INVESTIGATION OF GROUND WATER USING REMOTE SENSING AND GIS IN A WATERSHED - A CASE STUDY

By

Ganesh Chandra Padhi

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IN

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Dedicated to my friend

"SUDEEPTA"

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CERTIFICATE

This is to certify that the thesis entitled "INVESTIGATION OF GROUNDWATER USING REMOTE SENSING AND GIS IN A WATERSHED - A CASE STUDY" submitted in partial fulfillment of the 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 SRI GANESH CHANDRA PADHI 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 the investigation have been duly acknowledged by him.

Bhubanewsar

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Ganesh Ch. Padhi

(GANESH CHANDRA PADHI)

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LIST OF ABBREVIATIONS AND SYMBOLS

AAT	–	Arc Attribute Table
bgl	–	Below ground level
BPM	–	Buried pediment (moderate)
BPS	–	Buried sediment (shallow)
CAD	–	Computer Aided Design
CCT	–	Computer Compatible Tape
DBMS	–	Data Base Management System
DEM	–	Digital Elevation Model
DTM	–	Digital Terrain Model
DXF	–	Data Interchangeable File
EC	–	Electrical Conductivity
ERLAS	–	Earth Resources Laboratory Application Software
FCC	–	False Colour Composite
GEC	–	Ground Water Estimation Committee
GIS	–	Geographical Information System
GPS	–	Global Positioning System
GT	–	Ground Truth
ha	–	Hectare
HGM	–	Hydrogeomorphological
IRS	–	Indian Remote Sensing
ISRO	–	Indian Space Research Organisation
J.	–	Journal
LISS	–	Linear Image Self Scanner
lpm	–	Litre Per Minute
lps	–	Litre Per Second
LU/CC	–	Land use / Land cover
m	–	Meter
MSS	–	Multi Spectral Scanner
NASA	–	National Aeronautics and Space Administration
NNRMS	–	National Natural Resources Management System
ORSAC	–	Orissa Remote Sensing Application Centre
P	–	Pediment
PAN	–	Panchromatic
PAT	–	Polygon Attribute Table
RH	–	Residual Hill
RS	–	Remote Sensing
SAR	–	Sodium Absorption
SOI	–	Survey of India
Sq. Km	–	Square Kilometer
TDS	–	Total Dissolve Salt
TIFF	–	Tagged Image File Format
TM	–	Thematic Mapper
VES	–	Vertical Electrical Sounding
VF	–	Valley Fill
%	–	Percentage

CHAPTER I

INTRODUCTION

INTRODUCTION

1.1 GROUND WATER

Water, a dynamic and replenishable resource, is the most precious and versatile of the all the natural resources. For ages it has been the main source of inspiration for the human civilization. It's vital for the very existence of mankind and all other living beings and thus occupies an unique position in the resources endowment map of any country. Water plays an important role in moulding and promoting the economic development and advancement of a nation in the key sectors of agriculture, industry, energy and public health. Specially the contribution of water resources in the field of agriculture is of great relevance and importance in the context of agrarian economy of the country. Of late there has been a growing demand for water resources for the agricultural sector due to the accepted concept of irrigated agriculture to ensure higher productivity. The availability of limited surface water resources on one hand and the bottle neck condition for the development of agriculture being created due to inadequate irrigation facility on the other hand, has brought about a critical situation for seeking alternative sources like the ground water, which can not only supplement but also at timely supplement the surface water resources for achieving the desired results.

1.1.1 Ground water potential and utilisation.

The earth's total water resources are estimated at 1.37 x 10^8 Mha-m. Out of these global water resources, 97.2% is salt water and only 2.8% fresh water is available in this planet. Out of this2.8%, about 2.2%, is found on the surface and 0.6% lies under ground. Only 0.3% or about 41.1 x 10^4 Mha-m of fresh ground water can be economically extracted. The remaining quantities of ground water is available at a depth of above 800m. (Michel A.M. and S. D. Khepar, 1989).

Ground water is the largest source of fresh water on this planet excluding the polar ice-caps and glaciers. The amount of groundwater within 800m from the ground surface is over 30 times the amount of all fresh water in lakes and reservoirs and about 3000 times the amount in stream channels at anytime (Raghunath, 1987). The process of rapid urbanisation, industrialisation and above all higher crop production demand exploration of ground water urgently.

1.1.2. Advantages of Ground water over surface water irrigation

Ground water is the best option for drinking, domestic, industrial and irrigational use. Better land and water management can be achieved by using ground water through tube well irrigation.

It has many advantages over the surface or canal irrigation system (Garg, S.K., 1991).

Tube well can irrigate isolated land at the time of need as it is under direct control of the owner.

Unit cost of tube well is lower and hence affordable for the farmer.

Since the farmer has to pay for each unit of pumped water, irrigation efficiency will be very high.

Pumping ground water reduces the hazards of water logging and in turn salinity / alkalinity problem.

Since tube well is under command of the farmer, he can grow more than one or two crops in a year and can utilise drip or sprinkler irrigation system without much problem of chocking and clogging.

1.1.3. Ground Water Occurrence

The lithosphere (earth's sub-surface) can be divided into two general zones. The zone of rock fracture, where rocks are under stresses less than those required to close voids by internal deformation and the zone of rock flowage, which is below the zone of rock fracture and where all rocks are under stresses exceeding their elastic limits. There is an intermediate zone where strong rocks are fractured. In the zone of rock fracture sub-surface water exists and in the zone of saturation all communicating voids are filled with water under hydrostatic pressure. Water in the zone of saturation is called as the ground water or phreatic water.

1.1.4 Ground water recharge

The quantum of ground water available in a basin is dependent on the inflows and discharge at various points. The recharge of the basin depends on precipitation, infiltration from lakes, stream, canals etc., ground water availability in the basin of aquifer vicinity and artificial recharge if any. The discharge of the basin depends on pumping, surface outflows, seepage into lakes and rivers and evaporation. The surface contributes a lot to the ground water and the contribution is influenced by the topography of the area, the depth of soil and its permeability.

In an average India receives 400 Mha-m of annual rainfall. About 215 Mha-m of rainfall infiltrate into the soil. A major part of it, about 16.5 Mha-m is retained as soil moisture (sub-surface water). About 20% of the annual rainfall is responsible for recharging the ground water (Adyalkar and Rao, 1982).

1.2 REMOTE SENSING

Remote sensing is the art of science of collecting and interpreting information about an abject, area or phenomenon through analysis of data acquired by a device that is not in direct contact with the object, area or phenomenon under investigation. It is a multidisciplinary activity useful for providing information for inventory, monitoring and assessment of natural resources. Space based remote sensing supplies data and services for resources monitoring and management. It has the advantages of synopticity, frequent coverage of any area, regular data collection and less expensive as compared to other methods.

1.2.1 Basic Principle of Remote Sensing

In Remote sensing, the reflected, scattered or radiated electromagnetic energy from the earth surface is observed in different wave length bands (ultra violet to the far infra-red micro-wave regions) of the electro magnetic spectrum. The incident energy is provided by sun or by an active transmitter. The objects on the surface of earth have characteristics response to the incident electromagnetic energy and it has a unique radiation or emission characteristics in the E.M. spectrum depending upon the nature of the object. This is known as spectral characteristics lead to the identification of the objects on the earth. Apart from the spectral characteristics, remote sensing also utilizes spatial characteristics of objects i.e. size and shape of objects in relation to the surrounding. Modern remote sensing involves the acquisition of such data through sensors placed on satellites. The data is recorded either on photography films or magnetic tapes. The image that is obtained from satellite is then processed to obtain false colour composite (FCC) or hand copy or imagery. From this imagery various information about the natural resources are obtained.

1.2.2 Advantages of Remote Sensing

- It provides the unique possibilities for systematic, accurate and timely acquisition of information.
- It has the ability to obtain synoptic and frequent repetitive coverage of large and even inaccessible areas.
- It acts as a powerful common input media representing faithful, unbiased reproduction of natural features in the form of photographs/ imageries and there by economises the process of multi-disciplinary approach for planning of natural resources for integrated development.

1.2.3. Indian Remote Sensing Satellite Programme

Indian Space Research Organisation (ISRO) has the goal to use the space technology for the national development. Under Indian Remote Sensing Satellite Programme, so far ISRO has put in orbit seven satellites so far launched, six satellites (IRS-1A, 1B 1C, 1D, P2, P3) carried multi-spectral cameras and two (IRS-1C/1D) carried PAN - Chromatic camera and they are meant mainly for land, agriculture, water resources and cartographic applications, IRS-P4 which was launched during May 1999, is meant for oceanographic applications, though this can also be used for limited land applications.

The future of space based remote sensing in India can be categorised as under.

- Land, agriculture and water resources applications.
- Cartographic applications.
- Oceanographic application.
- Climatic / atmospheric application.

1.2.4. Remote Sensing for Ground water exploration

Remotely sensed data provide useful information about the forms and processes of earth. The occurrence and movement of ground water in an area is governed by several factors such as topography, lithology, geological structure, depth of weathering, extent of fractures, slope, drainage pattern, land use and land cover, climatic conditions and inter-relationship between these factors for delineation of ground water prospect zones, it is therefore, necessary to integrate the data on these terrain characteristics. This can be best achieved through the Remote Sensing and Geographical Information system (GIS) techniques.

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The advantages of remote sensing data for ground water investigation are as follows:

- This provides a reliable, near real time base line information.
- Topographic and thematic map preparation instead of ground survey.
- Characteristics of the object or land features (rock type, vegetation condition, land use 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 (orthophoto) generation for topographic, morph metric and geohydrologic data generation as a map alternative.
- Capable of operating in portions of electro-magnetic spectrum, which are beyond the photographic emulsion sensitivity.
- Relatively fast and economical for gross estimates as compared to any other method of surveying.
- Amenable to computer processing and compatibility to GIS packages makes the data easy to handle.

1.3. NEED OF THE STUDY

In a country like India, where the surface water sources are not adequate and where there are vast areas completely dependent on the mercy of monsoon even for drinking water, the role of ground water assumes great significance.

In Orissa, the irrigation potential created by the flow irrigation system is limited to12.10 lakh hectares, which represents only 12.4 per cent of the total cultivable area against 30 per cent in all India basis. It has been determined that it all the existing river system in the state are harnessed through reservoir or diversion weir project the maximum area that can be irrigated is 48.21 lakh hectares. Out of the total ground water potential of 2.54 Mha-m in the state only 5.34% has been utilised through public tube wells, shallow filter points and dug wells creating irrigation for 1.723 lakh ha in kharif and 1.034 lakh ha in rabi seasons.

The main area where ground water development can be taken up in the state of Orissa are the followings :

a) Rainfed erosional plain, which consists of an area of 82.4 thousand sq.km. The area has exploitable estimated storage of 1.91 Mha-m of ground water. It has the potential to provide irrigation for one million ha in kharif and 0.5 million ha in rabi season (Anonymous, 1977).

b) Rainfed alluvial tract which has scope for intensive water development over an area of 14,000 sq. km. The estimated storage and annually restorable quantum of ground water available for this tract have been assessed to be 4.2 and 0.915 Mha-m respectively (Anonymous, 1977).

A huge quantity of these available ground water remains unutilised which necessitates study regarding ground water exploration and potential in different areas. Considering the above facts the Kichna Nala Watershed under Bamara block in Sambalpur district was considered for the study.

1.4 OBJECTIVES OF THE STUDY

The main objective of the study is to demarcate and delineate all the possible features from satellite imageries and integrate those data with the thematic details analysed from toposheets to prepare a ground-water potential map of the study area (Kichna Nala watershed under Bamara block in Sambalpur district). The specific objectives of the study are:

1. To visually analyse the Indian Remote Sensing data available in imagery form to demarcate the details of geology, hydrogeomorphology, land use / land cover, drainage and lineaments.

2. To integrate all the above maps to develop ground water potential map of the study area, and

3. To assess the ground water quality of the study area both for irrigation and domestic use by analyzing some samples collected from existing wells of the study area.

CHAPTER II

REVIEW OF LITERATURE

REVIEW OF LITERATURE

INTRODUCTION

The socio-economic development of any country depends mainly on its natural resources, particularly earth resources. 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 realized 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 lunch 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-1A was successfully lunched on March17, 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 lunched so far by ISRO, six satellites (IRS-1A, 1B, 1C, 1D, P2, P3) carried multi-spectral cameras and two (IRS-1C and 1D) carried PAN-chromatic camera and they were meant for land, agriculture, water resources and cartographic applications IRS-P4. which was lunched during May 1999, is meant for oceanographic applications, though this can also be used for limited 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 exploration of ground water and its management.

2.1 REMOTE SENSING AND GIS, APPLICATION FOR HYDRO-GEOMORPHOLOGICAL MAPPING

Present day the river Yamuna is flowing east of Mathura. But the Hindu mythology places Yamuna in the vicinity of Govardhan and to the west of Mathura during the period of Lord Krishna. Saif-ud-din and Iqbal-ud-din (1999) carried out digital image processing using statistical analysis on IRS-IB, LISS-II data corresponding to the path to reconstruct the migratory history of Yamuna from Nandgaon to present day Mathura. The Yamuna river has progressively migrated from west to east during the period. Four channel courses of Yamuna were recognized between Mathura and Nandgaon, but which of these was the course of Yamuna that existed in the days of Mahabharata is still an enigma.

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

Visual interpretation of satellite images could help in the identification of present and past land forms. Mahammed Aslam and Balasubramanian (2001) visually interpreted IRS-IC LISS-III FCC to identify the palaeochannels of the Cauvery river in Karnataka State. In order to assess their inter-relationship with other hydrogeomorphic elements, various geomorphic units have been mapped. Major geomorphic units like alluvial plain, pediplain, valley fill, residual hill, ridges, meander scar, channel bars and water bodies have been demarcated. Considering the hydrogeomorphic set up of the palaeochannels, it is inferred from the study that the disposition of palaeochannels of the area are controlled by the geology, and structure and the prevailing geomorphic process.

Mohanty (2001) used IRS-ID LISS-III FCC of 2nd February 1998 and 28th November, 1998 in 1: 50,000 scale to generate thematic maps like land use / land cover map, hydrogeomorphology map, soil resource map and drainage map of the Bagjore micro-watershed, Bolangir district, Orissa. He integrated all these information to develop a land and water management plan for the area.

Gawande *et al.* (2002) carried out a detailed study of geology, geomorphology, hydrogeology and land use / land cover for the Kamthi and adjoining areas of Nagpur district (Maharastra) by visual interpretation of remote sensing data of IRS LISS-III, FCC of bands 2,3 and 4. The interpreted data was supplemented as well as cross-checked by field visits to add minor details of litho-units, nature of lithological contacts, geological land geomorphological features. Basing upon this study various litho-units viz., Archean metasediments, the Talchir shale, Barakar sandstone, Kamthi sandstone, basalt and alluvium have been mapped. Geomorphological units are mainly of denudational and fluvial origins and are represented by dissected plateaus, pediplains, pediments and alluvium. The land use / land cover study shows that a major part of the area is covered by agricultural land followed by settlement and wasteland.

Kumar *et al.* (2002) visually interpreted standard false colour composites (FCC) on 1:50,000 scale in conjunction with soil survey and prepared the physiographic soil map of the proposed command area of the Tillari irrigation project on Tillari river of Goa. They delineated thirteen mapping units indicating soil association at family level. Soil and land resource was evaluated for their land capability and irrigation suitability for its sustained use under irrigation. Land capability and land irrigability maps were also generated as attribute map. These maps were integrated to suggest a potential land use map. The study reveals that 14.66% area has no limitation and can be brought to intensive agriculture by double cropping.

2.2. REMOTE SENSING AND GIS APPLICATION IN GROUND WATER STUDIES

Howe *et al.* (1956) prepared ground water prediction maps of Iowa area from aerial photographs. They recognized three types of area relating to potential water bearing formations. For example: the most important class contained water bearing formations such as granular materials in alluvial plains, terraces, outwash deposits, moranic deposits and sandy like beds. Such regional ground water maps demonstrate the general ground water conditions. Thus indicating the areas most and least favourable for prospecting water. Hence such maps help to locate the sites of test wells, thereby reducing the cost of prospecting.

Agarwal (1989) made a study on hydrogeomorphological and structural analysis using photo interpretation and remote sensing techniques pertinent to ground water prospect in Jhansi and Lalitpur area of U.P. The study dealt with the visual interpretation of landsat imageries and aerial photographs at 1:50,000 and 1:60,000 scale respectively to review the geomorphology 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. (F.C.C) 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 emphasized 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.

Agarwala *et al.* (1992) made an attempt to delineate different hydrogeomorphological units in and around the immediate environs of Jhansi city of Uttar Pradesh with a view to establish a relation between the well yields and the hydrogeomorphic units using satellite remote sensing techniques. In general, a positive correlation observed between the geomorphic units and well yields with overlapping yields at the margin. The pediment residual hill complex is observed to provide wells with discharge ranging from 100 gallons per hour (gph) to 500 gph, while the well in shallow weathered, buried pediplain have yields in the range of 2000 to 10000 gph. Moderately weathered buried pediplain has discharges in the range of 8000 to 12000 gph and deeply weathered buried pediplain has discharges more than 12000 gph .

Tiwari (1993) delineated lineaments in the hardrock terrain under the semi-arid climatic zone of Western Rajasthan using the space borne and airborne data and their identification in field. Lineaments were identified with surface and sub-surface geological features for selection of drilling sties. The study has resulted in 100 per cent high yielding exploratory wells in the area.

Panigrahi *et al.* (1995) used Survey of India toposheets and satellite imagery of bands 2,3 and 4 for delineating the ground water potential zone map on a Survey of India toposheets 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 geo-resistivity 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 utilizable ground water is now used and there is vast scope of further exploitation of this resource.

Dutta (1996) conducted ground water study in the pediment 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 pediment zone has good ground water potential.

Tiwari *et al.* (1996) made a study to evaluate the ground water prospective zones in the Dhanbad district of Bihar, which faces acute water scarcity and is chronically drought prone. Landsat-5 MSS data of band - 2 & 4 and FCC of band - 2, 3 & 4 were interpreted visually to differentiate hydrogeomorphological units and to delineate the major trends of lineaments. The different geomorphic features identified in the study are linear ridges, residual hills, pediplains, buried pediments, dissected pediplains and lineaments. The study show that the pediplains and buried pediments are the promising zones for ground water prospecting.

Tiwari and Rai (1996) used landsat-5 MSS data of band 2,4 and false colour composite of band 2,3,4 to interpret 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 tube wells 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 categorized 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 information derived from remotely sensed data to obtain realistic picture through interpolation / extrapolation.

Kumar *et al.* (1999) used the Digital Basement Topography Modelling (DBMT) technology to derive basement topography and to identify lineaments in the Godavari sub-watershed of Bihar and analysed them to understand the ground water storage and retrieval in the area. Lineaments in the area are subtle in expression due to deeply buried pediplain. Attempt has been made in the study to delineate more authentic lineaments /fractures with the help of remotely sensed data and DBTM technology. The remotely sensed lineaments are important for ground water exploration and its authenticity can be further ascertained with DBTM.

Murthy *et al.* (1999) prepared the hydrogeomorphological map of Varha river basin which originate 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 groundwater development.

Subba Rao *et al.* (1999) prepared a geomorphologic map of the developing township of Vishakhapatanam metropolitan complex, Andhra Pradesh using the remote sensing techniques and used conventional methods to assess ground water prospects in that area. The geomorphic units delineated are denudational, fluvial and coastal. The study indicates that the fluvial and the rolling plains are promising zones for ground water occurrence. The denudational land forms are not considered as ground water potential zones, where as the ground water occurrence in the coastal plains is not suitable for any use because of its brackish nature.

Pratap *et al.* (2000) integrated various thematic maps using ARC/INFO GIS to delineate groundwater prospect zones in Dala-Renukoot area in Sonebhadra district, U.P. Thematic maps in respect of geology, geomorphology, slope, drainage, land use / land cover and lineaments were prepared on 1:50,000 scale using remote sensing and conventional methods. Each theme was assigned a weightage depending on its influence on the movement and storage of ground water and each unit in every theme map is assigned a knowledge based ranking from 1 to 5 depending on its significance to ground water occurrence. All the themes are overlaid, two at a time and the resultant composite coverage is classified into five ground water prospect categories.

Remote sensing and GIS techniques were integrated to delineate ground water potential zones and identification of sites for artificial recharge in Gaimukh watershed of Bhandara district, Maharastra. Based on the Normalized Cumulative Weightage Index (NCWI). Obi Reddy *et al.* (2000) divided the composite map classes into six ground water potential zones viz., excellent (yield more than 425 lps), very good (350-425 lps), good (275-350 lps), moderate (200-275 lps) poor (150-200 lps) and very poor (< 150 lps).

Jai Shankar *et al.* (2001) carried out hydrogeomorphological studies around Agnigundala mineralized belt of Andhra Pradesh using remote sensing IRS-IB and SPOT data for ground water exploration. Based on erosional and depositional characters of various geomorphoic units like hills (structural and denudatonial), pediments, buried pediments, plains and valley fills have been identified in various lithologies like granite, granite gneiss, biotite schist, phyllite, quartzite and dolomite. The ground water potentials of the individual geomorphologic units have been evaluated to obtain a complete hydrogeological picture of the area.

Sarkar *et al.* (2001) applied GIS, a potential tool for facilitating the generation and use of thematic information to ground water potentiality of the Shamri micro-watershed in Shimla taluk. The role of various parameters, namely drainage, lineament, lithology, slope and land use have been emphasized for delineation of ground water potential zones. IRS-IC PAN and

LISS-III FCC satellite images on 1: 25,000 scale topographic map of that area and field traverses were used as the data source for the study. A multi-criteria evaluation following probability weighted approach has been applied for overlay analysis that allows a linear combination of weights of each thematic map with the individual capability value. The resultant map indicated a high ground water potentiality in the flood plains, river terraces and river channels in the vicinity of the Shamri nala. Other sites of high potentiality include places showing break in slopes and crossing of lineaments.

The area in and around Guntur town in Andhra Pradesh faces an acute water problem. It represents plain land and gentle slope responsible for infiltration and ground water recharge. Adequate unexploited ground water resource is reported to be available in that area. Subba Rao *et al.* (2001) made an investigation to assess ground water favourable zones for development and exploration with the help of geomorphological units and associated features. The identified units and features by remote sensing technology with the integration of conventional information and limited ground truths are shallow weathered pediplains (PPS), moderately weathered pediplains (PPM), deeply weathered pediplains (PPD) residual hill (RH) and lineaments (L). The results show that the PPD, PPM and PPS are good, moderate to good and poor to moderate promising zones for ground water respectively. The RH is poor geomorphological unit in respect to ground water resource but adequate recharge of ground water can be expected surrounding the RH, as it acts as surface runoff zone. Lineaments parallel to the streams and intersecting lineaments are favourable indicators for ground water development.

Khan *et al.* (2002) carried out a study in a region in Western Rajasthan to delineate and characterize ground water prospect zone using IRS-ID LISS-III geocoded data on 1:50,000 scale. The information on lithology, structure, geomorphology and hydrology were generated and integrated to prepare groundwater prospect map for the study area. The information on nature and type of aquifer, type of wells, depth range, yield range, success rate and sustainability were supplemented to form a good database for identification of favourable zone. They have used Geographical Information System (GIS) to prepare data base on the above layers, analysis of relationship and integrated map preparation. On the basis of hydrogeology and geomorphic characteristics four categories of ground water prospect zones; high, moderate, low and very low are delineated.

Sankar (2002) made an investigation to evaluate the potential zones for ground water targeting using IRS-ID LISS-III geocoded data on 1: 50,000 scale in the upper Vaigai river basin covering parts of Madurai and Theni Districts in Tamil Nadu, which faces acute water scarcity and chronically drought prone. The geology geomorphology and lineament tectonic maps were generated and integrated to evaluate the hydrogeomorphological characteristics of the study area and to demarcate the ground water potential zones. More ground water prospective units identified are medium buried, pediment, deep buried pediment, flood plain, bajada, lineaments and intersection of lineaments. Non-potential areas like pediment, pediment inselbergs, shallow buried pediment and pediplain have also been identified.

2.3 QUALITY OF GROUND WATER

On the basis of total salt concentration and soluble salt percentage. Scafield (1936) and Wilcox (1998) classified the ground water. Kelley *et al.* (1948) suggested that the ratio of sodium to other cations (Ca^{++} and Mg^{++}) should not exceed one for good water. Cossidy (1949) proposed 'F' index (figures of merit) calculated by the ratio (Ca^{++} + Mg^{++}) / (Na^{++} + K^{+}) in ground water. A value of 0.5 or less was suggested for water of good quality.

Water posses no inherent quality except for some external condition. It is independent of the condition under which is to be used suggested by Bernstech (1967). Therefore water quality can be evaluated only in the context of a specified set of conditions, including soil properties, irrigation management, climate and crops.

Irrigation suitability can be evaluated on the basis of its potential of creating soil condition hazardous to crop growth suggested by Rhoodes (1972). He further concluded that water of a specified quality may be suitable under one set of condition but unsuitable for another.

Salinity of Ground Water

Sub-surface information and bore hole geophysical profiles have provided certain degree of information which has permitted construction of an apparent picture of the occurrence and disposition of the saline ground water bodies in the coastal tracts (Radhakrishna and Dutta, 1976). It's revealed from the study that in the out fall regions of the Baitarani, Brahmani, Mahanadi river basin the upper saline ground water body seems to have transversed for inland from the sea coast.

Standard Quality of Water for Irrigation.

Followings are the standard parameters for determining standard quality of water for irrigation.

(a) pH Value

The pH value of water is the measure of its acidity or alkalinity. pH value of 7 indicates a neutral solution, neither alkaline nor acidic. pH value more than 7 indicates alkalinity and less than 7 indicates acidic solution. The standard value and effect of pH on water quality has been shown in the Table 2.1 (Todd 1980; Garg 1982).

Table 2.1 Acceptable pH value for irrigation water

pH value	Water quality
8.5	Sodium percentage 15 or more and presence of alkaline earth carbonates
7.5-8.5	Sodium percentage within 15
7.0-7.5	Alkaline earth carbonates absent
7.0	Significant amount of hydrogen ions.

(b) Electrical conductivity

The salinity effect on crops can be studied observing the electrical conductivity of the irrigation water. Electrical conductivity is the reciprocal of electrical resistivity. The Standard value and effect of EC on crop has been shown on Table 2.2 (Todd 1980).

Table 2.2 Effect of EC on crop yield

Electrical conductivity in milli mhos /cm at 25^0C	Effect on crop
<2	Salinity effects mostly negligible
2-4	Yields of very sensitive crops may be restricted
4-8	Yields of many crops restricted
8-14	Only tolerant crops yield satisfactorily
>14	Only a few tolerant crops yield satisfactorily

(c) Sodium Absorption Ratio (SAR)

A ratio for soil extracts and irrigation water is used to express the relative activity of sodium ions in exchange reaction with soil.

$$SAR = \frac{Na^+}{\sqrt{[(Ca^{++} + Mg^{++} / 2]}} \qquad \ldots\ldots\ldots\ldots\ldots (2.1)$$

All constituents are expressed in milli equivalents per litre. The standard value and effect of SAR on salinity hazard has been presented on table 2.3.

Table 2.3 Effect of SAR on salinity

SAR valve	Degree of salinity hazard.
<10	Low
10-18	Medium
18-26	High
>26	Very High

(d) Total Dissolved Salts (TDS)

It is determined by weighing the residue after a sample of water has evaporated. It is expressed in terms of parts per million (ppm). The standard value and its effect on salinity are presented in Table 2.4.

Table 2.4 Effect of TDS on salinity

TDS Valve	Degree of salinity hazard
< 500 ppm	Safe
500-1000 ppm	Medium salinity
>1000 ppm	Critical salinity

(e) Sodium percentage

In saline soils sodium salt usually predominate because calcium carbonate and sulphate being less soluble are not.

Wilcox (1948) defined sodium percentage as given below

$$\% \text{ Na} = \frac{Na^{+} + K^{+}}{Na^{+} + K^{+} + Ca^{++} + Mg^{++}} \times 100 \qquad \ldots\ldots\ldots\ldots (2.2)$$

where all ionic concentrations are expressed in milli equivalents per liter. The standard value for the sodium percentage should not exceed 15 for good quality of water for irrigation purpose.

(f) Magnesium and Calcium ratio

At the same level of salinity and SAR, but with varying proportion of calcium and magnesium and adsorption of sodium by soils and clay minerals is more at higher Mg : Ca ratio. This is because the bonding energy of magnesium is generally less than that of calcium allowing more sodium adsorption. It suggests that soil sodicity would increase at the same SAR if the water contains higher proportion of magnesium to calcium. Thus it's desirable to analyse both calcium and magnesium in irrigation water separately in order to predict the soil sodicity hazard more accurately. It is more important if the Mg : Ca ratio in irrigation water happens to be more than 4.

Keeping the above methods for quality analysis groundwater the following classification for quality of water for irrigation purpose in given in table 2.5 (Todd 1980).

Table 2.5 Quality classification of water for irrigation purpose.

Sl. No.	Water class	% Na	EC x 10^3 at 25^0C	SAR (in meq / litre)
1.	Excellent	< 20	< 0.25	<10
2.	Good	20-40	0.25-0.75	10-18
3.	Permissible	40-60	0.75-2.00	18-26
4.	Doubtful	60-80	2.00-3.00	26-28
5.	Unsuitable	> 80	>3.00	>28

2.4 GROUND WATER MOVEMENT

In 1856, Henry Darcy observed that the flow rate through a porous medium when the flow is laminar, it is directly proportional to the head loss and inversely proportional to the length of the flow path. This is known on Darcy's law. (Todd 1980; Garg 1982 and Raghunath.1987).

This can be expressed mathematically in

$$V = \frac{K\Delta h}{L} = KI \quad \ldots\ldots\ldots\ldots\ldots\ldots (2.3)$$

Where,

V = Volume of water per unit cross sectional area of a column of permeable material expressed as velocity in m/day.

Δh = Difference in pressure head at the ends of the column in meter

L = Length of the flow path in meter

K = Coefficient of permeability (a constant dependent upon the character of the material) in $m^3/m^2/day$.

and I = $\Delta h/L$ = Hydraulic gradient (dimension less quantity).

2.5 EVALUATION OF AQUIFER PARAMETERS

Thiem (1906) considered flow to a completely penetrating well in a confined aquifer. He made the following assumptions (Garg 1982).

The aquifer is of infinite extent.

The aquifer is homogenous, isotropic and of uniform thickness.

At the beginning of pumping, the piezometric surface and/or phreatic surface are horizontal.

The aquifer is pumped at a constant discharge rate.

The pumped well penetrates the entire aquifer. So that the flow towards the well is horizontal.

Permeability is given by

$$K = \frac{Q}{2\pi b\,(h_2 - h_1)} \ln \frac{r_2}{r_1} \qquad \text{.....................} \; (2.4)$$

Where,

K = permeability, m/sec

Q = discharge of the well, m^3/sec

b = thickness of the aquifer, m

h_2 = head in the observation well no-2, m

h_1 = head in the observation well no-1, m

r_1 = radial distance of observation well no-1 from the main well, m

r_2 = radial distance of observation well no-2 from the main well, m.

Dupit (1963) derived the equation for flow towards a well in an unconfined aquifer on the basis of the following assumptions (Todd 1980, Garg 1982 and Raghunath 1989).

\# The velocity of flow is proportion to the tangent of the hydraulic gradient instead of the sine.

\# The flow towards the well is horizontal and uniform.

The equation is given by

$$Q = 2\pi khr\frac{dh}{dr} \quad \text{.................} \quad (2.5)$$

Where,

Q = discharge of the well, m^3/sec.

K = permeability, m/sec.

h = head of water, m.

$\frac{dh}{dr}$ = slope of the piezometric surface at a distance 'r' from the center of the well.

CHAPTER III

MATERIALS AND METHODS

MATERIALS AND METHODS

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

3.1. THE STUDY AREA

3.1.1 Location and Extent of the Study Area

Kichna Nala sub-watershed lies geographically between $21^0 48'$ N to $21^0 57'$ N latitude and $84^0 20'$E to $84^0 24'$E longitude at a distance of about 25km from the block head quarter Bamara and 90 km from the district head quarter Sambalpur in the state of Orissa as shown in fig 3.1. The watershed area is approximately 4826.1 ha and is included in the survey of India toposheet number 73C/05 in 1:50,000 scale. The watershed spreads mainly over nineteen village namely Dumermunda, Solbaga, Kesaibahal, Segapara, Balijori, Bandhkani, Kabaribahal, Mundapara, Dipupara, Routbahal, Nagadihi, Ardabahal, Lasratangar, Baladmal, Charmal, Kendumal, Bhalubahal, Panposh and Ramtileimal.

The Kichna Nala sub-watershed belongs to Mahanadi catchment and river Bheden sub-catchment. The natural drainage system of the watershed is Kichna nala, a tributary of river Bheden. Drainage pattern is mostly dendrite or sub-dendrite controlled by fractures, joints and lineaments.

3.1.2 Physiography of the study area.

The Kichna nala sub-watershed comes under the northern-western plateau of Orissa. The rock of this area is mostly of Granite gneiss, quarzite and alluvium type. The highest and lowest relief are at heights of 600 to 300m respectively above the mean sea level. The watershed is of elongated shape with undulated topography at the head and almost flat topography at the tail end.

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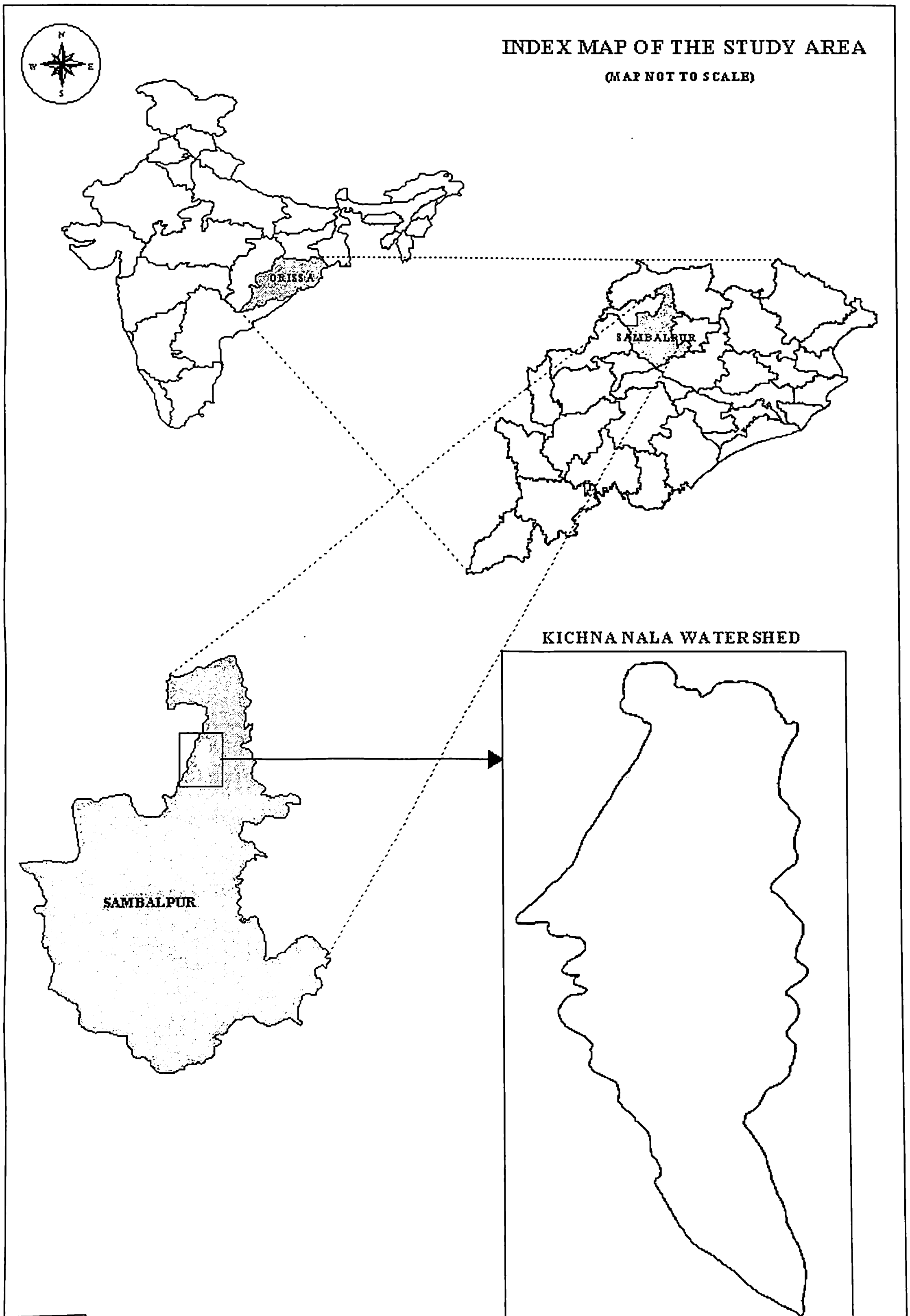


FIG - 3.1

The entire area includes mainly three zones, like runoff zone, infiltration zone and discharge zone. The runoff zone constitutes of hills, lateritic upland and inselbergs etc. with soil of gravelly sandy loam texture, shallow to moderate depth and well to excessively drained character. The infiltration zone constitutes of pediment and buried pediment with soil of sandy loam to clayey loam texture, moderately deep to very deep and moderately to well drained type. A particular type of sand stone is found in this zone of the study area which retains water and acts as a good aquifer (plate 3.1). The discharge zone constitutes of valley fill, flood plain, levee and lineaments etc. with soil of sandy loam texture with very deep lithology and moderately to excessively drained nature. A major part of the study area is under nearly level (0-1% slope) and very gently sloping (1-5%) category.

3.1.3 Climate

The climate of the study area is semi-arid. The average annual rainfall of the area is 1499mm, mostly being received by the south-west monsoon. The area experiences maximum temperature of 43^0C in summer and minimum of 5^0C in winter.

3.1.4 Population status

The village wise population status of the study area is presented here in the following table.

Table 3.1 Village wise population of the study area

Village	Total Population			SC		ST		Literates	
	Total	Male	Female	Male	Female	Male	Female	Male	Female
Routbahal	843	414	429	49	45	201	205	192	117
Lasratangar	207	98	109	5	5	41	40	47	21
Nagadihi	211	97	114	2	3	58	76	54	31
Bhalubahal	627	302	325	56	60	170	182	143	69
Ardabahal	918	389	529	69	105	156	256	185	238
Ram Tiliemaal	1065	507	558	40	48	364	342	227	89
Dumermunda	183	83	100	--	--	76	93	8	3
Solbaga	564	275	289	38	39	169	186	90	45
Baladmal	269	143	126	--	--	84	77	60	33
Kesaibahal	1365	701	664	68	61	355	345	333	209
Balijori	43	21	22	--	--	20	22	12	6
Kabaribahal	1856	937	919	97	102	548	534	375	184
Bandhkani	797	412	385	49	42	217	221	108	34
Panposh	367	189	178	40	32	35	32	109	42

Plate 3.1 Typical sand stone found in the study area

3.2 DATABASE USED FOR THE STUDY

3.2.1. Satellite imageries and false colour composite (FCC)

False colour composite refers to the composite image generated by remote sensing observations in green (0.52-0.59μm), red (0.62-0.68μm) and infrared (0.77-0.86μm) spectral bands and by assigning complementary colour i.e. blue, green and red respectively to above said observation bands of Indian Remote Sensing Satellite with different sensors.

IRS-ID FCC of band 2,3 and 4 of the following dates were used for the study which were collected from Orissa Remote Sensing Application Centre, Bhubaneswar.

1) 03 FEB, 2001 2) 14 MAY, 2001 3) 14 NOV, 2002

3.2.2 Topohsheets

The survey of India toposheet numbering 73 C/05 on a scale of 1:50,000 with contour interval of 20m was used to prepare the base map and to finalise the settlement location and transportation network, land use / land cover classes, hydrogeomorphological units and drainage pattern of the watershed. The toposheet covers an area of both 15 minutes latitudes and longitudes interval.

3.2.3 Rainfall data

The monthly rainfall data of Bamara block for last 15 years (1988-2003) were collected from the Ground Water Survey and Investigation Office, Sambalpur. The collected rainfall data is given in Appendix -1.

3.2.4 Ground Water quality data

The water quality data basing upon the tests of different standard parameters were collected from the Ground Water Survey & Investigation Office, Sambalpur. The tests have been conducted on the ground water samples collected from different test well of Bamara block. The water quality data is given in Appendix -2.

3.2.5 Vertical Electrical Sounding (VES) test results

The Ground Water Survey & Investigation Department of Govt. of Orissa has conducted several VES tests throughout the state for the investigation of ground water. The VES results of Bamara block were collected from the Ground Water Survey & Investigation Office, Sambalpur and were presented in Appendix - 3.

3.2.6 Other field data

Some other data such as the water table in the existing wells of the study area, their discharge and recuperation rate were collected from the field. A typical sand stone of the study area, which acts as a good aquifer was also collected from the field and its photograph is given in plate 3.1.

3.2.7 Ground Truth :

Selective ground truthing has been carried out in the area which seemed to be doubtful during the interpretation of satellite imageries. The geomorphoic classified in thematic maps related to the natural resources of the watershed were checked on the ground.

3.3. COMPONENTS OF GIS

3.3.1. Systems and peripherals used in GIS

1. Black and white CCAL Comp scanner
2. Silicon graphic computer (0_2) with unix operating system
3. Personal computer with Pentium-4 Micro Processor
4. HP-810 INKJET Colour Printer.

3.3.2 Software used in GIS

R2V ~ 2.1 version (Digitising software)

ARC/INFO~7.2 version (Editing & levelling)

ARC/VIEW ~3.2 Version (Designing and overlaying software)

MS-OFFICE (text and table addition software)

3.4 CONCEPTS AND METHODOLOGY

The methodology for the study involved two major steps that include the generation of thematic information and its analysis for ground water potentiality in the study area. The methodological approach is presented in the flow chart (fig - 3.2).

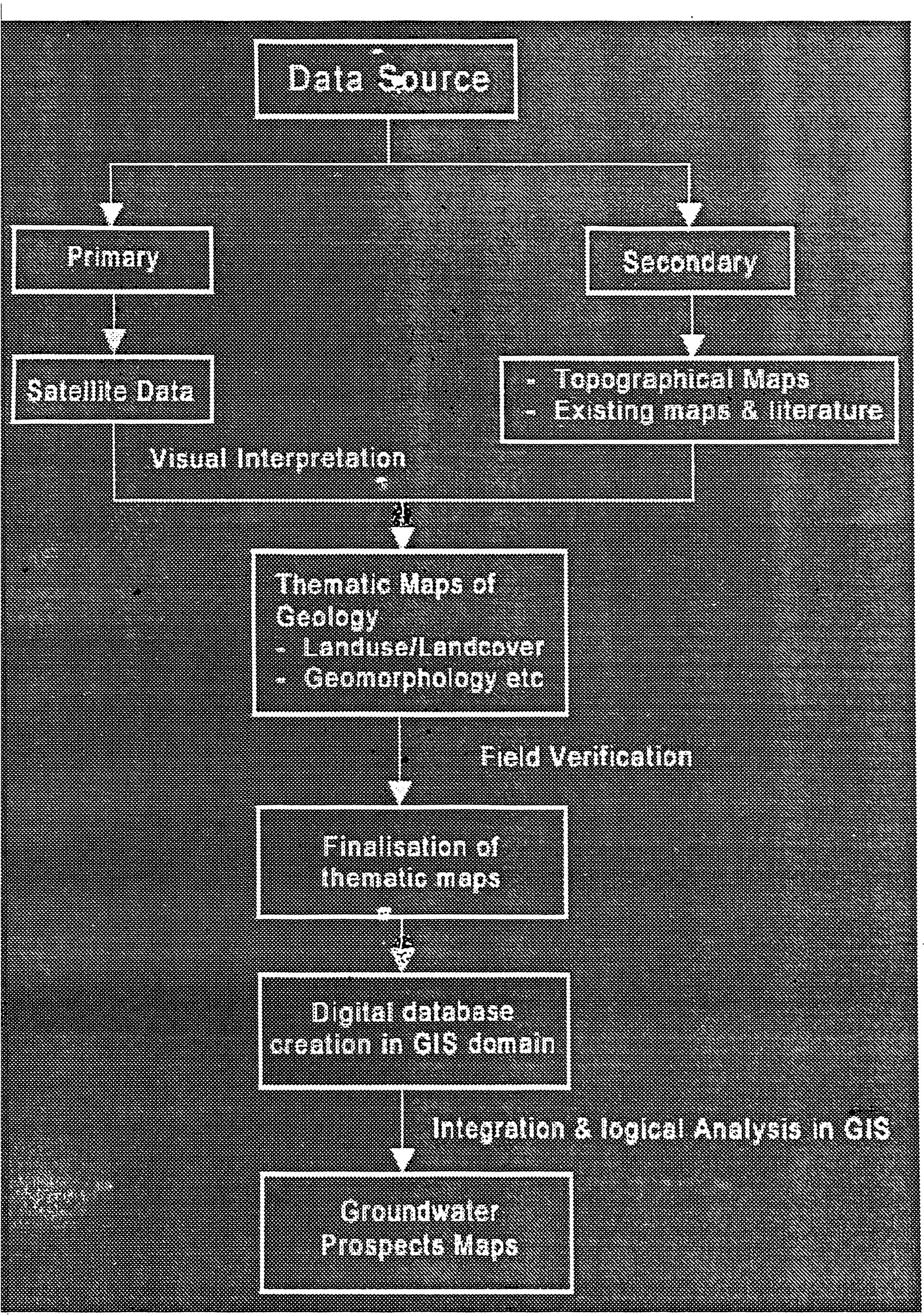


Fig-3.2 FLOW CHART OF METHODOLOGICAL APPROACH

3.4.1 Delineation of watershed

The Kichna nala watershed was first identified on the Survey of India (SOI) toposheet numbering 73 C/05 in 1:50,000 scale and then the watershed boundary was traced basing upon the contour and drainage network. Finally the watershed boundary was modified / corrected by overlaying the contour and drainage information over the latest geocoded satellite images in 1:50,000 scale and the Kichna nala watershed was delineated and was fixed for the study.

3.4.2 Preparation of settlement and road network map.

The settlement and road network map of the Kichna nala sub-watershed was prepared from SOI toposheet 73 C/05 in 1:50,000 scale. The transparent tracing film was placed over the toposheet and the base items like National Highway, State Highway, metalled and unmetalled roads, main drainage line, etc. were drawn. The village boundaries have been collected from the ORSAC and incorporated in the base map.

3.4.3 Preparation of land use / land cover map

Land use refers to man's activity and various use which are carried out on land. Land cover refers to natural vegetation, water bodies, artificial cover and other resulting due to land transformations. (Anonymous, 1994).

The following steps were adopted to prepare the land use / land cover map of Kichna nala sub-watershed.

The sub-watershed boundary was delineated using SOI toposheet in 1:50,000 scale.

Initial base map of the study area was prepared from SOI toposheet indicating watershed boundary and few control points like state highway, metalled and non-metalled roads, prominent rivers, etc.

The base map was superimposed on multi-season satellite FCC data which was illuminated by using a light table. Boundaries of various land use / land cover classes were demarcated by means of visual interpretation technique whose fundamental is based on size, shape, shadow, tone, texture, pattern and association characteristics of images.

After preliminary image interpretation, the findings were compared with ground truth.

Corrections and modifications were made wherever found necessary and the final pencil land used / land cover map of Kichna nala sub-watershed was prepared.

The flow chart showing the methodology for mapping land use / land cover units through visual interpretation techniques is shown in a flow chart (fig-3.3). Also the land use / land cover classification system is given in Appendix-5.

3.4.4. Preparation of hydrogeomorphological map

Hydrogeomorphology depicts different aspects like land form, land characterisation, geological information, etc. Information about different land form characteristics is a vital input for land management, soil mapping, etc. where as information about different geological aspects like lithology / rock types is an indispensable source to identify the occurrence of ground water potential zones (Anonymous, 1995).

The following steps were adopted to prepare the hydrogeomorphological map of Kichna nala watershed.

- The sub-watershed boundary was delineated by using SOI toposheet in 1:50,000 scale.
- Initial base map of the study area was prepared from the SOI toposheet, indicating watershed boundary and its few control points like state highway, metalled and non-metalled roads, prominent drainage lines etc.
- The base map was superimposed on multi-season satellite FCC data which was illuminated by a light table. Boundaries of various hydrogeomorphological units were demarcated by means of visual interpretation whose fundamental is based on size, shape, shadow, tone, texture, pattern and association characteristics of images. The structural information like folds, fractures, lineaments, etc. were incorporated.
- After preliminary image interpretation, the findings were compared with ground truths.
- Corrections and modifications were made wherever found necessary and the final pencil hydrogeomorphological map of Kichna nala sub-watershed was prepared.

The methodology for mapping the hydrogeomorphological units through visual interpretation techniques is shown in a flow chart in fig-3.4.

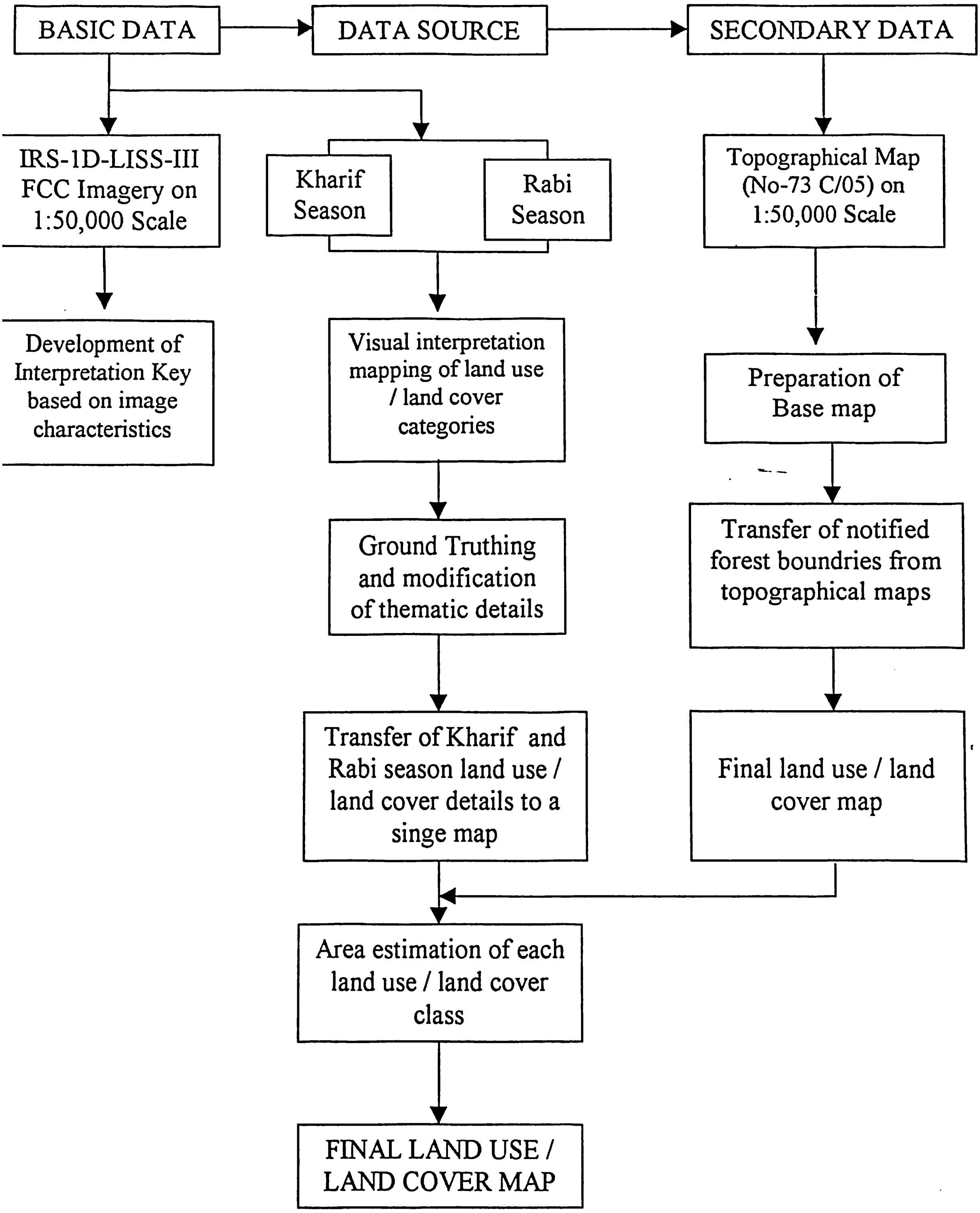


Fig. 3.3 Flow chart showing methodology for mapping land use / land cover through visual interpretation technique

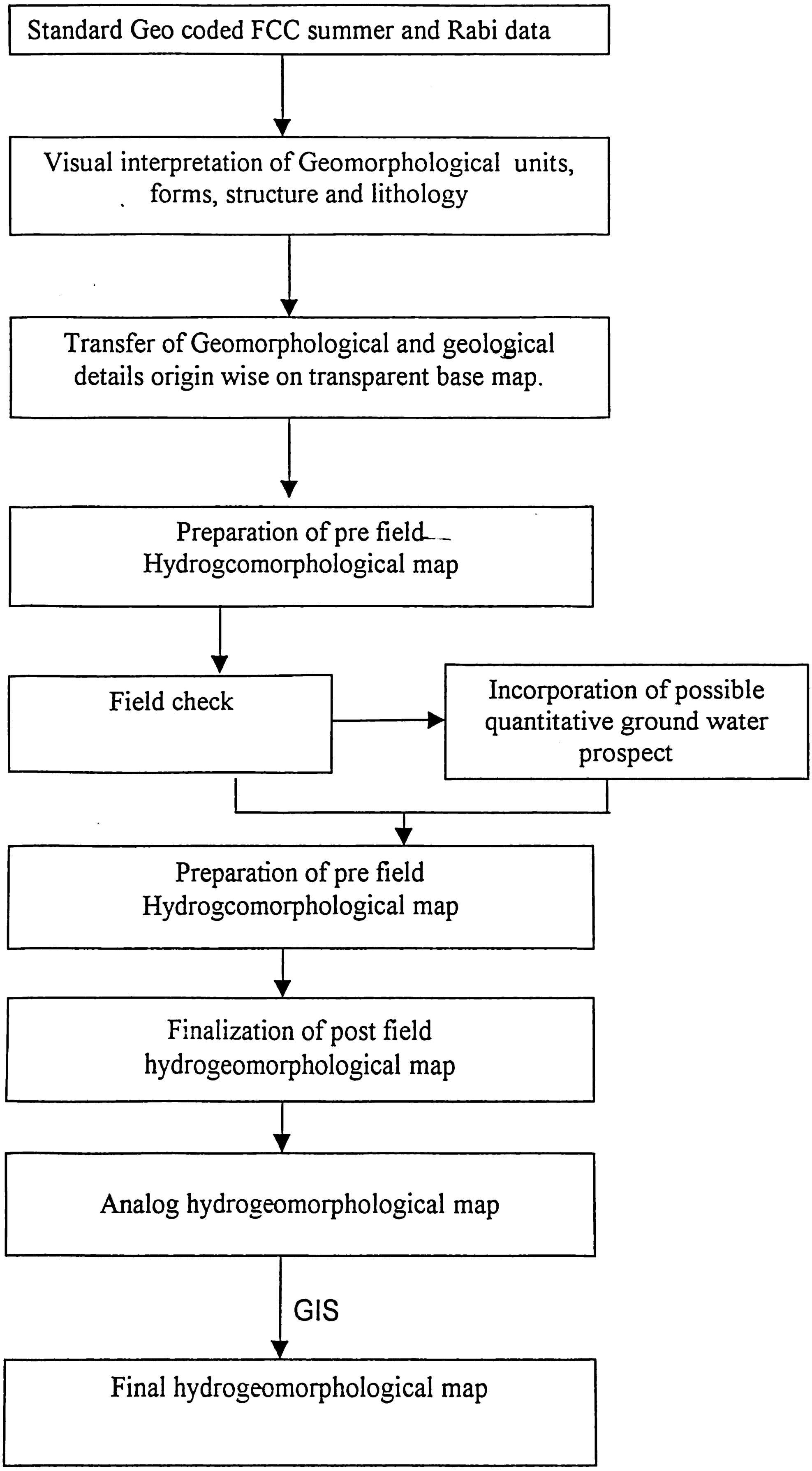


Fig. 3.4 Flow chart showing methodoogy for mapping hydrogeomorphological units through visual interpretation techniques.

3.4.5 Preparation of drainage and surface water body map

Drainage and surface water body map refers to the different drainage lines like major river, streams, streamlets, nalas etc. and the presence of different water bodies like tanks, reservoirs, ponds etc. (Anonymous, 1995).

Following steps are adopted to prepare the drainage and surface water body map of Kichna nala sub-watershed.

The sub-watershed boundary was delineated by using SOI toposheet in 1:50,000 scale.

Initial base map of the study area was prepared from the SOI toposheet, indicating watershed boundary and its few control points like state highway, metalled and non-metalled roads, prominent rives etc.

The base map was superimposed on pre-monsoon satellite FCC data which was illuminated by a light table. The drainage lines were drawn and the extent of the water bodies were demarcated by the post-monsoon satellite FCC data and by means of visuals interpretation technique.

3.4.6. Preparation of ground water potential map

3.4.6.1. Scanning of Thematic Maps

The smooth analog pencil traced thematic maps prepared from remote sensing satellite FCC data through visual interpretation technique can be converted into the digital raster image by manual digitization or scanning. The pencil copy thematic maps of Kichna nala sub-watershed were scanned in a black and white CCAL Comp Scanner with proper scanning width, DPI, binary (0-1) options etc.

3.4.6.2. Digitization of Thematic maps.

The raster image of the thematic maps were then stored in TIFF (Tagged Image File Format) files in form of point, line and polygon. The image quality of the raster images can be improved by providing contrast and threshold points. The vector co-ordinates of the point, line and polygon files were provided by manual or auto-tracing option with the help of mouse and the registration through control points (latitude and longitude) of the TIFF files were done and stored in CPP files. These TIFF and CPP files were converted to Data Interchangeable file (DXF) or ARC format using import / export utility. The conversion of raster image to vector image was mainly done by R2V~2.1 software package.

3.4.6.3. Working in ARC/INFO package environment.

The vector co-ordinate unit from pixel value in files were transformed into the geocoded ARC/ IMG unit (in GRID files) by using import / export utility to generate a coverage having single co-ordinate system. Then the editing of different map coverage were done by different options like dangle node, overshoot, under shoot etc. The topology building, clean command along with projection setting etc. are different sets of provisions to be provided. Then the leveling of features stored in PAT (Polygon Attribute Table for points polygon) and AAT (Arc Attribute Table for line) were done by providing different polygon id., line id. etc.

The generation of coverage, editing, leveling etc. were done by ARC/INFO~7.2 in a silicon graphic computer (O2) with Unix Operating System having Pentium-IV Microprocessor.

3.4.6.4. Working in ARC/VIEW package environment

The different thematic ARC/INFO coverage along with the attribute exported to the ARC/VIEW environment and different themes are created for different view. Different colours, symbols were given to different attributes to classify different features of a map. Then the geographical analysis of these maps were done by different procedures like

i) Overlaying Analysis

ii) Proximity Analysis

iii) Tabular and Statistical Analysis

iv) Data-base Query

i) Overlaying Analysis

This may be vector overlaying or raster overlaying. In this analysis map features and associated attributes are integrated to produce a composite map. Logical operators (AND, OR, NOT) and conditional operators (>, < =, <>) are used for this purpose.

The geohydromorphological map, drainage map and land use / land cover map were overlaid with reference to the common control points to analyse the correlation among the map features and finally to generate an integrated ground water potential map of the Kichna nala sub-watershed.

ii) Proximity Analysis (Buffer operation)

It is mainly done to locate the extent of area and to know the characteristics of the area surrounding a specified location or a particular structure. The lineaments present in the study area were allocated a width of 100-150m in the field by this buffer operation.

iii) Tabular and Statistical Analysis

The attribute and geographic data of the integrated land use / land cover map and ground water potential map were stored in tabular from with all available statistics.

iv) Data base Query

The database query used the individual LU/LC and buffered area id. to regenerate a new id. for the integrated ground water potential map.

Following all the above discussed procedures, the composite coverage resulted was the final ground water potential map of the Kichna nala watershed. This is further classified into 5 classes of ground water prospect zones basing upon the potentiality of the study area which have been discussed in the next chapter.

CHAPTER IV

RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

This chapter deals with the results obtained through analysis of satellite imagery with ground truthing, collection and analysis of rainfall data, water quality data, VES test results in the study area and integration of the information by GIS to develop a ground water potential map of the study area.

4.1 SETTLEMENT LOCATION AND ROAD NETWORK MAP OF THE KICHNA NALA SUB-WATERSHED.

The settlement location and road network map of Kichna nala sub-watershed was prepared to a scale of 1:50,000 and is presented in fig-4.1 with scale of 1: 65,000. The watershed spreads over nineteen villages namely, Dumermunda, Solbaga, Baladmal, Balijori, Kesaibahal, Kabaribahal, Segapara, Bandhkani, Mundapara, Dipupara, Nagadihi, Routbahal, Ardabahal, Bhalubahal, Lasratangar, Ram Teleimal, Charmal, Kendumal and Panposh. The settlements are mostly rural and economically backward. The road network shows different categories like state highway, metalled road and unmetalled road.

4.2 LAND USE / LAND COVER MAP OF THE AREA

Land use / land cover map of the Kichna nala sub-wateshed was prepared in a scale of 1: 50,000 through visual interpretation of IRS-ID LISS-III FCC data of 03 FEB, 2001, IRS-ID LISS-III FCC data of 14 MAY, 2001 and IRS-ID LISS-III + PAN FCC of 14 NOV, 2002. Then the spatial data inform of land use / land cover map with its different units were classified and presented in Table 4.1. The information on land use / land cover status of the sub-watershed is shown in fig-4.2 with a scale of 1:65,000.

3Raodnet (736x1064x16M jpeg)

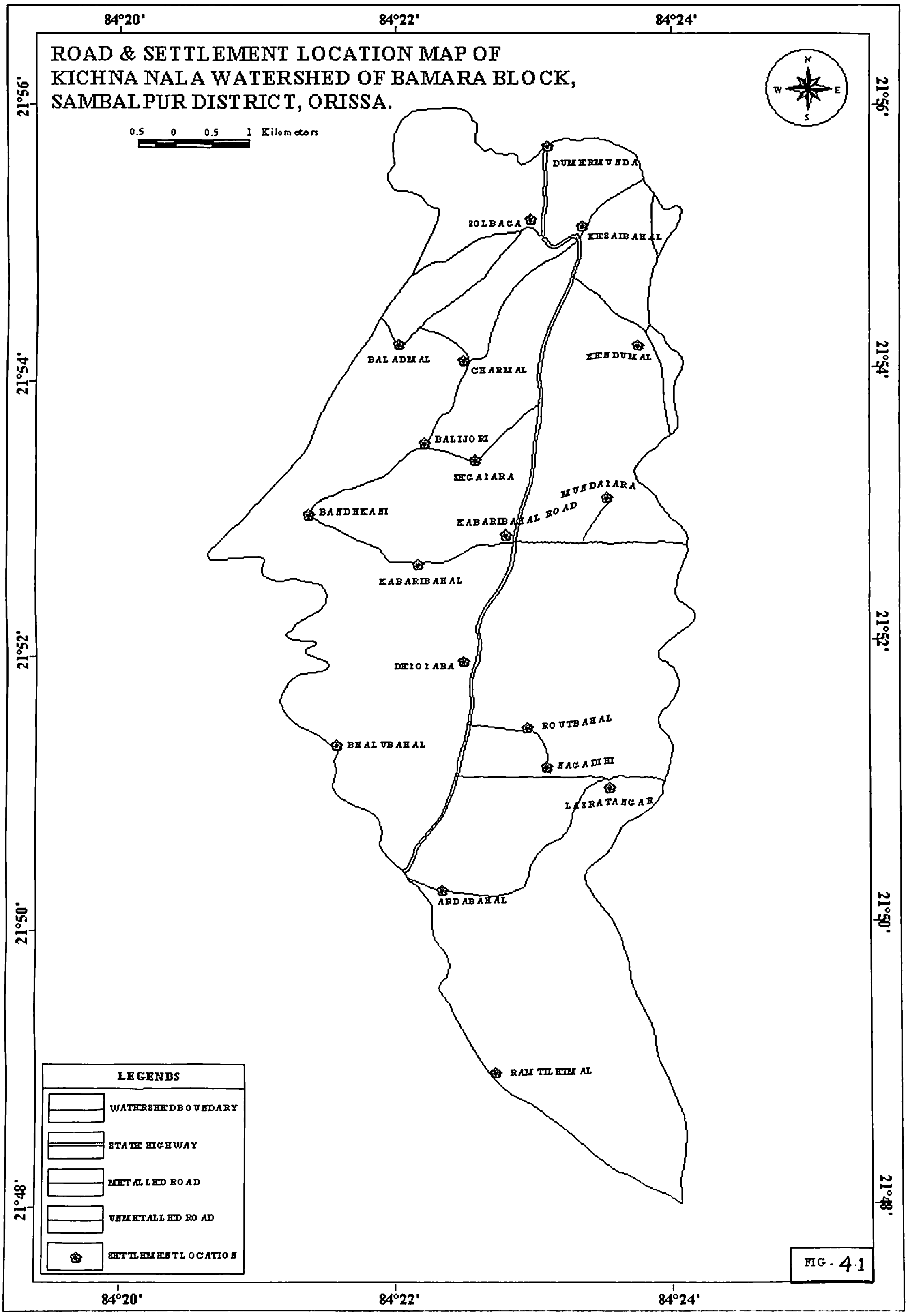


FIG - 4.1

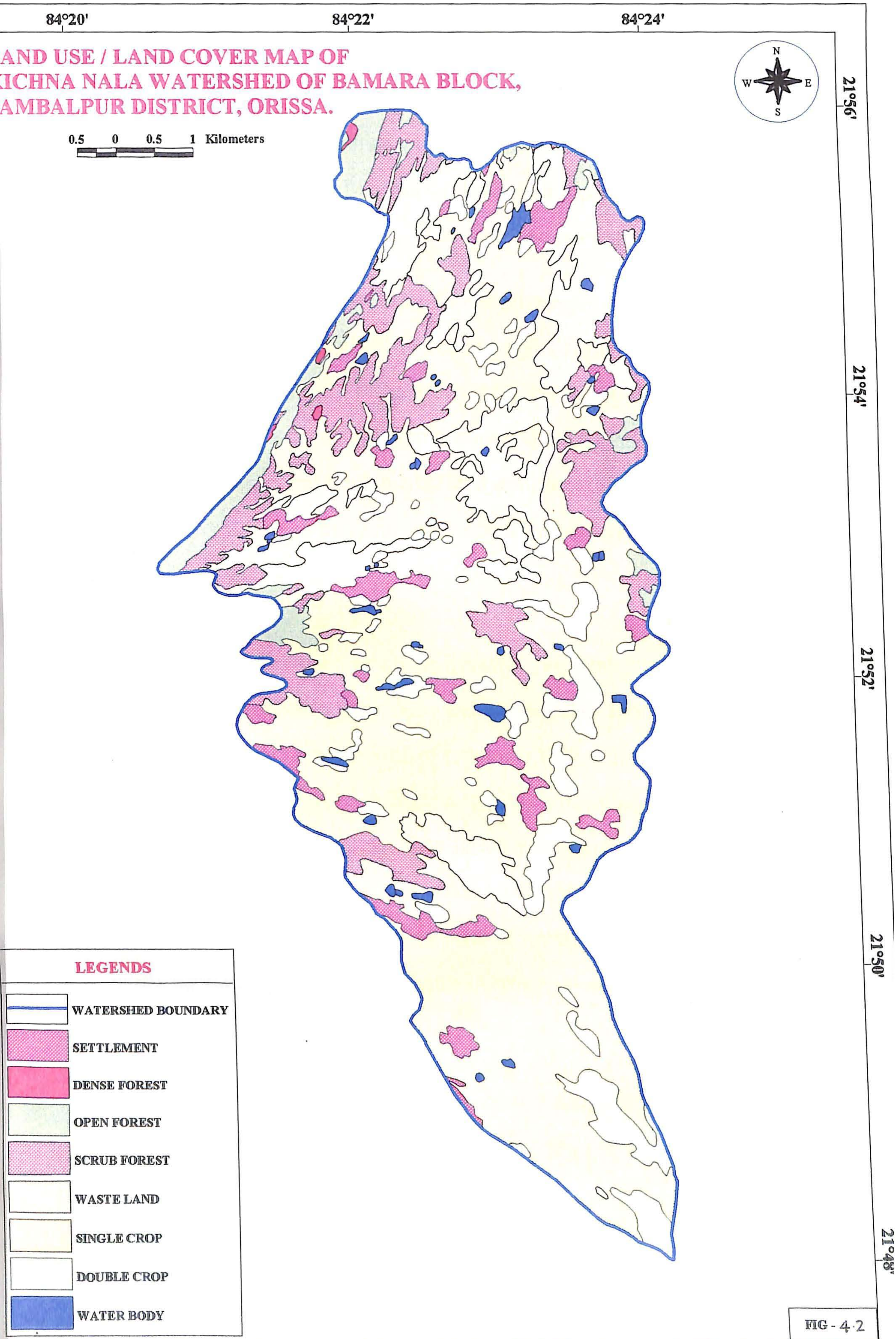
Table 4.1 Land use / land cover classification of Kichna nala sub- watershed

Map unit	Land use / Land cover class	Area (ha)	% of the total area
I.	**Built up land**		
1)	Settlement	250.898	5.199
II.	**Agricultural land**		
2)	Single cropped area	2726.117	56.487
3)	Double cropped area	372.809	7.725
III.	**Forest**		
4)	Dense Forest	6.960	0.144
5)	Open forest	174.926	3.625
6)	Scrub forest	602.810	12.490
IV.	**Waste land**		
7)	Land without scrub	637.058	13.200
V.	**Water bodies**		
8)	Reservoirs / tanks	54.525	1.130
	Total	**4826.103**	**100 %**

I. Built-up land (settlement)

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

The build-up lands in Kichna nala sub-watershed is constituted mostly of rural settlements. The total area occupied by this land category is 250.898 ha which is nearly 5.2% of the total area of the watershed.



84°20'
84°22'
84°24'
AND USE / LAND COVER MAP OF
KICHNA NALA WATERSHED OF BAMARA BLOCK,
AMBALPUR DISTRICT, ORISSA.
0.5 0 0.5 1 Kilometers
N
W
E
S
21°56'
21°54'
21°52'
21°50'
21°48'
LEGENDS
WATERSHED BOUNDARY
SETTLEMENT
DENSE FOREST
OPEN FOREST
SCRUB FOREST
WASTE LAND
SINGLE CROP
DOUBLE CROP
WATER BODY
84°20'
84°22'
84°24'

FIG - 4.2

II. Agricultrual Land

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

The agricultural land under crops may be single crop (Kharif only) or double crop (Kharif + rabi). The single cropped agricultural land of Kichna nala sub-watershed occupies 2726.117 ha which is 56.487% of the total area where as the double cropped agricultural land occupies 372.809 ha which is 7.725% of the total area. Most of the double crop land are nearer to reservoirs or tanks or nearer to the drainage course and are irrigated by them in rabi season.

III. Forest (Deciduous type)

Forest is an area bearing an association predominantly of trees and other vegetation type capable to produce timber and other products. Deciduous forest mainly shows the characteristic of shedding their leaves once in a year. Forest in the watershed can be categorised into three types such as, dense forest, open forest and scrub forest. The forest with vegetative crown density more than 40% of canopy cover is called dense forest and the forest with vegetative crown density within 20% to 40% of canopy cover is called open forest where as the forest with less vegetative crown density and with scrubs is called scrub forest.

The area under forest is 784.696 ha which is nearly 16.26% of the total area of the watershed. Dense forest, open forest and scrub forest occupy 6.960 ha, 174.926 ha and 602.810 ha having 0.144%, 3.625% and 12.490% of the total area respectively.

IV. Wasteland

The wasteland found in the study area are mainly culturable waste lands. These are described as the degraded, underutilized, detoriated land due to lack of soil and water management or natural causes and can be brought under vegetation cover with reasonable effort. These culturable wastelands mainly include the land without scrubs which occupy relatively higher topology like upland, highland, etc.

The culturable wasteland covers 637.058 ha of area in the watershed which is 13.2% of the total area.

V. Waterbody

This unit comprises the reservoirs, tanks and ponds etc. and covers an area of 54.525 ha in the watershed which is 1.13% of the total area. The drainage and surface waterbody map has been shown in fig.4.3.

The result shows that the Kichna nala sub-watershed is a potential region for agricultural development. Agriculture alone occupies about 64.212% of total watershed area but most of the agricultural land (56.487%) are single cropped. So, ground water can be effectively used to convert the single cropped areas into double cropped areas and agro-horticultural areas. The culturable wasteland constitutes 13.2% of the total area, which can also be planned for agro-horticulture, dryland horticulture etc.

4.3 HYDROGEOMORPHOLOGICAL CHARACTERISTICS OF THE STUDY AREA

The hydrogeomorphological units were identified and mapped through visual interpretation and GIS techniques in1:50,000 scale. Fig - 4.4 shows the hydrogeomorphological map of the Kichna nala sub-watershed in 1:65,000 scale and Table - 4.2 represents the hydrogeomorphological units of the area.

Table 4.2. **Hydrogeomorphological characterstics of Kichna nala sub-watershed.**

Map unit	Geomorphic unit	Ground water prospect	Area (ha)	% of total area
1	Residual Hill (RH)	Poor to Nil	163.509	3.338
2	Pediment (P)	Poor to Nil	2140.463	44.352
3	Shallow weathered buried pediment (BPS)	Moderate to poor	2120.523	43.938
4	Moderately weathered buried pediment (BPM)	Good to moderate	321.165	6.655
5	Valley fill (VF)	Very good	80.443	1.667
6	Lineaments	Excellent	--	--

The study area was broadly classified into three zones such as runoff, infiltration and discharge zone. The residual hills and the pediments constitute the runoff zone. The buried pediments, both shallow and medium represents the infiltration zone where as the valley fills and the lineaments are the discharge zones. Different hydrogeomorphological units representing their ground water prospects are discussed below.

I. Residual Hill (RH)

Residual hills are the end product of the process of pediplanation, which reduces the original mountain masses into a series of scattered knolls standing on the pediplains. These hills are having more resistant formations standing out prominently to differential erosion and weathering. In spite of their isolated occurrence, their continuity in a linear or curvilinear fashion gives indication that they are structurally controlled. The shape of the residual hills are controlled by different lithological composition, distribution and spacing of joints and fractures. The residual hills are identified in the imageries by gray tone and coarse texture in the black and white images and dark reddish colour in standard False Colour Composite with radial drainage pattern.

Residual hills are found on the northern and western boundary of the study area spreading over an area of 163.509 ha which is about 3.338% of the total area of the watershed. Here infiltration is very low and these units behave as runoff zone. Ground water potential is very poor on these geographic unit.

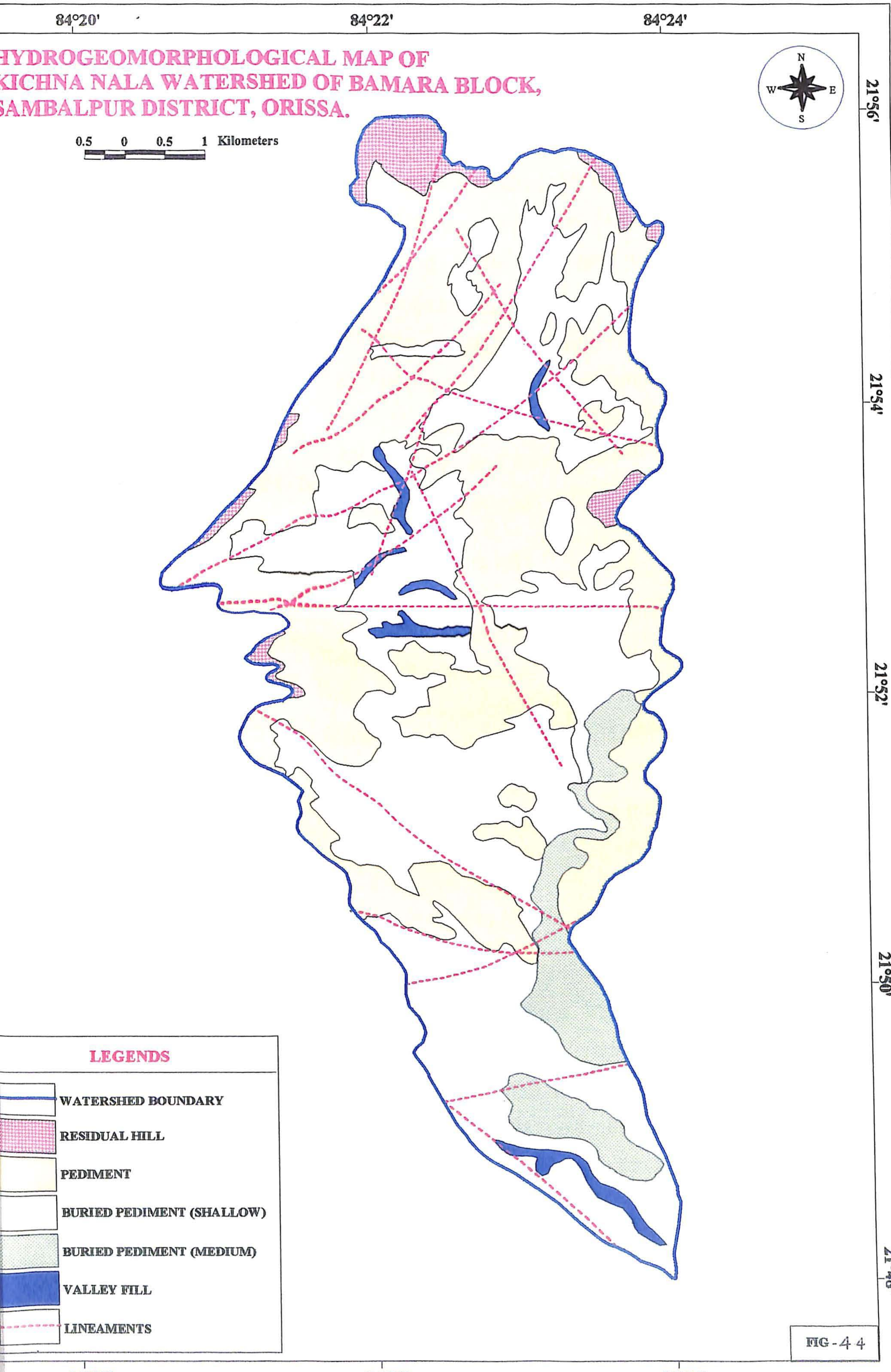

HYDROGEOMORPHOLOGICAL MAP OF
KICHNA NALA WATERSHED OF BAMARA BLOCK,
SAMBALPUR DISTRICT, ORISSA.
0.5 0 0.5 1 Kilometers
N
W
E
S
84°20'
84°22'
84°24'
21°56'
21°54'
21°52'
21°50'
21°48'
LEGENDS
WATERSHED BOUNDARY
RESIDUAL HILL
PEDIMENT
BURIED PEDIMENT (SHALLOW)
BURIED PEDIMENT (MEDIUM)
VALLEY FILL
LINEAMENTS

FIG - 4 4

2. Pediments (P)

Gently slopping isolated patches of rock surrounding the residual hills and ridges, which act as run-off zones, represent the pediment. Irregular dissected persons with a number of gullies are present in these regions. This is formed due to intensive weathering under semi-arid climatic conditions, representing final stage of cyclic erosion. They appear with gray tone on false colour composite image. Pediments are found around the residual hills and also in patches in the central part of the watershed. Such units cover an area of 2140.463 ha which is 44.352% of the total geographical area of the watershed. Sometimes it is transversed by fractures and joints permitting infiltration. The ground water potential is poor to moderate in such units.

3. Shallow weathered buried pediments (BPS)

This unit is basically a pediment zone and covered by various soil types. It consists of very low to moderately weathered zone with thickness of materials varying from 5 m to 15m. These units are found around the drainage lines of the study area and also in patches within the pediments. This covers an area of 2120.523 ha which is 43.938% of the total geographical area of the study area. The infiltration is moderate and ground water potential is moderate to poor in such units.

4. Moderately weathered buried pediments (BPM)

This unit is mainly formed due to high weathering of the horneblende biotitic gneisses under semi-arid climatic conditions. In this unit infiltration is moderately good. The thickness of weathered zone varies from 10m to 25m and favours a good amount of water to circulate within this zone before reaching the deeper fracture zone. Medium buried pediments are found around the main drainage line i.e. the Kichna nala and nearer to the watershed outlet. This covers an area of 321.165 ha which is 6.655% of the total area of the watershed. It favours a good amount of water to circulate within the zone before reaching the deep fractured zones. The ground water potential is good to moderate.

5. Valley Fills (VF)

Valley fills are consisting of unconsolidated alluvial materials like sand, silt and gravels, pebbles, etc. deposited along a valley. This unit acts as both recharging and discharging zones for ground water. Ground water occurs abundantly at shallow depth in this zone. The ground water potential is very good because of the topographical location at the bottom of the hill and geological composition consisting of highly porous materials. Depending upon the thickness of the fill, the prospect varies. Anamalously wide lateral extent is clearly indicative of the existence of palaeochannels. Sub-surface water potential is also good to excellent as the deposits harbour dense vegetation. It covers an area of 80.443 ha which 1.667% of the total watershed area.

6. Lineaments (L)

Lineaments are defined as the large-scale linear fractures, which express themselves in terms of topography of the under laying structural features. From the ground water point of view such features may include, valleys controlled by faulting and jointing, hill ranges and ridges, displacements and abrupt truncation of rocks, straight streams and right angles off setting of stream courses. The linear features can be measured and treated quantitatively like measurements of other geological properties, but it is necessary to use formal statistics that reflect the circular nature of the directional data.

Lineaments provide the pathway for groundwater movement and are hydrologically very important. Also they are important in rocks where secondary permeability and porosity dominant and inter-grannular characteristics combine in secondary openings influencing weathering and soil water and groundwater movements. The fracture zone forms an interlaced network of high transmissivity and serve as groundwater conduits in massive rocks in inter-fracture areas. The lineaments are tending in different directions extending over a considerable length and width (50-100m) in the sub-watershed. The lineament intersection points are considered as excellent groundwater potential zones.

In total, 16 lineaments were identified in the watershed and most of them are present in the northen part of the watershed. The lengths of the lineaments vary from 2 km to 5km.

4.4 GROUNDWATER POTENTIAL ZONES

Groundwater potential zones of the study area have been demarcated after integrating the geological and hydrogeomorphological data, recharge conditions of the terrain, lineament analysis and well details of the study area collected during the field verification. Five groundwater potential zones were identified as follows and also presented in fig - 4.5.

Excellent

The lineaments and the intersection points of lineaments are the excellent groundwater potential zones, which work as aquiducts and possess groundwater abundantly. The static water level may vary from 10m to 35m below ground level depending on the geomorphology. The yield in this zone is 200-300 lpm.

Good to very good

The geomorphic units in these zones are alluvial plains and valley fills which are found in pockets in the study area. Quaternary sediments mostly influence this zone. The aquifer materials are loose sediment in alluvial plain and unconsolidated sand and fractured rocks in valley fills. The static water level in this zone ranges between 15 to 25m bgl with a depth range between 50 to 120m are suggested which are expected to discharge 100 to 200 lpm with a high rate of homogeneity and success.

Moderate to good

This zone is dominated by alluvial plains, deep and moderate buried pediments mostly developed nearer to the drainage lines. The formations are mostly confined to weathered and fractured rocks, which influence the water table. The static water level of this zone ranges between 15 to 35m bgl and the recharge conditions are moderate to good. Suggested depth for tube wells is 70 to 120 m from which nearly 50 to 100 lpm of discharge is expected with a high rate of success for quaternary sediments and moderate rate of success for weathered and fractured rock aquifer.

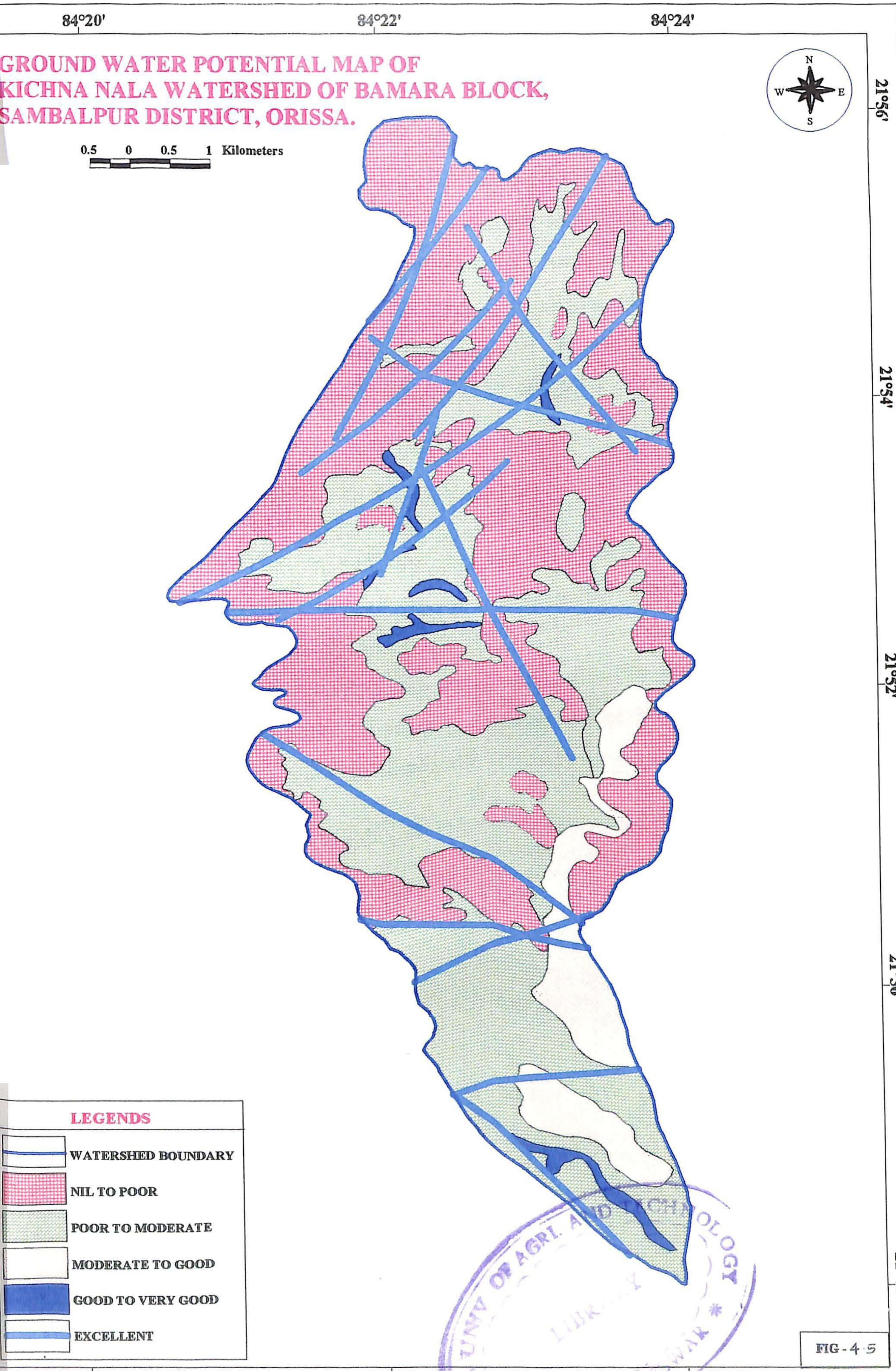

84°20'
84°22'
84°24'
GROUND WATER POTENTIAL MAP OF
KICHNA NALA WATERSHED OF BAMARA BLOCK,
SAMBALPUR DISTRICT, ORISSA.
0.5 0 0.5 1 Kilometers
N
W
E
S
21°56'
21°54'
21°52'
21°50'
21°48'
LEGENDS
WATERSHED BOUNDARY
NIL TO POOR
POOR TO MODERATE
MODERATE TO GOOD
GOOD TO VERY GOOD
EXCELLENT
84°20'
84°22'
84°24'

FIG - 4.5

Poor to moderate

This is mainly the shallow buried pediments which come under this zone. The aquifer material varies from loose sediments for alluvial plains to weathered and fractured rocks for buried pediments. The depth of weathering is low and not uniform. Therefore the aquifers in this zone are characterized by low yield, poor homogeneity and low to moderate rate of success. The recharge conditions are also either limited or moderate. Under these conditions, the suggested depth of tube wells varies between 60 to 100m which can yield 10 to 50 lpm.

Nil to poor

The geomorphic units of this zone are the pediments and the residual hills. Due to favorable slope conditions and surface characteristics, this zone is ideal for runoff generation and is not suitable for groundwater exploration, except the valley portion having very limited prospect. The aquifer are granite or / and quartzite formations having static water level 20 to 40m bgl. The expected discharge is less than 10lpm with poor recharge capacity.

Table-4.3 Groundwater potential zones of the study area

Sl. No.	Type	Geomorphological unit	Expected yield in lpm	Static water level bgl in m	Recharge condition
1	Excellent	Lineaments	200-300	10-35	Good
2	Good to very good	Alluvial plains, Valley fills	100-200	15-25	Moderate -good
3	Moderate to good	BPM,BPD, Alluvial plains	50-100	15-35	Poor-moderate
4	Poor to moderate	BPS, Pediments	10.50	20-35	Poor
5	Nil to poor	Pediments, Residual Hills (RH)	<10	20-40	--

4.5 GROUND TRUTHING

Basing upon the classification of ground water potential zones and geomorphic units in the Kichna nala sub-watershed, ground truthing was done to confirm the results. Wells (dug/tube) were observed at specific locations like lineaments, intersection of lineaments, pediments, BPM, BPS, Valley fills and their discharge were verified and found as per their classification.

4.6 BEST SITES FOR TUBE WELL CONSTRUCTION

The lineaments act as aqueducts and possess groundwater abundantly. The intersection points of lineaments are the most prospecting zones for groundwater with average yield of more than 300 lpm. Therefore, these intersection points are the most suitable site for tube wells. Basing upon the findings of the research work eighteen tube well sites have been proposed over the intersection points of lineaments in the watershed and are presented in the following table with their latitude and longitude. The proposed well sites are also represented in the road and location map of the study area in fig. 4.6.

Table - 4.4 Proposed tube well sites in the watershed

Sl.No	Latitude(N)	Longitude(E)	Village
1	$21^{0}55'12''$	$84^{0}22'12''$	Dumermunda
2	$21^{0}54'36''$	$84^{0}22'12''$	Baladmal
3	$21^{0}54'00''$	$84^{0}22'12''$	Charmal
4	$21^{0}54'00''$	$84^{0}22'48''$	Charmal
5	$21^{0}54'36''$	$84^{0}22'48''$	Solbaga
6	$21^{0}54'38''$	$84^{0}22'48''$	Solbaga
7	$21^{0}54'00''$	$84^{0}23'24''$	Kesaibahal
8	$21^{0}54'00''$	$84^{0}23'12''$	Kesaibahal
9	$21^{0}53'48''$	$84^{0}23'24''$	Kendumal
10	$21^{0}53'24''$	$84^{0}22'12''$	Balijori
11	$21^{0}53'24''$	$84^{0}22'12''$	Balijori
12	$21^{0}52'48''$	$84^{0}22'12''$	Kabaribahal
13	$21^{0}53'12''$	$84^{0}22'12''$	Segapara
14	$21^{0}52'48''$	$84^{0}21'36''$	Bandhkani
15	$21^{0}52'48''$	$84^{0}22'48''$	Kabaribahal
16	$21^{0}50'24''$	$84^{0}23'24''$	Lasratangar
17	$21^{0}50'24''$	$84^{0}22'48'$	Ardabahal
18	$21^{0}49'12''$	$84^{0}22'12''$	Ramtileimal

7Wellsite (736x1064x16M jpeg)

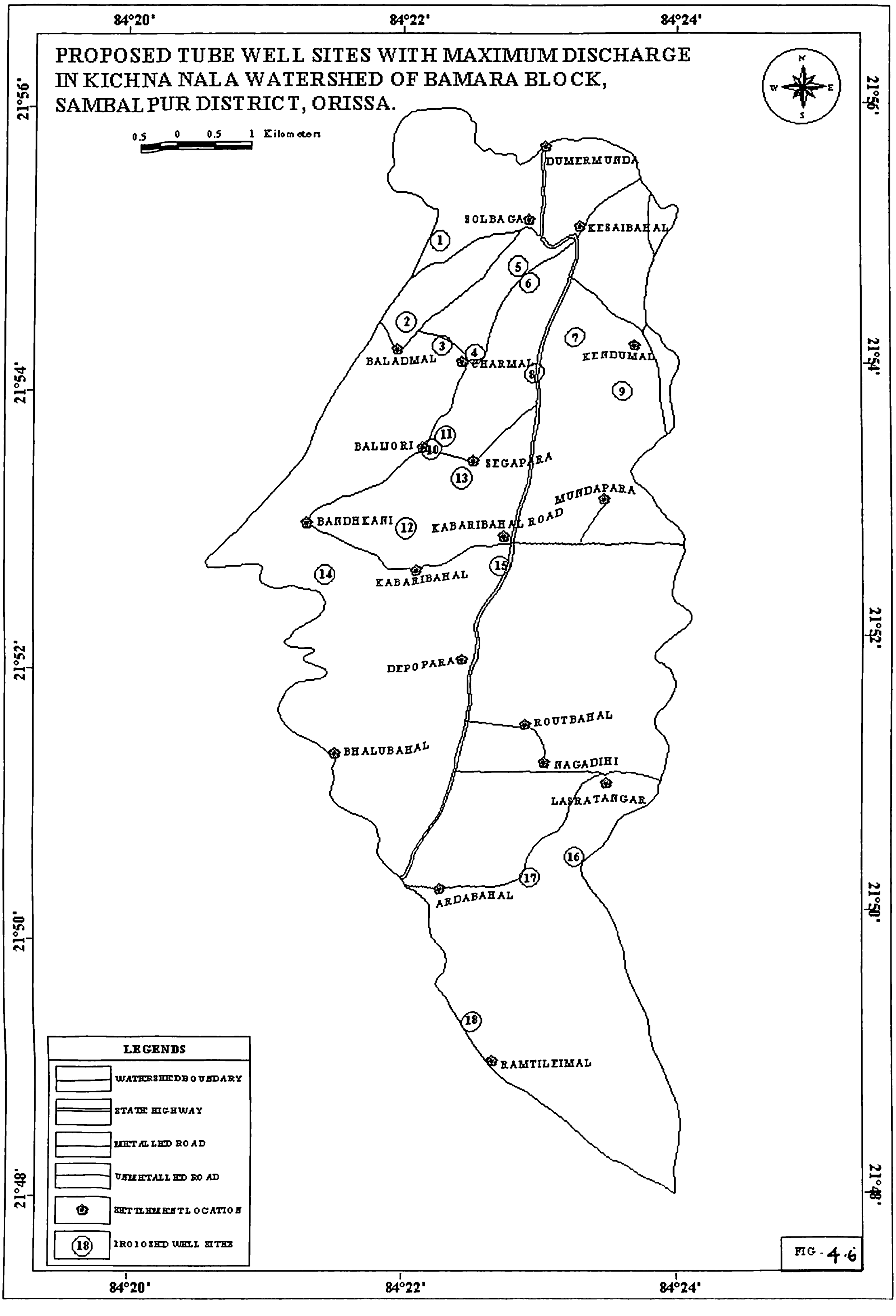


FIG-4.6

CHAPTER V

SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSION

5.1 SUMMARY

The present study entitled "INVESTIGATION OF GROUND WATER USING REMOTE SENSING AND GIS IN A WATERSHED - A CASE STUDY" was undertaken with the following objectives.

1. To visually analyse the Indian Remote Sensing data available in imagery form to demarcate the details of geology, hydrogeomorphology, land use / land cover, drainage and lineaments.
2. To integrate all the above maps to develop ground water potential map of the study area, and
3. To assess the ground water quality of the study area both for irrigation and domestic use by analyzing some samples collected from existing wells of the study area.

The watershed boundary of Kichna nala sub-watershed was delineated by using SOI toposheet and satellite imagery. The settlement location and road network map of the watershed was also prepared using the SOI toposheet. The present land use / land cover map of the watershed was prepared through visual interpretation techniques from IRS-ID LISS-III false colour composites to study the land use pattern. The drainage map was also prepared by tracing the primary, secondary and tertiary drainage lines from the SOI toposheet and satellite imageries. The hydrogeomorphological map was prepared by demarcating the geomorphic units to study the geomorphological features of the study area.

All the above said thematic maps were scanned, digitized, edited, labeled and analysed in GIS by using different software packages like R2V~2.1, ARC/INFO ~7.2 and ARC/VIEW~3.2 etc. to prepare the final maps. Eventually the final drainage map, hydrogeomorphological map, land use / land cover map and the well inventory data collected from the field were integrated in GIS to prepare a final ground water potential map of the study area. In this map the study area has been classified into five zones depending upon the ground water potential of the watershed.

5.2 CONCLUSIONS

1. The IRS data is superior to the information derived from the toposheets in many ways.

2. Kichna nala sub-watershed comprises rural settlements and partially developed transport network.

3. False Colour Composites (FCCs) can be effectively used for determining the ground water prospect and the zones of ground water exploitation.

4. Kichna nala sub-watershed is a potential region for agricultural development. Agriculture alone occupies about 64.212% of the total geographical area of the watershed, but most of the agricultural lands are single cropped (56.487% of the total area).

5. The Kichna nala watershed has been classified into 5 ground water potential zones depending on discharge and geomorphic units, such as Excellent (200-300 lpm), Good to very good (100-200 lpm), moderate to good (50-100 lpm), poor to moderate (10-50 lpm) and Nil to poor (<10 lpm).

6. The Kichna nala sub-watershed has good to very good ground water prospect in an area of 401.608 ha (BPM-321.165 ha and VF-80.443 ha) which is 8.32% of the total area, moderate to good in an area of 2120.523 ha (BPS) and nil to poor in an area of 2303.972 ha (RH-163.509 ha and Pediments -2140.463 ha) besides the lineaments which are excellent ground water potential zones.

7. Lineaments, which are the excellent zone for ground water prospecting are found 16 in numbers in the watershed with their lengths varying from 2 km to 5 km and width 50m to 100m.

8. Out of the 16 lineaments identified most of them are found in the northern part of the watershed.

9. The intersection of lineaments are the best ground water prospecting zone with discharge of more than 300 lpm and high recuperation rate.

10. Analysing the lineaments intersection points and ground verification in the watershed, eighteen sites have been selected and suggested for tube well construction with their latitude and longitude.

11. Dug wells can also be constructed in moderately weathered buried pediments and lineaments with very good discharge.

12. Remote sensing technique and GIS tools were proved to be very effective in investigation of ground water.

CHAPTER VI

SUGGESTIONS FOR FUTURE WORK

SUGGESTIONS FOR FUTURE WORK

Followings are the suggestions for future work for the exploitation of ground water and integrated development of the Kichna nala sub-watershed.

☞ The ground water potential map of the Kichna nala sub-watershed was developed by using Remote Sensing and GIS techniques. This technique may be further extended for the development of the ground water potential map for other watersheds of the Block and the District.

☞ The potentiality and the sustainability of ground water in the watershed may be assessed using remote sensing and GIS.

☞ Remote sensing and GIS techniques can also be used for the development of watershed management plan for the watershed.

☞ The different units of thematic maps may be interpreted by digital image processing technique in GIS through supervision or non-supervision or fuzzy methods with steps like image restoration, image enhancement and image extraction etc. instead of visual interpretation technique.

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APPENDICES

Rainfall data of Bamara Block, Sambalpur District.

Year	Collected information of rainfall data for different months of Millimeter											Total Annual Rainfall in mm			
	June	July	August	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Monsoon	Non-monsoon	Total
[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10[	[11]	[12]	[13]	[14]	[15]	[16]
1988-1989	288.4	321.8	403.6	144.6	6	--	--	--	--	--	--	5.8	1164.4	5.8	1170.2
1989-1990	411.2	400	198.3	259.8	--	--	--	--	31.6	12.9	80.1	103.7	1269.3	228.3	1497.6
1990-1991	76.7	420.1	100.9	176.8	134.3	11	--	30.8	--	8.6	8	--	908.8	58.4	967.2
1991-1992	119.6	275.4	642.4	246.8	57	42	34.2	--	7.2	2.6	20.4	53.6	1341.2	160	1501.2
1992-1993	84	324.4	374	142.8	1.2	28.2	--	--	--	17.8	16.2	84	926.4	146.2	1072.6
1993-1994	549.4	334	276	324.2	61.2	--	--	--	--	--	--	--	1544.8	0	1544.8
1994-1995	450.3	807.5	332.1	--	55.8	--	--	33	27.4	20	22.2	53.6	1645.67	156.2	1801.87
1995-1996	127	406	401.6	245.6	36.4	106.2	--	--	--	--	--	--	1216.6	106.2	1322.8
1996-1997	131.2	493.5	373.5	151.5	15.3	--	--	--	--	--	12.8	--	1165.014	12.8	1177.81
1997-1998	252.4	351.1	390.4	137	--	96.2	91.6	148.6	--	9.6	10.4	43	1130.9	399.4	1530.3
1998-1999	111	265.5	337.8	515.2	147.3	62.4	--	--	--	--	--	118.4	1376.8	180.8	1557.6
1999-2000	331.2	264.5	420.6	309.8	63	--	--	5.2	18.5	--	2.6	36	1389.1	62.3	1002.8
2000-2001	216.2	346.4	133.6	175	--	--	--	--	--	55.6	15	61	871.2	131.6	1149
2001-2002	311.2	825.6	262.2	--	--	--	--	30	--	9	--	11	1399	50	--
2002-2003	174.6	116.4	291.4	--	23.4	--	--	--	--	--		--	965.6	--	--

Appendix - II

DATA VALIDATION SHEET ON GROUND WATER QUALITY ANALYSIS OF BAMARA BLOCK

QUALITY NETWORK STATION DETAILS															
												Field determination			
Sl. No.	Location of Observation wells	Well Type	Station Code	Station Type	Well Use	Basin	Aquifer - Kind	Aquifer - Type	Lab. Sample No.	Date of Collection	Date of Analysis	pH	EC, µmhos/cm	Temp., oC	Colour Code
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
(1) Pre-monsoon period, 1998 (Baseline)															
1	Bamra	B	28M02A01	B	M	M	WR	P							
2	Juraboga	D	28M02M05	B	D	M	WR	P							
3	Juraboga	B	28M02A02	B	M	M	WR	P							
(2) Pre-monsoon period, 1999 (Baseline)															
1	Bamra	B	28M02A01	B	M	M	WR	P							
2	Juraboga	D	28M02M05	B	D	M	WR	P							
3	Juraboga	B	28M02A02	B	M	M	WR	P							
(3) Pre-monsoon period, 2000 (Baseline)															
1	Bamra	B	28M02A01	B	M	M	WR	P							
2	Juraboga	D	28M02M05	B	D	M	WR	P	379-1	18.04.2000				36	7
3	Juraboga	B	28M02A02	B	M	M	WR	P	380-1	18.04.2000				36	7
(4) Pre-monsoon period, 2001 (Baseline)															
1	Bamra	B	28M02A01	B	M	M	WR	P	070-1	21.02.2001		6.9	0.78	26.2	7
2	Juraboga	D	28M02M05	B	D	M	WR	P	100-1	22.05.2001				32.9	7
3	Juraboga	B	28M02A02	B	M	M	WR	P	109-1	22.05.2001				32.9	7
(5) Pre-monsoon period, 2002 (Baseline)															
1	Bamra	B	28M02A01	B	M	M	WR	P	258-1	5/25/02	6/7/02			27	7
2	Juraboga	D	28M02M05	B	D	M	WR	P	219-1	5/25/02	6/7/02			24.3	7
3	Juraboga	B	28M02A02	B	M	M	WR	P	224-1	5/25/02	6/7/02			28.1	7

REFERENCE :

Col. 3		Col. 5		Col. 6	Col. 7		Col. 8		Col. 9	
B	Bore Well	T	Trend Analysis	M - Monitoring	M	Mahanadi	WR	Weathere	P	Phreatic
D	Dug Well	B	Base Line Survey	D - Domestic use						

Source : DIRECTORATE OF GROUND WATER SURVEY & INVESTIGATION, ORISSA, BHUBANESW

ANALYSIS RESULTS

General							Alkalinity		Hardness		Major Ions				
Odour Code	Turbidity	pH	EC µmhos/cm	TDS mg/L	Temp.in degree C0	TS mg/L	Phen, as $CaCO_3$ mg/l	Total, as $CaCO_3$ mg/l	Total $CaCO_3$, mg/l	Ca, as $CaCO_3$, mg/L	Ca, mg/l	Mg, mg/L	Na, mg/L	K, mg/L	Cl, mg/L
17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
1		8.3		505		12	164	128	68	27.2	14.4			62.4	
1		8.1		301.5		0	80	44	28	11.2	3.84			22.69	
1		7.9	0.4	222		0	96	84	72	28.8	2.88	16		28.36	0
1		9.36	0.63	321		28	160	208	56	22.4	30.47	19	11.4	56.72	0
1		7.26	0.27	178		0	76	68	32	12.8	8.64	15.1	8.5	28.36	0
1	0	8.21	0.41	287	27		0	56	168	96	38.4	17.28	26.9	5.5	79.4
1	0	8.569	0.554	399	27		12	156	250	76	30.4	39.3	2.7	5.7	65.22
1	0.5	8.019	0.214	177.6	27		0	72	84	48	19.2	8.64	6	1.1	28.36

								Ion Balance		Carbonate Balance		
So_4, mg/L	Co_3, mg/L	HCo_3, mg/L	F, mg/L	NO_3, mg/l	NO_2, mg/l	Total Cations	Total Anions	(Total Cations - Total Anions) / (Total Cations + Total Anions)	Sodium / Chloride	If pH < 8.30 Is Phenol Alkalinity = 0 ? Write Yes or No	Remarks	TDS/EC
33	34	35	36	37	38	39	40	41	42	43	44	45
14.4	171										Excellent	
0	97.6										Excellent	
0	117.12		6.9				-0.07	0.86		Yes	Excellent	
33.6	126.88		5.65		0.4		0.05	0.33		No	Good	
0	92.72		6.1		0.3		-0.02	0.53		No	Good	
0.8	0	68.32	0	9.8		4.64	3.36	0.16	0.5	yes	good	0.7
12	14.4	161.04	0	12		5	4.96	0.004	0.06	no	good	0.72
1.9	0	87.84	0	5.25		1.95	2.27	-0.06	0.32	yes	excellent	0.83

APPENDIX-III

VES FINDINGS OF B/W SITES OF BAMARA BLOCK

Sl. No.	Name of the villages & name of the beneficiary	Testing Results		
		Res in ohm-mt	Thichness mt	Probable withologs
1.	GOVINDPUR (Jagannath Pr Choudhury	269.4 164.6 756.4	1.0 8.5 ∞	Laterite soil Laretire Hard rock
2.*	BAMPHEI (Sashi Bhusan Patel)	38.3 13.8 76.1 12.5 344.5	1.7 0.5 12.3 23.9 ∞	Sandy-clay Clay-loam Weathered zone May befractured Partly weathered rock
3.	HARIPARA (Chandra Kishan)	249.8 50.1 1301.7	1.4 7.7 ∞	Top soil Weathered rock Hard rock
4.	NUNIAMUNDA (Pabitra Ku. Chhatria)	48.7 7.4 2287.7	1.4 5.5 ∞	Top soil Highly weathered rock Hard rock
5.	LOLOBIRA (Chamar pradhan)	43.9 17.3 1076.5	1.0 4.3 ∞	Top soil Highly weathered rock Hard rock
6.	RAJBASA (Nityananda Chhatria)	360.5 127.8 2821.5	0.4 10.8 ∞	Top soil Weathered rock Hard rock
7.	SOLBAGA (Jagneswar Patel)	46.6 60.7 942.0	2.9 7.8 ∞	Sandy clay Weathered rock Hard rock
8.	SEGAPARA (Karam Kishan)	296.8 57.0 160.6 938.0	1.0 3.3 20.8 ∞	Top soil Sandy clay Weathered zone Hard rock
9.	BHIKAPALI (Patnakar Patel)	154.0 40.9 1316.1	6.3 3.4 ∞	Sandy clay Weathered zone Hard rock
10.	NUADIHI (Surendra Pr. Patel)	303.4 26.1 % 31824.5	1.6 5.2 ∞	Lateritic soil Weathered rock Hard rock
11.	KHOLBILUNG (Mahendra Naik)	17.0 75.4 1894.2	1.5 16.7 ∞	Top soil Weathered rock Hard rock
12.	BILUNG (Kokila ch. Patal)	286.2 %201231.8 % 10605 1171.6	72.4 %1784.7 %20892.22 ∞	Lateric soil Hard rock Hard rock Hard rock
13.	BHAGAPADA (Bhikari Ch. Patel)	87.2 12.7 1333.5	1.6 6.2 ∞	Top soil Weathered rock Hard rock
14	DUNGAJORE (Haldhar Patel)	114.8 52.2 31.7 34.7 516.0	1.5 4.9 7.0 9.4 ∞	Sandy soil Clay loam Weathered zone Fractured zone Hard rock
15.	GARPOSH (Kamal Ku. Kedia)	213.8 100.4 2382.1	2.4 3.6 ∞	Sandy loam Weathered rock Hard rock

* Found fesiable for ground water exploration.

Source : Groundwater Survey & Investigation, Sambalpur.

APPENDIX - IV

RESISTIVITY VALUE OF SOME COMMON ROCK TYPE

Sl. No.	Rock Type	Resistivity (ohm-m)
1.	Top soil	5-50
2.	Peat and clay	8-50
3.	Clay sand and Gravel mixture	40-250
4.	Saturated sand and Gravel	40-100
5.	Moist to dry sand and Gravel	100-3000
6.	Mudstones, Marls and Shales	8-100
7.	Sandstones and Limestones	100-1000
8.	Crystalline Rocks	200-10000

APPENDIX - V

LAND USE / LAND COVER CLASSIFICATION SYSTEM

1. Built up land	1.1 Built up land
2. Agricultural land	2.1 Crop land
	i) Kharif
	ii) Rabi
	iii) Kharif + Rabi
	2.2 Fallow land
	2.3 Plantation
3. forest	3.1 Evergreen / Semi-evergreen forest
	3.2 Deciduous forest
	3.2.1 Open forest
	3.2.2 Dense forest
	3.2.3 Degraded forest
	3.3 Degraded on scrub land
	3.4 Forest Blank
	3.5 Forest plantation
	3.6 Mangrove
4. Wastelands	4.1 Salt affected land
	4.2 Water logged land
	4.3 Marshy / Swampy land
	4.4 Gullied / ravenous land
	4.5 Land with or without scrub
	4.6 Sandy area (coastal and desertic)
	4.7 Stone quarry
	4.8 Barren rocky
5. Water bodies	5.1 River / Stream
	5.2 Lake / Reservoir / tank / canal
6. Others	6.1 Shifting cultivation
	6.2 Grass land / grazing land
	6.3 Snow covered / glacial area.

Dedicated to my friend

"SUDEEPTA"