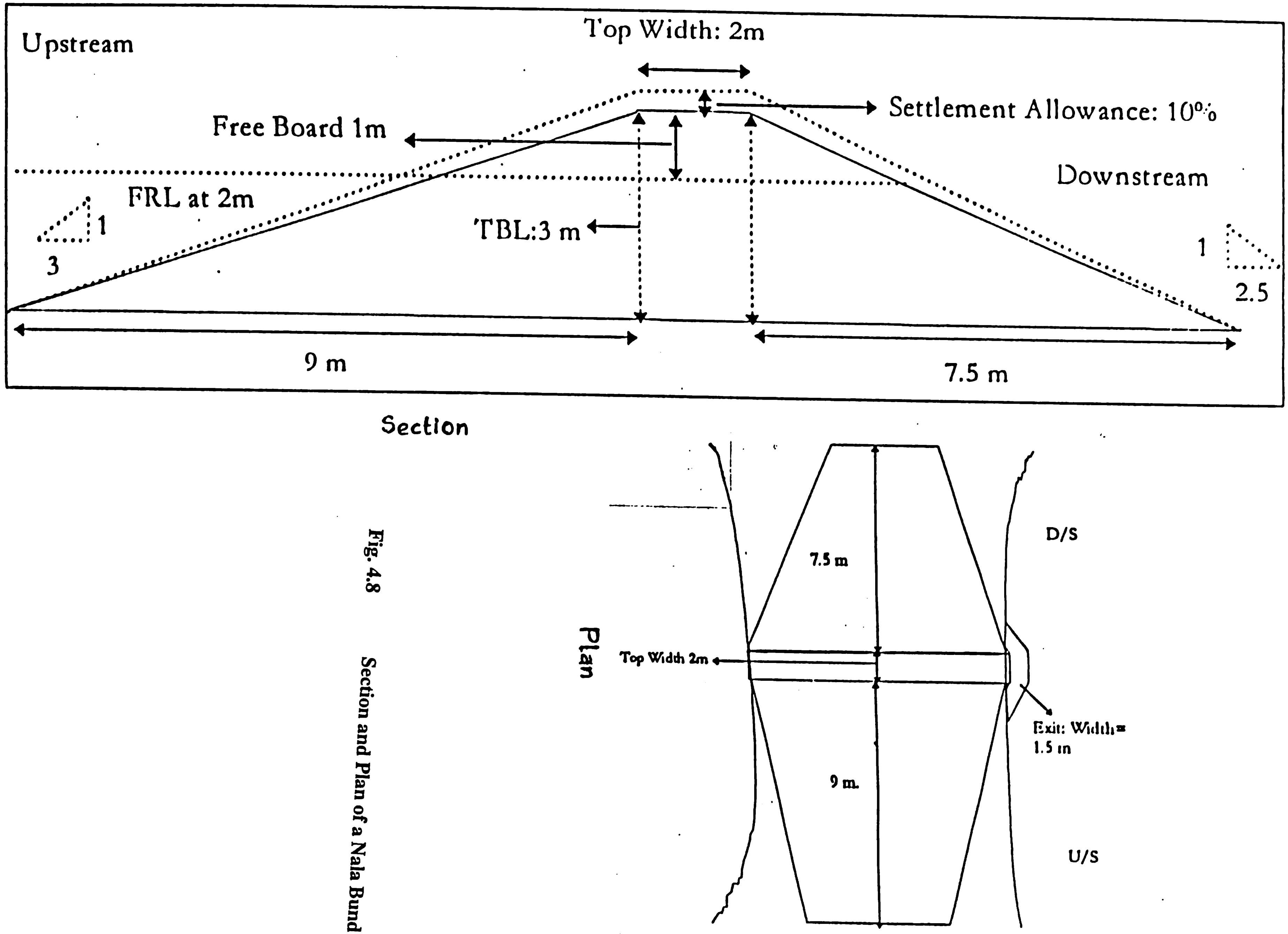


Fig. 4.8 Section and Plan of a Nala Bund

(d) The nala bund should have soils with adequate permeability and good fracture development to facilitate good groundwater recharge.

Considering the above conditions, eight numbers of nala bunds are proposed for the groundwater recharge in the watershed.

3. Check dams

Check dams are the gully control structures made on the drainage lines to reduce the velocity of runoff and to help in percolation of retained water.

Site conditions

(a) Check dams are constructed on lower order streams (upto third order).

(b) The stream is influent or intermittently effluent.

(c) Bed slope of the drainage line at the site should not be above 20 per cent because the check dam will not be able to withstand the high velocity of water flow.

(d) The average catchment area should be about 25 ha.

(e) A check dam should be made where the embankments are well defined and stable and high enough to accommodate peak flows even after the check has been made, thereby preventing water from rising over and cutting the banks. The height of the embankment at the location of the structure must be at least equal to the total of maximum depth of flow in the stream and the design height of the structure in the central portion of the drainage line

(f) Even though storage is not a primary condition in the case of check dam, enhanced water retention and groundwater recharge is a desirable objective. Hence, locating the structure in those sections in the drainage lines where the upstream slope is flatter may be advantageous. The flatter the upstream slope, the more would be the storage per unit height of the structure.

Four numbers of check dams are proposed for the water resources management in the watershed.

4. **Water harvesting structures**

Water harvesting structures are those structures constructed across the stream which harvest surface runoff during the monsoon rains.

Site conditions

(a) Since the primary objective of farm ponds is irrigation, the geology of the structure must be favourable for water storage. They should not be located in very heavy soils or impervious strata which may hinder groundwater recharge.

(b) The bed slope should be relatively low in the upstream of the site in order to maximise storage capacity.

(c) There should be adequate good cultivated land at the downstream to reap the benefits of the waters stored.

(d) As far as possible, the water harvesting structures should be located in the government lands or in the wastelands.

(e) There should be easy availability of the construction materials in the immediate surroundings.

Two numbers of water harvesting structures (impounding type) are proposed in the management plan.

Groundwater exploitation

Groundwater potential of Bagjore micro-watershed has been evaluated on the basis of geomorphology, lithology, structure, depth of weathering and lineaments.

Depending upon the availability of water resources, their mode of occurrence and problems associated with developmental activities, the micro-watershed is divided into two zones for the exploitation of groundwater resource.

(a) Zone of exploitation through deep tube well / bore well.

(b) Zone of exploitation through shallow dug wells.

Detailed description of the above zones is given below.

(a) Zone of exploitation through deep tube well / bore well

The deep seated fracture zones or the zones of prominent lineaments and lineament intersections are suited for exploitation through deep tube well / bore well. The exact site location should be confirmed by detailed hydrological study and electrical resistivity survey to understand the subsurface distribution of fracture and aquifer system.

The bore wells constructed in the fractures have limited yield which varies from 1 to 6 litres per second. For ensuring economic returns the water available from these wells is utilised for irrigation of plantation crops, vegetables oil seeds, onion etc. the net return from which per quantity of water used is of high order compared to raising of high duty cereal crops.

(b) Zone of exploitation through shallow dug wells

Areas covered by shallow thickness of alluvium, valley fills etc. are suited for shallow dug wells. Site for shallow dug wells is demarcated considering the weathered thickness with joints and fractures and nature of alluvium deposits. The unconsolidated alluvial deposits include alternate zones of clay and sand. The porous sand occurring next to ground surface or lying between two impervious zones of clay formation serves as the chief aquifer supporting different types of irrigation wells installed in this tract. The formation with a mixture of fine, medium and coarse sand as well as gravels in some locations in different proportions holds and easily yields sufficient water to support the installation of dug wells and filter point tube wells.

For the better storage capacity of wells and to compensate the long hours of pumping, adequate rain water harvesting measure in the upper stream is required.

4.9 Analysis of the rainfall data

The monthly rainfall data for last 30 years was collected from the office of the Collector, Bolangir and analysed with the help of a computer programme (SMADA). The monthly data was fitted to different distribution functions. The distribution of best fit was found out from chi-square test. Then the expected values of rainfall was found out for desired probability levels and return periods. Similar process was adopted for yearly and monsoon rainfall analysis. The results obtained are presented in Table 4.7 and 4.8.

Table 4.7 : Expected values of rainfall for different months and for different probability levels.

Best fit probability distribution	Month	Probability level (%)								
		90	80	70	60	50	40	30	20	10
Pearson Type-III	Jan.	-1.4	-1.32	-0.96	-0.25	0.88	2.59	5.17	9.39	17.8
Pearson Type-III	Feb.	-2.25	-1.36	0.16	2.29	5.12	8.91	14.2	22.2	37.1
Pearson Type-III	Mar.	-2.92	-1.66	-0.04	1.94	4.36	7.42	11.5	17.4	27.9
Pearson Type-III	Apr.	-5.42	-3.05	-0.28	2.93	6.75	11.4	17.6	26.3	41.5
2 Parameter Log Normal	May	3.02	4.87	6.87	9.21	12.1	15.9	21.4	30.2	45.6
3 Parameter Log Normal	Jun.	61	99	128	154	178	204	232	266	315
Gumbel Type-I External	Jul.	191	230	263	293	324	358	398	450	533
Normal	Aug.	132	211	268	317	363	409	457	515	594
3 Parameter Log Normal	Sept.	44	73	98	123	150	180	217	267	350
2 Parameter Log Normal	Oct.	4.55	7.58	11	15	20.1	26.9	36.8	53.1	88.4
Pearson Type-III	Nov.	-6.47	-4.98	-2.76	0.15	3.89	8.76	15.4	25.3	43.5
2 Parameter Log Normal	Dec.	0.01	0.01	0.02	0.04	0.06	0.09	0.15	0.27	0.6
Log Pearson Type-III	Annual	680	857	990	1104	1210	1312	1417	1531	1663
Log Pearson Type-III	Monsoon	606	763	882	986	1084	1180	1279	1390	1528

Table 4.8 : Expected values of rainfall for different months and for different return periods.

Best fit probability distribution	Month	Return Periods							
		200	100	50	25	10	5	3	2
Pearson Type-III	Jan.	65.04	52.85	41.34	30.34	17.78	9.39	4.19	0.88
Pearson Type-III	Feb.	113.1	94.16	75.99	58.63	37.14	22.22	12.23	5.12
Pearson Type-III	Mar.	78.04	65.87	54.02	42.53	27.93	17.40	10.0	4.36
Pearson Type-III	Apr.	111.6	94.87	78.33	62.22	41.50	26.28	15.33	6.75
2 Parameter Log Normal	May	197.5	150.7	112.2	80.76	48.57	30.15	19.33	12.11
3 Parameter Log Normal	Jun.	476.5	443.4	408.3	370.7	315	265.6	221.9	178.2
Gumbel Type-I External	Jul.	872.1	794.7	717.1	638.9	533.5	450	383.8	324
Normal	Aug.	827.9	782.9	733.7	679	594.3	514.8	440.7	362.9
3 Parameter Log Normal	Sept.	732.2	638.5	548.5	461.7	350.4	266.9	203.9	150.1
2 Parameter Log Normal	Oct.	395.5	296.3	216.2	152.2	88.43	53.13	33.05	20.06
Pearson Type-III	Nov.	133.1	111	89.66	69.14	43.46	25.34	12.96	3.89
2 Parameter Log Normal	Dec.	6.56	4.14	2.50	1.43	0.60	0.27	0.13	0.06
Log Pearson Type-III	Annual	1927	1894	1850	1789	1670	1531	1382	1210
Log Pearson Type-III	Monso on	1811	1772	1721	1654	1528	1390	1245	1084

4.10 Design of Different Soil and Water Conservation Structures

4.10.1 Design of contour bunds

Bunding or construction of small embankment is carried out to reduce the length of slope, to reduce the velocity of runoff water and to hold the water in the catchment for a longer period. Thus more water inflitrates into the ground and less runoff and soil erosion take place. When the bunds are constructed along the contours with some minor deviation to adopt to practical situation, they are known as contour bunds. If the bunds are constructed with some slope, they are known as graded bunds. In low rainfall areas (annual rainfall < 500 mm) where moisture is the limiting factor for crop production, contour bunds are adopted. In heavy and medium rainfall areas, the graded bunds with 0.2 to 0.3 percent slope are constructed.

When the land slope is 2-4%, contour bunding may be adopted. The design procedure of contour bund for lands having 2% slope is given below.

Design procedure

$$V.\,I. = S/a + b$$

And $$H.\,I = V.I./S \times 100$$

Where, V. I. = Vertical interval between consecutive bunds

H. I. = Horizontal interval

a and b = Constants depending upon the soil and rainfall characteristics of the area.

S = Land slope, percent.

For design purpose, value of $a = 10$ and $b = 0.6$ may be taken.

So, $V.\,I. = (2/10+0.6)\text{m} = 0.8$ m, $H.\,I. = 0.8/2\times100 = 40$ m (for $S = 2\%$).

Depth of impounding near the bund, $h = \sqrt{\dfrac{R \times V.I.}{50}}$

Where, R = 24-hour excess rainfall to be stored, cm.

V. I = Vertical Interval, m.

For, our purpose one-day maximum rainfall = 12 cm.

Runoff coefficient = 0.6

So, 24-hour excess rainfall for the area = R = 12×0.6 cm = 7.2 cm.

Hence, $h = \sqrt{\dfrac{7.2 \times 0.8}{50}} = 0.34$ m.

Allowing a freeboard of 15 cm,

total height of the bund (H) = (0.34 +0.15)m = 0.49 m, or say, 0.5 m.

The slope of seepage line in sandy loam soil is approximately 5 : 1

Therefore, base width required for he bund (B) = 1.5h + 5h

= 6.5h = 2.21 m.

Assuming a side slope of 1.5 : 1,

the top width of the bund (T) $= 2.21 - 0.5 \times 1.5 \times 2$

= 1.21 m.

So, the design parametes of the contour bund are

H = 0.5 m.

T = 1.21 m.

B = 2.21 m.

4.10.2 Design of Water Harvesting Structure

Water harvesting structures are constructed to store and harvest runoff water for useful purposes like agriculture, domestic and livestock use and aquaculture. These structures may be of two types.

(i) Impounding type

(ii) Dug-out type

In case of impounding type, a dam is constructed across the nallah to store the flowing water passing through it. In case of dug-out type, a pond is constructed by excavation to store the run-off water in it. In the present context, only impounding type of water harvesting structures have been discussed.

Runoff estimates and design of bund

Cactchment area = 10 ha. (0.1 km^2) (suppose)

75% dependable monsoon rainfall = 823 mm
(from rainfall analysis)
75% dependable monsoon yield = 2.62 ha.m. or say, 3 ha.m.
(using Strange's table)

Water requirement of paddy = 650 mm. (0.65 m)

Area that can be irrigated = 3/0.65 = 4.6 ha.

Live storage of reservoir (60% of 75% monsoon yield) $= 3 \times 0.6$

$= 1.8$ ha.m.

Considering a silt yield of 0.024 ha.m per sq.km and a reservoir life of 60 years,

dead storage required $= 0.1 \times 60 \times 0.024$

$= 0.144$ or say, 0.15 ha.m.

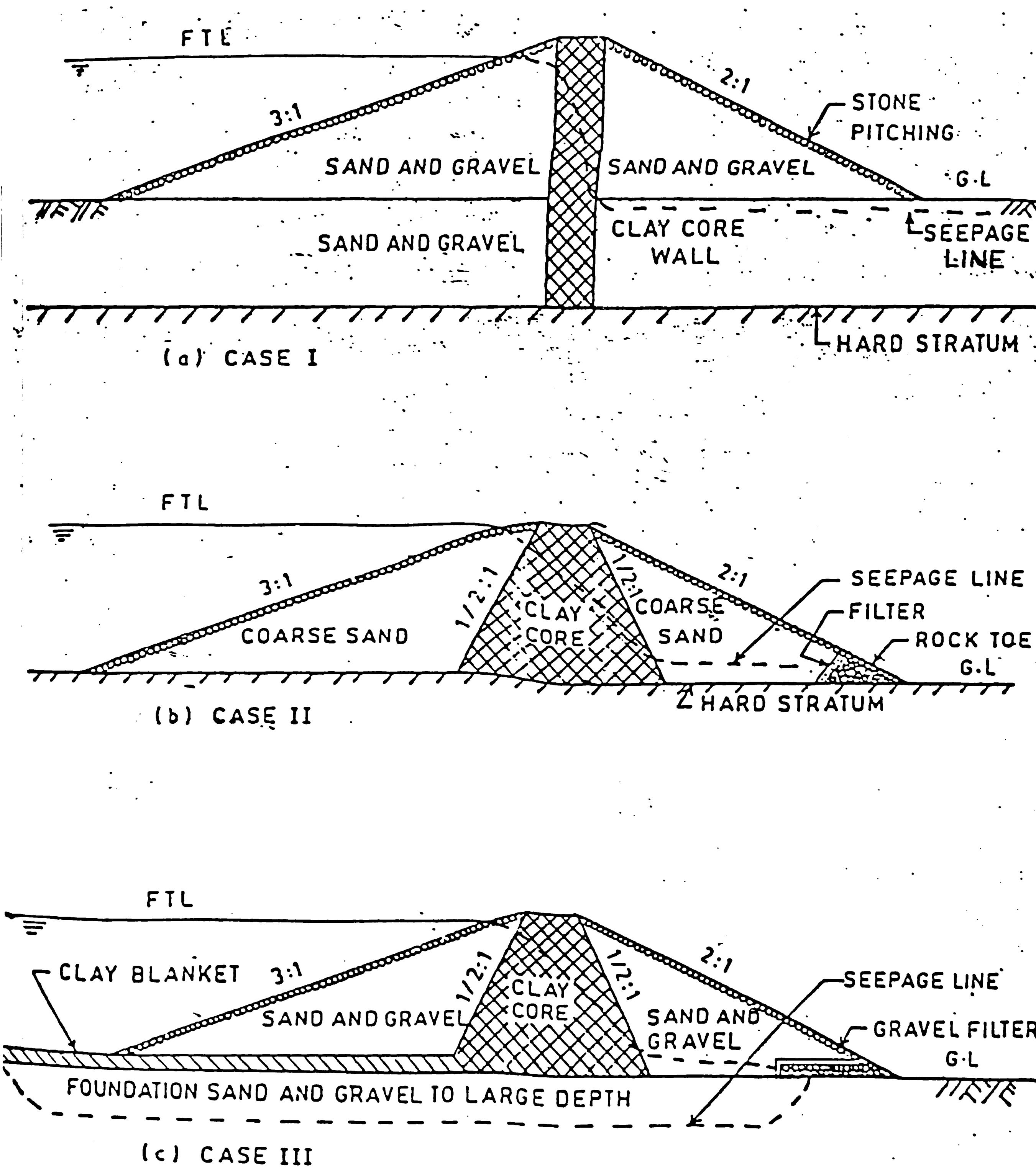


Fig. 4.9 Typical cross sections of earthen dams with different types of materials and on different types of foundations

Required total storage (Neglecting domestic and livestock use)

= Live storage + Dead storage

= (1.8+0.15)ha.m = 1.95ha.m or say, 2 ha.m.

For sandy soil, side slope of 3 : 1 and 2 : 1 may be provided to the bund in the upstream and downstream sides respectively. The height of the bund is to be designed to suit to the total required storage.

Design of waste weir

Calculation of runoff is to be done by any of the available formulae.

Suppose, Q = Peak rate of discharge = $2 m^3/sec$.

The crest length can be obtained from the weir formula,

$$Q = CLH^{3/2}$$

$$= 1.75L \times (0.3)^{3/2}$$

Where, H = depth of flow over the weir, m.

= 0.3 m (assumed)

or, $2 = 1.75L \times (0.3)^{3/2}$

or, L = 7 m.

Design of sluice

Discharge required for irrigating 10 ha with a duty of 930 $ha/m^3/sec$

= 10/930 = 0.01 m^3/sec.

Velocity through sluice, assuming a minimum driving head of 0.3 m,

$$V = C_d \sqrt{2gh}$$

$= \quad 0.67 \times \sqrt{(2 \times 9.81 \times 0.3)}$

$= 1.6$ m/sec.

Cross sectional area of sluice,

A $= Q/V = 0.01/1.6 = 0.00625\ m^2$ or say, $0.007\ m^2$

Diameter of pipe, $D = 2\sqrt{(A/\pi)} = 2\sqrt{(0.007/3.142)} = 0.09$ m or say, 0.1 m

So, the pipe diameter to be adopted = 0.1 m.

4.10.3 Design of check dam

First of all the value of the design peak runoff rate is to be calculated as,

Q = CIA/360 where

Q = Peak runoff rate, m^3/sec

C = Runoff coefficient

I = Rainfall intensity for the design frequency and for period of time of concentration, mm/hr

A = Catchment area, ha

The design procedure to handle a peak runoff of $2m^3$/sec is given below.

Discharge capacity of weir is given by

Q = $1.75\ LH^{3/2}$ where,

Q = Runoff, m^3/sec.

L = Length of crest, m.

H = Depth of flow over crest, m.

Supposing length of crest to be 5 m,

$$2 = 1.75 \times 5 \times H^{3/2}$$

or, $H = 0.38$ m.

Providing a free board, f = 0.2 m,

Height of wing wall above crest, d = H + f

= 0.58 m or say, 0.6 m.

Length of apron = 0.75 (h + d) + h

Where, h = height of fall

Suppose, proposed height of fall is 2 m.

So, Length of apron = 0.75 (2 + 0.6) + 2 m = 3.95 m or say, 4 m.

4.10.4 Design of Drop Structures

The drop structure is one of the most common gully control structure. Here the design of drop spillway is considered. It is a weir structure in which the flow passes through the weir opening to an apron or stilling basin located below the weir. Then the flow passes to a downstream channel at a non-erosive velocity. When the drop is limitted to about 3m, drop spillway is a suitable gully control structure.

Here the design procedure for a drop spillway is given to handle a discharge of 5 m^3/sec.

First of all, the discharge to be handled by the structure is to be worked out as follows.

Maximum flood discharge, Q = CIA/360 m^3/sec.

Where, C = Runoff coefficient

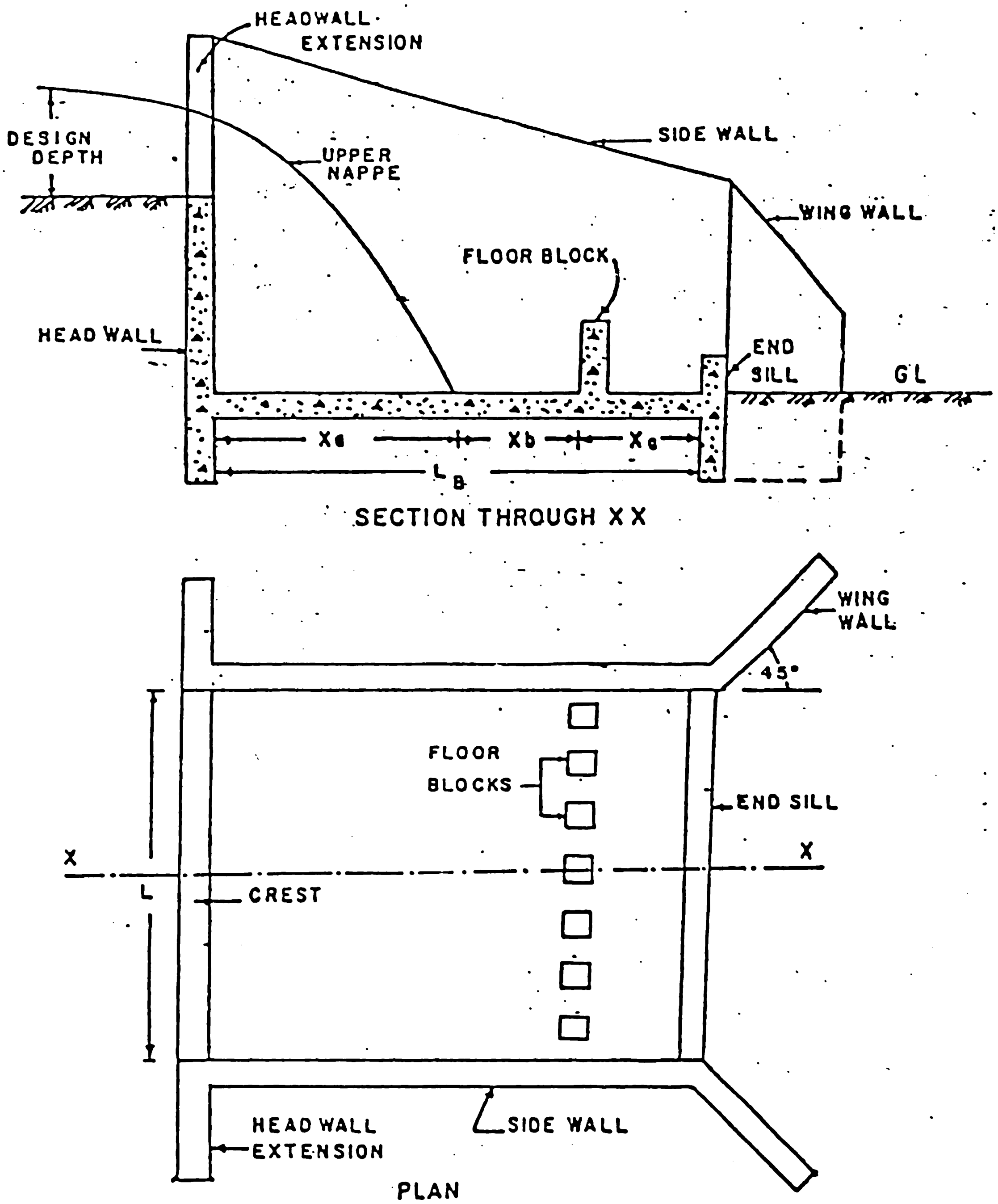


Fig. 4.10 Plan and sectional view of straight drop spillway

I = Rainfall intensity for the design frequency and for period of time of concentration, mm/hr.

A = Catchment area, ha

For our case, Q = 5 m^3/sec

Suppose, length of body wall, L = 6 m.

and height of body wall, h = 1.0 m.

Depth of flow over the crest, H $= (Q/1.75L)^{2/3}$

= 0.61 m.

Normal scour depth, d_n $= 0.473\ (Q/f)^{1/3}$

Where, Q = discharge, ft^3/sec

F = silt factor which is taken as 1.0 in view of steep bed slopes on upper as well as below the structure.

Substituting the values, d_n $= 0.473\ (176.44/1)^{1/3} = 2.65$ ft = 0.81 m.

Maximum scour depth, d_m $= 1.5\ d_n = 1.5 \times 0.81 = 1.22$ m.

Foundation depth, D $= 1.33\ d_m = 1.33 \times 1.22 = 1.62$ m.

Minimum top width, t $= 3H/2\rho$

Where, ρ = specific gravity of the material = 2.25 (assumed)

Therefor, $t = (3 \times 0.61)/(2 \times 2.25) = 0.41$ m.

Bottom width, T $= (h + H)/\rho = (1.0 + 0.61)/2.25 = 0.7$ m.

For further safety, add 0.3 m to the bottom width calculated by the formula. Hence provide a bottom width of 1.0 m.

Length of downstream solid apron (ft), $X = 6\sqrt{H}$

Where, $H = 2$ ft.

So, $X = 6\sqrt{2} = 8.5$ ft $= 2.6$ m.

Thickness of solid apron, $T_a = (h + H) / 5$

$= (1.0 + 0.61) / 5 = 0.322$ m.

or say, 0.35 m.

CHAPTER - V
SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSIONS

The present study entitled "DEVELOPMENT OF LAND AND WATER MANAGEMENT PLAN USING REMOTE SENSING TECHNIQUE - A CASE STUDY" was undertaken with the following objectives.

1. To delineate the watershed boundary.
2. To prepare the land use / land cover, hydrogeomorphology, soil resource, slope and drainage map of the watershed.
3. To study the land use pattern, groundwater prospect, morphometry, soil type and slope category of the watershed.
4. To develop a land and water management plan for the watershed.
5. To analyse the rainfall record of the watershed for desired probability levels and return periods.
6. To design the different proposed soil and water conservation structures.

The watershed boundary of Bagjore micro-watershed was delineated by using SOI topographical sheet and satellite imagery. The unique code assigned to it is 04-07-01-06-03-02-01-01 by ORSAC following the AIS & LUS guidelines. The present land use / land cover map of the watershed was prepared through visual interpretation techniques from IRS ID LISS false colour composites to study the land use pattern. The hydrogeomorphological map was prepared by demarcating the geomorphic units to study the groundwater prospect. The drainage map was prepared and morphometric parameters like bifurcation ratio, stream length, form factor, circularity ratio, elongation ratio, texture ratio, circularity index, drainage density and stream frequency etc. were computed to determine the shape of the watershed. Slope map for the watershed could not be prepared from SOI toposheet due to the fact that all the watershed area come under a single category i.e. nearly level. The soil map was prepared by studying pedons in ground condition followed by physico-chemical analysis of pedons in the laboratory in conjunction with analysis of the satellite imagery. At last the action plan for land and water resources development was generated by integrating the thematic maps. Then the different soil and water conservation structures proposed in the management plan were designed.

5.1 Conclusions

The following conclusions were drawn from the present study.

1. The IRS data is in many ways superior to the information derived from the toposheets.
2. Bagjore micro-watershed comprises rural settlements and under developed transport network.
3. The watershed is one potential micro-region for agricultural development. Agriculture alone occupies about 45.53 per cent of the total geographical area but all the lands are single cropped.
4. False colour composites are quite effective in determining the groundwater prospect and zones for groundwater exploration.
5. From morphometric analysis it is evident that the study area is nearly circular in shape and it is a highly dissected plain. The watershed has a high peak runoff for shorter duration due to its shape.
6. The bifurcation ratio for the watershed was found out to be 3.3433 which implies that the drainage pattern has not been distorted because of the structural disturbances suffered by the area.
7. The general texture of the study area ranges from loamy skeletal to fine loamy.

8. In total 10 different action items are recommended in a judicious manner for sustainable development.

9. Different soil and water conservation structures are proposed with sites for erosion control, groundwater recharge and water harvesting.

10. The analysis of rainfall record reveals that the monsoon is erratic and distribution of rainfall is uneven.

11. The micro-regions suitable for exploitation of groundwater through shallow dug wells, deep tube wells / bore wells are identified for which exact sites are to be confirmed by geophysical sounding.

12. The soil and water conservation structures proposed in the management plan are designed.

CHAPTER - VI
SUGGESTIONS FOR FUTURE WORK

SUGGESTIONS FOR FUTURE WORK

The following are the suggestions for future work, for the development of watershed project.

1. The watershed management plans for Bagjore micro-watershed has been developed by using remote sensing technique. This technique may be extended for developing the management plans for other watersheds of the district and the state.

2. Selection of species for forest, agricultural and horticultural plantation in the concerned micro-watershed may be selected as per people's requirement with due importance on the local varieties.

3. The sites for groundwater exploration may be confirmed by electrical resistivity survey.

4. The surface and groundwater potential of the watershed may be assessed using remote sensing technique for planning of cropping system of the watershed.

5. The cadestral maps and the thematic maps may be brought to the same scale for identifying the exact location of different recommended actions.

6. The benefit-cost analysis may be made for the integrated watershed management programme.

At last before implementation of the programme, the people's participation and views of the public is of utmost importance. They are to be explained in details about the recommendations and their views are to be incorporated for successful planning of the project and the programme is to be executed with their active participation.

BIBLIOGRAPHY

BIBLIOGRAPHY

Agarwal, A. K., D. Mishra. 1992. Evaluation of groundwater potential in the environs of Jhansi city, U. P. using hydrogeomorphological Assessment by satellite remote sensing technique. *Journal of the Indian Society of Remote Sensing-PhotonirvachaK.* 20 (2 and 3): 121-128.

Agarwal, C. S. and R. S. Sinha. 1983. Analysis of watershed gemorphology in Asan and song basins of Doon Valley (U. P.) with the aid of aerial photographs. *Proceedings of National Symposium of Remote Sensing in Development and Management of Water Resources, Ahmedabad.*

Agarwal, C. S. 1989. Geomorphological and Structural Analysis of Bundelkhand region using remote sensing technique. *Proceeding Vol. 1, Second National Symposium of Hydrology, J and K, Jan.* 4-5 : I 1-12.

Agarwal, C. S. 1998. Study of drainage pattern through aerial data in Naugarh area of Varanashi District, U. P. *Journal of the Indian Society of Remote Sensing-Photonirvachak.* 26 (4) : 169-175.

Agnihotri, Y., J. S. Sharma and S. P. Mittal. 1996. Boosting hill resource economy through watershed management in Hoshiarpur Shiwaliks. *Indian Journal of Soil Conservation.* 24 (3). 248-252.

Ahuja, R. L., M. L. Manchanda, B. S. Sangwan and R. P. Agarwal. 1992. Utilization of remote sensing data for soil resources mapping and its interpretation for land use planning of Bhiwani district, Haryana. *Journal of the Indian Society of Remote Sensing-Photonirvachak.* 20 (2 and 3) : 105-120.

Anonymous. 1995. *Technical Guidelines, Integrated mission for sustainable development.* National Remote Sensing Agency, Department of Space, Govt. of India.

Anonymous. 1988. *Watershed Atlas of India.* All India Soil and Land use survey. Department of Agriculture and Cooperation, Govt. of India.

Behera, S. C., S. Das, A. Kar, P. Narendra and S. Guha. 1997. Hydrogeomorphological mapping in Ground water exploration using remote sensing data. A case study in Keonjhar district, Orissa. *Journal of the Indian Society of Remote Sensing-Photonirvachak.* 25 (4) : 247-259.

Biswas, S, S. Sudhakar and V. R. Desai. 1999. Prioritisation of sub-watersheds based on morphometric Analysis of drainage basin - A Remote Sensing and GIS Approach. *Journal of the Indian Society of Remote Sensing-Photonirvachak.* 27 (3) : 155-166.

Bleeker, P. 1978. *The application of landsat imagery to soil degradation mapping of Sierra Leone at 1 : 10,00,000.* Food and Agricultural Organisation, Rome.

Chandel, R. S. and Asthana, D. 1990. Evaluation of remote sensing techniques for geological studies in eastern part of Doon valley. *Journal of the Indian Society of Remote Sensing-Photonirvachak.* 18 : (1and2) : 43-51.

Chaurasia, R., Minakshi and P. K. Sharma. 1999. Land use / land cover mapping and change detection using satellite data - A case study of Dehlon block, district Ludhiana, Punjab. *Journal of the Indian Society of Remote Sensing-Photonirvachak.* 27 (2) : 115-121.

Chhotaray, D. R. 2000. *Development of Watershed Plans using Remote Sensing Technique*. Unpublished M. Tech. Thesis, O. U. A. T., Bhubaneswar.

Dutt, C. B. S., P. P. Nageswara Rao, B. Manikiam, A. K. Gupta, G. Behera and K. Ganesh Raj. 1986. *Identification and mapping of wastelands at micro-level using remote sensing technique - An approach.* ISRO-NNRMS. Technical Report 58.

Dutta, M. and M. M. Jena. 1996. Groundwater study in the piedmont zone of mechi mahananda interfluve in Darjeling district, West Bengal using remote sensing techniques. *Journal of Indian Society of Remote Sensing-Photonirvachak.* 24 (1) : 43-52.

Govardhan, V. 1990. *Remote sensing and water management in command areas.* International book distributing co, Lucknow.

Gupta, K. S., M. Ahmed, M. Hussain, A. S. Pandey, P. Singh, K. M. Saini and S. N. Das. 1998. Inventory of degraded lands of Palamau district, Bihar - A Remote Sensing Approach. *Journal of the Indian Society of Remote Sensing-Photonirvachak.* 26 (4) : 161-168.

Hamza, A., A. Mani and F. Sadowaki. 1981. *Land use mapping from landsat imagery applied to Central Tunisia.* Proceedings of International Seminar on Remote Sensing of Arid and Semi Arid lands, Cairo. Egypt.

Jaiswal, R. K., R. Saxena and S. Mukherjee. 1999. Application of remote sensing technology for land use / land cover change analysis. *Journal of the Indian Society of Remote Sensing-Photonirvachak.* 27 (2) : 123-128

Kalyanaraman, S. 1999. Remote sensing data from IRS satellites – past, present and the future. *Journal of the Indian Society of remote Sensing-Photonirvachak.* 27 (2) : 59-69.

Katyal, J. C., R. P. Singh, S. Sharma, S. K. Das, M. V. Padmanabhan and P. K. Mishra, 1995. *Field Manual on Watershed Management.* Vol.-I. CRIDA, Hyderabad.

Karale, R. L. and A. K. Sinha. 1990. *Remote sensing with IRS-IA data for mapping of soil and land degradation.* National Seminar on Conservation of Land and Water Resources for Food and Environmental Security.

Kaur, R., S. K. Bandra, M. Bharanarayana and B. C. Panda. 1998. A numerical technique for delineation of soil mapping units using multi-spectral remote sensing data. *Journal of the Indian Society of Remote Sensing-Photonirvachak.* 26 (4) : 14-160.

Khatik, G. L., R. S. Kurothe and H. B. Singh. 1997. Impact of operational Research project on agricultural production through integrated watershed management. *Indian Journal of Soil Conservation.* 25 (2) : 157-161.

Kumar, A. and S. Tomar. 1998. Groundwater assessment through hydrogeomorphomorphological and geophysical survey – a case study in Godavari subwatershed, Giridih, Bihar. *Journal of the Indian Society of Remote Sensing-Photonirvachak.* 226 (4) : 176-183.

Maitra, S. 1999. Land forms and geomorphological classification of part of the upper Baitarani river basin. *Journal of the Indian Society of Remote Sensing-Photonirvachak.* 27 (3) : 175-184.

Mal, B. C. 1999. *Introduction to Soil and Water Conservation Engineering.* Kalyani Publishers, New Delhi.

Minakshi, R. Chaurasia and P. K. Sharma. 1999. Land use / land cover mapping and change detection using satellite data – a case study of Dehlon block, district Ludhiana, Punjab. *Journal of the Indian Society of Remote Sensing-Photonirvachak.* 7 (2) : 115-121.

Mishra, N., T. Satyanarayana and R. K. Mukherjee. 1984. Effect of topo-elements on the sediment production rate from sub-watersheds in upper Damodar valley. *Journal of Agricultural Engineering ISAE.* 21 (3) : 65-70.

Murty, V. V. N. 1998. *Land and Water Management Engineering.* Kalyani Publishers, New Delhi.

Murthy, K. S. R. and V. Venkatswara Rao. 1999. Mapping of hydrogeomorphological features in Varha river basin using remote sensing data. *Journal of the Indian Society of Remote Sensing-Photonirvachak.* 27 (2) : 71-79.

Nagaraja, R., N. C. Gautam and G. Chennaiah. 1986. Role of remote sensing for monitoring land use changes for planning and environmental conservation - A case study of Belgaum, Karnataka. *Journal of the Indian Society of Remote Sensing-Photonirvachak.* 14 (3) : 41-50.

Nautiyal, M. D. 1994. Morphometric analysis of a drainage basin using aerial photographs : A case study of Khairkuli Basin, District Dehradun, U. P. *Journal of the Indian Society of Remote Sensing-Photonirvachak.* Vol. 22 No. 4, PP. 251-261.

Nyonand, A. K. Sharma, J. Singh, K. S. Yadav and P. Singh. 1997. Rehabilitation of degraded ecosystems through watershed management - A success story. *Indian Journal of Soil Conservation.* 25 (2) : 162-166.

Palaniyandi, M. and V. Nagarathinam. 1997. Land use / land cover mapping and change detection using space borne data. *Journal of the Indian Society of Remote Sensing-Photonirvachak.* 25 (1) : 27-33.

Pande, V. C., R. S. Kurothe, H. B. Singh and T. N. Nambia. 1998. Farm resource development. A case study of watershed management in semi-arid tropics of Gujarat. *Indian Journal of Soil Conservation.* 26 (1) : 52-56.

Panigrahi, B., A. K. Nayak and S. D. Sharma. 1995. Application of remote sensing technology for groundwater potential evaluation. *Water resources management.* 9 : 161-173.

Panigrahi, S., R. P. Singh, A. S. Sharma and M. Chakraborty. 1995. Results on potential use of simulated IRS-IC wifs data for crop monitoring. *Journal of the Indian Society of Remote Sensing-Photonirvachak.* 23 (4) : 175-183.

Phadnawis. A. N., J. M. Birajdar, M. L. Nangre, Md. Asmatoddin, 1993. Resource management in rainfed watershed - Podalsingi, Maharashtra. *Indian Journal of Soil Conservation.* Vol 21 No.1 45-40

Prasad, S. N., Ratan Singh, Chandra Prakash, D. H. Rao, H. Gadekar, V. S. Katiyar, Arjun Pasan and R. Raghupathy. 1997. Impact of watershed management on runoff, water resource development and productivity of arable lands in South Eastern Rajasthan. *Indian Journal of Soil Conservation.* 25 (1) : 68-72.

Profali, R. M. and S. R. Singh. 1983. *Photogeomorphic analysis for evaluation and management of the Narmada basin.* Proceedings of National Symposium on Remote Sensing in Development and Management of Water Resources, Ahmedabad.

Rajora, R. 1998. *Integrated watershed management, A field manual for equitable, productive and sustainable development.* Rawat Publication, New Delhi, 190-201.

Rao, D. P. 1999. *Remote sensing for earth resources.* Association of exploration geophysicists, Hyderabad.

Ravindran, K. V., A. Jeyram. 1997. Groundwater prospects of Shahbad tehsil, Baran district, Eastern Rajasthan - A Remote Sensing Approach. *Journal of the Indian Society of Remote Sensing-Photonirvachak.* 25 (4) : 239-246.

Roy, A. Mead, Terry, L. Sharik, Stephen, P. Prisley and Joel. T. Heinen. 1981. A computerized spatial analysis system for wild life habitat from vegetation maps. *Canadian Journal of Remote Sensing.* 7 (1) : 34-40.

Sahai, Baldev. 1983. *Land use, forestry and hydrogeomorphology of Panchmahals districts Gujarat.* Proceedings of NNRMS, Seminar, Hyderabad.

Sahai, Baldev. 1985. *Land use and land degradation surveys.* Proceedings of the Symposium on Remote Sensing in Agriculture, Ahmedabad.

Sen, T. K., L. M. Pande, J. L. Sehgal, A. K. Maji, G. S. Chamuah. 1992. Satellite Remote Sensing in Soil Resource Inventory of Dibrugarh district. *Journal of the Indian Society of Remote Sensing-Photonirvachak.* 20 (2 and 3) : 95-104.

Sharma, H. S. 1981. *Perspectives in Geomorphology.* Vol. – II & IV. Concept Publishing Company, New Delhi.

Sharma, K. P., S. C. Jain and P. K. Garg. 1984. Monitoring land use and land cover changes using landsat images. *Journal of the Indian Society of Remote Sensing-Photonirvachak.* 12 (2) : 65-70.

Shih, S. F. 1988. Satellite data and geographic information system for land use classification. *Journal of Irrigation and Drainage Engineering, ASCE.* 114 (3) : 505-520.

Singh, R. P. 1984. *Remote sensing application to stream morphology and hydrology for management of Kaliaghai river basin, district Midnapore, West Bengal.* Unpublished M. Tech. Thesis, I. I. T. Kharagpur.

Singh, S. V. 1999. Watershed management - A holistic Approach to improve socio-economic status of the farmers. *Indian Journal of Soil Conservation.* 27 (3) : 243-245.

Sinha, B. K., A. Kumar, D. Srivastava and S. Srivastava. 1990. Integrated approach for demarcating the fracture zone for well site location. A case study near Gumla and Lohardaga, Bihar. *Journal of the Indian Society of Remote Sensing-Photonirvachak.* 18 (3) : 1-8.

Subudhi, A. P., N. D. Sharma and D. Mishra. 1989. Use of landsat thematic mapper for urban land use / land cover mapping. *Journal of Indian Society of Remote Sensing-Photonirvachak.* 17 (3) : 85-99.

Suresh, R. 1997. *Soil and water conservation Engineering.* Standard Publishers Distributors, Delhi.

Tiwari, A., B. Rai. 1996. Hydrogeomorphological mapping for groundwater prospecting using landsat - MSS images. A case study of part of Dhanbad district, Bihar. *Journal of the Indian Society of Remote Sensing-Photonirvachak.* 24 94) : 281-285.

Verma, V. K., A. Sood, P. K. Sharma, C. Singh and M. L. Manchanda. 1996. Resource constraint mapping and management in arid tract of Punjab. *Journal of the Indian Society of Remote Sensing-Photonirvachak.* 24 (1) : 11-23.

APPENDICES

APPENDIX - I

Rainfall Data of Deogaon Block, Bolangir (from 1970 to 1999)

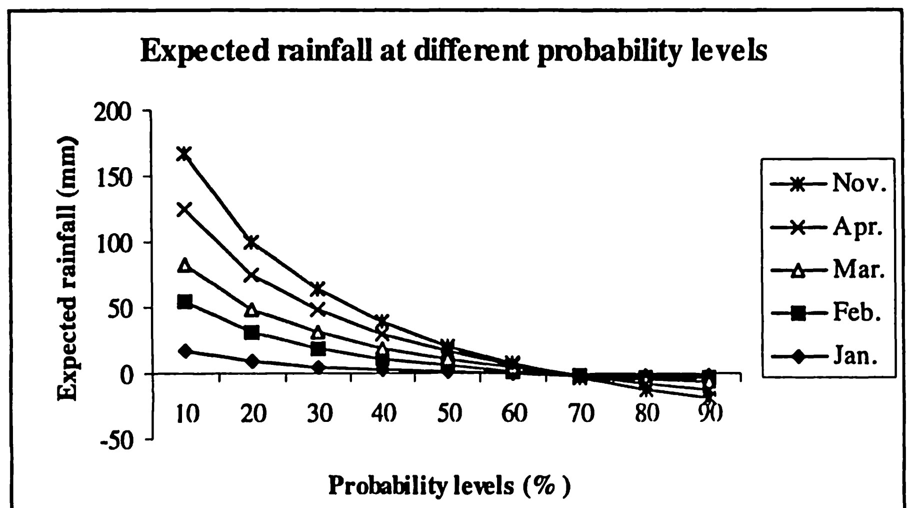
Year	Month												Annual	Monsoon
	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.		
1970	6.00	0.00	41.00	20.00	23.00	232.00	339.00	0.00	106.00	0.00	0.00	0.00	767.00	677.00
1971	0.00	0.00	0.00	0.00	38.00	296.00	52.00	0.00	0.00	0.00	0.00	0.00	386.00	348.00
1972	0.00	12.00	8.00	0.00	0.00	35.00	245.00	151.00	87.00	25.00	0.00	0.00	563.00	518.00
1973	0.00	0.00	9.00	10.00	12.72	123.69	429.19	167.48	106.93	98.49	0.00	0.00	957.50	827.29
1974	0.00	6.48	0.00	0.00	23.80	20.50	224.15	270.40	65.50	24.50	0.00	0.00	635.33	580.55
1975	0.00	87.00	0.00	0.00	7.10	84.25	684.31	522.24	133.20	54.68	0.00	0.00	1572.78	1424.00
1976	0.00	12.70	0.00	0.00	16.80	120.92	332.32	510.06	237.58	10.22	0.00	0.00	1240.60	1200.88
1977	0.00	0.00	0.00	15.45	16.78	193.80	195.45	385.10	148.40	8.50	62.00	0.00	1025.48	922.75
1978	4.50	19.00	20.50	0.00	0.00	159.50	361.00	551.50	101.50	5.50	12.00	0.00	1235.00	1173.50
1979	15.00	22.50	0.00	0.00	13.00	189.50	285.00	244.00	116.00	39.00	0.00	0.00	924.00	834.50
1980	0.00	0.00	5.00	5.00	0.00	250.70	365.60	216.00	318.60	40.00	0.00	0.00	1200.90	1150.90
1981	0.00	0.00	0.00	0.00	0.00	84.80	284.00	529.50	363.80	2.80	0.00	0.00	1264.90	1262.10
1982	0.50	40.20	41.50	57.30	12.80	174.10	304.50	582.30	3.50	0.00	0.00	0.00	1216.70	1064.40
1983	0.00	47.40	3.50	59.50	24.00	149.10	248.40	417.00	163.20	73.30	0.00	0.00	1185.40	977.70
1984	0.00	12.00	0.00	22.00	11.00	281.20	499.60	319.80	113.80	6.00	0.00	0.00	1265.40	1214.40
1985	5.00	0.00	0.00	0.00	7.60	105.80	304.80	596.80	677.40	63.60	0.00	0.00	1761.00	1684.80
1986	47.00	49.00	6.20	73.40	38.40	335.00	250.60	197.80	114.00	2.00	13.00	0.00	1126.40	897.40
1987	11.00	0.00	11.00	0.00	38.00	24.60	374.10	171.90	268.50	26.80	65.50	0.00	991.40	839.10
1988	0.00	0.00	0.00	5.00	0.00	202.50	287.00	192.20	151.00	102.00	0.00	0.00	939.70	832.70
1989	0.00	0.00	0.00	0.00	0.00	338.90	331.80	340.50	288.50	12.80	0.00	0.00	1312.50	1299.70
1990	0.00	0.00	38.00	60.00	91.00	256.00	442.10	293.30	340.50	348.00	94.40	0.00	1963.30	1331.90
1991	0.00	0.00	55.00	0.00	7.00	140.60	332.60	616.00	146.20	35.40	36.00	9.00	1377.80	1235.40
1992	0.00	0.00	0.00	25.00	18.00	289.00	613.20	570.90	132.10	10.00	0.00	0.00	1658.20	1605.20
1993	0.00	0.00	0.00	20.00	47.00	208.00	355.00	591.00	151.00	35.00	0.00	0.00	1407.00	1305.00
1994	0.00	31.00	0.00	0.00	0.00	426.00	534.80	588.00	267.70	16.00	0.00	0.00	1863.50	1816.50
1995	37.20	6.50	6.30	2.00	152.80	273.40	573.80	236.40	110.40	3.60	39.20	0.00	1441.60	1194.00
1996	4.80	0.00	34.00	6.00	0.00	96.20	243.60	259.40	59.40	12.20	0.00	0.00	715.60	658.60
1997	18.60	0.00	24.80	35.60	7.00	176.80	186.40	567.40	257.00	11.60	0.00	0.00	1285.20	1187.60
1998	17.00	24.20	8.80	0.00	0.00	137.80	317.20	128.60	73.40	57.10	52.00	0.00	816.10	657.00
1999	0.00	0.00	0.00	0.00	49.00	166.60	283.00	307.60	158.60	12.50	0.00	0.00	977.30	915.80
Total	**166.60**	**369.98**	**312.60**	**416.25**	**654.80**	**5572.26**	**10279.52**	**10524.18**	**5260.71**	**1136.59**	**374.10**	**9.00**	**35076.59**	**31636.67**
Mean	**5.55**	**12.33**	**10.42**	**13.88**	**21.83**	**185.74**	**342.65**	**350.81**	**175.36**	**37.89**	**12.47**	**0.30**	**1169.22**	**1054.56**

APPENDIX - II

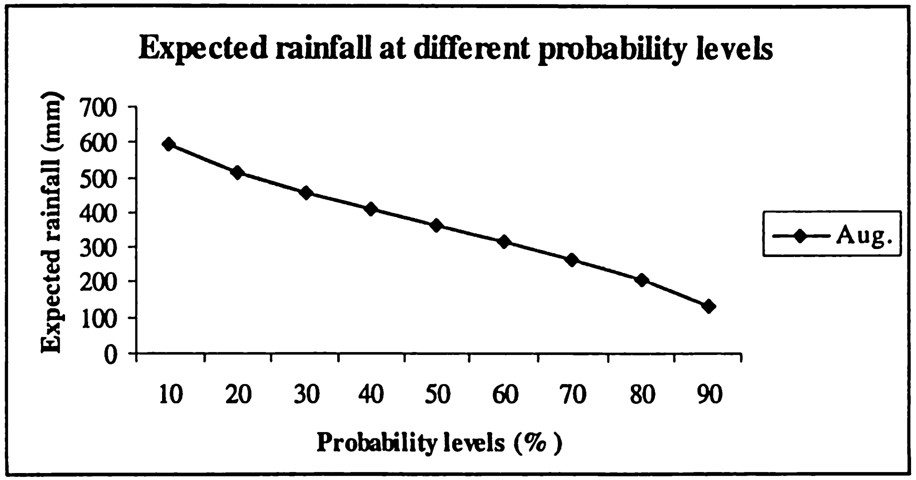
Monthly Average Temperature (^{0}C) of Last 15 Years (from 1981 to 1997)

Months	Average maximum	Average minimum	Monthly average
January	28.07	18.12	23.09
February	32.24	20.90	26.57
March	35.55	26.23	30.89
April	40.71	30.23	35.47
May	43.16	30.63	36.89
June	37.61	30.07	33.84
July	34.77	24.37	29.57
August	33.27	27.02	30.14
September	34.19	27.16	30.67
October	33.81	25.67	29.74
November	30.95	17.12	24.03
December	28.45	16.68	22.56

APPENDIX - III

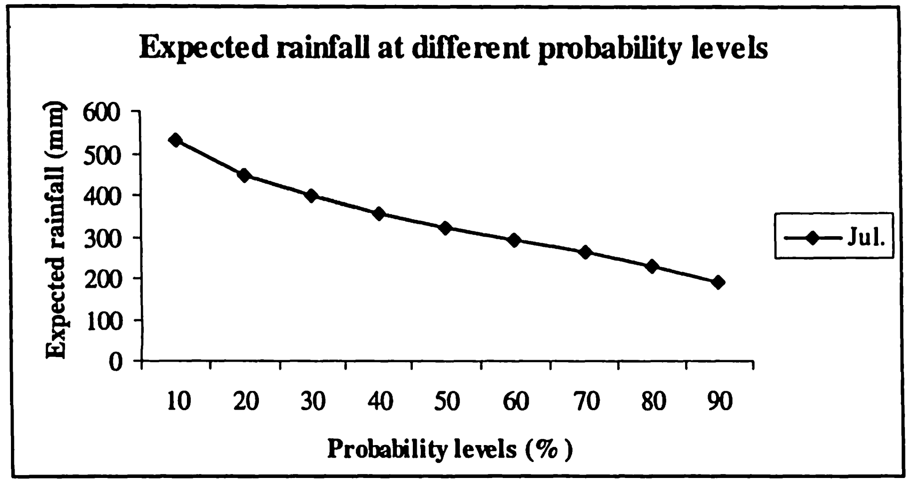


APPENDIX - IV

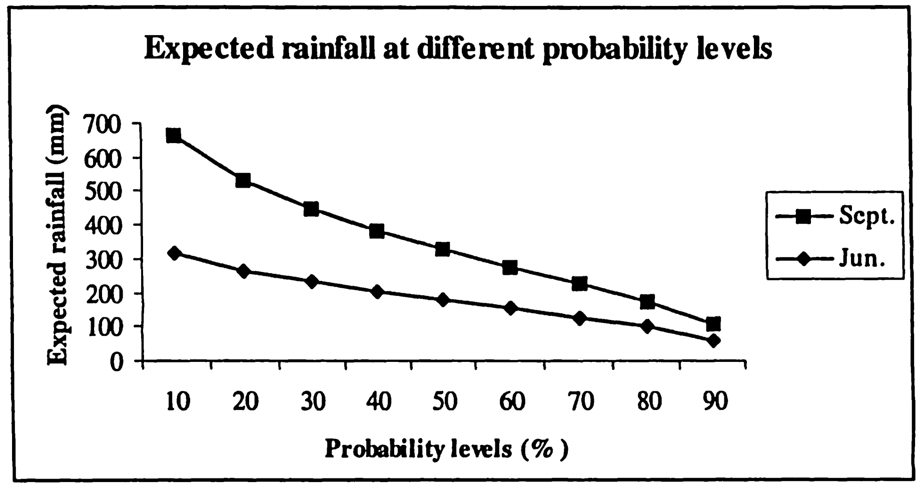


Expected rainfall at different probability levels
Expected rainfall (mm)
700
600
500
400
300
200
100
0
10
20
30
40
50
60
70
80
90
Probability levels (%)
Aug.

APPENDIX - V

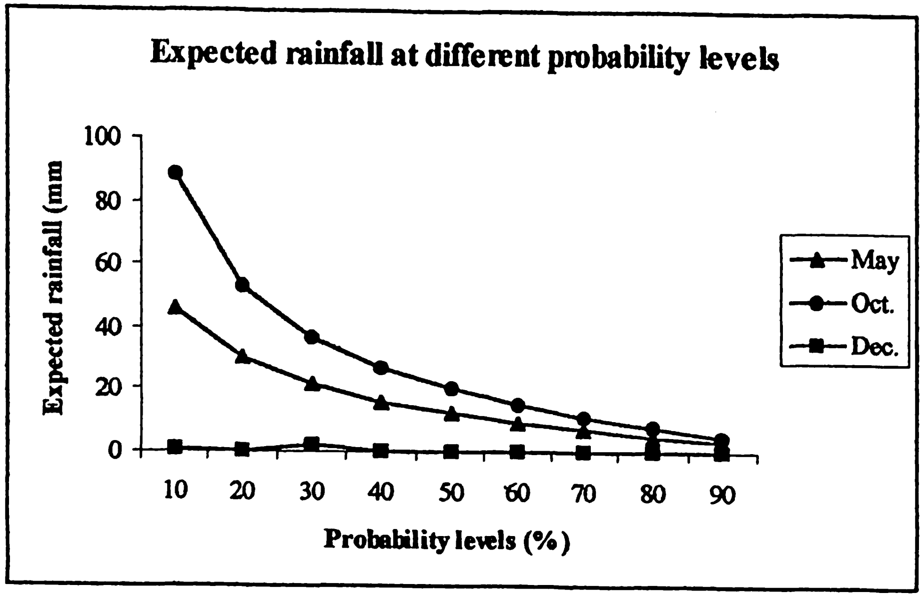

Expected rainfall at different probability levels
Expected rainfall (mm)
600
500
400
300
200
100
0
10
20
30
40
50
60
70
80
90
Probability levels (%)
Jul.

APPENDIX - VI



Expected rainfall at different probability levels

APPENDIX - VII



APPENDIX - VIII