सत्यमेव जयते

Government of India

Ministry of Water Resources, River Development & Ganga Rejuvenation

A report

on

Problems of Salination of Land in Coastal Areas of India and Suitable Protection Measures

Hydrological Studies Organization

Central Water Commission

New Delhi

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FOREWORD

Salinity is a significant challenge and poses risks to sustainable development of Coastal regions of India. If left unmanaged, salinity has serious implications for water quality, biodiversity, agricultural productivity, supply of water for critical human needs and industry and the longevity of infrastructure. The Coastal Salinity has become a persistent problem due to ingress of the sea water inland. This is the most significant environmental and economical challenge and needs immediate attention.

The coastal areas are more susceptible as these are pockets of development in the country. Most of the trade happens in the coastal areas which lead to extensive migration in the coastal areas. This led to the depletion of the coastal fresh water resources. Digging more and more deeper wells has led to the ingress of sea water into the fresh water aquifers turning them saline. The rainfall patterns, water resources, geology/hydro-geology vary from region to region along the coastal belt. These affect the extent of salinity along the coast. The whole coast line is affected by salinity although the extent of salinity is not the same.

To understand the effect of salinity in coastal States and the remedial measures adopted by them to tackle this problem, a Technical Committee has been formed with the members from Coastal States, Central Ground Water Board, Geological Survey of India and National Institute of Hydrology. This committee has made studies on the measures adopted by various coastal States to tackle the sea water ingress in coastal areas.

I take immense pleasure in presenting this report on "Problems of Salination of Land in Coastal Areas of India and Suitable Protection Measures". I would like to place on record the earnest efforts of Shri Ashwin B Pandya and Shri Ghanshyam Jha, both former Chairman, CWC and Chairman of the Technical Committee for guiding the entire team in the preparation of this report. I would like to compliment officers and staff of Hydrological Studies Organization of CWC for their efforts in preparing this report. I also express my sincere thanks to National Institute of Hydrology, Coastal State Governments, Central Ground Water Board and Geological survey of India for providing the necessary input for preparing and enhancing the effectiveness of contents of this report.

I hope this report will be useful for taking suitable measures to address the salinity ingress along the coastal areas.

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PROLOGUE

Coastal land salinity problems, commonly encountered along the long coastline of India, are attributed to the phenomenon of saltwater intrusion. Intrusion may occur through surface water bodies connected to the sea, such as estuaries and rivers, up to several kilometres inland from the river mouth which affects the agricultural, industrial and drinking water supply of adjoining coastal lands. At many locations, sea water entering through the creeks during high tides may submerge large areas of cultivable land that renders the fertile land progressively saline making it unfit for crop cultivation.

Saltwater intrusion in coastal regions acquires more serious dimensions when the intrusion occurs into the freshwater aquifer systems. The extent of subsurface saltwater intrusion may vary widely from place to place, e.g. in some instances, the area contaminated by saltwater is limited to small parts of an aquifer and to specific wells; in other instances, saltwater contamination is of regional extent and severely affects the groundwater supply of the region. Variations in hydrogeologic settings, spatial distribution of saline water, and history of groundwater withdrawals and freshwater drainage may lead to different pathways of saltwater intrusion into coastal aquifers. Suitable actions are needed to manage and prevent saltwater intrusion to ensure a sustainable development and socio-economic growth of the coastal regions of the country.

This report discusses in detail the occurrence of coastal land salinity, its impact on crop yield and environment, and various management techniques to mitigate the adverse impacts, including those of coastal flooding arising from storm surges and anticipated climate change. The state-wise physiography and drainage, hydrogeology, and, causes and extent of coastal land salinity along with suitable remedial actions taken up by the coastal states / union territories of India are dealt with separately in another chapter. The final chapter brings out the future programs proposed by the coastal states / union territories for mitigation of coastal land salinity.

The comprehensive report has been put together by the joint efforts of Central Water Commission and National Institute of Hydrology, Roorkee with support from various Central Agencies especially Central Ground Water Board and State Agencies of all coastal states and union territories. The inputs provided by scientists and engineers of both organizations including Dr. Anupma Sharma, Scientist, National Institute of Hydrology, Roorkee, are highly appreciated.

I am confident that the report will prove to be immensely useful in formulating and adopting suitable plans and policies for combating coastal land salinity in India.

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Preface

Salinity ingress in coastal areas is one of the major challenges for water resources planners of India. Salinity ingress in coastal areas poses a risk to the sustainable development of the coastal areas. Proactive salinity management is required to arrest the coastal salinity ingress.

In this report the suitable protection measures which have been adopted for protecting the coastal lands from salinity intrusion have been discussed. Some of these measures are already being implemented / adopted by some of the Coastal States, and other Coastal States may adopt such measures after duly considering local conditions.

The Hydrology (Central) Directorate of the Hydrological Studies Organisation (HSO) has made considerable efforts in co-ordinating with the state governments to prepare the report which has been titled as "Problems of Salination of Land in Coastal Areas of India and Suitable Protection Measures". National Institute of Hydrology provided technical information which was available with them while undertaking different studies on water management in Coastal States. The report is an outcome of dedicated efforts of scientists of National Institute of Hydrology, officers of Hydrology (Central) Directorate of Central Water Commission.

I express my sincere regards to Shri Ashwin B Pandya and Shri Ghanshyam Jha, both the former Chairman, CWC and Shri Narendra Kumar, Chairman, CWC and the Chairman of the Technical Committee for guiding the team with valuable suggestions and guidance for preparing the report. I would like to compliment the officers and staff of Hydrology (C) Directorate specially for their efforts in co-ordinating with States and for bringing out this report. I would like to thank Ms Anupama Sharma, Scientist-D, National Institute of Hydrology for providing valuable support in preparing the Report.

I would like to thank the State governments in providing the valuable information without which this report would have never been complete.

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CHAPTER 0

TECHNICAL COMMITTEE FOR ADOPTING SUITABLE PROTECTION MEASURES FOR PREVENTION OF SALINITY INGRESS IN THE COASTAL STATES/UNION TERRITORIES

0.1 INTRODUCTION

Salinity is the presence of soluble salts in soils or waters. Salinity processes can be natural linked with landscape and soil formation processes. The human activities can, however, accelerate salinity processes, thereby further aggravating the land and water degradation of the affected region. It can be a water issue when the potential use of water is limited by its salt content or its salt composition. It also becomes a land use issue when the concentration of salt or sodium adversely affects plant growth, degrades soil structure or causes soil erosion.

Salinity is an acute problem in the coastal States / UTs of Gujarat, Maharashtra, Goa, Karnataka, Kerala, Tamil Nadu, Andhra Pradesh, Odisha, West Bengal, Daman & Diu, Puducherry, Andaman & Nicobar Islands and Lakshadweep Islands. In the meeting taken by Hon'ble Prime Minister on 19.06.2014 the activities of various Ministries / Departments (viz. D/o Food & Public Distribution, D/o Consumer Affairs and M/o Water Resources) were reviewed and it was decided that the "Ministry of Water Resources will examine the problem of salination of land along the coast in a scientific manner with the help of the experts and suggest remedial measures. The State of Gujarat has implemented certain projects in this regard including damming rivers at their mouth to create fresh water banks which prevent ingress. The Ministry will study these models and prepare an action plan thereafter".

0.2 FORMATION OF THE TECHNICAL COMMITTEE

The adoption of suitable protection measures for prevention of salinity ingress depends upon various factors including site specific conditions, hydrology or availability of water resources; geology/ hydro-geology of area; suitability of site for construction of barrage or weir for storing surface water and for subsequently using them for maintaining the hydrological gradient towards sea side etc. It has therefore, been decided to prepare a broad outline report in consultation with State Governments/Union Territories and specialised organisation of State Government /Government of India in the related field. The scope of the report will be to provide broad outline of the measures to be taken to arrest or minimize the salinity ingress in the coastal States/Union Territories.

For this purpose a Technical Committee under Chairmanship of the Chairman, Central Water Commission was constituted vide order no. CWC/3/5(A)/Hyd(C)/2014/141-175 dated 03.09.2014 (copy kept at Appendix-I) with the following composition;

1	Chairman, Central Water Commission & Ex-officio Secretary to Government of India	Chairman
2	Chairman, Central Ground Water Board	Member
3	Ground Water Experts/Engineer-in-chief/Chief Engineer/Chief Engineer of Coastal States/UTs	Member
4	Chief Engineer, Designs (NW & S), CWC	Member
5	Engineering Geologist from Geological Survey of India	Member
6	Director, National Institute of Hydrology	Member
7	Scientist, NIH Roorkee	Member
8	Chief Engineer, HSO, CWC	Member-Secretary

0.3 FIRST MEETING OF THE TECHNICAL COMMITTEE

The 1st Meeting of Technical committee for adopting suitable protection measures for prevention of salinity ingress in the coastal states/union territories was held at Sewa Bhawan, CWC, New Delhi on 30th September, 2014. The State governments have attended the meeting and provided certain inputs in this regard. The Summary Record of Discussions of this meeting is given at Appendix-I.

0.4 SECOND MEETING OF THE TECHNICAL COMMITTEE

The 2nd Meeting of Technical Committee was held on 27th November 2014 under the Chairmanship of Chairman, Central Water Commission. The Members /representatives of the States and UTs have presented various measures adopted to arrest the salinity ingress and their future plan in this regard. The Summary Record of the Discussions of this meeting is given at Appendix-II.

0.5 THIRD MEETING OF THE TECHNICAL COMMITTEE

The 3rd Meeting of Technical Committee was held on 29th April 2016 under the Chairmanship of Chairman, Central Water Commission. In this meeting, proposals received from the member states and the concluding chapter "The Recommendations of the Committee" were discussed. The Summary Record of the Discussions of this meeting is given at Appendix-III.

0.6 EARLIER WORKS DONE FOR ADDRESSING THE PROBLEM OF COASTAL PROTECTION

Realizing the need of overall planning and cost effective solution to the coastal problems, the Govt. of India constituted the Beach Erosion Board in the year 1966 under the Chairmanship of Chairman, CWC (erstwhile CW&PC) initially, to guide and implement the programme of anti-sea erosion works in Kerala only. Chief Engineer-in-Charge of anti-sea erosion works of Kerala was appointed as the Member-Secretary. Besides the Chairman and Member-

Secretary, the Board comprised three Members, including Director, CW&PRS, Pune. The Govt. of India reconstituted the Board in 1971 and further in 1989 extending its jurisdiction to the entire coastline of the country. The Board held 24 meetings in all.

0.6.1 COASTAL PROTECTION AND DEVELOPMENT ADVISORY COMMITTEE (CPDAC)

With the objective of the development in the protected coastal zone and the pressure of population in the densely populated area in the coastal zone, the Beach Erosion Board was reconstituted and renamed as "Coastal Protection and Development Advisory Committee" (CPDAC) vide MoWR Resolution No.15/2/91-BM dated 17th April, 1995 with its Secretariat at the Central Water Commission to identify and develop the various resource potential available behind the protected areas. This committee was chaired by Member (RM), CWC with Chief Engineer (FMO) as the Member Secretary and having representations from all the coastal states/UTs. Coastal Protection and Development Advisory Committee provides a common platform to all concerned maritime States/UTs to discuss issues related to coastal protection and development. The Committee has given its recommendations in the past on various coastal related issues. The committee has so far held 14 meetings, with the last meeting being held in Goa, during 27-28th February, 2014.

0.6.2 SUB-COMMITTEES OF CPDAC

Sub-Committee of CPDAC on Performance Evaluation:

During the discussions of the 6th Meeting of CPDAC held at Puducherry on 7th April 2004, deliberations were held on the function (iv) of the CPDAC Resolution vide which CPDAC is mandated to "Review the performance of the work carried out by the States and evolve improved design techniques based on such experience from time to time." In view of this, Chairman, CPDAC constituted a Sub-Committee of CPDAC on Performance Evaluation, to visit sites in maritime States/UTs and submit its report to CPDAC.

The Terms-of-References (ToR) of the Sub-Committee were to review the performance of the works carried out by the States and evolve improved design techniques, and to arrange effective and timely monitoring of the coastal protection and development projects.

Sub-Committee has held various Meetings to review the performance of the coastal protection works. The sixth meeting of the Sub-Committee on Performance Evaluation of Coastal Protection Works was held at Gujarat in June, 2015 and the Report of the Sub-Committee was submitted to the CPDAC Secretariat in October, 2015.

Sub-Committee of CPDAC on Coastal Atlas:

In pursuance of the decision taken in the 11th Meeting of CPDAC held at Chennai during 4-5th January 2010 and to facilitate the preparation of the Coastal Atlas, a Sub-Committee of CPDAC on Coastal Atlas was reconstituted vide OM dated 29th January 2010. Since then, the reconstituted Sub-Committee on Coastal Atlas has had 2 meetings. The last meeting of the Reconstituted Sub-Committee on Coastal Atlas was held at CWC-HQ, New Delhi on 23rd September 2011.

Based on the Decision taken in the 11th CPDAC Meeting held at Chennai during 4-5th January 2010, the preparation of Shoreline Change Atlas of Indian Coast was initiated by Space Application Centre (SAC), Ahmedabad in collaboration with Central Water Commission. In the 14th CPDAC Meeting held at Goa during 27-28th February 2014, the publication of the prepared Shoreline Change was accepted by the committee. Further, the Shoreline Change Atlas was published in the Brain-Storming Workshop on "Implementation of Coastal Management Information System" held at CWC, New Delhi on 13/05/2014. Atlas has been prepared by SAC in six volumes as detailed below.

- Volume 1 covering Gujarat, Daman & Diu,
- Volume 2 covering Maharashtra & Goa,
- Volume 3 covering Karnataka & Kerala,
- Volume 4 covering Tamil Nadu, Puducherry & Andhra Pradesh,
- Volume 5 covering Odisha & West Bengal
- Volume 6 covering Lakshadweep & Andaman & Nicobar islands

SAC Ahmedabad has been requested to update the shoreline change data for 2012-13 time frame.

Sub-Committee of CPDAC on Coastal Data Collection:

In the 13th Meeting of CPDAC held at Mangalore on 9-10th February 2012, it was decided to constitute a Sub-Committee of CPDAC on Coastal Data Collection, Compilation and Publication. This Sub-Committee was constituted in January 2013. The First Meeting of Sub-Committee of CPDAC on Coastal Data Collection, Compilation and Publication was held under chairmanship of Chief Engineer (FM), CWC on 7th October, 2013 at CWC- HQ, New Delhi to discuss various issues on coastal data collection. The sub-committee discussed and finalized the list of parameters, frequency, methodology & schedule of observations for coastal data to be collected and format for compilation of selected parameters.

0.6.3 NATIONAL COASTAL PROTECTION PROJECT (NCPP)

NCPP was initiated with a view to explore the possibility of funding coastal protection works through external assistance. Currently two projects namely Ullal Coastal Erosion & Inlet Improvement Project in Karnataka and Mirya Bay Coastal Erosion and Protection Project in Maharashtra are under implementation under ADB aided Sustainable Coastal Protection and Management Investment Programme.

Considering the problems faced by the State Govts./Union Territories in taking up the anti-sea erosion works due to paucity of funds, the Beach Erosion Board (now renamed as Coastal

Protection & Development Advisory Committee), in its 23rd meeting held in July, 1994, requested the maritime States to formulate the proposals for protection of vulnerable coastal reaches from sea erosion in their respective states and send the proposals to Central Water Commission who will coordinate and prepare a consolidated National Coastal Protection Project (NCPP) based on proposals received from State Govts. for posing the same for external assistance.

Accordingly, the State Governments of Andhra Pradesh, Goa, Gujarat, Karnataka, Kerala, Maharashtra, Orissa, Tamil Nadu and West Bengal submitted their proposals for inclusion in the NCPP. These proposals were examined and compiled in Central Water Commission and a consolidated National Coastal Protection Project (NCPP) estimated to cost Rs. 1275.74 crore was prepared and submitted to Ministry of Water Resources in February 1999, for identifying the Funding Agency. In reply, Ministry of Water Resources advised to forward the NCPP along with necessary TAC/Investment clearance.

Meanwhile NCPP proposal, costing Rs.1275.74 crore was modified to Rs.1323.832 crore after incorporating the revised proposal of Goa and Gujarat.

As a part of a process of obtaining TAC/Investment clearance for the NCPP, copies of the consolidated National Coastal Protection Project were sent to various departments such as CW&PRS, Planning Commission, Ministry of Environment & Forests, Ministry of Surface Transport, National Institute of Oceanography, Chief Engineer (Project Appraisal), CWC and Director, Cost Appraisal (Irrigation), CWC, for their comments. The comments, received from the various departments, were sent to State Govts. in August, 1999, to recast their proposals in the light of the observations offered by various aforesaid agencies.

The consolidated report of National Coastal Protection Project (Phase–I), estimated to cost Rs. 623.702 crore, was prepared and submitted to Ministry of Water Resources in July 2002 incorporating proposals of the States of Karnataka, Maharashtra, West Bengal and UT of Pondicherry. Further, in a meeting held on 23rd August 2002 under the Chairmanship of Secretary (WR) to discuss National Coastal Protection Project Phase – I, it was decided that CWPRS may examine project report of NCPP Phase – I before processing it further and submit its report. The comments of CWPRS on NCPP Phase-I were received in December 2002, which were examined and the observations of CWC in respect of comments of CWPRS on NCPP Phase-I were sent to Ministry of Water Resources in January 2003. Meanwhile the NCPP proposals of Orissa and Tamilnadu States were also included in the consolidated report of National Coastal Protection Project and thereby, the cost of National Coastal Protection Project was revised to 1095.911 crore.

The revised consolidated report of National Coastal Protection Project (Phase – I), estimated to cost Rs. 1095.911 crore, incorporating proposals of states of Karnataka, Maharashtra, Orissa, Tamilnadu, West Bengal and UT of Pondicherry, was sent to Ministry of Water Resources in December 2002 for further necessary action. It was decided to take up the proposals of the remaining maritime States/UTs (Andhra Pradesh, Goa, Gujarat, Kerala, and UTs of Andaman & Nicobar Islands & Lakshadweep), which were likely to take more time for finalization due to delay in State TAC clearance and non-compliance of CWC's comments by State Governments/UTs, under National Coastal Protection Project (Phase-II).

In July 2004, Ministry of Water Resources directed to reformulate the National Coastal Protection Project covering all (12) maritime States/UTs. The consolidated National Coastal Protection Project (NCPP) is to be formulated after finalization of proposals of all the coastal States & UTs for protection of coastal areas from sea erosion with a view to explore possibilities of funding through external resources or other domestic resources. The proposals of Kerala, Maharashtra, Orissa, Tamilnadu, West Bengal and UT of Pondicherry have been found acceptable for inclusion in the Project, while; the compliance to CWC comments was not received from the coastal States of Andhra Pradesh, Goa, Karnataka and UT of Lakshadweep. Further action on compliance to CWC comments received from the Gujarat Government in February 2008 has not been taken since the Gujarat Govt. proposed same schemes under Flood Management Programme. The UT of Andaman & Nicobar Islands did not submit any proposal under NCPP. The NCPP was proposed to be completed within a period of five years.

Funding for NCPP could not materialize. Later on since XI Plan, specific anti-sea erosion problems are now being addressed under State Sector – Flood Management Programme of Ministry. Also as an outcome of discussions between the Government of India and the Asian Development Bank (ADB), a Project Preparatory Technical Assistance (PPTA) programme for preparing a Sustainable Coastal Protection and Management Project for the states of Maharashtra, Karnataka & Goa was taken up.

As an outcome of discussions between the Government of India and the Asian Development Bank (ADB), a Project Preparatory Technical Assistance (PPTA) programme for preparing a *Sustainable Coastal Protection and Management Project* for the states of *Maharashtra, Karnataka & Goa* was taken up.

PPTA Final report was completed in May 2009. Under PPTA an investment programme estimating to $404.6 million USD (revised) including ADB loan of $250 million has been envisaged. Further, the multi-tranche facility (MFF) for project was approved by ADB on 29th September, 2010 for and amount of $250 million USD.

ToR of PPTA also included preparation of one or two projects in each participating state for immediate implementation based on state's priority. Mirya Bay (Maharashtra), Coco and Colva Beach (Goa) and Ullal (Karnataka) projects were selected for implementation in first tranche and Feasibility Study and Design report for these projects were completed under PPTA.

Further after TAC approval, the Government of India and the Asian Development Bank (ADB) signed an agreement for the first tranche loan ($51.555 million loan- LN-2679-IND :) under the MFF on 17.08.2011 for Sustainable Coastal Protection and Management Investment Programme (SCP&MIP). Two projects namely Ullal Coastal Erosion & Inlet Improvement Project in Karnataka and Mirya Bay Coastal Erosion and Protection Project in

Maharashtra are under implementation with loan from ADB. Goa is not included under Tranche-1 as State Govt. of Goa did not pursue the TAC approval for its projects.

The Tranche-1 of Sustainable Coastal Protection and Management Investment Programme (SCP&MIP) was expected to be complete by 2014. However due to various reasons such as lack of readiness at approval, necessary civil works design adjustment, inadequate Project Management Unit staff, under-performance of appointed consultants and frequent replacement of various experts, there has been delay in implementation. Now, the closing date for Tranche-1 has been revised to 30-6-2017 after one extension for Tranche-1.

Under Tranche-1 action has been also taken in the State of Karnataka and Maharashtra to identify the prospective projects for Tranche-2 and subsequent tranches. The State Govt. of Karnataka has submitted of Tranche-2 projects. This has been accepted by Advisory Committee of MoWR,RD and GR at estimated cost of Rs.374.09 crore. The project proposal under Tranche - II includes 6 subprojects at project sites Someshwara, Yermal Thenka, Udyavara, Kodi Bengre, Maravanthe and Murudeshwara and 2 community protection subprojects at project sites Kodi Kanya and Pavinakurve.

CHAPTER 1
THE INDIAN COAST

1.1 INTRODUCTION

The coastal tract of peninsular India extends from Rann of Kutch in Gujarat to Malabar Coast in Kerala on the western coast, and, to Coromandal coast in Tamil Nadu up to Sunderbans delta in West Bengal on the eastern coast (Fig. 1.1). Apart from mainland India, the coastal stretch also includes the two island territories namely the Andaman & Nicobar Islands and the Lakshadweep Islands. The coastal length given by National Hydrographic Office (NHO) & Survey of India (SoI) in 1970 is widely accepted and adopted. As per the assessment, total coastal length of India is 7516.6 Km. India's mainland has a coastline of 5422.6 Km and Andaman & Nicobar and Lakshadweep Islands have total coastline of 2094 Km together. Figure 1.2 illustrates the location of nine coastal states (also refer Table 1.1) and four coastal union territories (UT) with the state/UT wise distribution of coastal length shown in Fig. 1.3. With less than 0.25% of the world's coastline, India houses more than 63 million people living in low elevation coastal areas (elevation less than 10 m above mean sea level). The 73 coastal districts (out of a total of 593) have a share of 17% of the national population, with nearly 250 million people living within 50 km of the coastline.

More than 100 rivers, including 14 major and 44 medium rivers discharge into the sea along the entire length of the coast. The mightier ones are the Ganga, Krishna, Godavari and Cauvery on the east coast and Narmada and Tapi on the west coast. The first one is River Ganga, which is known as Bhāgirathi-Hooghly and it goes on to become the Hooghly River and discharges into the Bay of Bengal near Sagar Island (It may be noted here that after entering Bangladesh, the main branch of the Ganga is known as the Padma; River Brahmaputra after flowing through Assam valley enters Bangladesh as River Jamuna and discharges into the Bay of Bengal after merging with the Padma and Meghna rivers). These rivers bring large quantities of sediments to the coast. Figure 1.1 shows the major river systems flowing to the sea on the Indian coast. India's coastal zone is endowed with abundant coastal and marine ecosystems which include a wide variety of mangroves, coral reefs, salt marshes, mudflats, estuaries, and lagoons that support unique marine and coastal floral and faunal biodiversity (MoEF, 2005) The coastal zone also provides sites for productive agriculture, extensive water-rich fertile delta plains, export-processing zones, industries, harbors, airports, land ports, and tourism. The coast is host to 77 cities and towns, including some of the largest and most dense urban agglomerations, industrial areas, tourist spots and port cities namely, Mumbai, Goa, Cochin, Chennai, Visakhapatnam and Kolkata that are present on both the east and west coasts of India. The equitable climate and the diverse array of livelihood approaches and opportunities have transformed the coastal areas into important hubs of intense agricultural, industrial and urban activities, thus paving the way for rapid socio-economic development of the country.

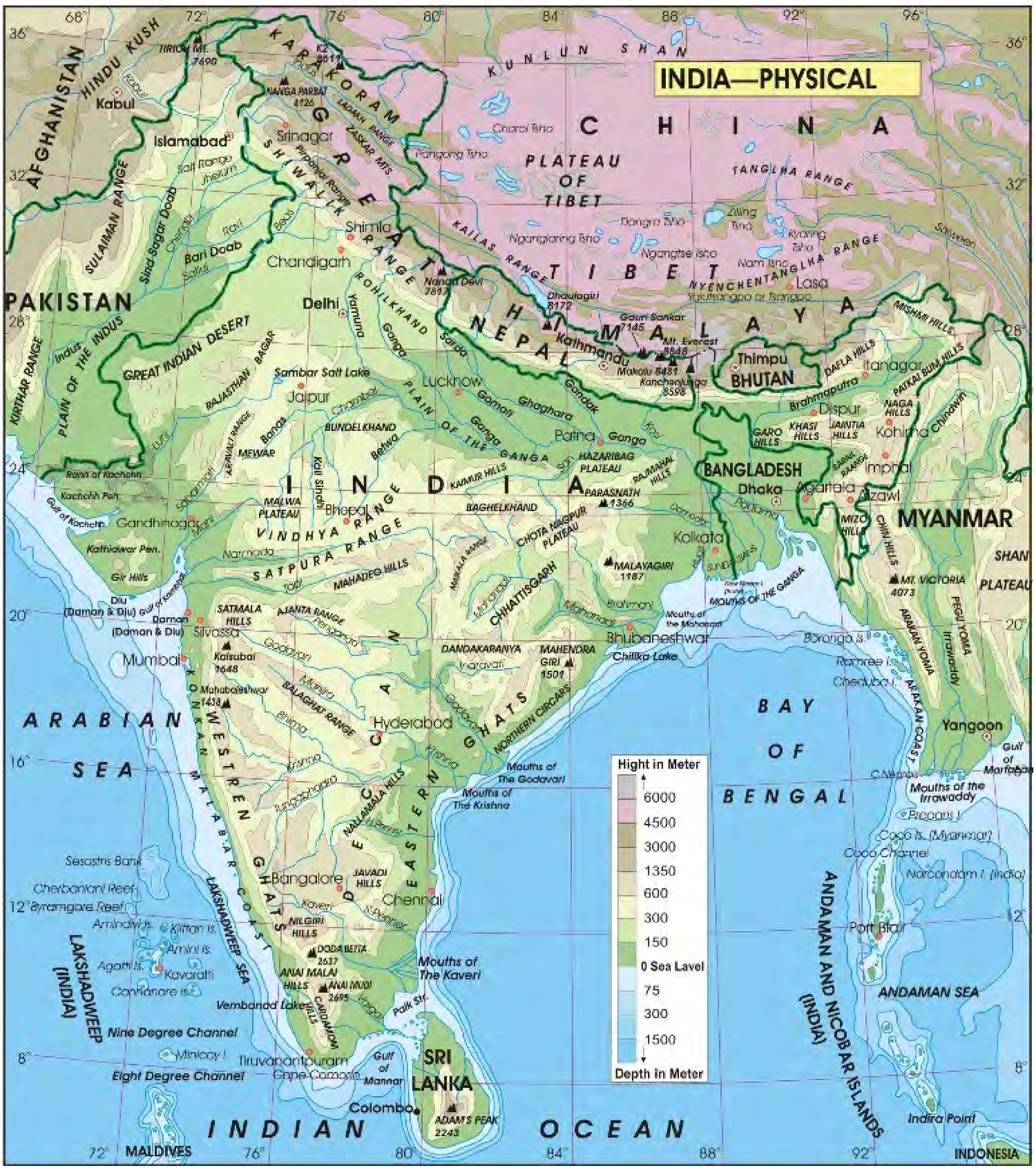


Fig.1.1 Physiographic map of India with major river systems

1.2 TOPOGRAPHY

Deccan plateau, the entire southern peninsula of India south of the Narmada River, is marked centrally by a high triangular table land. The Deccan's average elevation is about 600 m, sloping generally eastward. The *Eastern Ghats* and the *Western Ghats* are the two mountain ranges forming the eastern and western edges, respectively, of the Deccan plateau of peninsular India. These two ranges run roughly parallel to the Bay of Bengal and Arabian Sea coasts, respectively, from which they are separated by strips of fairly level coastal land. The eastern coast is, in general, characterized by a wider coast line compared to the western coast.

Fig. 1.2 Coastal states and union territories of India

Table 1.1 Coastal states and union territories

Coastal States	
1. Gujarat	2. Maharashtra
3. Goa	4. Karnataka
5. Kerala	6. Tamil Nadu
7. Andhra Pradesh	8. Odisha
9. West Bengal	
Union Territories	
1. Daman & Diu	2. Puducherry
3. Andaman & Nicobar Islands (Bay of Bengal)	4. Lakshadweep Islands (Arabian Sea)

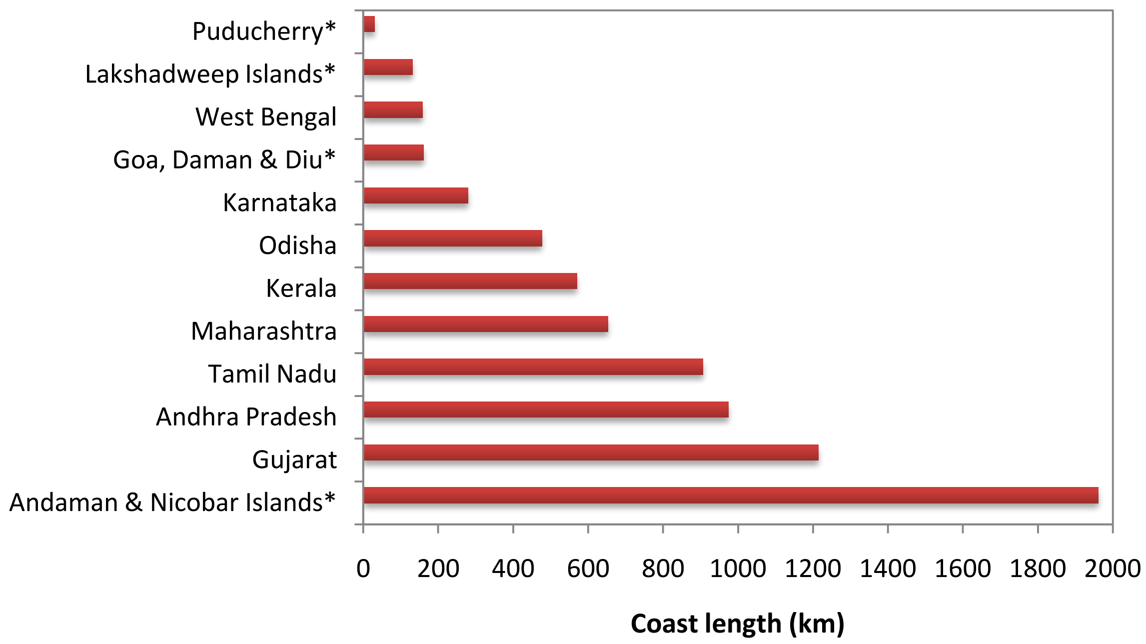


Fig. 1.3 Coastal length of different states and union territories*

The Eastern Ghats include several discontinuous and dissimilar hill masses that generally trend northeast-southwest along the Bay of Bengal. The narrow range has an average elevation of about 600 m with peaks reaching 1,200 m and higher. There is a 160 km wide gap in the mountain chain through which the Krishna and Godavari rivers reach the coast. Further southwest, beyond the Krishna River, the Eastern Ghats appear as a series of low ranges and hills.

The Western Ghats, also called the Sahyadris, form the crest of the western edge of the Deccan plateau. Their steep seaward slopes are deeply dissected by streams and canyon like valleys, but on the landward side their slopes are gentle and give way to wide, fully developed valleys. The range extends northward to the Tapi River and southward almost to Cape Comorin at India’s southern tip. The mountains reach elevations of 900 to 1,500 m in the north, rise less than 900 m in the area south of Goa, and are higher again in the far south, reaching an elevation of 2,637 m at Doda Betta mountain.

1.3 CLIMATE AND RAINFALL

Most of the coastal zone of India exhibits a tropical climate and experiences persistent high temperatures even during the coolest months. The west coastal lowlands and the Western Ghats experience tropical wet monsoon climate. Most of the plateau of peninsular India enjoys the tropical wet (dry) climate, except for a semi-arid tract to the east of the Western Ghats. Winter and early summer are long dry periods with temperature above 18°C. Summer is very hot and the temperatures in the interior low level areas can go above 45°C during May.

The southwest monsoon hits the coast of Kerala by the end of May or beginning of June and advances towards northern parts of the country. Orographic influence is dominant in the distribution of rainfall in this season, as the prevailing winds blow almost at right angles against the Western Ghats. It brings copious rainfall along the west coast. The annual normal rainfall along the west coast ranges from 300 mm in the northern and northwestern parts of Gujarat to 2500 mm in the southern part, with a maximum of more than 5000 mm in some areas of the Western Ghats. But, the region of high rainfall along the west coast is limited to a narrow belt having steep slopes between the Western Ghats ridge and the coastal plain (Fig. 1.4). Rainfall increases from the ridge of the Western Ghats towards the western steep slopes and rapidly deceases on the eastern lee side. The tropical climate of the Western Ghats complimented by heavy precipitation and favorable edaphic factors favors dense tropical forest growth and luxuriant growth of diverse plant species.

Along the east coast, the rainfall distribution is almost reversed, with higher rainfall of 1000 to 1500 mm in the northern parts and relatively less in the southern parts within the range of 400 to 1000 mm. The monsoon starts withdrawing gradually by early September and leaves the country by middle of October.

After the end of southwest monsoon, the northeast monsoon sets in and lasts for nearly three months, from October to December. It is a relatively dry season with less rainfall as compared to the southwest monsoon. The entire coast of Tamil Nadu and southern coastal part of Andhra Pradesh are the main rainfall receiving areas during this season.

1.4 COASTAL GEOMORPHOLOGY

The geomorphic setup of the Indian coast can be broadly grouped under East Coast and West Coast. The west coast is, in general, of submergence type with a number of islands, inundated stream courses adjoining the coast line, tidal creeks with rock-cut surfaces, etc. The west coast is rocky and pounded by big sea waves during monsoon. There is no extensive sedimentary deposition along the west coast except a few patches along Kerala and Maharashtra coast. The vast area along the structural depression / ancient inland bay near Gulf of Khambhat in Gujarat is filled by thick sediments. The fast flowing nature of the rivers from the Western Ghats has lead to formation of estuaries rather than deltas. A number of creeks run from the coast towards inland areas up to long distances carrying backwaters. The areas around these creeks in the lower reaches form typical marshy saline lands. There is less development of sand bars along the coast. Beach plains are confined at places as narrow discrete zones with number of tidal estuaries and lakes along the crenulated coastline. The other geomorphic features are sandy beaches, coastal sand dunes and mud flats, and alluvial tracts along the short stretched west flowing rivers.

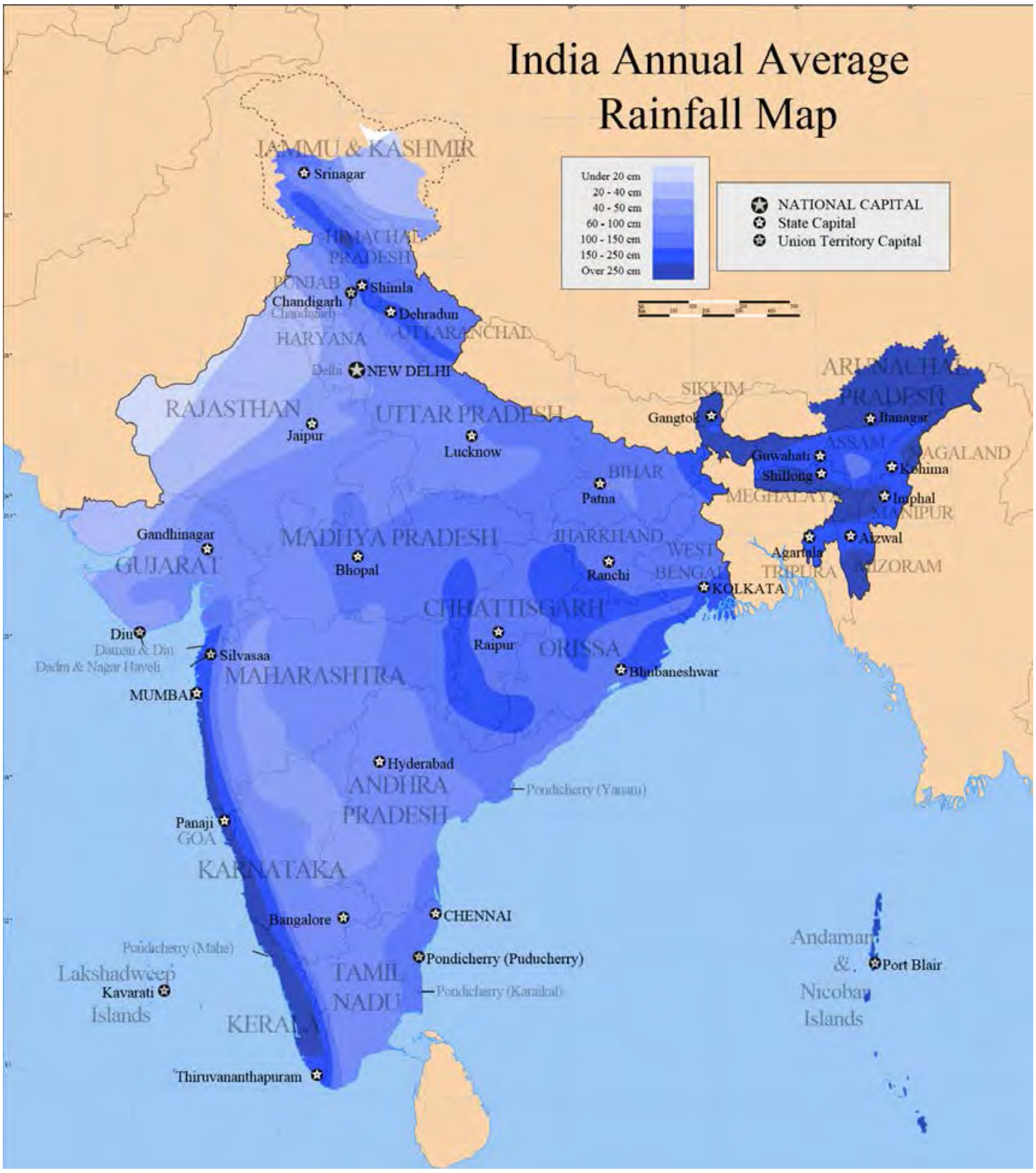


Fig. 1.4 Annual average rainfall map of India

In contrast, the vast coastal plains and the sedimentary deposits of east coast were formed in marine environment, and cover an area of about 1,50,000 km^2. The plains, formed due to progradation process, are extensive repositories of groundwater and other natural resources like lignite, oil and natural gas and radioactive minerals to some extent. Most of the major easterly and south-easterly flowing rivers, viz., Ganga, Mahanadi, Godavari, Krishna and Cauvery and a few minor rivers like Subarnarekha, Penner, Palar and Vaigai have developed well-defined deltaic platforms at their mouths. The extensive alluvial deposits formed due to the prograding nature of the coast have resulted in confining conditions for the underlying aquifers in sedimentary formations. Availability of huge water resources from major rivers and presence of fertile soils has transformed these coastal plains into food granaries of the country. Table 1.2 provides the list of coastal districts and characteristics features of the coastal line for the various coastal states / UTs of India.

Table 1.2 Coastal districts and characteristic features of coast line (after CGWB, 2014a)

State	Coastal districts	Characteristic features of coast line*
Gujarat and Daman & Diu	Kachchh, Morvi, Jamnagar, Devbhoomi Dwarka, Porbandar, Junagadh, Gir Somnath, Amreli, Bhavnagar, Anand, Ahmedabad, Vadodara, Bharuch, Surat, Navsari, Valsad and Daman (Daman & Diu)	Gulf of Kachchh and Gulf of Khambat with extensive continental shelf area and shallow coast; sandy intertidal zone with vast stretches of muddy or sand stone areas
Maharashtra	Palghra, Thane, Raigarh, Ratnagiri, Sindhudurg, Mumbai City, Mumbai Suburban	Rocky coastal belt broken by small bays, creeks and fringed with islands; no major rivers
Karnataka and Goa	Goa, Uttar Kannada, Udupi, and Dakshin Kannada	Straight coastline broken at numerous places by rivers, rivulets, creeks and bays; northern part is rocky coast
Kerala	Kasaragod, Kannur, Kozikhode, Mallappuram, Ernakulam, Kollam, Thrissur, Alappuzha, and Thiruvananthapuram	Chain of brackish water lagoons and backwaters parallel to the coast, beaches and estuaries
Tamil Nadu and Puducherry	Tiruvallur, Kancheepuram, Vilupuram, Puducherry (Karaikal), Cuddalore, Nagapattinam, Thanjavur, Thiruvarur, Pudukkottai, Ramanathapuram, Tuticorin, Tirunelveli, and Kanyakumari	Narrow belt of sand dunes, low lying beach, plains mostly formed by rivers
Andhra Pradesh	Srikakulam, Vizianagaram, Vishakhapatnam, East Godavari, West Godavari, Krishna, Guntur, Prakasam and Nellore	Coast line is smooth with inundations ; deltaic coast of Krishna and Godavari, marshy muddy coasts
Odisha	Baleshwar, Bhadrak, Kendrapara, Jagatsinghpur, Puri, Khordha and Ganjam	Coast is depositional, formed by Mahanadi, Brahmani and Baitarani delta
West Bengal	North 24 Parganas, South 24 Parganas Haora, Purba Medinipur	Ganga and Brahmputra river systems create large intertidal, deltaic mass. Hooghly mouth is uneven formed by massive sedimentation, coast sand riffed with numerous tidal creeks & estuaries

* Source: Ramesh & Ramachandran (2003)

1.5 COASTAL GEOLOGY

The eastern coast is generally characterized by a wider coast line when compared to its western counterpart. The evolution of the Indian coast has continued from continental plate movement through peri-cratonic basin formations during Mesozoic Era to the recent process of delta building. The east coast had a drastic change during Jurassic-early Cretaceous time (140 to 120 million years before the present) with the separation of continents (CGWB, 2014a).

Following the strong structural trends, the new coastline was formed, fringing the Indian Peninsula towards south of Narmada-Son-Damodar graben. The tectonic movements also truncated the existing NW-SE trending Godavari and Mahanadi rift valleys by transverse faults and produced a coastal palaeo-slope in easterly direction. Gondwana sedimentation in the rift valleys ceased and shallow marine sedimentation started all along the newly formed passive margin. Because of the stretched crust in this part and step-like faults causing easterly tilting subsidence NE-SW trending sedimentary basins, viz., Assam-Arakkan, Bengal, Mahanadi, Krishna-Godavari, Palar-Pennar and Cauvery were initiated. These basins were connected to open sea in the east and were bordered on the west by highlands and discontinuous Eastern Ghats. Except for the Assam-Arakkan basin, all other basins developed delta building process that has been continuously shaping up the east coastline of India since then. These basins are also the source of terrigenous clastic sediments to the coast and the Bay of Bengal.

The west coast originated subsequent to the east coast. It is partly limited by Western Ghats forming a prominent orographic feature along the western fringe of the peninsula. The edge of the continental shelf of the west coast is remarkably straight, representing a fault line that formed during Late Pliocene time. The block faulting and uplift of Western Ghats affected the coastal tract and got manifested through several major lineaments. The patchy occurrences of crystalline rocks and the sedimentary deposits are closely related to tectonics along the coast. In general, the west coast up to the Gulf of Khambhat, is dominated by the presence of crystalline rocks with extensive linear fault systems parallel to the coast. Sediments on the west coast are minimal owing to the fact that only a limited part of the peninsula with high relief terrain is drained before being deposited into the Arabian Sea. Also, the shifting of the western coastline through geologic time has been minimal. Further north, on the west coast, the Kathiawar sub-peninsula (Saurashtra) is underlain by sedimentary deposits and basaltic flows resting over the Proterozoic rocks. Sedimentary deposits controlled by tectonics and palaeo-climates got accumulated in the tectonic depression of Kachchh, Khambat and Narmada.

The coastal tracts of India have a complex geology, with lithological units ranging from recent fluvial and marine deposits to Archaean Crystalline rocks. On the east coast, thickness of alluvium is several hundred metres near the mouths of the major rivers like Cauvery, Krishna, Godavari, Mahanadi, Subarnarekha and Ganga. It decreases inland to a few metres near palaeo or existing delta heads where crystalline rocks occur. The alluvial plains with varying widths occur throughout the east coast up to Ramanathapuram in Tamil Nadu. The western coast, on the contrary has a narrow strip of recent alluvium and older unconsolidated deposits for a major part of its length.

Aquifers along the coastal tracts of India can be broadly classified into those in porous sedimentary formations and in fissured formations. The sedimentary tracts, all along the east coast and the coastal plains of Kerala and Gujarat are mostly occupied by ‘porous’ aquifers while a major part of the west coast and parts of Andhra and Tamil Nadu coast are occupied by ‘fissured’ aquifers. In the hard rocks, the shallow aquifers are, in general, in the weathered zone and deeper aquifers are in the underlying fracture zones. General hydraulic gradient of the ground water table in the unconfined shallow aquifers and piezometric surface of the deep aquifers in the coastal tract is towards the sea.

1.6 COASTAL SURFACE WATER RESOURCES

The *Western Coastal Plains* is a thin strip of coastal plain 50 km in width sandwiched between the Western Ghats and the Arabian Sea. The plains begin in Gujarat in the north and continue through the states of Maharashtra, Goa and Karnataka and end in the state of Kerala in the south. The Northern part of the west coast is called the Konkan (Mumbai-Goa), the central stretch is called the Kannad Plain while the southern stretch is referred to as the Malabar Coast. On its northern side there are two gulfs: the Gulf of Khambat and the Gulf of Kachchh. The rivers in these parts end up forming estuaries.

The *Eastern Coastal Plains* refer to a wide stretch i.e. 100 to 130 km of landmass of India, lying between the Eastern Ghats and the Bay of Bengal. These plains are wider and level as compared to the western coastal plains, and stretch from Tamil Nadu in the south to West Bengal in the north. Lake Chilka (largest salt water lake in India) is an important feature along the eastern coast. Deltas of many of India's rivers constitute a major portion of these plains. The rivers mainly Mahanadi, Godavari, Kaveri and Krishna drain these plains. The plains are locally known as Northern Circars in the northern part between Mahanadi and Krishna rivers and Coromandel Coast in the southern part between Krishna and Kaveri rivers. The coastal areas show wide variations in drainage characteristics from place to place. Coastal streams, especially in the west, are short and episodic.

In **Gujarat**, there are distinct sets of rivers. Rivers in the north-western parts e.g. Saraswati and Banas flow into the Rann of Kachchh, while rivers draining the central and southern coasts viz., Narmada, Tapi, Sabarmati and Mahi fall into the Gulf of Khambat. In Saurashtra many intermittent rivers like Bhadar, Minsar, Ojat, and Madhyvanti etc. rise in the central plateau of Saurashtra and meander in a radial pattern through the plains to meet the Arabian Sea. The coastal low-lying depressions known as ‘Ghed’ tend to get inundated by floodwater / tidal water. In the Kachchh region, long draining rivers are absent except a few like Khari and Nagmati which join the sea. The river Luni ends in the Rann of Kachchh.

In **Maharashtra** State, the Konkan Rivers drain a relatively narrow strip of land and none of the rivers have a course more than 100 km. Some of the important rivers viz. Amba, Kundalika, Savitri, etc. carry heavy discharge. A number of creeks in Maharashtra run up to long distances carrying backwaters. Out of these, the Thane and Vasai creeks are quite prominent. The areas around these, in the lower reaches form typical marshy saline lands. Though the general slope is westward, a number of rivers and streams also have north-south alignment in certain stretches, displaying structural control.

The two major rivers draining through **Goa** are Zuari and Mandovi. In **Karnataka**, the west flowing river system comprises rivers such as Sharavathi, Aganashini, Netravati, Gangavali and Kalinadi etc. that originate at an elevation ranging from 400 m to 1000 m amsl in the Western Ghats. The rivers generally flow westward and meet the Arabian Sea after a short run ranging from 50 km to 150 km. The rivers are very steep in the upper reaches, fairly steep in the middle reaches with relatively flat gradients near the sea. Between the basins of these rivers, there are a number of free catchments close to the sea, which have small streams directly draining into the Arabian Sea.

The coastal belt of **Kerala** is relatively flat and is criss-crossed by a network of interconnected brackish canals, lakes, estuaries and rivers known as the Kerala Backwaters. Kerala's west-flowing rivers that originate in the Western Ghats total 41 and include rivers such as Periyar, Bharathapuzha, Pamba, and Chaliyar etc. As Kerala's rivers are small and lacking in delta, they are more prone to environmental effects. The Kerala backwaters comprise a chain of brackish lagoons and lakes lying parallel to the Malabar Coast. The network includes five large lakes linked by canals, both manmade and natural, fed by 38 rivers, and extending virtually half the length of Kerala state. The backwaters were formed by the action of waves and shore currents creating low barrier islands across the mouths of the many rivers flowing down from the Western Ghats. The backwaters have a unique ecosystem - freshwater from the rivers meets the seawater from the Arabian Sea.

On the eastern coast of India, the coastal area of **Tamil Nadu** is drained by several rivers. Amongst them the major rivers are Cauvery, Ponnaiyar, Palar, Vaigai, Vaippar and Tambrapani. Flowing eastwards, these rivers originate in the Western Ghats. In **Andhra Pradesh** the major rivers draining the coastal area and nearby areas, in addition to Godavari and Krishna, are Nagavali, Vamsadhara, Yeleru, Gundlakamma and Pennar. The coastal plains of **Odisha** are drained by rivers of peninsular origin. The major rivers are Mahanadi, Brahmini, Baitarani, Rushikulya and Budhabalang. In **West Bengal** other than the Ganga-Brahmaputra system is river Subarnarekha that originates from the Chhotanagpur plateau and drains the western most part. Thus, Bay of Bengal, along the eastern coast receives huge river water from many large river systems like the Ganga-Brahmaputra, Mahanadi, Krishna, Godavari and Cauvery. These rivers exhibit their mature stage before splitting into distributaries to form extensive deltas. Table 1.3 lists the average annual potential for major river basins of the country that drain into the Arabian Sea or the Bay of Bengal (CWC, 2002).

Drainage congestion is a common problem in coastal plains with nearly flat slopes. In these areas, particularly in low lying coastal areas, disposal of surface runoff takes considerable time and surface drainage problem becomes acute. The accumulation of water affects the crops. Besides, the problem of water logging also exists in the coastal areas of West Bengal, Odisha and Andhra Pradesh (Planning Commission, 1981).

Table 1.3 Major river basins of India (CWC, 2002)

River	Catchment area (km^2)	Average annual potential in river (bcm/yr)
Ganga	861452	525.02
Brahmaputra	194413	585.60
Sabarmati	21674	3.81
Mahi	34842	11.02
Narmada	98796	45.64
Tapi	65145	14.88
Brahmani	39033	28.48
Mahanadi	141589	66.88
Godavari	312812	110.54
Krishna	258948	78.12
Pennar	55213	6.32
Cauvery	81155	21.36
Other river basins of country	248505	298.02

1.7 UTILIZATION OF COASTAL RESOURCES

The coastal area offers a wide variety of coastal and marine resources essential for India's economic growth. Most of the oil and gas reserves in India lie in the coastal and shallow offshore areas. Major petroleum reserves have been identified in the onshore and offshore regions like Bombay High, Gulf of Kachch, Godavari basin, offshore regions of Andhra Pradesh. Thirty-five per cent of the coastal stretch is laden with substantial placer mineral deposits which are distributed in pockets along the east and west coasts of the country with a resource availability of 340 metric tonnes. The coast offers enormous potential for renewable energy resources such as offshore wind, tidal, wave and future ocean thermal energy. A significant share of India's economic infrastructure, including petroleum industries, maritime facilities, and import-based industries, is located on the coasts, as are the 197 major or minor ports and 308 large-scale industrial units. Coastal fishing generates employment for a million active fishermen, and the post harvest fisheries sector employs another 1.2 million people in 3,638 fishing villages and 2,251 fish landing centers. The annual production is 2.7 million tonnes.

Cultural and archaeological sites of prehistoric and/or historic significance dot the eastern and western coasts. The abundant coastal and offshore marine ecosystems include some 6,740 km^2 of mangroves, including part of the Sundarbans and the Bhitarkanika, which are among the largest mangroves in the world. The rich coastal biodiversity includes the world famous coastal lagoons of Chilka, Pulicat and Vembanad as well as the Rann of Kachchh. There are major stocks of corals, fish, marine mammals, reptiles and turtles, sea grass, and abundant sea weeds.

The water supply demands for coastal areas of the country are mainly met from surface water (pumped from inland sources) and groundwater. Rainwater harvesting and desalination are beginning to be practiced in areas facing water scarcity. Since the demand for the surface water sources are ever-increasing in the hinterland, the sustainable source for freshwater requirement of the coastal areas is groundwater. Coastal aquifers are valuable sources of freshwater, however, the quality of coastal groundwater is subject to various influences, discussed later. Table 1.4 provides the annual replenishable groundwater resource and the stage of groundwater development in the coastal states/ union territories (UT) of India.

Table 1.4 Groundwater resources potential in coastal states/ UTs as on March 31, 2011 (CGWB, 2014b)

State/Union Territory	Annual Replenishable Groundwater Resource (bcm/yr)	Development (%)
Andhra Pradesh	35.89	45
Goa	0.24	28
Gujarat	18.57	67
Karnataka	17.03	64
Kerala	6.69	47
Maharashtra	33.95	53
Orissa	17.78	28
Tamil Nadu	21.53	77
West Bengal	29.25	40
UT of Andaman & Nicobar	0.308	4.44
UT of Daman & Diu	0.018	97
UT of Lakshadweep	0.011	67
UT of Puducherry	0.189	90
Total	**181.456**	**Average 54.418**

In the 21st century, India is witnessing a rush to occupy its coastal corridors. Industries, ports, housing projects, infrastructure projects, all are headed towards our long coastline. In view of the rich coastal resources and enormous potential offered in terms of livelihood security, coastal settlements and communities have grown hugely in the recent decades. All such activities have pushed the demand for freshwater in coastal regions which is exerting increasing stress on the coastal water resources.

1.8 COASTAL AREA HAZARDS

Despite the richness and diversity of coastal resources and the capacity to sustain many different forms of economic development, coastal areas are prone to several natural hazards. Storms, cyclones, tidal surges, flooding, coastal erosion etc. bring about large scale destruction of life, property and natural resources in the coastal regions of the country every year. The 1999 ‘Super Cyclone’ which devastated the Orissa coast was one of the severest to hit Indian coasts. In addition, due to the proximity to the sea, coastal regions are also exposed to the major risk of progressive salinization of land with a potential to cause enormous damage to the fast growing coastal economy.

1.8.1 Coastal Erosion

Changes in the shoreline due to coastal erosion lead to loss of resources and degradation of coastal ecosystems. Erosion in one area may lead to accretion in another area, which is a transient phenomenon. Results of a recent study (Rajawat, 2014) show that 45.5% of the coast of India is under erosion, 35.7% of the coast is getting accreted, while 18.8% of the coast is more or less stable in nature. Highest percentage of the shoreline under erosion is in Nicobar Islands (88.7%), while percentage of accreting coastline is highest for Tamil Nadu (62.3%). The state of Goa has highest percentage of stable shoreline (52.4%). The analysis shows that the Indian coast has lost a net area of about 73 km^2 during time frame of 1989-91 and 2004-06. In Tamil Nadu, a net area of about 25.45 km^2 has increased due to accretion, while along Nicobar Island about 93.95 km^2 is lost due to erosion. Technological options available to control/prevent erosion include construction of seawalls on the eroding coast and soft engineering measures such as coastal vegetation, beach nourishment, etc..

1.8.2 Flooding due to Cyclones and Storm Surges

The coast of India is one of the worst affected regions of the world exposed to nearly 10% of the world's tropical cyclones. There are 13 coastal states/union territories encompassing a total of 84 coastal districts that get affected by cyclones. Four states (Andhra Pradesh, Odisha, Tamil Nadu and West Bengal) and one union territory (Puducherry) on the east coast and one state (Gujarat) on the west coast are more vulnerable to cyclone disasters. Strong winds/squalls, torrential rains and inland flooding, and storm surges occurring during a cyclone have the potential to cause severe destruction in the areas near the coast. Besides the risk to human life and property, the inundation of low lying coastal areas by seawater during storm surges, destroys vegetation and reduces soil fertility.

Coastal storms can be devastating because of their sheer speed and effects on coastal water level. Onshore winds and atmospheric pressure fluctuations combined with wave effects create storm surges. In semi-enclosed seas like the Bay of Bengal, storm surges may attain heights of several metres. Surges plus high waves penetrate considerable distance inland, especially on low-lying coasts like mudflats and deltas. Heavy loss of lives and damage to properties usually accompany storm surges. Saltwater inundation due to flooding from the sea and consequential groundwater salinization are also part of storm surge damage. In addition, banks of water bodies may get flooded due to rise of water level as a result of precipitation and river discharge and may lead to water logging in the adjacent areas.

1.8.3 Sea Level Rise due to Climate Change

Sea level rise is a major climate change impact that will have wide ranging effects on coastal environments (IPCC, 2007). During the 21st century, the rate of sea level rise is projected to be several times higher than that measured over the past century. Recent projections suggest that sea level may be ~0.6 to 1.5 m higher than present by 2100 (Jevrejeva et al., 2010), and

~2 m higher under extreme warming scenarios (Grinsted et al., 2010). In view of the large population living along the coastal lines, even small increases in sea level can have significant societal and economic impacts through increased coastal erosion, susceptibility to storm surges, inundation of low lying areas, saltwater intrusion into groundwater, loss of coastal wetlands, and stresses on ecosystems and community infrastructure.

1.8.4 Tsunami

Tsunami may get generated by under-sea earthquakes. The tsunami waves travel at a speed of more than 700 km in deep sea. The waves have a very long wave length of more than 750 km and a very short crest of height often less than 1 m. These waves slow down when they enter continental shelf areas due to which the wave length decreases and the crest starts peaking up. Very near to the shore line, the crest takes the shape of a wall and enters the coast. The tsunami that struck the coast of India on Dec. 26, 2004, reportedly had a crest height of around 10 m on the east coast and 5 m on the Kerala coast. Maximum damage occurred in low lying areas near the coast, with high causalities in thickly populated areas. The mangroves, forests, sand dunes and coastal cliffs provided the best natural barriers against the tsunami in affected areas. On the other hand, heavy damage was reported in areas where sand dunes were heavily mined and where coastal vegetation was less.

1.8.5 Salt Water Intrusion and Progressive Coastal Land Salinization

Rapid economic growth in recent years has propelled newer and larger investments in coastal zones. Together with real estate growth in larger urban areas and accelerated tourism activities, these have contributed to a sharp increase in the demand for basic infrastructure to support the fast-growing rural, semi-urban and urban populations in the coastal zones; the demand for water supply being the most significant. Many coastal communities rely on potable groundwater for meeting their water requirements. Often it is the only reliable source, seawater not being potable without expensive desalination. However, indiscriminate large-scale pumping of groundwater may lead to progressive saltwater intrusion in the freshwater coastal aquifer system that ultimately renders the groundwater unfit for human consumption and other uses. Irrigation of crops using saline water may also result in degradation of soil and wide spread destruction of fertile coastal lands. During extended droughts, decreased river flow allows the saline water to migrate up the estuary to inland areas that may further contribute to land salinization. In addition, rise in sea level will also cause seawater to migrate upstream and inundate low-lying areas.

Coastal land salinization and salt water ingress are major hazards encountered along the Indian coast which can hamper the rapid socio-economic growth of the coastal states and the economy of the country as a whole. As India has a lengthy sea coast spread over nine states and four union territories, the problem of salinity in coastal areas is a national problem and requires detailed studies in all the coastal states. The subsequent chapters discuss the problem of coastal land salinity and suitable remedial measures in detail.

CHAPTER 2
COASTAL LAND SALINITY AND REMEDIAL MEASURES

2.1 SALINITY

Salinization is a global issue of serious concern because it reduces the potential productivity and use of land and water resources. In coastal regions, that are in close proximity to the sea, salinization may lead to changes in the chemical composition of natural water resources, degrading the quality of water supply to the domestic, agriculture and industrial sectors, loss of biodiversity, taxonomic replacement by halo-tolerant species, loss of fertile soil, collapse of agricultural and fishery industries, changes in local climatic conditions, and creating health problems; thus, affecting many aspects of human life and posing major hindrance to the economic development of the region.

Salinity by definition is the presence of soluble salts in soils or waters. Salinity processes are natural processes closely linked with landscape and soil formation processes; however, human activities can accelerate salinity processes, thereby further aggravating the land and water degradation of the affected region. Salinity is taken as a water issue when the potential use of water is limited by its salt content or its salt composition. It becomes a land use issue when the concentration of salt or sodium adversely affects plant growth, degrades soil structure or causes soil erosion. Thus, coastal land salinity may be identified in terms of:

a) Groundwater salinity areas where either the water stratum for great depths is saline or the saline groundwater is overlain by a shallow freshwater layer (thickness ~ 10 m) that forms due to rainfall recharge only.
b) Soil salinity areas where the top soil is saline.

The present document mainly deals with issues pertaining to water salinity in coastal areas. Soil salinity arising from water salinity is dealt with in brief.

Salinity in water is usually defined by the total dissolved solids content (TDS, mg/L or g/ L) or the chloride content (Cl, mg/L) although the chloride ion comprises only a fraction of the total dissolved salts in water. Table 2.1 provides the average concentrations of the major dissolved elements or ions of seawater with an approximate concentration of 35000 mg/L (Goldberg et al., 1971; Hem, 1989). The principal ions in seawater, chloride and sodium have long residence times, low geochemical reactivity, and are essentially inert. The Cl/TDS ratio varies from 0.1 in non-marine saline waters to 0.5 in marine-associated saline waters.

Water that contains salt is able to conduct electricity. The potential of a solution to pass an electric current is called electrical conductivity (EC) and it is usually measured in microSiemens per centimeter (µS/cm). The electrical conductivity of a solution increases as the concentration of salt in a solution increases. Thus, the water salinity can also be defined by its electrical conductivity which is the principal parameter used nowadays to measure the salt content in water. For most waters, TDS in mg/l is equivalent to approximately 0.64 or 0.67 times EC in µS/cm.

Table 2.1 Average major ionic composition of seawater (Hem, 1989)

Constituent	Concentration (mg/l)
Chloride (Cl)	19000
Sodium (Na)	10500
Sulphate (SO_4)	2700
Magnesium (Mg)	1350
Calcium (Ca)	410
Potassium (K)	390
Bicarbonate (HCO_3)	142
Bromide (Br)	67
Strontium (Sr)	8
Silica (SiO_2)	6.4
Boron (B)	4.5
Fluoride (F)	1.3
Iodide (I)	<1

Although waters with TDS concentrations greater than 1000 mg/L are used for domestic supply in some areas where water of lower TDS concentration is not available, water containing more than 2,000 to 3,000 mg/L TDS is generally too salty to drink (Freeze and Cherry, 1979). As per the Bureau of Indian Standard (BIS, 2004), the desirable limit of TDS for drinking water is 500 mg/L and the permissible limit in the absence of an alternate source of water is 2000 mg/L. According to World Health Organization (WHO, 1996), water containing TDS concentrations below 1000 mg/L is usually acceptable to consumers, although acceptability may vary according to circumstances. However, the presence of high levels of TDS (> 500 mg/L) in water may be objectionable to consumers owing to the resulting taste and to excessive scaling in water pipes, heaters, boilers, and household appliances. Because of its high salt content, 2% of seawater mixed with fresh groundwater can render the water unusable in terms of BIS drinking water standards.

For mapping of groundwater salinity areas, the classification method used in this report defines *freshwater* as having a TDS concentration of less than 1000 mg/L; waters with TDS concentration greater than 1000 mg/L are considered to be saline (or brackish). Zones with TDS less than 500 mg/L are considered to be having potable water. Water with TDS concentration exceeding that of seawater is termed brine. Although there are different types of brines in terms of chemical composition, the largest numbers of brine samples represent concentrated seawater containing mostly sodium chloride. For the purpose of mapping zones with quality of groundwater suitable for irrigation, the Indian Standard Guidelines for the Quality of Irrigation Water (IS: 11624–1986; Reaffirmed 2001) is adopted (BIS, 1987) in terms of hazardous effect of total salt concentration of irrigation water on crop as provided in Table 2.2. The Table 2.2 also lists the categories of irrigation water quality in terms of varying salt concentration. In the present report, the water salinity zones are shown for EC < 1500 μS/cm, 1500 μS/cm < EC < 3000 μS/cm, EC > 3000 μS/cm, which correspond to irrigation water quality rating in terms of low, medium and high hazardous effect of saline water.

Table 2.2 Water quality rating of irrigation water

Irrigation water quality rating in terms of hazardous effect of saline water (BIS, 1987)			Guidelines for evaluation of irrigation water quality (Richards, 1954)		
Hazard	**Range of EC (μS/cm)**	**Range of TDS (mg/L) approx.**	**Category**	**Range of EC (μS/cm)**	**Range of TDS (mg/L) approx.**
Low	< 1500	<1000	**Excellent**	<250	< 167
Medium	1500 – 3000	1000-2000	**Good**	250-750	167- 500
High	3000 – 6000	2000 - 4020	**Permissible**	750-2250	500 - 1500
Very high	> 6000	> 4020	**Doubtful**	2250-5000	1500 - 3300
			Unsuitable	>5000	> 3300

Besides the total dissolved salt concentration, high levels of individual dissolved constituents may limit the use of water for domestic, agriculture, and industrial applications. High levels of TDS may be associated with high concentrations of other constituents such as chloride, sodium, sulfate, boron, fluoride, etc. WHO (1996) recommends that the chloride concentration of the water supply for human consumption should not exceed 250 mg/L. Similarly, many crops including fruit and vegetable varieties are sensitive to chloride concentration (upper limit 250 mg/L) in irrigation water. In addition, long-term irrigation with water enriched with sodium results in a significant reduction in the hydraulic conductivity of the soil that affects its fertility. Again, the industrial sector mostly demands water of high quality. For example, the high-tech industry requires water with low levels of dissolved salts. Hence, the salinity level of water is one of the limiting factors that governs its suitability for various applications.

This chapter investigates the different mechanisms of salinization of coastal lands. Since groundwater quality degradation is a conspicuous phenomenon in coastal areas, the different mechanisms of salinization of coastal groundwater are discussed in detail, in the subsequent section.

2.2 COASTAL GROUNDWATER SALINITY AND ITS OCCURENCE

In general, fresh groundwater is present in those parts of the subsurface that are most actively involved in the water cycle (mostly shallower domains of the sequence of geological layers), and usually exists as ‘meteoric water’. As such, fresh groundwater is often relatively young and tends to be actively renewed. However, at greater depths, groundwater is replenished at much smaller rates. As a result, originally fresh groundwater often turns saline because of mineralization processes during the very long residence time underground, while aquifers originally filled with saline groundwater have not been refreshed because they are beyond reach of active fresh groundwater flows. Therefore, in general, groundwater salinity tends to increase with increasing depth.

Origin of saline groundwater can be categorized according to marine, terrestrial, natural and anthropogenic types. In coastal areas, due to the interplay of several factors, groundwater salinity may be encountered even at shallower depths. Enhanced knowledge on saline groundwater can aid in effective utilization and sustainable management of coastal fresh groundwater resources. Knowing the origin of the groundwater salinity can provide water resources managers the opportunity to forecast changes in the salinity characteristics and to develop effective measures to manage the coastal water resources sustainably. The major factors behind origin of groundwater salinity in coastal areas are briefly discussed below (Weert, 2009).

2.2.1 Marine Origin of Groundwater Salinity

Connate saline groundwater: In sedimentary formations of marine origin: seawater was deposited together with the rock matrix and may still be present in the interstices, unless it has been flushed away.

Marine transgressions: Over the geological time scale, coastal lowlands became flooded by the sea during marine transgression periods. During the flooding, the denser seawater percolated downwards because of its higher density compared to fresh water, turning fresh coastal aquifers into saline groundwater reservoirs. Within a period of hundreds of years, vast freshwater aquifers may turn saline due to marine transgressions.

Incidental flooding by seawater: When sea levels are exceptionally high, e.g. during a *tsunami*, or during *high tides*, low-lying coastal plains may become temporarily flooded by seawater. Compared to marine transgression, the period of such flooding is much smaller, still large extents of shallow depths of coastal aquifers may become salinized due to the infiltration of seawater pooled on the ground surface. For instance, extensive parts of south eastern coastal India were flooded by seawater by the December 2004 tsunami causing groundwater salinization. Submergence of unprotected wellheads during such flooding may even lead to entry of saline water to deeper aquifers depths via the well screens. The tsunami inundation in coastal tracts resulted in contamination of groundwater supplies by locally raising the salinity from potable levels to more than 8000 mg/l of TDS. Peak salinity occurred within 1 month as the saline water infiltrated. Salinization persisted for more than 10 months in the contaminated coastal region (Violette et al., 2009).

Lateral intrusion of seawater: Lateral seawater intrusion occurs in coastal zones because of interaction between the sea water and hydraulically connected coastal aquifers. Under natural undisturbed conditions, a seaward hydraulic gradient exists in the aquifer with freshwater discharging into the sea. The heavier saltwater flows in from the sea and a landward thinning ‘saltwater-wedge’ develops beneath the lighter freshwater. The resulting saltwater-freshwater interface is not a firm boundary but exists as a transition zone (or zone of dispersion) reflecting changes in salinity (Fig. 2.1). An approximate estimation of the depth to the interface (neglecting dispersion) is given by the Ghyben-Herzberg relation (see Box A).

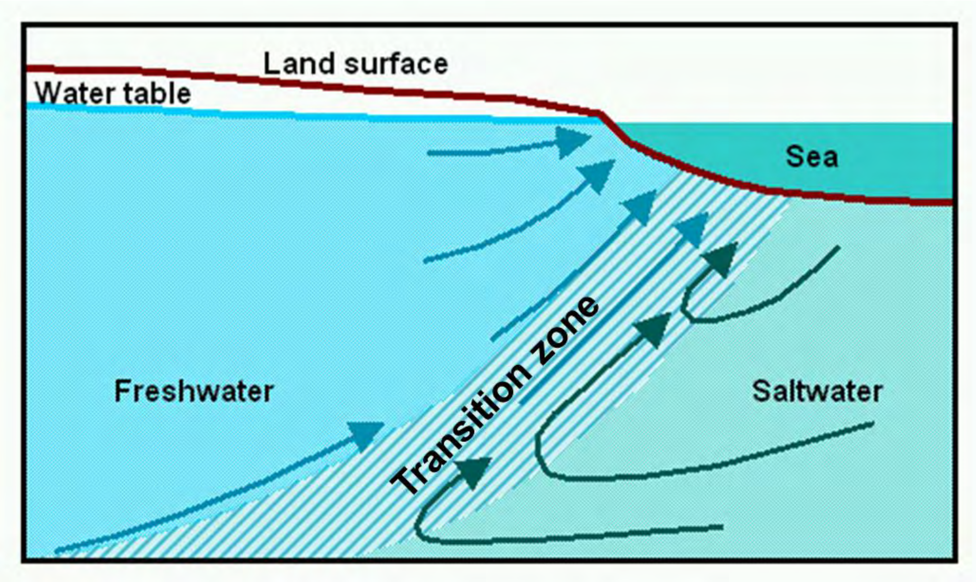


Fig. 2.1 Saltwater wedge in a coastal aquifer (NIH, 2014a)

The natural dynamic equilibrium existing between freshwater and saltwater in coastal aquifers is disturbed by groundwater withdrawals and land use changes that decrease the groundwater replenishment. The inland changes in discharge or recharge modify the flow within the freshwater region, inducing a corresponding movement of the interface. A reduction in freshwater flow due to overdraft causes the interface to move inland and results in the encroachment of seawater into the aquifer (Figs. 2.2(a)-(b)). Conversely, the interface retreats following an increase in freshwater flow. The extent of intrusion is governed by the groundwater recharge to the aquifer, hydrogeology of the region and the manner and degree of groundwater development (Sharma, 2006). Often, in coastal regions, when a shallow freshwater layer is pumped that is underlain by a saline water layer, localized *upconing* of saltwater (Fig. 2.3) may occur and the freshwater well may start yielding saline water (Shalabey et al. 2006). This anthropogenic induced intrusion can be a relatively fast process, depending on the hydraulic pressures changes and hydraulic conductivity of coastal aquifers.

Lateral seawater intrusion in coastal areas may be enhanced by surface water bodies connected to the sea, such as estuaries and rivers (greatly increasing the coastline length) if conditions allow seawater to travel inland through these bodies. Pumping from coastal wells can draw saltwater downward from such surface sources of saline water. This type of intrusion, shown in Fig. 2.4, is usually more local in nature with a potential to contaminate portions of the aquifer near the river. It typically occurs within the zone of capture of pumping wells where significant drawdown of the water table causes induced surface infiltration. In such situations, decreased estuarine river discharge because of upstream water allocation or during drought conditions (extended low flows) may increase seawater intrusion. Again, several rivers with extremely low hydraulic gradient may further bring the seawater intrusion risk to aquifer locations in inland regions.

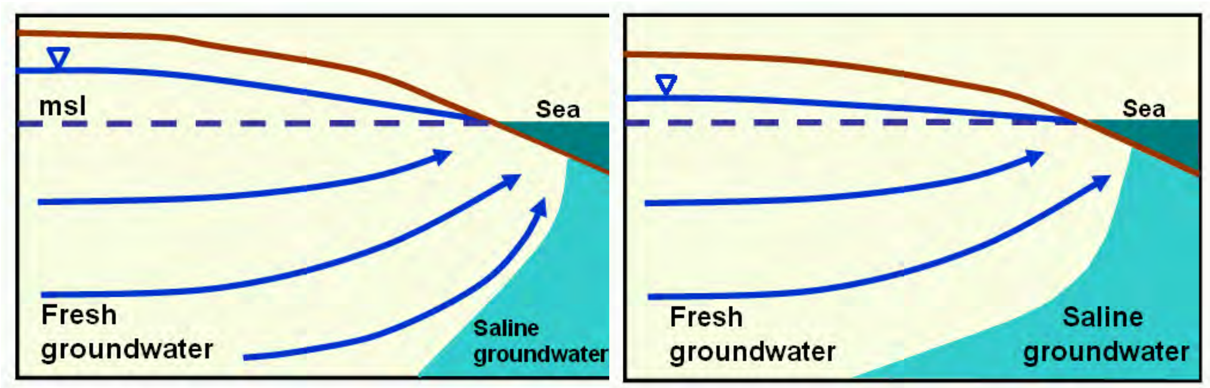


Fig. 2.2 Development of saltwater wedge in a coastal aquifer (a) Pre-development scenario with raised water table (b) Post-development scenario with lowered water table.

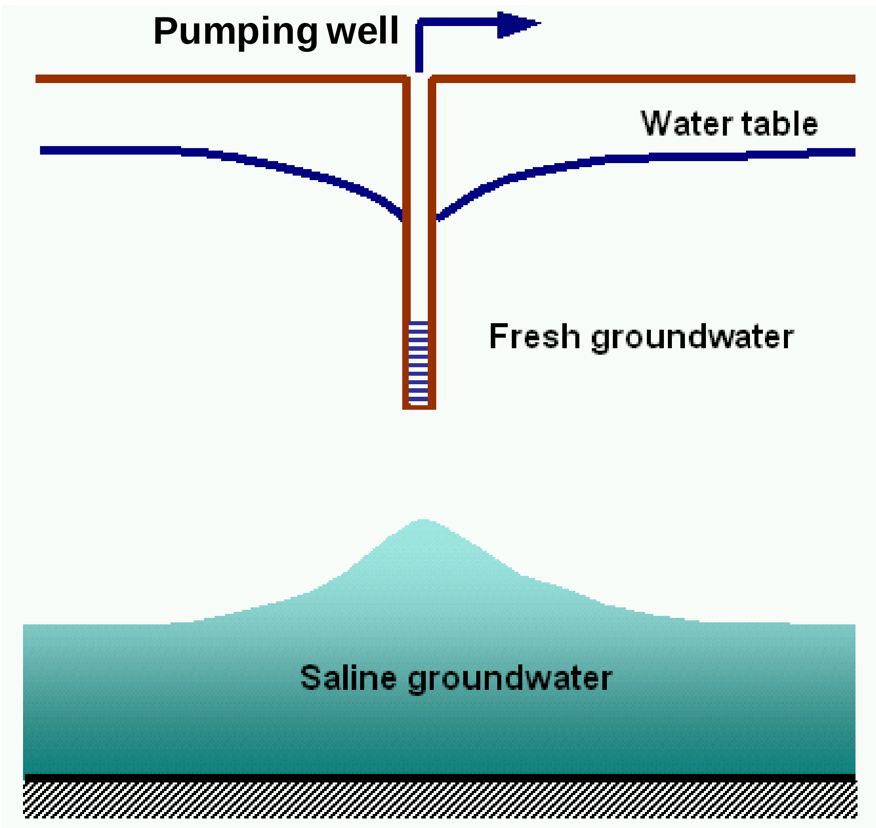


Fig. 2.3 Saltwater upconing below a pumping well.

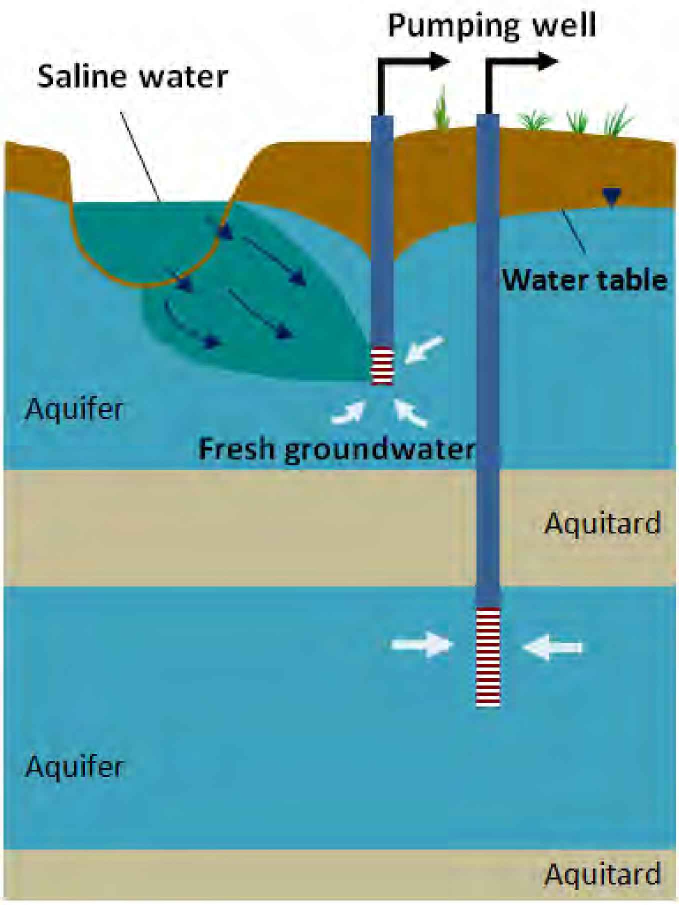


Fig. 2.4 Leakage of brackish/saline water from surface water into groundwater in an estuarine environment (NIH, 2014a)

Box A: Estimate Depth to Freshwater - Saltwater Interface

In the absence of water quality data, a relatively simple equation known as the '*Ghyben-Herzberg relation*' (named after two European scientists who derived it independently in the late 1800s), can be used to estimate the depth to saltwater and the thickness of freshwater in an unconfined aquifer. The equation relates the elevation of water table above msl to the depth of the interface between the freshwater and underlying saltwater zones of an aquifer, and is based on the balance of the height of two columns of fluids of differing density. Taking the thickness of the freshwater zone above sea level as 'h' and that below sea level as 'z', as shown in Fig. A-1, the thickness of the two zones is related by (Bear, 1979)

$$z = \frac{\rho_f}{\rho_s - \rho_f} h \tag{1}$$

where ρ_f is the density of freshwater, and, ρ_s is the density of saltwater.

Freshwater has a density of about 1000 kg/m^3 at 20^{o}C, whereas that of seawater is about 1025 kg/m^3. Although the difference between the density of freshwater and seawater is small, Eq. (1) shows that this density contrast can result in about 40 ft thick zone of freshwater below msl for every 1 ft of freshwater above msl, i.e.:

$$z = 40h \tag{2}$$

The total thickness of freshwater zone is the sum of freshwater zones above and below sea level i.e. $h + z$. The Ghyben-Herzberg relation for calculating the thickness of freshwater zone is based on a number of simplifying assumptions. It is assumed that hydrostatic conditions exist within the aquifer, which implies that no vertical gradients exist within the aquifer. This assumption incorrectly causes the thickness of freshwater zone to be represented as zero at the coast where the elevation of the water table is zero. In reality, the freshwater zone must have some thickness for freshwater to discharge to the sea. It also is assumed that there is a sharp boundary between freshwater and saltwater zones at the interface. However, as discussed earlier, freshwater and saltwater are miscible fluids and a zone of transition (dispersion) develops at the interface.

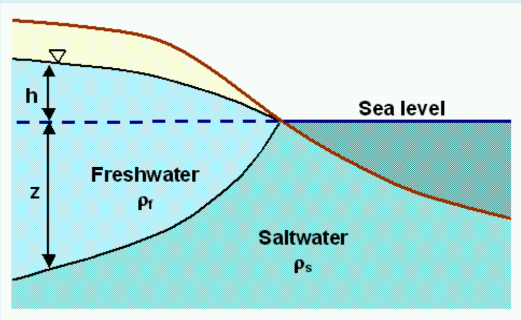


Fig. A-1 Simplified freshwater-saltwater interface in a coastal unconfined aquifer

*Seawater sprays***:** The lower mass of air in coastal zones is rich in salt particles originating from the sea. These salt particles get absorbed by rains and become part of groundwater recharge, thus contributing to groundwater and soil salinisation. The affected parts are usually limited to small zones along the coasts.

2.2.2 Natural Factors for Terrestrial Origin of Groundwater Salinity

Evaporation processes: In areas with shallow water table conditions, groundwater salinity may develop when climatic conditions favour evaporation (or evapotranspiration through phreatophytes) such as in arid and semi-arid regions while flushing of accumulated salts is poor (Yechieli and Wood, 2002). Therefore, lakes in closed basins in such areas should have provisions for outflow of water as it turns saline.

*Dissolution of naturally occurring subsurface soluble minerals***:** Groundwater may acquire salinity by dissolving salts from evaporate formations (halites) or carbonates layers, when flowing through such subsurface bodies. In arid regions, if conditions favour dissolution of salts from the aquifer matrix, groundwater may become brackish to saline even when flowing through porous medium of which only a limited fraction consists of easily dissolvable materials.

Geothermal origin: In regions of significant igneous activity, highly mineralized water may be present. This water, which has not been part of the hydrological cycle, yet, is called 'juvenile water'.

2.2.3 Anthropogenic Factors for Terrestrial Origin of Groundwater Salinity

*Irrigation***:** Irrigation supplements water required for optimal crop evapotranspiration. Large-scale irrigation may induce rise of water table (water-logging) and evaporation losses directly from the shallow water table, which leaves behind a residue of relatively mineralized water in the soil. This residue may be absorbed by the soil matrix, drain to the surface water system or percolate below to the root zone. It then may reach an aquifer and contribute to a progressive increase in the salinity of groundwater. In addition, irrigation using brackish water may lead to salinization of the underlying soil and groundwater system. Increase in groundwater salinity can range from a few metres to tens of metres below the water table.

*Anthropogenic pollution***:** Anthropogenic pollutants such as fertilizers, domestic, industrial and agricultural effluents may enter the groundwater system and contribute to localized increase in salinity of groundwater. Leakage of brackish water from aquaculture ponds may cause local salinization of underlying shallow groundwater.

2.3 SALINIZATION OF COASTAL LANDS

2.3.1 Complexities Due to Time Factor and Spatial Overlap of Processes

In coastal areas, zones with saline groundwater of different origins overlap. In low-lying coastal zones and delta areas, groundwater salinity is often caused by past marine transgressions and recent incidental flooding. In some cases, connate saline groundwater adds up to the total observed groundwater salinity. Evaporation induced salinization is significantly exacerbated when the evaporating groundwater is enriched in dissolved salts in the aquifers. Seawater sprays also contribute to the soil and water salinity. Each of the processes described above has its own time scale. The existing fresh/salt water distribution in a coastal aquifer is, thus, quite often defined by the long-term hydro-geological and physiographic history of the region.

2.3.2 Primary Paths of Salinization

a) Lateral seawater intrusion – *caused by rising sea-level or falling inland groundwater levels*.
b) Vertical downward seawater intrusion – *mainly from saline surface water carried inland by tidal creeks and estuaries and from repeated storm saltwater surges* (possible future transgression of the coast may also lead to vertical intrusion). Periodic inundation of an area by saline water can cause vertical percolation of saline water in the aquifer. A phreatic aquifer is quite vulnerable to such processes, while a confined aquifer overlaid by less pervious clay or silt, is less susceptible to vertical percolation. Repeated inundation of a region may also lead to soil salinity (refer Section 2.4.2)
c) Migrating pre-existing pockets of subsurface saline water - *from vertical intrusion, lateral intrusion, or relic seawater* that was deposited with the aquifer sediment. Buried ancient stream channels and faults also are potential pathways for ingress of saltwater.

The rate of saltwater intrusion along all these paths may be significantly affected by pumping. Climate change-driven sea-level rise may provide sources of saltwater in new places inland of the current coastal zone, and new saltwater intrusion would occur along these paths.

Saltwater intrusion reduces freshwater storage in coastal aquifers and can result in the abandonment of freshwater supply wells when concentrations of dissolved ions exceed drinking-water standards. The degree of saltwater intrusion varies widely among localities and hydro-geologic settings. In many instances, the area contaminated by saltwater is limited to small parts of the aquifer and has little or no effect on wells pumped for groundwater supply. In other instances, contamination is of regional extent and has substantially affected groundwater supplies. The extent of saltwater intrusion into an aquifer depends on several factors, including the total rate of groundwater that is withdrawn compared to the total freshwater recharge to the aquifer, the distance of the stresses (wells and drainage canals) from the source (or sources) of saltwater, the geologic structure and distribution of hydraulic properties of the aquifer, and the presence of confining units that may prevent saltwater from moving vertically toward or within the aquifer.

2.3.3 Formation of Salt-Affected Soils

An excessive accumulation of salts in the soil causes a decline in productivity. Soil salinity is the term used to designate a condition in which the soluble salt content of the soil reaches a level harmful to crops. Soil salinity affects plants directly through reduced osmotic potential of the soil solution and the toxicity of specific ions (such as boron, chloride and sodium). If the salts are mainly sodic salts, their accumulation increases the concentration of sodium ions in the soil's exchange complex, which in turn affects soil properties and behavior. Thus, salinity can also have direct effects on plant growth through deleterious modification of such soil properties as swelling, porosity, water retention, and permeability (Hillel, 1998)

Saline soils usually occur in areas that receive salts from other locations, and water is the primary carrier. The sea may be the source of salts as in soils where the parent material consists of marine deposits that were laid down during earlier geologic periods and have since been uplifted. The sea is also the source of the salts in low-lying soils along the coastlines. Sometimes salt is moved inland through the transportation of spray by winds. More commonly, however, the direct source of salts is surface and ground waters. All of these waters contain dissolved salts, the concentration depending upon the salt content of the soil and geologic materials with which the water has been in contact. Waters act as sources of salts when used for irrigation. They may also add salts to soils under natural conditions, as when they flood low-lying land or when groundwater rises close to the soil surface (USDA, 1954).

The accepted classification of soil salinity is based on total salt concentration (as measured by its electrical conductivity) and on the relative concentration of sodium. Soil sodicity (or alkalinity) is characterized by ESP (exchangeable sodium percentage) which gives the amount of adsorbed sodium on the soil exchange complex expressed in percent of the cation exchange capacity in milliequivalents per 100 gm of soil. Since, experimental determination of ESP is tedious, time consuming and subject to errors, the sodium adsorption ratio (SAR) of the soil solution is taken as an index of the soil sodicity. SAR is defined by the ratio $\mathrm{Na^+}/\sqrt{(\mathrm{Ca^{2+}}+\mathrm{Mg^{2+}})/2}$, where all cation concentrations are in meq/litre.

The major factors responsible for the formation of two principal categories of salt-affected soils are discussed below (Abrol et al., 1988).

(a) Saline soils

When groundwater is the only source available for irrigation, high salinity of the irrigation water can cause a buildup of salts in the root zone, particularly if the internal drainage of the soils is restricted and leaching, either due to rainfall or applied irrigation, is inadequate.

Saline seeps are the result of excessive leaching that results from reduced evapo-transpiration after a change in land use from a natural forest vegetation to a cereal grain crop or a shift in cropping pattern such as the introduction of a fallow season in a grain farming system. The percolating water passing through saline sediments is intercepted by impermeable horizontal layers and conducted laterally to landscape depressions causing extensive soil salinization (Doering and Sandoval, 1976).

Salinity problems are also caused by the ingress of sea water through tidal waves, underground aquifers or through wind transport of salt spray. Soluble salts have also been continually exchanged between land and sea - most transfer of salts from the sea taking place through the uplift of marine sediments and exposure on the earth’s surface. For soils of semi-arid regions where rainfed agriculture is practised, serious salinity problems can arise if the rainfall is only approximately equal to the evapotranspiration and soluble salts are present in the root zone from either marine deposits or other sources.

Salinity problems are most extensive in the irrigated arid and semi-arid areas. In every river basin, prior to the introduction of irrigation, there exists a water balance between the rainfall on the one hand and stream flow, groundwater level and evaporation and transpiration on the other. This balance is disturbed when large additional quantities of water are artificially spread on the land for agriculture. An important new contribution to groundwater is introduced in the form of seepage from irrigation channels, from irrigation water added over and above the quantities actually utilized for meeting the evapotranspirational needs of crops, and obstructions in the natural drainage brought about by new developments in the area. These new additions to the groundwater will raise the subsoil water level or may form a perched water table. Studies (Gardner and Fireman, 1958; Sharma and Prihar, 1973) have shown that once the water table is within 1 to 2 m of the soil surface, it can contribute significantly to evaporation from the soil surface and therefore to the root zone salinization. Salinization problems can be more severe when the salinity of groundwater is high, as is usually the case in arid regions.

Localized redistribution of salts can often cause salinity problems of a significant magnitude. Soluble salts move from areas of higher to lower elevations, from relatively wet to dry areas, from irrigated fields to adjacent unirrigated fields, etc. Salts may also accumulate in areas with restricted natural drainage caused by the construction of roads and rail lines or other developmental activities. Evaporation of stagnant waters may leave considerable amounts of salts on the soil surface.

(b) Sodic soils

Groundwater containing carbonate and bicarbonate is one of the chief contributing factors in the formation of sodic soils in many regions. Highly sodic soils can develop in a closed basin with an excess of evaporation over precipitation if the inflowing water has a positive residual sodicity. Similarly, groundwater containing residual sodicity could result in the formation of sodic soils when the groundwater table is near the surface and contributes substantially to evaporation.

Thus, the problem soils can be separated into three groups: s*aline, saline-sodic, and nonsaline-sodic soils.* A saline soil is one whose saturation extract indicates an EC > 0.4 S/m at 25°C but whose ESP < 15. Such soils usually have pH values less than 8.5 and are ordinarily well flocculated. Saline-sodic soils are defined as having a saturation-extract EC > 0.4 S/m and ESP > 15. Such soils when leached, become highly dispersed and exhibit higher pH values. Nonsaline-sodic soils EC < 0.4 S/m and ESP > 15. Such soils often exhibit very high pH values (8.5 - 10).

Saline and sodic soils account for a very large fraction of salt affected soils. Another category of salt-affected soils which, though less extensive, are commonly encountered in coastal zones are acid-sulphate soils. These soils have pH below 3.5 to 4.0 that is directly or indirectly caused by sulphuric acid formed by the oxidation of pyrite. Potential acid sulphate soils occur in tidal swamps. When exposed to oxygen through drainage or disturbance, these materials produce sulfuric acid, often releasing toxic quantities of iron, aluminium and other metals. Pyrite formation is favoured in brackish and saline mangrove swamps dissected by tidal creeks where deposition and build up of coastal sediments is slow (Abrol et al., 1988).

2.4 OCCURRENCE OF GROUNDWATER AND SOIL SALINITY IN COASTAL STATES

2.4.1 Overview of Groundwater Salinity

The most important factor affecting the quality of groundwater in coastal aquifers is the sea water, which contains a number of chemical constituents in very high concentrations as compared to groundwater. The shallow groundwater in a major part of the west coast between Daman (UT) and Thiruvananthapuram (Kerala) exhibits EC less than 750 µS/cm except in a few patches around Raigarh in Maharashtra and Udupi in Karnataka where higher EC upto 3000 µS/cm is observed. Further north, along the coast of Gujarat, the EC of shallow groundwater, in general, ranges from 1500 to 4500 µS/cm except in the area between Sikka and Hadiyana of Jamnagar coast.

However, certain coastal tracts of Kachchh and Saurashtra coasts and parts of Gulf of Kachchh and Gulf of Khambat show EC values above 4500 µS/cm. EC is upto about 20000 µS/cm near Vinjhan (Kachchh coast), 6000 µS/cm around Dwarka, 15000 to 18000 µS/cm around Mangrol-Veraval (Saurashtra coast), 11000 to 12000 µS/cm near Shikarpur-Kumbhariya (Gulf of Kachchh) and 6000 to 12000 µS/cm near Jantram and Bhavnagar (Gulf of Khambat) (CGWB, 2014). Along east coast, the EC of groundwater in the shallow aquifers varies, in general, from 750 to 3000 µS/cm except for a few patches with EC less than 750 µS/cm around Digha on the coast of West Bengal and Kendrapara and Puri on the coast of Odisha. In the northern part of Andhra Pradesh coast, the EC is mostly in the range of 750 to 1500 µS/cm, while in the southern part it is mostly in the range of 1500 to 3000 µS/cm, although there are patches with EC values in the range of 3000 to 4500 µS/cm on the coast of Andhra Pradesh and Tamil Nadu. Shallow aquifers with very high EC in the range of 7000 to 22000 µS/cm are encountered only in the southern coastal districts of Tamil Nadu, viz., Pudukkottai, Ramanathapuram, Tuticorin and Tirunelveli. Thus, the quality of groundwater in coastal aquifers shows considerable variation from place to place, depending on a host of factors including climate, geomorphology, geology, hydrogeological setting and extent of anthropogenic influence. Figure 2.5 shows the spatial distribution of EC in groundwater in shallow aquifers of India.

2.4.2 Overview of Salt Affected Soils

The problem of coastal soil salinity in India encompasses (1) coastal saline soils situated in humid and sub-humid areas (2) coastal saline soils of arid areas and (3) coastal acid saline soils. Salt affected soils occur within a narrow strip of land adjacent to the coast and up to 50 km wide. These areas generally have an elevation of less than 10 m above mean sea level (amsl) and include the low-lying land of river deltas, lacustrine fringes, lagoons, coastal marshes, and narrow coastal plain or terraces along the creeks. As per the estimates given by Bandyopadhyay et al. (1988), the coastal saline soils are spread in an area of about 3.1 Mha (Table 2.3) in the coastal tracts of West Bengal, Orissa, Andhra Pradesh, Puducherry, Tamil Nadu, Kerala, Karnataka, Maharashtra, Gujarat, Goa and Andaman & Nicobar Islands. This estimate includes about 0.57 million hectares of salt affected area under mangrove forests.

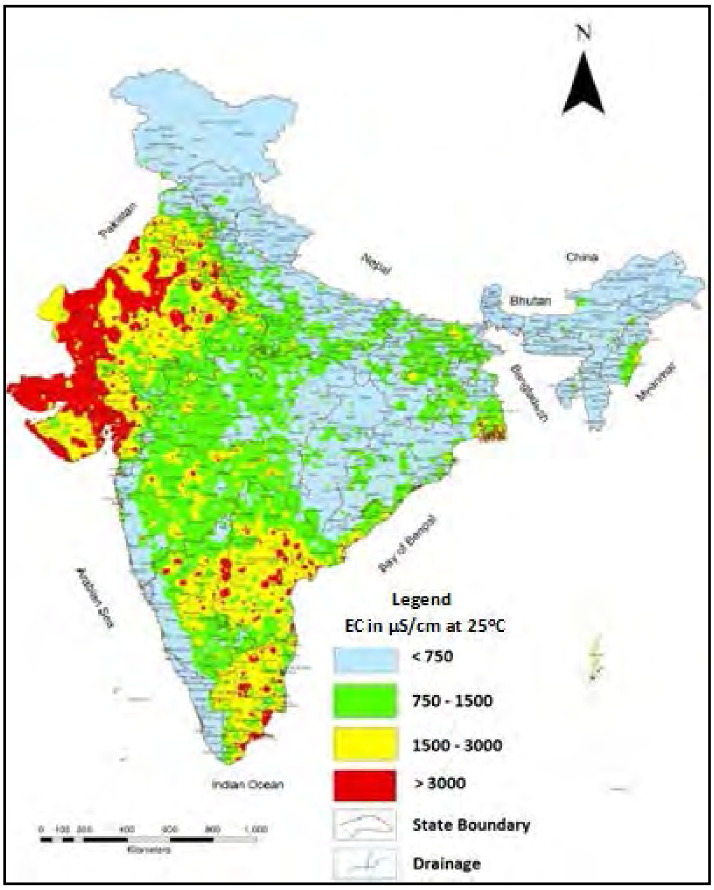


Fig. 2.5 Distribution of EC in groundwater in shallow aquifers (CGWB, 2014a)

Coastal saline soils are different from inland saline soils in the sense that the inland soil salinity is due to secondary salinization from high water table conditions caused by the introduction of irrigation in arid and semiarid areas. The salinity problem in coastal soils arises during the process of their formation itself due to marine influence and frequent tidal inundation of the coast land with sea water and ingress of seawater along the estuaries, creeks, drains and rivers. The effect of tides is manifested in the regular rise and fall of the water level of the estuarine channels and creeks. The repeated inundation with highly saline water renders the soil saline. The salinity of coastal soils varies with the season and is at its maximum in May. Salinity decreases with the onset of monsoon and is generally lowest during September in areas receiving rain from south-west monsoon. Moreover, groundwater with high salt content is present at shallow depths in coastal areas because of low lying nature of these areas and their proximity to sea. These salts accumulate on the surface of the soil due to the capillary rise of saline groundwater during dry periods of the year.

Table 2.3 Extent of coastal saline soils in India (Bandyopadhyay et al., 1988)

State	Area (thousand hectares)
West Bengal	820
Gujarat	714
Orissa	400
Andhra Pradesh	276
Tamil Nadu	100
Karnataka	86
Maharashtra	64
Kerala	26
Goa	18
Puducherry	1
Andaman & Nicobar Islands	15
Salt affected area under mangrove forests	574
Total	**3094**

The important areas needing attention are the Sundarbans of West Bengal, the delta areas of Krishna, Godavari and Cauveri, Kari soils in Kerala, Khar lands of Maharashtra and coastal areas of Gujarat and Rann of Kachchh. The saline soils are referred to as Khazan lands in Goa and Khar lands in Maharashtra. The nature of the problem is different in different parts and so the problems associated with these lands also vary. The saline soils of Sundarban in West Bengal are probably the result of inundation of backwaters from sea. In Kerala, the Kari soils are peaty in nature, containing 10-40% organic matter. These soils are present in are low lying areas that remain submerged under water during the monsoon. In Maharashtra, the problem areas occur in the districts of Ratnagiri and Thana. Soil salinity also occurs in Uttar Kannada district of Karnataka. In Gujarat, the problem is widespread in Saurashtra region and in the districts of Ahmedabad, Amreli, Bharuch. These soils have been primarily recovered from sea and are further formed by gradual silting by the sediment brought down by the rivers draining in these areas. Thus, for example, Kathiawar (in Saurashtra) was formerly an island which has risen slowly and become connected with the mainland.

Except for Sundarbans in West Bengal and the Great and Little Rann of Kachchh in Gujarat, the coastal saline areas (with top layer saline), are limited to a strip along the coast both on the east and the west of Peninsula. The saline region is somewhat wide in the district of

Medinipur and in the coastal districts of Odisha but the width of the saline zone tapers off on the east coast towards Kanyakumari in Tamil Nadu. On the west coast, the saline region is very narrow on account of the narrow width of Western Coastal Plains. Inundation of the saline strip is more common on the west coast where the tidal effect is quite substantial. On the east coast because of the littoral drift and formation of land and the proximity of sand dunes to the sea, tidal effect is not so prominent.

2.5 IMPACT OF COASTAL LAND SALINITY ON CROP YIELD, URBAN AND NATURAL ENVIRONMENT

WHO recommends that the chloride concentration of the water supply for human consumption should not exceed 250 mg/L. Agriculture applications also depend upon the salinity level of the supplied water. Many crops are sensitive to chloride concentration in irrigation water (an upper limit of 250 mg/L). In addition, long-term irrigation with water enriched with sodium results in a significant reduction in the hydraulic conductivity and hence the fertility of the irrigated soil. Similarly, the industrial sector demands water of high quality. For example, the high-tech industry requires a large amount of water with low levels of dissolved salts. Hence, the salinity level of groundwater is one of the limiting factors that determine the suitability of water for a variety of applications.

Agricultural Production

Salinity affects plant growth resulting in lower crop yields and reduced agricultural production. Excess salinity reduces the osmotic activity of plants and thus interferes with the absorption of water and nutrients from the soil. As soil salinity increases, most plants find it increasingly difficult to extract water from the soil. Increased levels of salt can disturb the balance of plant nutrients in the soil and some salts (e.g. chloride, sodium and boron) in excess are phytotoxic to certain plants. When these concentrations reach toxic levels, effects are most noticeable in the leaves, particularly in the leaf margins. Symptoms include necrotic spots, leaf bronzing and, in highly toxic cases, defoliation. Although there is a wide range of salt tolerance in plants, most normal crop and pasture plants are not highly salt-tolerant and will eventually wither and die under saline conditions. Plant salt tolerance for crops is defined as the ability of plants to survive and produce economic yields under saline conditions. The yields of some particularly sensitive plants, such as carrots, beans, avocados and strawberries are affected by saline water with EC as low as 700 μS/cm.

Salinity in irrigation water may also affect the physical and chemical properties of soil, resulting in surface soil compaction and erosion. High levels of salt can dehydrate soil bacteria and fungi and reduce soil health, which is dependent on good microbial activity for the formation of organic matter and nutrient recycling. The breakdown in soil structure, together with the associated loss of plant cover, results in a greater exposure of the soil to erosion. Sheet, rill, gully and wind erosion is commonly caused by salinity. In extreme cases, badly affected land may need to be removed from agricultural production if management options to improve salinity are unsuccessful or are not economical.

In addition to reduced agricultural production, there are also costs associated with protecting land from further degradation, groundwater monitoring, fencing, revegetation and repairing damage to farm infrastructure such as pipes, roads, and buildings.

Urban Environment

Salinity and associated waterlogging can have a serious impact on infrastructure, buildings and houses. Salinity damage to houses, buildings and infrastructure includes: deterioration of brick, mortar and concrete structure; corrosion of metal buried in the ground or set in structural concrete; structural cracking, damage to buildings because of shifting or sinking of foundations; breakdown of road concrete, bitumen and asphalt with associated cracking and crumbling of the road base; damage to underground pipes, cables and other infrastructure due to the breakdown of unprotected metal, cement and other materials; loss of amenity in recreational areas such as gardens and sports grounds due to the appearance of bare, exposed patches where grass and other plants cannot grow; prolonged water-logging; failure of septic tanks caused by high water table rendering them inoperable which may lead to other environmental and health problems.

Other less tangible costs are decline in property values or lost revenue because of the reduced capacity to use an asset on salinized lands. Increasing water salinity places pressure on municipal water supplies and results in increased treatment and infrastructure costs. Where the water for domestic supplies is 'hard' (i.e. when calcium or magnesium content is high), water may require extensive and expensive treatment before it is suitable for human use. Hard water can result in damage to hot water systems and other household appliances, and increased use of soaps, and detergents. Higher levels of salt concentrations in water can significantly impact the manufacturing and food processing industries where water of low salinity is an important requirement. The future development of these industries may not be economically viable in areas that are at risk from rising salinity levels.

Natural Environment

There is a natural variation in the ability of plant and animal species and ecosystems to tolerate salinity. The ecosystems most likely to be affected by salinity are rivers and riverbanks, wetlands, and vegetation in lower parts of the landscape.

Some plants, such as mangroves, have adapted to saline conditions. These plants, called halophytes, grow successfully in saline environments because they have specially adapted mechanisms that allow the plant to deal with the presence of excess salt. However, for most plants, rising groundwater and increasing salinity have a negative impact on plant growth and seed germination. Water logging causes poor soil aeration, starving plants of oxygen. The immediate effects of salinity on plants that are not adapted to salt include leaf drop, leaf burn, stunted growth, poor seed germination and tree death. But, salinity also affects the health of vegetation communities, as fewer young plants survive to adulthood to replace the previous generation. The composition of vegetation communities may also change as salt tolerant plants become dominant in salt affected areas. Further, salinity above 1500 µS/cm may reduce the diversity and abundance of aquatic plant and invertebrate communities. However, plant and animal communities from different wetlands may respond to different levels of salinity in different ways.

2.6 MANAGEMENT OF COASTAL LAND SALINITY

Whether people, living in the groundwater salinity affected areas, are really being affected by the salinity is very much dependent on their groundwater use. When people are hardly using any groundwater, their vulnerability to groundwater salinity hazards is obviously low. However, risks on account of soil salinity remain.

The effective design and implementation of measures for control of groundwater salinity is very much dependent on the local context. Some potential measures have a mitigation objective and aim at keeping groundwater salinity levels below harmful thresholds. Other measures have a more adaptive approach and accept the high groundwater salinity encountered but adjust groundwater use in such a way that the salinity level is not harmful. Among the hydraulic measures to be considered are the optimisation of the pattern and intensity of groundwater abstractions and the development of hydraulic barriers with injected water to reduce further seawater intrusions and upconing. Furthermore, the creation of strategic fresh water reserves (both surface and sub-surface) by means of rainwater harvesting and managed aquifer recharge, by conjunctive use of surface and brackish water and by desalinisation of inland brackish groundwater for the provision of drinking water. Sufficient drainage in irrigated areas avoiding water-logging and the application of smaller quantities of chemical inputs in agriculture reduce the salinity build-up in rural areas. So does sufficient treatment of the waste water that is increasingly being used as a source for irrigation in water scarce regions. In order to develop optimal solutions for managing coastal soil and water salinity, specific information about the climate, topography and hydrogeology of the region, origin of water salinity, available water resources and land use etc. are required.

2.6.1 Soil Salinity Control and Reclamation Measures

Depending on the local conditions, reclamation of the salt-affected soils can be carried out by preventing the tidal water inundation through construction of bunds, leaching of salts from the soil profile and through application of suitable amendments in the case of the acid sulphate soils and sodic soils, and, adoption of other suitable soil-water and crop management practices.

Protective embankments

As a first step towards reclamation of the coastal saline soils and control further salinization, the land must be protected from inundation of sea water by constructing protective embankments/ bunds. Such embankments have been constructed in Sundarbans (West Bengal), Maharashtra, Karnataka and Odisha etc., usually with a free board of about 1 m above the high tide level. The top width of the embankments ranges from 1 m to 4 m. To reduce damage from constant erosive action of waves, a suitable shelter with trees or grasses around these structures is effective to minimize wave action (shelterbelts also prevent the drifting of saline sands into the inland areas). The embankments are provided with one way sluice gates. The purpose of the sluice is to prevent the ingress of sea water into the land side and at the same time, allowing the inland excess water to drain to the sea.

Surface drainage

In surface drainage, ditches are provided so that excess water will run off before it enters the soil. However the water intake rates of soils should be kept as high as possible so that water which could be stored will not be drained off. Field ditches empty into collecting ditches built to follow a natural water course. A natural grade or fall is needed to carry the water away from the area to be drained. The location of areas needing surface drainage can be determined by observing where water is standing on the ground after heavy rain. The surface drainage problem becomes acute during monsoon months in the low lying flat coastal tracts due to heavy rainfall, low infiltration rate and lack of a well defined drainage system. The surplus water that needs to be drained can be estimated by a simple water balance analysis involving rainfall and potential evapotranspiration. In addition to the rainfall, the runoff from the upstream watersheds also contributes to flooding of these areas as the rivers and drains overflow. If desired, channelization in the catchment will directly route the excess rain water from the different zones to the discharge outlet. This is to be streamlined with opening of the sluice gate more frequently and for longer periods to maintain the desired water levels in the region. While designing the surface drainage system, the rainfall pattern and crop requirements should be taken into consideration. For example in the Sunderbans, West Bengal, the most critical period for surface drainage is the month of July and beginning of August when the heaviest storms occur and the farm work is in progress; young transplanted rice seedlings may get damaged under prolonged submergence. On the other hand, the most critical period in. the south coastal areas of Andhra Pradesh and Tamil Nadu may be October and November due to the cyclonic storms and the harvesting time of kharif rice crop.

Sub-surface drainage

Persistence of shallow water table with poor quality groundwater in any area calls for a good subsurface drainage system. Due to marine origin and the impeded surface and subsurface drainage, soils in coastal regions can be highly saline and present unfavorable characteristics for crop growth. Open ditches as sub-surface drains with suitable drain spacing and dimensions (depending upon the soil hydraulic conductivity) can be employed effectively to leach out salts and keep the water table low. Open drainage ditches are advantageous for removing large volumes of either surface or subsoil water from land and for use where the water table is near the surface and the slope is too small. Other types of sub-surface drainage systems may consist of buried tiles or perforated pipes or in some cases pumped drainage wells

Leaching of soluble salts

Methods commonly adopted to remove soluble salts from the root zone include the following (Abrol et al., 1988):

Scraping: This involves removing the salts that have accumulated on the soil surface, by mechanical means. The method shows limited success and might temporarily improve crop growth; the ultimate disposal of salts poses a major problem.

Flushing: Washing away the surface accumulated salts by flushing water over the surface is sometimes used to desalinize soils having surface salt crusts. Because the amount of salts that can be flushed from a soil is rather small, this method does not have much practical significance.

Leaching: This is by far the most effective procedure for removing salts from the root zone of soils. Leaching is most often accomplished by ponding fresh water on the soil surface and allowing it to infiltrate. Leaching is effective when the salty drainage water is discharged through subsurface drains that carry the leached salts out of the area under reclamation. Leaching may reduce salinity levels in the absence of artificial drains when there is sufficient natural drainage, i.e. the ponded water drains without raising the water table. Leaching should preferably be done when the soil moisture content is low and the groundwater table is deep. Leaching during the summer months is, as a rule, less effective because large quantities of water are lost by evaporation. The actual choice will however depend on the availability of water and other considerations. In some parts of India, leaching is best accomplished during the summer months because this is the time when the water table is deepest and the soil is dry. This is also the only time when large quantities of fresh water can be diverted for reclamation purposes. Other factors to be taken into consideration are described below.

- Quantity of water for leaching
  It is important to have a reliable estimate of the quantity of water required to accomplish salt leaching. The initial salt content of the soil, desired level of soil salinity after leaching, depth to which reclamation is desired and soil characteristics are major factors that determine the amount of water needed for reclamation.

- Water application method
  The quantity of salts removed per unit quantity of water leached can be increased appreciably by leaching at soil moisture content that is less than saturation, i.e. under unsaturated conditions. In the field, unsaturated conditions during leaching are obtained by adopting intermittent ponding or by intermittent sprinkling at rates less than the infiltration rate of the soil.

- Soil Amendments
  Whether an amendment (e.g. gypsum) is necessary or not for the reclamation of salt-affected soils is a matter of practical importance. Saline soils are dominated by neutral soluble salts and at high salinities sodium chloride is most often the dominant salt although calcium and magnesium are present in sufficient amounts to meet the plant growth needs. Since sodium chloride is most often the dominant soluble salt, the SAR of the soil solution of saline soils is also high. The decision to use an amendment for the

reclamation of saline soils having excess neutral soluble salts and a high SAR of soil solution (i.e. saline-sodic soils) would depend on soil infiltration characteristics and the electrolyte level of the irrigation water. Light textured soils and those having a favourable infiltration rate are not likely to respond to gypsum application. In heavy textured soils, and where such soils are leached with low electrolyte water, application of an amendment is desirable to hasten reclamation. When any large-scale reclamation is undertaken, the need for application of amendments and their quantities must be established by trials on an experimental scale. In Orissa state, organic residues have been used to correct the salinity hazards in the soil. In the loamy soils of Tamil Nadu, application of organic matter and gypsum were found to be beneficial, whereas in the sandy soils the green manure alone at the rate of 5000 kg/ha was found to improve the soils. In the Khar land of Maharashtra, the soils were ploughed deep and rice was grown. The application of organic and green matter was also recommended. Application of sulphur, gypsum, green manure, and farmyard manure in sodic soils of Andhra Pradesh was found to improve the soil properties and grain yield of rice. In Tamil Nadu and Karnataka, application of gypsum was found to be useful in sodic soils.

Groundwater is a critical water supply resource for the millions of inhabitants along the coastal margins of India. Salinization of these vital repositories of freshwater also contributes to the accumulation of salts in the soil with deleterious impacts on the fertility of the land and regional economy. Reclamation of such salt-affected coastal aquifers entails huge effort, expenditure and may take many years. Sometimes damage to the affected land is irreversible. Management of the threat of seawater ingress is, thus, critical for protection of coastal land and water resources. Controls regarding soil salinity management have been discussed in Section 2.6.1. Strategies for sustainable development and management of coastal groundwater, which are more extensive in nature, are elaborated below.

2.6.2 Coastal Groundwater Salinity Management Strategies

To preserve groundwater resources in the coastal zones, it is necessary to manage the threat of seawater ingress. Management strategies can generally be placed into following three categories with the ultimate goal of preserving groundwater resources for current and future use (Bear, 1999; Bear et al., 2004; ACASA, 2011; Sharma & Kumar, 2013):

I. Scientific Monitoring, Assessment and Modeling
II. Behavioural and Institutional Approaches, and
III. Engineering Measures

I. Scientific Monitoring, Assessment and Modeling

Scientific monitoring and assessment form an essential starting point for effective management of seawater intrusion. As specific aquifer dynamics can vary greatly from location to location, these tools give decision makers an in-depth, localized understanding of their coastal freshwater resources and enable them to make sound and informed decisions. The groundwater development and management of coastal aquifer systems should form part of integrated water management, comprising surface water and groundwater, both in terms of water quantity and water quality, and taking into account the water demands.

Data Collection and Monitoring

The types of data required for groundwater studies in coastal and deltaic areas, where saltwater intrusion plays a role, relate to records of (a) well logs, geophysical surveys and hydro-geological parameters (b) climate data and natural recharge, (c) Water levels (water table and piezometric levels, surface water levels, (d) groundwater quality (chemical and isotopic composition, particularly salinity, and sources of groundwater pollution), (e) Surface water (natural outflow, availability and quality of surface water for artificial recharge), (f) present and past abstractions of groundwater, present and past artificial recharge (if any), (g) Water demands, at present and estimates for the future (h) Ecology (flora and fauna, and their relation to the groundwater table regime, and (i) Relative sea-level rise.

Observation-well networks that monitor groundwater levels and groundwater quality are indispensable for determining the effects of groundwater development on groundwater levels and groundwater storage and for monitoring the location and movement of saltwater-freshwater interface; in essence, they serve as warning or detection systems of any landward flow of subsurface saltwater. It is particularly important to emphasize the long-term commitment required for effective monitoring and assessment of saltwater intrusion. Again, elevated salt content within a well does not necessarily reflect intrusion; rather, active saltwater intrusion (characterized by a prolonged shift in the saltwater-freshwater interface) can be definitively identified only with numerous samples over a longer period of time. Such monitoring and assessment contributes to a thorough understanding of existing conditions in coastal aquifers and constitutes a necessary first step for understanding human impact on water and ecological resources, for assessing whether available water supplies will be adequate to meet future needs, and in determining both the severity of any seawater ingress and the best approach(es) in adapting to the impacts of climate change.

Scientific Assessment and Modeling

Another essential tool in the assessment of coastal aquifer dynamics is that of scientific modeling. It has emerged over the past four decades as one of the primary tools that hydrologists use to understand groundwater flow and saltwater movement in coastal aquifers. Modeling is a numerical way of conceptualizing the physical processes by which groundwater flow and solute transport occur in the groundwater system. Modeling helps identify the different factors (such as recharge) that influence groundwater movement. Models can be further enhanced to incorporate the effect of water density (e.g., salinity) on groundwater flow, and they can be employed to identify conditions under which groundwater pumping and availability is optimized and seawater intrusion is limited. Specifically, these simulation-optimization models allow us to calculate favourable groundwater yields by identifying the optimal pumping rates, well locations, and human interventions (such as artificial recharge) that are most efficient. Modifying the pumping pattern or relocating the pumping locations further inland using the simulation-optimization model as a decision making tool can substantially reduce the intrusion (NIH, 2014a).

II. Behavioural and Institutional Approaches

The second group of coastal aquifer management strategies fit into the category of behavioural and institutional approaches aimed towards ensuring sustained water quality and quantity over the long term.

Water supply and demand management

With regard to water supply-related policies, the natural choice might be to limit the amount of groundwater abstracted and, potentially, to relocate wells farther inland. In order to do this, water demand management in the form of water saving measures should be adopted. Various water saving measures are implemented at locations around the world that are highly prone to salinization. Other drivers like an overall water scarcity, naturally force people to adapt to such water saving practices. Possible water-saving measures are reduction of non-beneficial evaporative and leakage losses, increase of irrigation efficiency, a change to less water demanding production processes and land uses and to find alternative sources of water other than groundwater (surface water or re-use of waste water).

Salt tolerant crops

Groundwater salinity is also managed by adjusting groundwater use to poorer groundwater quality levels. In many coastal agricultural areas where only marginal quality water is available and where soil conditions are negatively affected by salinity, farmers are still able to grow crops profitably by changing to more salt-tolerant crops (Weert et al., 2009; NIH, 2014b). Often the crop adaptation is accompanied by nutrients augmentation (in fertilizers) and soil quality improvement (e.g. adding gypsum sulphuric acid, and iron pyrite to reduce the negative effects of soil sodicity).

Usage of blended water

In cases of marginal quality groundwater, it is judicious to use this water in conjunction with better quality water. The poor quality groundwater could physically be blended with more freshwater to provide water with an acceptable salinity level for application. Alternatively, the poor quality groundwater could be applied in an alternating fashion with better quality surface water. The freshwater is used to meet the evaporative crop demand but also to flush the plot that prevents soil salinity build up significantly.

Coastal protection measures

In coastal zones that are prone to regular seawater flooding and seawater spray, various coastal protection measures consisting of e.g. levees, dikes, natural protection like dunes and mangrove vegetation, shelterbelt plantation with high and dense trees, afforestation of waste lands can limit the susceptibility to salinization. Further, in coastal areas with high evaporation rates, shelterbelts also help in reducing evaporation losses.

Institutional instruments

Farmers in salinity prone areas often rationally measure the investment costs needed for fighting salinity against the losses caused by salinity in case of non-action. On a larger scale, policymakers, agriculturists and natural resources managers need to estimate how much groundwater salinity is allowed in a certain area before complex and strongly interrelated systems of nature and society are significantly affected. Some of the consequences caused by salinity in such complex systems may be irreversible or may trigger even larger scale problems (like socio-economic problems caused by unemployment and migration of farmers that abandon their land due to severe salinity problems). The governmental and non-governmental organizations dealing with groundwater management and those dealing with soil management, agriculture and livelihood development have a responsibility to help make individuals mitigate, adapt to or compensate for the salinity problems (Weert et al., 2009).

Institutional instruments that are practiced to control groundwater salinity are:

- regulatory (like well registration, licensing, groundwater abstraction rights and quota, land use restrictions, emission rules),
- economic (subsidies for individuals or groups/sectors to invest in new technologies to manage salinity, investments in governmental aquifer storage and recovery programs, environmental taxes to discourage salinity increasing practices, compensation for financial losses caused by salinity)
- advisory (enabling access to information, expertise, funding and creating awareness and training).

Policy and plan development

The technical, scientific, behavioural and institutional approaches of coastal aquifer management (ideally) come together in the development of policies and plans that deal with coastal groundwater salinity in an integrated way. Such a policy should contain an integrated and strategic vision on coastal groundwater management for a certain area and for a certain period.

III. Engineering Measures

The third group of coastal aquifer management strategies consists of various engineering measures that can be employed as a way to prevent seawater intrusion into estuaries and as control measures where groundwater withdrawals have caused water levels in aquifers to fall significantly below mean sea level.

The same techniques can and must be utilized also in those cases where continuity of a controlled groundwater exploitation must be assured. These include seawater barriers, aquifer storage and recovery (ASR) systems, increased recharge, and skimming wells (Barlow and Reichard, 2010; Pool and Carrera, 2010; Saravanan et al., 2014; NIH, 2014a,b). The effectiveness of engineering techniques depends a lot on local conditions.

(i) Control Measures for Seawater Intrusion into Estuaries

During extended droughts, decreased river flow allows the saline water to migrate up the estuary. A rise in sea-level will also cause seawater to migrate upstream. The general methods of preventing seawater intrusion up estuaries are similar for sea-level rise, drought conditions, and storm surge. Storm surge elevates the ocean in relation to the estuary water level, causing seawater intrusion. A major difference is that storm surge and drought conditions last for a limited duration, whereas the sea-level rise is expected to last much longer.

In order to minimize seawater migration, provisions must be made for low-flow augmentation and water conservation requirements during periods of low flow. Water from rainfall is stored in large surface reservoirs and released continuously during droughts to maintain a flow that helps push back the seawater from migrating upstream. The planning agencies should recognize the need to sustain stream flows to protect freshwater intakes and in-stream uses (including fish migration and fish production), as well as treated-waste assimilation, recreation, and salinity repulsion. An economic justification is usually necessary, showing that the cost of the mitigation is less than the anticipated benefits.

The prevention of seawater ingress can be achieved by various measures including:

- *Barriers*. Dams can be constructed that physically prevent the seawater from moving past a certain point in the estuary. Injection barriers can also be employed successfully.

    - *Tidal Regulator*: It is a gated structure constructed near the mouth of a river to prevent the ingress of tidal water through the river channel (Fig. 2.6). The tidal regulator is a solid wall with regulating gates. The top portion of the gates is kept above the maximum tide level. Generally gates remain closed so that tidal water does not enter the upstream areas. During floods in the inland area, gates are opened and regulated so as to allow the discharge of the excessive flood water without creating undesirable submergence of the lands in the upstream area. The crest level of the masonry wall is kept below high tide level to avoid submergence beyond certain limits depending upon the location of adjoining coastal villages and cultivable lands. Cut-off wall is provided upto the impervious layer below the foundation. The upstream reservoir formed as a result of structure may be used for crop irrigation. The reservoir also acts as a source of recharge to the groundwater system.

    - *Bandhara*: Where the height of tide water is limited, the construction of a solid non-gated wall with crest 1 m above high tide level may be considered for reducing the overall construction cost.

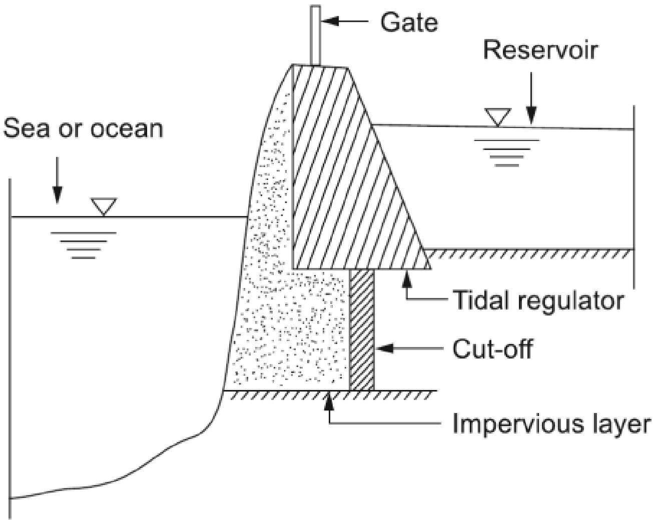


Fig. 2.6 Schematic diagram of a tidal regulator (Das and Saikia, 2013)

- *Restricting construction of pathways for seawater intrusion*. Construction of drainage canals to reclaim land by lowering the water table in coastal areas where groundwater is present at shallow depths also permits seawater to migrate into inland areas and allows a pathway for saltwater intrusion to occur; this should be minimized.
- *Alternate sources of water*. Water users may be able to obtain water from other sources that are not endangered by saltwater intrusion.
- *Restrictions on use of water*. During periods of higher sea-level or drought, stricter conservation and restrictions on export of water from the river basin may be considered for short durations.

(ii) Control Measures for Seawater Intrusion into Coastal Aquifers

Control methods for seawater intrusion have been employed or seriously considered only in areas where withdrawals of water have caused groundwater levels to fall significantly below mean sea level. Because of the very slow velocity with which the saltwater moves, many areas with serious overdrafts have not yet lost their aquifers as sources of freshwater. However, the problem must be solved eventually because once seawater has invaded an aquifer, it could take hundreds of years to regain the groundwater quality. One of the dangers to freshwater aquifer supplies could be the migration of seawater up an estuary that recharges an aquifer. If the water levels in the aquifer fall below this saltwater level due to groundwater withdrawals, the saltwater would recharge the aquifer.

Several control strategies can be used to prevent or retard seawater intrusion into aquifers. The control strategies include:

- *Seawater barriers.* One attractive solution is to design seawater barriers that prevent seawater from flowing inland, thereby protecting groundwater pumping zones. Different types of barrier designs can be considered: low permeability subsurface barriers, and, hydraulic barriers viz., injection hydraulic barriers, extraction hydraulic barriers and mixed hydraulic barriers

- *Aquifer storage and recovery (ASR).* Technique used is a particular type of artificial recharge whereby freshwater is injected into the aquifer (through a well) during high-supply seasons and then recovered (pumped to the surface) during low-supply seasons.
- *Increased recharge.* Spreading of water on the land in upland recharge areas allows more percolation (infiltration of water into the aquifer), which retards saltwater intrusion.
- *Skimming wells*. In coastal regions where freshwater is underlain by saltwater and saltwater upconing is a common problem, skimming wells are employed to restrict the salt concentration in the pumped water to an acceptable limit.

Combinations of above techniques can also be effectively employed. Combinations of an extraction and an injection hydraulic barrier, or, increased recharge with injection barrier are quite effective in preventing seawater ingress in coastal aquifers.

Low permeability subsurface barriers

Low permeability subsurface barriers (Fig. 2.7) consist of vertical walls placed inland to block seawater intrusion. There are three types of subsurface barrier walls: slurry walls, grout cutoffs, and steel sheet piles. Slurry wall construction involves pumping a slurry made of water and bentonite clay into a trench. Grout cutoffs are constructed by injecting a liquid, slurry, or emulsion under pressure into the soil. The injected fluid will occupy the pore spaces and will solidify to form an impermeable wall. Sheet piling involves driving lengths of steel that connect together into the ground to form a thin impermeable barrier to flow. These three types of barriers must be connected to an underlying impermeable geologic zone (Atkinson et al., 1986).

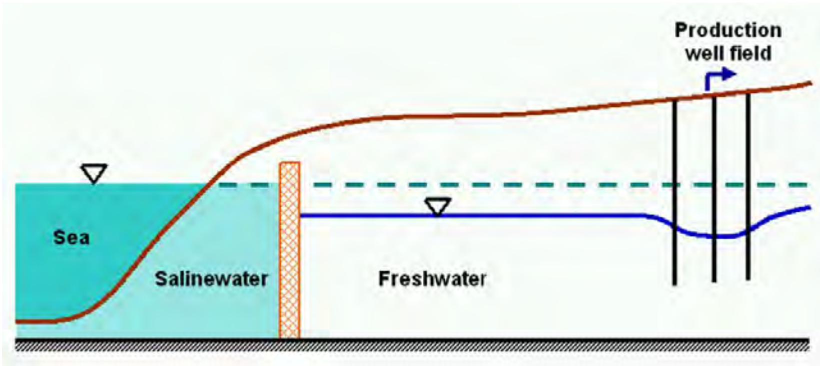


Fig. 2.7 Low permeability subsurface barrier (NIH, 2014a)

The subsurface barrier is located between the seawater and the production wells and constructed parallel to the coast. It is likely that such a barrier could be effective only in relatively shallow formations. The effectiveness of the barrier must be monitored to determine the magnitude of seawater penetration. Additionally, in cases of large fresh groundwater discharges to sea, a barrier can be constructed at an appropriate location to intercept the flow and increase the aquifer freshwater capacity.

This system requires considerable engineering and investment. The drawback is that even in the uppermost aquifer layer where the cost may not be prohibitive, the backwater effect or storm surges could cause coastal lowlands to become waterlogged. Moreover, it may be counterproductive if pumping stops or sources of contamination exist in upstream areas. In such a scenario, a semi-impermeable barrier instead of an impermeable barrier should be constructed, through which contaminated groundwater may seep through seaward.

Hydraulic Barriers

(i) *Injection hydraulic barriers* (Fig. 2.8) inject water into the aquifer, which raises the water table / piezometric head and maintains a ‘pressure ridge’, thus preventing saltwater from flowing inland (Bray and Yeh, 2008) and protecting the inland groundwater production well fields. This pressure ridge may be achieved with a line of injection wells paralleling the coast that are located landward from the toe of the interface or seawater wedge to provide enough space for freshwater to flow seaward. Thus, the pressure of recharged water can push the interface seaward. The injected wells are injected with high quality water or highly treated, reclaimed water. Regular groundwater level and geochemical monitoring is needed to know about the efficient performance of the hydraulic barrier system and aquifer water quality improvement. It also allows managers to make an accurate, informed decision regarding the amount of water that should be injected in the system to prevent seawater intrusion.

With some water planners it is a point of contention that injection barriers are inefficient because they inject freshwater into the ocean, which is not necessarily the case. It has been demonstrated (Abarca et al., 2006) that their efficiency is greater (i.e., the allowable increase in inland pumping exceeds the recharged flow rate) because they not only increase available resources but also protect inland wells. The main disadvantages of this corrective measure are: the need for high-quality water whenever injection is undertaken through wells and the need for space if recharge through basins is necessary. Recharge wells overcome the high cost of the water spreading technique in areas where suitable land is scarce and/or expensive. These injection barriers also require considerable maintenance to control well-screen clogging. Injecting high-quality water reduces the frequency of well clogging, increases the operating life of the well, and reduces cleaning costs. In addition, chlorination of the injected water helps to protect the well casing, prevents potential leaks, and reduces near field bio-fouling of the formations. When there is clogging and the injection head has increased above acceptable levels, redevelopment of the injection wells is necessary.

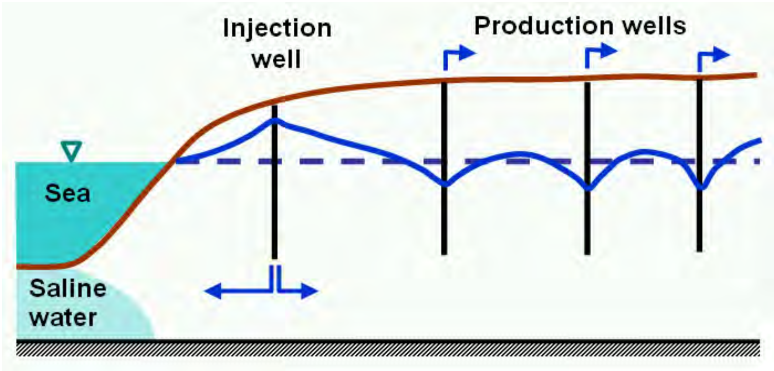


Fig. 2.8 Injection hydraulic barrier (NIH, 2014a)

Supply line pressure must be closely monitored and carefully controlled to prevent injection head fluctuations that could disrupt the well's gravel pack or even damage the injection well itself. Injection wells should be supplied with pressure either individually or in small groups. This will prevent the complete collapse of the pressure ridge barrier in cases of shut down due to accidents or malfunctions. Abandoned barrier wells should be thoroughly plugged to prevent the infiltration of contaminated surface waters into the aquifer. Wells are typically plugged with cement slurries; the exact composition of the slurry should be tailored to the specific geology of the well site.

(ii) *Extraction hydraulic barriers* (Fig. 2.9) pump near the shore employing a line of wells that are constructed adjacent to the coast between the interface toe and the coastline and pumped to form a 'trough' at the groundwater level, thus intercepting inflowing seawater (Todd, 1980). The exact location of the barrier should be based on the shape of the interface. In addition to withdrawing seawater through extraction wells, the groundwater level along the line of extraction wells will also be lowered, which will cause seaward movement of freshwater. Eventually a new groundwater dynamic equilibrium may be achieved.

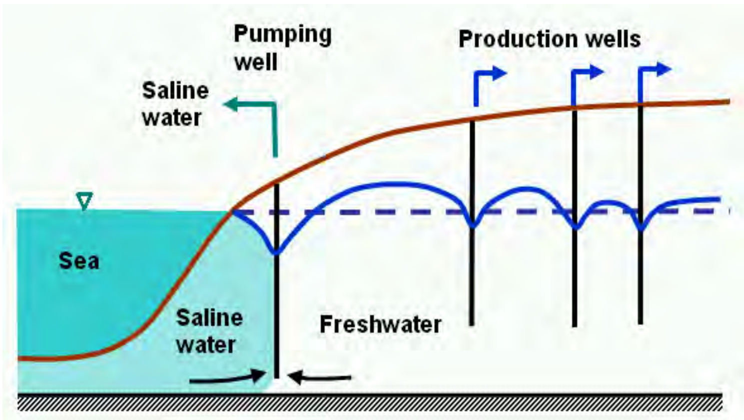


Fig. 2.9 Extraction hydraulic barrier (NIH, 2014a)

This technique requires that the amount of freshwater that can be withdrawn must be reduced. Without reducing the pumping rate, it is impossible for the system to achieve equilibrium. The amount of saltwater to be pumped should be estimated. Withdrawing less water than is actually required to control seawater wedge will lead to the following problems: (a) the freshwater region may be intruded by saline water; and (b) a positive seaward hydraulic gradient may not be formed. Conversely, pumping more water than the required amount causes saltwater and freshwater to be withdrawn from the aquifer. Ideally, the amount of saltwater pumped should be slightly higher than the rate at which seawater is intruding.

Seawater intrusion is impeded as long as the barrier pumps. The water pumped is brackish and normally is discharged into the sea. In practice, this system is often applied with minimum or no planning. It is a common knowledge that inland production wells are protected by coastal wells and inland well owners are prepared to go to great lengths to keep coastal wells pumping. However, these barriers often end up pumping much more freshwater than saltwater, leading to a mixing of freshwater with seawater at the wells and to a reduction in freshwater resources. Nevertheless, extraction barriers may be the only possible corrective measures to prevent seawater intrusion in aquifers where the water level cannot be raised. They may also be used to feed desalinization plants.

(iii) *Mixed hydraulic barriers* (Fig. 2.10) are injection-pumping systems. Such a system may be used to inject freshwater at inland locations, landward of the toe, while seawater intruded into the aquifer is extracted along the coast. Corrective measures may also be used to pump at locations of the aquifer that are well connected to the sea while injecting at locations that are well connected to the land. Therefore, a well-designed mixed barrier can prove to be much more sensitive in controlling ingress than other barrier systems.

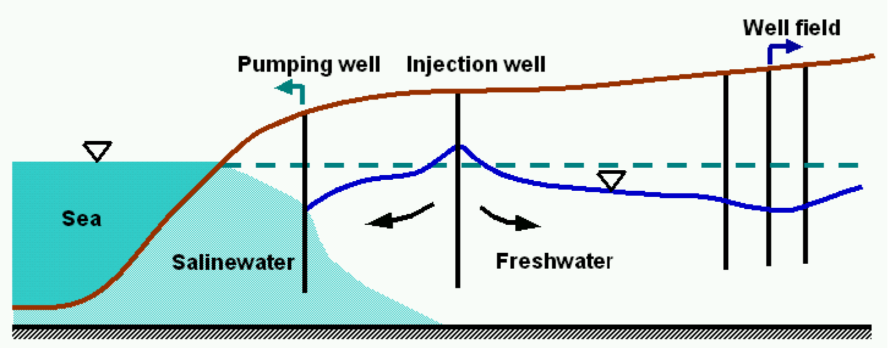


Fig. 2.10 Mixed hydraulic barrier (injection-pumping system) (NIH, 2014a)

To improve the operation and efficiency of the hydraulic barriers, groundwater modeling and optimization techniques can be employed to develop optimal operation and effective management strategies. Mathematical modeling and optimization tools can specifically be used to

- simulate the complex hydraulic barrier operations,
- determine the optimal management strategy of the existing barrier facilities,
- identify the optimal candidate sites for additional injection/extraction wells, and

– investigate alternative and competing management strategies that may be cost effective in addressing the seawater intrusion problem.

Aquifer Storage and Recovery (ASR)

Cyclic injection, storage, and withdrawal of freshwater in brackish aquifers is a form of aquifer storage and recovery (ASR) that can beneficially supplement water supplies in coastal areas. ASR is basically the cyclical storage of treated surface water in a suitable aquifer, when water is available, and subsequent recovery of the same water to augment flows in a coastal distribution system to meet peak daily and emergency demands. The ASR technology is becoming an increasingly important groundwater management tool in coastal plains, where groundwater is the predominant source of water supply for public, agricultural, and industrial purposes, but its sustainability is threatened by increasing demand, seawater ingress, and limited freshwater recharge. ASR provides the opportunity for water users to store treated drinking water and manage water resource demands that often vary seasonally. In addition, ASR has many secondary benefits, such as the potential to reduce disinfection by-products during storage, improve regional groundwater levels during seasonal to long-term storage periods, and locally reduce the effects of seawater intrusion. The local hydrogeology can dramatically affect the success of an ASR program. It may be noted that although ASR is not a source of water, it is a powerful water management tool.

Increased recharge

A different approach to combat salinization especially in areas affected by lateral seawater intrusion and upconing is the artificial recharge of aquifers with fresh groundwater. Artificial recharge can be accomplished by increasing the infiltration of freshwater from surface water bodies. For example, *check dams* constructed across stream beds, serve to slow the runoff, store or divert surplus water flowing to the sea towards the end of monsoon and enhance the infiltration of (fresh) surface water into the groundwater system. Also, specially designed *infiltration tanks* and *recharge basins* are useful in recharging the groundwater system. The intake of water to such tanks is restricted to its local catchment, which may not serve the purpose, and therefore, the infiltration tanks can be connected to the check dams by construction of regulators and feeder channels. Surplus monsoon flood water can be diverted through regulators to feed the infiltration tanks and recharge basins.

C*anals/channels* excavated parallel to the coast help in trapping monsoon overland flow and recharging the aquifer in the vicinity of coast. Such channels laid parallel to the coast also serve as link channels that support transfer of water from a water surplus basin to a basin affected by low rainfall and thus provide ready supply of water for irrigation to the croplands along the coast. Other artificial recharge techniques include recharge through *injection wells*, *gravity head recharge wells*, and *recharge pits and shafts*. The freshwater that is recharged may have various sources like harvested rainwater, river runoff, and treated (desalinized) waste water. Suitability of artificial recharge structures is to be determined as per site specific hydrogeological characteristics. For details on planning and design of recharge structures, refer the Manual on Artificial Recharge of Groundwater (CGWB, 2007).

Skimming wells

The problem of 'saltwater upconing' is a common localized occurrence in coastal aquifers. The withdrawal of freshwater overlying saline groundwater results in saltwater upconing leading to inferior quality of pumped water and degradation of the aquifer. In such situations, skimming wells can play an important role in augmenting irrigation supplies as well as controlling water logging and soil salinity problems. Skimming wells are designed to restrict the salt concentration in the pumped water to an acceptable limit.

Traditionally, the skimming well configurations such as partially penetrating (single or multi strainer) well, radial collector well etc., have been employed to skim the freshwater. More recent configurations include the compound well systems comprising two closely spaced wells. The screens of these two wells are located at different depths with an objective of reducing the effective upconing. The commonly adopted arrangements are: scavenger and recirculation well systems (Saravanan et al., 2014). The scavenger well system consists of two wells viz. production well and scavenger well, in a single bore hole or side by side. The production well taps the freshwater zone while the scavenger well taps the saline water zone. These wells pump fresh and saline waters from the same site simultaneously without mixing, through two separate discharge systems. The rise of saline water due to upconing caused by pumping from production well is countered by the downconing of the interface caused by pumping from scavenger well. In a recirculation well system the screens of both the wells are located in the freshwater zone. The freshwater is pumped through the production well, and a portion of it is injected back into the aquifer through the recirculation well. The rise of saline water due to pumping of freshwater through production well is countered by the downconing of the interface caused by recharging through recirculation well.

The key factors in developing a sustained skimming technology for a given coastal field are: selection of suitable skimming technique, proper design of well configuration in terms of screen positions, and operation of well in terms of permissible discharge and pumping schedules. Proper design and optimal well operation can be achieved through simulation-optimization models.

It is to be noted that while engineering technologies can prove effective in addressing problems of groundwater quality and quantity in a coastal aquifer system, they are generally more expensive, invasive, and site-specific than the adaptation options of scientific monitoring, assessment and modeling, and, behaviour and institutional approaches.

2.7 MITIGATION OF POTENTIAL EFFECTS OF CLIMATE CHANGE, STORM SURGES AND COASTAL FLOODING

The Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC) has estimated that global mean sea level has risen by 190 mm between 1901 and 2010 and is further estimated to increase over the next few years. Over the period 1902-2010, global mean sea level rose by 0.19(0.17 to 0.21) m. The rate of sea level rise since the mid 19^{th} century has been larger than the mean rate during the previous two millennia. Global mean sea level will continue to rise during the 21st century. The rate of sea level rise will very likely exceed the observed rate of 2.0(1.7 to 2.3) mm/year during 1971 to 2010 and 8 to 16mm/year during 2081 to 2100.

The United Nations Framework Convention on Climate Change (UNFCCC) has also acknowledged through its Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC) that due to sea level rise projected through the 21st century and beyond, coastal systems and low lying areas will increasingly experience adverse impacts such as submergence, coastal flooding and coastal erosion. Impacts of relative sea level rise may include dry land loss of coastal region due to erosion, dry land loss due to submergence, wetland loss and change, increased flood damage through extreme sea level events (storm surges, tropical cyclones, etc.), saltwater intrusion into surface water (backwater effect), and saltwater intrusion into coastal aquifer that may cause rise of water table and impeded drainage conditions (Wong et al., 2014).

Impact of sea level rise and storm surges in coastal region can result in submergence of low lying areas and flooding of coastal regions that further complicate the issue in terms of loss of land and coastal land salinization besides the potential to cause severe damage in the affected parts. To mitigate the effects of sea level rise in areas where the risk is greatest (especially low elevation coastal zones with elevation amsl less than 10 m) and reduce the effects of storm waves and storm flooding, requires additional protection measures tailored to the specific geomorphology of that region. Depending upon the site specific conditions, different measures can be considered to defend our coastlines against the threat of sea level rise. Similarly, to protect against saline water inundation of coastal plains and prevent back flooding that may occur from water level rise in the main river system, various suitable strategies can be implemented for floodgate and drain management on coastal floodplains. All such techniques/ strategies are summarized below.

2.7.1 Drain Management on Coastal Floodplains

Floodgates are traditionally 'one-way' structures that operate by draining water from land on the upstream side and excluding tidal ingress from downstream. When the water level on the upstream (i.e. behind the floodgate) is higher than that of the water on downstream, the gate opens and upstream water is discharged. Water at the same level on either side of the floodgate or higher on the downstream side, causes the floodgate to close which restricts the upstream movement of saline water. Floodgates also prevent back flooding that may occur as a result of high rainfall events on the land leading to rise in water levels on the main river system. Floodgates may be tidal floodgates, sluice gates, or winch gates.

In cases, where water needs to be prevented from flowing downstream into another water body, retention structures may be designed. Various types of floodgates opening devices and retention structures along with their operation and advantages / disadvantages are listed in Annexure 2.1.

Selection of the type of floodgate opening device or retention structure depends on the characteristics and design of drainage system which requires detailed assessment of site conditions.

Preventing flooding of low-lying lands from high tides / high river discharge

To prevent flooding of low-lying lands during either high tides or periods of high river discharge, elevated earthen embankments (dikes) are raised along tidally influenced channels in estuaries and coastal sections of rivers or along channel systems that drain wetlands. To control the flow of upland water into diked estuarine zones or river reaches and to prevent estuarine intrusion behind those dikes, structures known as 'flood boxes' are used. A flood box may be simple i.e. a single culvert running through a dike wall, or complex in design e.g. a concrete structure that is the size of a small bridge and includes two or more culverts, deflecting wing walls, and pilings, both up and downstream.

Tidal flood gates are attached to the discharge ends of the culverts. The gates close during incoming tides to prevent tidal (saline) waters from moving upland, and open during receding tides to allow upland waters to flow through the culvert and into the estuary side of the dike. Tide gates can be placed at the mouth of streams or small rivers, where the estuary begins or in tidal non-riverine channels that drain marshes, tributary streams, or field drainage ditches that connect to sloughs (Giannico and Souder, 2005; refer Fig. 2.11). Tide gates may have different designs and can also be manually operated. Some gates are very efficient mechanically, allowing no water to move upstream during flood tide and hindering or preventing fish passage; while others of new design may allow fish passage and regulated estuarine connectivity. Based on requirements of a region and resources, tidal flood gate with desired features may be selected. Schematics of a few different types of tide gates are illustrated in Annexure 2.2.

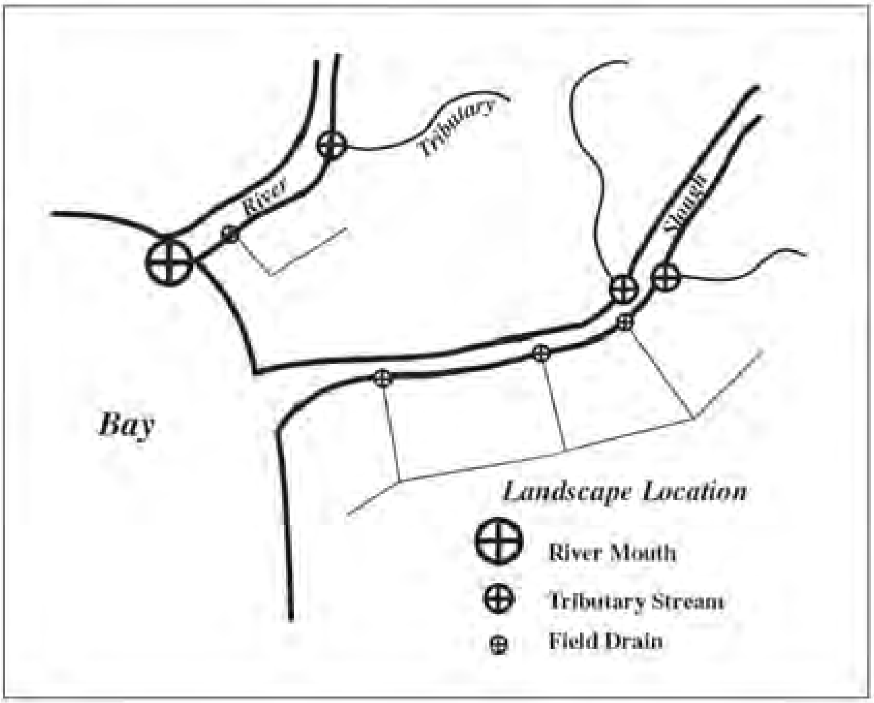


Fig. 2.11 Tide gate locations at the mouth of river, small tributaries, tidal non-riverine channels, and field drainage ditches (Source: Giannico and Souder, 2005)

2.7.2 Coastal Protection Strategies against Climate Change and Sea Level Rise

The present report does not address the issues pertaining to climate change in coastal areas. However, it is pertinent to note here that extreme rainfall events may cause drainage congestion in coastal plains for which suitable drainage management of these areas is essential. Similarly, frequent droughts will require water conservation measures, inter-basin transfer of water from water surplus to water deficit basins, managed aquifer recharge for subsurface storage of freshwater and maintaining a positive hydraulic gradient of water table, besides capping the groundwater pumpage in the region.

Climate change induced sea level rise and storminess may increase incidents of biophysical impacts (flooding, coastal instability, changes to biophysical systems) and socioeconomic impacts (damage to property, infrastructure, human safety risks, etc.). In terms of sustainability, such impacts pose a significant socio-economic challenge to coastal areas. Following coastal regions are exposed to the greatest risks (Parkes et al., 1997): low-lying areas, areas with frequent storm conditions and high storm surge levels, areas of coastal infrastructure and property, areas of sensitive ecology, areas of rapid coastal erosion, and perigean spring high water areas, i.e., the largest monthly tides. Dealing with the coastal land salinization arising from this long-term problem requires coastal protection measures or best environmental practices based on the criteria of 'impact on natural dynamics', 'impact on habitat' and 'contribution to coastal defense' (CPSL, 2001). These coastal protection measures may be explored and implemented as per site specific conditions under two categories namely hard structures and soft options. Hard structures imply construction of dykes, seawalls, breakwaters etc. while soft options involve beach nourishment, conservation of wetlands, shelterbelt plantation, etc. for reducing severity of coastal flooding.

The IPCC classification of coastal adaptation strategies consists of *retreat, accommodation,* and *protection* (Nicholls et al., 2007; Wong et al., 2014). *Protection* aims at advancing or holding existing defense lines by means of different options such as land claim; beach and dune nourishment; the construction of artificial dunes and hard structures such as seawalls, sea dikes, and storm surge barriers; or removing invasive and restoring native species. *Accommodation* is achieved by increasing flexibility, flood proofing, flood-resistant agriculture, flood hazard mapping, implementation of flood warning systems, or replacing armored with living shorelines. 'Armoring' is the practice of using hard structures (e.g. seawalls, breakwaters etc.) to hold back the sea and prevent the loss of sediment. However, these structures may increase the rate of coastal erosion, remove the ability of the shoreline to carry out natural processes, and provide little habitat for estuarine species. The approach of 'living shorelines' uses plants (such as wetland plants, submerged aquatic vegetation), sand, and limited use of rock to provide shoreline protection and maintain valuable habitat. *Retreat* options include allowing wetlands to migrate inland, shoreline setbacks, and managed realignment by, for example, breaching coastal defenses allowing the creation of an intertidal habitat. The appropriate measure may depend on several factors requiring a careful decision-making and governance process.

2.7.3 Climate Resilient Coastal Protection and Management Project (CRCP&MP)

During the year 2014, an agreement was signed by the GoI with ADB for Technical Assistance (TA) programme namely TA 8652-IND: Climate Resilient Coastal Protection and Management Project (CRCP&MP) to support mainstreaming of climate change consideration into coastal protection and management at the national level and in the two focal states (of Karnataka and Maharashtra) where the Sustainable Coastal Protection and Management Investment Programme (SCP&MIP) is already operational under external assistance from ADB. This TA is being financed by grant amounting to Two Million USD ($) from Global Environment Facility (GEF) & administered by Asian Development Bank (ADB). This is scheduled to complete by 2017. The MoWR, RD&GR is the Executing Agency. Four components are proposed for the CRCP&MP. Components two, three and four link to the components of the baseline project (SCPMIP); component 1 is a new additional component. Component 1 & 4 are focused on National Level whereas the component 3 & 4 are specific to focal states only. Following table shows the 4 components under the CRCP&MP:

Components of CRCP&MP

Component 1	Analysis of Climate Change Impacts in Coastal Areas and Preparation of Guidelines for Climate Change Adaptation for the Indian coast.
Component 2	Climate Resilient Shoreline Planning and Management in Two Focal States
Component 3	Climate Resilient Coastal Investments in Two Focal States
Component 4	Institutional Strengthening, Capacity Building and Enhanced Awareness for Climate Resilient Coastal Protection and Management.

National component are being implemented through CW&PRS whereas State specific components are being implemented through the concerned State Govt. Three specific studies have been given to National research institutes for analyzing the Climate Change Impacts in Coastal Areas. The details are given below:

Studies assigned to the institutes under CRCP&MP

National research institutes	Climate Change Impact study
National Institute of Oceanography (NIO), Goa	Sea Level Rise, Wave
Indian Institute of Technology (IIT), Delhi	Storm Surge
Indian Institute of Technology (IIT), Bombay	Wind, Precipitation, Sea Level Pressure

2.8 COASTAL REGULATION ZONE NOTIFICATION 2011

For the purpose of conserving and protecting the coastal areas and marine waters, the Coastal Regulation Zone (CRZ) Notification was issued in 2011 by the Ministry of Environment and Forests, Govt. of India. The notification restricts the setting up and expansion of any industry, operations or processes and manufacture or handling or storage or disposal of hazardous substances in the CRZ area. Prior to proposing any structures etc. in the coastal zone, it is imperative to be aware about the recent CRZ Notification. Annexure 2.3 summarizes in brief the CRZ Notification 2011 regulations pertaining to the water resources and related interventions in coastal zones.

CHAPTER 3
MANAGEMENT OF COASTAL LAND SALINITY IN INDIA

3.1 GUJARAT

3.1.1 General

With the longest share of the Indian coast line, the coastline of Gujarat runs for a distance of about 1214.70 km. A total of 16 coastal districts cover about 68% area of the state and comprise about 58% of its dynamic groundwater resource. The coastal tracts encompass the coastal tracts of districts namely Kachchh, Morvi, Jamnagar, Devbhoomi Dwarka, Porbandar, Junagadh, GirSomnath, Amreli, Bhavnagar, Anand, Ahmedabad, Vadodara, Bharuch, Surat, Navsari, and Valsad, besides the Union Territory of Daman (Daman & Diu). Figure 3.1.1 shows the locations of the coastal districts; sparsely/ medium populated areas in villages and highly populated urban areas in towns and cities, variation in average annual rainfall (1971-2005) across the coastal districts areas and the general land use / land cover in coastal areas. Distribution of rainfall in the region of Kachchh district is erratic and scanty rainfall is a regular feature here. In Peninsular Gujarat, the average annual rainfall is 510 to 760 mm, although in the central parts around Jungadh the rainfall is higher upto 1100 mm. In southern districts, such as Vadodara and Bharuch, the variation of rainfall is from 760 to 1525 mm, while still further south around Surat, Navsari and Valsad districts, the rainfall is higher and varies from 1525 mm to 2000 mm.

3.1.2 Physiography and Drainage

The coastal area of Gujarat of about 28,500 km^2 is the largest in the country and provides a wide variety of coastal features due to its varied physiography, geomorphology and coastal processes. Based on geomorphic characteristics, the Gujarat coast is divided, from west to east, into five regions, namely Rann of Kachchh, the Gulf of Kachchh, the Saurashtra coast, the Gulf of Khambat, and the South Gujarat coast (Fig. 3.1.2a). The Rann of Kachchh (area about 22,000 km^2) remains saline desert for the larger part of the year and marshy during the monsoon when it remains inundated partly by river water and partly by tidal water. When dry, the surface is covered by a layer of salt and shingle. It does not support any vegetation except in a few small raised areas where some fresh water is available. The Rann is further divided into the Great Rann (northern parts of Rann) and the Little Rann (eastern parts of Rann). On the west of the Great Rann of Kachchh lies the lower Indus deltaic plain which is characterized by tidal creeks and mangroves. The coastline in the Gulf of Kachchh has extensive mudflats and is highly indented with a number of rocky islands. Here, the coast is fringed by coral reefs and mangroves. Algae, salt marsh, dunes, and salt pans are very common.

In Peninsular Gujarat, the Saurashtra coast has numerous cliffs, islands, tidal flats, estuaries, embayments, coastal depressions or low-lying areas locally termed as ‘Ghed’, sandy beaches, dunes, spits, bars, bays, marshes, and raised beaches at some places. The coast, in Gulf of Khambat is indented by estuaries and consists of mudflats, dunes, and beaches. The south Gujarat coast is relatively uniform and is indented by a series of creeks, estuaries, marshes and mudflats. The Gujarat coast, from Great Rann to south Gujarat coast, presents evidence for both emergent and submergent coasts (http://guj-nwrws.gujarat.gov.in; Schwartz, 2005).

In Gujarat, there are two distinct sets of rivers. The rivers Rupen, Saraswati and Banas in the northwest parts flow into the Rann of Kachchh, while the major rivers draining the central and southern coast of Gujarat, viz., Narmada, Tapi, Sabarmati and Mahi fall into the Gulf of Khambat. The coast of south Gujarat is formed by the alluvium brought down by the rivers Sabarmati, Mahi, Narmada and Tapti. The coastal plain slopes down gently along with these rivers towards the west and south-west (Fig. 3.1.2b).

In Kachchh area, long draining rivers are absent except a few like Khari and Nagmati which join the sea. The river Luni ends in the Rann of Kachchh. There are numerous small rivers in the Kachchh region. Those flowing north disappear in the Rann, while the remaining join either the sea or the Gulf of Kachchh. Some of the main rivers are Khari, Nagmati, Suvi, Nayra, Bela, Sakara, Kharod, Kankavati, Bhukhi, etc. Dams have been constructed across Khari, Nagmati, Suvi, Kankavati etc. for irrigation water supply / water storage schemes to tide over water scarcity conditions that frequently affect this region (http://india-wris.nrsc.gov.in/)

In Saurashtra, there are many intermittent rivers like Bhadar, Ojat, Madhyvanti, Noli, Megal, Hiran, Saraswati, Singwada, Singwadi, Rupen and Machundri carrying rain water to the sea. Out of these, river Bhadar is the longest. These rivers rise in the central plateau region of Saurashtra and meander in a radial pattern through the plains to meet the Arabian Sea. The narrowness of the river mouths and sandbars at their mouths impede the flow of floodwater causing inundation of the ‘Ghed’ and the coastal depressions. When the sandbars get breached by the accumulated flood water in the Ghed, tidal water from sea enters the Ghed and gets accumulated in the low-lying parts. A number of small dams have been constructed on the rivers in Saurashtra region meeting the drinking and irrigation water supply needs.

3.1.3 Hydrogeology

Along Gujarat coast, the sedimentary formations ranging in age from Upper Cretaceous to Quaternary form the major aquifer systems. They occur under unconfined to confined conditions. In general, the unconfined aquifers occur down to 40 m bgl, whereas the semiconfined to confined aquifers extend from 30 m to more than 200 m bgl. The Kachchh coast largely comprises mud and marshy lands. The alluvium and wind-blown sand deposits along Malia – Lakhpat reach is 15 to 40 m thick and form the unconfined aquifer. The Miliolite limestones of Pliestocene age exposed along the coastal tracts of Kachchh and Saurashtra form potential aquifers because of their highly pervious nature. The porosity as well as thickness of the Miliolite aquifer decrease inland. In Saurashtra, the underlying Gaj and Dwarka Beds have low to moderate permeability due to their clay content. The Supra-Trappeans and the Deccan Trap forming bed rock in the coastal tract have low permeability due to their secondary porosity. In the coastal tract of Kachchh, the sediments grouped as Manchar Series (Tertiary) also form unconfined aquifer. The depth to water level varies from 3 to 10 m bgl in general. In southern Gujarat, the aquifers in the Tertiaries of maximum thickness 100 m of sandstone, shale, limestone and gravel, give moderate yields through shallow tubewells. Figures 3.1.3a-b show aquifer systems and soil depth in the coastal districts of Gujarat, while Figs. 3.1.4a-b show the variation in depth to groundwater level for the year 2011.

3.1.4 Groundwater Salinity

The EC of shallow groundwater in the coastal margins, in general, ranges from 1500 to 4500 µS/cm except in the area between Sikka and Hadiyana of Jamnagar coast. However, there are strips of Kachchh and Saurashtra coasts and parts of Gulfs of Kachchh and Khambat where EC values are above 4500 µS/cm. The quality of groundwater in the Miliolite limestone is good but mostly in areas 2 to 4 km inland from the coast, since the coastal tracts are affected by seawater intrusion. In Gaj beds, the quality of formation water is, in general, only marginally fresh due to inherent salinity of formation water and intercalation of clays. In the mainland coastal tracts of southern Gujarat, the shallow groundwater is mostly brackish to saline, except further south in Valsad district where EC is less than 1500 µS/cm (Fig. 3.1.4c). The quality of groundwater in deeper aquifer is saline in large parts.

3.1.5 Causes and Extent of Coastal Land Salinity

Along the coastal tracts of Gujarat, salinity of groundwater broadly varies with geological formations and their disposition with reference to the coast (Fig. 3.1.5a). It is influenced by factors like sea water ingress, inherent salinity of the formations deposited under marine conditions and the structural features. Also, several creeks under tidal influence allow the sea water to invade and deteriorate the groundwater quality in the phreatic aquifers. Thus, the soil and groundwater salinity is a combined effect of a) inherent formation water salinity, b) sea water encroachment due to groundwater overdraft, c) tidal water incursion through creeks/ estuaries, d) saline water percolation in low lying marshy lands inundated by sea water, e) irrigation with saline water, and f) salt laden winds / sea sprays. In addition, in such fresh-saline aquifers, where freshwater is underlain by saline water at deeper depths, the overdraft of groundwater causes salt water upconing of the underlying saline water.

Along Saurashtra coast, the Bhavnagar-Una section is affected by sea water ingress and inherent salinity and the Una-Madhavpur section has prominent sea water ingress while the Madhavpur-Maliya section has the effects of all factors like inherent salinity, sea water ingress, tidal inundation, marshy land seepages and saline alluvium. In Kachchh area along Maliya-Lakhpat section, the groundwater salinity occurs due to a combination of various factors listed above. The fresh-saline groundwater interface along the Gujarat coast in terms of 2000 ppm TDS contour is discussed below along different sections of the coast.

Lakhpat-Maliya-Mandvi-Mundra-Gandhidham (Kachchh coast)
Along this section on Kachchh coast, in the year 2004, the 2000 ppm TDS contour was traced by Groundwater Department, Gujarat, about 25 km inland in Lakhpat-Naliya area and 10-15 km in Mandvi area. Near Gandhidham the 2000 ppm TDS contour was traced near Anjar located about 22 km inland. Near the creeks and along the coastline the TDS was upto 10,000 ppm. However, patches of groundwater zones with TDS less than 2000 ppm were traced near Jakhau, Vadapaddhar-Lathedi, Bhujpar, and Mundra, located about 10 to 5 km inland.

Okha-Maliya (Gulf of Kachchh)
The 2000 TDS contour is almost parallel to the coast line and 10 to 20 km inland, as per 2004 investigations. The contour was traced closest to the sea between Khambaliya-Jamnagar where basalts are exposed. On the coast line the TDS goes up to 6000 ppm.

Okha-Porbandar-Madhavpur (Saurashtra coast)
Along Okha-Madhavpur section, the 2000 ppm TDS contour in 1997 was, in general, 7-12 km inland. However, all along this section there were patches of groundwater with TDS < 2000 ppm very close to the coast line.

Una-Bhavnagar (Gulf of Khambat)
Along Una-Bhavnagar section, the TDS contour of 2003-04 is quite close to the coastline. Presence of fresh groundwater was observed near the coast at Jaspara.

Further, the marine Tertiaries and the Mesozoic formations of Kachchh hold saline groundwater. The upper or near surface part of these formations receiving monsoon recharge gets flushed and holds freshwater in storage for a moderate period. A vast low lying tract in the Central Gujarat (structural trough filled up with very thick Tertiary sediments and alluvial cover), holds saline groundwater as well as pockets of brine. It causes sub-surface outflow of highly saline groundwater to the adjoining areas of Saurashtra and Kachchh. In the coastal parts of mainland Gujarat occupied by poorly permeable basalts, groundwater is affected by salinity over a limited area. However, in the low-lying coastal tracts of Surat, Bharuch and Vadodra districts with rivers under tidal influence, the groundwater is saline (CGWB, 2014).

3.1.6 Remedial Measures
To address the severe problem of water and land salinity in the coastal regions of Gujarat, that posed a major threat to agriculture, animal husbandry, rural economy and urban development of the coastal stretches, the State Government appointed two High Level Committees (HLC-I and HLC-II) in 1970s and 1980s. The Committees opined that the problem of poor recharge, extensive withdrawal of groundwater, intrusion of tidal waters through creeks/ estuaries and the increase in salinity has to be considered in its totality. No single solution will be applicable to the entire affected area or will be sufficient in isolation. Various measures involving engineering, agriculture, forestry, social and legal aspects have to form a part of an integrated approach to reduce the water and land salinity problem and improve conditions in the salinity affected areas. The Committee recommended several

salinity prevention techniques, outlined in Table 3.1.1, including construction of a large number of structures to achieve the following objectives:

1. To control surface and subsurface salinity ingression along the coastal stretches.
2. To recharge and enhance the quality of underground aquifer of the coastal belt.
3. To promote agricultural activities by providing surface water facilities to the farmers in and around the constructed civil structures.
4. To achieve an overall improvement in socio-economic conditions of the village community in vicinity of the constructed civil structures

Table 3.1.1 Salinity prevention techniques recommended by HLC-I and HLC-II in Gujarat

Salinity Control Techniques	**Recharge Techniques**
• Tidal regulators • Bandharas • Fresh water barrier • Extraction barrier • Static barrier	▪ Check dams ▪ Recharge tanks ▪ Recharge wells • Spreading channels • Afforestation
Management techniques	**Land reclamation**
• Change in cropping pattern • Regulation of groundwater extraction	• Coastal land reclamation

The Committee observed that no recharge or salinity control scheme will give its full long term advantage, unless supported by proper management strategies such as control over the pumpage and use of groundwater, conjunctive use of groundwater and surface water and cultivation of less water intensive crops that are also salt tolerant. Groundwater recharge techniques such as check dams, recharge tanks, spreading channels and recharge wells as well as afforestation measures were found to feasible in augmenting the groundwater recharge. Similarly, tidal regulators and bandharas were found to be effective in preventing upstream movement of tidal water through river channels. However, the implementation of freshwater barrier was not considered feasible, in view of the large heterogeneity in subsurface arising due to occurrence of cavities in milliolite limestone that required substantial quantity of freshwater. The Committee, although, recommended to explore the possibility of utilisation of Narmada water in this region. Similarly, the extraction barrier that involves continuous pumping and needs elaborate maintenance system, was not considered economically feasible due to high initial and recurring costs.

The figures 3.1.5 (a), 3.1.5 (b), 3.1.5(c), 3.1.5(d) shows the salinity affected area in reaches 1. Una-Madhavur, 2. Bhavnagar-Una 3. Madhavpur-Okha and 4. Okha-Malia respectively. The following Table 3.1.2 shows the salinity affected areas (Taluka wise/District Wise).

Table 3.1.2 Salinity Affected Areas Taluka Wise/District Wise

Sr. No.	Year	Reach	Taluka	District	Salinity Affected area in Ha.
1	2010-11	Bhavnagar-Una HLC-II	Bhavnagar	Bhavnagar	2201
2			Talaja	Bhavnagar	5276
3			Mahuva	Bhavnagar	12399
4			Rajula	Amreli	6031
5			Jafarabad	Amreli	2594
6			Una	Gir-Somnath	14451
		Total :1			**42952**
7	2010	Una-Madhavpur HLC-I	Mangrol	Junagadh	19213
8			Maliya (H)	Junagadh	5102
9			Veraval	Gir-Somnath	19090
10			Kodinar	Gir-Somnath	14390
11			Una	Gir-Somnath	19327
		Total :2			**77122**
12	2010	Madhavpur-Okha HLC-II	Mangrol	Junagadh	8800
13			Kutiyana	Porbandar	6200
14			Ranavav	Porbandar	684
15			Porbandar	Porbandar	57196
16			Kalyanpur	Jamnagar	57620
17			Okha-Mandal	Jamnagar	56054
		Total:3			**186554**
18	2010	Okha -Maliya HLC-II	Khambhaliya	Jamnagar	20938
19			Lalpur	Jamnagar	2438
20			Jamnagar	Jamnagar	19562
21			Dhrol	Jamnagar	0
22			Jodiya	Jamnagar	43375
23			Maliya (M)	Morbi	77000
24			Morbi	Morbi	6840
		Total :4			**170153**
25	1982-83	Maliya-Lakhapat	Bhachau	Kachchha	63500
26	1981-82		Anjar	Kachchha	24300
27	1980-81		Mundra	Kachchha	54470
28	1979-80		Mandvi	Kachchha	62390
29	1980-81		Abadasa	Kachchha	107780
30	1981-82		Lakhapat	Kachchha	37590
31	1982-83		Rapar	Kachchha	21100
		Total			**371130**
		Grand Total			**847911**

The works recommended by HLC-I and HLC-II in the areas of Saurashtra and Kutch are given in Table 3.1.3.

Table 3.1.3 Works recommended by HLC-I and HLC-II in Gujarat

Sl. No	Particulars	Works recommended by HLC		
		Saurashtra	Kutch	Total
1	Tidal regulators	38	15	53
2	Bandharas	87	40	127
3	Recharge reservoirs	47	0	47
4	Recharge tanks	62	25	87
5	Recharge wells	1330	150	1480
6	Afforestation (ha.)	50750	10000	50750
7	Nalla plugs	65400	20000	85400
8	Spreading channel (km)	360	166	526
9	Check dams	838	740	1578

Table 3.1.4 and 3.1.5, respectively, provide the remedial measures taken up in the Saurashtra and Kachchh regions of Gujarat and the corresponding benefitted areas. Figure 3.1.6 b and Fig. 3.1.7 illustrates the works implemented in Kachchh and Saurashtra region, while Figs. 3.1.8-3.1.14 show views of a bandhara, spreading channel, tidal regulator, recharge reservoir and check dam constructed in the area.

Table 3.1.4 Remedial Measures adopted in the Saurashtra region of Gujarat

Sl. No	Particulars	Completed	Storage capacity (Mm^3)	Benefitted area Direct/ Indirect (ha)	Expenditure (Rs. in crore)
1	Tidal Regulators	14	178.58	19970	108.79
2	Bandharas	31	69.18	17183	63.72
3	Recharge Reservoirs	18	45.96	7770	29.03
4	Recharge Tanks	32	2.82	3459	9.71
5	Recharge Wells	397	-	-	-
6	Afforestation (ha.)	5867	-	-	-
7	Nalla Plugs	4487	-	-	-
8	Spreading Channel No(Km)	31 (205Km)	2.45	29997	102.91
9	Check dam	672	24.77	8661	29.63
	Total	1195 structures; 4487 nalla plugs 5867 ha afforestation; 205 km channel	322.85	84790	344.48

Table 3.1.5 Remedial measures adopted in the Kachchh Region of Gujarat

Sl. No.	Particulars	Completed	Storage capacity (Mm^3)	Benefited area (ha)	Expenditure (Rs. in crore)
1	Medium Irrigation Schemes	20	281.74	21292	N.A.*
2	Minor Irrigation Schemes (Panchayat)	170	298.45	34517	N.A. *
3	Bandharas	53	90.51	35710	212
4	Big River Checkdam (Cost Rs. > 25 lac)	343	88.90	26612	166
5	Small Checkdam (Cost Rs. < 25 lac)	521	13.26	7345	54
6	With Public Participation (under 80:20 & 60:40)	5937	116.12	38845	214
7	Tanks & Safe Stages Works	1697	144.20	30529	66
8	Radial Channel work	3	4.71	930	3
9	Recharge Wells	805	0.00	0	5
10	Recharge Tanks	3	0.09	100	1
11	Deepening of Tanks	82	1.38	590	7
	Total	9634	1039.36	196470	728

*Sl. No. 1 & 2 schemes completed 25 years ago and the expenditure details not available.

The list of works completed in the State of Gujarat in Kachchh and Saurashtra region is given in Annexure 3.1A & Annexure 3.1B respectively.

Benefits of Remedial Measures

The following benefits have been observed on completion of various works related to remedial measures for arresting salinity in the coastal tracts.

1. Significant increase in agriculture land, inland water area, mangroves; while, decrease in land cover of coastal mud, saline land and area occupied by the aggressively invasive plant Prosopis Juliflora.
2. Decrease in area inundated by seawater; prevention of seawater intrusion through creeks and estuaries in the upstream locations.
3. Construction of bandharas and embankments on creeks have aided the conservation of freshwater runoff and prevented mixing of tidal seawater with freshwater stored in coastal depressions. The added advantage of irrigation water schemes, thus developed, has facilitated irrigation of crops in saline coastal tracts leading to increased crop yields. This way a larger area of land has been brought under cultivation. In many areas, two crops instead of one crop are being cultivated in a year. The overall water quality has improved and the extent of barren land has also been reduced.
4. Construction of check dams/ nalla plugs on river reaches has enabled more runoff to infiltrate the ground surface and recharge the groundwater thereby raising the water table. The additional storage of groundwater has aided timely crop irrigation during dry spells and drought periods in the region. These structures have controlled both the soil erosion

and loss of fertile, nutrient laden sediments from the catchments. Increase in irrigation has facilitated leaching of salts from the soil.

5. Spreading channels have facilitated lift irrigation along the coastal tracts and transfer of water from a water surplus basin to a water deficient basin.
6. Womenfolk have benefitted by the construction of structures such as bandharas which has increased their access to potable water and reduced their routine drudgery of walking 2-4 km to fetch water for domestic use, improving the general lifestyle. The time saved can be devoted to more productive economic activities. Better quality of potable water also implies better health condition of the village community.
5. Significant change in socio-economic conditions of the villagers living in the proximity of bandharas has been recorded. This is reflected in the increased agricultural productivity and income generation of farmers. It also has long-term positive implications in terms of employment generation and general improvement in living conditions of rural mass. Further, improvement in socio-economic conditions has checked migration from the villages and encouraged the farmers to continue with agriculture as their major means of livelihood. Cultivation of additional crop in a year has doubled the employment opportunities for agricultural labourers.
6. Afforestation measures along the coast line have helped in reducing salinity arising from salt laden winds and aided better yields of crop. In inland areas, larger forest and vegetation cover implies larger detention time for surface runoff in upland areas, that increases infiltration of water and reduces severity of flooding in downstream areas.
7. Other benefits of afforestation along the coast (as well as mangroves along creeks) include protection from storm surges. An overall increase in forest / vegetation cover and floral biomass in coastal wetlands/marshes and water bodies due to water availability during larger part of the year increases biological carbon sequestration that aids in reducing the impact of climate change.

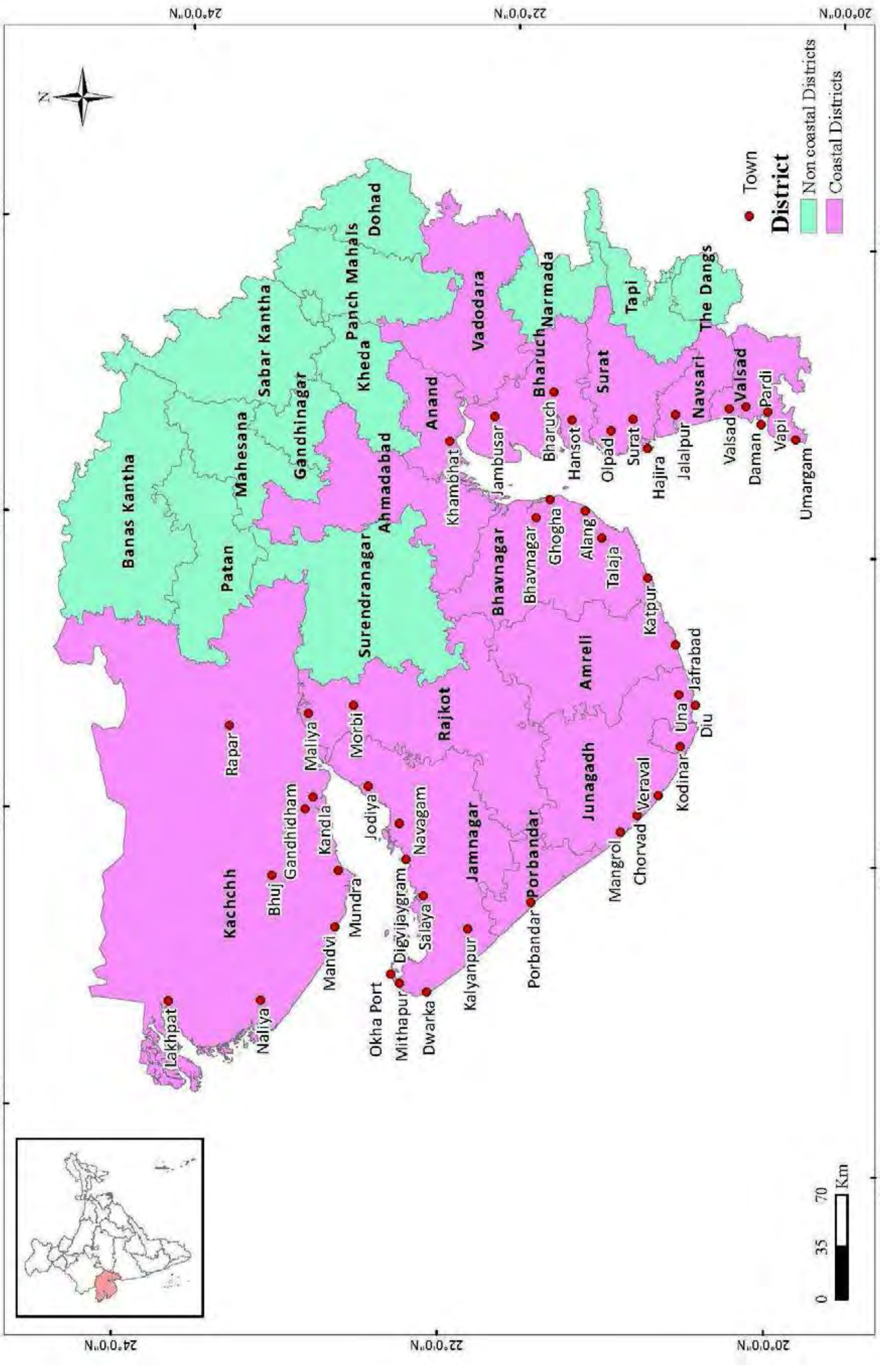


Fig. 3.1.1(a) Administrative map of Gujarat showing coastal districts

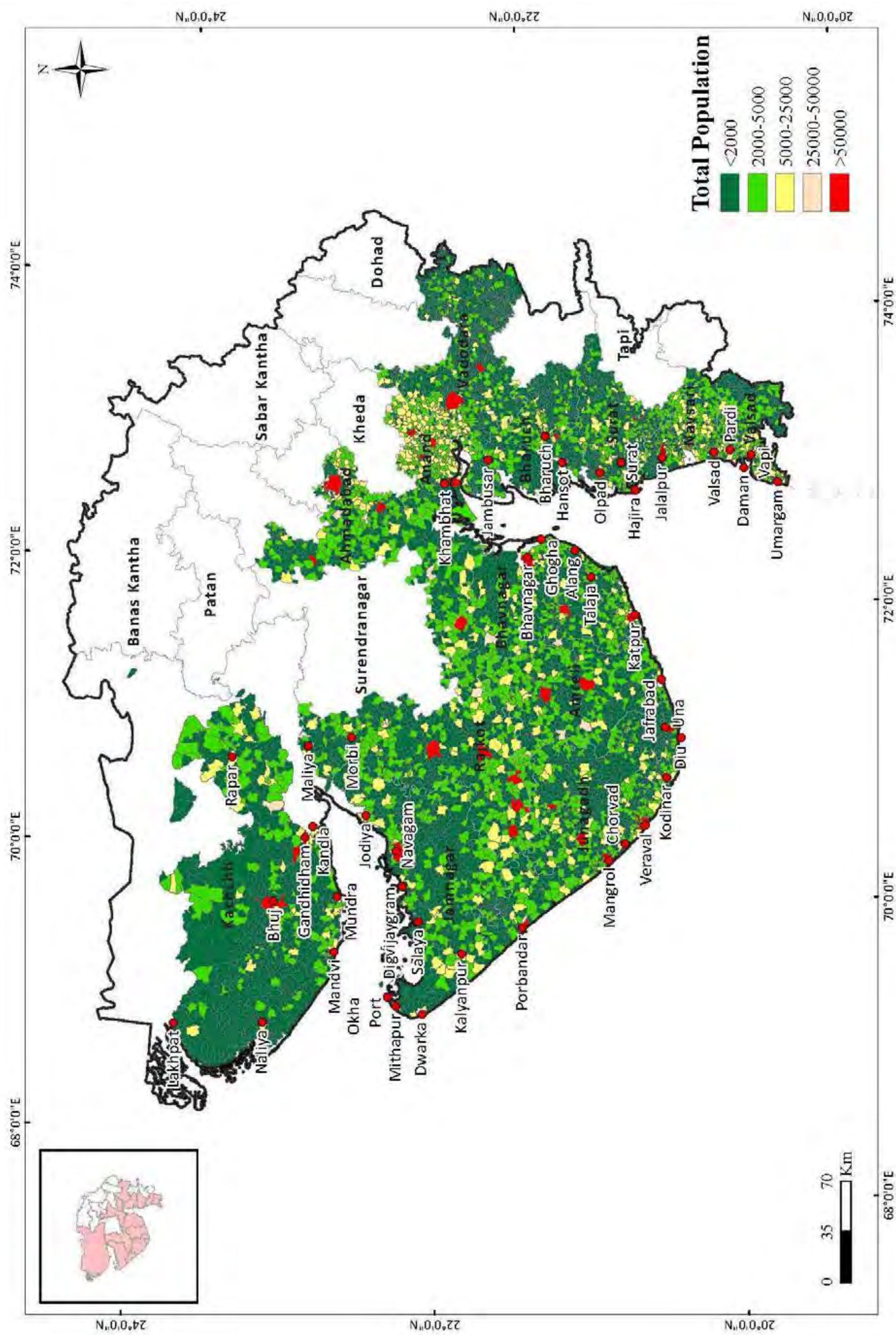


Fig. 3.1.1(b) Population distribution of coastal districts of Gujarat

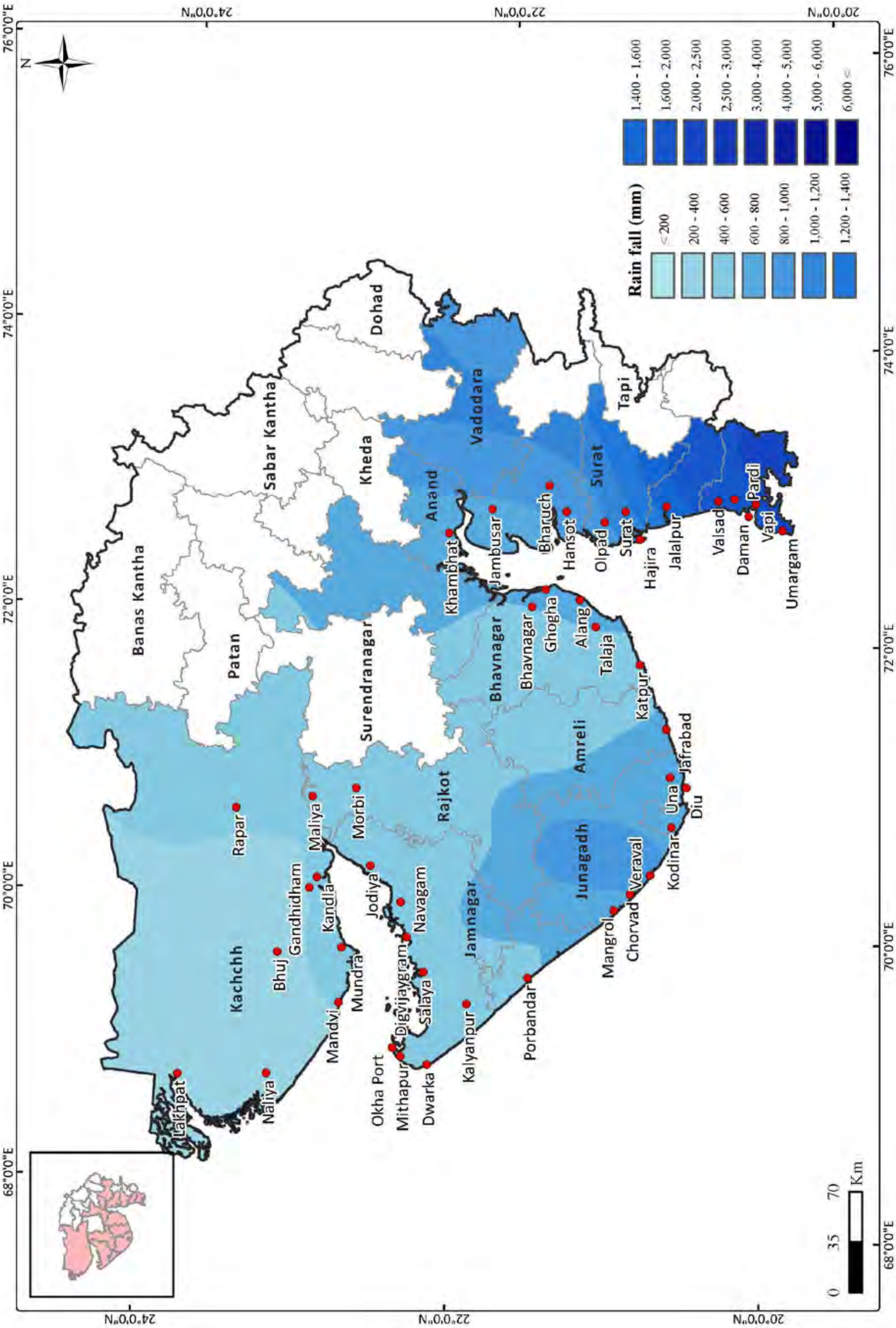


Fig. 3.1.1(c) Rainfall distribution of coastal districts of Gujarat

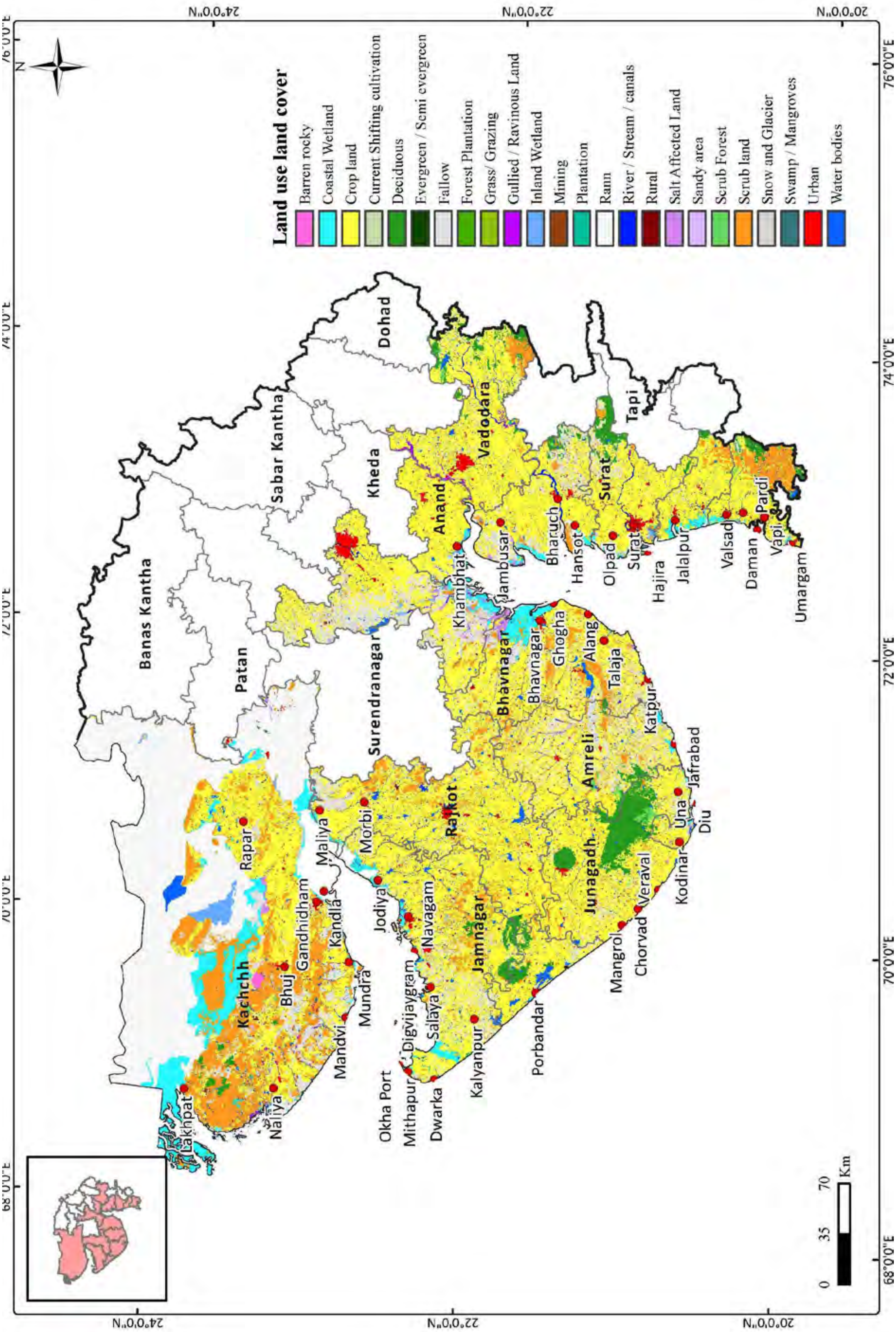


Fig. 3.1.1(d) Land use and land cover of coastal districts of Gujarat

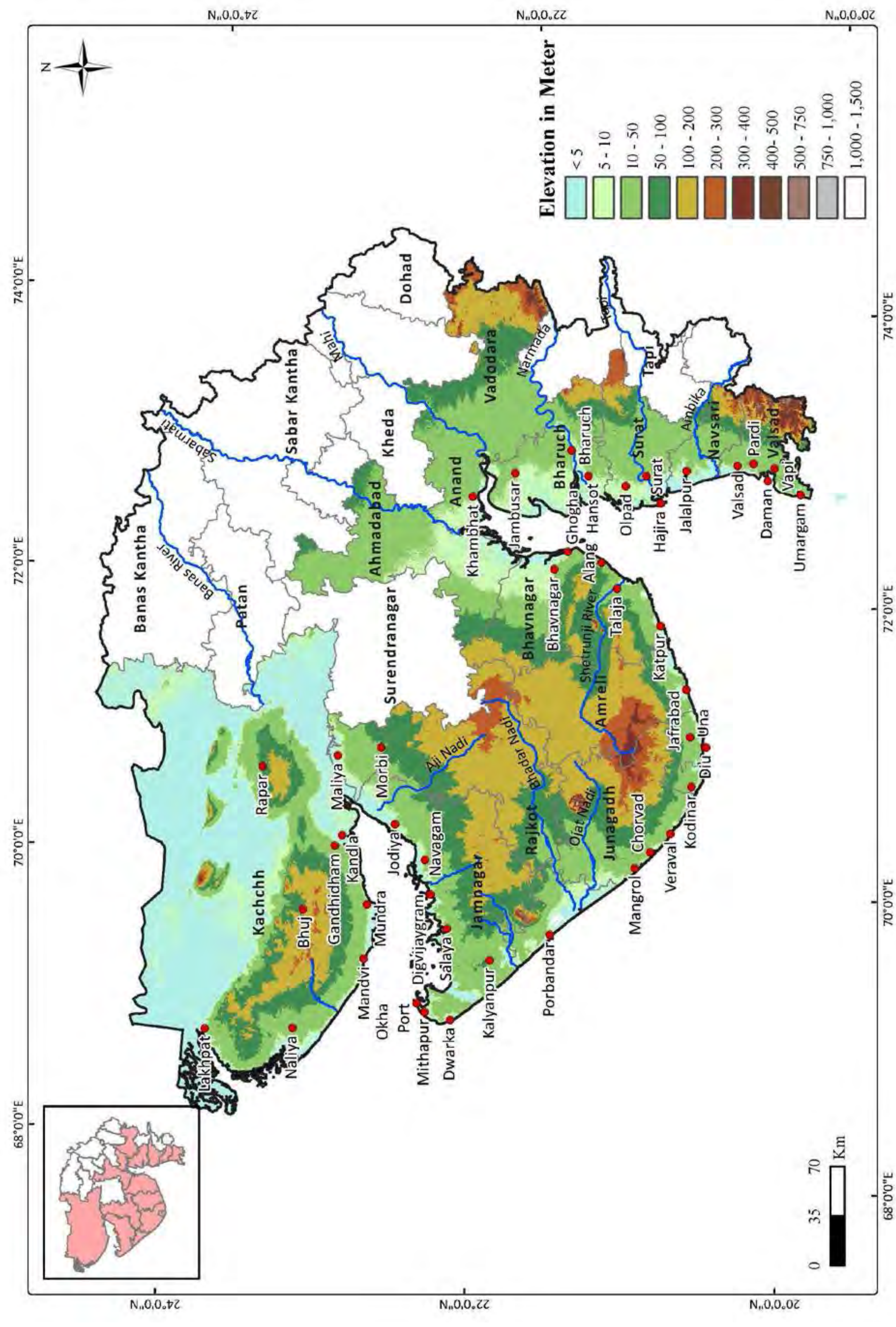


Fig. 3.1.2 (a) Physiographic map of Gujarat

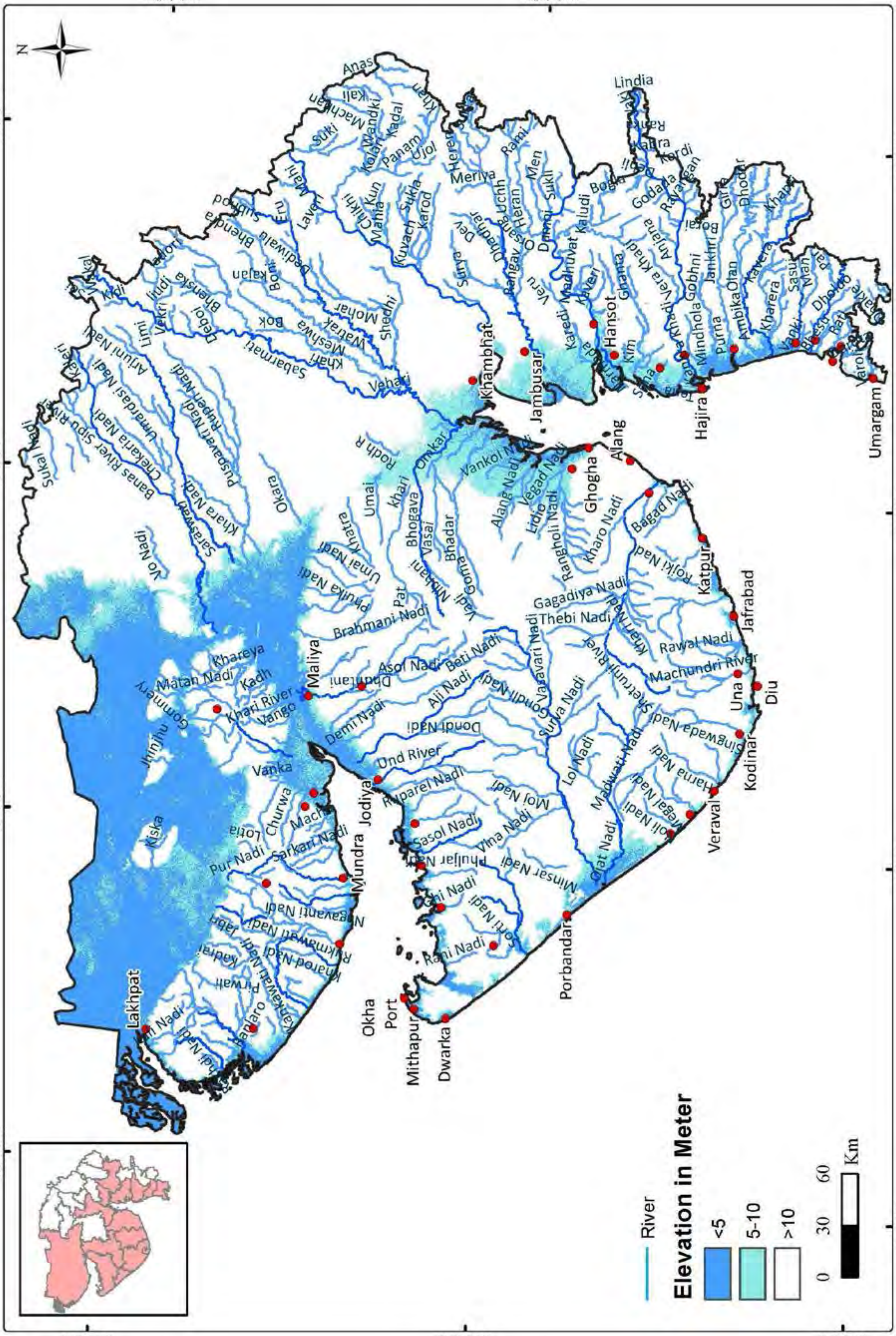


Fig. 3.1.2 (b) Drainage map of Gujarat showing low elevation coastal areas (< 10 m amsl)

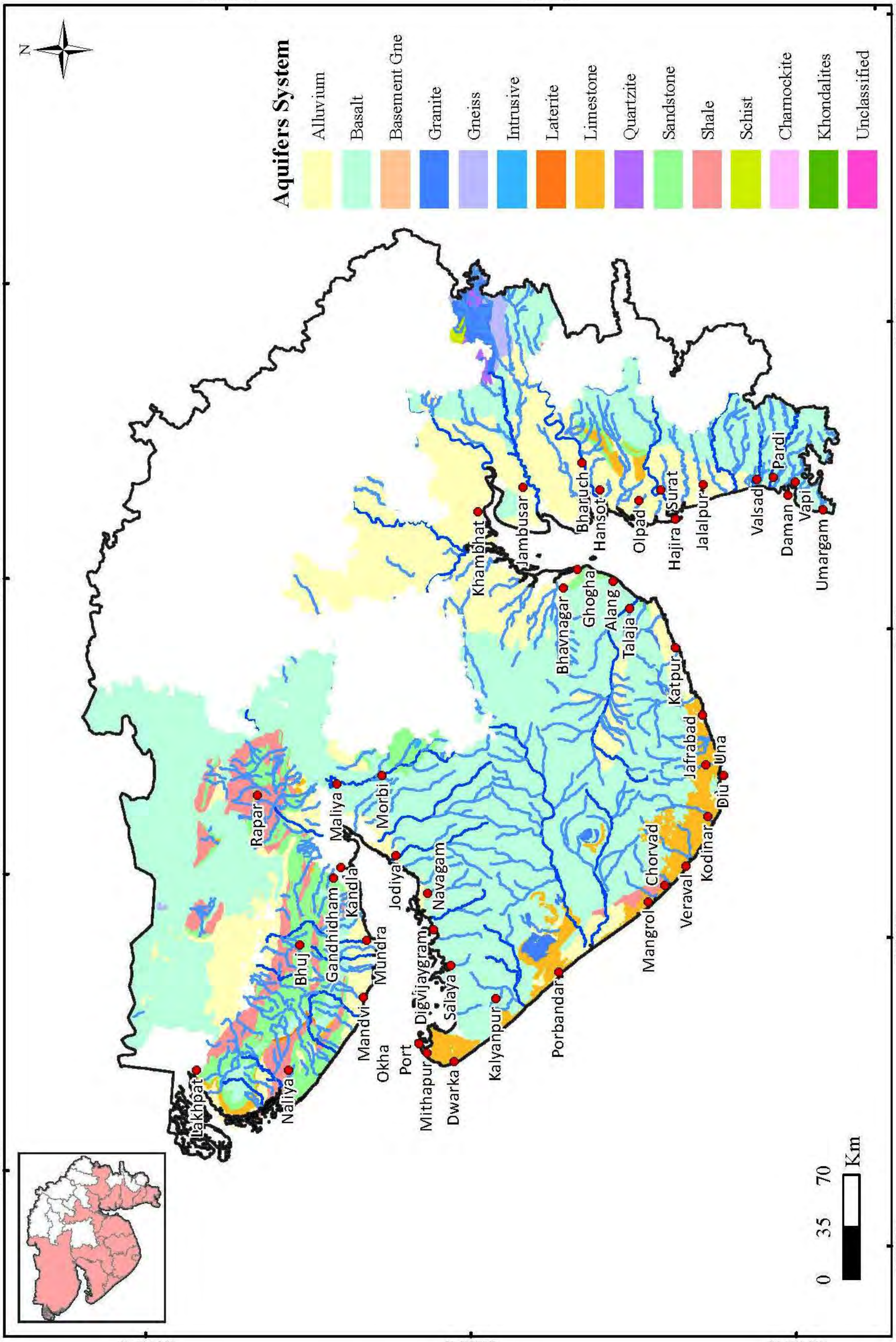


Fig. 3.1.3 (a) Aquifer map of coastal districts of Gujarat

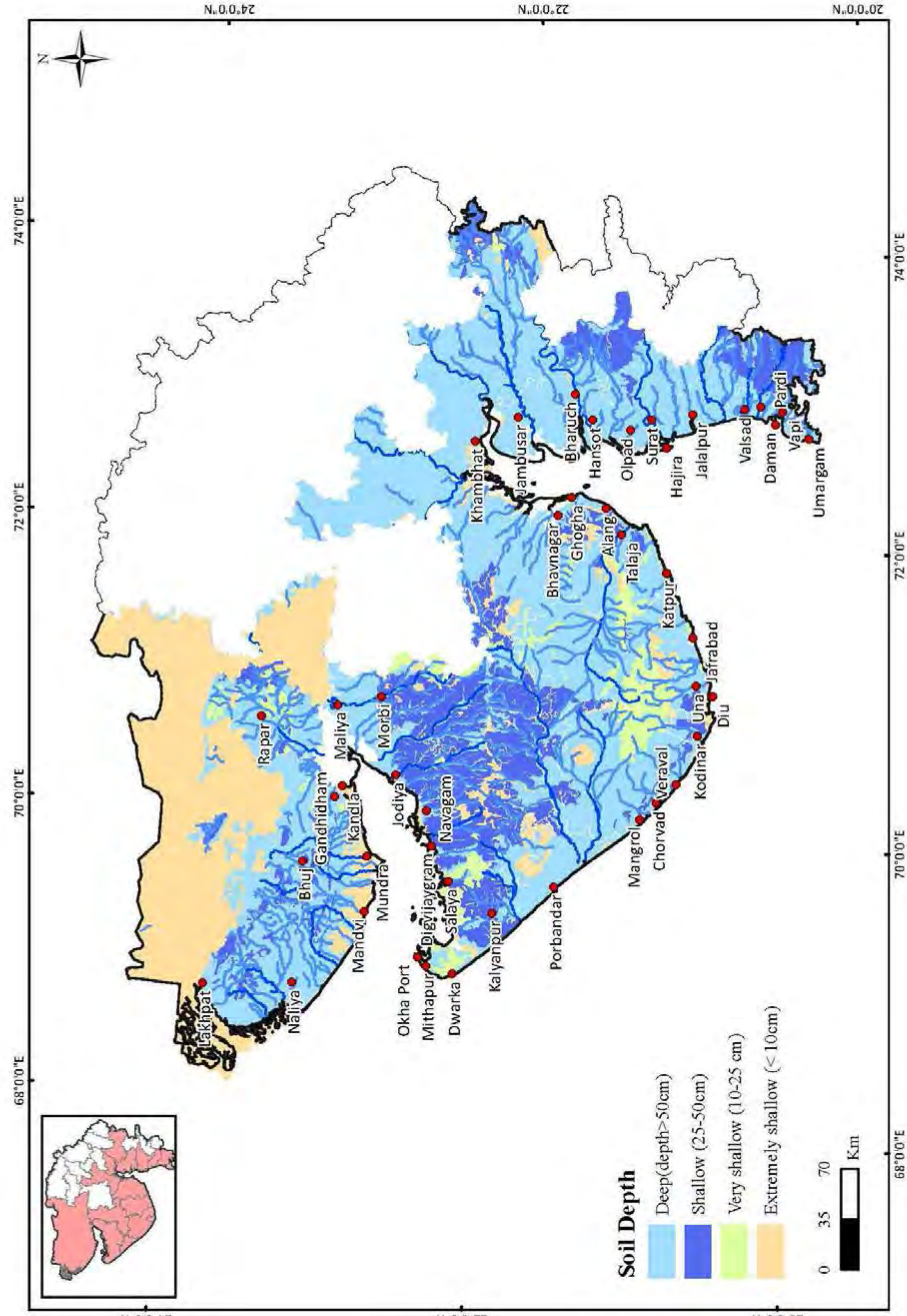


Fig. 3.1.3 (b) Soil depth map of coastal districts of Gujarat

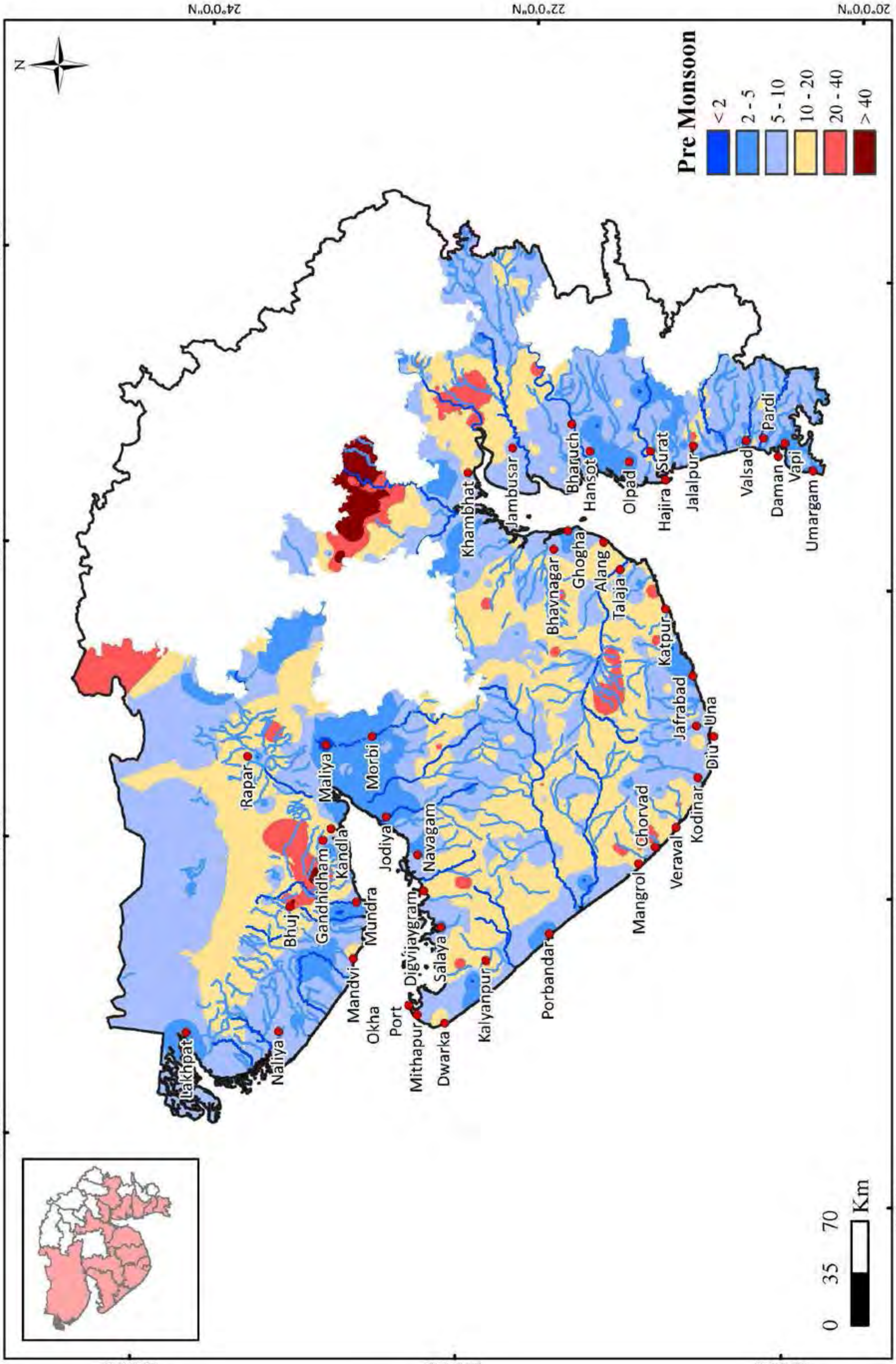


Fig. 3.1.4 (a) Pre-monsoon water level of coastal districts of Gujarat (in meters)

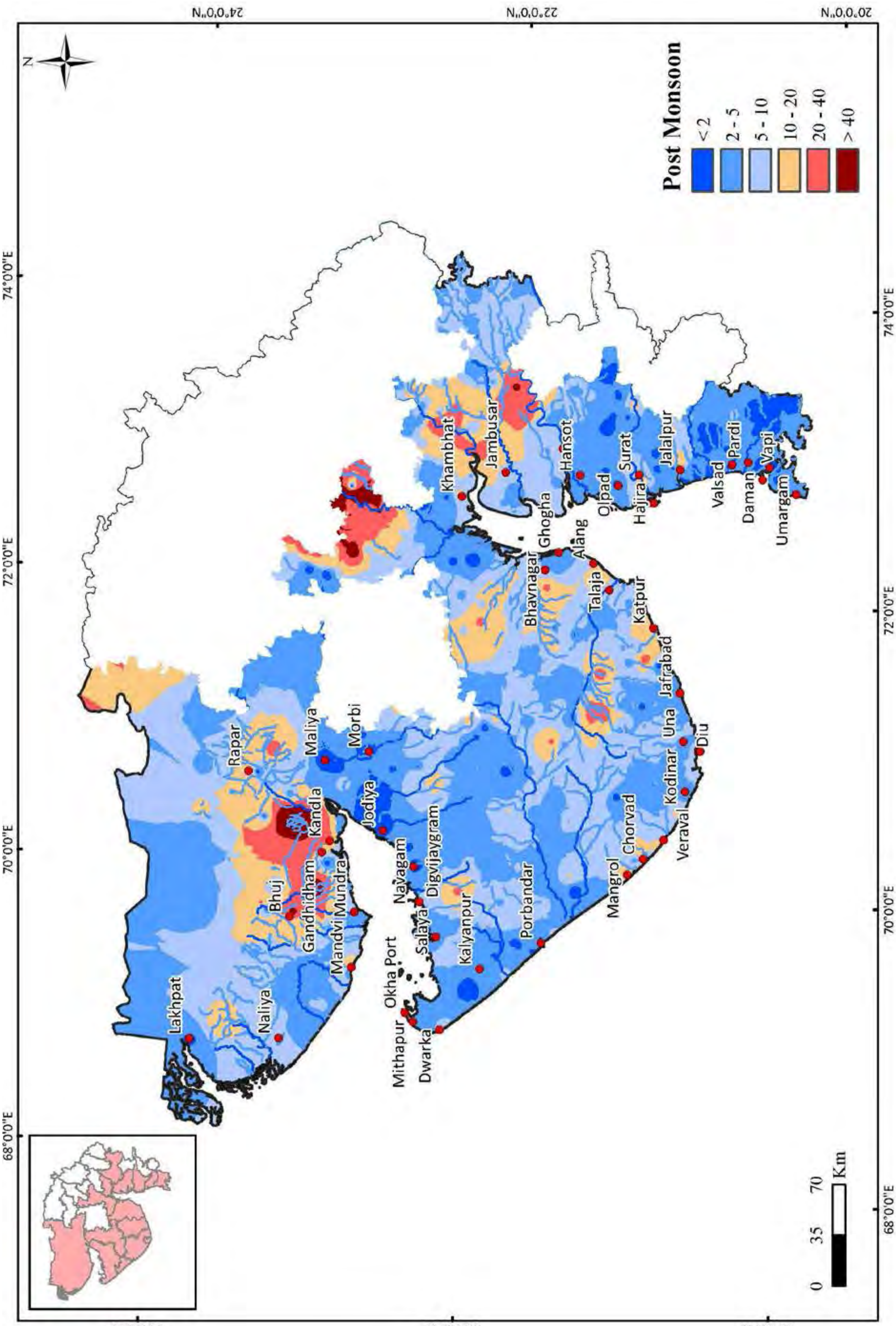


Fig. 3.1.4 (b) Post-monsoon water level of coastal districts of Gujarat (in meters)

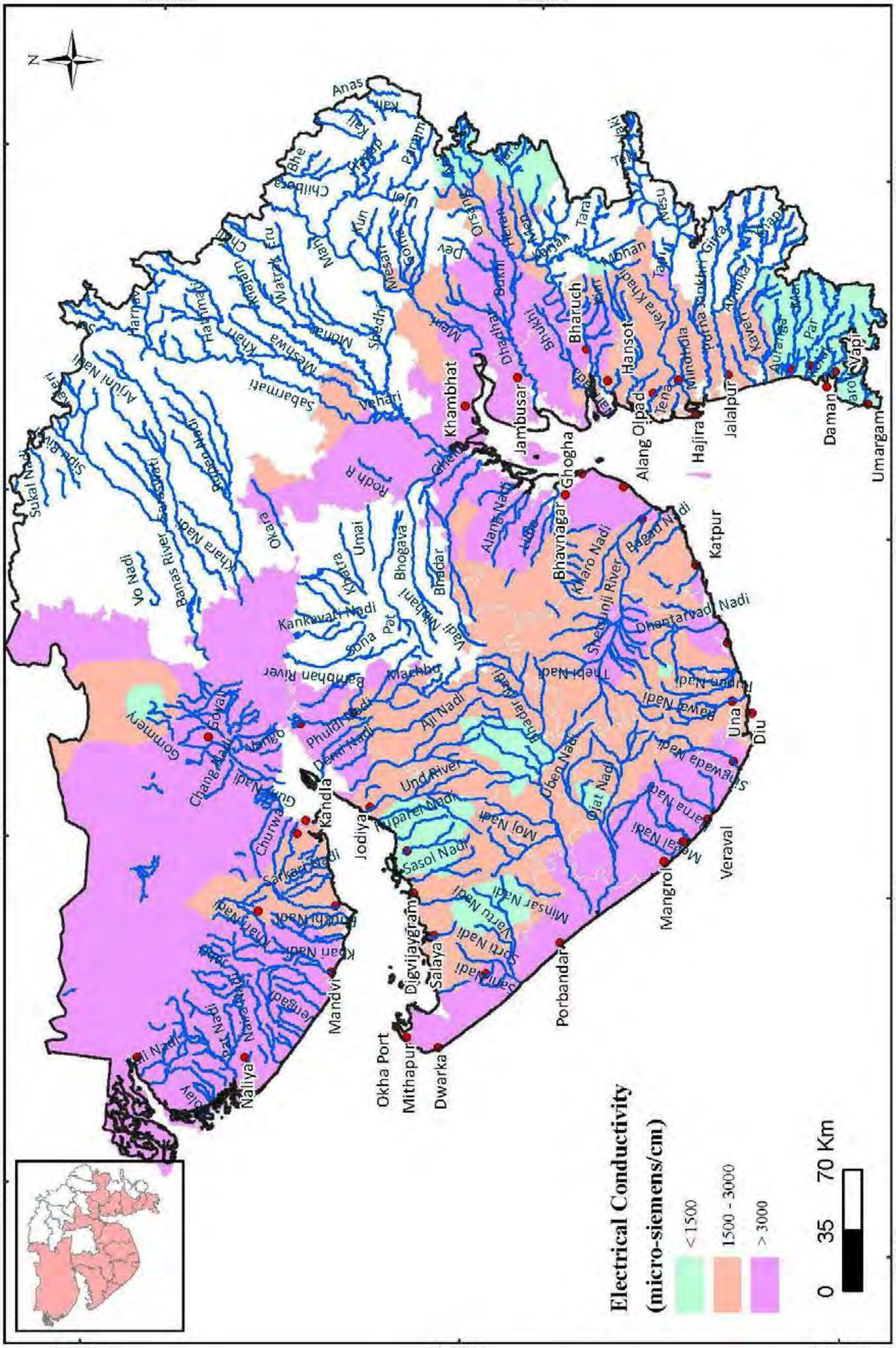
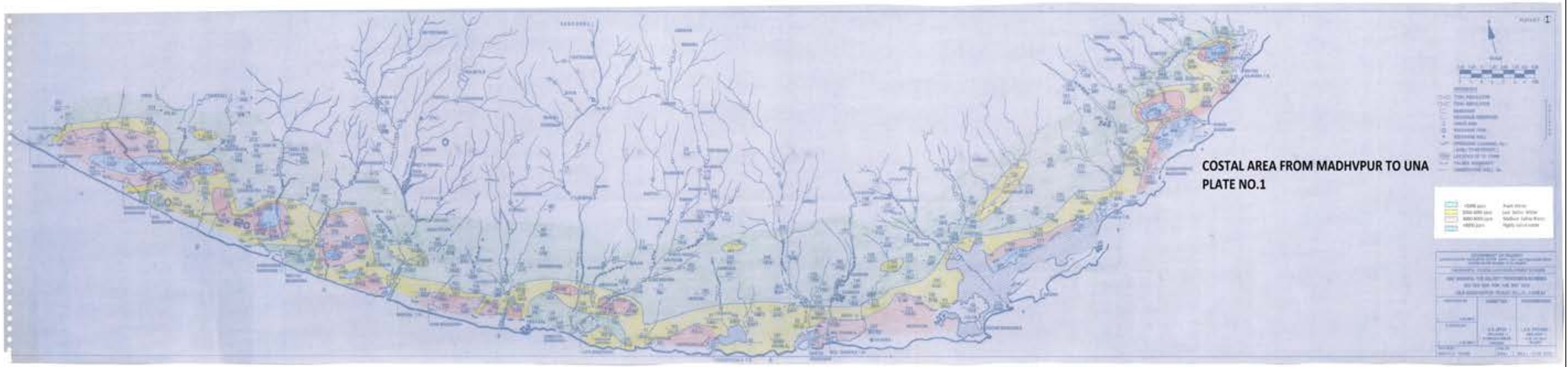


Fig. 3.1.4 (c) EC map of shallow groundwater for coastal districts of Gujarat



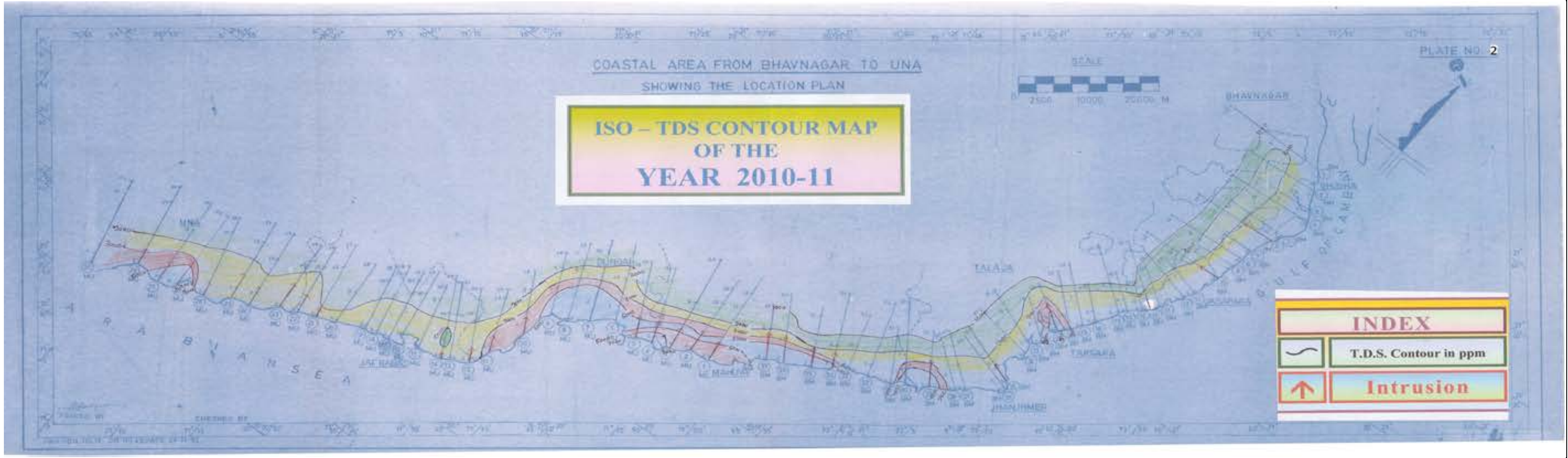
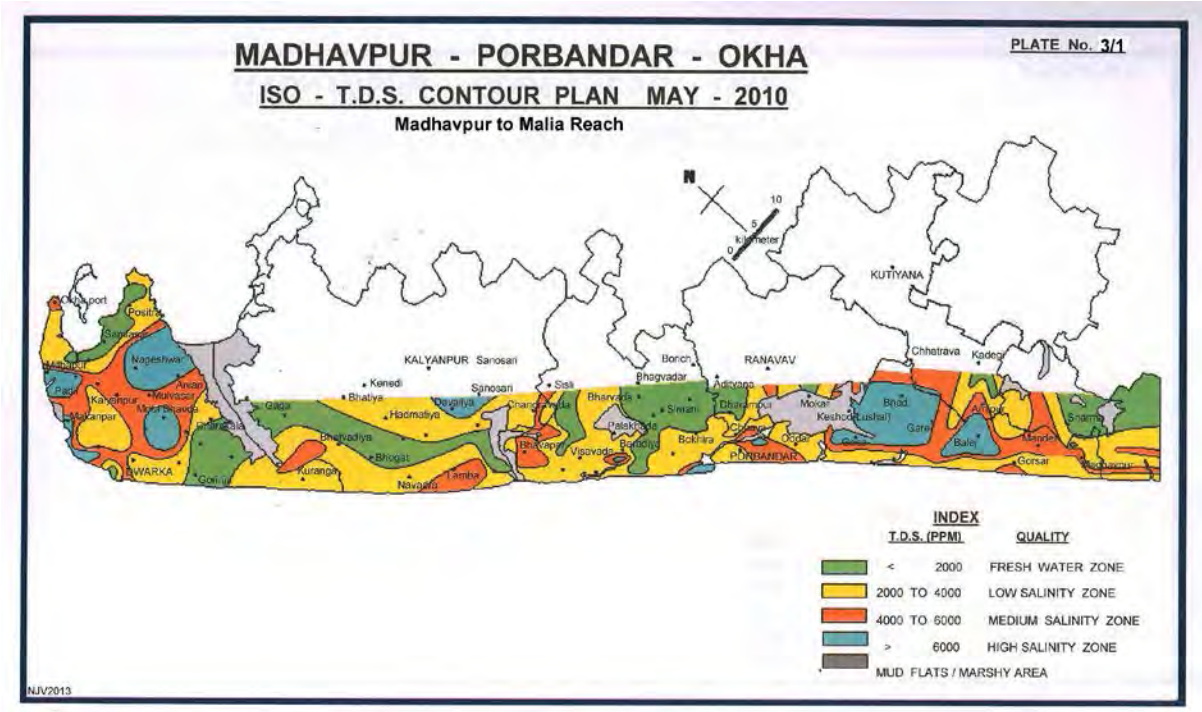
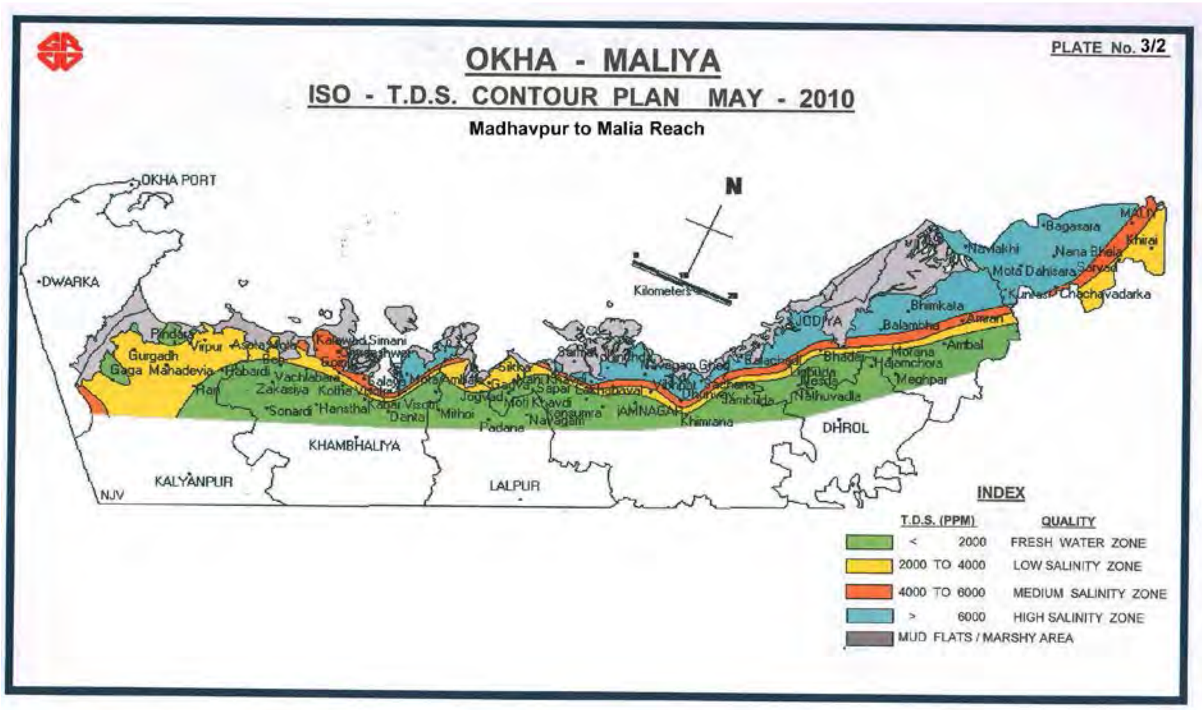


Figure 3.1.5 (a) Salinity Affected region from Una to Madhavpur Figure 3.5.1 (b) Salinity Affected region from Bhavnagar to una

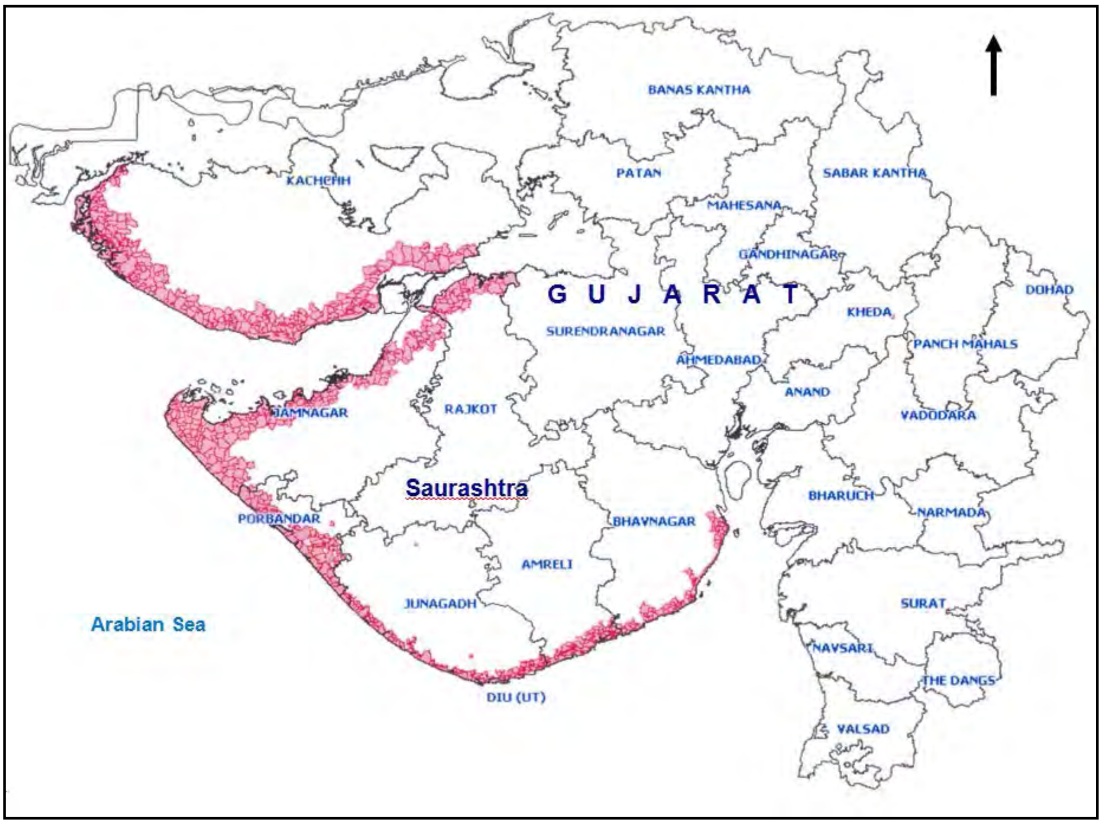


(c)

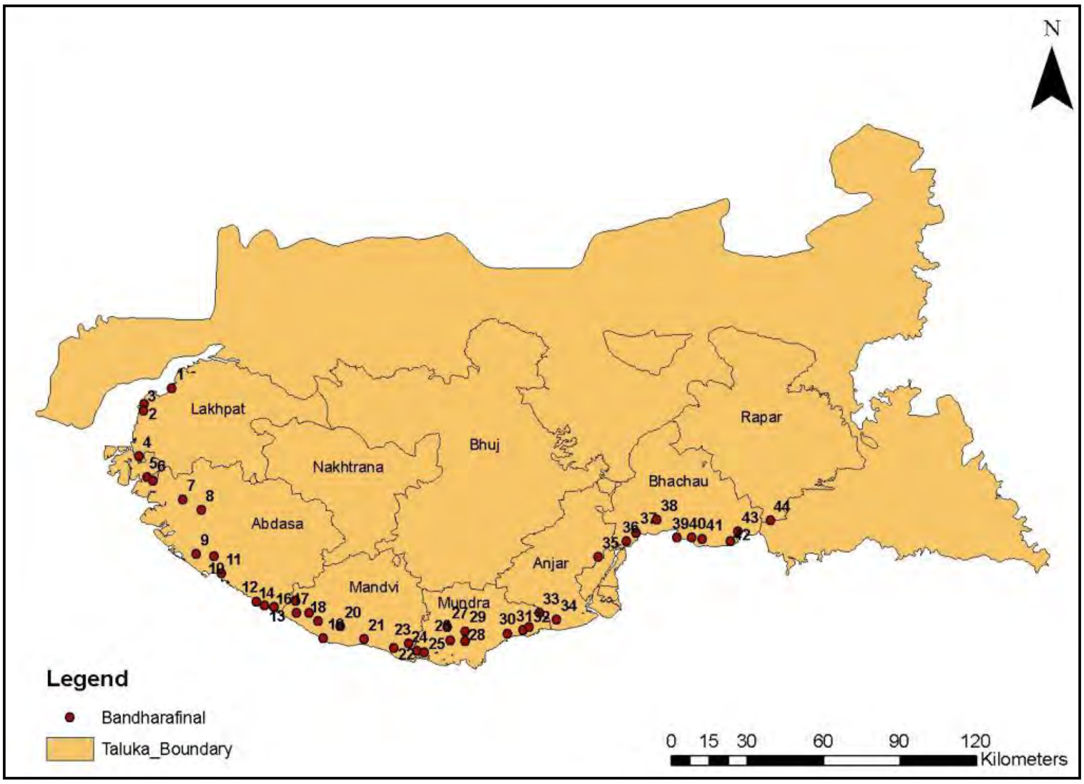


(d)

Figure 3.1.5 (c) Salinity Affected region from Madhavpur to Okha Figure 3.1.5 (d) Salinity Affected region from Okha to Malia



(a)



(b)

Fig. 3.1.6 (a) Salinity affected areas in Saurashtra and Kachchh; (b) Location of bandharas in Kachchh district.

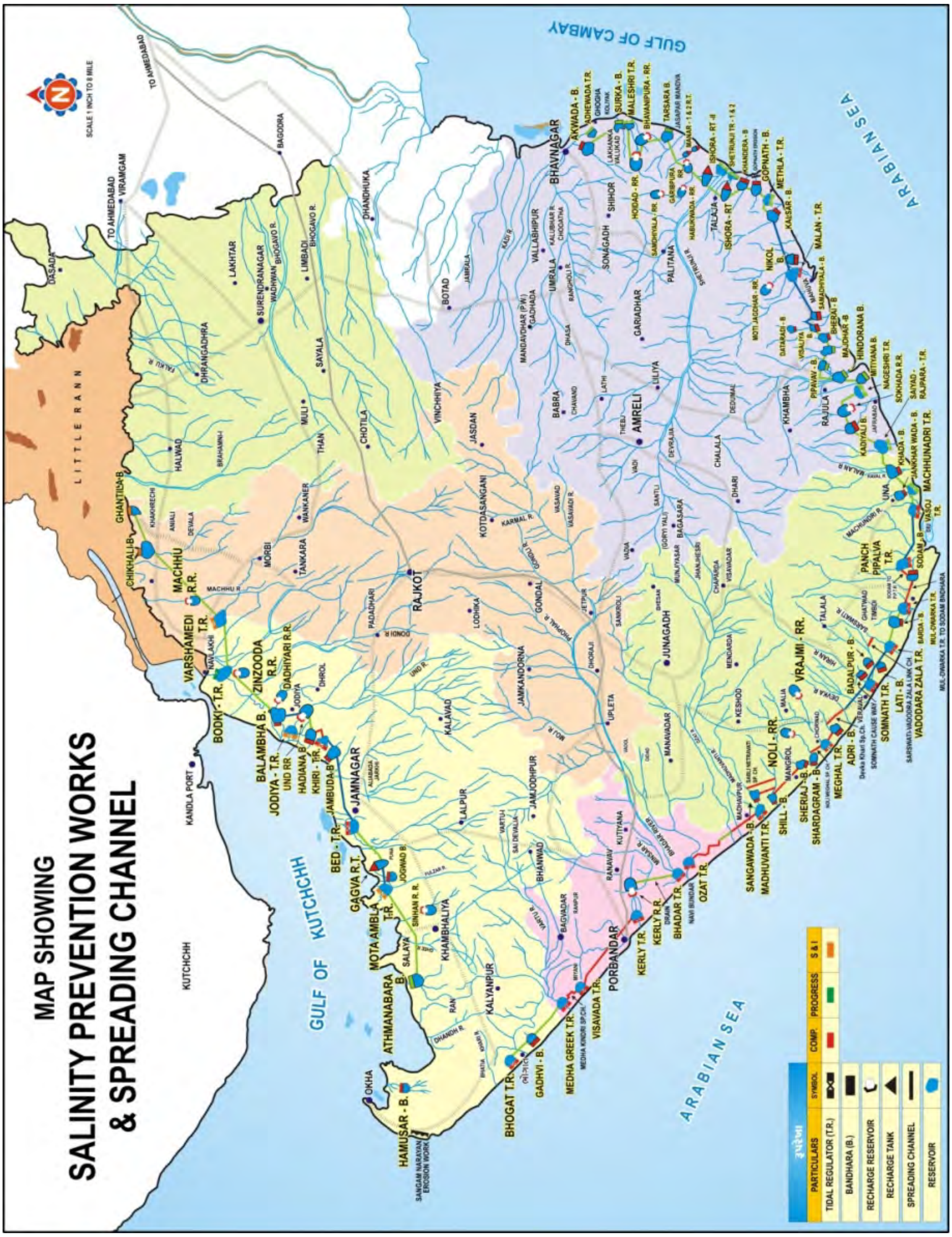
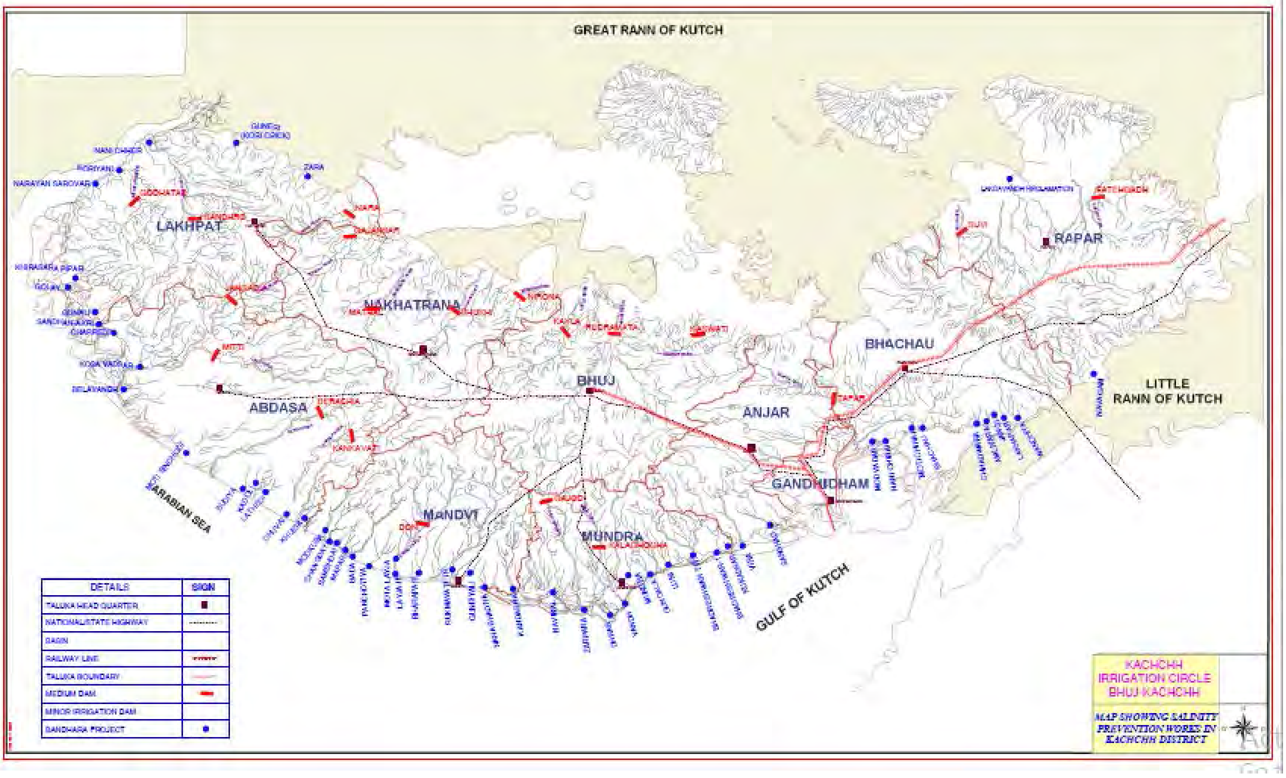


Fig. 3.1.7(a) Salinity intrusion prevention works implemented in Saurashtra region.



3.1.7 (b) Salinity Prevention Works in the Region of Kutchch

Fig. 3.1.8 View of bandhara at Lathedi, Abdasa taluka, Kachchh.

Fig. 3.1.9 View of spreading channel between Jambuda and Khiri tidal regulator constructed parallel to the coast.

3.1.10 View of Meghal Tidal Regulator under Rajkot circle

3.1.11 View of Somanath Bandhara under Rajkot Circle

3.1.12 View of Und Recharge Reservoir

3.1.13 View of Ozat-Madhuvanti Spreading Channel

3.1.14 View of Thepda Check Dam

3.2 MAHARASHTRA

3.2.1 General

The zone on the western coast of Maharashtra is also known as the Konkan region. It is a narrow terrain with an average width of 60 km between the west coast and the ridgeline of Sahyadri. The length of the coastal region is 720 km and is located between the state of Gujarat in the North and the union territory of Goa in the South. The undulating low-land of Konkan region encompasses the coastal tracts of districts namely, Thane, Raigarh, Ratnagiri, Sindhudurg and Mumbai urban area that comprise 10% of its total areas. Figure 3.2.1 shows the locations of the coastal districts; sparsely/ medium populated areas in villages and highly populated urban areas in towns and cities, variation in average annual rainfall (1971-2005) across the coastal districts areas and the general land use / land cover in coastal areas.

3.2.2 Physiography and Drainage

Numerous hills and detached ridges dominate the Konkan region. The northern part of the region located in the Thane and Raigad districts and major part of Sindhudurg district are comparatively flat or less undulating. The southern part of the Konkan coast is more rocky and rugged (Fig. 3.2.2a). High hills and elevated plateaus cut by numerous creeks are found close to the coast. Along the coast, marine land forms like lagoons, creeks, mud flat marshy lands and sand beaches are present. The coastline of Maharashtra exhibits a crenulated, irregular outline with a number of stream courses submerged within the sea. Inter-stream areas project as ridges into the sea. Beach development is sporadic and disconnected. Rocky cliffs of basalt along the coast suggest that wave-cutting action is more prominent than the deposition by streams.

The Konkan rivers drain a relatively narrow strip of land and none of the rivers have a course more than 100 km. In the north, Konkan, Pinjal, Vaitarna, Bhatsai, and Ulhas rivers drain the area north of Thane creek and converge on Thane-Dharamtar creeks. The important rivers Amba, Kundalika, Savitri, Vashishti, Shastri, Kajvi, Waghothan and Gad of south Konkan coastal area carry heavy discharge. A number of creeks run from coast towards inland area up to long distances carrying backwaters. Out of these, the Thane and Vasai creeks are quite prominent. The areas around these creeks, in the lower reaches form typical marshy saline lands (refer Fig. 3.2.2b).

3.2.3 Hydrogeology

All along the Konkan coast a narrow strip of unconsolidated beach sands occurs, varying in width from a few tens of metres where the hills form a sea face, to a few hundred metres in the areas near the coastline having flat topography. Wherever the coastal topography is flat, the beach sands merge landwards into low-lying mud flats, which in some cases extend a few kilometers inland. The depressions in such mud flats form saline lands. The coastal alluvium, wherever it is locally extensive, assumes importance as moderate groundwater reservoirs.

Fluviatile alluvial deposits occur along river courses and form locally significant hydrogeological units wherever they have adequate thickness (more than 10 m) and considerable lateral extent. The alluvium generally comprises silts, clays, sands, gravels and occasionally the cobble beds. The coarser granular layers like sand, gravel and pebble beds form productive aquifers but have generally limited geometry, as these form lenses embedded in finer sediments. If the alluvium has considerable thickness (10 - 40 m), the deeper sand lenses occurring below clay layers act as semi-confined aquifers. Local patches of alluvial deposits occur along the courses of Vaitarna and Ulhas Rivers (Thane), Patalganga, Amba and Kundalika rivers (Raigarh), lower reaches of Vaishishti, Shastri, Kajvi, Machkundi and Karni rivers (Ratnagiri) and lower reaches of Wagothan, God, Karli and Terekhol Rivers (Sindhudurg) and their tributaries (Figs. 3.2.3 a-b)

Semi-consolidated calcareous sandstone (locally known as Karal) occurs along the Konkan coast underlying the beach deposits and at places exposed as outcrops. The area covered by this formation is about 1200 km^2. The thickness of this formation is up to 10 m at places but may be more. The Karal forms a distinct local hydrogeological unit, which yields good discharge to dug wells. Laterites, both primary and secondary, occupy extensive areas of low-lying tracts, coastal parts and high plateau of Sahyadri ranges, concealing the underlying Deccan Trap. In the coastal areas of Ratnagiri district, marked by thick laterite capping, both primary and secondary laterite form potential shallow aquifers. A large part of the coastal tract is occupied by the lava flows of basaltic rocks (the Deccan Traps). Groundwater in these basaltic rocks occurs mostly in the upper weathered and jointed/fractured zones, generally upto 15 to 20 m depth. Yield of wells in jointed and weathered massive basalt ranges from 15 to 80 m^3/day, whereas in Vesicular and Amygdaloidal basalts it ranges from 4 to 90 m^3/day. The transmissivity of these aquifers ranges from 18 to 38 m^2/day.

The pre-monsoon decadal mean water level (1998-2007), in general, ranges from 2-5 m below ground level (bgl) in Thane and Raigarh districts in the north Konkan region and 5-10 m bgl in Ratnagiri and Sindhudurg districts in the southern region, except some patches where water levels are more than 15 m bgl. In the post monsoon period, the water level rises to 2 m bgl or less in most of the northern part while towards south it rises to 2-5 m bgl. Groundwater level in isolated patches remains within 10-15 m bgl. The decadal water level trend (1998-2007) along the coast of Maharashtra exhibits only minor changes in its pattern. A declining trend of 1 to 2 m is observed during pre-monsoon and post-monsoon seasons in the northern districts of Thane and Raigarh due to groundwater development. However, in the southern districts of Ratnagiri and Sindhudurg, where stage of groundwater development is rather low, rising trend of water level in the range of 1to 2 m is observed. Figures 3.2.4a&b show the depth to groundwater level maps for the year 2011.

3.2.4 Groundwater Salinity

All along the Konkan coast, brackish to saline groundwater is present in the beach sands and mud flats forming the coastal alluvium. The topographic depressions in mud flats form saline lands. In the coastal alluvium in Thane district, quality of groundwater is fresh in the elevated lands (EC 600 to 2000 µS/cm) but brackish to saline (EC up to 4000 µ S/cm) in the lowlands. In Raigad district, groundwater in shallow dug wells is fresh to brackish. In the beach sands of Ratnagiri district, the quality of water is slightly brackish near the creeks. In the coastal alluvium of Sindhudurg district south of Achra creek in Malvan - Devgad - Kelus - Shiroda area the quality of water is fresh to brackish with EC ranging from 70 to 4400 µS/cm. The fluviatile alluvial deposits along river courses generally hold fresh to slightly brackish groundwater where alluvial thickness is small (less than 10 m) but in areas where the alluvium is thicker and poorly drained the ground water quality is brackish or even saline. Also the quality of groundwater in areas with rivers experiencing tidal backwater effects is brackish or saline.

Underlying the beach sand and mudflats, in the semi consolidated calcareous sandstone, the quality of water is slightly brackish and is locally used for horticulture purposes (Coconut / Arecanut gardens). Owing to the physiographic, climatic and hydrogeological conditions, the TDS is generally less than 500 mg/l except at a few places in Thane and Raigarh districts. The area is mainly hilly, covered by porous laterite capping and receives good rainfall. Due to the steep topographic gradient and heavy rainfall, the flushing of aquifer is regular and the groundwater quality is fresh. The higher values of TDS in a few groundwater samples of Thane and Raigarh districts may be attributed to anthropogenic sources. The groundwater samples having high sodium also indicate mixing of seawater with groundwater at a few locations (Fig. 3.2.4c). It is reported that there is a possibility of sea water intrusion in parts of Mumbai metro city, viz., Colaba, Dharvi, Khar, Andheri, Chembur and Malad due to intensive development of groundwater (CGWB, 2011).

3.2.5 Causes and Extent of Coastal Land Salinity

The region receives plentiful rainfall from the south west monsoon. In a width of about 15 km from the coast line, deep deposits of soil exist on account of erosion on the steep slopes of Sahyadri and transportation of this eroded material by rapidly flowing streams down the Western Ghats to the low lying coastal tracts. During the high tides, salt water from the sea inundates the agricultural land along the numerous creeks thereby damaging the fertile land and rendering the soil saline. The coastal lands with saline soils (called the Khar/Khajan lands) which exhibit increased content of soluble salts pose special management problems. The Khar lands in the Konkan area are spread along the banks of 58 creeks. The tidal effect in the above creeks ranges from 20 to 30 km from their mouth to the inland areas. Table 3.2.1 provides the details of coastal length and number of creeks in the four rural districts as well as the respective area of the salinity affected parts.

Table 3.2.1 Coastal length of rural districts and the saline affected area in Maharashtra

Sl. No.	District	Coastal Length km.	No. of Creeks	Saline Area (ha)
1	Thane & Palghar	127	12	21757
2	Raigad	121	7	30117
3	Ratnagiri	238	19	6794
4	Sindhudurg	120	20	4516
	Total	606	58	63184

The Khar lands that occur along the sea coast and creeks are unfit for cultivation mainly due to salinity. The sea water enters through the creeks during high tides and submerges large areas of cultivable land. These periodical inundations render the land progressively saline and in time make it completely unfit for growing any crop. The Khar lands in Maharashtra do not have any other source of irrigation and cultivation in the area is possible only in Kharif season

3.2.6 Remedial Measures

The state of Maharashtra established Kharland Board in 1948 for Kharland development works. The Government of Maharashtra later dissolved the Kharland Board and started taking up the works of construction and maintenance of Kharland Development by enforcing the Maharashtra Kharland Development Act-1979. The Schemes proposed have been implemented by Kharland Development Circle. Government of Maharashtra developed the Master Plan of Kharland Development Schemes in 1981-82 and planned to reclaim 49120 hectares of Kharland through 575 Kharland Schemes along creeks and sub-creeks.

Construction of Kharland Bunds: Through construction of embankments along the banks of creeks, the tidal waters are restricted from entering into and submerging the agricultural lands The flood water from upland area is allowed to go into the sea through the cross drainage works constructed in the embankments. One way gates are provided to the cross drainage works in order to restrict the saline water from the sea to enter into the agricultural lands. A typical section of the Karland bund adopted in Maharashtra is given in Fig. 3.2.5 and a few pictures showing the Kharland Schemes adopted in different places shown in Figs. 3.2.6 – 3.2.8.

Table 3.2.2 gives the number of completed and ongoing schemes and the respective reclaimed areas in the rural coastal districts of the state.

Table 3.2.2 List of completed and ongoing schemes in the rural coastal districts in state of Maharashtra

Sl. No.	District	Master Plan		Completed Schemes		Ongoing Schemes	
		Number	Reclaimed area (ha)	Number	Reclaimed area (ha)	Number	Reclaimed area (ha)
1	Thane	35	5187	29	4148	2	680
2	Palghar	73	8457	55	7411	0	0
3	Raigad	165	22559	133	19965	2	170
4	Ratnagiri	170	6794	83	3616	10	584
5	Sindhudurg	132	6136	104	5725	1	59
	Total	575	49133	404	40865	15	1493

The expenditure incurred in construction of these schemes during the last four years is given in Table 3.2.3.

Table 3.2.3 Expenditure incurred since 2011-15 in Maharashtra State

(Expenditure in Lakhs)						
Sl. No.	Year	Thane	Raigad	Ratnagiri	Sindhudurg	Total
1	2011-12	271.43	624.31	107.43	89.43	1092.60
2	2012-13	305.28	503.38	136.92	188.60	1134.18
3	2013-14	411.63	543.92	276.72	416.00	1648.27
4	2014-15	594.59	1373.70	231.34	390.61	2590.24
	Total	1582.93	3045.31	752.41	1084.64	6465.29

District wise completed and ongoing Kharland schemes in Maharashtra are included in Annexure 3.2A & Annexure 3.2B respectively. The completed and the ongoing schemes in the district of Thane, Phalgar, Raigad, Ratnagiri and Sindhudurg are shown in the figures 3.2.9-3.2.15.

Benefits of the remedial measures

The following benefits are accrued from the remedial measures adopted by Maharashtra.

Environmental Aspects

- Prevention of salinity ingress occurring through creeks.
- Freshwater recharge
- Stoppage of saline water from entering into adjoining fresh water drains.
- Ecological balance maintained by enriching area under mangrove vegetation on creek side.
- Creation of better environment for fish breeding on creek side in mangrove area.
- The embankments also restrict the coastline erosion due to tidal surges.

Socio-Economic Benefits

- Help poor farmers with small land holdings to take paddy crop on the protected areas including fruits, vegetables and other useful crops.
- By improving agriculture system, yield of paddy can be increased; increase in employment avenues and economic status.
- Having provided necessary support and confidence in staying at their native places, by means of protection through the saline embankments, migration of local population to other places in search of better livelihood is minimized.
- To protect the villages near coastal area from floods, cyclone, tidal surges.
- To protect the people near the coastal areas from the effects of Tsunamis and Cyclones.
- To protect the property of the people from the effects of Tsunamis and Cyclones.
- To protect the drinking water from salinity ingress.
- To provide emergency exit at the time of Tsunamis and Cyclones.

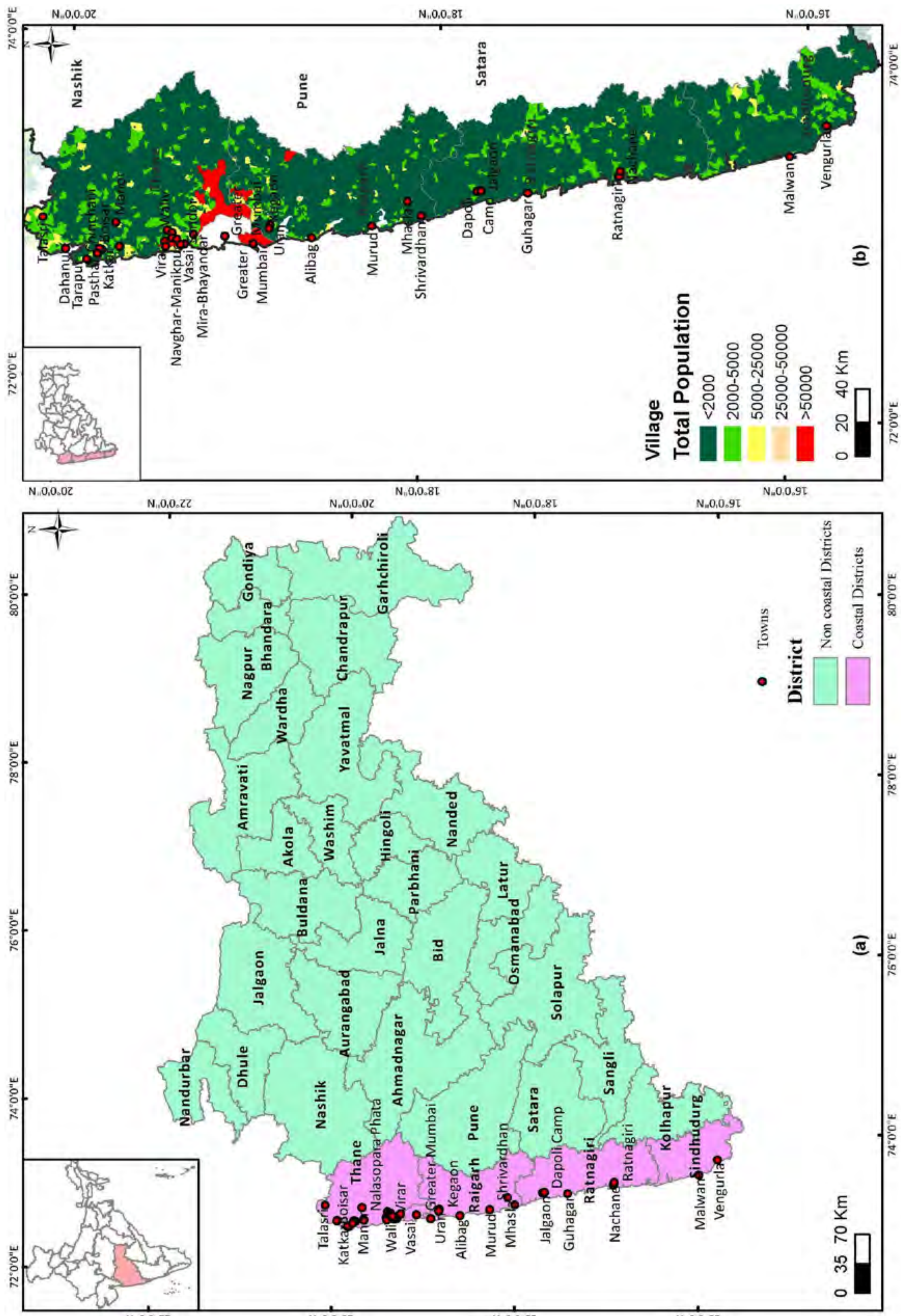


Fig. 3.2.1(a) Administrative map of Maharashtra showing coastal districts (b) Population distribution of coastal districts of Maharashtra

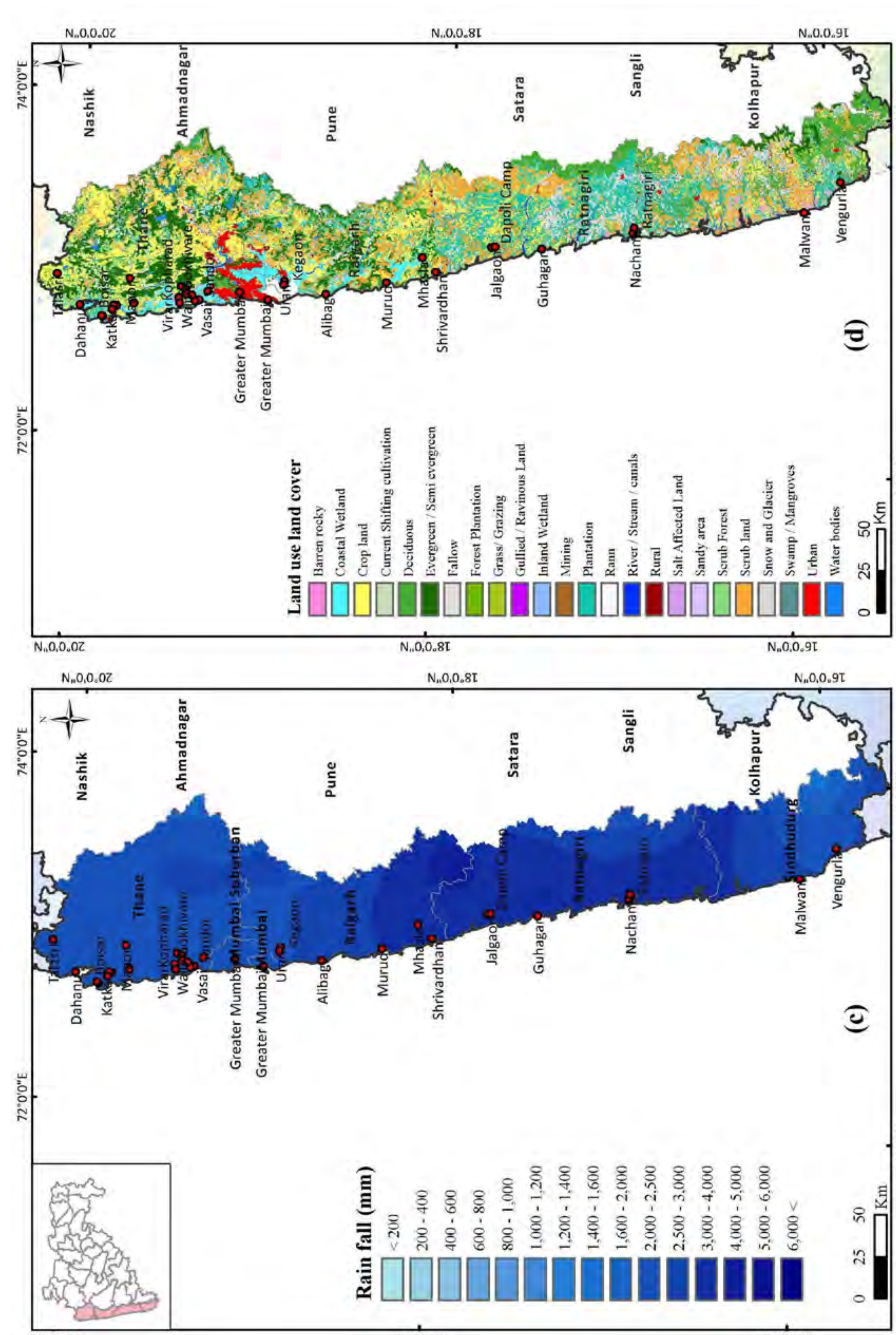


Fig. 3.2.1 (c) Rainfall distribution of coastal districts of Maharashtra (d) Land use and land cover of coastal districts of Maharashtra

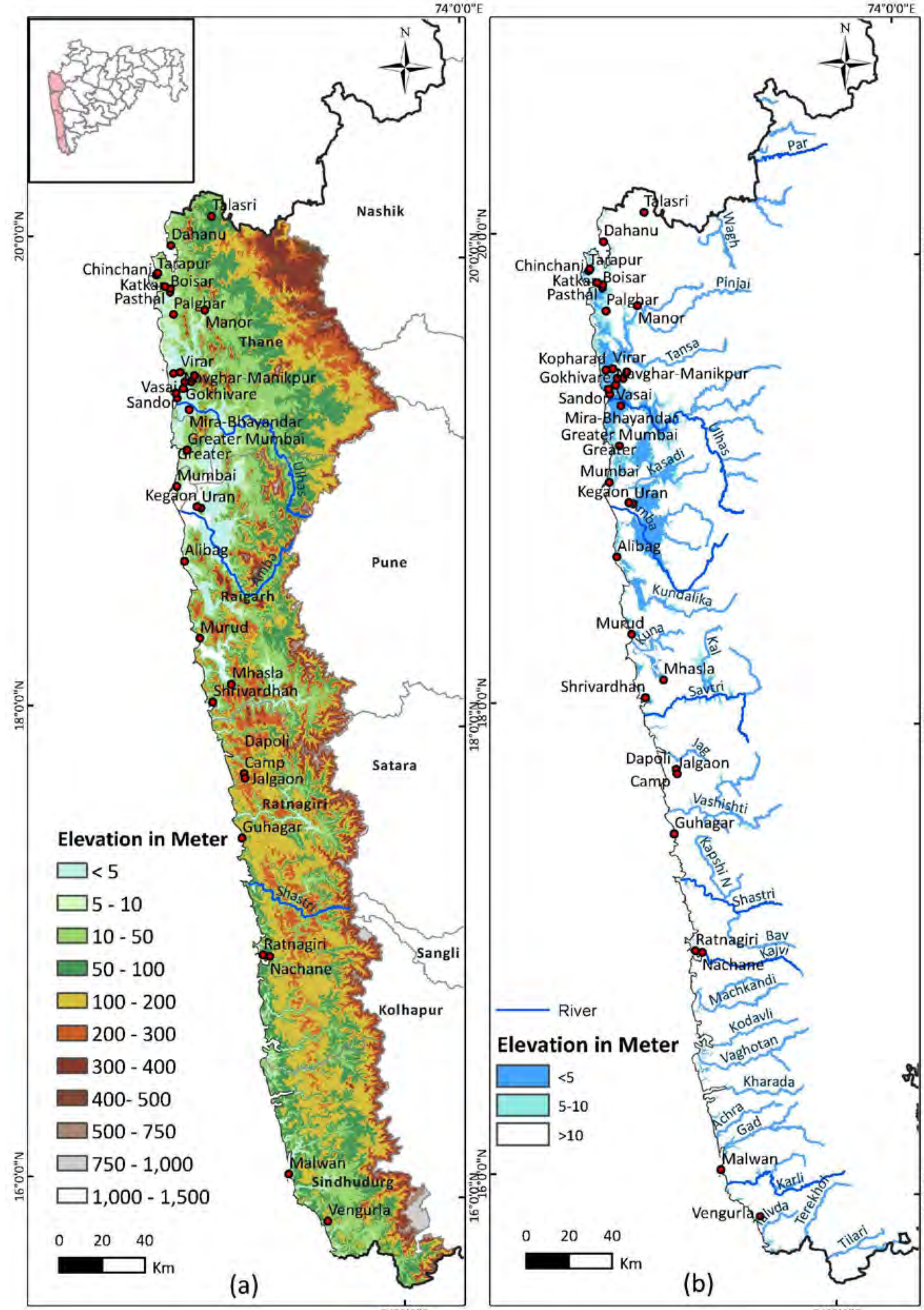


Fig. 3.2.2 (a) Physiographic map of Maharashtra (b) Drainage map of Maharashtra showing low elevation coastal areas (< 10 m amsl)

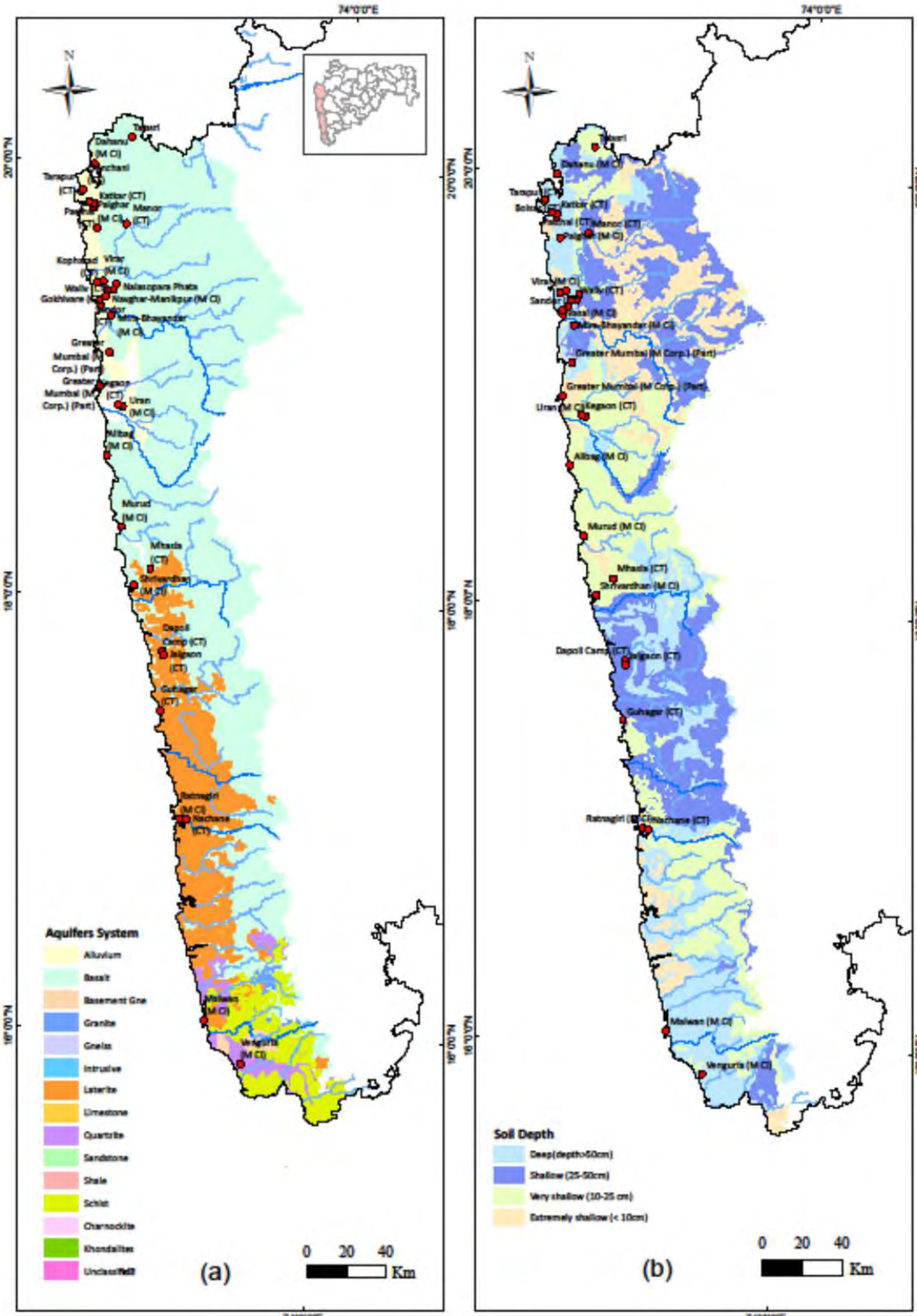


Fig. 3.2.3 (a) Aquifer map of coastal districts of Maharashtra (b) Soil depth map of coastal districts of Maharashtra

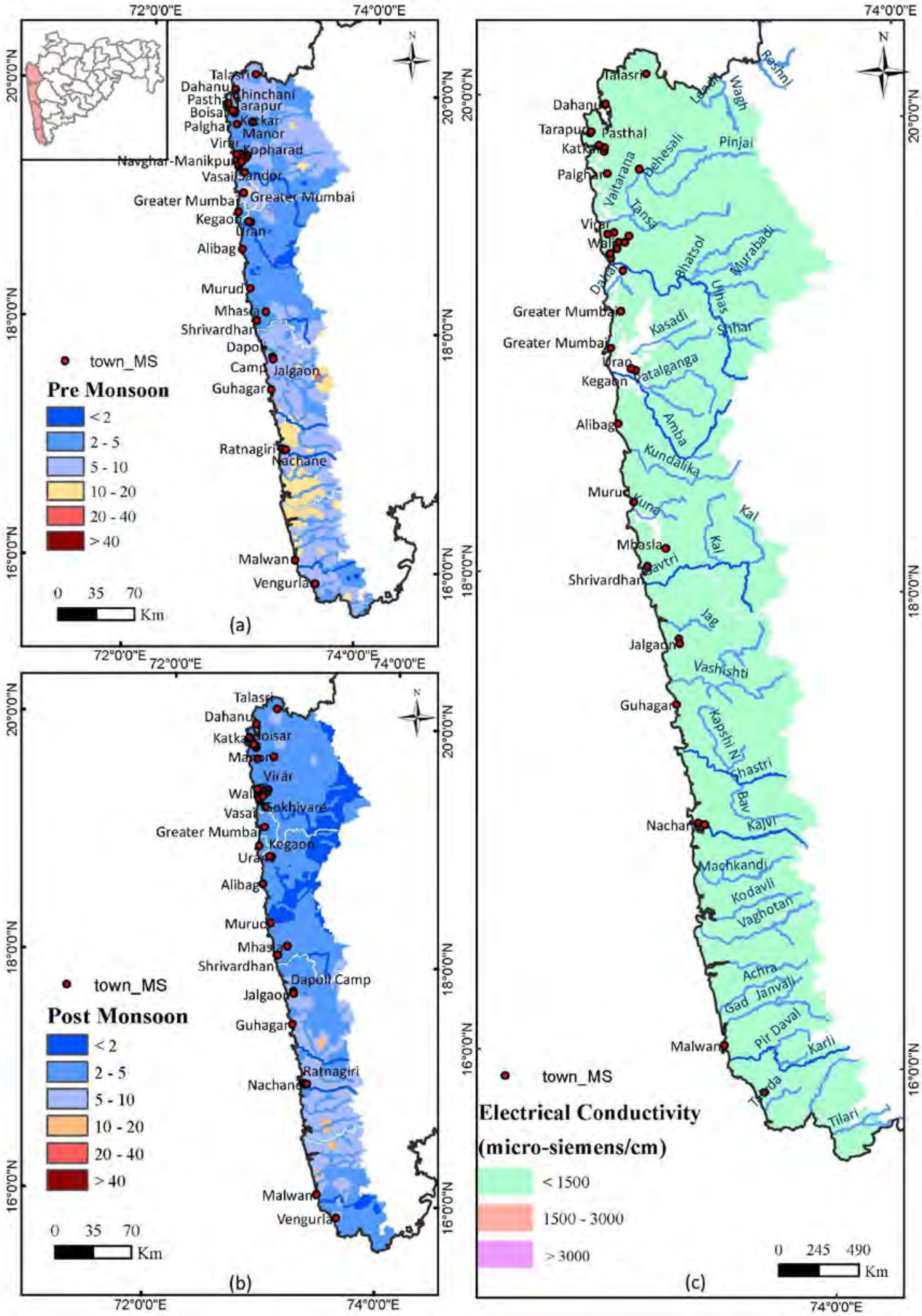
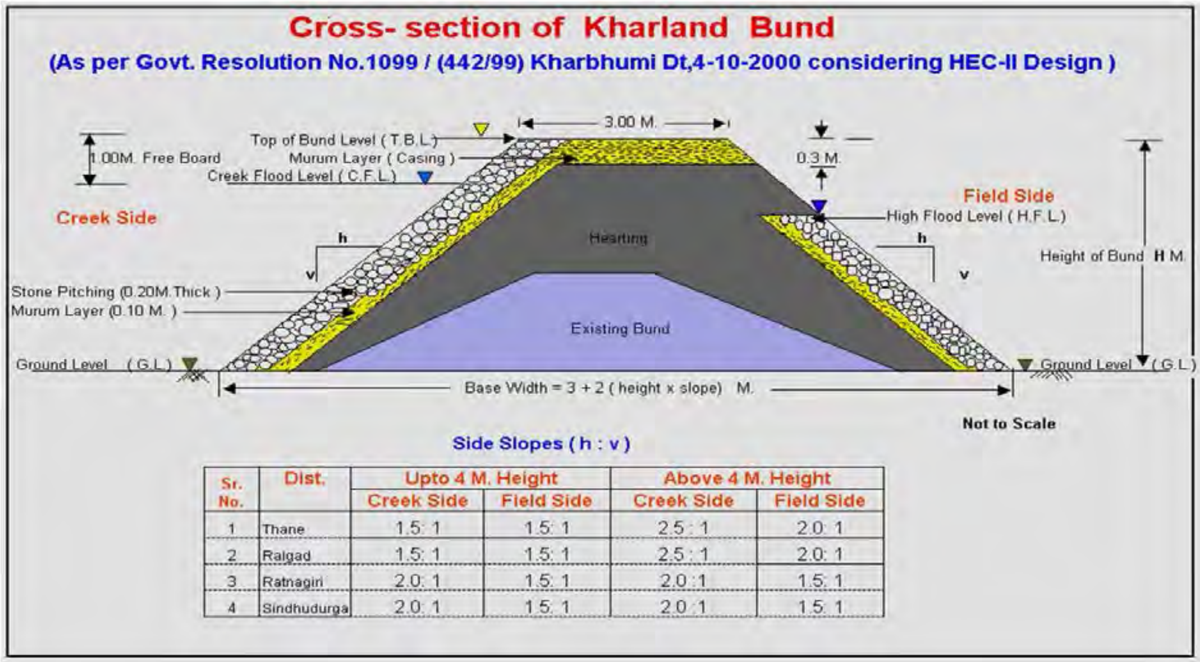


Fig. 3.2.4 (a) Pre-monsoon water level of coastal districts of Maharashtra (in meters) (b) Post-monsoon water level of coastal districts of Maharashtra (in meters) (c) EC map of shallow groundwater for coastal districts of Maharashtra



Sr. No.	Dist.	Upto 4 M. Height		Above 4 M. Height	
		Creek Side	Field Side	Creek Side	Field Side
1	Thane	1.5: 1	1.5: 1	2.5 : 1	2.0: 1
2	Raigad	1.5: 1	1.5: 1	2.5 : 1	2.0: 1
3	Ratnagiri	2.0: 1	1.5: 1	2.0 :1	1.5: 1
4	Sindhudurga	2.0: 1	1.5: 1	2.0 :1	1.5: 1

Fig. 3.2.5 Typical cross section of kharland bund in Maharashtra

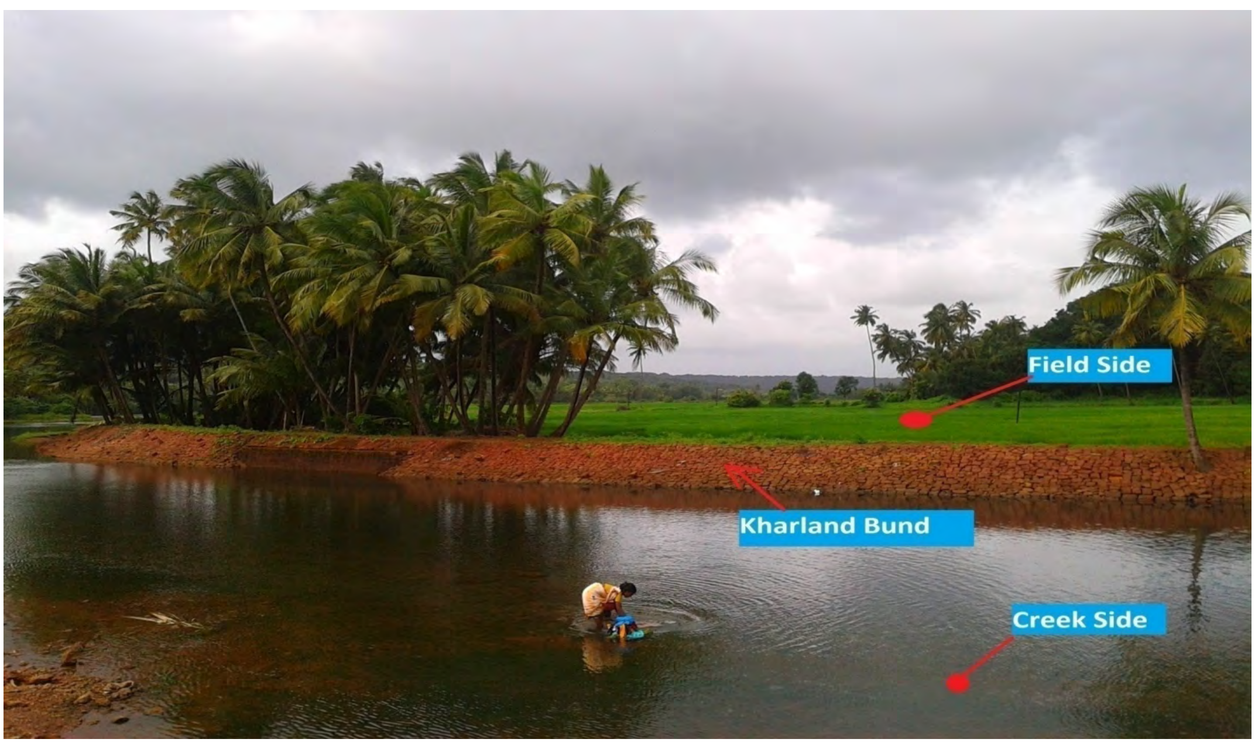


Fig. 3.2.6 Baparde Kharland Scheme Ta. Deogad, Dist. Sindhudurg, Maharashtra

Fig. 3.2.7 Manjare Kharland Scheme, Ta. Sangameshwar, Dist. Ratnagiri, Maharashtra

Fig. 3.2.8 Nevare Chinchavane Kharland Scheme, Ta. & Dist. Ratnagiri, Maharashtra

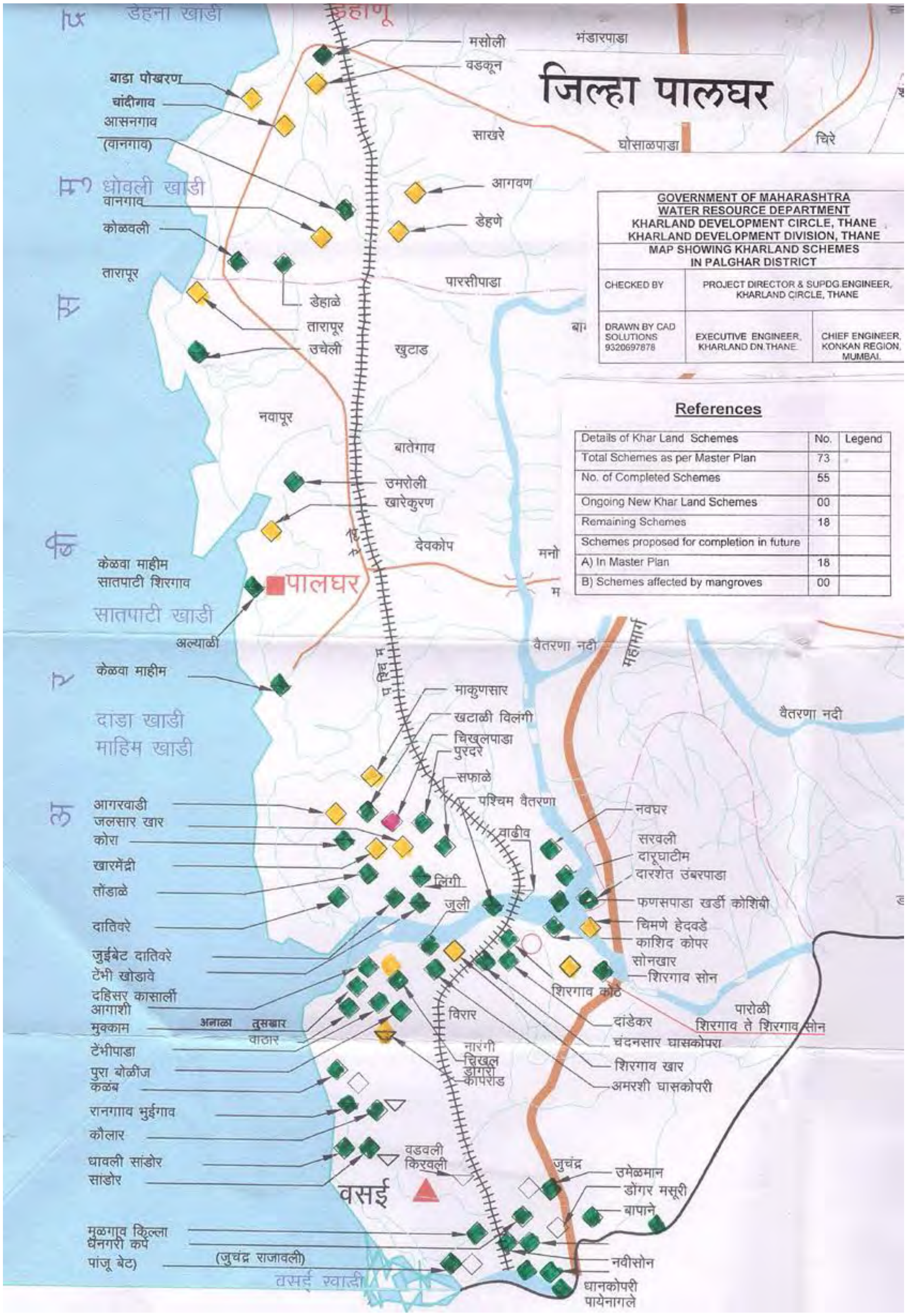


Fig 3.2.9 Schemes in the Phalgar District

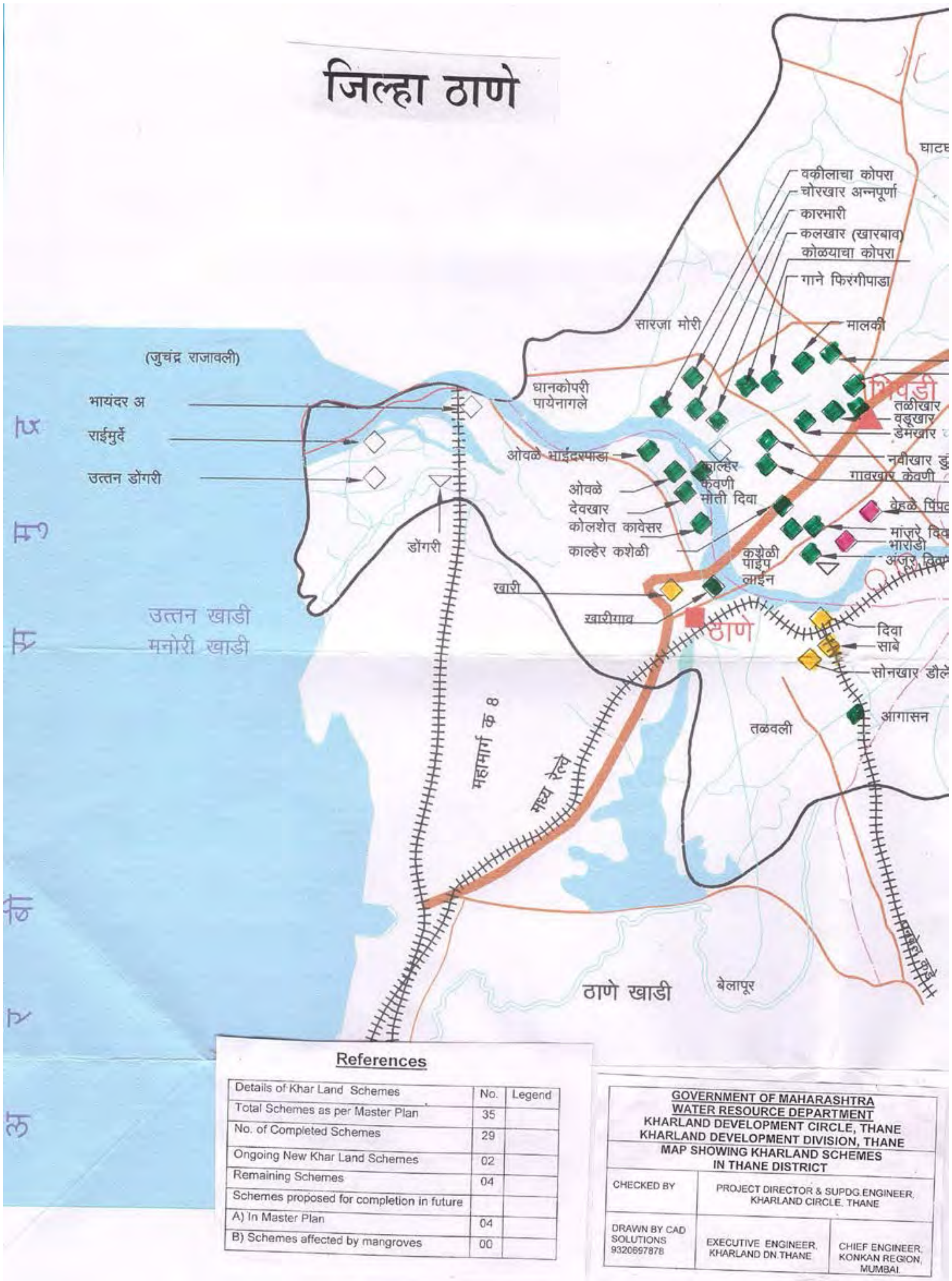
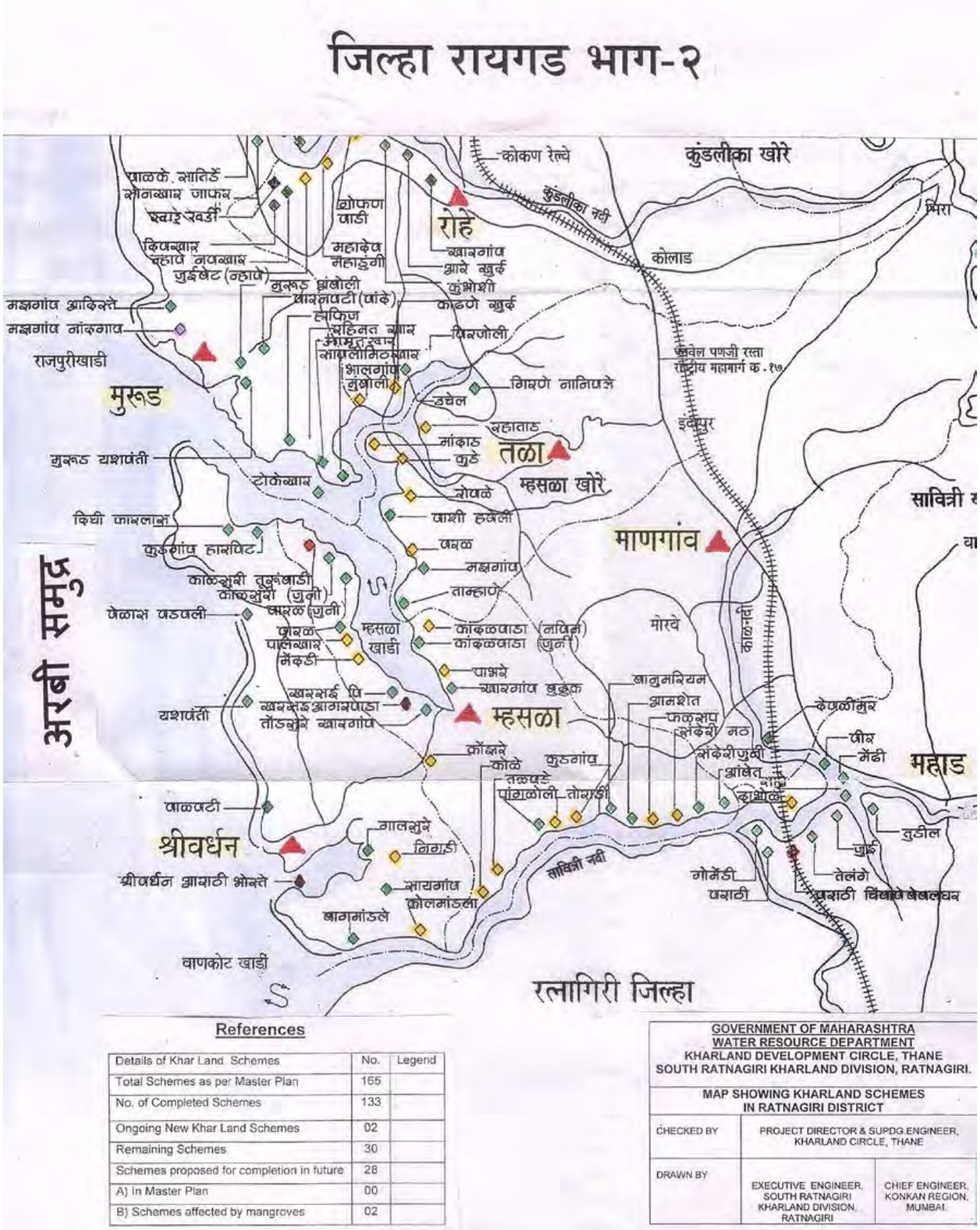


Fig 3.2.10 Schemes in Thane District

Fig 3.2.11 Schemes in Raigad District-I



Details of Khar Land Schemes	No.	Legend
Total Schemes as per Master Plan	165	
No. of Completed Schemes	133	
Ongoing New Khar Land Schemes	02	
Remaining Schemes	30	
Schemes proposed for completion in future	28	
A) In Master Plan	00	
B) Schemes affected by mangroves	02	

Fig 3.2.12 Schemes in Raigad District-II

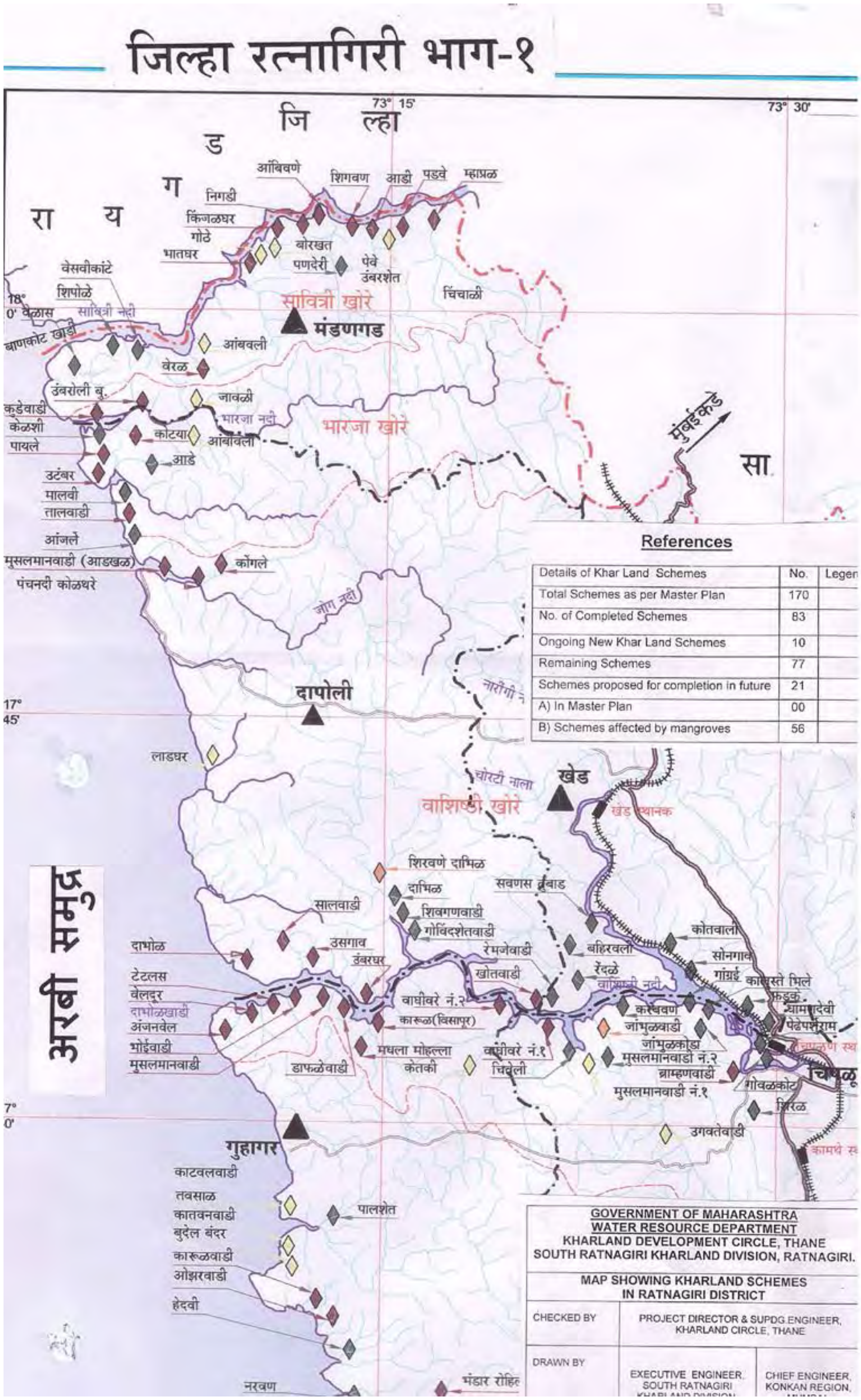


Fig 3.2.13 Schemes in Ratnagiri District-I

Fig 3.2.14 Schemes in Ratnagiri District-II

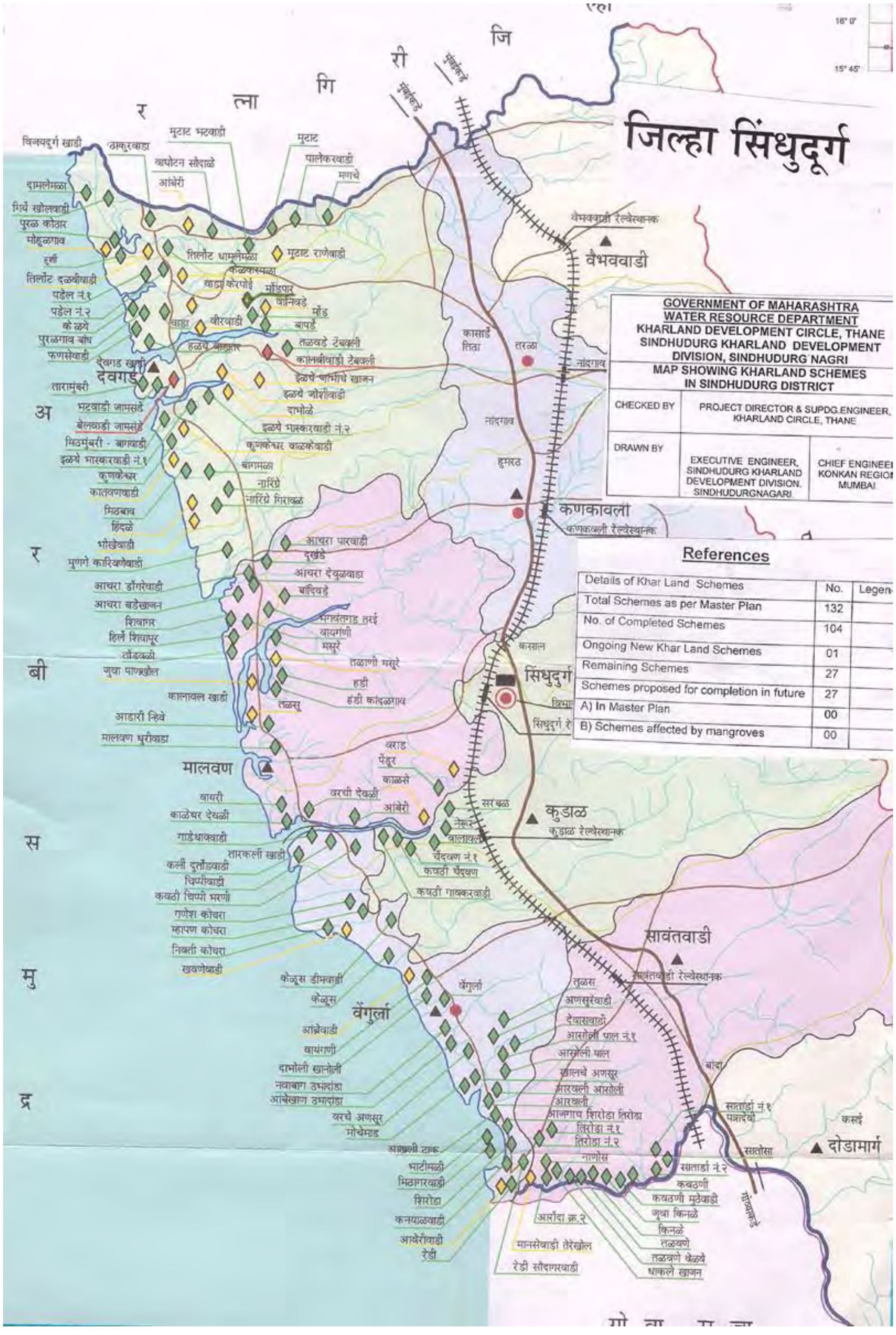


Fig 3.2.15 Schemes in SindhudurgDistrict

3.3 KARNATAKA

3.3.1 General

Along the 280 km long coast line of Karnataka, in the three districts of Uttara Kannada, Dakshina Kannada and Udupi, there occurs a narrow strip of coastal alluvium underlain by the Precambrian crystallines. Its width varies from a few metres to 4 km at places. The coastline of Karnataka is indented with a number of river mouths, creeks, promontories and cliffs. In north Karnataka, the coastal low-land becomes narrow and gets confined to small pockets along the lower courses of streams. Towards south, the low-land is somewhat wide. Figure 3.3.1 shows the locations of the coastal districts; sparsely/ medium populated areas in villages and highly populated urban areas in towns and cities, variation in average annual rainfall (1971-2005) across the coastal districts areas and land use / land cover conditions. The population map shows that the southern coastal districts are more populated compared to northern districts.

3.3.2 Physiography and Drainage

Broadly, three parallel belts of landform are noted in the coastal plain. Immediately adjacent to the coast, a relatively narrow belt of recent deposits form beach ridges, estuarine mud flats or marshes, backwater lagoons, pocket beaches, spit and bar systems and the valley plains. It is generally flat or gently sloping (elevation upto 30 m). The city of Karwar is on beach ridges. It is reported that the beach ridges are slowly vanishing along the coast especially at Karwar and Majali, owing to urbanization and other developmental activities (Hanamgond and Mitra, 2007). Rocky islands are present near the coast indicating submergent as well as emergent coast. This belt is followed by about 60 m high erosion platform, which is about 20 km wide in south and well dissected by steep sided valleys. Further inland, the third belt of isolated hills of height 91-305 m, are observed towards south east of Honavar and near Karwar (Fig.3.3.2a)

There are 14 rivers draining the Karnataka coast (Fig. 3.3.2b). The prominent are Netravati, Gurupura, Gangoli, Hangarkatta, Sharavathi, Aganashini, Gangavali and Kalinadi. The other rivers like Kumaradhara, Nandini, Shambavi and Swarna etc. also drain the coastal area. There are a number of smaller streams joining these rivers and finally the sea.

3.3.3 Hydrogeology

Coastal alluvium comprises fine to medium grained sand, clay and gravels. The thickness of alluvium is around 35 to 45 m near the coast and gradually decreases landward up to 10 m. In the alluvial areas groundwater occurs under water table condition. A well-defined clay layer at places has lead to semi-confined to confined groundwater conditions in the alluvial aquifers. Figures 3.3.3a-b provide the geology and soil depth in the coastal terrain. The yield of the dug wells ranges from 1.8 to 297 m^3/day in sand and 18 to 36 m^3/day in clay. The transmissivity values range from 37 to 781 m^2 /day for sand, 24 to 132 m^2 /day for sandy clay and 2 to 20 m^2/day for the clayey beds. In laterites, groundwater occurs under unconfined condition. Laterites form productive aquifers in areas close to valley portions. The transmissivity ranges from 385 to 4348 m^2/day. The yield of wells in laterites ranges from less than 2 to 280 m^3/day. The fissured formations along the coastal Karnataka are occupied by the Dharwarian group of rocks represented by chlorite, schist, amphibolite, quartzites, phyllites, limestones, dolomite and intrusives of basic nature. In these formations, groundwater occurs under unconfined conditions in the weathered mantle. In granitic gneiss in shallow weathered zone, the transmissivity values range from 5 to 141 m^2/day and the yield of the wells ranges from 14 to 85 m^3/day. Figures 3.3.4 a-b show the depth to water level during pre- and post monsoon for the year 2011.

3.3.4 Groundwater Salinity

In the coastal plains of Karnataka, water in the shallow aquifers is in general fresh with EC less than 1000 µS/cm, except localized pockets in and around Hangarkatta in Kundapura block of Udipi district where EC and chloride are reported to be 4230 µS/cm and 980 ppm, respectively (Fig. 3.3.4). The water in the aquifers in beach sand has EC in the range of 132-744 µS/cm. Relatively higher EC of water in some wells in beach sand is due to contamination by high tides. It is observed that water in laterites have less EC than that from beach sand. Salinity present in groundwater is caused on account of marine depositional environment and tidal influence in rivers/ streams.

In the coastal tract of Karnataka, the fresh-saline groundwater interface is observed very close to the coast line with in a kilometer and primarily due to tidal waves. The interface is at a distance of about a kilometer in sandy areas and about 500 m from the tidal tract of estuaries (Environment Report, 2003). Since the coastal districts of Karnataka receive an annual rainfall more than 3000 mm, salinity is not noticed during monsoon period due to dilution by heavy rains (Planning Commission Report, 1981). The interface is observed in the months from October onwards.

3.3.5 Causes and Extent of Coastal Land Salinity

Total annual rainfall in the coastal areas varies from 3000 to 5000 mm, resulting in heavy floods during monsoon. Flood waters in the rivers of the coastal area discharge in the Arabian Sea. Though there is abundant flow during monsoon, there is shortage of water for drinking and other purposes during summer. In summer season, when there is lean flow in these rivers, sea water enters the river course (upto 5 to 15 km upstream) during high tide and mixes with freshwater enhancing the salinity and making it unfit for agricultural and drinking purposes (Fig. 3.3.5). Further this saline water encroaches upon the habitated lands and adjoining agricultural lands rendering these unfit for agriculture. If water is drawn from open or bore wells adjoining the river channels, the saline water movement is induced into the subsurface that affects groundwater quality. Groundwater extracted from such open and bore wells can not be used for meeting the drinking water needs, resulting in acute shortage of drinking water supply. Vegetation in the area is also gets affected/ degraded due to soil and water salinity. The soil becomes more and more saline (‘Kharland’) from October onwards. Coastal land inundation is at its peak in January and February due to high tidal waves (refer Table 3.3.1). As a result, rabi crops are raised only in the upper reaches of coastal trcts which do not get submerged but possess sufficient residual moisture content for crop growth. With the onset of the monsoon, the salts get diluted and are washed back into the sea.

The figure 3.3.6 shows the coastal rivers flowing through the State of Karnataka.

Table 3.3.1 Salt water affected areas in Dakshina Kannada and Udupi districts

Sl.No.	Zone/river basin	Affected coastal zone	Remarks
1	Nethravathi River Basin	Up to 10 km from sea	Dakshina Kannada
2	Gurupura River Basin	Up to 10 km from sea	Dakshina Kannada
3	Nandini River Basin	Up to 4 km from sea	Dakshina Kannada
4	Shambavi River Basin	Up to 5 km from sea	Dakshina Kannada
5	Sankadagundi hole River Basin	Up to 4 km from sea	Udupi
6	Yedamavina hole River Basin	Up to 5 km from sea	Udupi
7	Byndoor hole River Basin	Up to 6 km from sea	Udupi
8	Varahi River Basin	Up to 8 km from sea	Udupi
9	Chakra River Basin	Up to 6 km from sea	Udupi
10	Kolluru River Basin	Up to 5 km from sea	Udupi
11	Seetha River Basin	Up to 8 km from sea	Udupi
12	Swarna River Basin	Up to 7 km from sea	Udupi
13	Udyavara River Basin	Up to 9 km from sea	Udupi
14	Madisalu River Basin	Up to 5 km from sea	Udupi
15	Shambavi River Basin	Up to 6 km from sea	Udupi
16	Pangala River Basin	Up to 4 km from sea	Udupi

The figures 3.3.7, 3.3.8 and 3.3.9 show the extent of saline land affected in the districts of Uttar Kannada, Dashikna Kannada Udupi respectively.

3.3.6 Remedial Measures

Besides construction of salinity ingress prevention structures, the 'Kharland Schemes' have been implemented in Karnataka to effectively prevent salinity problems in the coastal tracts of the state.

- *Construction of Salt Water Exclusion Dams (SWED*): SWED are vented dams constructed across rivers/ streams at the confluence of the sea up to high tide level. Such structures are kept open during rainy season to mitigate floods in the river and later closed to prevent the ingress of sea water in to the rivers. General practices followed in designing the SWEDs are provided in Annexure 3.3A.
- *Kharland Schemes*: These are schemes wherein Earthen Bunds with stone revetment to the slopes and sluices with wooden needles (wooden plank shutters filled with puddle earth in between the planks) are constructed along the banks of the river/ and streams which will be kept open during rainy season and floods and are closed thereafter to prevent ingress of sea water in the cultivable lands.

A subcommittee has been constituted exclusively for SWED works by Govt. of Karnataka. This committee has been constituted to study the functioning and effectiveness of the existing structures, suggest remedies to overcome defects, if any, as well as measures to maintain the

existing structures in proper condition and suggest improvements in design of new Salt Water Exclusive Dam works.
The list of existing SWED in the Dakshina Kannada and Udupi, the Karland Schemes in Uttara Knnadaarea provided in Annexure 3.3B. The typical SWED shemes are shown in Figs. 3.3.10-3.3.13.
The expenditure incurred in development of SWED schemes is provided in Table 3.2.2.

Table 3.3.2 Expenditure incurred for development of SWED

S. No	District	Salt Water Exclusion Dams	
		No. of works	Expenditure incurred (Rs. lakh)
1	Dakshina Kannada	18	958.05 (cost of 11 schemes; rest are old schemes and cost not available)
2	Udupi	44	2960.08 (cost of 35 schemes; rest are old schemes and cost not available)
3	Uttara Kannada	81	1582.32(cost of 49 schemes; rest are old schemes and cost not available)
	Total	143	5500.45 (cost of a total of 95 schemes only)

Benefits of remedial measures

Table 3.3.3 provides the area benefitted under SWED schemes, in terms of the increase in irrigation potential.

Table 3.3.3 Area benefitted under SWED schemes

S. No	District	Salt Water Exclusion Dams	
		No. of works	Irrigation potential (ha)
1	Dakshina Kannada	18	1627.53
2	Udupi	44	4609.9
3	Uttara Kannada	81	9599.02
	Total	143	15836.45

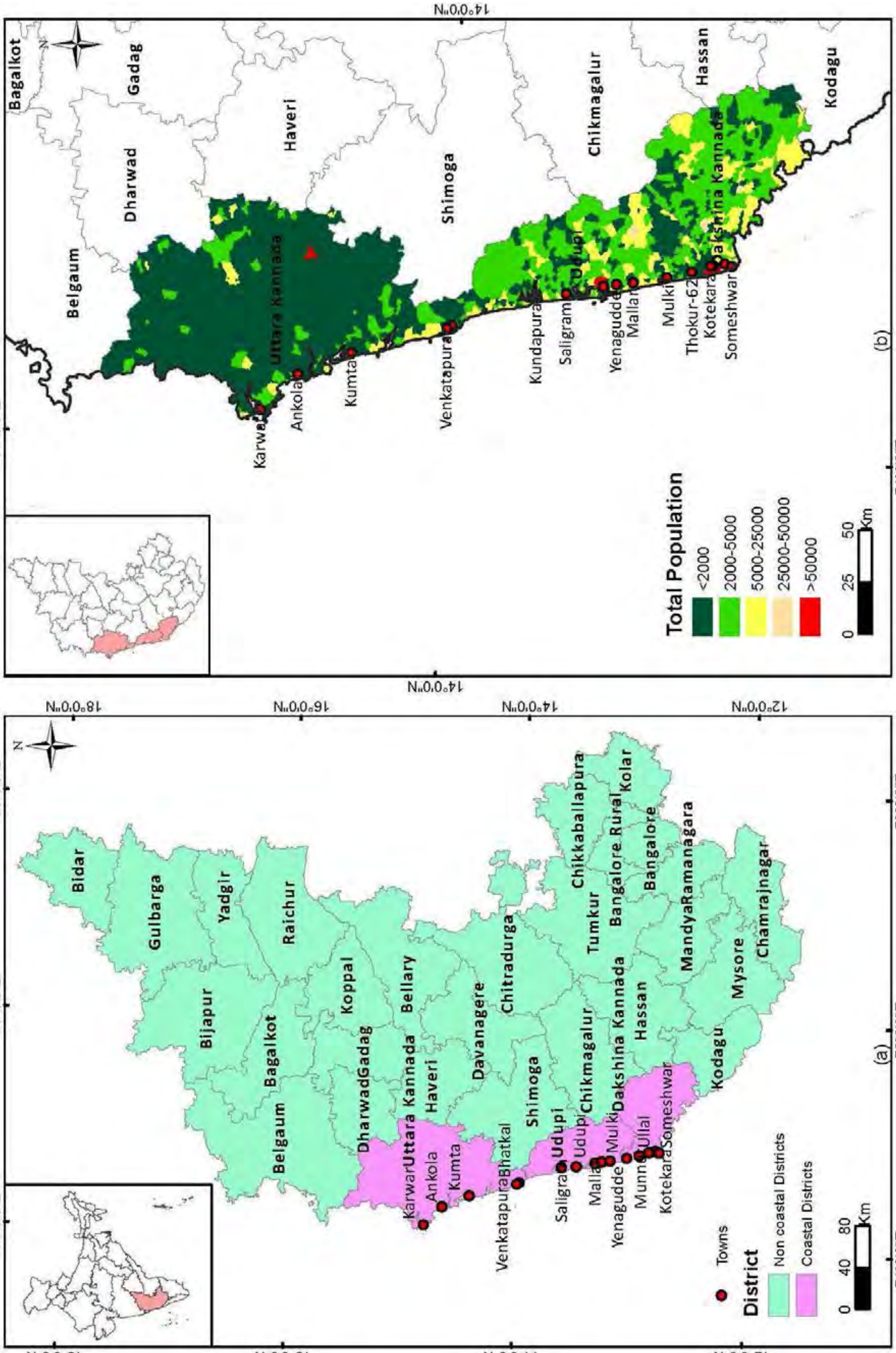


Fig. 3.3.1(a) Administrative map of Karnataka showing coastal districts (b) Population distribution of coastal districts of Karnataka

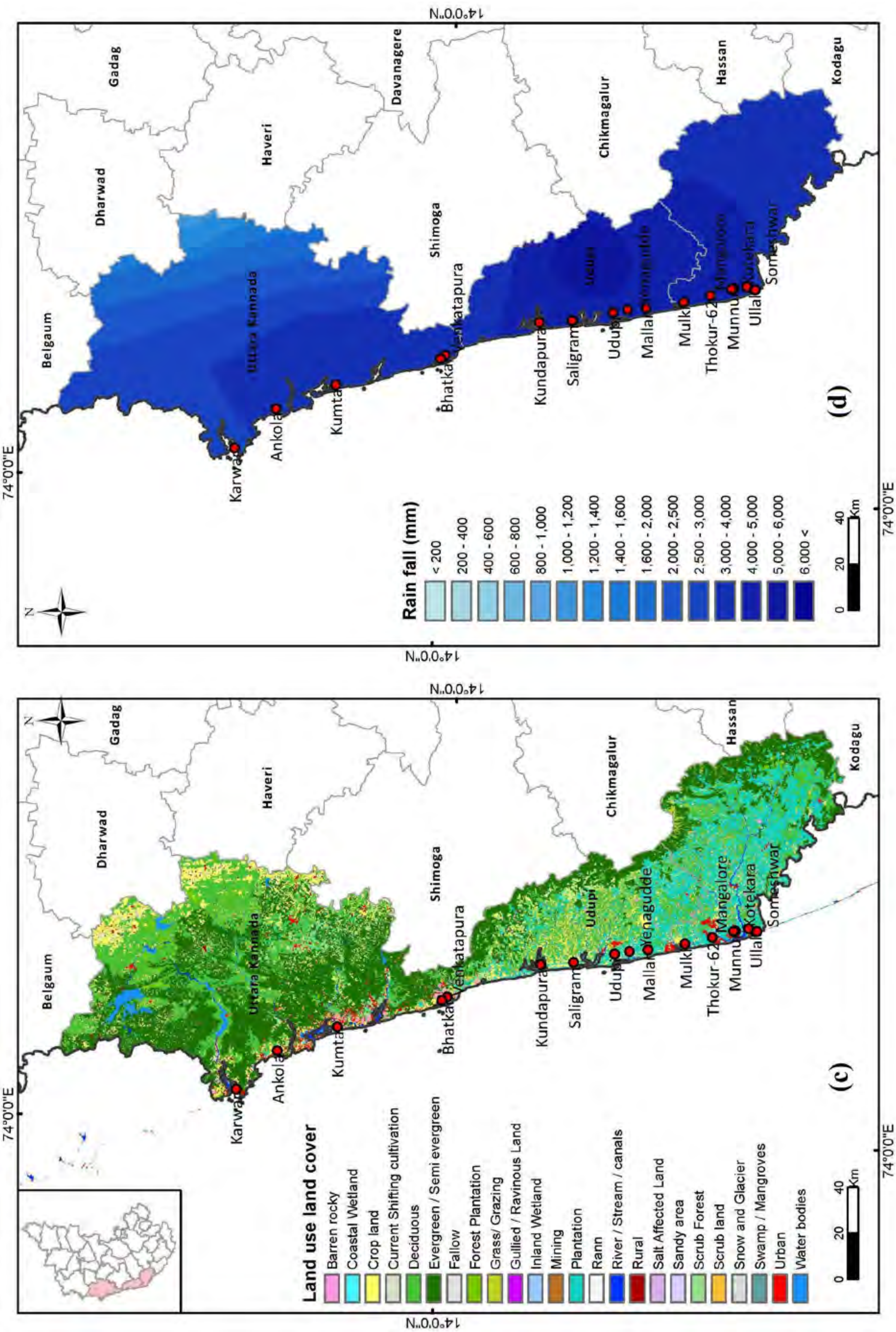


Fig. 3.3.1 (c) Land use and land cover of coastal districts of Karnataka (d) Rainfall distribution of coastal districts of Karnataka

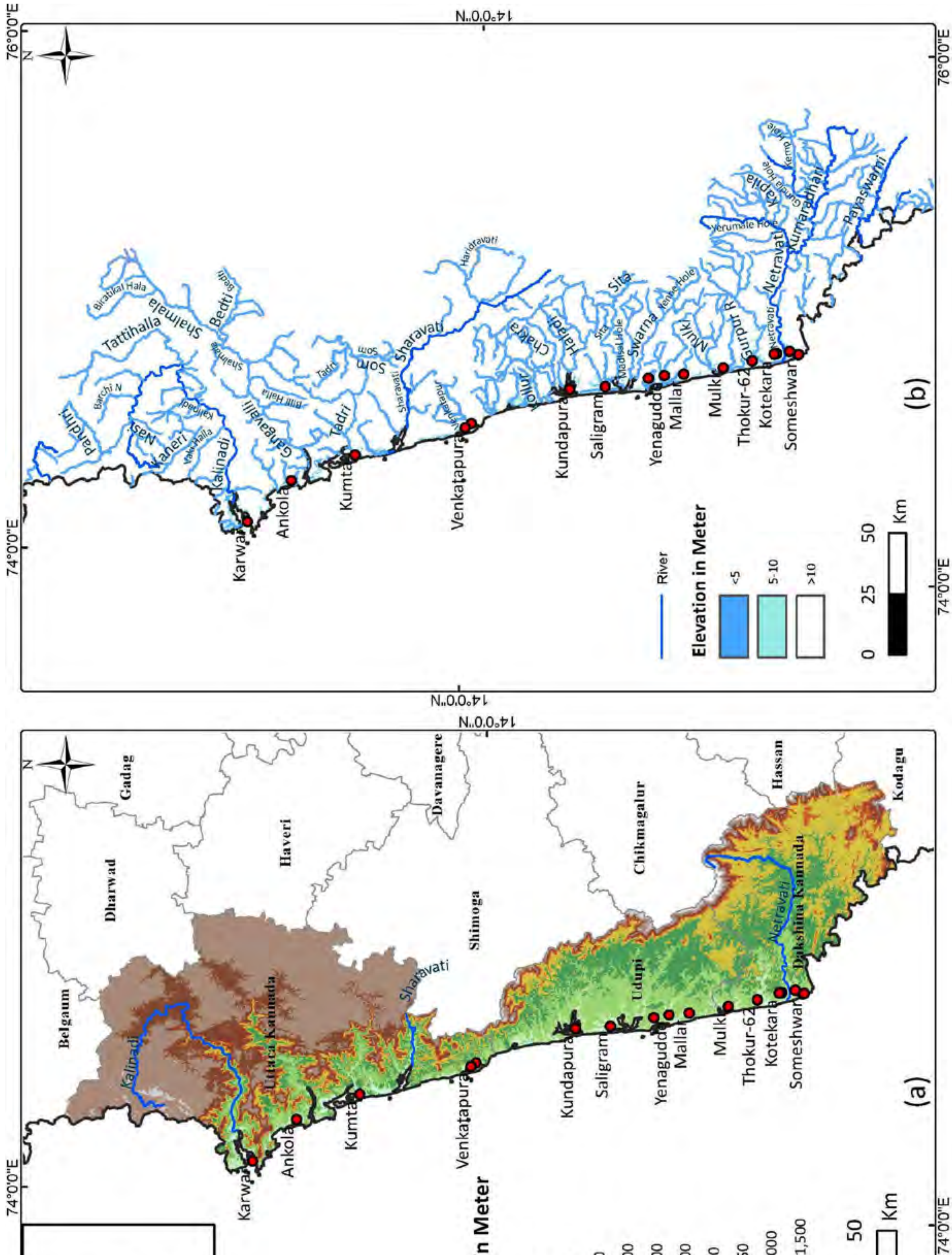


Fig. 3.3.2 (a) Physiographic map of Karnataka (b) Drainage map of Karnataka showing low elevation coastal areas (< 10 m amsl)

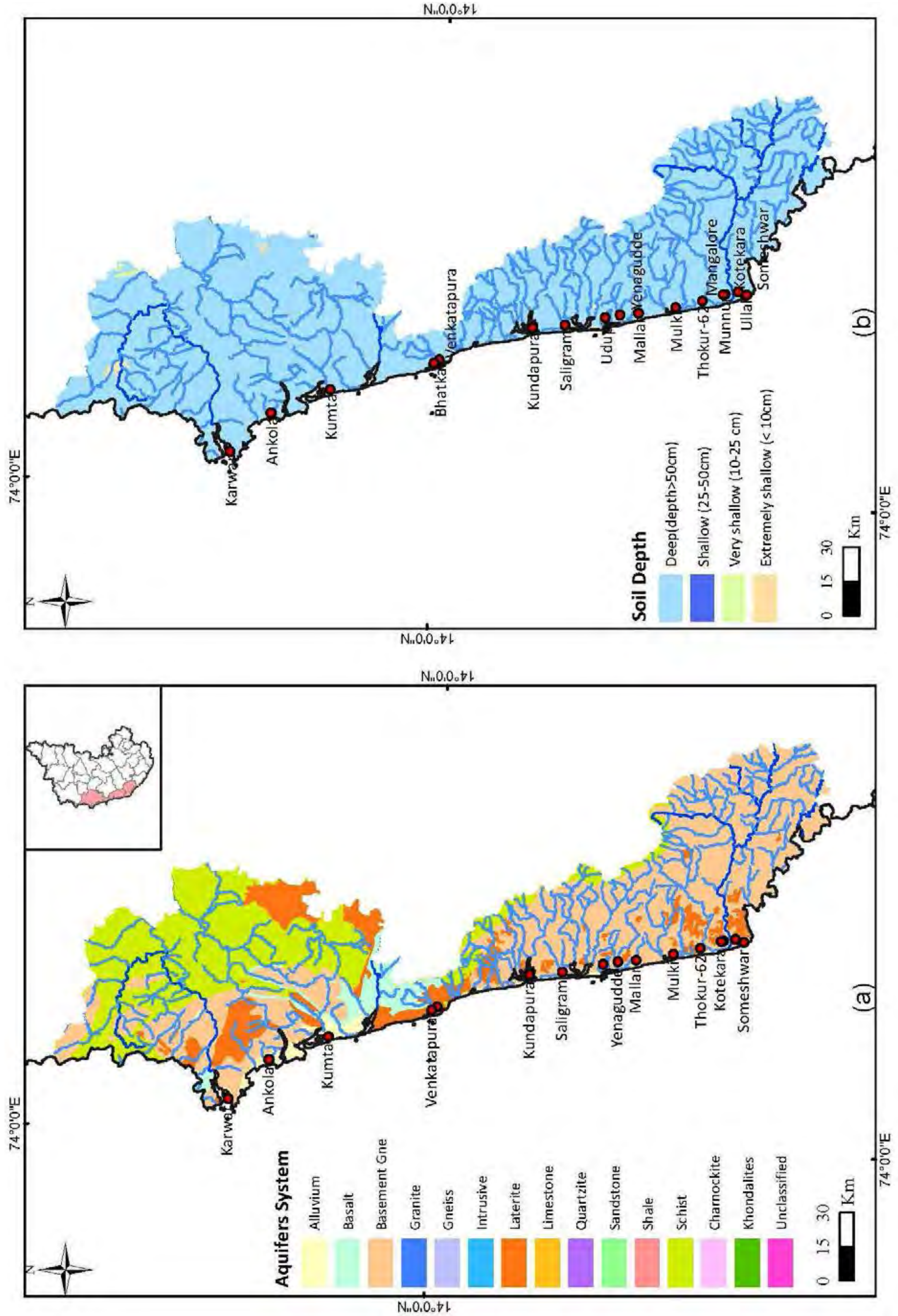


Fig. 3.3.3 (a) Aquifer map of coastal districts of Karnataka (b) Soil depth map of coastal districts of Karnataka

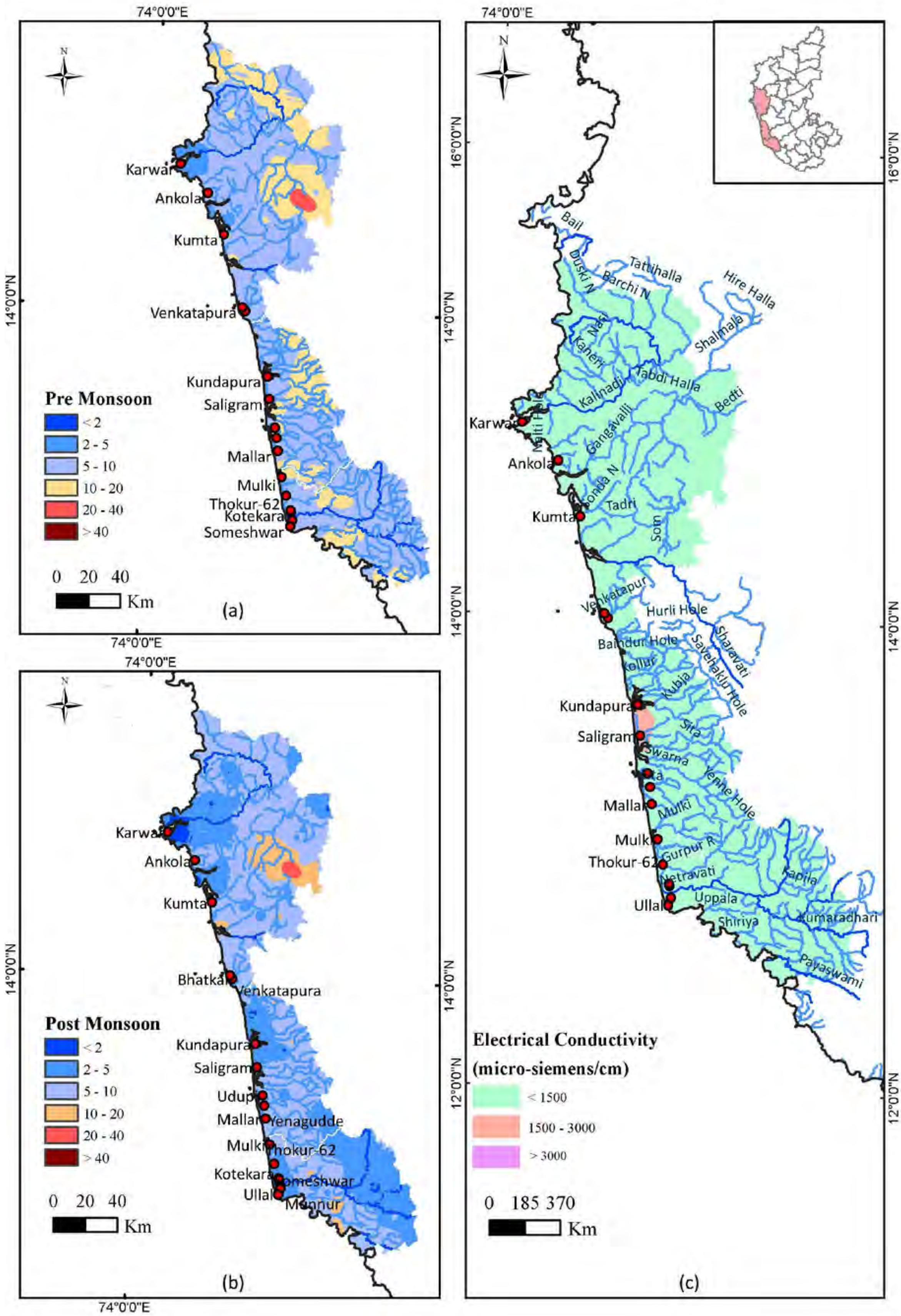


Fig. 3.3.4 (a) Pre-monsoon water level of coastal districts of Karnataka (in meters) (b) Post-monsoon water level of coastal districts of Karnataka (in meters) (c) EC map of shallow groundwater for coastal districts of Karnataka.

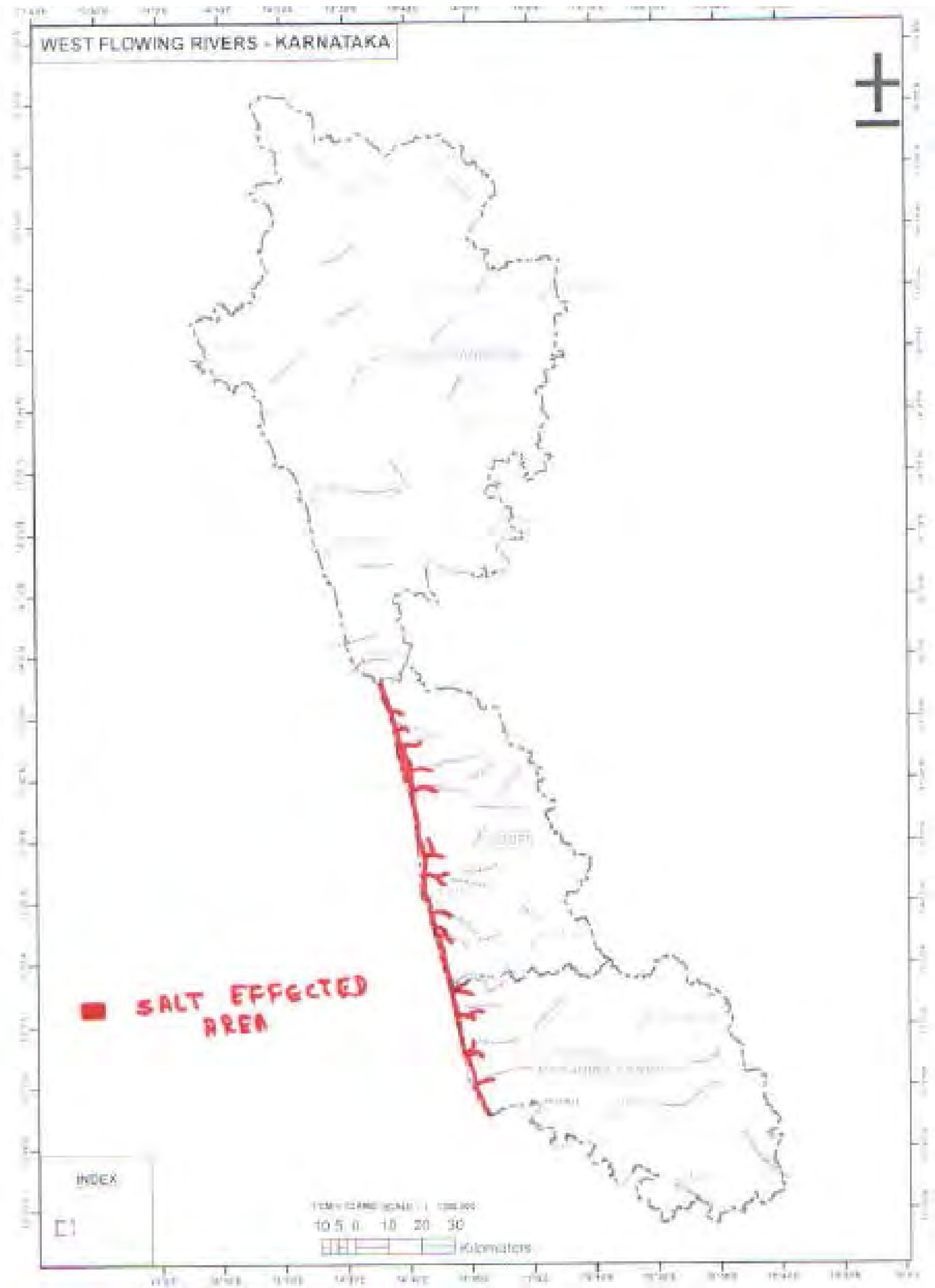


Fig. 3.3.5 Salt affected area in coastal districts of Karnataka.

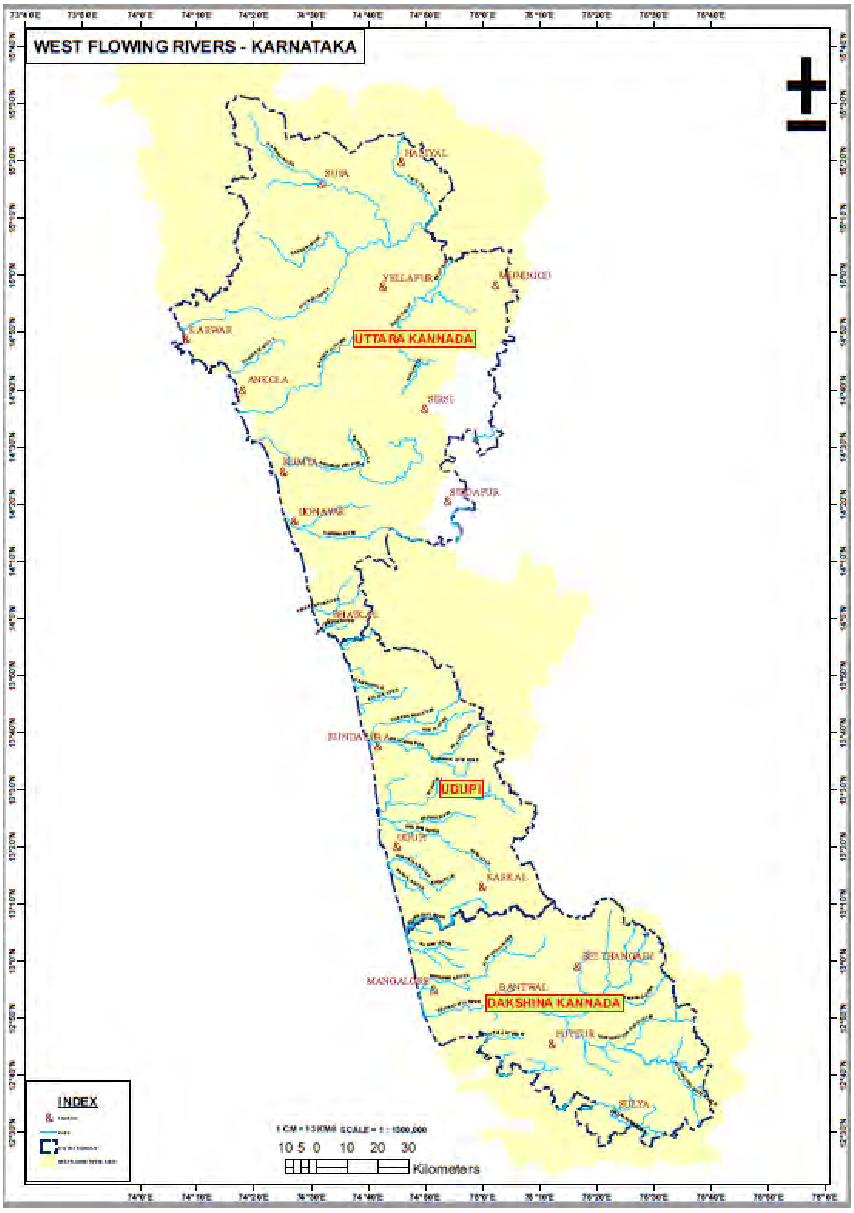


Fig. 3.3.6 West Flowing Rivers in the State of Karnataka

Fig. 3.3.7 Salt affected area in coastal district of Uttar Kannada

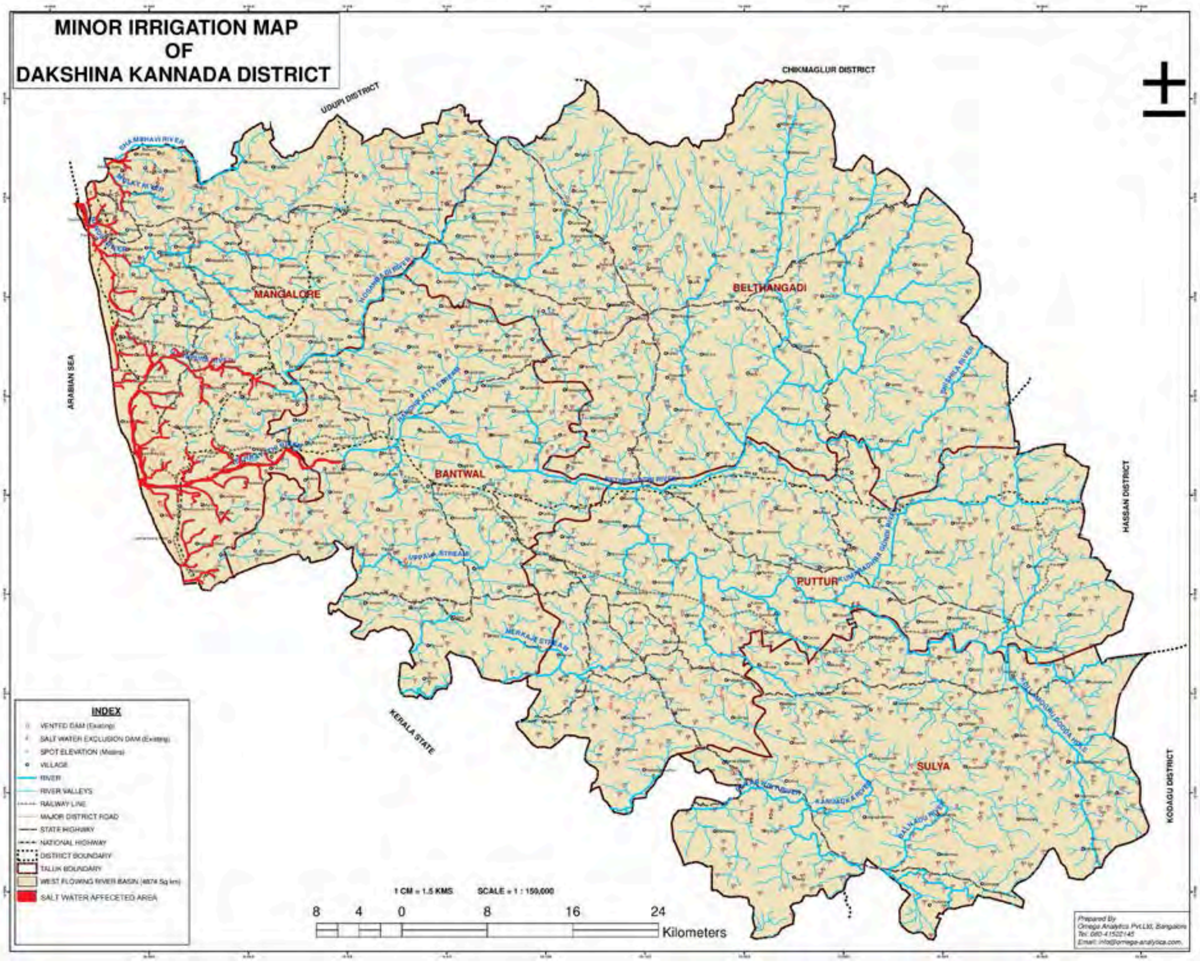


Fig. 3.3.8 Salt affected area in coastal district of Dakshina Kannada

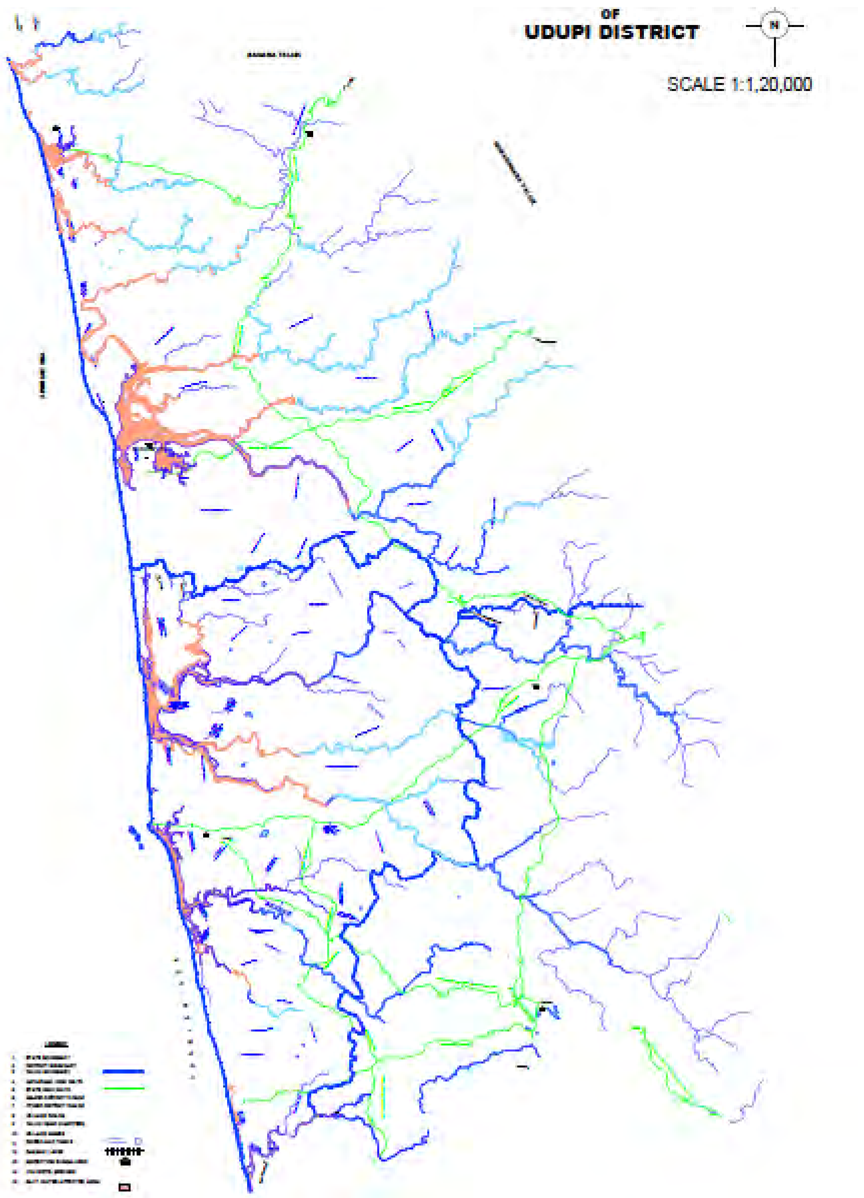


Fig. 3.3.9 Salt affected area in coastal district of Udupi

Fig. 3.3.10 SWED at Uggelbettu in Udupi Taluk, Karnataka

Fig. 3.3.11 SWED at Koderi in KundapurTaluk, Karnataka

Fig. 3.3.12 SWED at Hejamadi-Kokarani, Udupi TQ, Karnataka

Fig. 3.3.13 SWED at Kemthur, Udupi TQ, Karnataka

3.4 KERALA

3.4.1 General

The state of Kerala, located on the South-western tip of India, has a coastline about 569.70 km long with nine districts bordering the Arabian Sea, namely, Kasaragod, Kannur, Kozikhode, Mallappuram, Ernakulam, Kollam, Thrissur, Alappuzha, and Thiruvananthapuram, that account for 65% of the geographical area of the state and about of 84% of its groundwater resource. Figure 3.4.1 shows the locations of the coastal districts; sparsely/ medium populated areas in villages and highly populated urban areas in towns and cities, variation in average annual rainfall (1971-2005) across the coastal districts areas and land use / land cover conditions. The population map shows that compared to other coastal states, most parts of the coastal districts in Kerala are highly populated. Rainfall is heavier in the northern districts and large part of the land is under plantation land use, besides crop cultivation and forest cover.

3.4.2 Physiography and Drainage

The coastal plain of Kerala is drained by a large number of rivers (totaling 41) flowing westwards with their tributaries originating from Western Ghats. Most of these rivers drain into lakes before reaching the sea. The main rivers which commence from the Western Ghats are Chandragiri, Kuppam, Beypore, Bharatapuzha, Periyar, Meenachil, Pampa and Manimala etc. Out of these, Bharatapuzha is the longest river. The rivers viz., Periyar, Achankovil, Manimala, Muvattupuzha, Kallada, Ittikara run for small distances and flow into the Vembanad or Ashtamudi lakes. Figure 3.4.2 show the physiography and drainage of the coastal districts.

Though richly endowed with surface water sources such as rivers, tanks and ponds and having an average annual rainfall exceeding 3000 mm, the topographic and geomorphic settings of the state allow utilization of only a small portion of the available resources. Nearly 88 percent of the total geographical area of the state is underlain by crystalline rocks devoid of any primary porosity, which limits the groundwater prospects of the state.

In alluvial formations with multiple aquifer systems in part of the coastal tract, quality is often a constraint in the optimal development of available resources. Increasing population, rapid urbanization, industrial development and human interventions in the ecosystem have resulted in increasing pressure on the limited groundwater resources over the last few decades in the state.

3.4.3 Hydrogeology

In coastal plains of Kerala, the recent alluvial deposits form the most potential phreatic aquifer in the state. It is being tapped by dug wells and filter point wells extensively. The density of open wells in the coastal tract is 200 per km^2 (Kerala SCSTE, 2008). In general, the dug wells are sunk down to a depth of 10 m. The maximum thickness of alluvium is about 100 m around Kattoor in Alappuzha district. At places where the thickness is large, it is tapped by shallow tube wells. The depth to water level ranges from less than a metre to about 6 m. Filter point wells are feasible wherever the saturated sand thickness exceeds 5 m within a depth of 12 m bgl. The yield of the shallow dug wells ranges from 15 to 50 m^3/day, while that of filter point wells ranges from 20 to 60 m^3/day. Large diameter wells are present along valleys and topographic lows with yields ranging from 0.5 to 6 m^3/day. The laterites occurring at higher elevations and on slopes get completely desaturated in summer. In the Tertiary sediments, groundwater occurs under unconfined to confined conditions. Out of the Tertiary formations, viz., Warkali, Quilon, Vaikom and Alleppey, the Warkali and Vaikom hold the most potential aquifers. Aquifers in Warkali bed are mainly composed of medium to fine grained sands that range in thickness from 5 to 40 m and yield of the wells ranges from 260 to 1210 m^3/day. The piezometric head ranges from 2.8 m amsl in Kandiyoor area to 10 m bmsl in Alleppey town. The water supply system between Quilon and Ernakulam mostly depends on this aquifer. Tube wells of 150 m depth tapping this aquifer for the water supply of Alleppey town and nearby villages are pumped for 8 to 24 hrs a day. Due to heavy draft and large concentration of wells, the water level has gone down beyond 10 m below msl in the area. Limestone beds in Quilon formation form local aquifers of low yield. Vaikom Bed constitutes a prolific aquifer system amongst the Tertiaries with the thickness of the granular zone ranging from 6 to 65 m. Brackish formation water is present in the Alleppey bed as indicated by electrical logging. The geology of the coastal districts and soil depth is shown in Figs. 3.4.3a-b.

In the coastal plain of Kerala, auto flow conditions were observed during the years 1986-88 in some of the wells tapping Vaikom aquifer. The areas with auto flowing condition extend from Quilon to Cochin and near Trichur along the coast. Eastward it is traced up to Kottayam. The piezometric head varies from 1.63 to 4.4 m above ground level. A sag in the piezometric surface is observed around Kuttanad area and in north where it is 1 m above msl. Around Quilon, the piezometric surface is 5.0 m below msl. This may be due to extensive pumping in the area. Aquifers in Warkali bed show piezometric head ranging from 2.8 m above msl in Kandiyoor area to 10 m below msl in Alleppey town. The depth to groundwater level during pre- and post-monsoon is shown in Fig. 3.4.4a.

3.4.4 Groundwater Salinity

Shallow aquifers: In Kerala coastal plain, the EC of shallow groundwater is in the range between 10 to 700 µS/cm, except in certain pockets close to back water channels which are under the influence of tides. Some of these areas are Chellanum in Ernakulam district and Azhikode in Trichur district. However, the values rarely exceed 3000 m µS/cm (Fig. 3.4.4b).

Deeper aquifers: The water from the Tertiary aquifers are characterized by higher concentrations of Bicarbonate, Fluoride and Iron compared to the water from the phreatic zones and also compared to that of the deeper aquifers in the hard rock areas. This is due to the combination of biological and geochemical processes that continued during the long residence time of water in

Tertiary aquifers. Isotope analyses indicate that these aquifers are not getting rapid recharge from the overlying surface water bodies. The surface waters are separated by a thick clay layer from the Tertiary aquifers. Thus, the water in Tertiary aquifers is not affected by the quality of surface water or that in the phreatic zone. The chemical composition of water from Tertiary aquifers is stable. The studies conducted in the SIDA assisted Coastal Kerala Ground Water Project (1983-88) indicated no conspicuous variation in chemical quality of water in the deep aquifers with time and pumping. These studies show that the quality of water from deeper aquifers has not changed over a period of 30 years indicating no salt water fresh water mixing. The brackishness in part of the Tertiary aquifer is not due to mixing of sea water with fresh ground water but is due to the diffusion of salinity from the intercalated clay layers (Fig. 3.4.5).

3.4.5 Causes and Extent of Coastal Land Salinity

All the coastal districts experience salinity issues arising from salinity in rivers (and lakes) that discharge directly to the sea through estuaries/backwaters particularly during summer months. Salinity is experienced in reaches up to 30 km from the river mouth and affects the agricultural, industrial and drinking water supply of these regions. The extent of salinity varies depending on the tidal action from place to place and the intensity of rain. During summer months when fresh water flow is less, salinity intrusion is considerable. Also, construction of break waters for fishing harbours/ fish landing centres causes entry of saline water freely into rivers and lakes and through river mouths during summer season. Increase in salinity may result in closure of several factories, industries, refineries etc. especially in Ernakulam district where the industrial belt including Kochi refinery, FACT etc. depends largely on the water from river Periyar.

Since the water recharging the groundwater is also affected by salinity, intrusion of saline water contaminates shallow groundwater and drinking water supplies. This is mainly experienced in the Kuttanad region in Alapuzha district where the groundwater level is lower than the mean sea level. Cultivation of different crops like paddy, coconut and arecanut is affected due to intrusion of tidal water in mainland region. Usually, temporary bunds/ marginal bunds are constructed along the river mouth to prevent entry of saline water into the agricultural land. Uncontrolled sand mining and dredging has also resulted in increase in salinity thereby making the water unreliable for any purpose.

The district wise area affected by salinity is given the table 3.4.1

Table 3.4.1 District wise area affected by Salinity

Sl. No.	District	Affected area in sq. km	Project Cost Expected (Rs. In crores)
1	Kasaragod	30.50	68.00
2	Kannur	23.30	36.15
3	Kozhikode	40.00	35.00
4	Malappuram	45.70	29.75
5	Thrissur	110.00	87.00

6	Ernakulam	687.51	30.00
7	Kottayam	80.62	23.50
8	Alappuzha	446.00	10.00
9	Kollam	29.00	24.80
	TOTAL	**1492.63**	**344.2**

The 'State of Environment Report 2005' prepared by a committee constituted by Kerala State Council for Science, Technology and Environment (KSCSTE) raises apprehension on the impact of climate change on water resources due to sea level rise. The suggestions to mitigate the problem include measures such as tidal regulators/ bunds, check dams and increased river flow. Various remedial measures and details of salinity affected areas are listed in Tables 3.4.2-3.4.3.

3.4.6 Remedial Measures

A large number of schemes to ameliorate the problem of salinity incursion through surface water bodies have been implemented in Kerala. Table 3.4.2 summarizes the different structural works carried out related to salinity intrusion prevention schemes, while Table 3.4.3 lists the salt affected areas in different coastal districts and the various schemes implemented in these regions. The expenditure incurred in construction works totals to Rs. 294.58 crores.

Table 3.4.2 Remedial measures adopted in Kerala

Sl. No.	Particulars	Works
1	Salinity intrusion barriers	1
2	Permanent VCB (Vented Cross Bar)	1
3	Regulators	2
4	Regulator cum bridge (RCB)	4
5	Bunds	Large Number
6	Lock cum regulator	3
7	Tidal bunds	Large number
8	Salt water exclusion works (SWE)/ Salt water exclusion vented cross bar (SWEVCB)	76
9	Anicut	4
	Total	91 + large number of bunds

Annexure 3.4A gives the details of the schemes carried out in the state of Kerala.

Table 3.4.3 Existing schemes in Kerala for prevention of salinity intrusion

District	Salinity Affected Areas	Existing Schemes
Thiruvananthapuram District:	Salinity affects crops, industrial production, drinking water supply etc. The extent varies depending on the tidal action from place to place and the intensity of the rain. Tidal action causes entry of saline water freely into rivers and lakes even in summer season through the river mouths. Low-lying areas are affected by salinity.	A salinity intrusion barrier has been constructed in Vamanapuram river at Parakadavu
Kollam Distrct	Low-lying areas of Kollam are affected by salinity	Existing structure to prevent salinity ingression: i) Paravur-Pozhikkara regulator. ii) check dam and salinity-cum-bridge to prevent salt water intrusion in Paravur kayal to Vatta kayal in Ward No.8 in Thrikkovilvattom Panchayath iii) tidal bund at Vettiyathodu, Valanjavarambu, Mookanikkara at Kizhakethubhagam in west-Kallada panchayath.
Alappuzha District	Low-lying areas of Alapuzha are affected by salinity.	Existing structures to prevent salinity intrusion • Thaneermukkom bund and Thottapally regulator. • Temporary bunds to prevent salinity during summer season in Alapuzha district.
Ernakulam District	Salinity affected places along banks of Periyar river include: Pathalam, Manjummal and Purrappallikkavu. Other salinity affects: Drinking water distribution, agricultural land, Industrial water supply to Kochi refinery, FACT, TCC , Binani Zinc, BSES, IRE and water supply to parks including Wonderland, Infopark are affected by saline intrusion. An increase in salinity may result in shutdown of factories in Eloor Edayar industrial belt, Cochin Refineries etc. and affect agricultural activity in and around Aluva.	Existing schemes: Temporary tidal bunds across Periyar river in Panchayaths municipality including 261 m long earthen bund at Purrapallikkavu across Periyar river.
Thrissur District	Salinity affected Municipalities and Panchayaths: Kudyathur, Eriyad, Edavilayu, S.N.Puram, Mathilakam,	Existing schemes: • Temporary bunds at Munayam, Puthenthodu, Idiyanchira, and Orumanayur. Temporary

	Perinjanam, Nattika, Edthiruthy, Kaipamangalam, Kattoor, Valappad, Thlikulam, Vadanapppilly, Eyrdiyur, Padiyur, Vadkkekad, Punnayur, Punnapurkulam, Charvakkad, Venkitayur, Manalui, Parventy Panchathat, and Guruvayur. Salinity affects the areas near banks of Karuvannur river at Munayam, Enamakkal, Puthenthodu, Idiyanchira, and Orumanayur. Salt water ingress and soil salinity may damage 1300 ha of cultivable Kole lands.	bunds removed during monsoon season to avoid flooding in rivers • Permanent regulators at Koothamakkal and Orumanayur have controlled salt water intrusion to a certain extent in Karuvannur river.
Malappuram District	Coastal area for a length of 50.367 km is affected by soil salinity and saline water intrusion. Salinity affects Bharathapuzha river basin in Malappuram District. Alangod, Veliyamkode, Perumbadapp, Nannamukku, Marancherry, Ponnani Municipality, Tirur Municipality, Purthur, Magalam, Vettam, Niramaruthur, Tanur, Parappanangadi, Vallikkunnu, Munniyur in Thirurangadi Taluk, Eranad taluk, Vazhkkad, Cheekode, Vazhayur Panchayat are affected by salinity. Bharahapuzha river banks get affected by salinity at Chamravattom area (Ponnani)	Existing scheme: • Regulator cum bridge constructed in Bharathapuzha at Chamravattom, RCB across Tirur-Ponnanipuzha and across Biyyar lake to control salt water intrusion. • Nearly 70 structures constructed in Kadlundipuzha. • Reconstruction of Mannumpuram SWEVCB in Mannumpuram thodu in Poorapuzha at Parappanangadi Panchayat.
Kasargod District	Salinity affected areas: Hosabettu-Bangara Manjeshwar in Manjeshwar Panchayat, Uppala in Meenja Panchayat, Manihithu in Mangalapady Panchayat/Shiriya-Olayam in Mangalpady Panchayat. Bambrana in Kumbla Panchayat. Kimmikkathu in Kumble Panchayat. Kanchikkatta in Kumble Panchayat. Mogal river, Chandragiri river, Chitnari river, Adothi thodu. Backwater of Bekal river, Valapothu	Existing schemes to reduce salinity: Uppala Anicut, Bambrana Anicut, SWE dam at Kottakunje in Mogral Puthu Panchayat, RCB at chithari in Ajanur Panchayath, VCB Adottu in Ajanur Panchayath, SWE VCB at Malankunnu in Udumba Panchayat, SWE VCB Valapothu in Chemnad Panchayath, Nambiarkkal Anicut in Nileshwar river, Rananchira SWECB in Kariyamkode river, Purathekkai VCB, SWECB Anicut at Thalachal in Trikaripur Panchayat, Edachakkai Anicut at Azhikkal in Pande Panchayath.

	thodu, coastal area in Nileshwar Municipality. Directly affected by salinity: 22 km of coastal area in Valiyaparambu Panchayath, 10 km backwater in Trikanipur Panchayat, 6 km of backwater areas in Padu Panchayat and about 5 km of backwater in Cheuvathur Panchayat Detailed study needed in: Kavani river, Edachakkai river, Maicha river and Karngakode river.	Ongoing works: regulator at Barikkara in Muliyar Panchayat and renovation of Nambiarkkal Anicut.
Kannur District	Salinity affected areas: coastal areas of Kannur District and downstream reaches of all rivers. Parts of Madayi Ezhome, Cheuthazham, Kunhimangalam, Ajarakudy, Edakkad, Elagnoor, Kadmboor, Muzhappilangadi, Peralassery, Puzhathy, Valapattanam, Narth, Pappinissery, Vengad, Chokli, Dharmadam, eranhli, Kariyad, kathirur, New Mahi and Pinanaji Panchayat and parts of Tahlassery Municipality are affected by salinity.	Existing schemes: Marginal bunds constructed along the river banks and salt water exclusion cross bars at the river mouth to prevent saline water entry in the fields. Salinity in these areas reduced to great extent after construction of above structures.
Kozhikode District	Salinity affected areas: coastal areas of Vatakara taluk, Koyilandy taluk and Kozhilide taluk; Kuttiady river, Mahe river; areas of Korappuzha, Alalpuzha, Parayilchirpm, some portions of Ramrpuzha and Kadlundi Puzha, up to Payyolichirpu in Thuryur Panchayat. In some areas up to 30 km length of rivers viz. Mahe & Kuttiyady are affected. Other areas affected: Kadalundim Feroke, Kakkodi, Thalakkulathur, Ulliyer, Atholim Peruvaya, Olavanna, Chelannur, Perumanna, Chemenchery, Chengottukavum Moodadim Thikkodim Payyoli, Chorode, Eramala, Onchiyam, Azhiyur, Koyilandy Municipality, Vatakara Municipality, Kozhikode Corporation (Beypore, Elathur,	Existing schemes: RCB at Karanakathu across Chaliyar river for arresting salt water intrusion and for storage of freshwater. Salinity reduced to great extent after the construction of these structures including bunds. Ongoing works: VCB at Kalchira in Chelannur Panchayat; SWE/VCB at Mundanthodu at Thottumukku in ward No.14 of Chekiyad Panchayt.

	Vellayil, Kothipalam)	

The figures 3.4.6 to 3.4.9 show the remedial measures adopted in the State of Kerala.

Benefits of remedial measures

By the construction of above regulator / Vented cross bars, large scale salinity incursion has been prevented. The benefits of such structures along the state are given below.

a. Since most of the people depend on water from lakes along the coastal stretches, construction of Lock-Cum-Regulator to prevent the entry of saline water has helped them to access to drinking water.
b. By construction of SWEVCBs and SWESs the saline water has been restricted from further intrusions thereby preventing salinity in ponds / tanks in the nearby area. Therefore, people could depend more on sources of water free from salinity.
c. Improvements to agriculture have considerable increased in place where the structures are constructed. In Thrissur District, it has been specifically reported that there is significant improvement in the yield generated from agriculture.
d. In case of Ernakulam District, prevention of salinity has helped to provide clean and uninterrupted drinking water to Greater Cochin area and Info Park. Also water free from salinity benefitted industries such as refineries. FACT situated at Ambalamugal.
e. Construction of temporary bunds in several parts of the coastal districts has helped the local residents to access more clean water for domestic purposes.
f. Construction of RCBs and putting temporary bunds have helped to prevent saline water entering Kole lands in Thrissur District and some parts of Malappuram District thereby protecting one of the largest wetlands in Kerala.
g. Construction of regulator and temporary bunds have helped to prevent large quantity of saline water entering to the different Padashekharams in Kuttanad region in Alapuzha district known as the "rice bowl of Kerala" thereby protecting large quantities of paddy cultivation.
h. Again, in Ernakulam district, by the construction of Bhooththankettu barrage, reduction of salinity was achieved through releasing of water. Therefore, most of the people residing downstream of river Periyar could access water for their daily livelihood.

The following are some major permanent structures constructed to prevent salinity ingress.

1. Thaneermukkom bund.
2. Thotappally spillway.
3. Madambam RCB
4. Manjummal RCB
5. Chamravattom RCB
6. RCB at Thrithala
7. RCB at Attappilly
8. Kariyar RCB

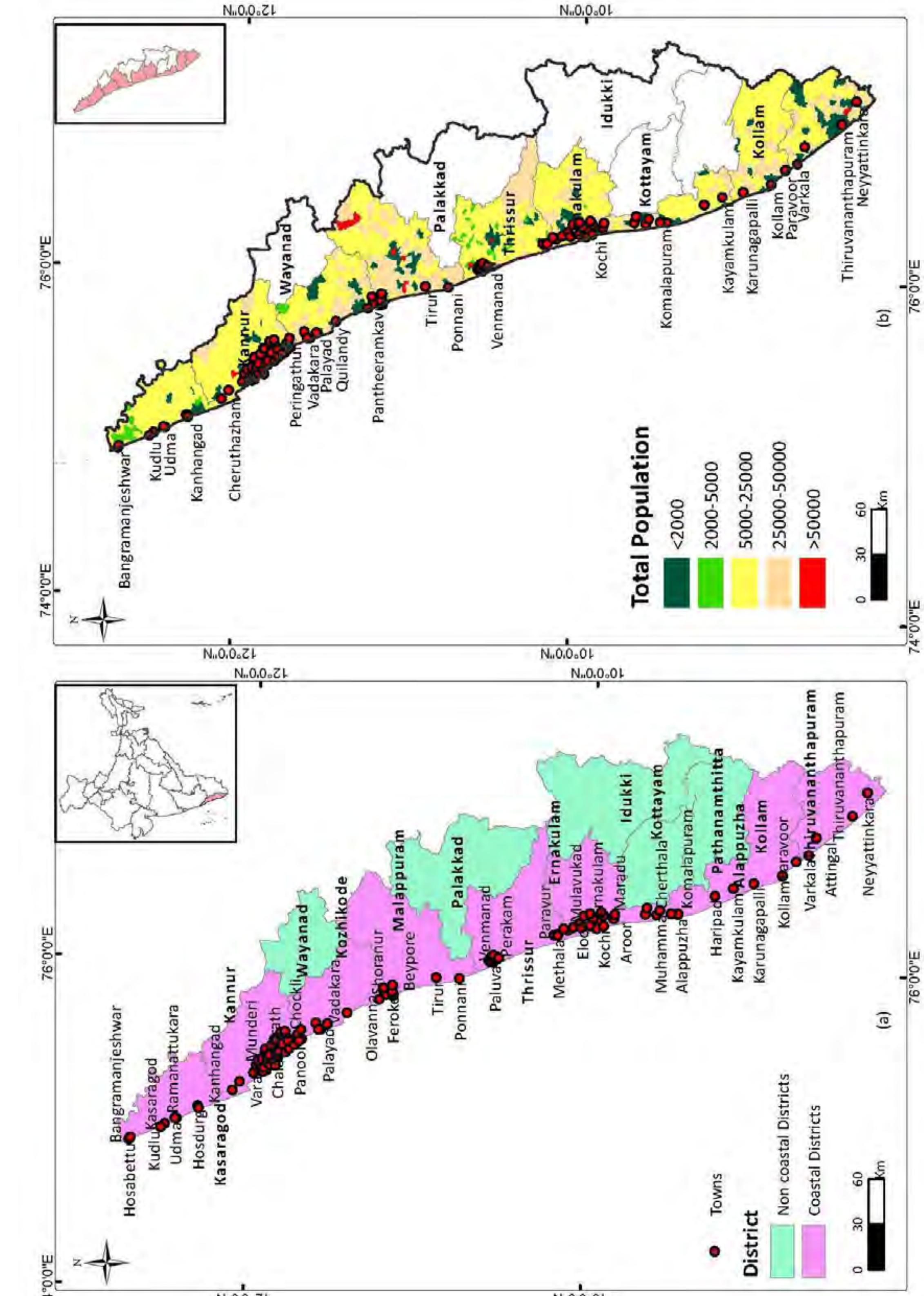


Fig. 3.4.1(a) Administrative map of Kerala showing coastal districts (b) Population distribution of coastal districts of Kerala

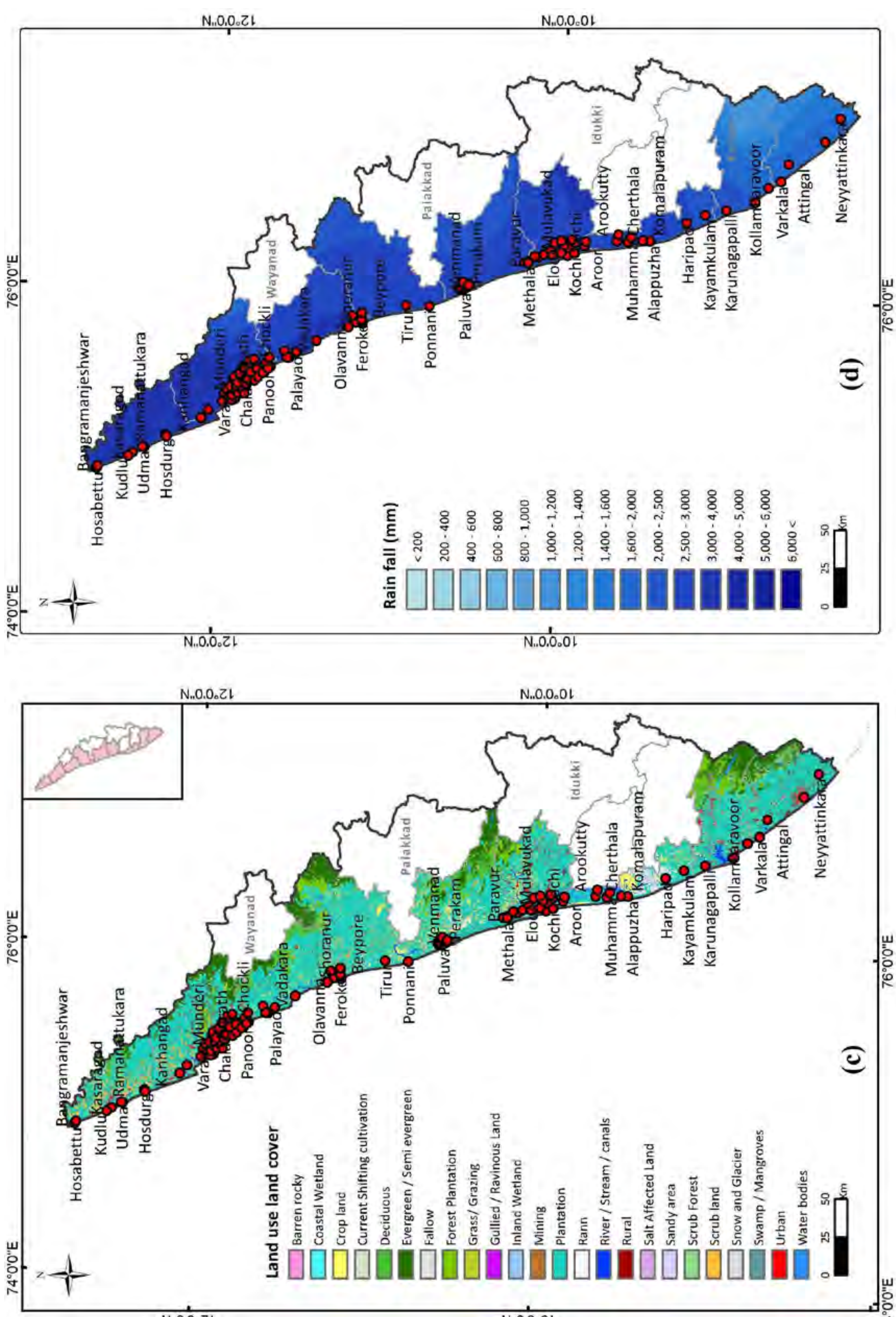


Fig. 3.4.1 (c) Land use and land cover of coastal districts of Kerala (d) Rainfall distribution of coastal districts of Kerala

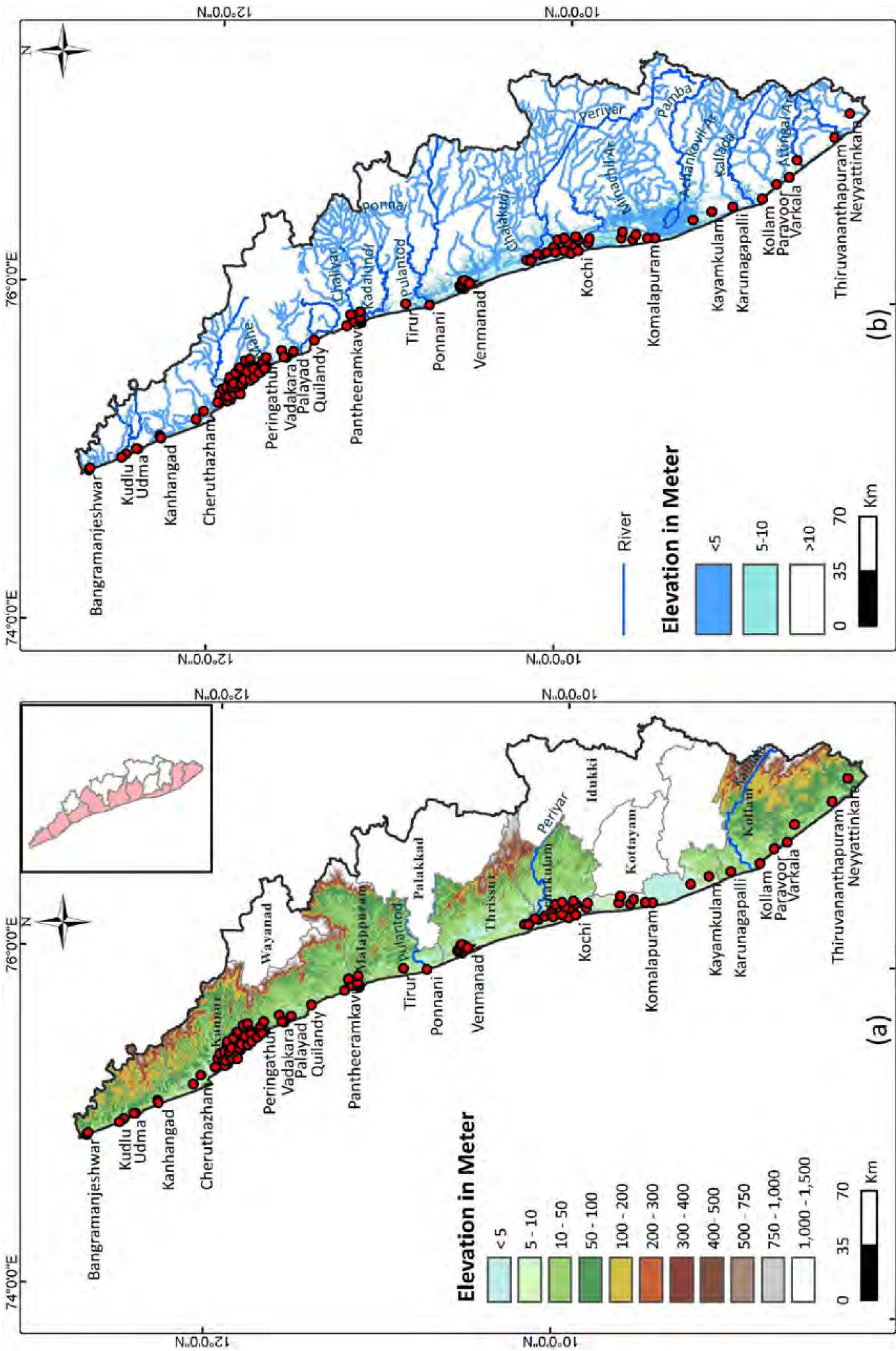


Fig. 3.4.2 (a) Physiographic map of Kerala (b) Drainage map of Kerala showing low elevation coastal areas (< 10 m amsl)

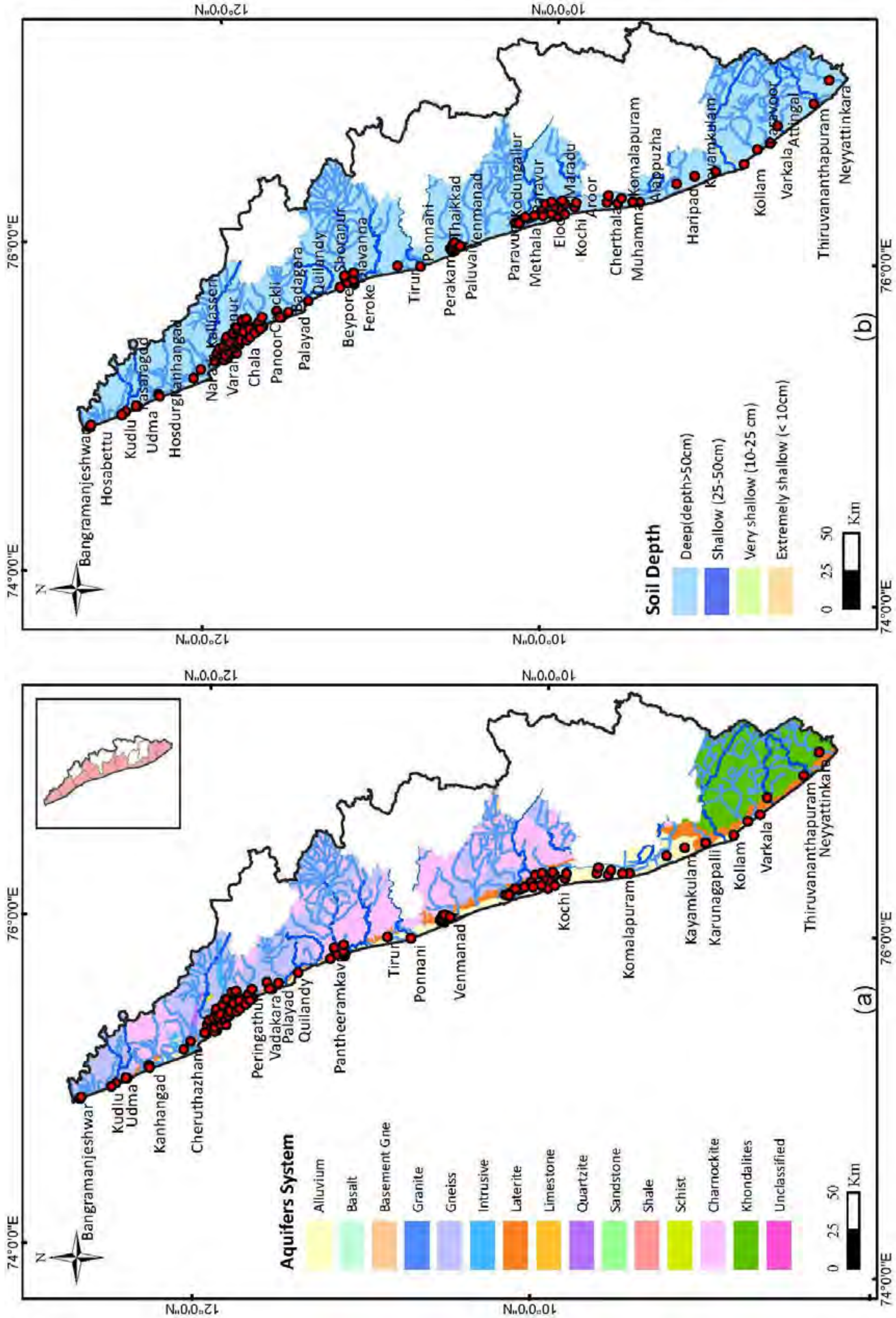


Fig. 3.4.3 (a) Aquifer map of coastal districts of Kerala (b) Soil depth map of coastal districts of Kerala

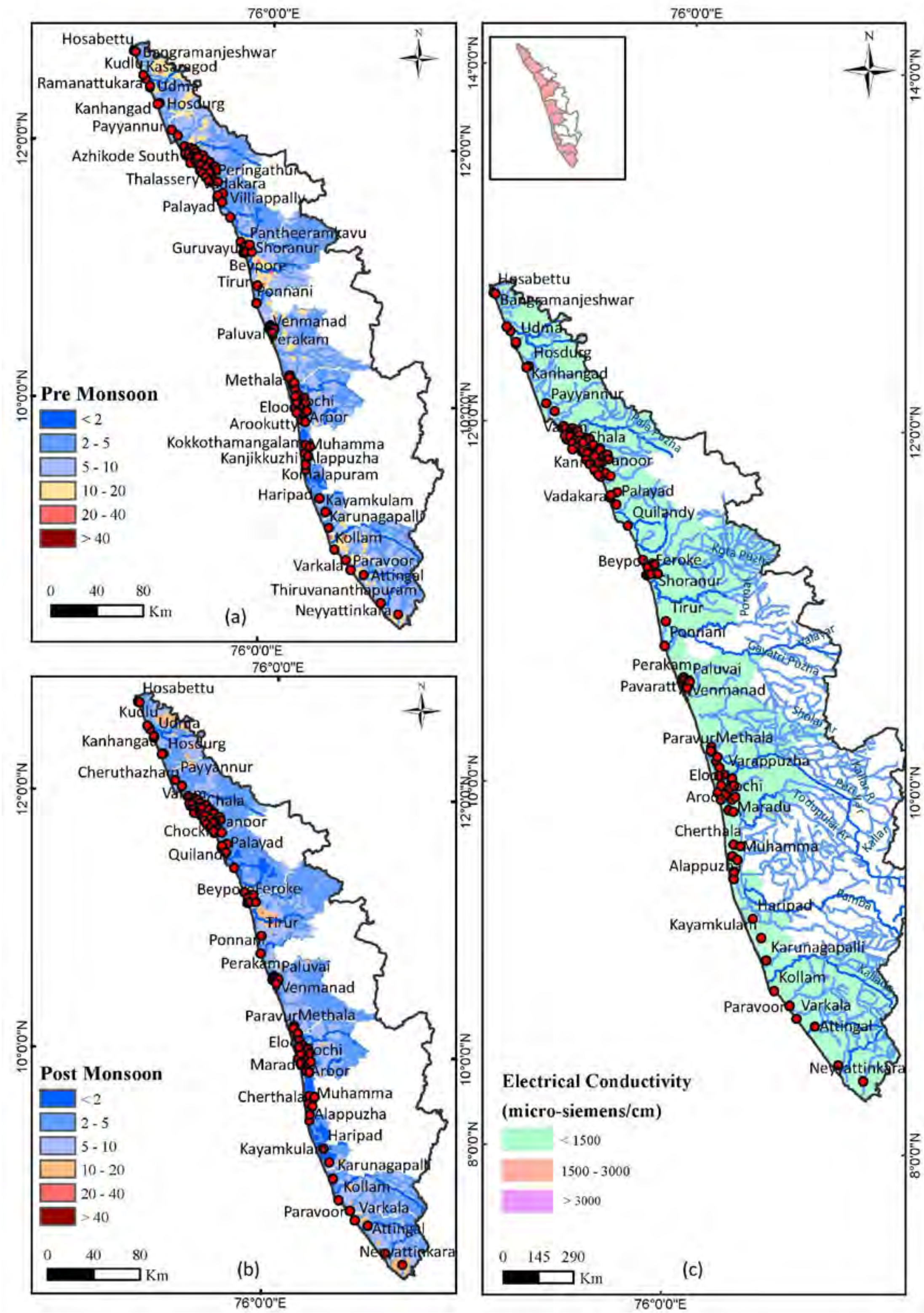


Fig. 3.4.4 (a) Pre-monsoon water level of coastal districts of Kerala (in meters) (b) Post-monsoon water level of coastal districts of Kerala (in meters) (c) EC map of shallow groundwater for coastal districts of Kerala

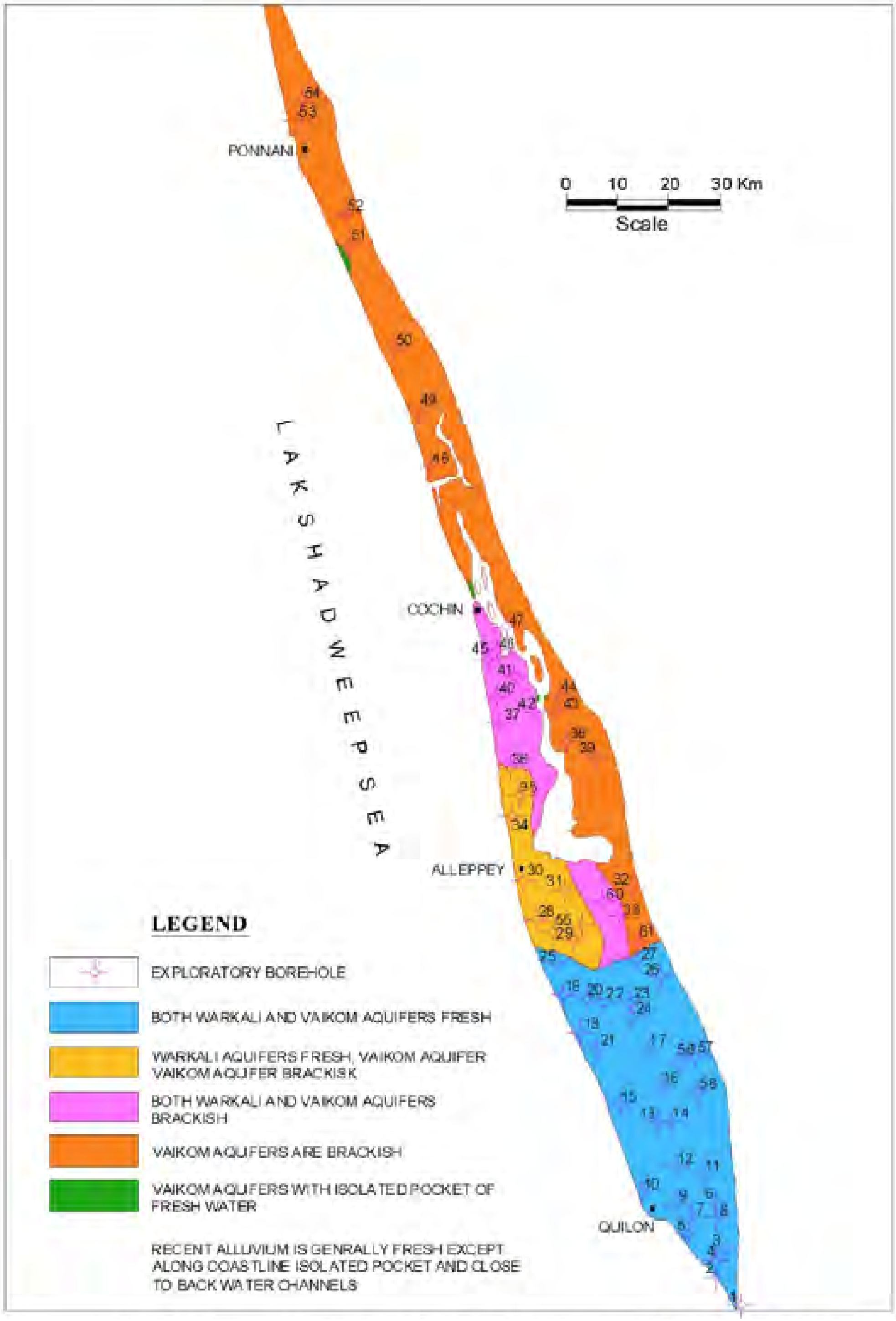


Fig. 3.4.5 Lateral extent of fresh and saline groundwater along Kerala coast, CGWB (2014a).

Figure 3.4.6 Uppala Anicut in Kasaragode District on Uppala River

Figure 3.4.7 Salt water extrusion dam across Mogral River at Kottakkunje in Mogral Puthur Panchayat

Fig 3.4.8 Kavanakallu Regulator cum bridge across the river Chaliyar

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Fig 3.4.9 Koothumakkal Regulator

3.5 TAMIL NADU

3.5.1 General

Tamil Nadu, the southern-most state of India, is bounded by Bay of Bengal in the east, the Indian Ocean in the south and the states of Kerala, Karnataka and Andhra Pradesh in the west, north-west and north, respectively. The geographical extent of the state is 1,30,058 km^2, with a shoreline of about 906.90 km. It is the sixth most populous state in India with a total population of 7,21,38,958 (as per 2011 Census), of which 62% of the people are engaged in agriculture. The coastal region of Tamil Nadu encompasses the costal tracts of 13 districts namely, Tiruvallur, Chennai, Kancheepuram, Vilupuram, Cuddalore, Nagapattinam, Thanjavur, Thiruvarur, Pudukkottai, Ramanathapuram, Tuticorin, Tirunelveli, and Kanyakumari. The area receives bulk of the rainfall from the northeast monsoon during the months of October, November and December. Figure 3.5.1 shows the locations of the coastal districts; sparsely/ medium populated areas in villages and highly populated urban areas in towns and cities, variation in average annual rainfall (1971-2005) across the coastal districts areas and land use / land cover conditions. The land use map reveals that a major part of the land in coastal districts is under crop cultivation.

3.5.2 Physiography and Drainage

The coastal plain in Tamil Nadu stretches from Kanyakumari with a width of about 1 km and attains its maximum width of about 150 km near Cauvery River. The coast is bounded on the west by hard crystalline Pre Cambrian rocks. The low gradient coastal plain exhibits associated landforms like vast tidal flats, continuous beach ridges, estuaries and lagoons and a narrow but fairly continuous beach. The area is drained by a number of rivers such as Palar, Cheyyar, Pennaiyar, Cauvery, Moyar, Bhavani, Amaravathi, Vaigai, Gundar, Tamiraparani, Nambiyar, Pazhayar, Kodayar etc. that flow from the Western Ghats (Fig. 3.5.2a, 3.5.2b). The coastline comprises a number of cusps, spits and wave cut platforms and several paleo-shorelines. Some of the paleo-shorelines extend inland suggesting periods of transgression and regression. The ongoing geodynamic process is generally progradation along the coast, which is modified at several places by erosion and deposition by aeolian and fluvial agents. The eastern areas of the central part of the state are marked by the depositional regime of many rivers manifested by typical fluvial features like levees, channel bars and palaeo-channels, back swamps and vast flood plains (GSI, 2006).

3.5.3 Hydrogeology

In Tamil Nadu, diverse hydrogeological formations are present; nearly 73% of the state is occupied by hard rocks, while the semi consolidated and unconsolidated formations are mainly confined in the eastern part which forms the coastal tract. The crystalline formations comprise of charnockites, granite gneisses, khondalites and mixed gneisses with intrusion of quartz veins, pegmatites, dolerite dykes and syenites etc. They mostly outcrop in the western and central parts.

In the coastal areas, the crystallines are exposed mainly in the southern parts in the districts of Ramanathapuram, Tuticorin, Tirunelveli and Kanyakumari. The thickness of weathered zone in these areas varies from a few metres to tens of metres. Underlying the weathered zone in these rocks are fractures and joints at places. In the hard rock area, groundwater is mainly developed through dug wells and dug cum bore wells tapping the weathered zone, in which the yield of open wells varies from 86 - 260 m^3/d. In dug wells tapping the soft rock formations including sedimentary formations, the yield is up to 430 m^3/d.

A strip of alluvial cover is present all along the coast having its maximum width in Cauvery delta between Cuddalore and Nagapattinam. In the coastal tract, the aquifers exhibit wide variation both laterally and vertically. The sediments in the extreme northern coastal tract of Tamil Nadu in the districts of Tiruvallur, Kancheepuram and Chennai are represented by alluvium both younger and older, boulder bed and the coastal sands of Quaternary age, underlain by a sequence of Tertiary sandstones, clays and shales and the Gondwana sandstones and shales. The area falls in the sub-basins of rivers Cooum, Kortalaiyar, Araniyar and Palar rivers where recent alluvial deposits form important repositories of groundwater. The thickness of alluvium in Kortalaiyar-Araniyar sub-basin ranges from 9 to 50 m. In three groundwater potential areas of this region viz., Minjur, Panjetty and Tamaraipakkam, groundwater occurs both under water table and confined conditions. An intensive development of groundwater in Minjur area (located north of Chennai city), to meet the water supply of Chennai city and industries, has led to decline in water levels and also caused saline water ingress. Figures 3.5.3a and 3.5.3b show the geology and soil depth in the coastal districts, while Figs. 3.5.4a and 3.5.4b show the depth to groundwater levels during pre- and post-monsoon for the year 2011.

The aquifers in Tertiaries and Gondwanas in this area have only limited yield prospects. In the coastal stretch of Pennaiyar river basin, the nonproductive zones occur towards north, highly productive zones in the central part, and freshwater aquifers overlain by saline water in the southern part.

In the area around Puducherry and Cuddalore, the potential aquifers in the area are confined to alluvium, Tertiaries and Createaceous formations. Groundwater occurs both under unconfined and confined conditions in these aquifers. Further south, the Cauvery delta forms the coastal tract. The shallow aquifers occurring within 100 m bgl have one to five granular zones with a total thickness of 3 to 54 m, while the deeper aquifer groups between 100 to 450 m bgl have one to five zones with a cumulative thickness of 11 to 103 m. The quality of water in alluvial aquifers deteriorates towards the coast.

The Vaigai basin of Ramanathapuram district is completely influenced by marine environment and there are a number of water-bearing zones but the quality of formation water is highly saline. In the southernmost Kanyakumari district, the sedimentary sequence is mostly absent and the crystallines are exposed. In some areas of the coastal tract, sand dunes are the only source for freshwater as in Rameswaram, Mandapam etc.

3.5.4 Groundwater Salinity

In the coastal tracts of Tamil Nadu and Puducherry, the location of fresh-saline groundwater interface has varied with time depending on the groundwater pumpage and recharge conditions. For example, in Minjur area, the interface was recorded about 3.5 km inland in 1972. It has moved to about 15 km inland at present.

During exploratory drilling program in the coastal area of Tamil Nadu, CGWB grouped depth-wise the granular zones encountered in the sediments viz., 0 to 100 m bgl, 100 to 300 m bgl and 300 to 500 m bgl and analyzed the water quality to demarcate the existing fresh-saline water interface in these zones**.** Investigations revealed that the interface in shallow zone (0-100 m) is relatively more inland than in the deeper zones (100-300 m). Further deep (300-500 m), the interface is relatively inland in comparison to that in the depth zone of 100-300 m, but less than that in the shallow depth zone of 0-100 m. Figure 3.5.4c shows the variation in EC of groundwater at shallow depths. Figure 3.5.5 illustrates the position of freshwater-saltwater interface at different aquifer depths.

In Puducherry, the quality of groundwater in general is good and has EC less than 750 µS/cm, except in places along the coast viz. Murungapakkam, Kirumampakkam, Kilparikelpet and Uchimedu where EC has been found to exceed 5000 µS/cm, which may be attributed to seawater ingress but needs further field investigations.

Reasons for Sea Water Intrusion

Sea water intrusion in coastal aquifers occurs where there is excess withdrawal of groundwater. It develops reverse hydraulic gradient in the inland which induces seawater intrusion. The density of Sea water is slightly higher than the density of the fresh water. Hence fresh water floats on sea water under equilibrium condition. In the coastal land, the ground water floats above Mean Sea Level at normal condition. When fresh water, which is floating above the sea level, is extracted beyond its limit (Potential) ground water level goes down below the Mean Sea Level, thus activating the sea water to intrude into fresh water aquifer.

Problem of Salinity Ingress in Tamil Nadu State

The uses of ground water for irrigation, drinking and for industrial sector have increased manifold over the past three decades, resulting in over-exploitation of available ground water in many blocks including coastal area. Tamil Nadu having a coastal length of 1076 Km spread over 13 districts as given in Table 3.5.1.

Table 3.5.1 Coastal Districts and the Coastal lengths in the State of Tamil Nadu

S.No.	Coastal district	Coastal length (Approx. Km)
1.	Chennai	19.0
2.	Thiruvallur	27.9

3.	Villupuram	40.7
4.	Pudukottai	42.8
5.	Thanjavur	45.1
6.	Thiruvarur	47.2
7.	Tirunelveli	48.9
8.	Cuddalore	57.5
9.	Kanyakumari	71.5
10.	Kanchipuram	87.2
11.	Tuticorin	163.5
12.	Nagapattinam	187.9
13.	Ramanathapuram	236.8
	Total	**1076.0**

The rapid, erratic and excessive development in the coastal areas activates sea water intrusion towards landward.

In spite of various safe guarding measures taken to conserve and properly manage the ground water in Tamil Nadu, the State is experiencing shortage/scarcity of water, especially in the coastal areas for drinking purposes and the ground water table is fast depleting.

Hence, there is an urgent need to replenish ground water aquifers through artificial recharging techniques, in order to avoid wastage of rain water and for improving the ground water in quality and quantity, thereby relieving the stress on the water sources available at long run, which otherwise will be available for irrigation and other purposes for that locality. There is substantial lowering of water table in many parts of coastal Tamil Nadu, which stimulates the intrusion of sea water land ward.

In coastal cities and towns, viz., Chennai, Cuddalore, Chidambaram, Nagapattinam, Tuticorin, etc., as there is rapid increase in industrial and other institutional activities and also increase in urban population, the extraction of ground water has increased manifold and the use of Ground Water for irrigation has also increased. These activities induce intrusion of Sea water towards land (westward). It was first reported in early 1966 at North Chennai (Minjur-Athipattu) in Kosasthalaiyar river aquifer, where Water Resources Department was tapping ground water for domestic and industrial purposes. Later, deterioration in ground water quality and lowering of water-table in coastal areas viz.,Ennore, Thiruvanmiyur, Cuddalore, and in Mahendrapalli, Pudupattinam, Mahanam, Thirumullaivasal, and Edamanal areas of Kollidam Block, Nagapattinam, and in Thiruchandur, Udangudi, and Santhankulam of Thuthukudi dt., etc., were reported.

The State Ground & Surface Water Resources Development Data Centre (formerly known as Ground Water wing) of the Public Works Department is continuously monitoring the ground water levels and the quality over past decades. Out of 386 blocks in the State 8 blocks are reported as Salinity blocks. The table 3.5.2 provides the details of the salinity affected areas.

Table 3.5.2: Statement showing the Salt Water Ingress in the Coastal Districts of Tamil Nadu

District	Taluk	District			Taluk		
		District-Total Area-H	Salt Water Ingress-Affected Area-H	% Affected	Taluk-Total Area-H	Salt Water Ingress-Affected Area-H	% Affected
Chennai	Chennai	16725	15866	94.9	16725.3	15866	94.9
Cuddalore	Chidambaram	372450	49628	13.3	61921.1	20863	33.7
	Cuddalore				66112.1	28174	42.6
	Kattumannarkoil				43022.2	259.641	0.6
Kancheepuram	Chengalput	432512	88274	20.4	76421.4	26359.9	34.5
	Cheyyur				26543.5	18851.2	71.0
	Maduranthagam				110969	13642.5	12.3
	Sriperumpudur				64381.6	12.9222	0.0
	Tambaram				22887.6	13061.2	57.1
	Tirukalukkundram				36666.9	16470.1	44.9
Kanyakumari	Agastheeswaram	168008	53205	31.7	28084.7	24425.4	87.0
	Kalkulam				62937	14785.5	23.5
	Thovala				38011.4	440.217	1.2
	Vilavancode				32647.3	8726.31	26.7
	Vilvancode				7252.44	7199.17	99.3
Nagapattinam	Kizhvelur	227457	127432	56.0	36523.5	6646.04	18.2
	Mayavaram				25627.3	142.138	0.6
	Nagapattinam				30833	26200.5	85.0
	Sirkazhi				44482.3	26323.5	59.2
	Tarangampadi				27705.8	21555	77.8
	Vedaranniyam				56024.8	37689.4	67.3
	Vedranniyam				21315.7	8557	40.1
Pudukottai	Aranthangi	463700	38144	8.2	37743.3	2626.7	7.0
	Avudayarkovil				71579.1	35454.1	49.5

Ramanathapuram	Kadaladi	403574	151324	37.5	70299.1	43371.7	61.7
	Mudukulattur				39905.5	65.5798	0.2
	Paramakudi				72537.7	4082.71	5.6
	Ramanathapuram				47894	39698.8	82.9
	Tiruvadanai				125576	62601.2	49.9
Thanjavur	Pattukkottai	342837	43583	12.7	50187.6	17410	34.7
	Peravurani				61443.9	26675.8	43.4
Thiruvallur	Ambattur	361082	35826	9.9	73225.3	35804.1	48.9
	Ponneri				18871.1	1544.27	8.2
Thootukudi	Ottapidaram	466553	105504	22.6	75210.6	17469.1	23.2
	Sattankulam				48544.9	25085.1	51.7
	Srivaikundam				60742.5	8042.46	13.2
	Tiruchendur				35993	17062.9	47.4
	Tuticorin				34810	17155.3	49.3
	Vilathikulam				110193	22534.3	20.4
Tirunelveli	Radhapuram	705106	46778	6.6	88391.6	44592	50.4
Tiruvarur	Kudavasal	214564	24267	11.3	36857.1	671.974	1.8
	Nannilam				20142	11897.6	59.1
	Tiruturaipoondi				54045.9	17754.6	32.9
	Tiruvarur				32671.1	16679.9	51.1
Villupuram	Dindivanam	716892	32201	4.5	99265.3	17386.2	17.5
	Vanur				46186.7	16306.4	35.3
	Villupuram				91234.9	15.2863	0.0

3.5.5 Causes and Extent of Coastal Land Salinity

The use of groundwater for irrigation, drinking and for industrial sector has increased manifold over the past three decades in coastal areas of Tamil Nadu, resulting in over-exploitation of groundwater in many blocks. In spite of various safe guarding measures taken to conserve and properly manage the groundwater in Tamil Nadu, the groundwater table is depleting and the state is experiencing shortage/scarcity of water accompanied by seawater ingress, leading to increased groundwater salinity in coastal tracts. For sustainable management of groundwater in Tamil Nadu, critical areas have been identified for addressing groundwater salinity problem that has arisen due to anthropogenic reasons or exists due to in-situ salinity in subsurface. These areas are listed below.

- Minjur area, North of Chennai city, Chennai District: Seawater intrusion problem
- Tiruvanmiyur-Kovalam Tract, Southern part of Chennai City: Seawater intrusion reported.
- Cuddalore Coast: Seawater intrusion reported due to heavy pumping at SIPCOT and *insitu* salinity.
- Ramanathapuram, Nagapattinam, Thanjavur Tiruvarur and Tuticorin Districts: *Insitu* salinity
- Kuttam-Radhapuram area, Tuticorin District: Seawater intrusion reported.

Table 3.5.3 describes the areas in coastal districts of Tamil Nadu that are either vulnerable or already have been affected by seawater encroachment mainly due to excessive groundwater pumpage. Salinity also exists due to sea water incursion up to several kilometres inland through river mouths during high tides, and, due to marine depositional environment in the coastal areas. In some areas, localized salinity problems in shallow groundwater have been reported from brackish water aqua farms.

Report of the Committee on Effective Utilisation of North–East Monsoon

The Report of the Committee on Effective Utilisation of North–East Monsoon Generated flood waters constituted by the State Government has stressed the need for prevention of sea water ingress and has recommended specific schemes in the various basins of the State.

Report of the Task Force Committee – Vision 2023

The Report of the Task Force Committee – Vision 2023 constituted by the State Government has recommended the following

1. Increasing the Storage Capacity of selected tanks and storages located in the coastal belt with specific reference to the Kazhuveli Swamp

2 Clearing and Improving the City Waterways and Prevention of Sea water Intrusion.

Table 3.5.3 Salinity affected areas in Tamil Nadu

District/Location	Inference	Recommendations by State Department
Thiruvallur District : Mouthambedu – Minjur	Minjur-Mouthambedu areas of North Chennai aquifer are affected by sea water intrusion due to heavy withdrawal of ground water by Metro water for domestic and industrial water supply. Reverse hydraulic gradient was up to 16 km from the sea coast and there is a likelihood of movement of interface towards west if the same rate of pumping (3 mgd/l.) by the Metro water continues.	• Indiscriminate pumping of groundwater by Metro water should be controlled. • Sand quarrying in the river bed should be banned. • Artificial recharge of the aquifer may be attempted by constructing check dams at appropriate locations to recharge the aquifer.
Besant Nagar – Thiruvanmiyur area	Because of indiscriminate pumping of ground water by various agencies in the South Chennai aquifers, the delicate aquifer system in Besant Nagar area is affected with water quality deterioration which indicate the possibility of sea water encroachment. If the present rate of pumping is continued, the interface may move towards west and affect the areas in Adyar region.	• Quantum of pumping in the Besant Nagar (Urur, TNHB Colony) should be regulated. • Rainwater harvesting should be made compulsory in all buildings in this area. • In Thiruvanmiyur area, rate of pumping by various agencies should be regulated otherwise,it is a matter of time before this area will also meet the fate of Minjur- Mouthembedu.
Ramanathapuram District.	• Aquifer in the entire coastal areas yields only poor quality of groundwater which is due to marine depositional environment. • In the sand dune areas as well as the Teri sand whenever the rainfall recharge is appreciable, the quality improves; in the deeper marine formation the quality becomes poor. No sea water encroachment.	Rain water harvesting is recommended in the highly porous sand which quickly gets recharged, thereby the quality of ground water improves.

Cuddalore District	• In Cuddalore District, the shallow phreatic aquifer in areas close to sea coast show poor quality water which is attributed to the presence of sea water. • Medium and deep bore wells touching Tertiary aquifer yields good quality of ground water (SIPCOT). • Deep wells south of Puduchatram, at Pichavaram, Killai, Chidambaram yield poor quality of ground water which is due to their proximity to the back waters as well as due to the marine depositional environment.	Outcrop for recharge to the deep Tertiary aquifer near Cuddalore District lies to the west near Neyveli. As long as good recharge is there, the quality won't be affected. However, the rate of pumping by various agencies for industrial purposes should be regulated so as to safeguard the Tertiary aquifers.
Nagapattinam District	Narayanapuram and Mahendrapalli of Sirkali Block show poor quality of groundwater which is due to the presence of large number of brackish water aqua farms. The seepage from the ponds as well as the effluents from the ponds contaminates the shallow aquifers. Medium aquifer of Pliocene and upper Miocene yield poor quality water, where as deeper aquifer yields good quality of water. No sea water encroachment in the district.	While giving clearance for the aqua farms, care should be taken to adhere strictly to the guidelines issued by aqua culture authority.
Pudukkottai District	Groundwater in the middle and deep aquifer is good. Poor quality in shallow aquifer is due to marine depositional environment and not due to sea water intrusion. There is no large scale extraction of groundwater.	Good quality groundwater available in deep aquifers can be better utilized for drinking needs of local population as well as for irrigation purposes.
Thoothukudi District	• Seawater encroachment in central parts (Kuthiraimozhi Teri) and southern parts (Udankudi), due to heavy pumping by farmers and poor rainfall which has lowered the water level below msl. • In Northern parts near	• Rain water harvesting in Teri areas is recommended. • Artificial recharge by filling up tanks in Sadyaneri, Thangikulam and Puthantharurai by implementing the

	Tambaraparani, salinity is attributed to the presence of salt pans.	Sadyaneri Kalvoy Project (starts from Marudhur anicut and reaches Puthantharvai Tank).
Tirunelveli& Kanyakumari District	Valliyur block of Tirunelveli District is affected by sea water encroachment particularly Chettikulam and Srirenganarayanapuram, because of heavy pumping for intensive coconut plantations coupled with hydro morphological set up of the region.	• Pumping around Chettikulam and Srirenganarayanapuram should be restricted. • Artificial recharge though Radhapuram Channel during June to September by constructing check dams at appropriate locations.

3.5.6 Remedial Measures

The Report of the Committee on 'Effective Utilisation of North–East Monsoon Generated Flood Waters' constituted by the State Government has stressed the need for prevention of sea water ingress and has recommended specific schemes including artificial recharge techniques in the various basins of the State. The Report of the Task Force Committee – Vision 2023 constituted by the State Government has recommended (i) Increasing the storage capacity of selected tanks and storages located in the coastal belt with specific reference to the Kazhuveli Swamp (ii) Clearing and improving the city waterways and prevention of sea water intrusion.

There is a need to prevent the intrusion of sea water both through surface and subsurface media. This involves provision of suitable structures quite close to the confluence point of rivers (river mouth) with the sea. At the same time, these structures must be capable of discharging the maximum flood discharges without outflanking the banks. Tail-end regulators with shutters are the necessary appropriate structures and in certain places check dams also serve the purpose.
The following structural measures are adopted by the State of Tamil Nadu to arrest the problem of salinity intrusion:

Construction of check dams

This concept is adopted where there is possibility of safely disposing the flood discharges to the sea without facing any problem of flooding in the coastal areas. The crest level of these check dams on rivers are kept above the high tide level thereby avoiding the sea water ingress through the rivers during high tides. The fresh water stored on upstream side acts as storage for lift irrigation, besides recharging the groundwater and preventing sea water intrusion through the subsurface. The table 3.5.4 gives the sample details of the check dams constructed in the State of Tamil Nadu.

Table 3.5.4 Sample Details of Check Dams Constructed in Tamil Nadu

Sl. No.	Scheme	River Basin
1	Construction of check dam across Kosasthalaiyar river near Edayanchavadi village in Thiruvallur District.	Kosasthalaiyar (works not yet taken up)
2	Construction of check dam across **Vaippar**river near **Vaippar** Village in Vilathikulam Taluk of Thoothukudi District.	Vaippar (Completed)
3	Construction of check dam across **Thambraparani** river near Serndamanglam village (Mukkani) in SrivaikuntamTaluk of Thoothukudi District.	Thamiraparani (Change of site near Punnakayal, will be resumed soon)
4	Construction of check dam across **Gadilam** river near **Koothapakkam** village in Cuddalore Taluk and Cuddalore District.	Gadilam (Completed)

Report on Construction of Check Dam across Vaippar Rver near Vaippar Village to Vilathikulam Taluk of Thoothukudi District

Vaippar Basin is located in the drought prone taluks of Vilathikulam and Ettayapuram in Thoothukudi District. Out of 130 Km length of vaippar River, 55 KM length flows in Thoothukudi District. Vaippar River originated in the eastern slope of Western ghats and falls into Gulf of Mannar near Vaippar Village. Vilathikulam taluk of Thoothukudi district. Due to sea water intrusion through Vaippar river mouth, both surface water and ground water in around this area has become saline. Due to this, agriculture activities were totally affected. To avoid sea water intrusion, the villagers have formed earthen bund across Vaippar as a temporary measure. During flood period, earthen bund gets damaged. Hence, the public have represented in many occasions through petitions for construction of Pacca check dam across Vaippar River to arrest sea water intrusion.

Accordingly the government have accorded administrative sanction for an amount of Rs. 1477.35 Lakhs for the above Check Dam implemented under World Bank aided IAMWARM Project. The work was completed on 30.09.2014

Now, Saline water intrusion is prevented and the water stored in check dam attributes to augment Ground Water Level in more than 7 villages. The Expenditure incurred for the construction of Check Dam is Rs. 1451.81 Lakhs.

Report on Construction of Check Dam across Thambraparani River near Serndamanglam Village (Mukkani) in Srivaikuntam Taluk of Thoothukudi District

Tamiraparani river is the only perennial river in Tamil Nadu State. In Thoothukudi District, Check Dams were not provided below Valavallan Check Dam and upto Punnakkayal seashore across Thambraparani River.

In order to recharge the ground water and to arrest the sea water intrusion, the public and ryots have requested to construct a check dam across Thambraparani River at Mukkani in Serdamangalam Village of Srivaikuntam Taluk in Thoothukudi District. Considering the request of the public, the Hon'ble Chief Minister of Tamil Nadu has made an announcement for the Construction of Check Dam at Mukkani. Based on that, the Government of Tamil Nadu accorded the Administrative Sanction for an amount of Rs 25.75 Crore with NABARD Assistance.

Further, tenders have been called for and agency has been settled. The site was handed over on 24.01.2016. But during the execution of preliminary work, a road protest was contested by the People of Mukkani and surrounding villages on 07.03.2016 and hence transportation was severely affected. Therefore, the work has been stopped. The demand of the public is to construct the Check dam beyond 3 km downstream site i.e. Nearby Punnakkayal. The work can be resumed only after the next level meeting.

The expenditure so far incurred for this work is Rs. 31.88 Lakhs.

By constructing the above Check Dam the following benefits will be accrued: -

1. The ground water will be recharged and Ground Water Table will be considerable raised in and around the area of Mukkani
2. Sea-Water intrusion will be arrested to the maximum extent
3. The existing Water Sources may be additionally improved
4. The Irrigation Lands of this area will be stabilized. Moreover, 990 Acres of Land will be additionally benefitted.
5. The Water table of the existing 19 Wells in the area will be improved.

Details of construction of Check dam across Gadilam river near Koothapakkam Village in Cuddalore district

The sea water enters the Gadilam River near its mouth and flows inland for a distance of 6.5 Km through Gadilam River. To prevent the intrusion of sea water and to improve the groundwater quantity and quality, a check dam was constructed across Gadilam River near Koothapakkam

village under World Bank aided IAMWARM Project at an estimated cost of Rs 1,625 lakh (Fig. 3.5.6)
To accommodate the maximum flood level, a flood bank is formed with minimum free board of 1 m above water surface elevation, at 2.8 km upstream and 500 m downstream on both banks.
By implementing this scheme the 53 number of wells benefitted in the zone of influence on d/s stream side of Check Dam is and the sea water intrusion is also arrested. The check dam height is 2.00 m, the water will be stored for a length 3200 m and about 20 mcft of water will be stored annually. By impounding the water in the check dam level of water in the bore wells and open wells in the adjacent Cuddalore town have been raised.

Construction of tail end regulators

This concept is adopted where the flood discharges are heavy and there is a need to quickly dispose the flood waters without inundation/flooding of upland areas. The gated structure helps to store the receding flood waters and also prevents sea water ingress. The freshwater stored on upstream side acts as storage for lift irrigation, besides recharging the groundwater and preventing sea water intrusion through the subsurface. For the tail end regulators to be fully functional, some sea side bunds are required to protect the farms from higher tides and storm surges; thus, effective drainage through the bunds is incorporated into the planning. The tail end regulator serves the following functions:

- With gates closed, storage of adequate freshwater in the river channels is available to irrigate the agricultural lands by gravity or pumps.
- To allow discharge of surplus flood flows into the sea with minimum head loss.
- To halt the ingress of sea water and to protect fertile lands and communities from salinity intrusion through river channels. There may be a need for additional tail end regulators on the minor drains.

Depending upon the location, the regulators may have some environmental impacts especially for a small percentage of water users downstream of the regulator. The river water downstream of regulator would effectively become saline with possible impacts on the coastal communities. Provision of piped and/ or canal (not connected to sea) supply from freshwater storage upstream of the regulator can be made.

Construction of tail end regulators with diaphragm wall

This type of structure is being proposed in major rivers such as Kollidam and Palar. Apart from preventing surface sea water ingress these structures will help in long way to prevent subsurface intrusion. These structures are helpful in creating significant storages in upstream side and will play a major role in the last mile irrigation and storage of water for drinking purposes.

Coastal protection structures

The Rubble Mound Sea (RMS) wall and groynes may be constructed to reduce the erosion of sea shore and acts as barriers on the shore for sea water encroaching the inland area. The RMS walls obstruct the flow of saline water near the shore which also plays major role in reduction of salinity ingress in coastal areas.

Construction of recharge wells

The recharge wells are constructed in the water spread area in the tanks (lakes). It consists of construction of open well of rectangular dimension of 12.00 m x 10.00m size to depths ranging according to the soil conditions in the range of 6 m to 20 m with necessary berms and walls to retain the earth.

Excess water during surplus flow period will be recharged through the recharge well structure by collection of water over FTL and recharge through the top permeable strata. In addition to this, to improve the recharge in the hard rock strata through fissures and faults drilling of 110mm diameter naked boreholes in vertical direction at the bottom is proposed. Necessary filter media in Coarse aggregate using HBG stone jelly at bottom most layer and fine aggregates using river sand at top filter media is proposed in this recharge structure. The top of open well will be provided with Mild Steel fabrication and weld mesh works to avoid any mishap and casualty either to human or animals.

The details of the recharge wells are provided at the Annexure 3.5A.

Construction of Recharge Shafts:

Recharge Shafts are the most efficient and cost effective structures to recharge the aquifer directly. These can be constructed in areas where source of water is available either for some time or perennially. Following are the site characteristics and design guidelines:

(i) To be dug manually if the strata is of non-caving nature.

(ii) If the strata are caving, proper permeable lining in the form of open work, boulder lining should be provided.

(iii) The diameter of shaft should normally be more than 2 m to accommodate more water and to avoid eddies in the well.

(iv) In the areas where source water is having silt, the shaft should be filled with boulder, gravel and sand to form an inverted filter. The upper-most sandy layer has to be removed and cleaned periodically. A filter should also be provided before the source water enters the shaft.

(v) When water is put into the recharge shaft directly through pipes, air bubbles are also sucked into the shaft through the pipe, which can choke the aquifer. The injection pipe should therefore be lowered below the water level. The main advantages of this technique are as follows:

- It does not require acquisition of large piece of land as in case of percolation tanks.
- There are practically no losses of water in the form of soil moisture and evaporation, which normally occur when the source water has to traverse the vadose zone.

- Disused or even operational dug wells can be converted into recharge shafts, which do not involve additional investment for recharge structure.
- Technology and design of the recharge shaft is simple and can be applied even where base flow is available for a limited period.
- The recharge is fast and immediately delivers the benefit. In highly permeable formations, the recharge shafts are comparable to percolation tanks. The recharge shafts can be constructed in two different ways viz. vertical and lateral. The details of each are given in the following paragraphs.

The construction of proposed recharge shaft is illustrated below:

- Drilling of bore hole of diameter 0.200 m to a various depth of 35m, 55m and 70 m.
- Reaming of bore hole of diameter 0.200 m to 0.35 m to a various depth of 35m, 55m and 70 m.
- Necessary PVC casing (plain & ribbed screen) pipes are to be erected up to the total depth. End caps on both ends of the bore holes are to be provided.
- Compressor development for bore hole has to be done.
- After completing the bore hole, filter trench is to be constructed by erecting the RCC Hume Pipe of 600 mm Dia and top of the Hume pipe with RCC circular slab.
- The Gap between the bore hole and the filter trench is to be filled to 0.30 depth of 40mm broken stone jelly and then with 0.15 m coarse sand.
- Top of the recharge trench is to be covered with RCC circular slab with holes.
- Necessary display boards explaining the details of the recharge structure are to be displayed to have good exposure about ground water recharge.

Benefits of remedial measures

The following benefits are accrued from the remedial measures adopted by Tamil Nadu.

- Prevention of sea water intrusion through river channels.
- Augmentation of groundwater recharge.
- Improvement in the quality of groundwater which contributes to drinking water security in coastal area.
- Last mile irrigation can be effectively implemented.

The Table 3.5.5 gives the details of all the recharge structures constructed during 2008-15

Table 3.5.5 The consolidated statement of all Recharge Structures constructed under MPRAS Scheme in from 2008-15

Sl No	Type of Structure	No of structures
1	Check Dam	6310
2	Recharge Shaft	1402
3	Sub Surface Dyke	7
4	Percolation Pond	638
5	Bed Dam	6
6	Weir	1
7	Diaphragm Wall	2
8	Gully Plugging	38
9	Contour Bund	6
10	Nalla Bunds	8
11	Village Pond/village Tank	532
12	Farm Pond	3489
	Total	**12439**

The District wise details are provided at Annexure 3.5B

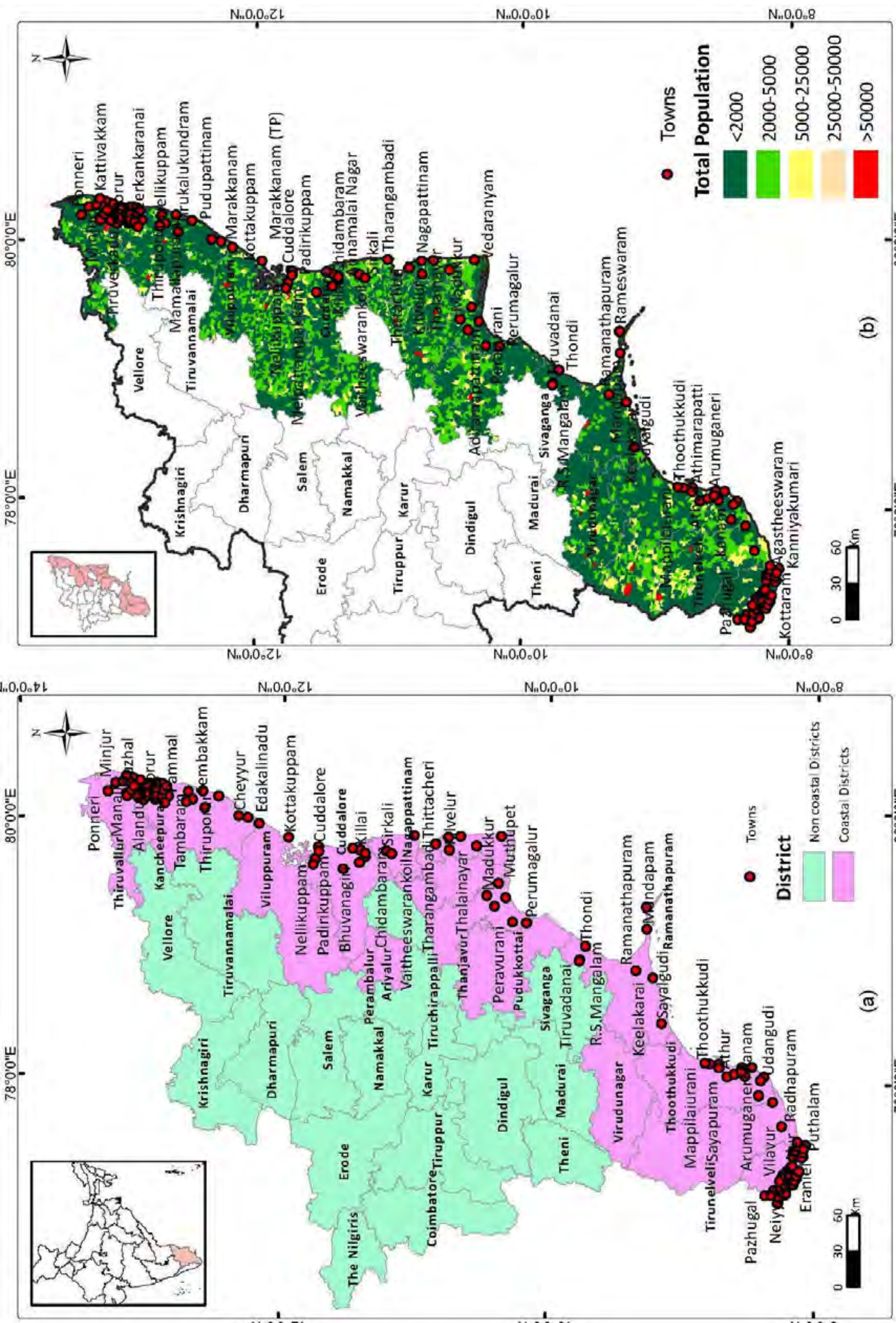


Fig. 3.5.1(a) Administrative map of Tamil Nadu showing coastal districts (b) Population distribution of coastal districts of Tamil Nadu

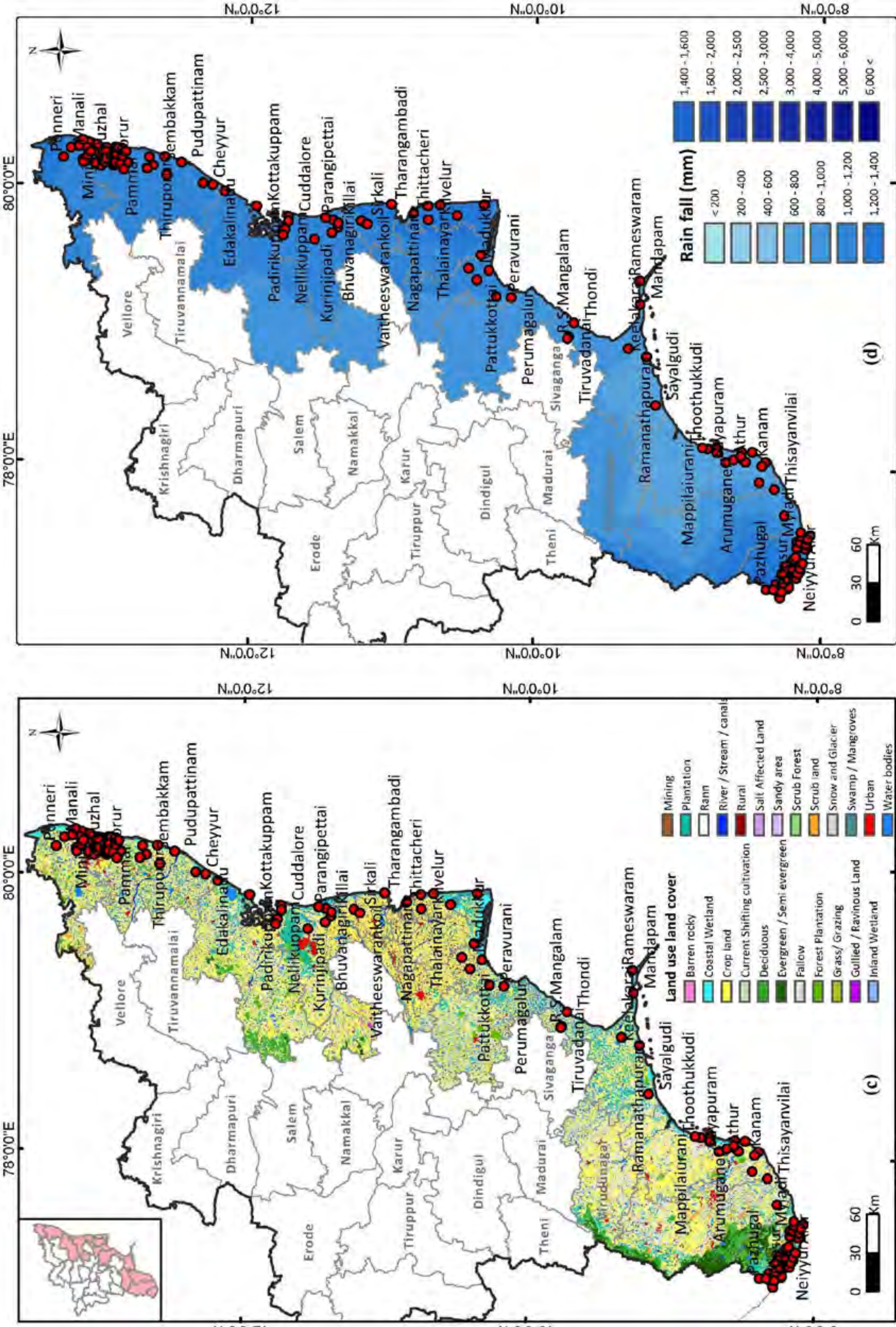


Fig. 3.5.1 (c) Land use and land cover of coastal districts of Tamil Nadu (d) Rainfall distribution of coastal districts of Tamil Nadu

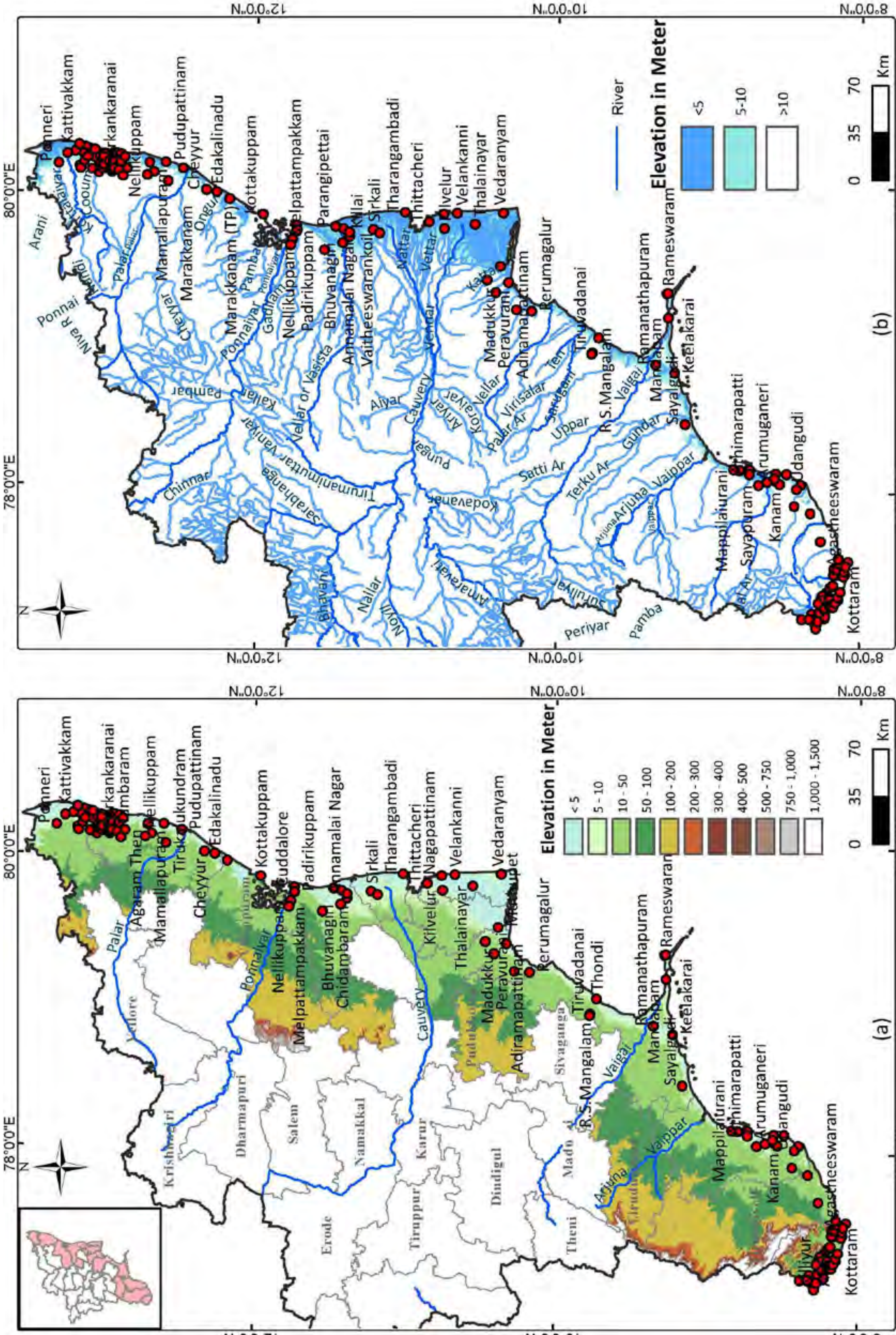


Fig. 3.5.2 (a) Physiographic map of Tamil Nadu (b) Drainage map of Tamil Nadu showing low elevation coastal areas (< 10 m amsl)

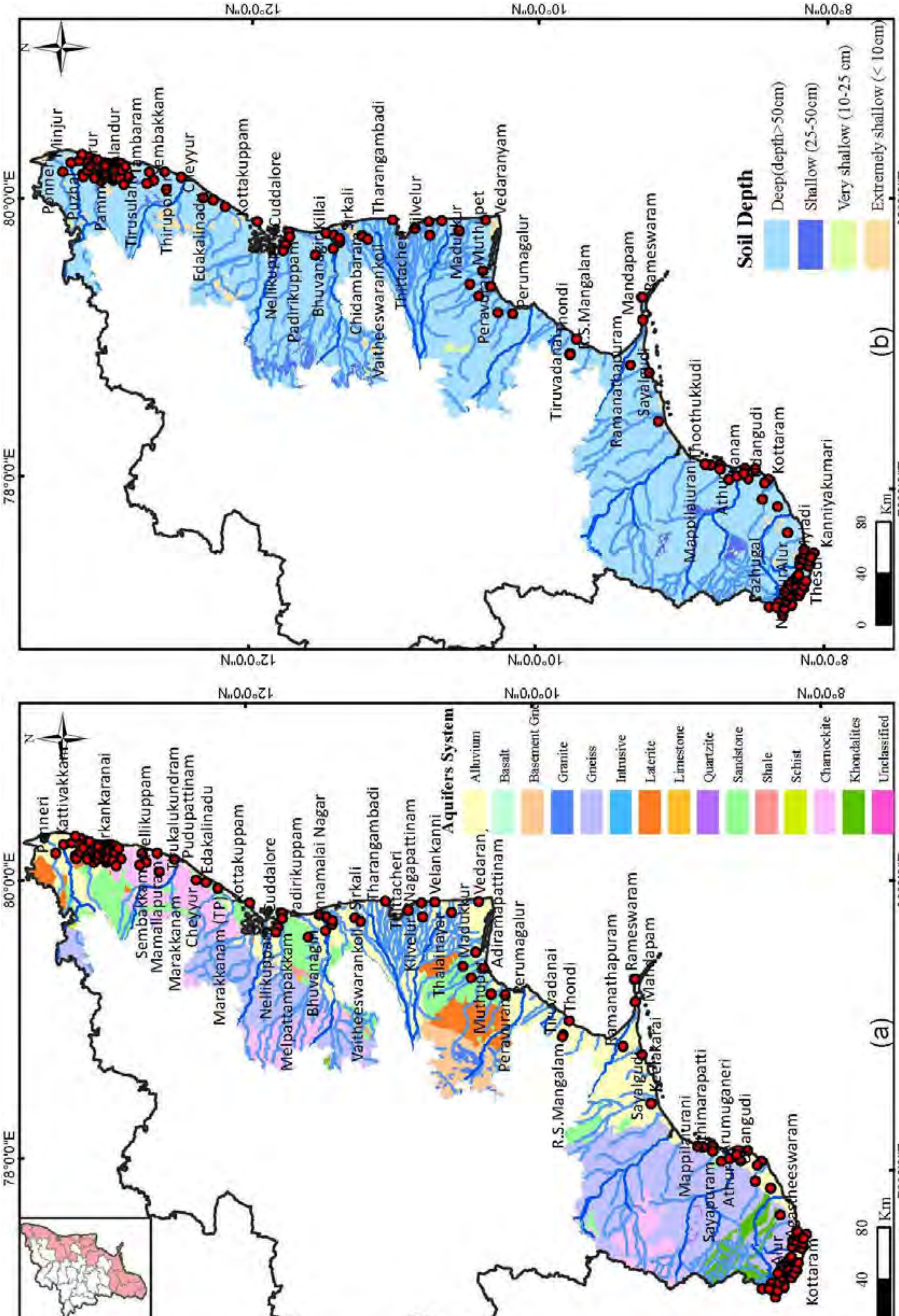


Fig. 3.5.3 (a) Aquifer map of coastal districts of Tamil Nadu (b) Soil depth map of coastal districts of Tamil Nadu

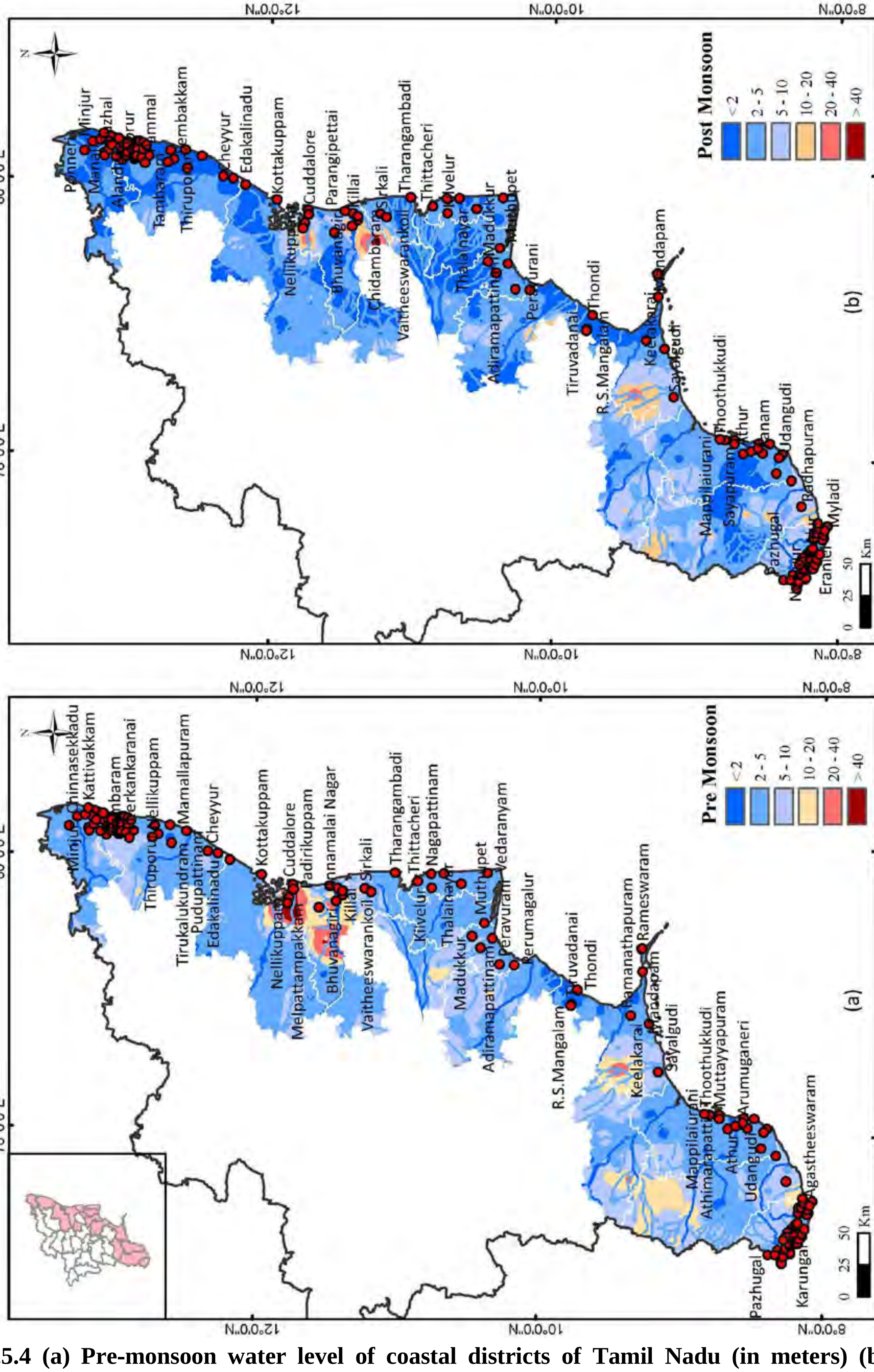


Fig. 3.5.4 (a) Pre-monsoon water level of coastal districts of Tamil Nadu (in meters) (b) Post-monsoon water level of coastal districts of Tamil Nadu (in meters)

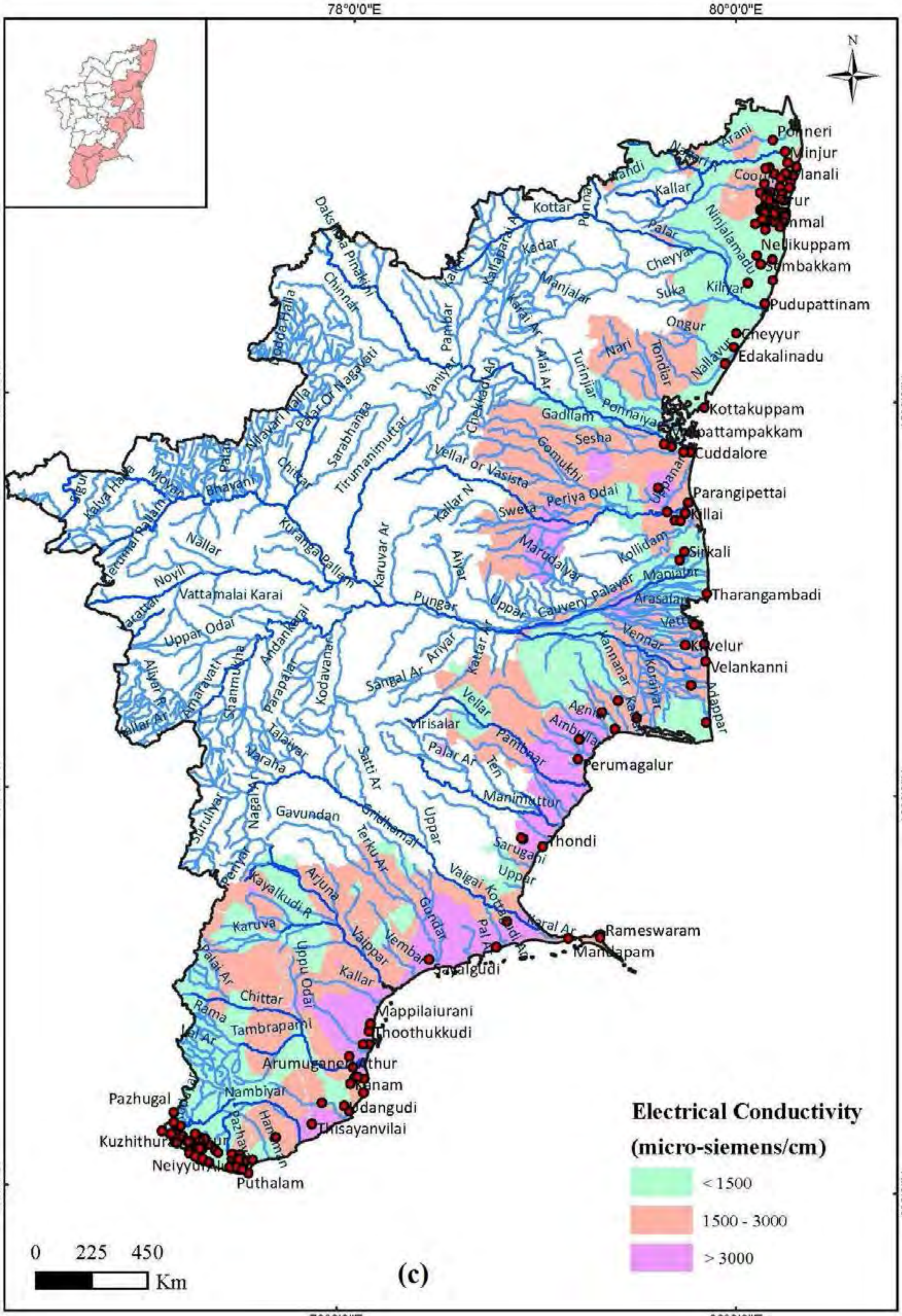


Fig. 3.5.4 (c) EC map of shallow groundwater for coastal districts of Tamil Nadu

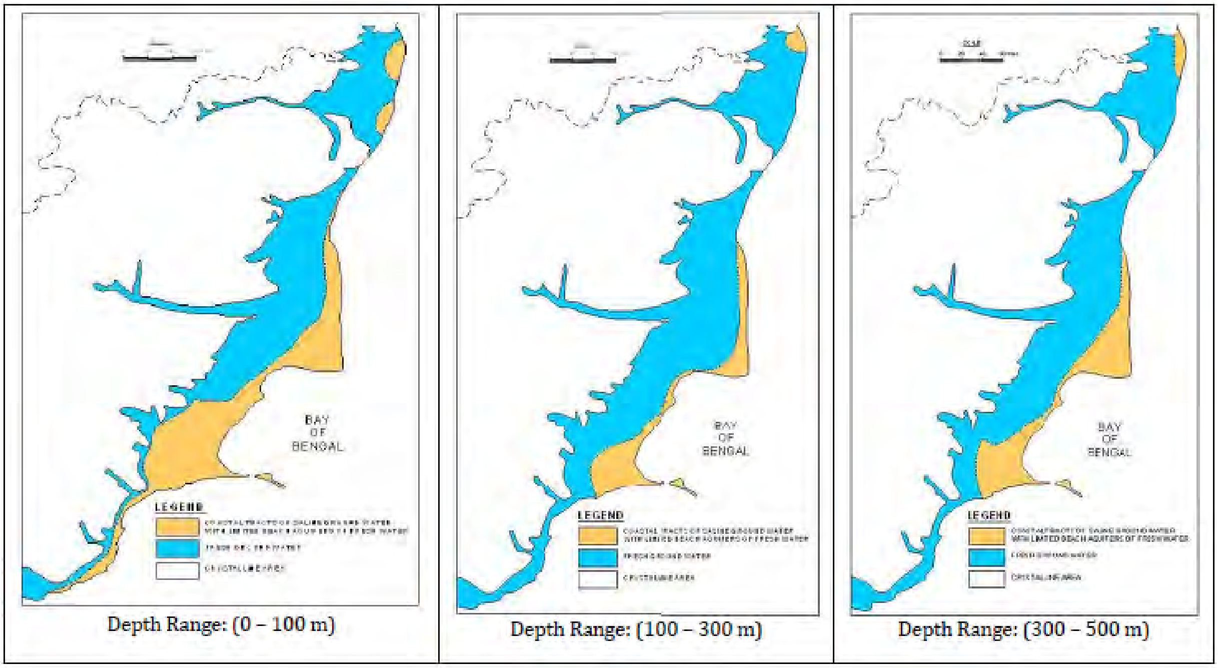


Fig. 3.5.5 Freshwater-saltwater interface at different depths in coastal aquifer system of Tamil Nadu, CGWB (2014a)

Fig. 3.5.6 Check Dam in Koothapakkam Village of Cuddalore District

3.6 ANDHRA PRADESH

3.6.1 General

Andhra Pradesh has the second largest coast line in the country with a length of 973.70 km. Out of the 13 districts of the state, 9 districts are located along the coastal line, namely, Srikakulam, Vizianagaram, Vishakhapatnam, East Godavari, West Godavari, Krishna, Guntur, Prakasam and Nellore. Coastal Andhra Pradesh has humid to sub-humid conditions. The total annual rainfall in the 9 coastal districts ranges from 757 mm in Prakasam District to 1139 mm in East Godavari District. Over 90% of the rainfall is received in the months from June to October. Figure 3.6.1 shows the locations of the coastal districts; sparsely/ medium populated areas in villages and highly populated urban areas in towns and cities, variation in average annual rainfall (1971-2005) across the coastal districts areas and land use / land cover conditions. Among the coastal states, Andhra Pradesh accounts for the maximum area under canal irrigation. The major canal irrigated areas are present in the Godavari and Krishna deltas in the coastal regions.

3.6.2 Physiography and Drainage

In addition to Godavari and Krishna, the main rivers draining the coastal area and nearby areas in Andhra Pradesh are Nagavali, Vamsadhara, Yeleru, Gundlakamma and Pennar. The major coastal plain with gently undulating land is drained by the two rivers systems Godavari and Krishna and extends from Guntur district, across Krishna, West Godavari districts up to East Godavari district, The other important coastal plain is in Nellore district near the mouths of Pennar, Swarnamukhi and Kandaleru rivers. The delta plain of river Godavari occupies an area of 1700 km^2. River Godavari gets divided into two main distributaries, viz., Gautami and Vasishta, that are further sub-divided into minor distributaries before joining the Bay of Bengal. The Krishna river maintains a unique curvilinear path from its delta head up to the coast. It forms a 95 km wide delta plain extending from Vijayawada up to the coast with a total area of 6322 km^2. The first channel of the river starts near Avanigadda, but the present day river gets divided into three main distributaries i.e. Golumuttapaya, Nadimieru and main river channel just before entering the sea.

The coastal area is bordered by Archaean group of rocks on the western side. The coastal plain is of prograding nature and formed due to shedding of sediment load by the mighty rivers Godavari and Krishna and other minor rivers, as revealed by the presence of sand bars and spits all along the shoreline, besides the presence of lagoons and inland lakes. The Kolleru natural lake was formed as a natural inland bay when the shoreline was inland. The prograding process of the entire Godavari – Krishna coastal plain left the Kolleru lake in a land locked position. Due to the constant inflow of water from rivers like Tammileru, Budameru and other minor streams, the lake water has remained fresh. The marine landforms like beach ridge complexes and mud flats occur between the lake and the present day coast line. Figures 3.6.2a-b show the physiography and drainage of the coastal districts.

3.6.3 Hydrogeology

Godavari Delta Plain: The delta has evolved in four stages and four major strand lines are deduced from reconstruction of beach ridges. The oldest beach ridge is supposed to be in direct contact with the Tertiary sandstones. The deltaic alluvium comprises black, sticky clay, silt, sand and gravel in varying proportions, deposited under fluvial and marine environments. The levees and paleo river channels, on the left bank of river Godavari have a great influence on groundwater conditions in the area

Krishna Delta Plain: It is estimated that there were four long duration shore-lines (leading to strand-lines) before the formation of present day cuspate shoreline near Divi Seema. The delta system appears to be more active on the left bank of the present day river channel. The levees, formed along the main river channel between Vijayawada and Avanigadda, support fresh groundwater aquifers in the area. The palaeo-channels and beach ridges act as fresh groundwater banks for the farmer communities in the Krishna deltaic plain.

Pennar Delta Plain: Though the Pennar river formed a well developed delta earlier, there is no well defined present day delta. The main river swings towards northeast from Nellore onwards and joins the Bay of Bengal directly without getting distributed into different river channels. The marine depositional landforms along the coast indicate that the coastal plain is prograding in nature. From the orientation of the beach ridges and other features, 3 major strand lines are traced. The lower plain around Iskapalle-Muthukuru-Nellore got developed in marine environment, while the upper deltaic plain in Sangam-Nellore, was developed in fluvial environment.

Figures 3.6.3a-b show the geology of the coastal regions and soil depth, while Figs. 3.6.4a-b show the depth to groundwater level during pre- and post-monsoon for the year 2011.

3.6.4 Groundwater Salinity

In Andhra Pradesh, the coast was subjected to marine transgressions and regressions in the past as seen from strand lines. The river deltas are of prograding nature indicating that the existing formations were previously submerged under sea; and, the salinity could have been imparted during the time of sediment deposition. Field surveys indicate a lot of variation in quality of water both spatially and depth-wise. The complexity in distribution of salinity both vertically and spatially can be attributed to depositional environment and hydrogeological frame work. Thus, it could be inferred that the geomorphic evolution of the coast had an impact on the occurrence of aquifer zones. However, groundwater abstraction, tides/cyclones and aquaculture practices, have also contributed in various degrees to groundwater salinity though locally.

Broadly, fresh water is confined to paleo-channels, levees and paleo beach ridges of sand dune complex in the multi-aquifer system of Krishna delta. Saline water occurs in tidal flats, mangrove swamps, back swamps. In the beach ridge – sand dune complex located close to the coast in Prakasam district, the water is fresh having EC of 280 µS/cm down to a depth of 18 m and moderately fresh down to a depth of 45 m bgl. For deeper aquifers, wells beyond 100 m in deltaic aquifers are invariably saline, with maximum EC of 46000 µS/cm except for a few locations like Pedapurapudi (1517 µS/cm) and Musalipadu (2200 µS/cm). In wells constructed in palaeo-channels in Godavari delta, the water is fresh down to depths varying from 8 to 70 m, with EC varying from 810 to 2130 µS/cm, below which saline water occurs. However in paleo-channels of Krishna delta, the fresh water is limited to much shallower depths of 20 m.

In Pennar delta, the beach sand dunes all along the coast line occur in a narrow strip of width varying from a few metres to 4 km with thickness varying from 6 to 7 m. These dunes form potential perched fresh water aquifers. The sand dunes are underlain by clay zones and the sediments below it contain brackish to saline water. The paleo-channels in the Pennar deltaic plain are good sources of freshwater (upto 864 m^3/d) and have been developed extensively. Pennar delta in Nellore district holds potential fresh water aquifers in Pennar, Swarnamukhi and Kandaleru alluvium upto a depth of around 85 m. Highly saline water exists beyond 120 m in deeper aquifers underlying the alluvium at Kudithipalem, Devispet, Mypad, Veguru and Chinnapallepalem.

Specifically, the saline groundwater at moderate to deeper levels is observed to be due to resident seawater in the subsurface. Quality of this in-situ saline water in the aquifers has not changed much over the period of time due to small hydraulic gradient in the coastal plains. Groundwater at shallow depths, in parts of coastal plains of East Godavari district and Krishna Delta, has become fresh over period of time due to constant flushing of in-situ saline water by the continuous irrigation from canal networks and seepage from the barrages. Sea water ingress, near the coast, occurs locally where saline groundwater is pumped for various activities like domestic, agriculture, aquaculture, and other infrastructural activities (CGWB, 2014). Figure 3.6.4c shows the variation in EC of groundwater at shallow depths.

3.6.5 Causes and Extent of Coastal Land Salinity

In Andhra Pradesh, in canal commands alone, the areas affected by water logging and salinity are estimated to be 2.74 lakh ha and 1.15 lakh ha, respectively. In many commands, there has been a rise in the water table and consequent degradation of soils through water logging and secondary salt build-up, which leads to reduction in crop yields. An area of about 0.04 Mha comprises saline soils in the coastal tracts of Andhra Pradesh. The State Ground Water Department records depict that almost all the coastal districts are suffering from the problem of groundwater salinity. As per the analysis by Ground Water Department, 38 mandals fully and 26 mandals partially in coastal districts are identified as saline groundwater mandals (East Godavari - 10, West Godavari - 14, Krishna - 13, Guntur - 12, Prakasam – 13 and Nellore – 2). Integrated study using remote sensing, hydrogeology, hydrochemistry and geophysical investigations revealed the extent of salt water intrusion upto the north part of the Kolleru lake which is about 40 km from the coast line.

Major reasons cited for increasing salinity include groundwater withdrawal for drinking and agriculture purposes that leads to saltwater upconing in areas where freshwater is underlain by saline water; water logging in canal commands resulting in rise of water table and soil degradation; intrusion through surface channels during high tides; possible seepages from aqua farms with localized impacts; overuse of fertilizers; and, drainage congestion near natural depressions such as Kolleru lake.

3.6.6 Remedial Measures

1. Salinity control in canal commands by leaching of salts through: (a) Surface drainage (b) Subsurface drainage (closed system, open system), and (c) Combination of surface and subsurface drainage.
2. Construction of subsurface cum surface dykes.
3. Utilization of groundwater recharge wells to reduce the groundwater salinity.
4. Maintenance of minimum flows in almost all the rivers.
5. Provision of gates in irrigation drains in deltaic areas to arrest sea water incursion through drains during high tides.

Additional remedial measures undertaken by the State Ground Water Department, Andhra Pradesh, involve monitoring the groundwater levels and quality of command areas and coastal areas and furnishing the same to Command Area Development Department for suitable actions like horizontal and vertical drains; use of chemical amendments such as gypsum, sulphur, iron sulphates etc. for soil reclamation under close technical supervision in some regions; and, application of rice straw, green manuring locally adopted by farmers to treat saline soils in some areas viz., Machiliptnam.

Further, it is envisaged that with higher rainfall on the east coast, it should be possible to bring drainage water from that region through controlled channels to leach the top soil in the saline areas and also use the water for artificial recharge.

Benefits of Remedial Measures

- Effectiveness of subsurface drainage systems in improving crop yields: Four years after installation of subsurface drainage system results revealed that about 1.01 t ha^{-1} increase was observed in dry season (rabi) rice yield in the area.
- Effectiveness of subsurface drainage systems on groundwater quality: To observe the groundwater quality in the pilot area and in control fields, 24 observation wells were installed

(pilot area-12, control -12) and the water quality was monitored at fortnight intervals. Groundwater quality (salinity) improved 40% in pilot area compared to control fields.

- For salinity control in commands by leaching of salts using subsurface - surface drainage systems it is noticed that unit depth of water removes 80% of the salts from a unit soil depth.
- By constructing subsurface cum surface dykes the salt water intrusion towards upstream of the dyke is stopped even during summer and there is no yield reduction during lean periods.
- The recharge wells are effective in reducing the salinity due to dilution in a radius of upto 500 m from the well.
- Prevention of salinity in irrigation drains in deltaic areas during high tides.

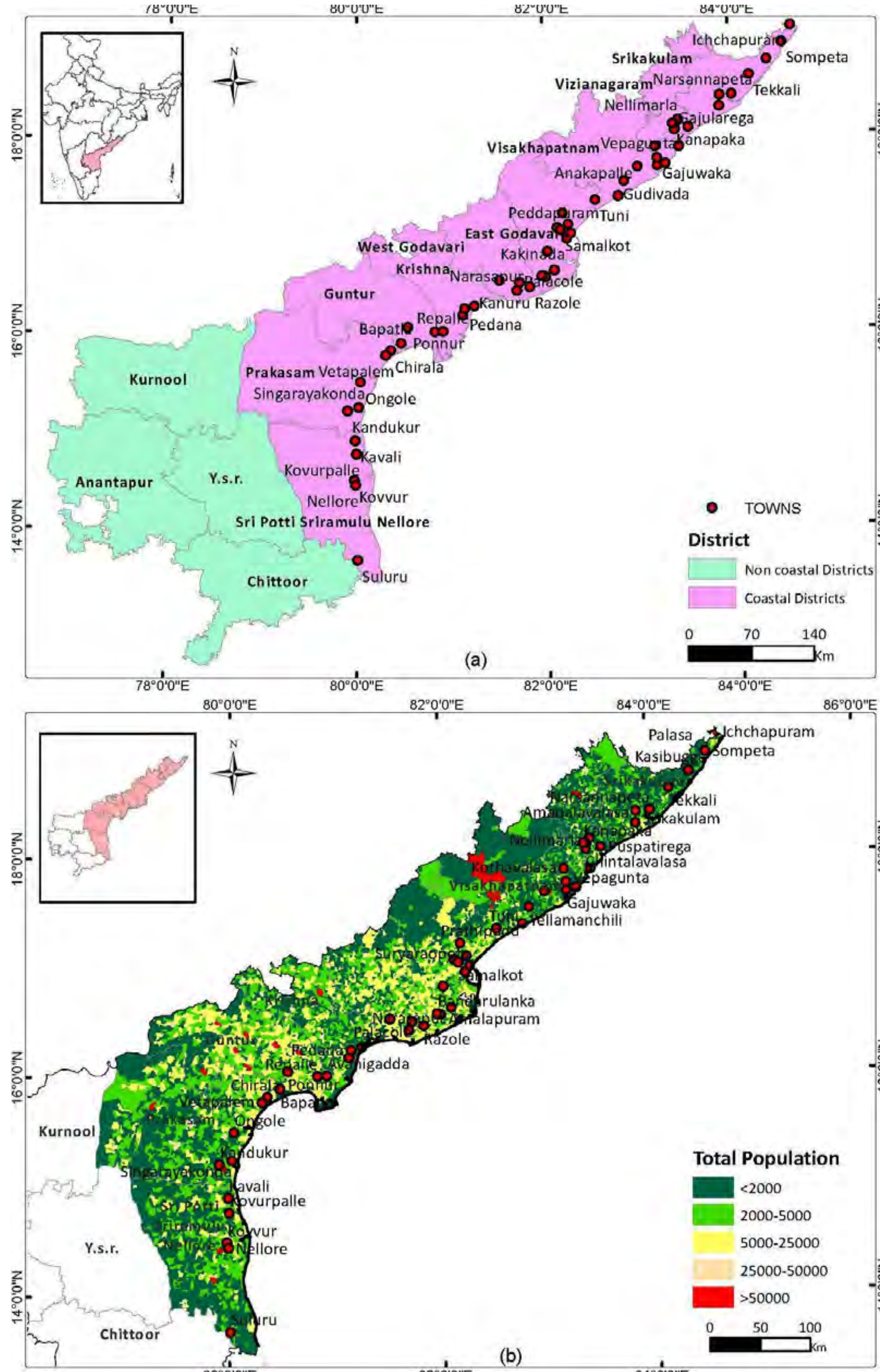


Fig. 3.6.1(a) Administrative map of Andhra Pradesh showing coastal districts (b) Population distribution of coastal districts of Andhra Pradesh

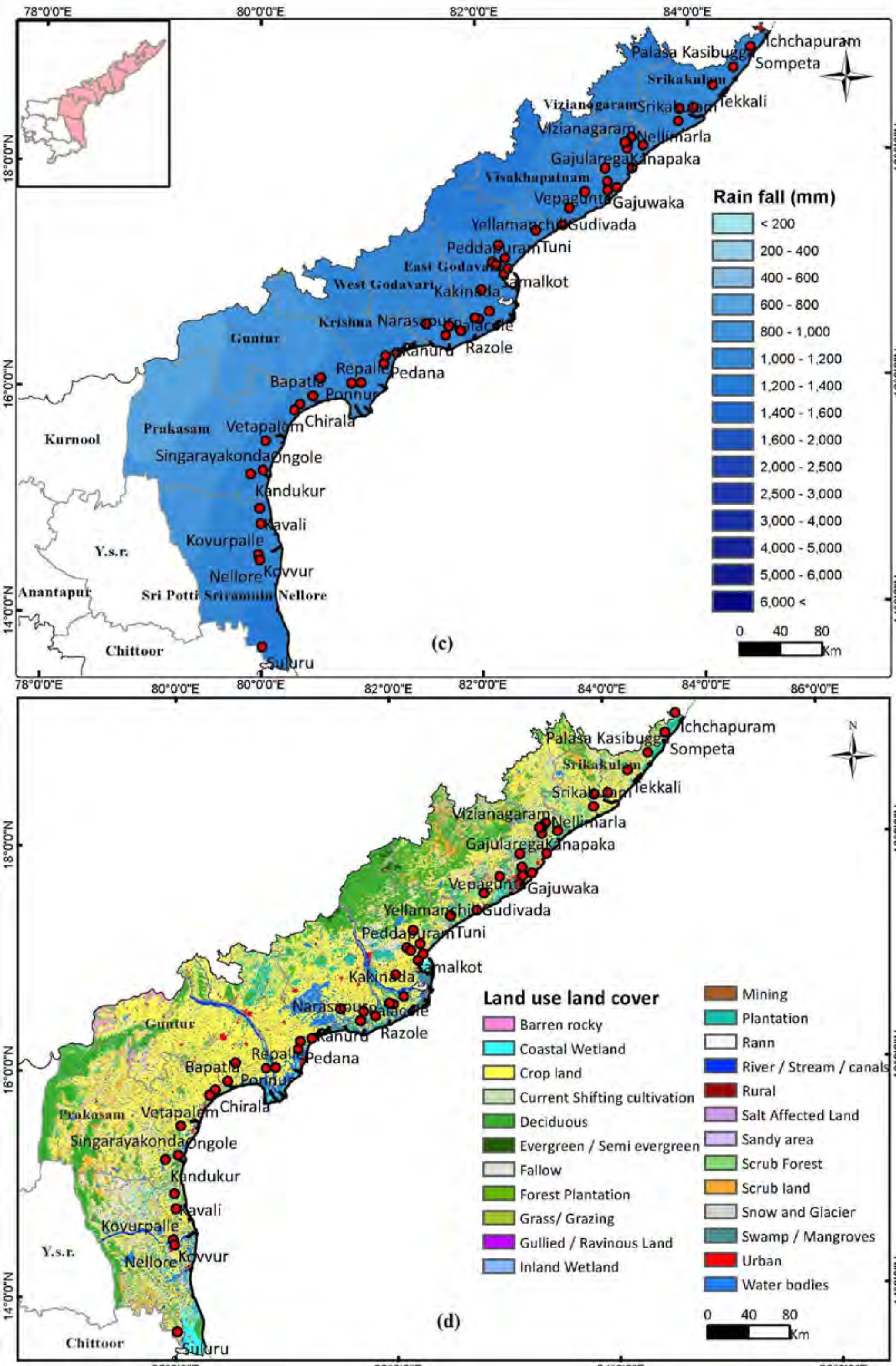
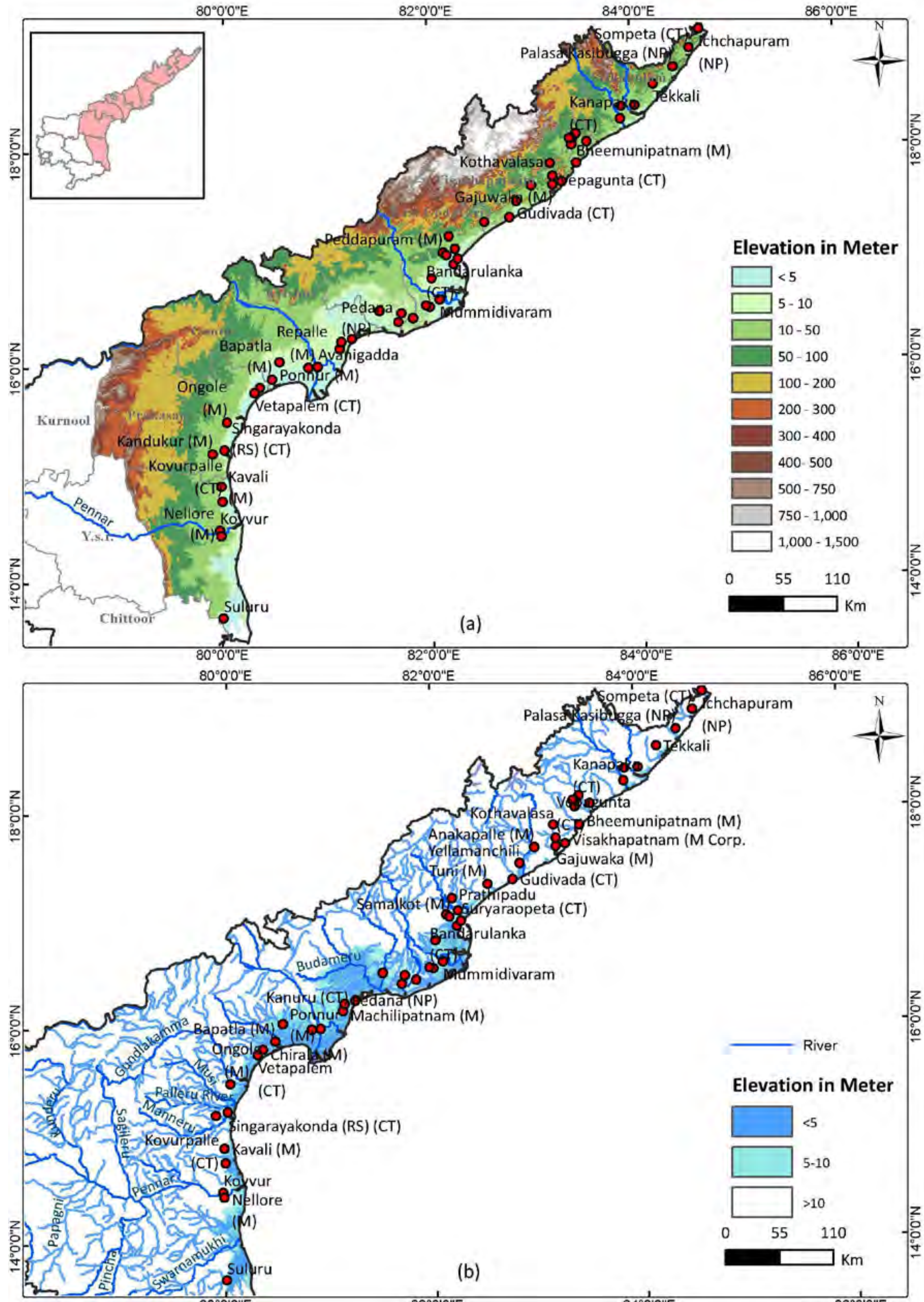


Fig. 3.6.1(c) Rainfall distribution of coastal districts of Andhra Pradesh (d) Land use and land cover of coastal districts of Andhra Pradesh



3.6.2 (a) Physiographic map of Andhra Pradesh (b) Drainage map of Andhra Pradesh showing low elevation coastal areas (< 10 m amsl)

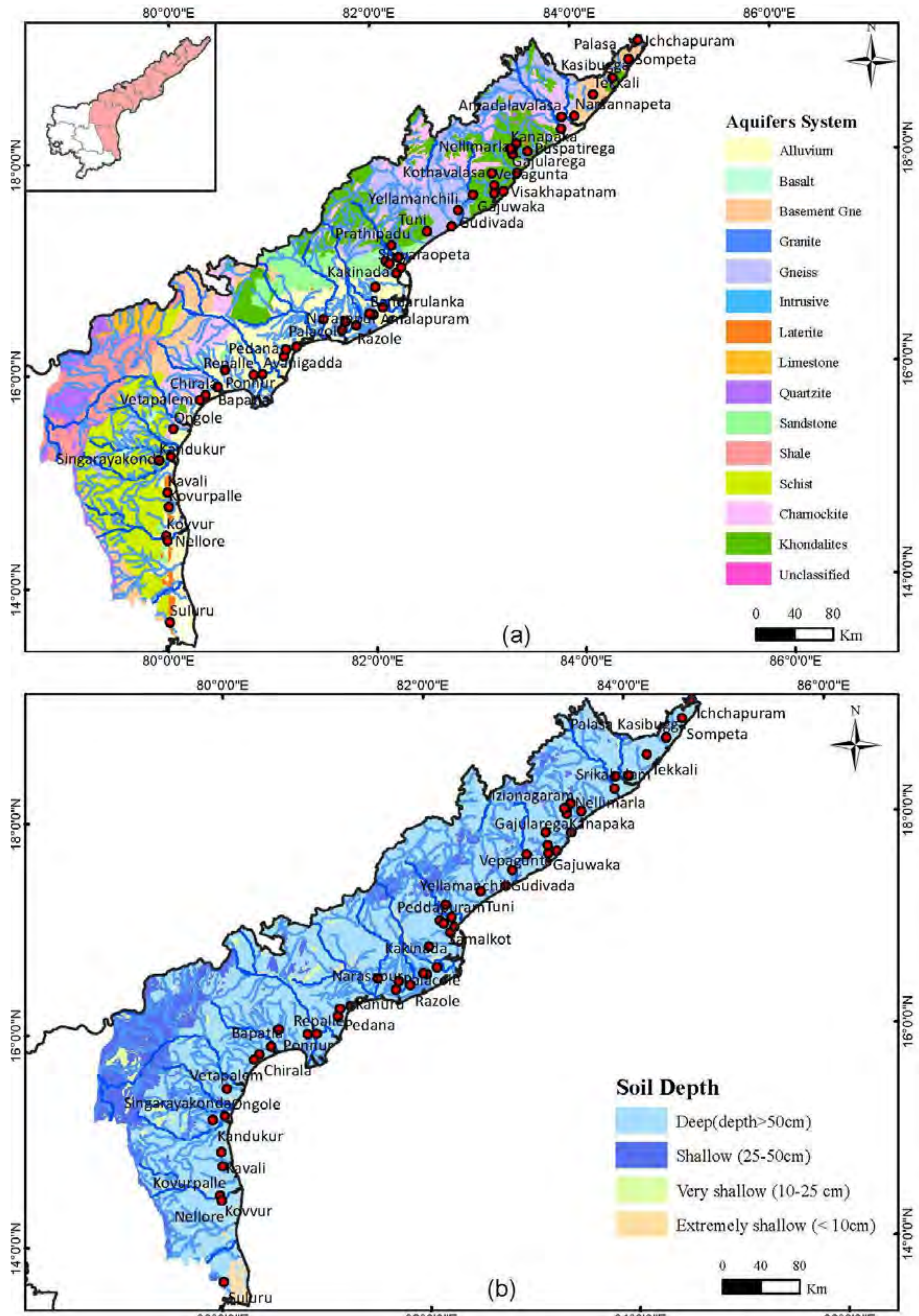


Fig. 3.6.3 (a) Aquifer map of coastal districts of Andhra Pradesh (b) Soil depth map of coastal districts of Andhra Pradesh

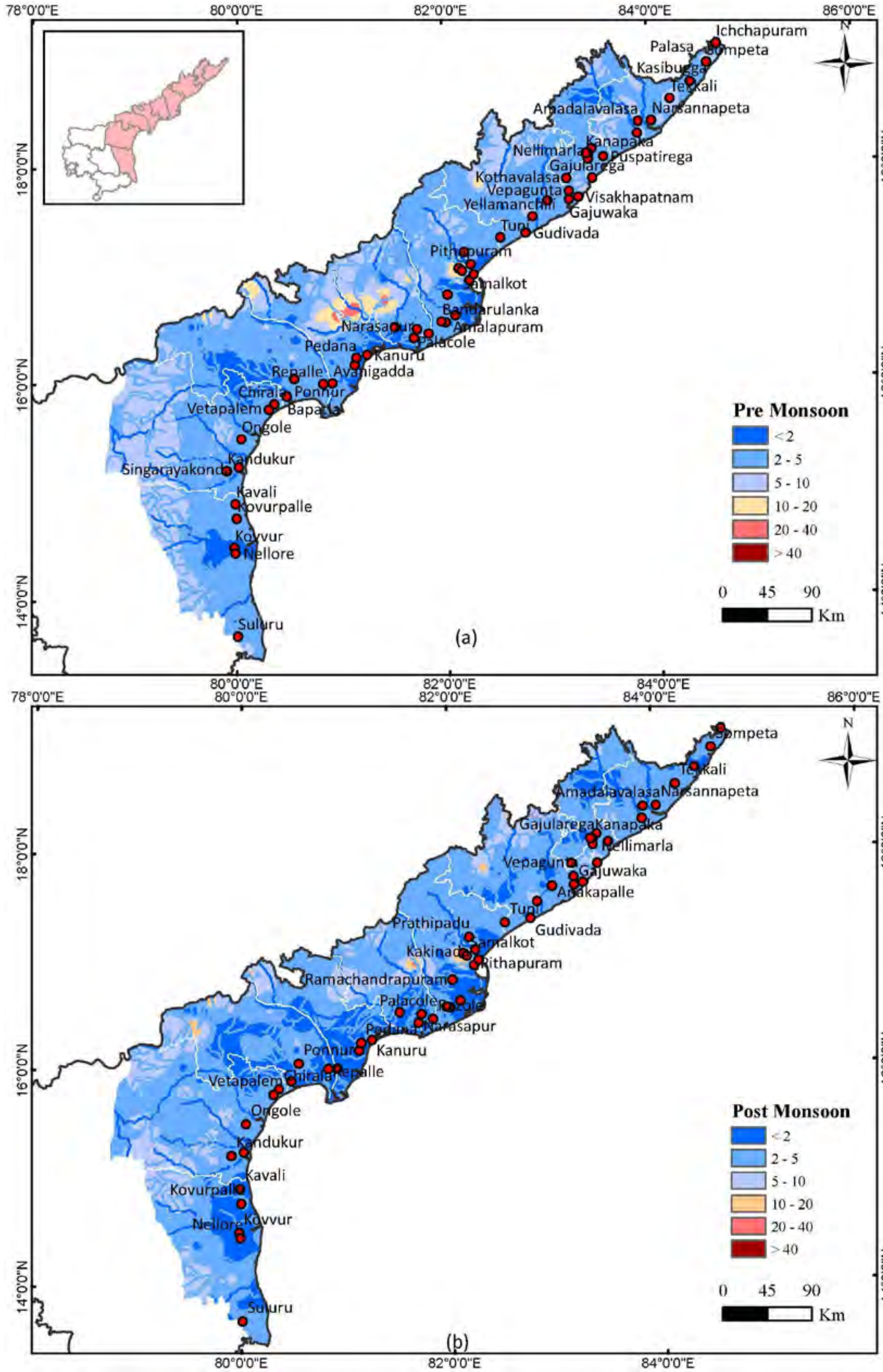


Fig. 3.6.4 (a) Pre-monsoon water level of coastal districts of Andhra Pradesh (in meters) (b) Post-monsoon water level of coastal districts of Andhra Pradesh (in meters)

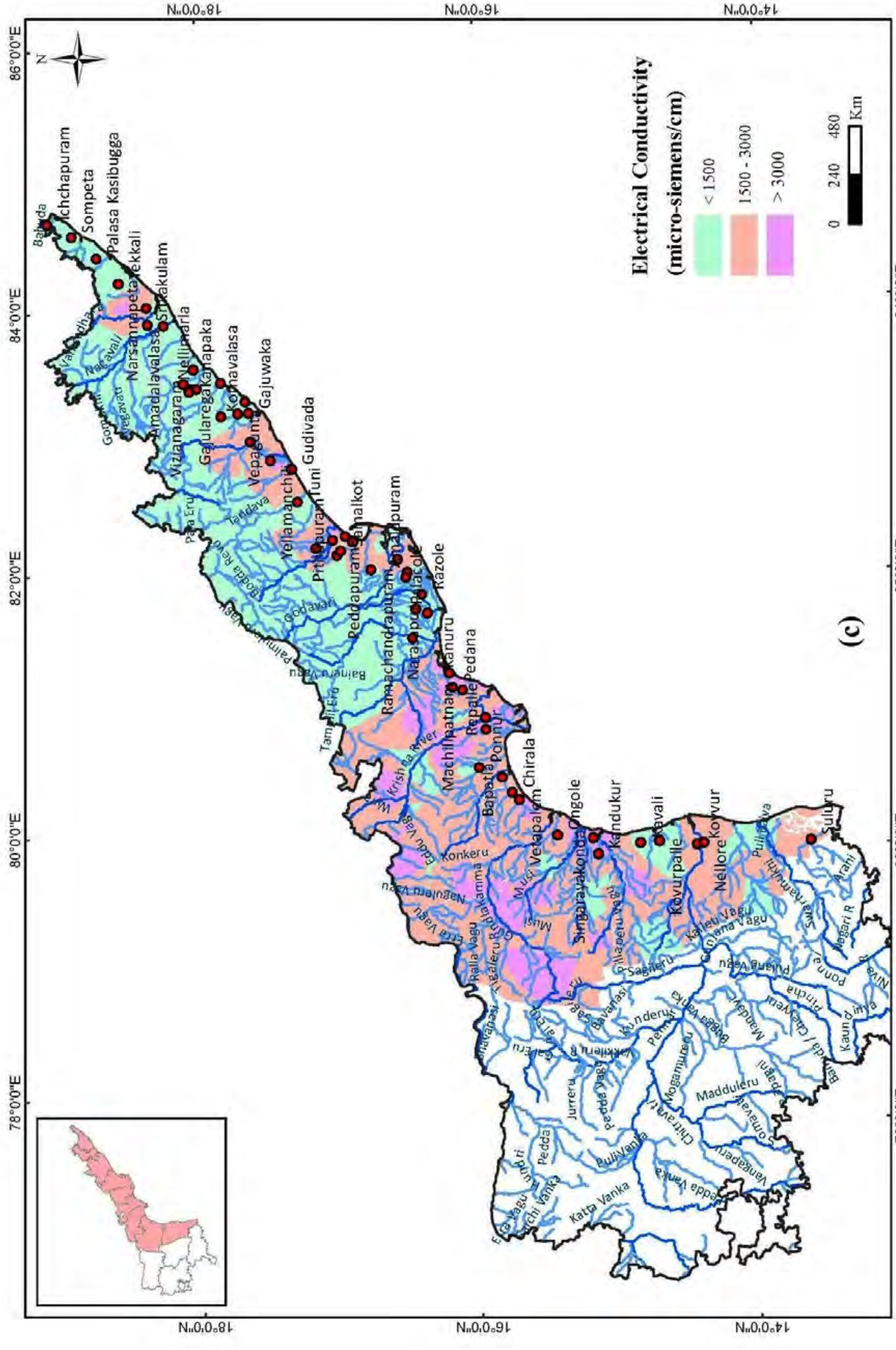


Fig. 3.6.4 (c) EC map of shallow groundwater for coastal districts of Andhra Pradesh

3.7 ODISHA

3.7.1 General

Odisha has only 15% of its area in coastal districts, with 32% of the dynamic ground water resources of the state.The length of the coastal region is about 476.40 km and encompasses the coastal tracts of districts namely, Baleshwar, Bhadrak, Kendrapara, Jagatsinghpur, Puri, Khordha and Ganjam. Figure 3.7.1 shows the locations of the coastal districts; sparsely/ medium populated areas in villages and highly populated urban areas in towns and cities, variation in average annual rainfall (1971-2005) across the coastal districts areas and land use / land cover conditions. The land use map shows that a major part of the area is occupied under agricultural land. The coastal tract of Odisha is one of the most disaster prone areas, frequently subjected to cyclones as well as severe flooding induced by storms. The number of cyclonic disturbances (depressions and cyclonic storms) in a year ranges from 4 to 15. The frequent cyclonic storms create havoc in the coastal area causing the agricultural low-lying areas to remain submerged under a sheet of seawater for a period of time, thereby adversely affecting the soil and the water quality of the shallow coastal fresh water aquifers.

3.7.2 Physiography and Drainage

The coastal plain of Odisha exhibiting a low gradient is drained by rivers of peninsular origin. The major rivers are Mahanadi, Brahmini, Baitarani, Rushikulya and Budhabalang (Figs. 3.7.2a-b). Owing to the gentle slope, particularly in low lying coastal areas, disposal of surface runoff takes longer and surface drainage problem becomes acute. The coastal plain is bordered on the west by the Archaean crystalline basement rocks of the Eastern Ghats. The eastern boundary of the Eastern Ghats is believed to be a fault responsible for the formation of the coastal depression. In the deltaic plain and coastal tracts, the basement tectonics are hidden under the thick cover of Quaternary (dune sands, alluvium - clay, silt, gravel and sand, and laterite) and Tertiary (clay, gritty sandstone, gravel, loosely cemented sandstone, arenaceous limestone and clay stone) sediments. The coastal tract has several ridge and depression structures which are possibly the surface expression of numerous fault zones (Om Prakash et al., 2001).

The arcuate shaped delta complex of Mahanadi and Brahmini-Baitarani rivers protrudes for about 60 km into the Bay of Bengal. The upper delta plain displays anastomose distributaries, flood plains and abandoned channels. The lower delta plain is characterized by tidal marshes and flats, tidal creeks, channels and estuaries and paleo sand ridges etc. The coastal lakes developed in the region are Chilka, Sar and Samang, of which the large brackish water Chilka lake is one of India’s hotspots of biodiversity.

At least 10 per cent of the 436 km Odisha coast is prone to high erosion; the stretches near Puri, Chandrabhaga, Gopalpur, Satabhaya and Pentha are the most vulnerable. The Odisha coast is subject to a strong littoral drift. The process accompanied by the sediment movement leads to a constant changing shoreline and causes changes in profile of several estuaries along the coast.

3.7.3 Hydrogeology

On its western side, the coastal plain is bordered by the Archaean crystalline basement rocks, viz., granite, gneiss, charnockite, khondalite and quartzite of the Eastern Ghats. The Mahanadi delta was developed during Upper Pleistocene to Holocene and the deltaic sediments were deposited on the Mio-Pliocene floor. The delta plain of Mahanadi starts close to Cuttack, about 60 km from the coast line, while that of Brahmani-Baitarani starts near Jajpur in Odisha. Almost up to 35 km inland, palaeo sand ridges are present. There are four strand lines each consisting of a number of parallel ridges. Flood plains in this delta are wide spread.

In the coastal tract of Odisha, recent to sub-recent sediments were deposited by various rivers to build up deltas at their mouths, which later on got merged. The lithology is characterized by cyclic sedimentation of sand and gravel with subordinate clay. Besides, alluvium of recent age occurs in numerous narrow disconnected pockets adjoining most of the river courses. The maximum width of the alluvial plain is about 100 km wide covering more than 20,000 km^2 in Mahanadi delta area. The thickness of alluvium is about 150 m near the coast.

In Balasore and Bhadrak tract, in a 10 km wide strip along the coast, aquifers are generally saline at the top and freshwater aquifers occur at depths. At Karanjasole, freshwater aquifers occur below 165 m depth. Further south in Ghanteswar- Chandbali- Krushnapur area, freshwater occurs below 165 to 173 m depth and tapped through deep tube wells. In the remaining part of the district, adequate thickness of freshwater aquifer occurs within 300 m depth. In the Jaleswar-Basta-Baliapal Remuna- Balasore tract freshwater aquifer occurs within 100 m depth.

In large areas falling in Rajkanika – Aul – Rajnagar –Pattamundai – Kendrapara -Marshaghai, Mahakalpara, Kujang, Patkura and Ersama blocks, aquifers down to a depth of 60 to 320 m are saline to brackish in nature, and freshwater occurs below this depth. In areas to the west of the saline tract, freshwater aquifers occur within 100 to 150 m and both shallow and medium deep tubes well are feasible. In the saline tract, only deep tube wells are feasible. At Tirtol, shallow freshwater (within 52 m depth) is underlain by brackish to saline aquifer down to a depth of 160 m, below which, the second group of freshwater aquifer occurs. At Khandatari, about 10 km west of Tirtol, no saline water is encountered within 184 m depth.

In Puri and Khurda Tract, the aquifer and the Aquiclude formation is quite irregular. In the eastern part of Puri district falling in parts of Nimapara, Gop, Balipatna, Kakatpur, Astarang (West) blocks, fresh water occurs within a depth of 100 m below which groundwater is brackish to saline in nature. In the Puri-Brahmagiri-Siruli tract, aquifers are generally saline, at all depths down to the bedrock except in local pockets. In the area around Sakhigopal, groundwater is slightly brackish to saline down to the bed rock (282 m). In Puri town, freshwater aquifers occur at shallow (within 40 m depth) as well as at deeper depths (135 - 200 m depth). The deeper freshwater zone pinches out towards northeast. At Astarang, only the dug well zone (within 15 m depth) contains freshwater, beyond which aquifers are brackish to saline. In Pipili area, only shallow tubewells are feasible. Figures 3.7.3a-b show the aquifer systems and soil depth in the coastal districts of Odisha, while Figs. 3.7.4a-b show the variation in depth to groundwater level for the year 2011.

3.7.4 Groundwater Salinity

In the coastal tract of Odisha, a considerable area of around 5400 km^2 falling in the districts of Balasore, Bhadrak, Jajpur, Kendrapara, Jagatsinghpur, Cuttack, Puri and Khurda suffers from groundwater salinity hazard. It is confined to the region extending from east of Kasba Kumurda - Balasore- Gopalpur - Basudevpur- Kothar - Chandikhole - Salepur - Raghunathpur - Niali - Pipli - Chilka up to the coast line. The saline ground water zone in the coastal tract has a width around 15 km in the extreme northeast around Karanjasole, and 1.5 to 5 km in the northern part between Balasore and Saud/Kalyani sector. In the extreme southeast, it extends for 2 to 3 km around Chilka Lake. The salinity of groundwater is prominent in the deltas of Mahanadi-Brahmani, Subarnarekha. However, the shallow Phreatic fresh water aquifers occur as localized pockets in coastal sand dunes and paleo channels throughout the coastal tract. Groundwater salinity in this region is mainly of geogenic origin. Broadly, fresh/saline groundwater zones are found to exist in the multi-aquifer system as follows: i) fresh water zone overlying saline water zone, ii) saline water zone overlying fresh water zone, iii) alternate fresh and saline water zone and iv) saline water with or without fresh water zones (< 4 m thick). Figures 3.7.4c shows the EC of groundwater at shallow depths, while Fig. 3.7.5 shows the saline zone along the coastal tracts.

3.7.5 Causes and Extent of Coastal Land Salinity

In the multi-aquifer systems of the coastal region, groundwater salinity is mainly a geogenic phenomenon. The saline tract extends from Chandaneswar (Baleswar District) to Brahmagiri (Puri District). Table 3.7.1 gives the district wise areas affected by salinity. The width of the tract varies from 10-55 km in different coastal districts.

Table 3.7.1 Areas affected by salinity in the coastal districts of Odisha

Sl. No.	Coastal District	Saline Groundwater Area (Ha)
1	Ganjam	11688
2	Puri	53016
3	Jagatsinghpur	57849
4	Kendrapara	213143
5	Bhadrak	125083
6	Baleshwar (Balasore)	59379
7	Jaipur	19367
	Total	**539525**

According to hydrogeological and hydrochemical profiling surveys by State Ground Water Department, parts of 7 coastal districts covering 42 blocks, suffer from salinity problem in different magnitudes. The details are indicated in Table 3.7.2 below (also refer Fig. 3.7.5).

Table 3.7.2 Groundwater salinity status in coastal tracts of Odisha

Sl. No.	District	Sl. No.	Block		Saline Groundwater Area (ha)
			Partly Saline	Fully Saline	
1	Balasore	1	Bahanaga		640
		2	Balasore		21283
		3	Baliapal		16344
		4	Basta		1272
		5	Bhogarai		18566
		6	Remuna		1274
2	Bhadrak	7	Basudevpur		21161
		8		Chandabali	68411
		9	Dhamnagar		11150
		10	Tihidi		24361
3	Ganjam	11	Chhatrapur		1648
		12	Chikiti		3185
		13	Ganjam		2700
		14	Khalikote		1055
		15	Rangeilunda		3100
4	Jagatsinghpur	16	Balikuda		8500
		17		Erasama	37482
		18	Kujanga		7957
		19	Naugaon		3910
5	Jajpur	20	Bari		4209
		21	Binjharapur		6458
		22	Dasarthpur		8700
6	Kendrapara	23	Aul		19336
		24	Derabish		8570
		25	Garadapur		500
		26	Kendrapara		16960
		27		Mahakalapada	40200
		28		Marshaghai	18850
		29	Pattamundai		20700
		30		Rajakanika	28970
		31		Rajnagar	59057
7	Puri	32	Astaranga		5550
		33	Brahmagiri		7812

		34	Delanga		2090
		35	Gop		10320
		36	Kakatpur		4000
		37	Kanasa		3120
		38	Krushnaprasada		7631
		39	Nimapada		4455
		40	Pipli		1090
		41	Puri		6128
		42	Satyabadi		820
			Total Area		**539525**

In the event of large scale drilling of wells without proper cement sealing and technical supervision, the alternating fresh and saline aquifers of the region are likely to become interconnected, resulting in conversion of fresh aquifers to saline aquifers. Moreover, the coastal sand dunes, which are the repositories of fresh groundwater in saline affected areas, need to be protected as they are the only sources of drinking water in these areas. Coastal land salinity in the region is also affected by the high coastal erosion rates along the shoreline of Odisha.

3.7.6 Remedial Measures

The Geographical location and physicalenvironment of the Odisha coast make it vulnerable to frequent cyclonicdistributions. The high wind speed together with torrential rain and stormsurge associated with cyclonic disturbances damages to the coastalsettlement. Erosion of coastal bank is a regular phenomenon during high tidecompounded with Cyclone in Bay of Bengal. To check the saline ingress in Odisha generally following measures are being under taken.

- Construction of Saline Embankments facing to the Bay ofBengal and adjacent to the river mouths.
- Construction as well as renovation of Creek irrigation projectswith construction of control structures to check the salinityingress in the command.
- Construction of Sea Wall at vulnerable reaches of the coast line to check the inundation of the adjoining area from storm surge.

Construction of different type structures:

- **Control Sluice:** Control sluice are being constructed at mouth of the creeks or sub creeks to control the saline ingress due tidal effect in to the command area.
- **ln stream structures:** ln stream structures / Check dams are being constructed across the creeks, nallahs at suitable location so as to check the saline ingress and to facilitate storage of sweet water flowing to the sea for irrigation as well as domestic purpose.
- **Construction of Saline Embankment:** Saline Embankments along with necessary bank protection works are being constructed at strategic location i.e adjacent to the river mouth and adjoining area to provide protection from saline inundation.

Projects undertaken to arrest the salinity intrusion are listed in Table 3.7.3, while the expenditure incurred is given in Table 3.7.4.

Table 3.7.3 Remedial measures adopted in Odisha

Sl. No.	Project	Works (Completed + Ongoing)
1	Renovation creek projects	16
2	Construction of creek projects	9
3	Irrigation project with sluice	1
4	Instream structures	3
5	Check dam	1
	Total	30

Table 3.7.4 Expenditure incurred in completed and ongoing works

Sl. No.	District	Completed (Rs in cr)	Ongoing (Rs in cr)
1	Kendrapara	17.22	13.77
2	Bhadrak	9.42	2.84
3	Jagatsinghpur	12.10	3.60
4	Puri	2.52	12.88
5	Khurda	-	14.15
	Total	41.2663	47.25

The details of the completed and ongoing schemes are given in Annexure 3.7A & Annexure 3.7B respectively.

The Photographs of already taken up schemes are given in Fig 3.7.7 to Figure 3.7.10.

Benefits of Remedial Measures

The following benefits are accrued from the remedial measures adopted in Odisha.

1. Coastal erosion is prevented.
2. A vast area of crop land protected from salt water intrusion in paddy fields, thereby increasing crop yields.
3. Coastal villages remain protected and become less vulnerable to coastal flooding and cyclone.
4. Sea beaches are improved along with sand dune stabilization.
5. Nesting sites for Olive Ridley Turtles remains protected.

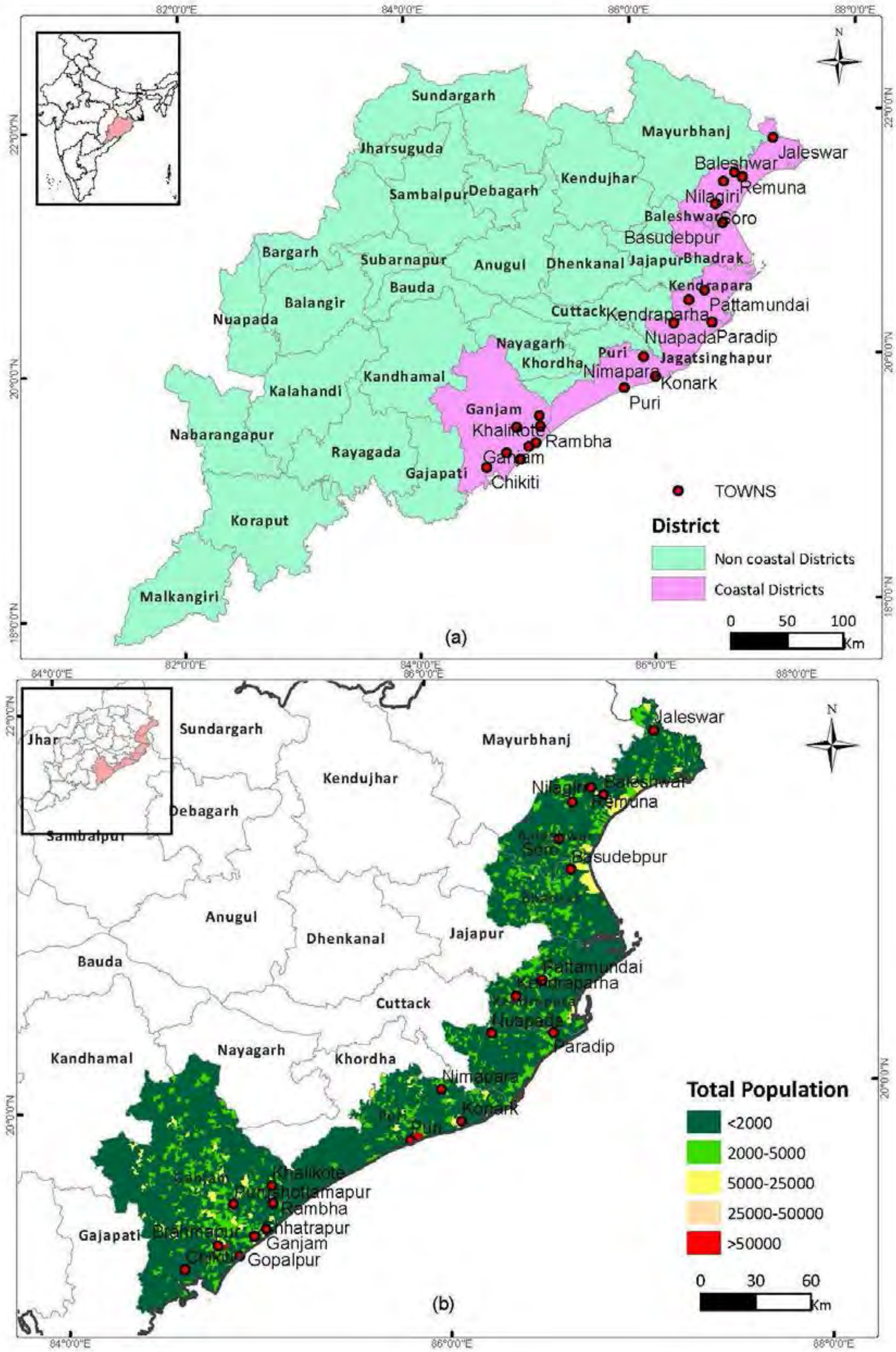


Fig. 3.7.1(a) Administrative map of Odisha showing coastal districts (b) Population distribution of coastal districts of Odisha

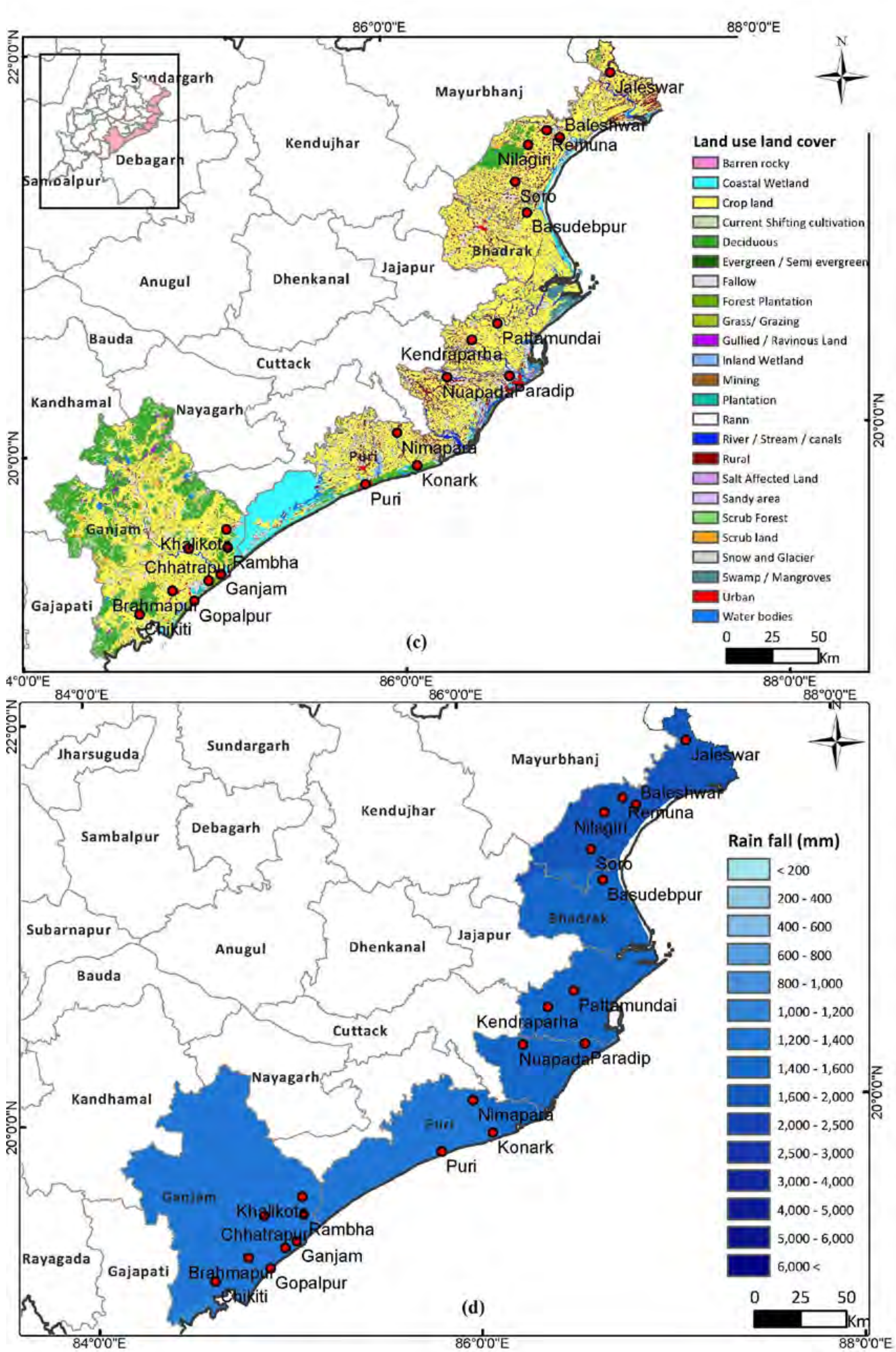


Fig. 3.7.1(c) Land use and land cover of coastal districts of Odisha (d) Rainfall distribution of coastal districts of Odisha

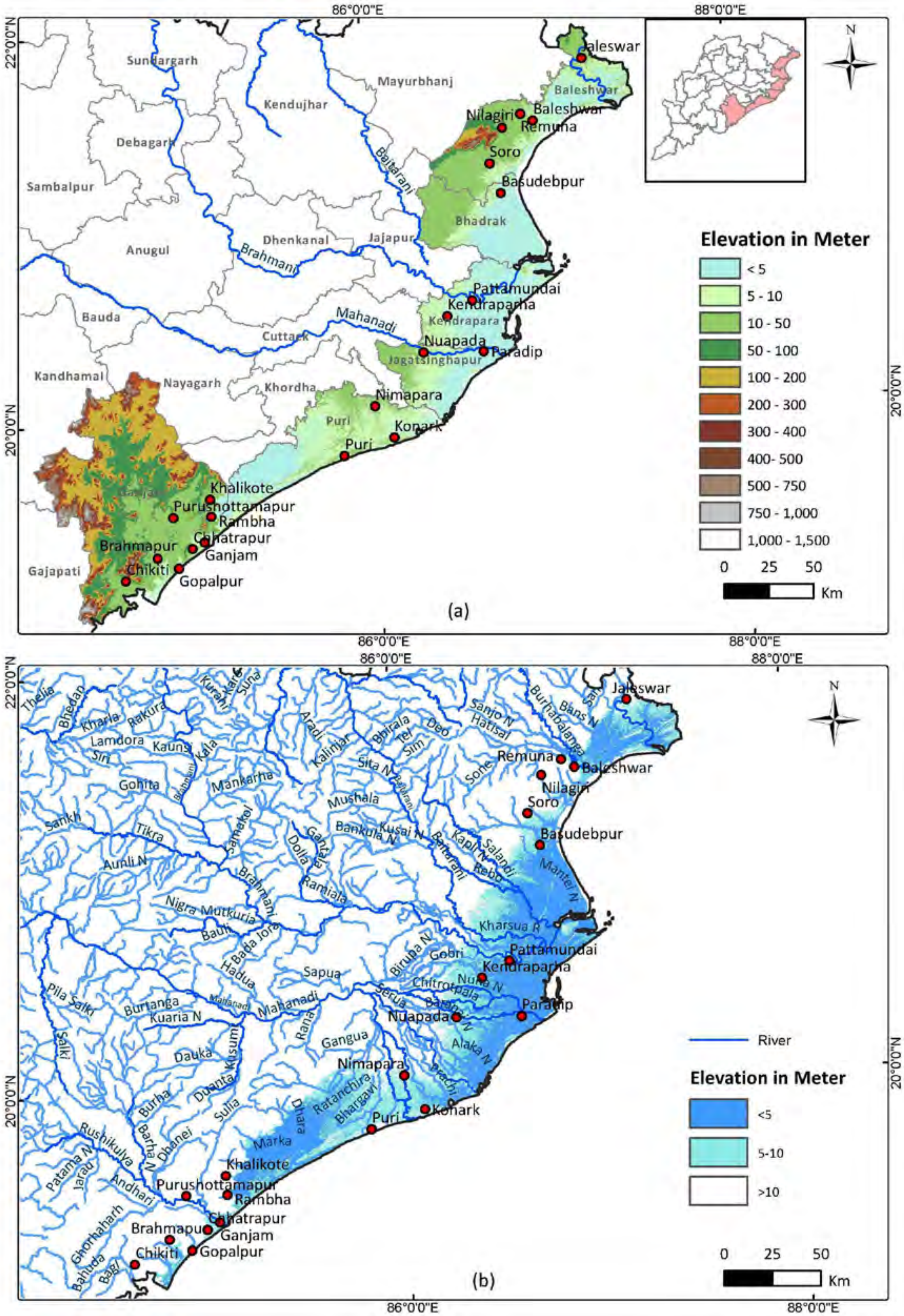


Fig. 3.7.2 (a) Physiographic map of Odisha (b) Drainage map of Odisha showing low elevation coastal areas (< 10 m amsl)

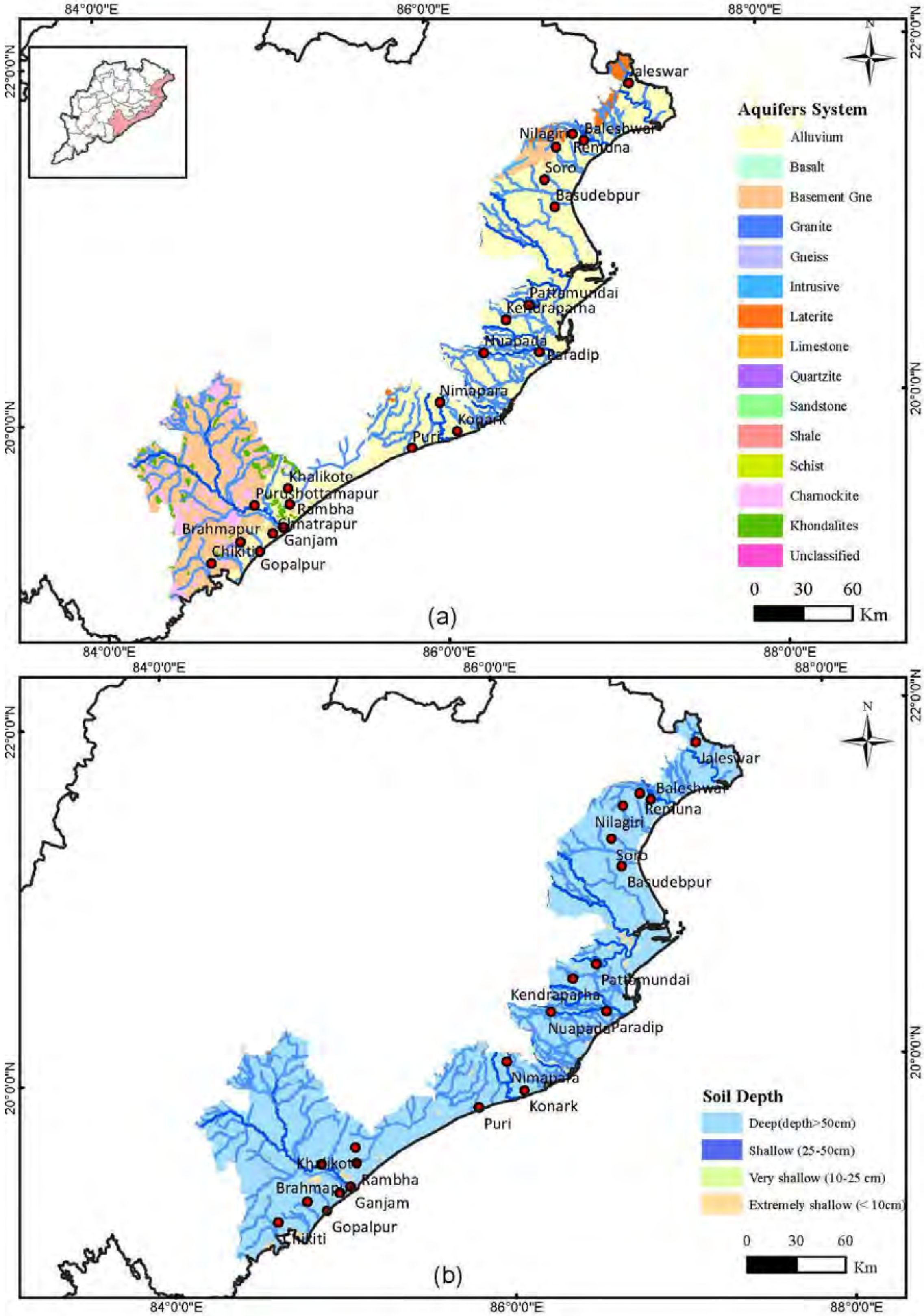


Fig. 3.7.3 (a) Aquifer map of coastal districts of Odisha (b) Soil depth map of coastal districts of Odisha

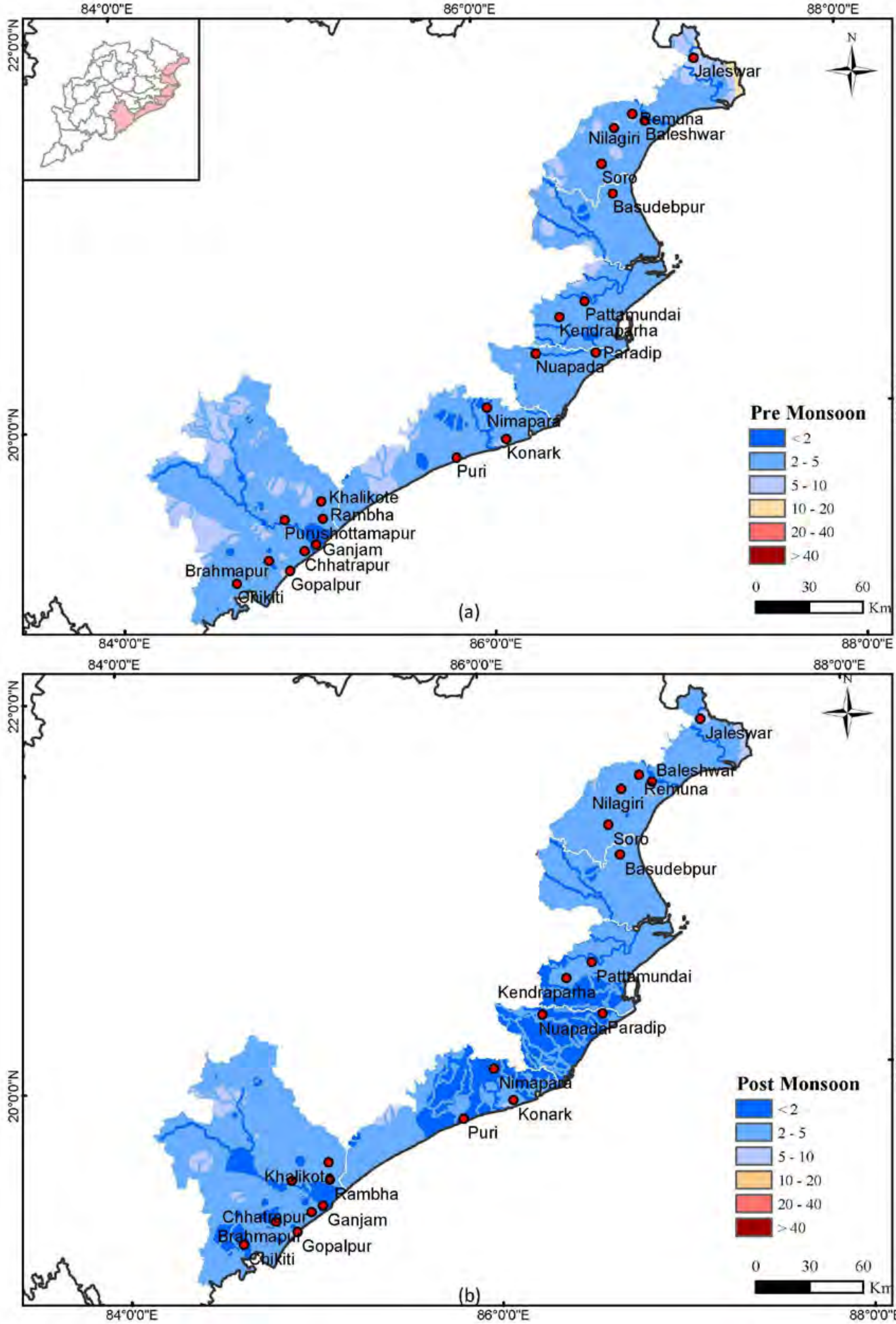


Fig. 3.7.4 (a) Pre-monsoon water level of coastal districts of Odisha (in meters) (b) Post-monsoon water level of coastal districts of Odisha (in meters)

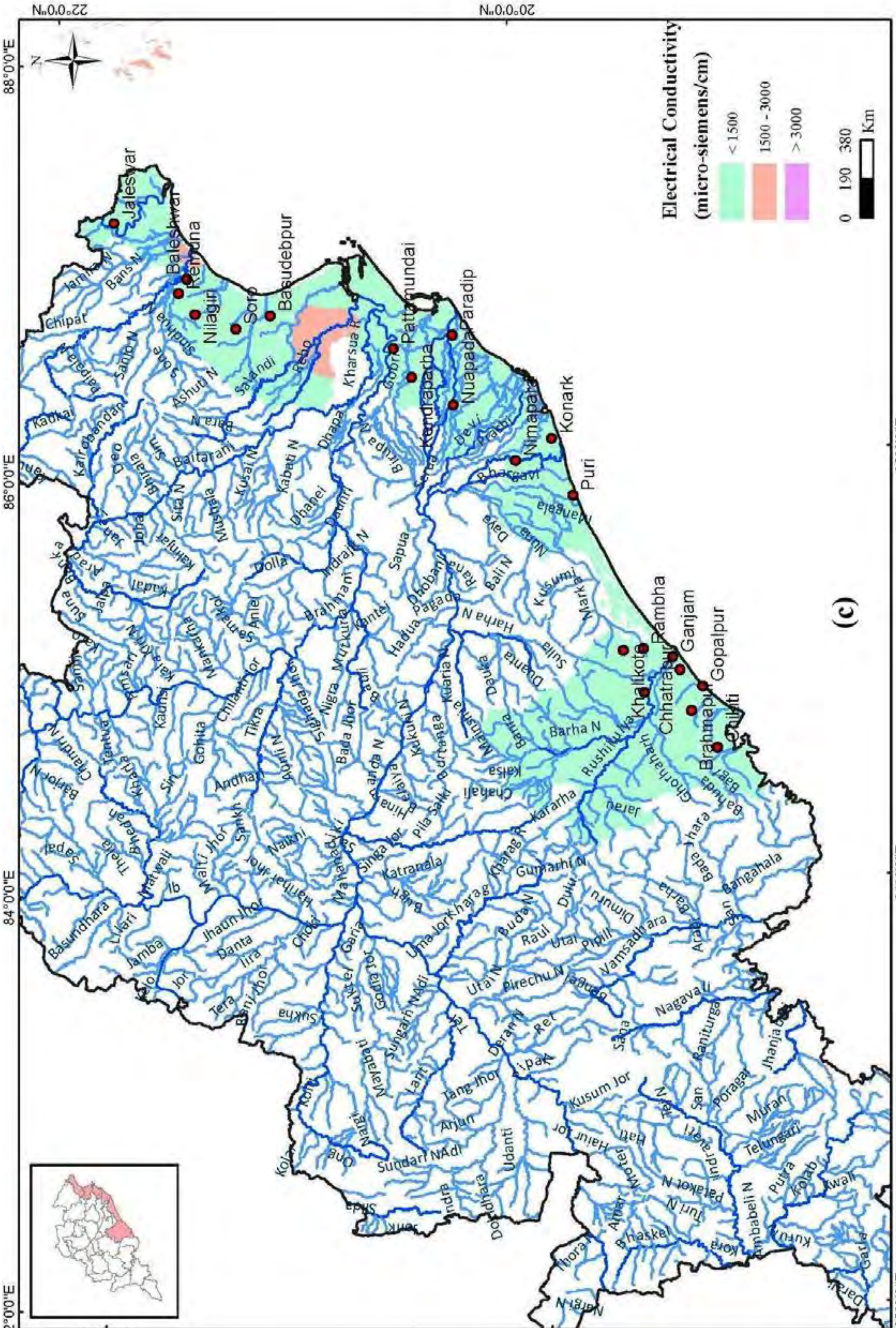


Fig. 3.7.4 (c) EC map of shallow groundwater for coastal districts of Odisha

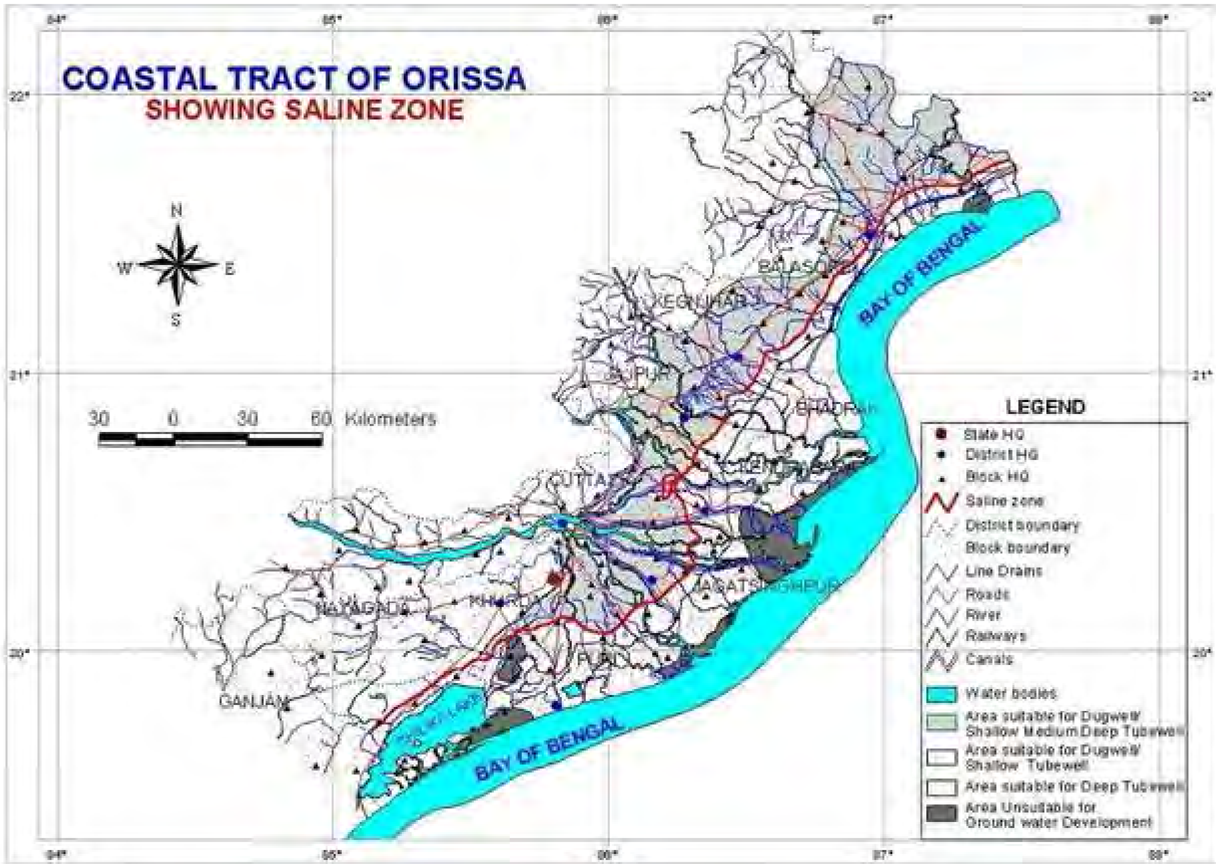


Fig. 3.7.5 Coastal tract of Odisha showing saline zone

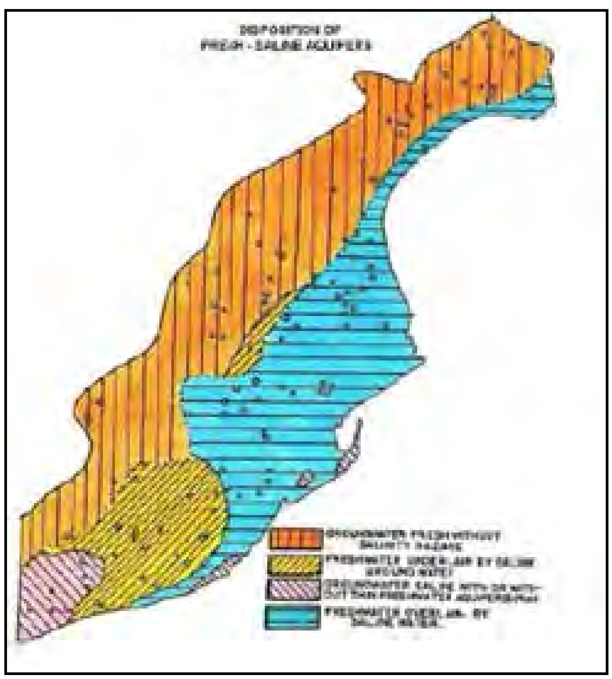


Fig. 3.7.6 Disposition of fresh-saline aquifers in coastal Odisha, CGWB (2014a)

Fig 3.7.7 Control Sluice at Rambhila

Fig 3.7.8 Talasuan Creek Irrigation Project

Fig 3.7.9 Malliatutha Check Dam

Fig 3.7.10 Rabi Paddy Crop in Command area of Kaliaghai Creek, Aul

3.8 WEST BENGAL

3.8.1 General

The state of West Bengal has a coastline about 157.50 km long consisting of four coastal districts namely North 24 Parganas, South 24 Parganas, Haora, and Purba Medinipur. Starting from a narrow strip of land from its south-west corner at the West Bengal-Orissa border near Digha, the coastal area gradually becomes wider towards east and ultimately meets the eastern boundary bordering Bangladesh. Though the area covered under coastal districts is 32%, the dynamic groundwater resource in the aquifers is only 3%, as the groundwater in these districts exists mostly under confined condition in deep aquifers. The average rainfall in the State is 1750 mm. In the Himalayan Region i.e. in northern parts, the average rainfall ranges from 2500 - 6000 mm, while in the southern part, average rainfall ranges from 1400 - 2100 mm. Figure 3.8.1 shows the locations of the coastal districts; sparsely/ medium populated areas in villages and highly populated urban areas in towns and cities, variation in average annual rainfall (1971-2005) across the coastal districts areas and land use / land cover conditions. The land use maps show that large parts of the coastal districts are occupied by agricultural land.

3.8.2 Physiography and Drainage

The geography of the state is unique in the sense that its northern part is in the Himalayan Range, whereas the extreme southern part touches the Bay of Bengal and is covered by the Active Delta of the Sundarbans Mangrove forest in the south-western estuarine tracts of the Ganga-Brahmaputra system. The coastal region of the districts of South 24 Parganas and North 24 Parganas is popularly known as Sundarbans. The Sundarbans region is bounded by the river Hugli on the west, Bay of Bengal on the south, Ichhamati-Kalindi-Raimangal Rivers on the east, and "Dampier-Hodges Line" on the north (CSSRI, 2003).

The coastal region mainly comprises of recent and sub-recent alluvial plains which gradually merge with the deltaic plain inclined towards the south-east direction. The region belongs to the broad geographic unit 'Alluvial and Deltaic Plains' of West Bengal. Under this region, geomorphic sub-units such as lower alluvial plain, deltaic flood plains, marshy / inundated area, coastal sand dunes, coastal plains, etc. predominate. In the district of Medinipur, coastal sand dunes, coastal plains and deltaic flood plains dominate. In Haora, geomorphic sub-units like natural levee and deltaic plain predominate. Damodar is the main river in the estuarine part of Haora district, whereas, Rupnarayan, Haldi and dry Rasulpur are the major rivers in the coastal part of Purba Medinipur district. In the deltaic plains of the districts of North and South 24 Parganas (Sundarbans), depositional activities of the streams are prominent. The major physiographic divisions of the area are: (i) low lying flood plains, (ii) paleo channels and oxbow lakes, and (iii) deltaic plains. In low lying flood plains category, most of the area is nearly level to very gently sloping. Paleo channel and oxbow lakes are mostly found in the North 24 Parganas district. Most of these areas are under water during most part of the year and get exposed only during a few months of the dry period (pre-monsoon). The deltaic plains are confined to the south-east part of the North and South 24 Parganas districts and cover about 60% of the coastal area of West Bengal (Chakrabarty 1991, 1995). These low lying marshy lands with elevation below the high tide mark get submerged under brackish water during high tides. The tide levels are also quite high in this region with highest tide levels up to 4.5 m.

In the Sundarbans region, the river Hugli with its tributary systems meanders severely in its confluence with the Bay of Bengal and is divided into a number of branches, enclosing and intersecting the delta. In the process it leaves a number of meandering scars, which include dead channels, creeks, brackish water lakes, swamps, etc. Both the districts (North and South 24 Parganas) are traversed by a number of moribund rivers, which are primarily spill channels of Hugli River. Six major estuarine rivers, viz., Muri Ganga, Saptamukhi, Thakuran, Matla, Gosaba and Herobhanga meet the Bay of Bengal on their southern mouths and are interconnected with each other through numerous criss-cross creeks and small rivers creating about 102 islands of which 54 islands have been cleared and converted to habitated lands and the rest are still part of the Sundarbans mangrove ecosystem. These tidal estuarine rivers carry the seawater from the Bay of Bengal during high tide and inundate the mangrove forests at regular intervals. The river Hugli (Ganga) in the west is the main river carrying freshwater from upstream reaches of lower Ganga delta into the Sundarbans (Indian part), since most of the other estuarine rivers have lost their earlier connections with river Ganga over time (Morgan and McIntire, 1959). Figures 3.8.2a-b show the physiography and drainage of the coastal landscape of West Bengal.

Based on tidal amplitude, the West Bengal coast can be sub-divided into two different coastal environments:

- The macro tidal (tidal range > 4 m) Hugli estuarine plain characterized by a network of creeks encompassing the islands with spectacular mangrove vegetation and off-shore linear tidal shoals from Sagar Island to the border of Bangladesh to the east.
- Meso tidal (tidal range 2 – 4 m) Medinipur (Digha-Sankarpur-Junput) coastal plain to the west of the Hugli estuary with rows of sandy dunes separated by clayey tidal flats from Sagar Island to Orissa border to the west.

Due to heavy rainfall, flat topography, low hydraulic conductivity of soil and shallow water table the coastal region of West Bengal is subjected to severe waterlogging conditions during monsoon.

3.8.3 Hydrogeology

The geological formations in the coastal tract of West Bengal forming part of the Lower Ganga plain comprise sediments deposited under fluvial, lacustrine and marine environments. The alluvial materials are transported by the Ganga-Brahmaputra river systems and their distributaries have built up the land with the deposit of alluvial materials that is about a few hundred meters deep. In the coastal tract of West Bengal encompassing the districts of S 24 Parganas, North 24 Paraganas (partly), Haora (partly) and East Medinipur (partly), alluvium of

Recent to Pliestocene ages and the Tertiary sediments form the aquifers. The alluvium comprises sands of varying grades, micaceous, with gravels and kankar. The sands are, in general, fine to very fine. Medium to coarse grained sands are of limited occurrences. The nature of aquifer material as well as the geometry of aquifer changes spatially. In general, there is a thick blanket of clay at the top whose thickness varies from 15 to 76 m with increasing thickness towards south. Also, a thick basal clay bed occurs at depths ranging from 152 (North 24 Parganas district) to 414 m (Kolkata area). The aquifers in between these shallow and deep clay layers in the broad depth range of 70 to 360 m bgl are under confined condition and are mostly tapped either for irrigation or drinking water supplies. In the northern part of South 24 Parganas district, however, there exists a shallow aquifer system within 50 m bgl mostly tapped for domestic use by shallow tube wells. It is followed by second and third aquifer systems in the depth ranges of 70 to 160 m BGL and 170 to 400 m, respectively. Each aquifer system comprises one or several interconnected aquifers (CGWB, 2014). In the coastal tracts of East Medinipur district, several alignments of sand dunes are observed near Digha, Contai and Khejuri. The sand dunes are the major shallow level sources of groundwater in these areas. Figures 3.8.3a-b show the geology and soil depth in coastal districts. The depth to groundwater level during pre- and post-monsoon of year 2011 is shown in Figs. 3.8.4a-b.

3.8.4 Groundwater Salinity

The salinity problem in coastal aquifers of West Bengal is mostly due to the presence of sea water (as connate water) with different degrees of salinity getting entrapped during marine transgression or through deposition of sediments under marine depositional environment. Slow movement of groundwater in coastal area with a long residence time (that permits contact with a stationary coastward salt water body) also causes quality deterioration. The coastal areas are prone to frequent cyclonic storms. During the cyclonic storms, high tidal waves enter deep into inland areas and also along the tidal creeks, the influent seepage from which further deteriorates the quality of groundwater.

In the coastal stretch a clay blanket 20 – 30 m thick is generally present below which brackish water occurs within 120 m depth on the western part of Hugli river and within 150 – 180 m on its eastern part. Freshwater occurs in coastal tract of East Medinipur within a depth span of 120 - 360 m sandwiched between saline/brackish water zones. In the extreme south-eastern part of the coastal belt, brackish water occurs within 360 m depth. The fresh and brackish water zones are separated by a 15 – 20 m thick impervious clay layer.

In an area of 150 km^2 around Contai, Purba Medinipur district, aquifers contain brackish to saline water at various depths except in shallow and sand dune aquifers. Also in some localized pockets in South 24 Parganas district, sand horizons containing freshwater occur within a zone of 20 – 50 m. Drilling in the rapidly growing Haldia industrial complex has revealed that sediments down to a depth of 115 mbgl are generally argillaceous in nature with few sand horizons containing brackish to saline water. Below the depth of about 115 m, the sediments are by and large arenaceous down to depths of little over 300 m. These sandy aquifers contain fresh groundwater. Below the depth of 305 m, the unconsolidated sediments by and large comprise clayey material with sub-ordinate sand horizons. Figure 3.8.4c shows the EC of groundwater at shallow depths. Table 3.8.1 provides the broad depth-wise ranges of occurrence of freshwater and saline water in West Bengal, while Fig. 3.8.5 illustrates the disposition of fresh and saline aquifers in coastal tracts.

All the aquifers are recharged by monsoon rain but the piezometric surface of the deep aquifer is depressed by 9 m during January to March due to heavy withdrawal for cultivation. Due to increasing demand and withdrawal of groundwater from the deep aquifer, there is real threat of saline water ingression unless excessive withdrawal is regulated. The areas of concern are mainly Haldia and Digha-Sankarpur region (http://www.iczmpwb.org).

Other factors contributing to water salinity include coastal erosion and storm surges during cyclones that are frequent on the east coast (that is Bay of Bengal) and inundate vast areas of coastal tracts with seawater. Coastal erosion is a key issue in Digha-Sankarpur area, since it increasingly shifts the coastline inland making more areas susceptible to groundwater salinity.

Table 3.8.1 Broad depth-wise ranges of occurrence of freshwater and saline water in West Bengal

Depth Range of Saline/Brackish Water Zone (m bgl)	Depth Range of Fresh Water Zone (m bgl)	Areas
0 – 160	160-300	Kolkata, Bhangar, Sonarpur
0-110	110-280	Tamluk
0-130	130-290	Mahisadal, Nandigram, Sutahata
0-150	150-300	Diamond Harbour, Falta, Mograhat, Budge Budge, Bishnupur
0-15	15-150, 150-300	Dune area parts of Contai, Khejuri
0-170	170-300	Nandigram, Khejuri, Sandeshkhali and entire South 24 Paraganas district
0-200	200-300	Sagar Island
0-330	300-360	Basant, Gosaba
0-300	-	Contai

3.8.5 Causes and Extent of Coastal Land Salinity

In West Bengal, groundwater salinity at different depths in the coastal districts is found over an area of about 10,000 km^2 (refer Table 3.8.1 and Fig. 3.8.4c). The salinity of groundwater in the coastal tracts of West Bengal is mainly *insitu*. The coast being essentially regressive in the geological past, transgression of saline water along estuaries and also the sedimentation under estuarine conditions are possible explanations for the *insitu* occurrences of brackish/saline groundwater in the coastal tract (Sinha Ray, 2000). Sluggish movement of groundwater in

mostly level coastal areas and the long residence time permits contact with salt water zones which also induces water quality deterioration. In addition, the coastal areas are witness to frequent cyclonic storms. During the cyclonic storms, high tidal waves enter into inland areas and also along the tidal creeks, the seepage from which further degrades the quality of groundwater. Coastal erosion is another factor that contributes to increase in water and land salinity as it gradually shifts the coastline inland making more areas susceptible to salinization.
Following problems have been observed in the state of West Bengal coast and estuaries

- Damage of sea dykes and river embankments due to high tides and severe cyclones like 'AILA (2009)' disaster turning a huge agricultural land into waste land.
- Increase of salinity within Sundarbans estuaries due to unavailability of upland discharges.
- Hilsa fish not migrating upstream; famous Sundari trees fail to survive with high saline water in the estuarine islands; slow forest growth and reduced productivity of forest site.
- Migration of local people to other places to maintain their livelihood.
- Flooding of fresh water ponds due to tidal surges killing varities of sweet water fishes.
- Ground water quality of 59 blocks of west Bengal is poor with respect of salinity (beyond permissible limit).

The demarcation of the areas affected by salinity is given in Fig-3.8.6 salinity limit of Deltaic and coastal West Bengal (25384.284 Sq KM.)

3.8.6 Remedial Measures

The cultivated lands are protected with dykes or protective embankments against the saline water ingression from the sea, tidal rivers and estuaries. During rainy season the surface drainage is implemented through one-way sluice gates provided in the embankment. In the rainy season water table is shallow and near to the ground surface. Although the rainfall is poor and its distribution is erratic during the remaining period of the year, the soil remains sufficiently wet throughout the year due to upward capillary flow of water from the shallow groundwater table present within 2 m of soil depth. Since the water of the shallow groundwater table is affected by salinity to various degrees, the soil salinity also gradually increases after the cessation of monsoon until the next monsoon starts. Evaporation of moisture takes place from soil surface while salts accumulate in the root zone soil, and maximum concentration of salts is, thus, observed in the surface soil during summer.

In many cases, particularly in the Sundarbans region, the height of tide is above the mean ground elevation of the lands. Circuit earthen embankments along the tidal rivers have been constructed for preventing ingress of saline water and thereby facilitating cultivation of crops. In Sundarbans area a number of sluices have been constructed, e.g. Piyali River Closure and Mani River Closure. Garan Bose River closure is in progress. These closures prevent saline water entry to upland areas through the river courses. The gradient of the tract is very poor (average slope 0.2

meter per 25 km) with flat surface and the land is scarcely above the high water mark (Table 3.8.2). At times the saline tidal water overflows the landmass creating marshy patches. In other parts, the tidal deposits have raised the land gradually above mean sea level.

Table 3.8.2. Mean elevation of agricultural lands of coastal region of West Bengal (CSSRI, 2003)

District	Mean Elevation (m) above msl
North 24 Parganas	1-2
South 24 Parganas	1-2
Medinipur	2-3
Haora	2-4

The embankments along the water courses are at times breached by tidal floods. During the super cyclone Aila that hit the shores during high tide on May 25, 2009, tidal surges of up to 6.5 m affected coastal blocks. This surge of water damaged and washed away over 1,743 km of embankments that had guarded the inland ecology and human habitations of the islands for over a century. With the tidal surge, huge amount of salt water intruded the agricultural lands and remained stagnant for a long period of time. Due to this flood, salinity of the soil increased which severely affected the agricultural production. In light of above, long-term studies are required to understand the water flow dynamics and sedimentation patterns, accretion and erosion pattern in different islands through high resolution satellite images for selection of locations for new embankments in Sundarbans. Thus, closure of some rivers in a scientific manner and construction of embankments in planned manner needs to be implemented for improving the water and land salinity conditions in coastal region of West Bengal.

Following steps are taken for prevention of salinity ingress

- Repair and construction of sea dykes, embankments and sluice structures.
- A collaborative study for ensuring the Environmental Flow to Sundarbans (Indian part) has been taken up with school of oceanographic studies, Jadavpur University.
- Controlling ground water uses in the region (as per Water Resources, Management, Control and Regulation Act, 2005). After this act no permit has been issued for groundwater withdrawal.

The different protection works for prevention of Salinity Ingress taken up in different districts is given in Table 3.8.3. The work taken up under the AILA project for repair and construction of damaged Embankment at Sundarbans is given in table 3.8.4. The details of sluices taken up is provided in table 3.8.5. The Expenditure incurred under AILA project is given in table 3.8.6.

Table-3.8.3 Different Protection Works for Prevention of Salinity Ingress

District	Length of Embankment/Barrier in km			Sluice in no		
	Existing	Under construction	Proposed	Existing	Under construction	Proposed
South 24 Parganas	2410.0	Nil	Nil	231	6	3
North 24 Parganas	829.6	21.229	5	579	1	8
Purba Madinipur	215.5	Nil	Nil	65	1	Nil
Total	3455.1	21.229	5	875	8	11

Table-3.8.4 Area to be benefited Under 'AILA' Scheme

District	Length of embankment/ dykes		Sluice to be constructed	Area to be protected	Population to be benefited (as per 2011 census)	Mouza and Block to be Benefited
	Total damaged	Constructed				
South and North 24 Parganas	778Km	71.430km	302 nos	2100 Sq. Km	20lakh	500 Mouzas & 19 Blocks

Table-3.8.5 Details of Sluices under 'AILA' project

Type of sluice	Nos of sluices in the length of embankments		Total	Total cost in lakh
	In North 24 Parganas District	In South 24 Parganas District		
1-vented	7	190	197	2947.12
2-vented	28	68	96	2611.2
3-vented	-	9	9	354.96
Total	35	267	302	5913.28

Table-3.8.6 Expenditure Statement of AILA project

District	Approved estimated cost	Fund received upto 29/2/2016	Fund utilized 29/2/2016
South and North 24 Parganas	5032 crore	653.971 crore	512.886crore

The remedial measures taken up are provided in Fig. 3.8.7 Typical Cross section of Embankment without armoring for AILA project, Fig. 3.8.8 Typical Cross section of Sluice for AILA project and Fig.3.8.9 Typical Cross section of anti-erosion measures for AILA project

Effectiveness and benefits of the remedial measures

From AILA project 2100 sq. Km land area will be protected and about 20 lacks of people will be directly benefited. Irrigation potential was created as 60374 ha, but utilised 39976 ha by 10970 nos of tube wells in the coastal areas. Through palliative measures taken up post 'AILA' by I &W Dte, reclamation of substantial quantity of agricultural land is possible. Withdrawal of ground water has been stopped under Water Resources, Management, Control and Regulation Act, 2005 of West Bengal and thereby restricting further drawdown of aquifers.

Table -3.8.7 Revised Year Wise Financial Phasing of AILA Project Works

Year	Phasing of Expenditure (Rs in crore)	Fund Received (Rs in crore)	Fund Utilised (Rs in crore)
2009-10	107.110	107.110	107.110
2010-11	187.858	525.75	187.858
2011-12	17.0767	-	17.0767
2012-13	51.3489	-	51.3489
2013-14	30.716	-	30.716
2014-15	47.8602	4.119	47.8602
Total	441.9698	636.979	441.9698

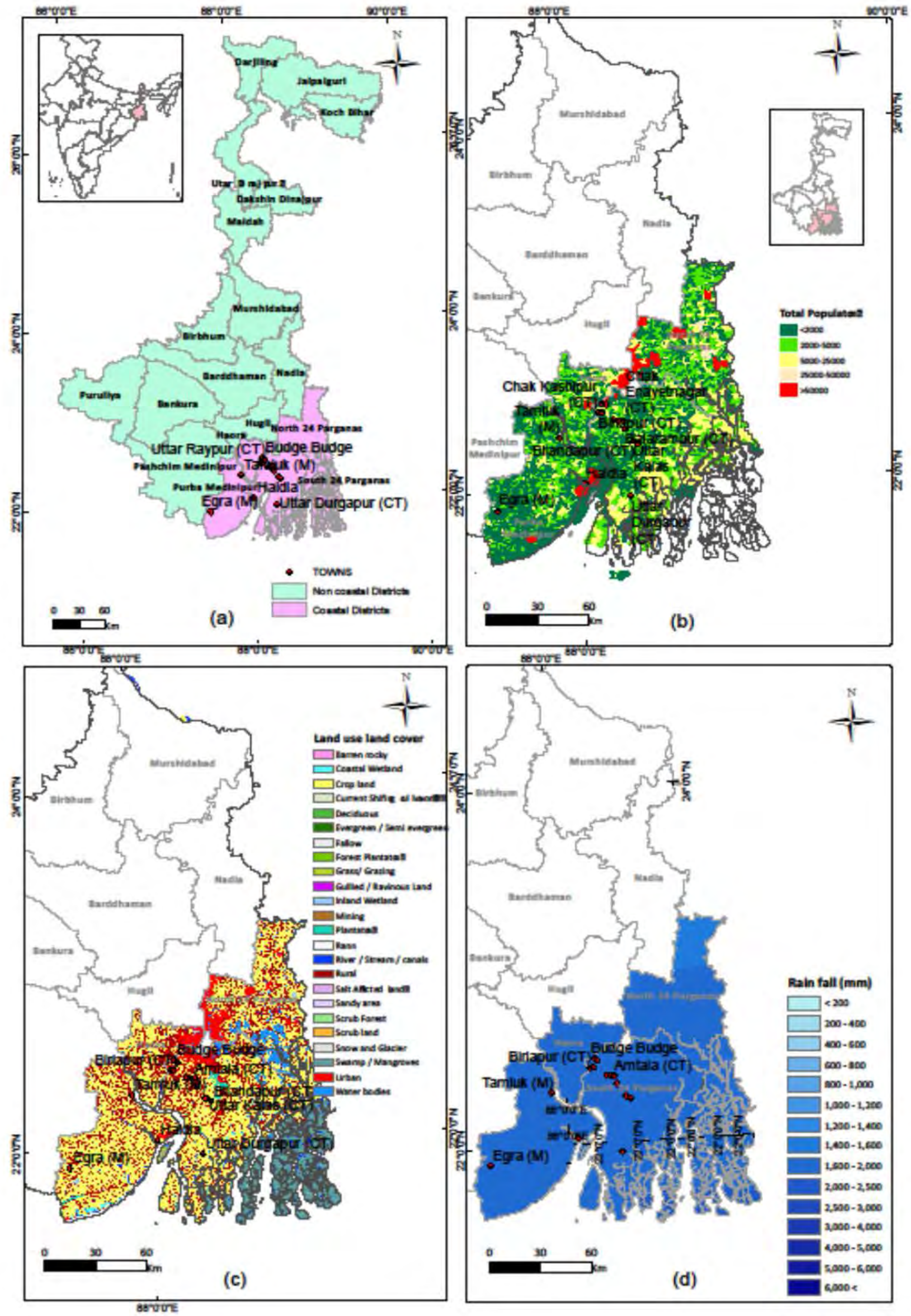


Fig. 3.8.1(a) Administrative map of West Bengal showing coastal districts (b) Population distribution of coastal districts of West Bengal (c) Land use and land cover of coastal districts of West Bengal (d) Rainfall distribution of coastal districts of West Bengal

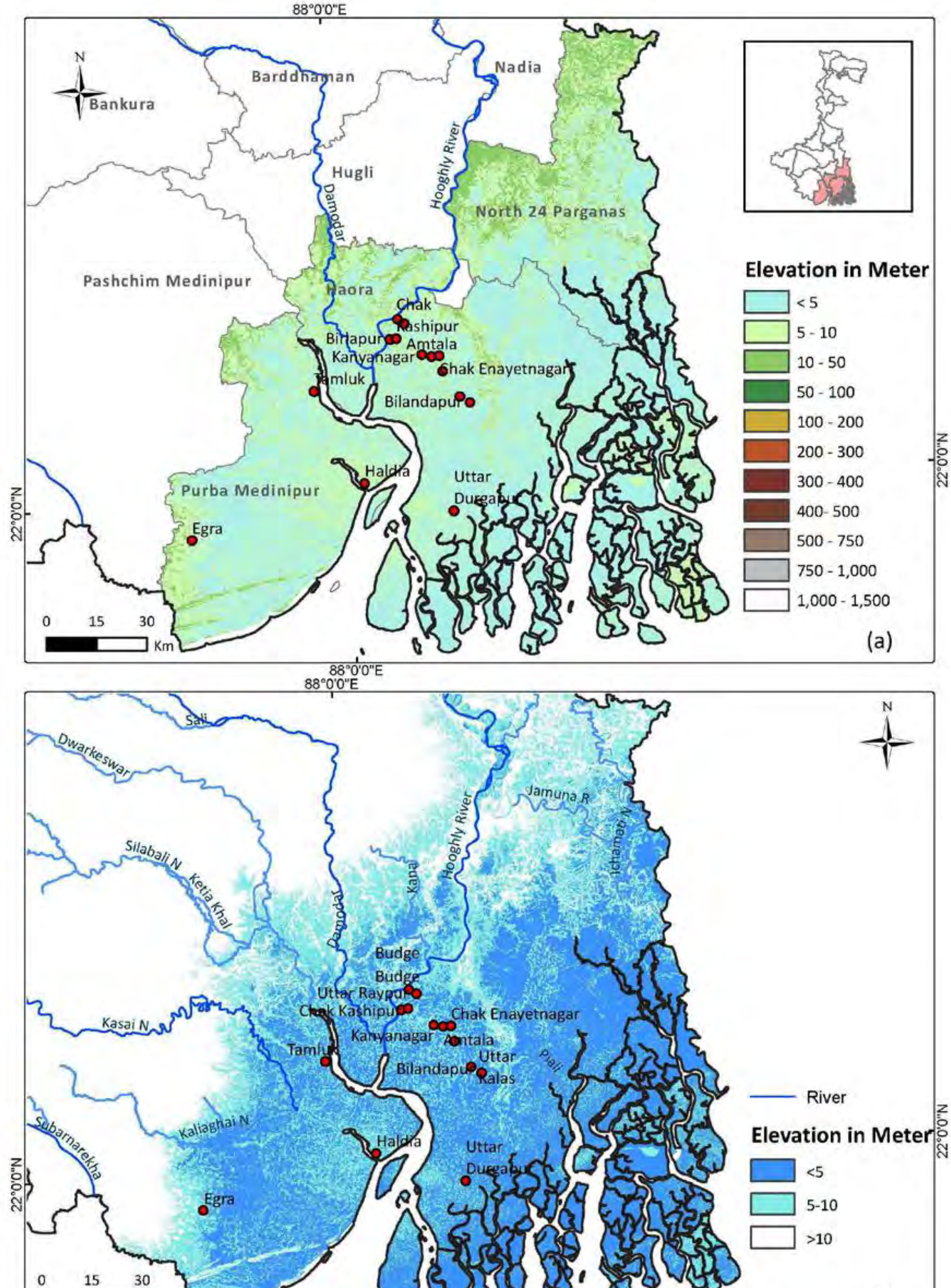
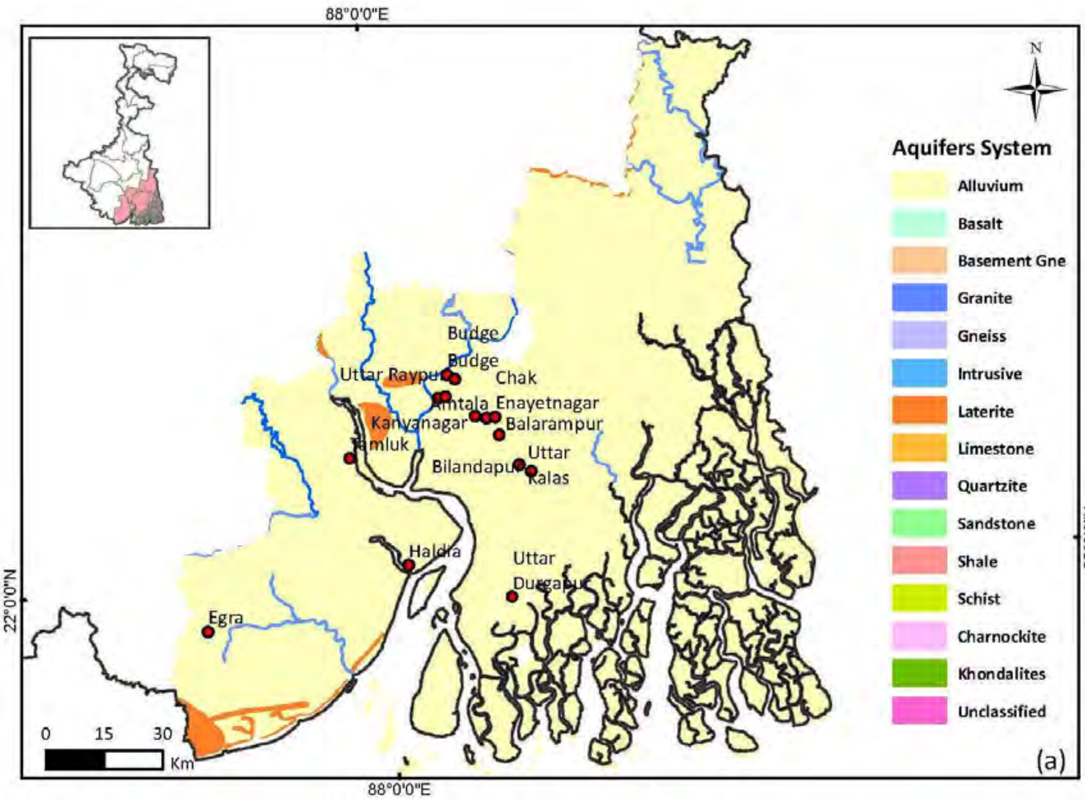


Fig. 3.8.2 (a) Physiographic map of West Bengal (b) Drainage map of West Bengal showing low elevation coastal areas (< 10 m amsl)



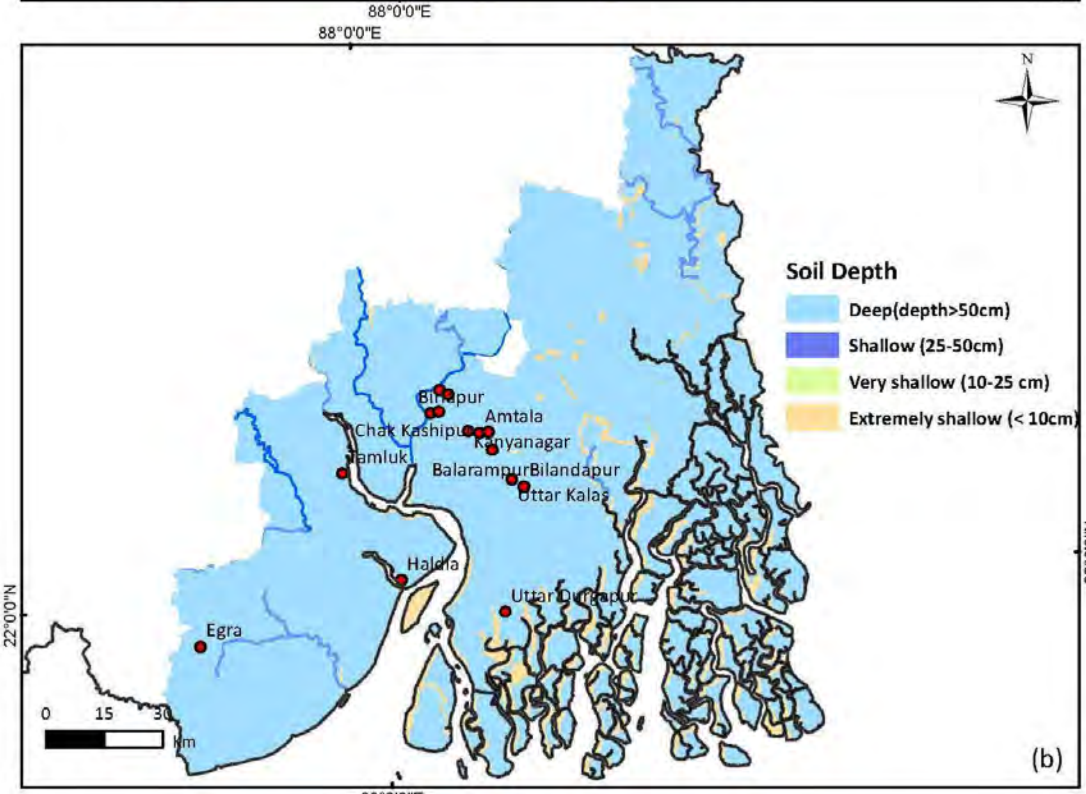


Fig. 3.8.3 (a) Aquifer map of coastal districts of West Bengal (b) Soil depth map of coastal districts of West Bengal

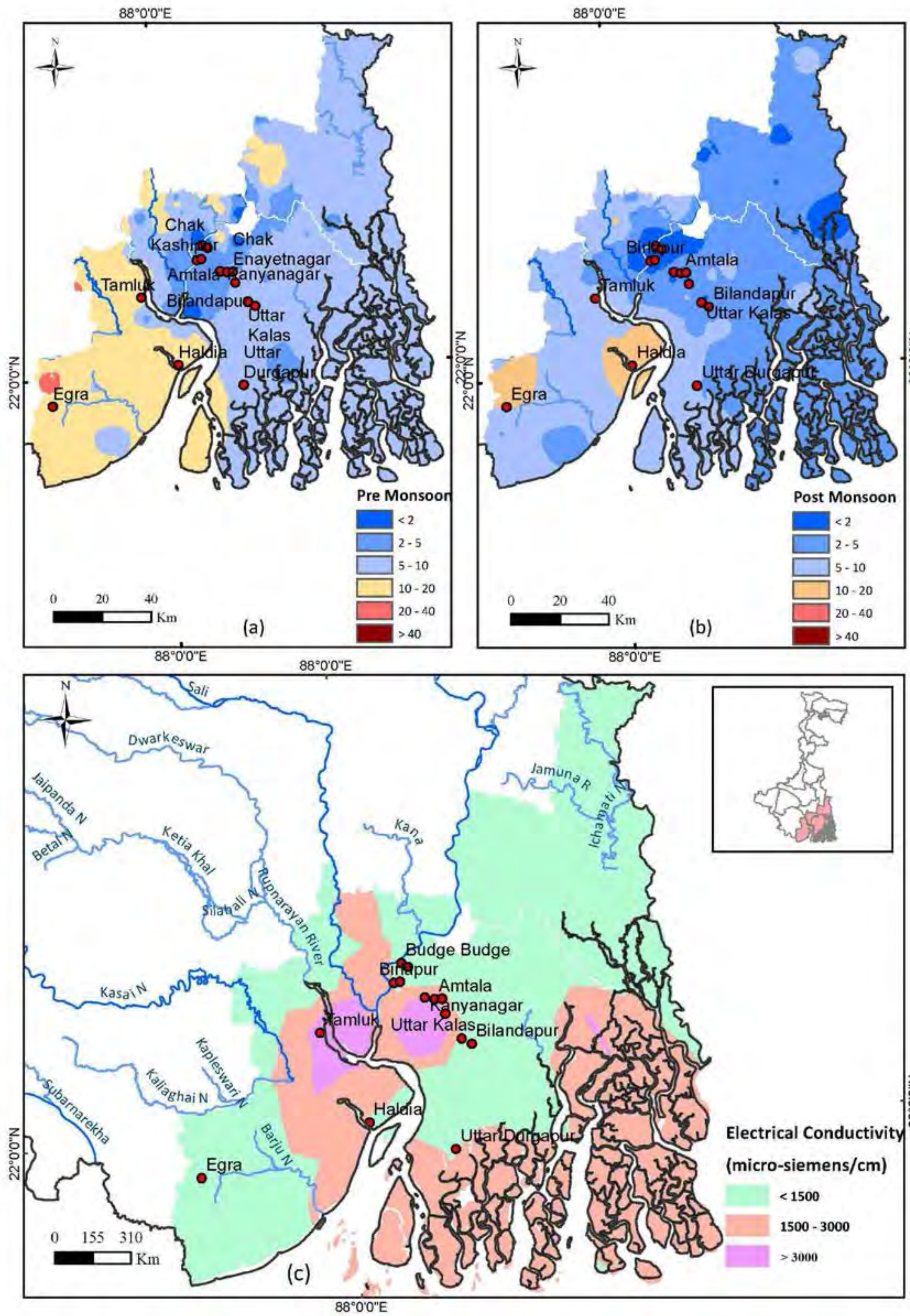


Fig. 3.8.4 (a) Pre-monsoon water level of coastal districts of West Bengal (in meters) (b) Post-monsoon water level of coastal districts of West Bengal (in meters) (c) EC map of shallow groundwater for coastal districts of West Bengal

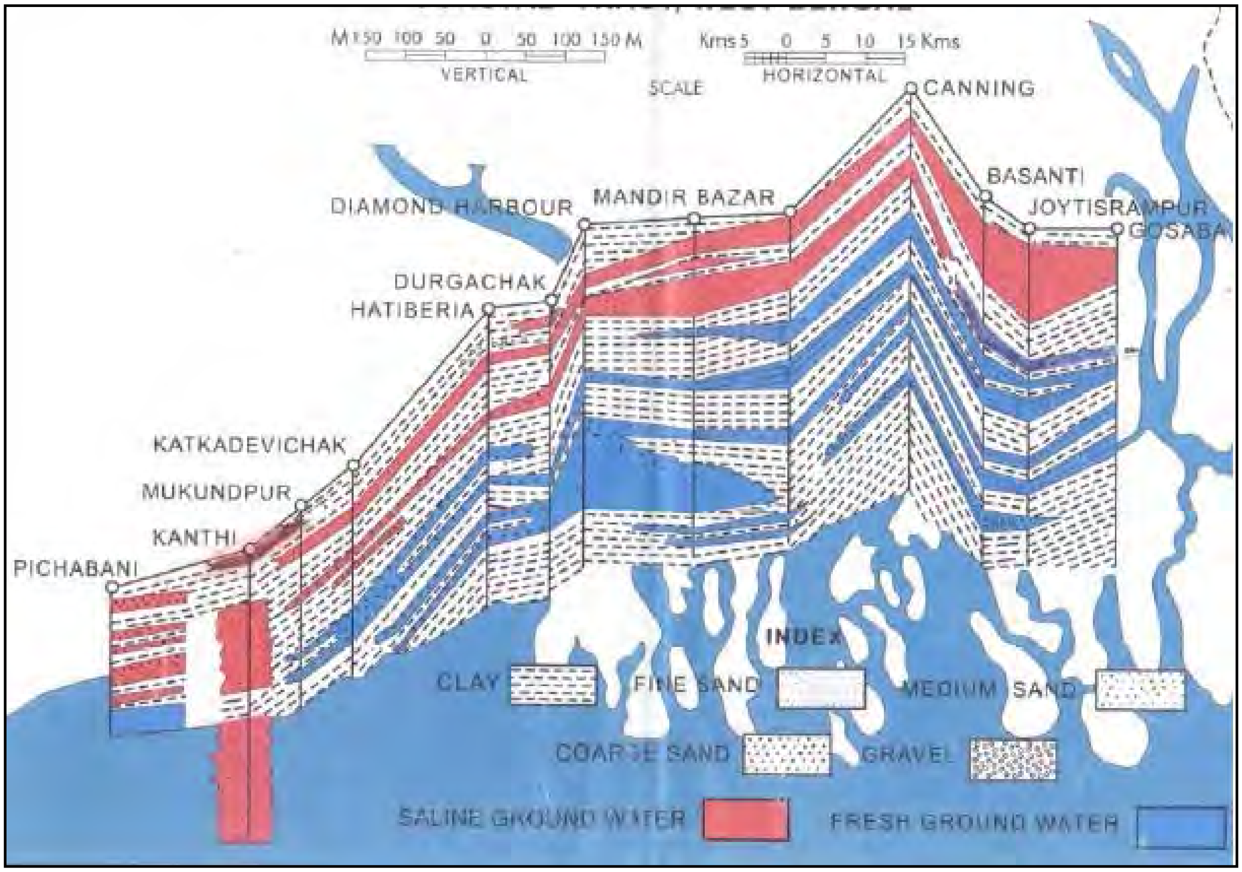


Fig. 3.8.5 Disposition of sub-surface fresh saline aquifer in coastal tract of West Bengal (CGWB, 2014b)

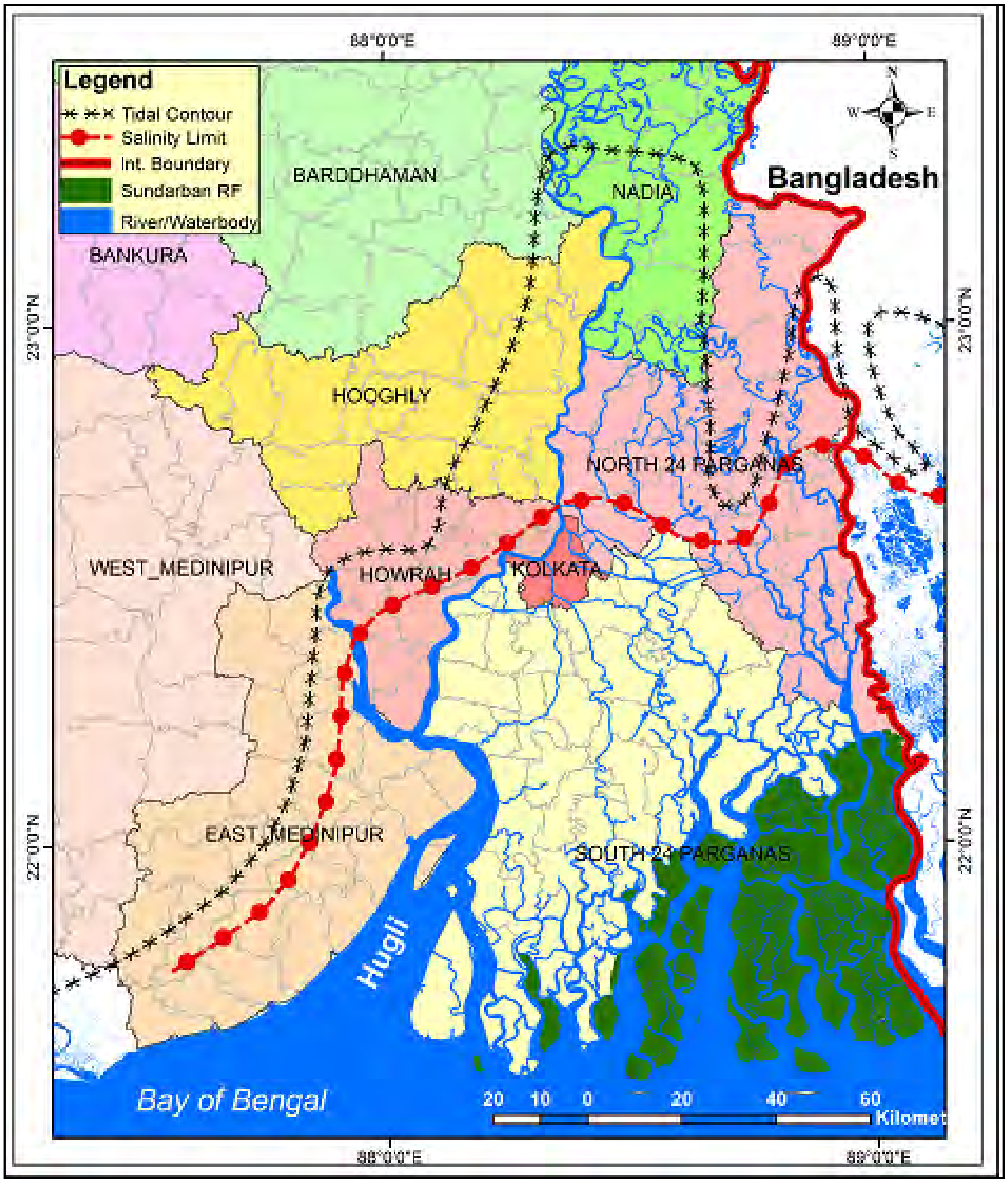


Fig-3.8.6 Salinity limit of Deltaic and coastal West Bengal(25384.284 Sq KM.)

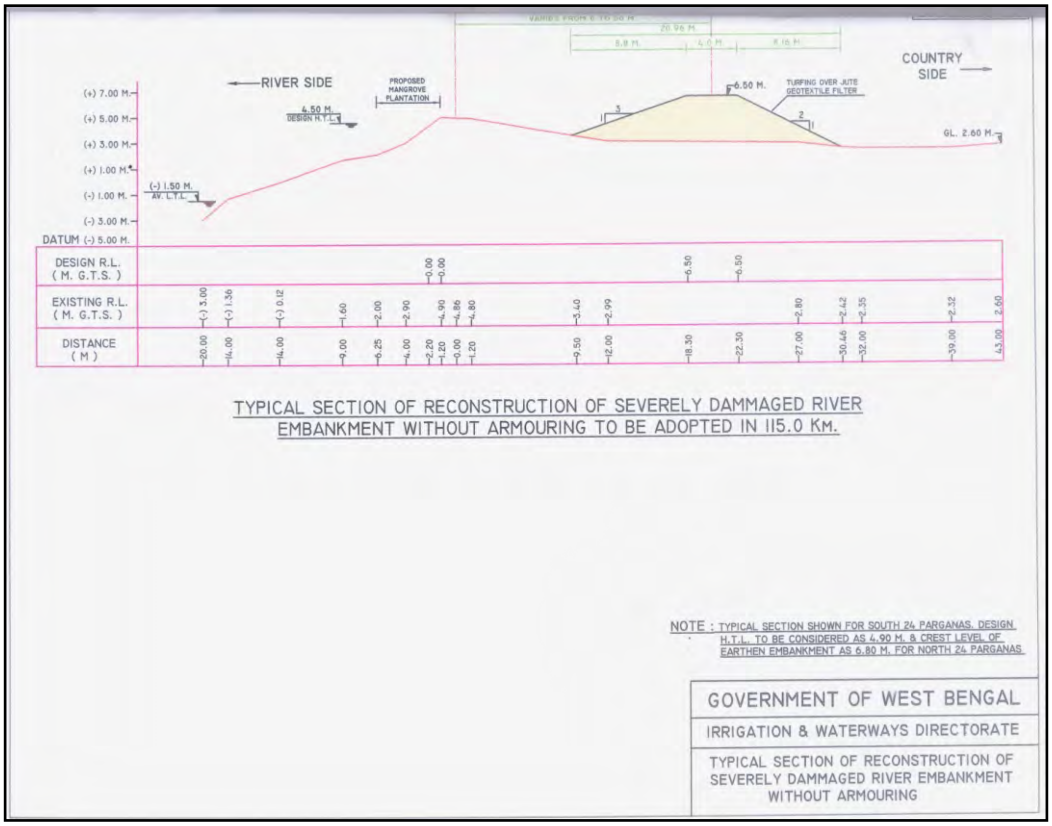


Fig. 3.8.7 Typical Cross section of Embankment without armouring for AILA project

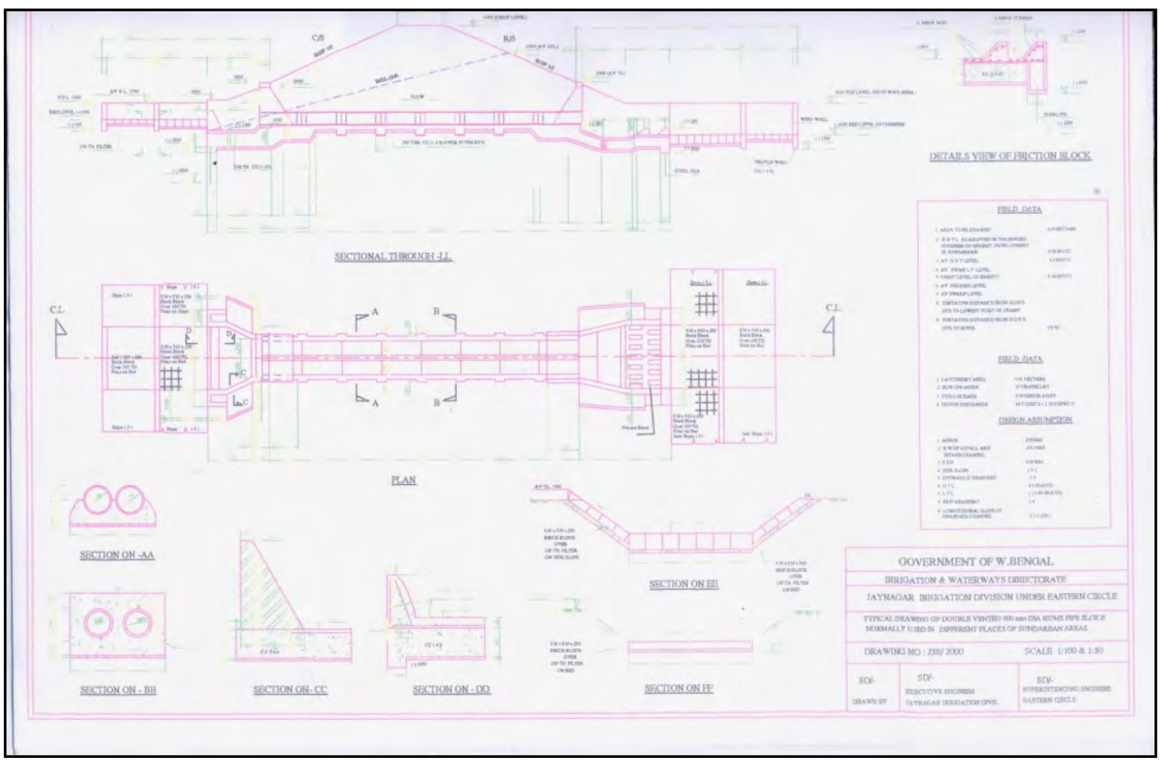


Fig. 3.8.8 Typical Cross section of Sluice for AILA project

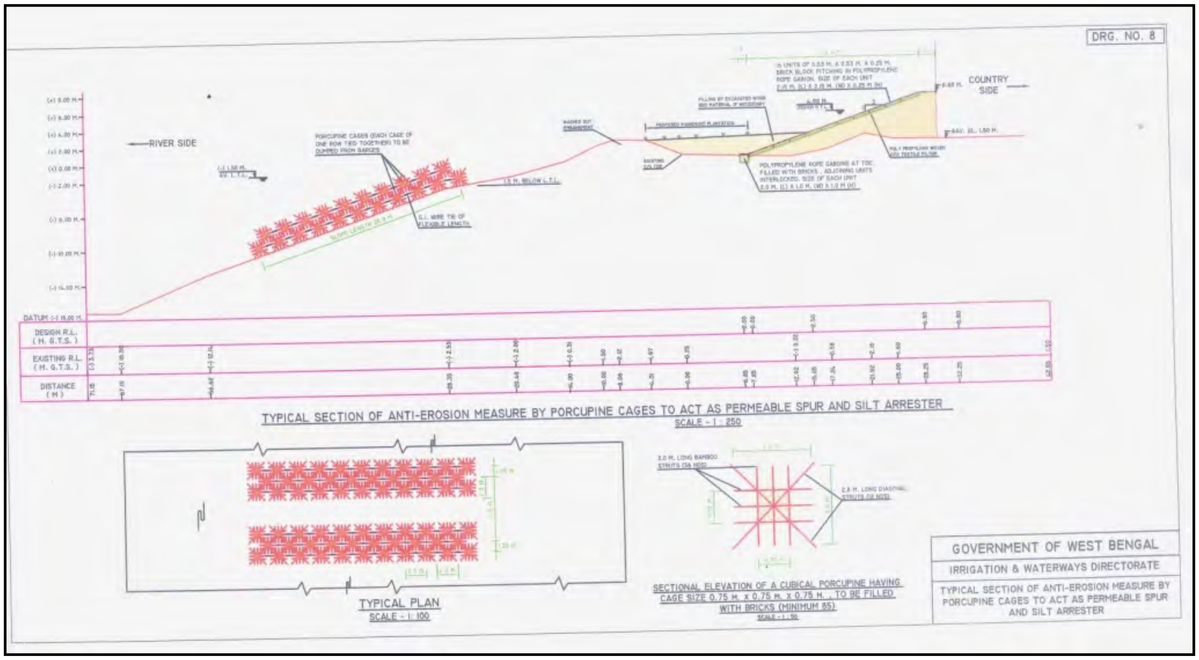


Fig.3.8.9 Typical Cross section of anti-erosion measures for AILA project

3.9 PUDUCHERRY

3.9.1 General

The union territory of Puducherry, with a total area of 492 km^2, consists of four small unconnected districts: Puducherry (293 km^2), Karaikal 160 (km^2) and Yanam (30 km^2) on the east Coromandel Coast (on the Bay of Bengal) and Mahe (9 km^2) on the west Malabar Coast (on the Arabian Sea). Puducherry and Karaikal have the largest areas and population, and are both enclaves of Tamil Nadu. Yanam and Mahe are enclaves in the states of Andhra Pradesh and Kerala, respectively.

The main territory of Puducherry lies on the east coast, about 180 km south of Chennai. Some of Puducherry's districts are themselves amalgamations of non-contiguous enclaves or 'pockets'. The Puducherry district comprises of 11 such pockets, some of which are very small and entirely surrounded by the territory of Tamil Nadu; while Mahe district is made up of three pockets. The Puducherry district itself is divided into seven communes (panchayats), viz, Puducherry, Ozhukarai, Bahour, Ariyankuppam, Villiyanur, Nettapakkam and Mannadipet and comprises 164 villages. The Karaikal district consists of six communes, comprising 100 villages. The districts of Puducherry, Karaikal and Yanam receive an average rainfall of 1200 mm and Mahe receives 3300 mm of rainfall due to its location on the Western Ghats. Figure 3.9.1 shows the locations of the coastal districts; sparsely/ medium populated areas in villages and highly populated urban areas in towns and cities, variation in average annual rainfall (1971-2005) across the coastal districts areas and land use / land cover conditions.

3.9.2 Physiography and Drainage

All four districts of Puducherry are located in the coastal terrain. Puducherry region lies discontinuously at the tail end of two river basins viz., Rivers Gingee and Pennaiyar; Karaikal is located at the tail end of the fertile Cauvery delta; Yanam is situated as a tiny pocket at the tail end of Godavari basin; and, Mahe is situated at the tail end of Mahe river (refer Fig. 3.9.1). Five rivers in Puducherry district, seven in Karaikal, two in Mahe, and one in Yanam drain into the sea, but none of the rivers originate within the territory.

The Puducherry region in general is a flat peneplain with an average elevation of 15 m above msl. The terrain becomes a little undulating with prominent high grounds varying from 30 to 100 m above msl towards northwest and northeastern parts of the region. Three major physiographic units are generally observed, viz., (i) Coastal plain, (ii) Alluvial plain and (iii) Uplands. The 'Coastal Plain' extends as a narrow stretch for about 22 km with a width of about 400-600 m along the Bay of Bengal. Major part of the coastal plain is gently sloping land with a chain of sand dunes stretching all along the coast and marked by other associated landforms such as spit bars, mud flats, lagoons and tidal inlets. The 'Alluvial Plain', formed due to the two major rivers namely Gingee and Ponnaiyar, is a monotonous plain in general with slope ranging from 1 to 3%. Besides the rivers and major canals, surface depressions exist all over the terrain that serve as surface water reservoirs. About 140 small and two big tanks that are interlinked are utilized for agricultural purposes and also to recharge the groundwater. The high grounds are known as ‘Uplands’ with elevations of about 30 to 100 m above msl. These uplands suddenly emerge from the low lying alluvial plain country forming a prominent feature of the landscape and are popularly known as ‘Les Montagnes Rouges’ or the ‘Red Hills of Puducherry’. The hills are intersected by a number of gullies and deep ravines giving rise to badland topography.

The Karaikal region, at the tail end of Cauvery delta, is drained by seven distributaries of Cauvery viz., Nandalar, Nattar, Vanjiyar, Nular, Arasalar, Tirumalarajanar, and Puravadaiyanar that discharge into the Bay of Bengal. A network of canals branch out from these rivers to feed the irrigation channels. Covered by a thick mantle of alluvium of variable thickness, the topography of the region is flat displaying a gentle slope towards the Bay of Bengal in the east.

The Yanam district lies 870 km from Puducherry and forms an enclave in the East Godavari District of Andhra Pradesh. The town of Yanam lies some 14 km inland from the mouth of Godavari river, where the Koringa (Atreya) branch separates from the Gauthami Godavari. The entire region is composed of a flat, monotonous terrain without any distinct topographical feature.

On the other side of Indian Peninsula, on the Malabar coast, Mahe is the smallest enclave of the union territory inside Kerala. Mahe town is located on the south bank of Mahe river near its juncture with the sea. Mahe district is bounded on the south-west by the Arabian sea, on the north by Ponniyar (Moolakadavu) river and on the other sides by a stretch of calcareous hills of medium height which are linked to the Western Ghats by a series of wooded hillocks.

3.9.3 Hydrogeology

Groundwater occurs in geological formations that are broadly classified into two hydrogeological units viz., (i) Fissured and fractured crystalline formations and (ii) Porous sedimentary formations. In crystalline formations of Puducherry district, groundwater generally occurs under phreatic conditions in the weathered mantle and under semi-confined conditions in the fissured and fractured zones at deeper levels. The thickness of weathered zone ranges from 2 - 12 m. The yield of large diameter wells tapping the weathered mantle of crystalline rocks ranges from 144 - 720 m^3/d and can sustain pumping for 2 - 6 hours per day.

The porous sedimentary formations occur in almost the entire region of Puducherry district and are represented by the semi-consolidated formations of Cretaceous and Tertiary and the unconsolidated Quaternary formations of Recent age. Broadly, the Vanur-Ramanathapuram sandstone (Cretaceous), the Cuddalore sandstone (Tertiary) aquifers, and the shallow Alluvial (Quaternary) aquifers constitute the three major potential aquifer systems in the region. Groundwater occurs in these formations both under water table as well as under confined conditions and is being developed by means of dug wells, dug-cum-bore wells and tube wells. The phreatic aquifer comprises mainly of Alluvial aquifer and Tertiary and Cretaceous aquifers in patches. In case of Cretaceous aquifer, some of the areas have not been considered for development as the overlying Tertiary aquifer exhibits high potential.

The Vanur-Ramanathapuram sandstone (Cretaceous) aquifer consisting of sands and calcareous sandstones occur in the north-western part of Puducherry Region. The thickness of these aquifers ranges from 38 - 92 m, and the yields of tube wells tapping these aquifers vary between 1150 - 2160 m^3/d. The Cuddalore sandstone (Tertiary) aquifer of Mio-Pliocene age comprising sandstones, sands and gravels, occupy an extensive area and constitute the most potential aquifers. The thickness of these aquifers ranges from 20 - 245 m. Groundwater occurs mainly under confined conditions and is developed by means of tube wells of depths between 27 – 366 m bgl with yields varying between 290 - 4300 m^3/d. The Alluvial aquifers comprising sand and gravels occupy nearly 3/4th of the region. These aquifers form the most potential shallow aquifer system in the area. The thickness of these aquifers ranges between 5 - 34 m. Thick alluvial aquifers under water table or semi-confined conditions occur in the area bordered by Thirukanji, Odiyampet, Tavalapet, Villiyanur, Mangalam and Satyamangalam. Figures 3.5.31a-b show the geology and soil depth of the Puducherry district while Figs. 3.5.32a-b illustrate the depth to groundwater level for the year 2011.

The aquifer system of Karaikal region consists of unconsolidated unconfined to confined alluvial aquifer, confined Karaikal beds of Pliocene age, and confined Cuddalore sandstone formation of Miocene age.

3.9.4 Groundwater Salinity

In Puducherry district, the EC values in major parts of the alluvial aquifers are less than 1500 µS/cm which increase to around 2000 µS/cm near the coast in the east, central and small patches on southwestern part. A localized patch with increase in salinity of more than 30,000 µS/cm is observed along the coastal belt which may be attributed to sea water contamination. In Tertiary aquifers, the EC values are less than 1500 µS/cm in major part of the region, except some patches along the coast where maximum EC value of 8280 µS/cm have been recorded at Murungapakkam, which may be due to sea water encroachment. In the Cretaceous aquifer system, the EC values are less than 1500 µS/cm except for a pocket in the western part where higher EC values of 7280 µS/cm have been observed at Madagadipet. In Karaikal district, the TDS of groundwater in both alluvial and deep aquifer systems ranges from 1000 to 2500 mg/L.

3.9.5 Causes and Extent of Coastal Land Salinity

Puducherry Region

In Puducherry region, groundwater is the main source of water supply for irrigation, drinking and industrial needs. The water consumption in respect of agriculture, industrial and domestic sectors is about 81%, 16% and 3%, respectively. According to estimates of groundwater resources as on March 2013, the net annual groundwater availability is 7,699 ham and the annual groundwater draft for all sectors is of the order of 13,769 ham, which is leading to over-exploitation of groundwater in Puducherry region. Due to the expanding needs and consequent over-exploitation, groundwater levels in general are witnessing a decline throughout the region resulting in sea water encroachment along the coastal tracts. It has been observed that the sea water ingression in the southern parts is to an extent of 3-4 km inland while in the areas near the city it is 2 km inland and in the northern parts it is 1 km inland (Fig. 3.9.2).

Karaikal region:

The quality of groundwater in both alluvial and deep aquifer systems is mineralized with TDS ranging from 1000 to 2500 mg/L. For irrigation, the farmers use groundwater in conjunction with surface water. As per March 2004 estimates, the net annual groundwater availability is 6,441 ham and the annual groundwater draft for all sectors is 1202 ham. However, due to salinity encountered in the groundwater system, development of groundwater in Karaikal region is limited. Conjunctive use of groundwater with surface water is the best alternative solution to utilize the available groundwater resources.

Mahe and Yanam regions:

There is very little scope to develop groundwater in Mahe region as thick lateritic capping overlies the massive granite, which is a very poor aquifer. As this area is situated on the western coast with steep slopes, there is no scope for further development of groundwater.

In Yanam region, groundwater is saline in both shallow and deep aquifers and there is very limited possibility for developing the source. Godavari River is being utilized for meeting water demands and for future growth.

Consequent to the intrusion of sea water into shallow alluvial and top portion of tertiary aquifer (upto a depth of 120-140 mtrs below ground level) along the costal tract of Puducherry Region, the quality of ground water in shallow tubewells upto a depth of 35 – 40 mtrs bgl as well as in deep tubewells upto a depth of 90-140 mtrs bgl located especially in the southern part of coastal region have gradually become saline since 1980s onwards. The above problem ultimately deteriorate the quality of soil in the coastal area(Plate-VII). As a result an extent of 1860 ha land in the coastal area has been affected due to salinity especially in the southern part of the coastal area, which accounts 6.33% of total area of Puducherry region. Additionally the sand mining in the river courses have also increase the extension of back water, which also aggravated the problem of sea water intrusion. Besides, an account of the tsunami occurred in Pondicherry in the year 2004, the sea water inundation in the inland has occurred to a distance of 1 – 2.5 kms which also degraded the soil health of land. Owing to the above problems the crop yield has affected considerably and also the cultivable area become barren.

In Karaikal region the quality of ground water is generally saline in nature and especially 50% of the geographical area located in eastern part of Karaikal region is unsuitable for tapping potable ground water and also 50% length of 7 nos. of tributaries of Cauvery river containing backwater. Owing to the above problems, the salinity problem in the lands along the coastal tract is severe which accounts around 2918 ha (20% of the total area of Karaikal) (Plate-VIII) and in other parts the salinity problem in soil is slight to moderate. Owing to the above problems the agriculture activity in Karaikal region along the costal tract is badly affected and the scarcity in the availability of canal water as well as the salinity nature of ground water also ordered to the problem.

3.9.6 Remedial Measures

In order to halt the intrusion of sea water into the groundwater system in Puducherry region and improve the health of soil in the saline affected area, several actions / measures have been taken as follows:

i. Subsidy assistance, Technical assistance and Machinery assistance were extended to the farming community for construction of replacement tubewells tapping potable water from deeper zones in lieu of failed tube wells.

ii. Schemes were undertaken for improving the irrigation and drainage channels especially in the coastal pockets of Puducherry for better drainage.

iii. Attractive incentives / subsides were extended to the farming community for undertaking reclamation works especially in the tsunami affected areas and also community tubewells were constructed in coastal tract / tsunami affected areas for providing assured irrigation to the holdings of farmers with an objectives to improve the quality of the land.

iv. Check dams / bed dams were constructed across the river courses to impound the flood water for enhancing the recharging to the groundwater and also rain water harvesting programs were implemented widely in Puducherry region.

v. In Karaikal region, on farm development works were undertaken during the period 1982-1990 to provide better irrigation and drainage facility in the lands and construction of 90 community tubewells was undertaken for providing potable water for irrigation. The groundwater pumped from tubewells is utilized by the farmers for irrigation in conjunction with surface water. In addition, oil engines were distributed to the farmers for pumping water from the canals for irrigation.

vi. Coastal tail end regulators (seven in number) were constructed across the river courses of Karaikal region to limit the backwater and to impound flood water. The water impounded due to tail end regulators has helped to improve the quality of groundwater. The impounded water is also being used for supply of drinking water to nearby hamlets.

vii. Artificial lakes were created in three places in Karaikal region.

viii. With a view to halt the intrusion of sea water further into groundwater aquifers and to control the exploitation of groundwater, Executive regulatory orders are in force since 1980 onwards and to strengthen the measures, the Groundwater Act titled “The Pondicherry Groundwater (Control & Regulation) Act 2002” was enacted in the year 2004. The provisions of the Groundwater Act are strictly enforced. Further, the construction of new tubewells within 6 km from sea coast except for drinking purposes has been banned since 1988 onwards. The provisions contained in the Ground water Act are strictly enforced through a separate body titled “Pondicherry Ground Water Authority” which was established in the year 2004.

ix. In order to promote the harvesting of rain water for groundwater recharge, the construction of rain water harvesting in all buildings (including industrial units and institutions) has been made mandatory in the Town and Country Planning Act.

Physical and financial progress of remedial measures

a) 26 numbers of check dams already constructed involving expenditure of Rs.80.00 crores across the river courses to impound flood water. Construction of check dams proposed to be continued / under construction at 9 locations.

b) 84 numbers of irrigation tanks in Puducherry region were renovated with an outlay of Rs. 34.73 crores by availing European assistance. Renovation work was undertaken during 1999 -2008.

c) 7 numbers of coastal tail end regulators across the river courses in Karaikal region were constructed to prevent the extension of back water and to impound flood water which will improve the quality of ground water in the nearby areas. The project of construction of regulators across the river courses in Karaikal region is proposed to be continued.

d) In Karaikal region, the main source of irrigation is commanded by Cauvery river but since 1980 onwards there is scarcity on the timely availability of water for irrigation due to Cauvery dispute and also due to hydrosalinity problem in ground water of Karaikal, on account of which it could not be used directly for irrigation. In order to tide over the scarcity on the availability of river water, Government of Puducherry has constructed 90 community tubewells for irrigation by spending an amount of around Rs.15 crores under community tubewell scheme. During the year 2015-16, a total of 13 tubewells with an outlay of Rs.1.50 crores are proposed to be constructed and the work is under progress.

e) Subsidy assistance at 100% subject to a maximum of Rs.1 lakh per farmer extended to farmers for constructing farm ponds of size 2000 m^2 for impounding canal water / rain water that can be used for critical irrigation of crops. Under the scheme, subsidy assistance of Rs. 98 lakhs was extended to 161 farmers during the period 1990-91 to 2009-10 and 161 ponds with a total water holding capacity of 6.94 lakh m^3 were constructed. The scheme is being continued.

f) Drilling machineries (Power rigs and Hand bore sets etc.,) required for constructing tube wells for irrigation purpose are hired out to the needy farmers at subsidized hire rates. Since 2000 onwards on an average 25-40 numbers of tube wells have constructed every year by farmers duly engaging the departmental machineries. Besides subsidy assistance to the general farmers are extended at 65% subject a maximum of Rs.1.20 lakhs per tube well per farmer for constructing tube wells for irrigation purpose. Similarly 90% of subsidy assistance to SC farmers subject a maximum of Rs.2.00 lakhs per tube well per farmer are extended for the similar purpose. Additionally attractive subsidy assistance are extended for water conservation works. The above schemes are being continued and every year an amount of Rs.70 -90 lakhs are provided for extending the subsidy to farmers.

g) The maintenance of irrigation and drainage channels in the command area of the major tanks especially along the coastal tract are undertaken every year before the on set of monsoon by PWD.

h) With an objective to reclaim the lands which were affected during the tsunami 2004 subsidy assistance were extended to the farming community. An amount of Rs.52 lakhs was extended to 87 nos. of the farmers at Rs.60,000 per acre in the year 2005 and also 5 numbers of deep community tube wells were constructed in the costal tract of Puducherry region for irrigation and during the year one more tube well has been constructed especially in the tsunami affected packet. An amount of around Rs1 crore has been spent for the above purpose. Besides Rs.2.5 crores have been earmarked to construct undertake 13 numbers of community tube wells for providing potable water for irrigation in Karaikal region and tube well construction works are under progress.

Benefits of Remedial Measures

a) Construction of tube wells and over exploitation of groundwater have been regulated.
b) Intrusion of sea water further into the Puducherry region has been minimized.
c) Owing to the renovation of tanks / lakes in Puducherry region, their water holding capacity has increased from 46 MCM to 75 MCM, which is aiding conjunctive usage of surface water and groundwater for irrigation. Besides the salinity in groundwater in certain places of coastal area has decreased owing to groundwater recharge and less pumpage of groundwater.
d) As a result of the check / bed dams constructed across the river courses as well as recharge programs undertaken hitherto, groundwater recharge has increased. The recent groundwater potential assessment report reveals that the stage of development of groundwater which was 179% in the assessment year 2004 has come down to 139% as on 2013.
e) The reclamation of land undertaken in the year 2006 along the coastal tract has improved the quality of the soil / land.
f) The canal / flood water impounded in the coastal tail end regulators in Karaikal region has improved the quality of groundwater in and around these areas.

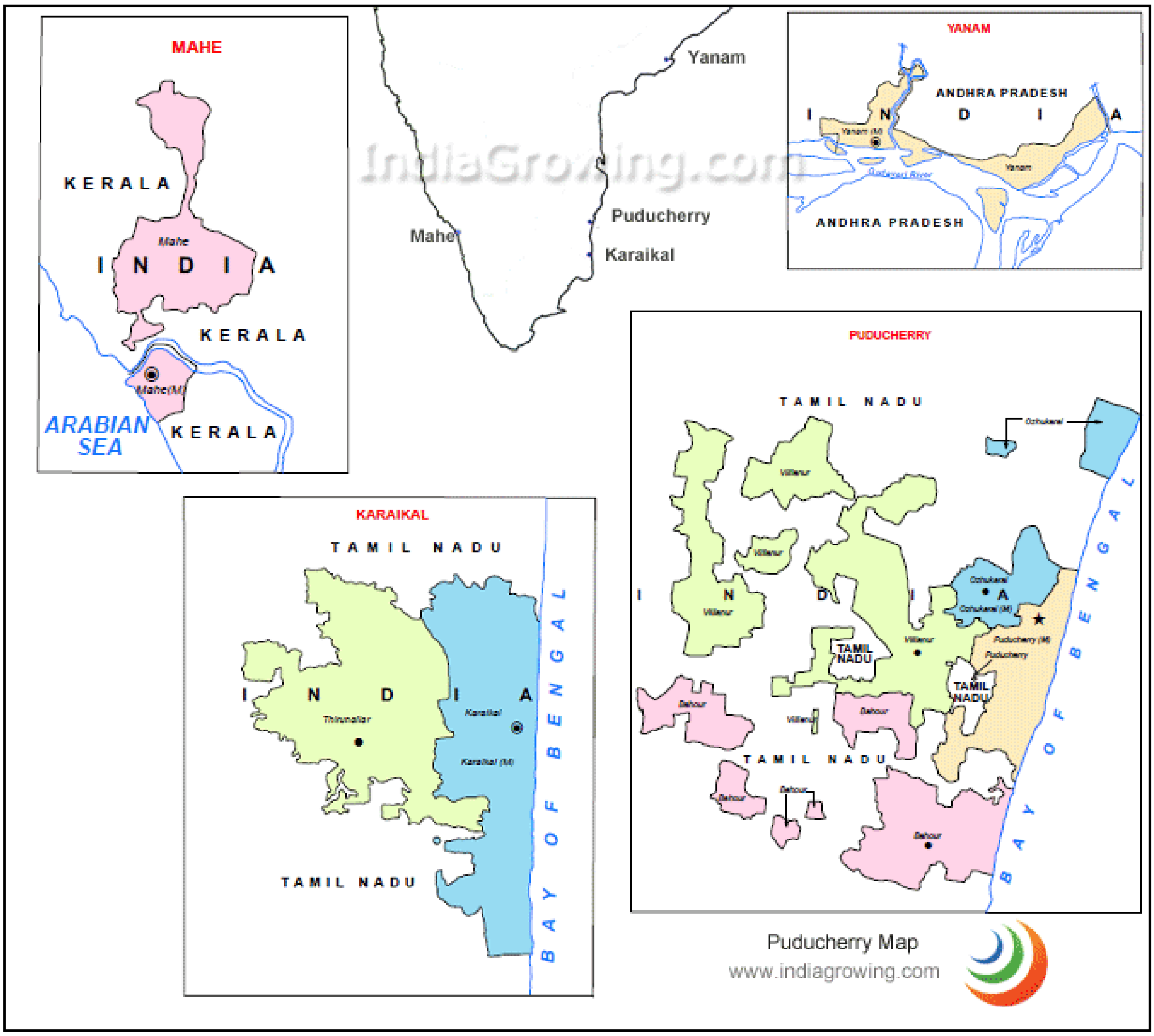


Fig. 3.9.1 Locations of coastal districts in Union Territory of Puducherry.

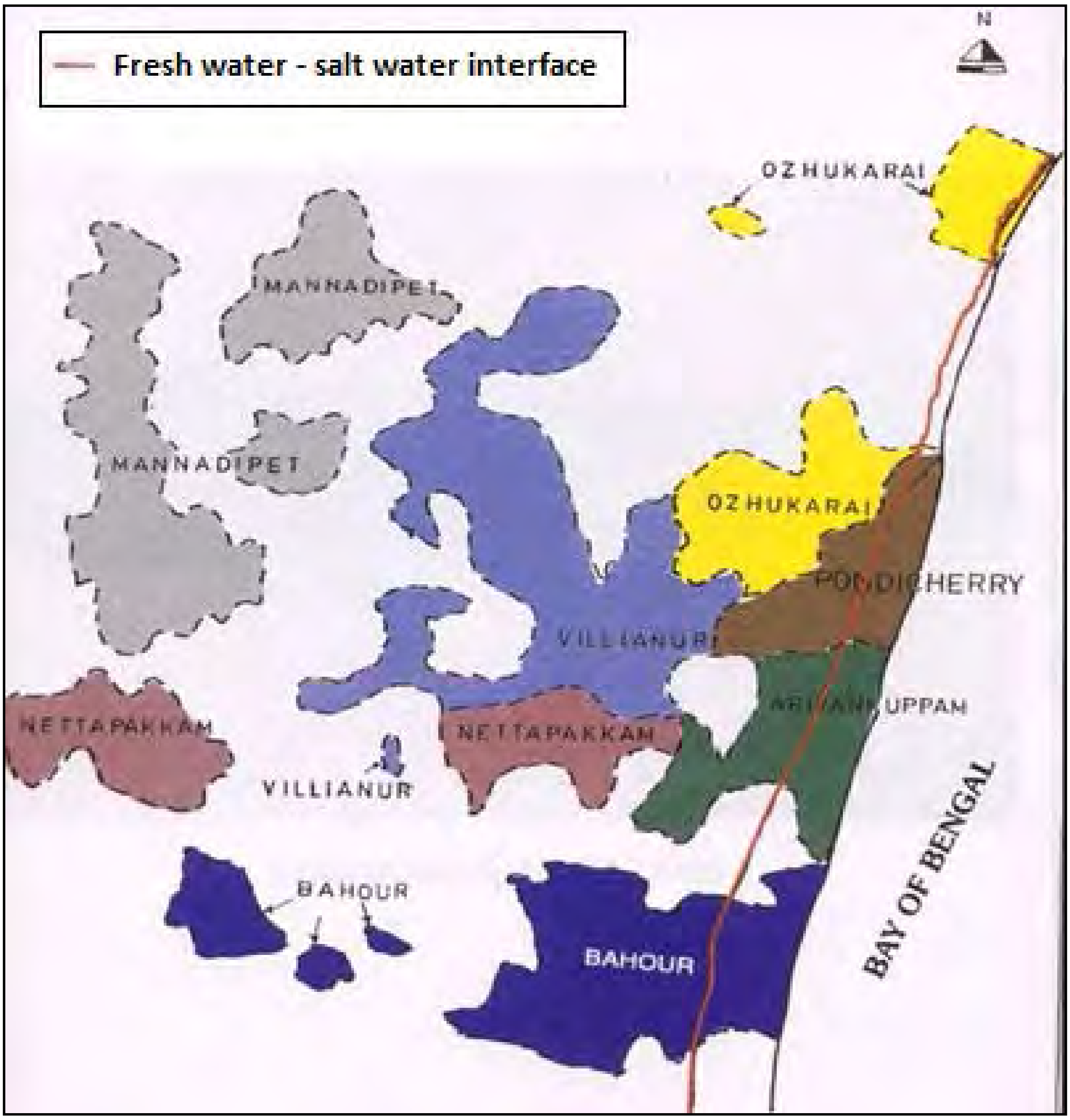


Fig. 3.9.2 Position of fresh water – salt water interface in Puducherry district.

3.10 GOA

3.10.1 General

The coastline of Goa runs for nearly 119 km on the western coast. Most of the state constitutes part of the Konkan region. On the northern boundary of the state runs the Terekhol river, which separates Goa from Maharashtra, while on its south the Uttar Kannada district of Karnataka is located. On the east lie the Western Ghats and in the west the Arabian Sea. Sonsogor, with an altitude of 1,167 m, is the highest peak located in the mountain range of Western Ghats. The state is divided into two districts: North Goa and South Goa. Panaji is the headquarters of the North Goa district and Margao of the south district. Due to its proximity to the Arabian Sea, the climate of Goa is warm and humid for most of the year. The state receives copious rainfall with an average of 3000 mm from the south west monsoon. As a result of orographic influence, rainfall increases towards the Western Ghats and about 32% of the annual rainfall is received during the month of July. Figures 3.10.1a-d show the locations of the two coastal districts, variation in average annual rainfall (1971-2005) across the districts and the general land use / land cover in coastal areas.

3.10.2 Physiography and Drainage

Topographically, the state of Goa can be divided into three distinct sub-regions, namely (i) the coastal plains with dominant marine landforms and comprising the talukas of Tiswadi, Bardez, Salcete and Mormugao that cover about 22 per cent of the total geographical area; (ii) the intermediate or transitional sub-mountainous region with undulating uplands, covering about 35 per cent of the area; and (iii) the interior hilly region ranging from 300 to 1,200 meter in height and covering 43 per cent of the remaining area (Figs. 3.10.2 a-b).

Goa is drained by nine major rivers flowing generally from East (Western Ghats) to West (the Arabian Sea). An exception is the Sal river in south Goa which follows a north-east to south-west course due to the presence of west coast fault. The major rivers are namely, Terekhol, Mandovi, Zuari, Chapora, Sal, Talpona, Saleri, Canacona and Galgibagh. These nine rivers and their 42 tributaries play a significant role in the economy of the state. Of the nine rivers, the Mandovi and Zuari alone together drain 2553 km^2, which constitutes about 70% of the total geographical area of the state. The rivers in Goa are a major source of potable water and provide irrigation water supply for crop production, produce biotic resources, support barge-based transport of ore from the mining areas to the port, and ferry people and goods to different parts of the state. All the rivers are subject to tidal influence up to a great distance landwards from their mouth; in some cases, to a distance of about 40 km inland. The salinity factor in the river varies sharply between the monsoon and non-monsoon period and so does the quality of water in wells located along the banks, which tends to get saline as the summer months advance.

3.10.3 Hydrogeology

Seventy percent of the area of the state is covered by laterite capping. The coastal alluvium occurring along the coastal plains constitute about 1% of the geographical area. In coastal Goa, the recent alluvium and the thick laterite cappings form potential aquifers. The alluvial aquifers comprise fine to coarse sand and gravel with intercalation of sandy loam in the alluvium. Thickness of alluvium varies from a few meters to about 22 m. The thickness of sand and gravel bed varies from 3 to 3.5 m in the depth range of 10 to 20 m bgl. The yield ranges from 155 to 260 m^3/day. The transmissivity values range from 25 to 178 m^2/day. The laterites are either insitu, particularly in plateau areas, or detrital origin generally occupying the valley portions. Besides inherent porosity, the laterites are highly jointed and fractured which control the water bearing capacity. The thickness of laterites extends up to 30 m and the depth to water level varies from 1.21 to 9.54 m bgl.

Fissured crystalline formations also constitute important aquifers in the state. The depth to water level in these rocks varies from 2.12 to 7.27 m bgl. The transmissivity varies from 0.9 to 35 m^2/day. In dugwells tapping metavolcanics and metasedementaries, the depth to water level ranges from 2.12 to 7.27 m bgl. The depth of exploratory bore wells ranges from 37 to 200 m and yields range from as low as 16 to 2200 m^3/day. The transmissivity values range from 0.25 to 346 m^2/day. Figures 3.10.3a show the aquifer systems, while Figs. 3.10.4a-b show the variation in depth to groundwater level for the year 2011.

3.10.4 Groundwater Salinity

Groundwater salinity in coastal tracts exists due to marine depositional environment and tidal influence in rivers/ streams (CGWB, 2010a,b). In North Goa district, groundwater in dug wells and borewells in areas around the seasonal river Baga and along Chapora river is brackish to saline due to seawater ingress. Similarly, in South Goa district, groundwater in and around Marmugao taluka, especially in locations close to and in the vicinity of creeks shows high EC and chloride values indicating brackish to saline nature of groundwater. In areas confined to the coastal reaches of Sal River, groundwater is brackish and unsuitable for drinking. Salinity is more pronounced during May when fresh water flow is minimum and maximum seawater ingress takes place through creeks. Figures 3.10.3b shows the EC of groundwater at shallow depths.

3.10.5 Causes and Extent of Coastal Land Salinity

The major cause of coastal land salinity is the marine depositional environment and tidal influence in rivers/ creeks. Figures 3.10.5a-b and 3.10.6 show the areas affected by salinity in the two districts. Saline soil in the North Goa district occurs in the flood plains of Zuari and Mandovi rivers in Tiswadi, Bardez and Ponda taluks. In South Goa district, saline soil occurs in the flood plains of Zuari, Sal, Saleri, Talpona and Galjibagh rivers in Salcete, Marmugao, Quepem and Canacona talukas. The saline soil with high pH is deep, poorly drained and shows reduced permeability.

3.10.6 Remedial Measures

The agricultural lands that are subject to inundation by the neighbouring river are protected by bunds and are termed *Khazan* lands. These salty low lying flat lands were originally mangrove swamps/mudflats lying along both the banks of the rivers of Goa. The early settlers in these places who migrated from mountainous uplands slowly reclaimed the lands over the centuries by constructing an intricate system of bunds (dykes) and sluice gates all along the river and started cultivation practices in these lands. The total length of earthen bund protecting Khazan lands is estimated at around 420 km. Figure 3.10.7 illustrates the locations of Khazan lands in Goa.

The Khazan land consist of four main components: the bundh, the manas (wooden sluice gate), the pôiim (internal water bodies) and the crop fields - elevated portion of land for cultivation. The bundh is a 2-3 m high dam made of clayey soil from the marshlands or mudflats. It protects the Khazan from inundation with brackish water from the estuary at high tide, and also helps to maintain water level in the Khazan during monsoon. The manas (sluice gate; Fig. 3.10.8) is a simple mechanism that allows water from the pôiim to drain out into the neighbouring estuary during low tide while automatically closing during high tide to prevent brackish water from entering the Khazan. The water stored in pôiim is also drawn for irrigation.

The state proposes to adopt new and innovative technologies for implementing the mechanism of operation of sluices and earthen bunds in a scientific manner. Further, to arrest the tidal ingress, the State Water Resources Department has undertaken construction of open type bandharas across the tidal affected rivers and elsewhere for development of fresh water storages for irrigation and other purposes. The State has also passed the 'Goa Ground Water Regulation Act 2002' to regulate and control the development of groundwater resources.

The bunds which were constructed are now in dilapidated conditions, due to which there is growth of marine vegetation all along the fields, pollution of fresh water bodies and flooding of fields thereby posing a danger to the villages. For protecting these bunds the Soil Conservation Division of Directorate of Agriculture is operating the scheme of "Repairs/Maintenance of notified bund "in the state as per the following categories of work.

1. **Category I:** --- Subsidy at 50% of the cost of repairs of notified protective bunds subject to a maximum of Rs. 6000/-- per hectare of benefited area is given to the tenant association on successful execution of the work under Govt. Supervision and with prior approval.
2. **Category II** :-- Repair of the protective bund with 100% initial investment by the Govt, and recovering 50% of expenditure incurred on such repairs with 6% interest in ten annual installment from the tenants association / beneficiaries.
3. **Category III**: -- Strengthening / Remodelling of notified protective bund withmorrum / alluvial clay filling of 4mts. Top width belonging to the tenants association of minimum 10 nos. of beneficiaries . The repair is taken with 100% initial investment by the Govt, and recovering 10% 0f the expenditure incurred on such repairs in ten annual installments.

By the above scheme, repairs/ maintenance works of external notified bunds only were covered. Since, internal bunds also from integral part of Kazan land protection, necessity of protection these bunds were also felt. Accordingly, scheme for such bunds was made and is being implemented along with W,R.D. The funds for these works are made available under centrally sponsored R.K.V.Y. scheme at 100% Government cost. Fund to the tune of Rs. 159 crores also has been earmarked for these works.

So far 50 bunds have been repaired between the period 2004-2014 under category II &III as stated above under the state Government scheme. Even after repairs, though much of the command remained uncultivated for various reasons, efforts are being made to motivate farmers to bring such uncultivated land under cultivation.

The details of the expenditure incurred by the state Government for undertaking repairs/ maintenance of bunds under below mentioned categories during period 2004-2014 is given below.

Table 3.10.1 Expenditure incurred for taking up remedial measures in the state of Goa

Sl No	Year	Expenditure Incurred (Lakhs)		
		Category-I	Category-II	Category-III
1	2003-04	26.86	45.00	
2	2004-05	28.13	90.83	
3	2005-06	44.83	114.40	
4	2006-07	33.84	144.00	
5	2007-08	45.11	178.80	
6	2008-09	35.70	43.32	
7	2009-10	69.72	259.98	
8	2010-11	53.90	737.50	
9	2011-12	38.45	373.56	
10	2012-13	41.03	660.56	
11	2013-14	35.29	954.83	
Total		452.86	3602.78	

Figures 3.10.9 and 3.10.10 shows the works taken up in Tiswadi Taluka and Bardez Taluka.

Benefits of Remedial Measures

Khazan lands are ecologically, economically and socially very important for both agriculture and pisciculture. These unique agro ecosystems covering an area of about 17,500 ha constitute the agriculture bowl of the state of Goa. The local farming community traditionally practices rice cultivation by growing salt–tolerant species during monsoon. The system of pôiim and sluices offer opportunity for shrimp aquaculture as a secondary but lucrative occupation. These lands also serve as emergency storm water receptacles and play a major role in preventing flooding of inland areas. The mangrove vegetation near the external or internal bunds serves as a natural anti-erosive barrier for the coastline.

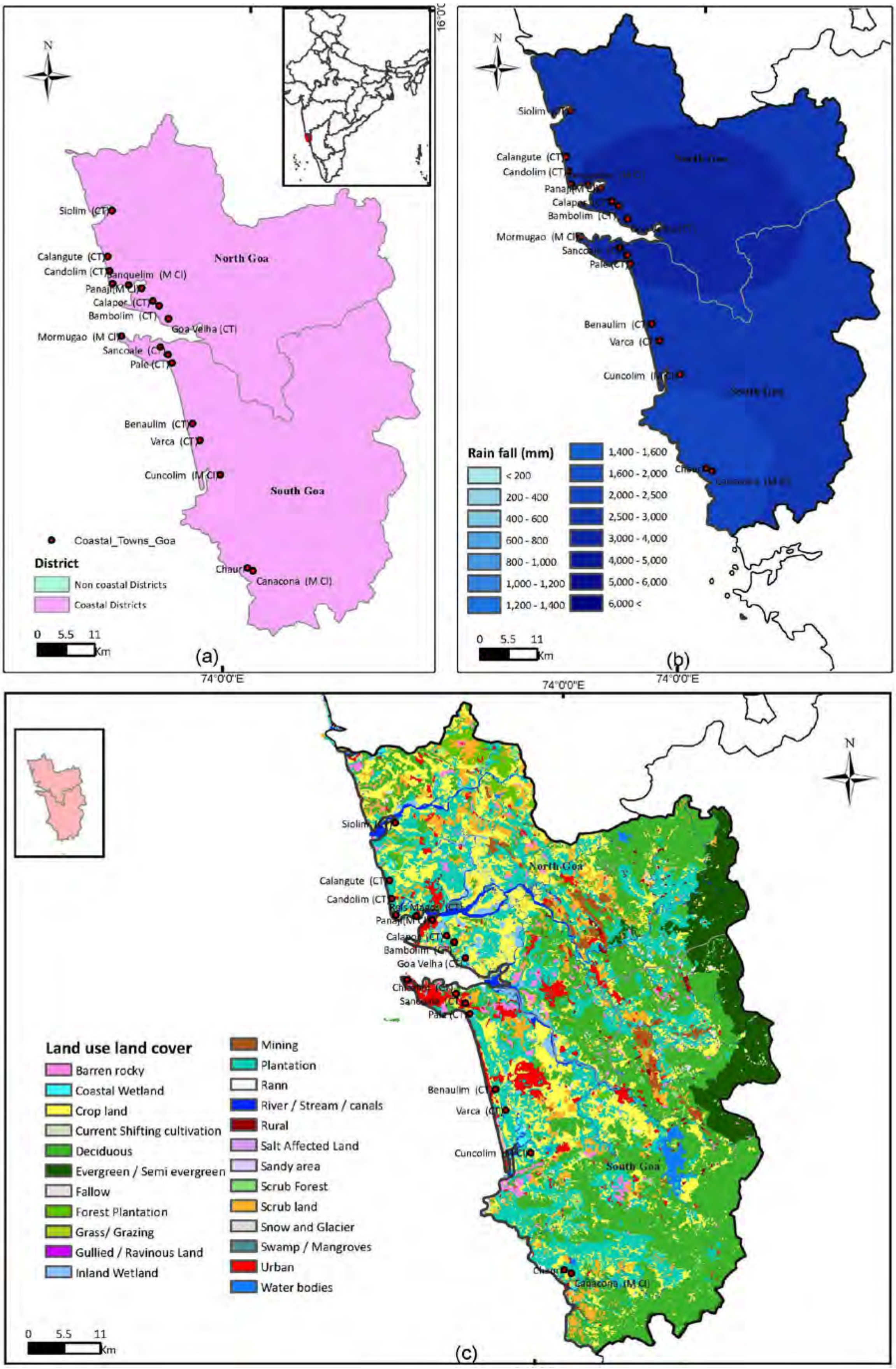


Fig. 3.10.1(a) Administrative map of Goa showing coastal districts (b) Rainfall distribution of coastal districts of Goa (c) Land use and land cover of coastal districts of Goa

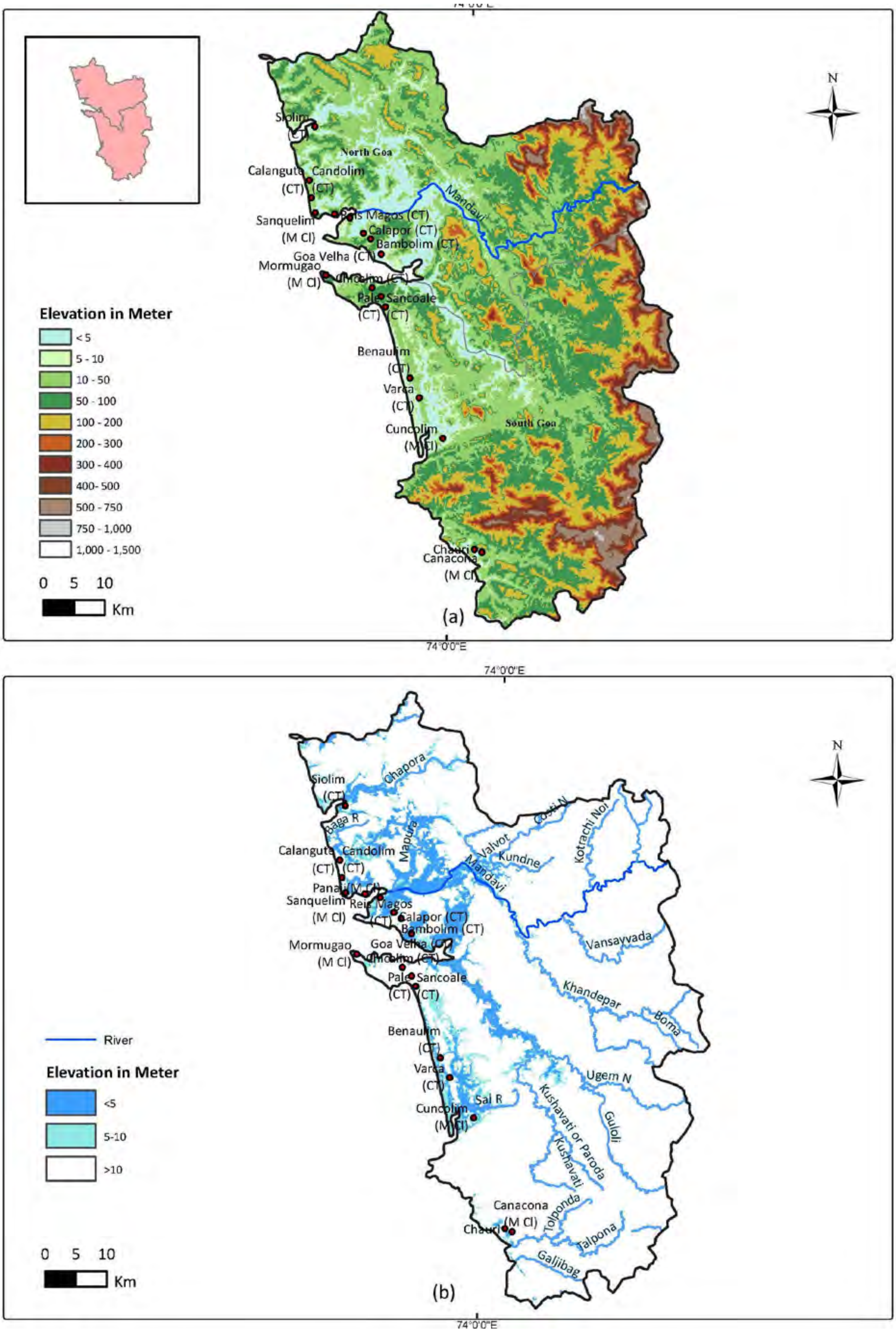
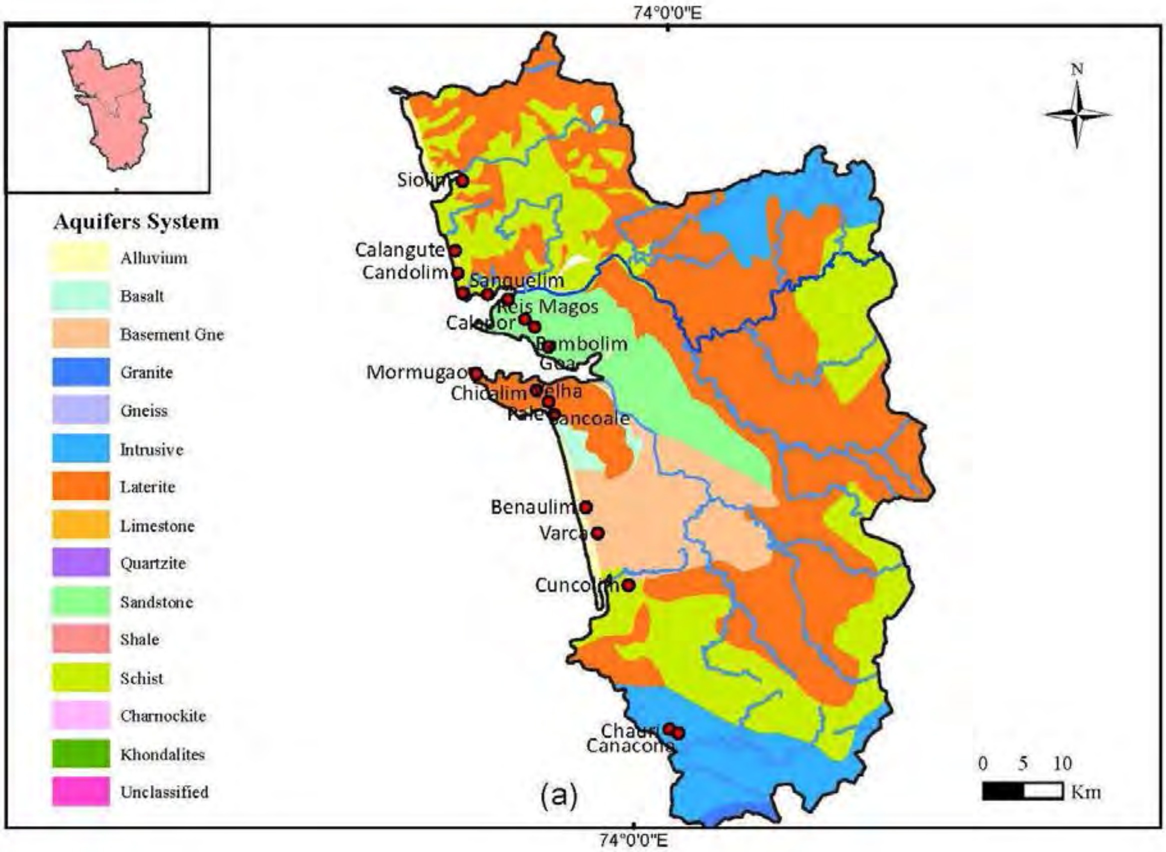


Fig. 3.10.2 (a) Physiographic map of Goa (b) Drainage map of Goa showing low elevation coastal areas (< 10 m amsl)



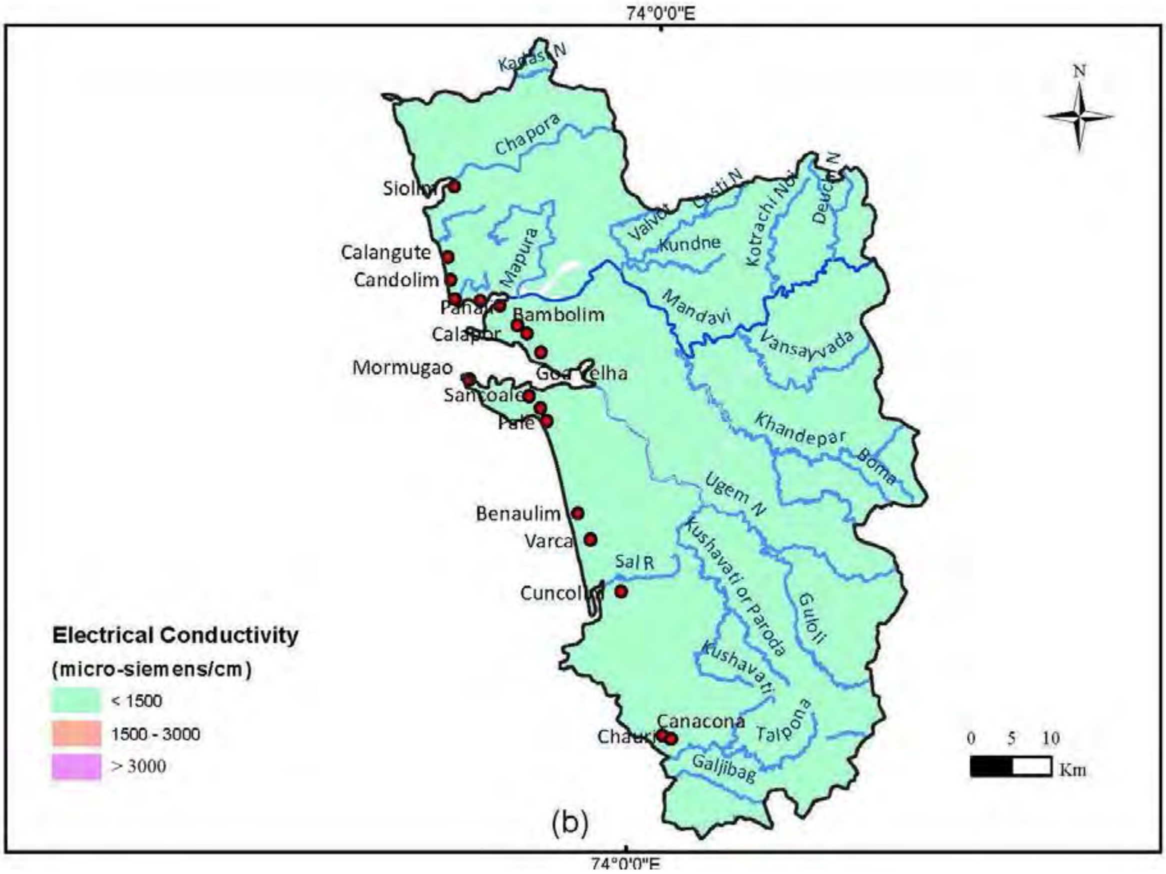


Fig. 3.10.3 (a) Aquifer map of coastal districts of Goa (b) EC map of shallow groundwater for coastal districts of Goa

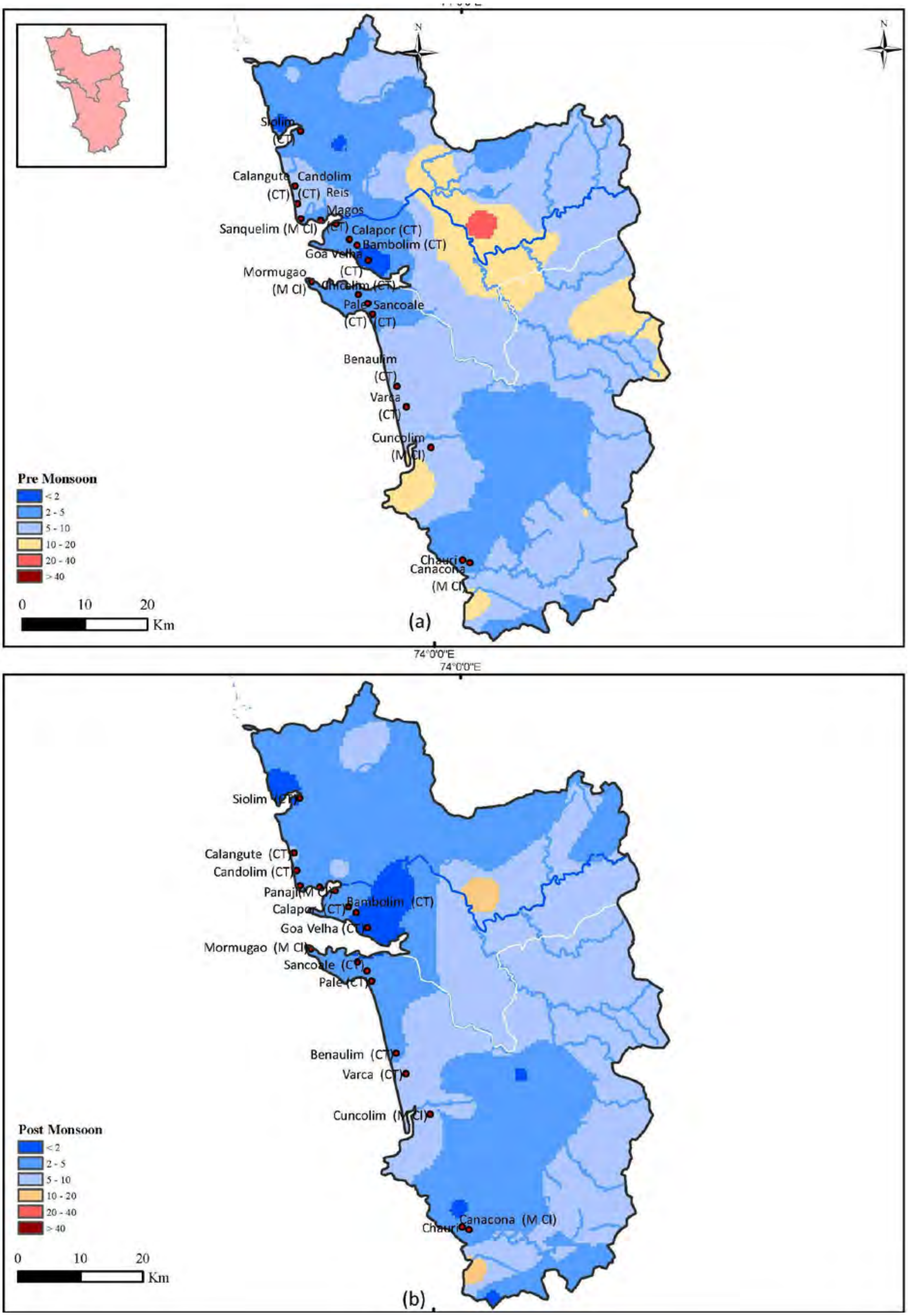
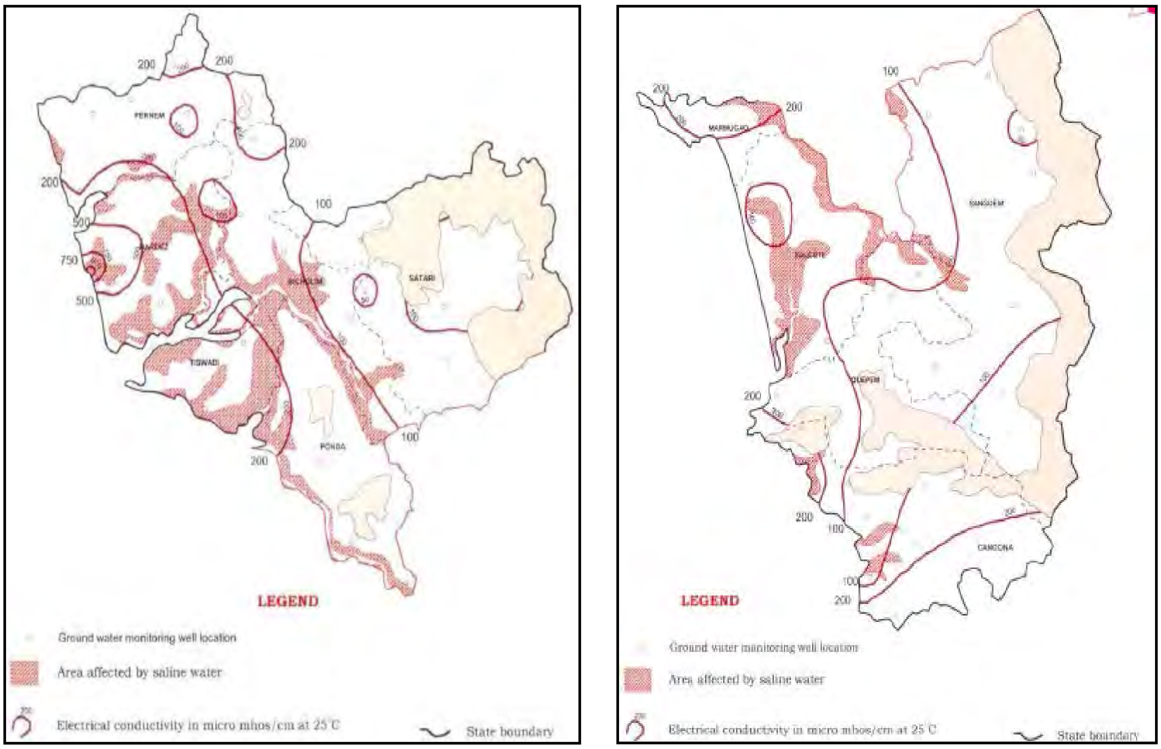
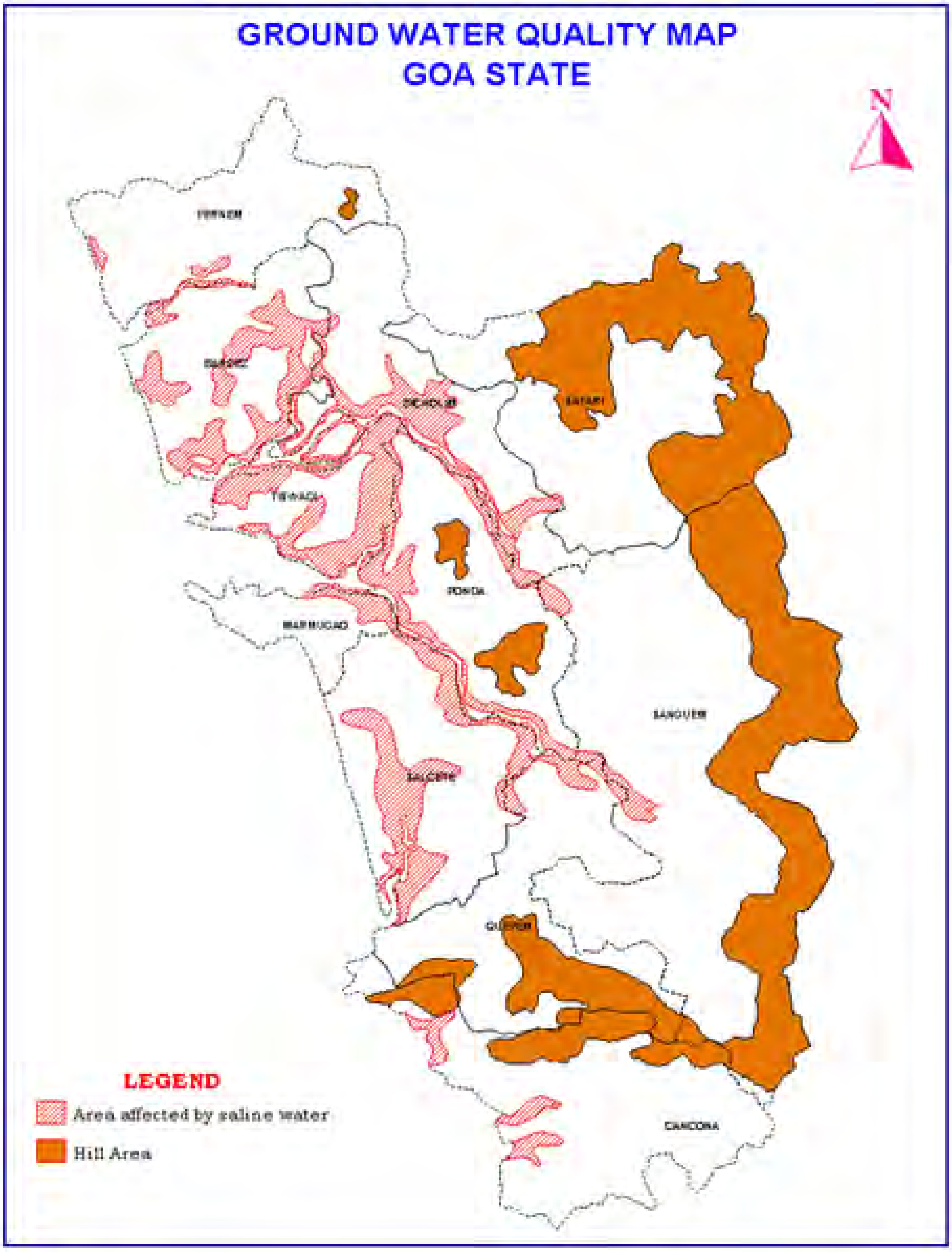


Fig. 3.10.4 (a) Pre-monsoon water level of coastal districts of Goa (in meters) (b) Post-monsoon water level of coastal districts of Goa (in meters)



(a) **(b)**

Fig. 3.10.5 a-b Areas affected by salinity in Goa (a) North Goa district (b) South Goa district (CGWB, 2010 a,b)



3.10.6 Map showing the Areas affected by Salinity and the Hill Areas.

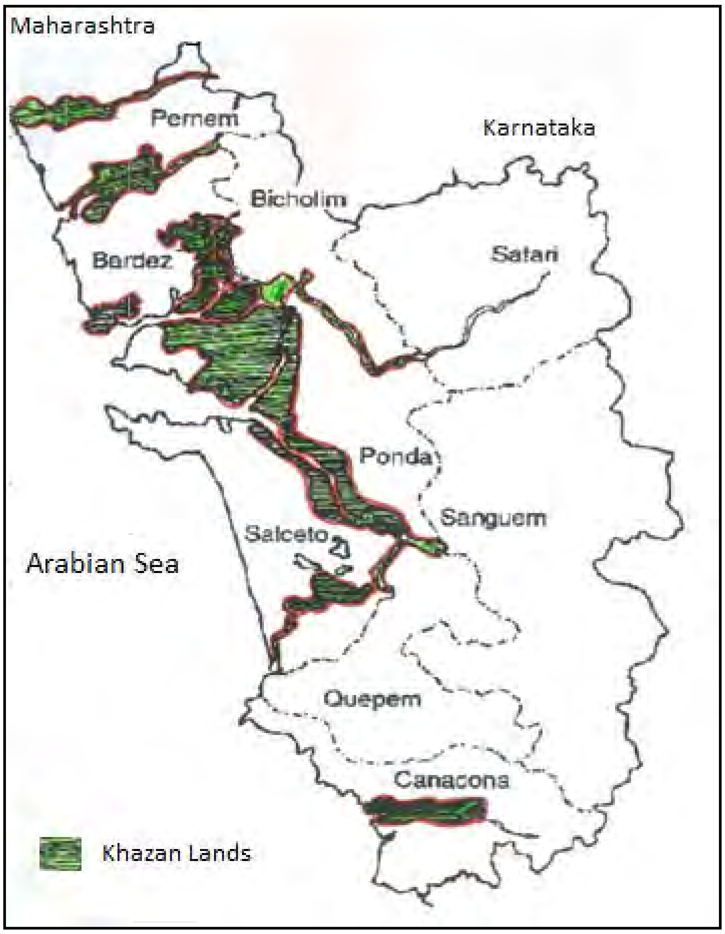
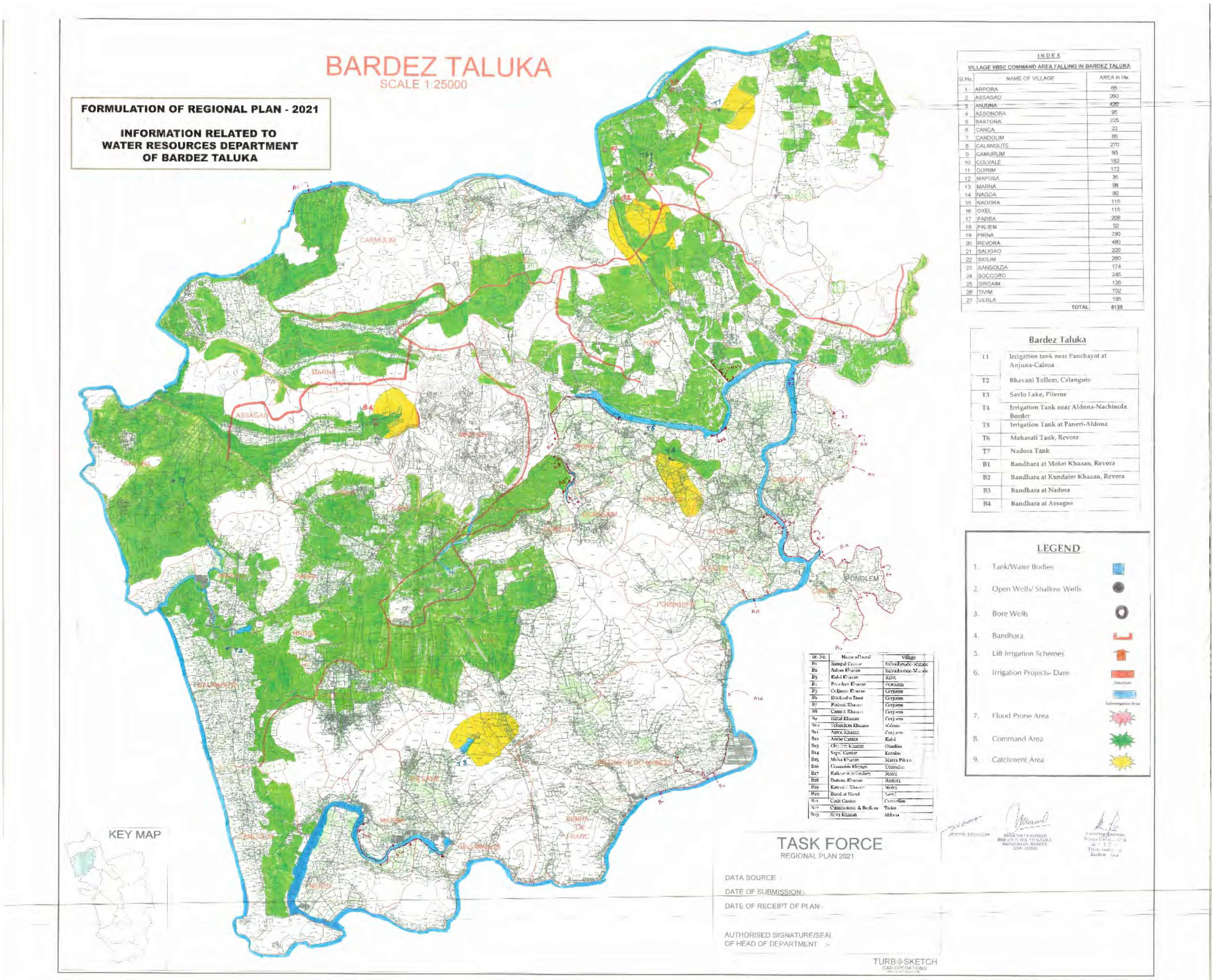


Fig. 3.10.7 Locations of Khazan lands in Goa

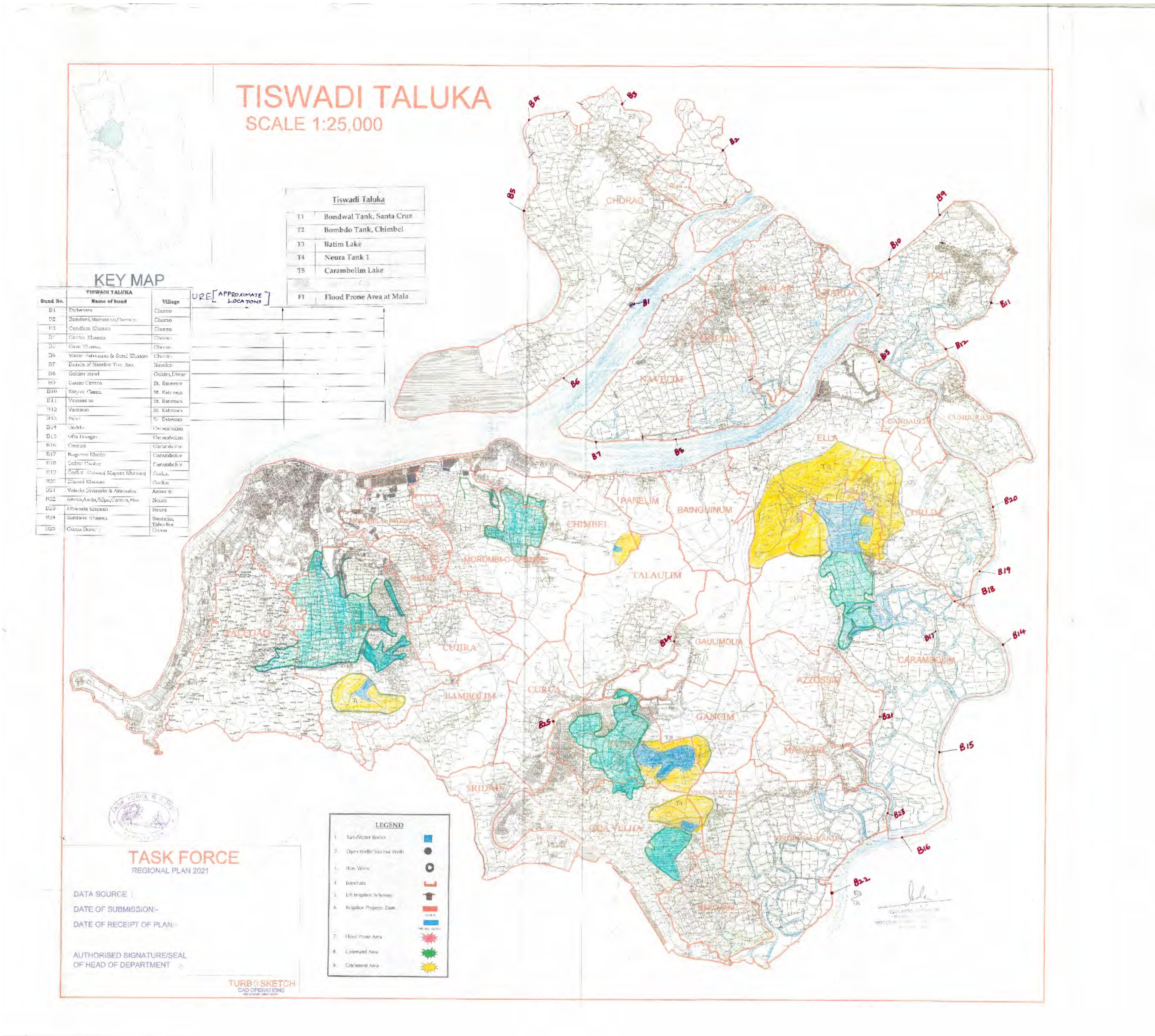
Closed sluice gate with wooden doors

Slightly opened sluice gate

Fig. 3.10.8 Sluice gates in Khazan lands



3.10.9 The Projects Executed in the Bardez Taluka



3.10.10 The Projects Executed in the Tiswadi Taluka

CHAPTER 4
FUTURE PROGRAMS FOR MITIGATION OF COASTAL LAND SALINITY

Future programs have been proposed by the coastal states / union territories for mitigation of coastal land salinity both on the east coast and west coast of India. The programs have been formulated based on site specific conditions, causes and extent of salinity affected areas in different rivers basins of coastal regions. Previously, in Chapter 3, the physiography and drainage, hydrogeology, existing groundwater salinity, causes and extent of coastal salinity, and remedial measures already adopted by states with their benefits have been brought out in detail for each of the coastal states and union territories of Puducherry and Goa. In subsequent sections, the various additional measures needed in future for arresting salinity intrusion in different coastal states /union territories are discussed.

4.1 GUJARAT

The state of Gujarat has two major regions viz., Saurashtra and Kachchh that are affected by salinity. As per the recommendations of HLC-I and HLC-II (refer Chap. 3, Section 3.1), various measures have been adopted to tackle the severe problem of water and land salinity in these coastal regions of the state. The salinity prevention measures include construction of a large number of structures to: (i) control salinity ingress in surface water bodies and subsurface formations along the coastal tracts, (ii) recharge and enhance the water quality in aquifers along the coastal belt, (iii) promote agricultural activities by providing surface water for irrigation to the farmers in and around the constructed civil structures, and (iv) achieve an overall improvement in socio-economic conditions of the village community in vicinity of the constructed civil structures.

The measures already adopted in the state are discussed in Chapter 3. In line with the committees' recommendations, a total of 2306 structures are further planned in Kachchh region, whose details are given in Table 4.1.

Table 4.1 Proposed works with expenditure in Kachchh Region of Gujarat

Structure	Number	Area Benefitted (in Ha)	Approx. Cost (in cr)
Bandhara	13	6640	151.94
Big check dam	354	17288	277.23
Small check dam	2000	11292	178.95
Total	2367 (check dams and bandharas)		**607**

The details of the proposed works of Bandhara, Small and Big Check Dam is given at Annexure 4.1A

In the region of Saurashtra, a total 45 numbers of Salinity Prevention Schemes are planned to be taken up in next five years, whose details are given in Table 4.2. The list of proposed works in Saurarashtra region is provided in Annexure 4.1B.

Table 4.2 Proposed works and expenditure in Saurashtra Region of Gujarat

Structure	Number	Approx. Cost (in cr)
Tidal Regulator and bandharas	16	328.16
Spreading channel	10	103.38
Anti sea erosion works	2	8
Recharge tank & other salinity control works	17	42.50
Total	45	**482.05**

Problems in implementing future programs

Major bottlenecks in implementing these works are acquisition of forest land falling under submergence, poor foundation strata, and private land acquisition. The problems stated above are some of the major hindrances in timely completion of the schemes. Planned progress can be achieved, if these problems are solved within stipulated time.

4.2 MAHARASHTRA

The state of Maharashtra has proposed the Kharland schemes whose district wise details are provided in Table 4.3. The district wise proposed schemes are enclosed as Annexure 4.2A.

Table 4.3 Proposed works and expenditure in Maharashtra

Sl. No.	District	No. of works	Reclaimed area (ha)	Work cost (Rs in cr)	Financial program for years 2015 - 2018 (Rs in cr)		
					2015-16	2016-17	2017-18
1	Thane & Palghar	22	1673	26.94	2.10	13.52	11.31
2	Raigad	27	1371	61.17	4.50	29.99	26.67
3	Ratnagiri	75	2270	7.04	0.00	4.95	2.08
4	Sindhudurg	24	321	13.08	0.50	8.56	4.02
	Total	**148**	**5635**	**108.23**	**7.10**	**57.04**	**44.09**

Problems in implementing future programs

Following difficulties are encountered in construction of salinity prevention works:

1. Inadequate funds to carry out maintenance and repair of existing Kharland schemes which have been deteriorated by floods and tides.

2. For execution of Kharland Schemes, exemption from CRZ act is necessary which consumes a lot of time.
3. Inadequate technical staff.

4.3 KARNATAKA

The state of Karnataka has proposed 151 salt water exclusion dams and 175 river protection works in the three districts of Karnataka. The details are given in Table 4.4.

Table 4.4 Proposed works and expenditure in Karnataka

Sl No	District	Salt Water Exclusion Dams/ Kharland schemes			River protection works	
		No. of works	Irrigation potential (ha)	Cost (Rs in cr)	No. of works	Cost (Rs in cr)
1	Dakshina Kannada	18	1,198	37.90	30	50.00
2	Udupi	30	2,191	61.15	118	50.55
3	Uttara Kannada	103	11,669	240.00	27	341.00
	Total	**151**	**15,058**	**339.05**	**175**	**441.55**

The district wise proposed SWED projects in Dakshin Kannada & Udupi districts and Uttara Kannada districts are given in Annexure 4.3A & Annexure 4.3B respectively. Similarly, the district wise proposed river protection works in Dakshin Kannada & Udupi districts and Uttara Kannada districts are given in Annexures 4.3C & Annexure 4.3D respectively.

4.4 KERALA

The state of Kerala has proposed works with an expenditure of Rs 300 cr whose details are provided in Table 4.5

Table 4.5 Proposed works in Kerala

Sl. No.	Particulars	Works	Expenditure (Rs in cr)
1	Regulators	1	NA*
2	Regulator cum bridge	5	NA
3	Bunds	2	NA
4	Check dam	6	NA
5	Lock cum regulator	2	NA
6	Salt water exclusion works/ Salt water exclusion vented cross bar	10	NA
	Total	**26**	**344.20**

*NA – Not available

The details of the proposed schemes are given in Annexure 4.4A.

4.5 TAMIL NADU

Cauvery Delta

In Cauvery Delta, the terrain for a distance of about 25 km upstream from the coast is almost flat which impedes the drainage of flood flows. Any rise in sea level could worsen effective drainage of flood water into the sea and also aggravate saline water ingress into the fertile lands. The Cauvery Delta is one of the selected locations by the Asian Development Bank (ADB) for the study of impact on surface water and groundwater due to perceived rise in sea level that might be caused by climate change.

In this scheme, protection of the coastal area in the Cauvery Delta will be ensured, since the structures proposed to be constructed would act as flood absorbers, facilitating effective use of flood water through recharging the groundwater and preventing the saline water ingress into the fertile lands. This scheme will benefit an area of about 4.50 lakh acre under Cauvery, Vennar, Grand Anicut Canal System and Lower Coleroon Anicut System covering the districts of Tiruvarur, Nagapattinam and a part of Thanjavur.

Further, the Climate Adaptation through Sub-Basin Development Programme (CASDP) supports the implementation of the Government of India National Action Plan on Climate Change (NAPCC) of 2008 and National Water Mission (NWM). As part of support to the NAPCC, the Asian Development Bank has prepared sub-basin profiles and a strategic frame work for climate change adaptation in 3 sub basins all over India. As a first stage of this project it is proposed to take-up works in the following rivers/ drains of the part of Lower Vennar System of the Cauvery Delta: (a) Adappar (b) Harichandranadhi (c) Pandavayar (d) Vellaiyar (e) Valavanar Drain, and (f) Vedaraniyam Canal

The Detailed Project Report for the part of Lower Vennar System has been prepared at a cost of **Rs. 84,063 lakh**. This project consists of the following components to prevent seawater intrusion into land area.

Table 4.6 Components of Lower Vennar System of Cauvery Delta in Tamil Nadu

Sl. No	Type of Structure	New (quantity)	Reconstruction (quantity)	Repair (quantity)
1.	Regulators	4	9	13
2.	Bed Dam / Grade Wall	4	1	15

Anticipated benefits

1. Construction of tail end regulators near the sea mouth would prevent the ingress of salt water and conserve fresh water for irrigation.
2. The groundwater level would be raised, creating a larger hydraulic gradient to arrest the landward intrusion of seawater.

Financial aspects of project

The above scheme is proposed to be implemented at a total cost of about **Rs.1,56,000 lakh** out of which the loan assistance from Asian Development Bank will be Rs.1,09,200 lakh and the State's share will be Rs. 46,800 lakh.

Construction of Tail End Regulators Excluding Cauvery Delta

The State is actively working towards mitigating the problem of sea water ingress and creation of storage for last mile irrigation and drinking water. Several proposals have been formulated. Some of these schemes that are under consideration of the State Government are given in Table 4.7.

Table 4.7 Proposed works in Tamil Nadu apart from Cauvery Delta

Sl. No.	Name of Proposal	Basin	Approx. Cost (Rs in cr)
1	Construction of tail end regulator across Palar river at Vayalur village in Thirukalukunramtaluk of Kancheepuram District	Palar	200.00
2	Construction of tail end regulator across Paravanar river in Sirupalaiyur - Manikkollai village of Chidambaram-Cuddaloretaluk of Cuddalore District	Paravanar	15.00
3	Construction of tail end regulator across Vellar river Adivaraganallur village in Chidambaram taluk of Cuddalore District.	Vellar	70.00
4	Construction of tail end regulator across five arms of Thamirabarani river near the confluence point with sea in Thoothukudi District.	Thamirabarani	80.00
5	Construction of tail end regulator across Hanumanathi river in Chettikulam village of Radhapuramtaluk in Tirunelveli District	Hanumanathi	5.00
6	Construction of tail end regulator across Pazhayar in Thamaraikulam village of Kanyakumari District.	Pazhayar	15.00
7	Construction of tail end regulator across Kuzhithuraiyar in Vilanvankodetaluk of Kanyakumari District	Kuzhathuraiyar	30.00
	Total		**415.00**

4.6 ANDHRA PRADESH

In the state of Andhra Pradesh, studies have been carried out by different organisations during the last decade addressing the issue of groundwater salinity in various sections of the coast tract. These studies are isolated in nature and require a more integrated approach to fill in the data gaps and provide effective solutions to the groundwater salinity problem.

It is proposed to carry out rigorous integrated studies to tackle salinity problem existing along the entire coastline. This requires multidisciplinary approach involving all the concerned organisations to share the monitored data and also fill the data gaps with primary data in order to prepare a comprehensive plan to tackle the salinity problem. The proposal for mitigating the coastal land salinity comprises the following major objectives:

1. To carry out systematic study of salinity ingress of coastal area and delineation of affected areas.
2. To implement suitable remedial measures.

The budgetary proposal for carrying out the systematic study is given in Table 4.8.

Table 4.8 Proposed budgetary requirement of Andhra Pradesh State to carry out the survey

Sl. No	Item (for integrated studies)	Budget (Rs in cr)			
		1st year	2nd year	3rd year	Total
1	Man power	3.75	3.75	3.75	11.27
2	Equipment	0.84	0.05	0.05	0.94
3	Travel, transport and technical study tours / visits	0.61	0.60	0.26	1.48
4	Water Analysis (2000 samples @ Rs. 3000/-) and/ or equipment upgradation in existing water quality labs/ chemicals and other consumables	0.20	0.20	0.20	0.60
	Total	**5.41**	**4.61**	**4.26**	**14.29**

Budgetary provisions that may be required for taking up any works for implementation of remedial measures will be projected in due course based on the outcome of systematic studies/surveys.

4.7 ODISHA

The state of Odisha has proposed to take up remedial measures listed in Table 4.9. The district wise budget is given in Table 4.10.

Table 4.9 Proposed works in Odisha

Sl. No.	Project	Works (Proposed)
1	Renovation of creek projects	6
2	Construction of creek projects	12
4	Renovation of drain	1
5	Instream structures	3
6	Inlet sluice	1
	Total	**23**

Table 4.10 Proposed district wise expenditure in Odisha

Sl No	District	Budget (Rs in cr)
1	Kendrapara	22.37
2	Bhadrak	9.80
3	Jagatsinghpur	58.0
4	Puri	cost not assessed
5	Khurda	cost not assessed
	Total	**90.1743**

The scheme wise details are placed in Annexure 4.7A.

4.8 WEST BENGAL

In the nearly flat coastal topography of West Bengal, groundwater salinity is mainly *insitu* influenced by estuarine conditions, frequent cyclonic storms and coastal erosion. Comprehensive long-term studies are required to understand the water flow dynamics, sedimentation patterns, accretion and erosion pattern in different islands for selection of locations for new embankments in affected areas. Supply of safe drinking water for the coastal population is a major issue. The state has prepared an estimate for an approx. amount of Rs 1500 cr to provide safe and sustainable drinking water supply in the saline affected areas. Details of the action program need to be prepared by the "Sundarbans Water Supply Committee".

4.9 PUDUCHERRY

Future plans/ schemes required to reduce the salinity problem along with associated cost estimate for 5 years in given in Table 4.11.

Table 4.11 Proposed plans in the Union Territory of Puducherry

Sl No	Project	Cost (Rs in cr)
1	Desiltation of lakes	35
2	Renovation of 600 village ponds in phased manner	20

4	Construction of check /bed dams across the river courses in Puducherry region	45
5	Construction of recharge shafts in water holding area of check dams	10
6	Construction of regulators across river courses	15
	Total	**125**

4.10 GOA

According to the Water Resources Department, Goa, about 30% of the earthen bunds in Khazan lands which are in dilapidated condition require improvement. On an average, expenditure of about 900 lakh is incurred on up keep of these bunds annually by the State Government. It is proposed to adopt new and innovative technologies for putting the mechanism of operation of sluices and earthen bunds in a scientific manner. For this purpose, estimated funds to the tune of Rs. 200 crore are required for proposed restoration of eroded bunds, sluices etc.,

The proposed works to be taken up the government of Goa for protection of Salinity ingress are given below in Table 4.12

Table 4.12 Proposed Works of Government of Goa

Sl No	Work	Length in Mts	Area Protected in Ha	Estimated Cost (Appx) in Lakhs
1	New Works Approved by the Government	6135	239	1351
2	List of works submitted to WRD for accord of Technical Sanction	17601	1190	2692
3	List of Estimates under preparation	61200	3076.88	11665
	Total	849.36	4506.88	15708
	Add provision for technical staff and mobility @1%			157.08
	Total			15900 (say)

The details of the works are given at Annexure 4.10A.

CHAPTER 5
RECOMMENDATIONS OF THE COMMITTEE

5.1 INTRODUCTION

Salinity water ingress problem is multi disciplinary in nature involving hydrology, geology, ground water aquifer system, hydrogeology etc. The problem needs to be tackled in surface and ground water front also. The sharing of this knowledge has been made possible by constituting a Multi Disciplinary Expert committee consisting of Experts from State Government, and from government of India. This Expert committee has met three times.

During the meetings it was discussed that the extent of salinity along the coast varies from Gujarat to Kerala on west coast and from Tamil Nadu to West Bengal on the east coast. The Rainfall patterns along the coast differ along with the soil conditions. The coastal areas are the most vulnerable places as most of the population settlements happen to be on the coast. The Metro cities, Mumbai, Chennai and Calcutta are located on the Coastal Stretches.

Suitable Measures are to be taken to tackle the affect of salinity along the coast line and prevent the salinity ingression on to the inland areas. Due to different coastal conditions the remedial measures to be adopted varies differently along the coast.

The State of Gujarat is the State where the salinity is affected to the highest order being an arid region and receiving very scanty rainfall. The State of Gujarat has taken up salinity control structures, recharge techniques, Management techniques and land reclamation to overcome the salinity intrusion.

The other States Maharashtra, Karnataka, Kerala, Tamil Nadu, Orissa have taken up structural measures to arrest the salinity ingression into the inland areas. Andhra Pradesh, Goa, Daman & Diu, are yet to take up any measures to tackle the salinity intrusion.

5.2 MEASURES ADOPTED

Most of the State governments have adopted different measures to tackle the problem of salinity ingress into the inland areas. Gujarat is the first state to adopt such measures and has also obtained considerable benefits, which are discussed in chapter 3.1.

The committee has studied measures adopted by all the coastal states and has classified the various measures adopted under the following Categories

1. Salinity Control Techniques

2. Recharge Techniques
3. Management Techniques/Land Reclamation

The tables 5.1, 5.2 and 5.3 show different measures adopted by the State Governments which have been grouped into the categories as discussed above.

Table 5.1 Salinity Control Techniques

Sl No	Measures Adopted	Sl No	Measures Adopted
1	Regulators (Tidal regulator, Tail end Regulator, Regulator cum Bridge, Lock cum Regulator, Inlet Sluice/Control Sluice)	5	Bunds
2	Bandharas	6	Vented Cross Bar
3	Kharland Schemes	7	Nalla Plugs
4	Salt Water Exclusion Dams		

Table 5.2 Recharge Techniques

Sl No	Measures Adopted	Sl No	Measures Adopted
1	Check Dams / Instream Structure	4	Recharge Reservoirs/ Spreading Channel
2	Recharge Tanks	5	Recharge Shaft
3	Recharge Wells	6	Afforestation

Table 5.3 Management Techniques/Land Reclamation

Sl No	Measures Adopted	Sl No	Measures Adopted
1	Cropping Pattern	4	Reclamation of Land
2	Minimum flow in rivers	5	Anti Sea Erosion Works
3	Regulation of Ground Water Extraction	6	Desiltation of lakes

These measures have been discussed in detail below.

5.2.1 Salinity Control Techniques

Regulators

Tidal Regulators

The river beds have flat slopes near the mouth and tides are running into the land for considerable distance due to which the village wells surrounding the estuaries have turned saline due to the constant process of tidal ingress into the land. As a result of over drawl of sweet water from these wells process of contamination is increasing year by year and more and more number of wells are turning saline which are affecting agricultural lands and production there from. Besides, direct infiltration of sea water takes places through river beds and contaminate ground water. It is therefore necessary to stop the tidal ingress into the land by sealing the mouths of these rivers by way of constructing suitable structures near their mouths.

The height of these structures would be kept as to keep submergence of land to the minimum and yet the projects remain economically viable.

The structures with gates on the large rivers are known as Tidal regulators will be constructed with impervious cut off below the foundation. Such cut off will be taken down to relatively impervious strata which will enable to prevent tidal ingress even through foundation strata to directly contaminate the ground water. Thus, the tidal regulator will be designed and constructed in such a way that it would not only arrest the tides entering the estuary from surface but it would also be possible to prevent seepage of sea water into the land and polluting sweet ground water.

The top of the gate will be kept above maximum tide level during the year. For design of Tidal Regulator one has to deal with maximum tide level or highest tide level. Normal practice of keeping the top of the gate is about 1 meter above highest tide level so that the waves from the sea do not splash above the gates and pollute the sweet water reservoir on the upstream side.

Extra exercise is also necessary to study the submergence on the upstream of this structure when the maximum design flood passes over the structure. If a suitable depression is available on the upstream of the structure and if it is convenient to store water at a higher level without increasing the submergence substantially and affecting surrounding villages it can be attempted to raise the crest of the Tidal Regulator to store more sweet water for irrigation use.

High tide range indicates the difference between H.W.O.S (High water of Spring tide) and L.W.O.S (Low water Spring Tide), while high tide level indicates level corresponding to the highest high water of spring tide (H.H.W.O.S.). The lowest low water of spring tide (L.L.W.O.S.) represents the chart datum. High level tide is connected with the G.T.S Bench mark which is normally fixed on every port. The tide levels are measured from chart datum.

The main function of the Tidal Regulator is to prevent the tidal ingress into the lands by sealing the mouth of the river. Hence, generally the gates remain in closed condition around the year to prevent the entry of tide water into the lands.

During floods, gates are opened and regulated as per flood forecast so as to allow the flow of the excessive flood water without creating undesirable submergence of the land in the upstream. As soon as the flood starts receding the gates are closed to store fresh water on upstream side. The stored sweet water will improve the existing water supply of the affected villages situated near Tidal Regulators.

The sweet water reservoir which will be created behind Tidal Regulator will be used for irrigation in the surrounding command areas through lift. It is proposed to install pumps of suitable capacities and lay the pipelines in the surrounding fields to do irrigation. It will be possible to do such irrigation three to four times during monsoon and protect Kharif crop. As the gates are provided on the Tidal Regulators, it will be possible to fill the reservoir during every flood in the monsoon by proper regulation of gates. Incidentally, it will also be possible to increase recharge to the ground water through the command area. Thus the recharge of sweet water through the command area will be over and above that which will take place through the bed of the reservoirs.

The reservoir water will improve the surrounding village wells; thereby water supply problems of the surrounding villages will also be solved to a great extent.

The lands around the reservoirs will be leached out of salts through the use of sweet water for irrigation and will make it possible to fetch higher yields from the same fields.
The layout plan of Meghal Tidal Regulator provided by Gujarat is enclosed at Plate-1(a) to 1(d).

Tail End Regulator

This concept is adopted wherever the flood discharges are heavy and where there is a need to quickly dispose the floods without inundation/flooding of up lands. This gated structure will help to store the receding flood waters and will also prevent the sea water ingress. The fresh water stored in upstream side acts as storage for lift irrigation, besides recharging the ground water levels and preventing sea water intrusion through the sub surface.

Tail end regulators can serve three important functions:

i. To head up the irrigation supply adequately with gates closed so that there could be effective withdrawals in the channels above to feed the irrigation lands by gravity or pumps.
ii. To allow passing of flood flows to the sea with minimum head loss
iii. To halt the ingress of sea water inland to protect farms and communities from salinity intrusion especially at high tides and during storm surges. There may be a need for additional tail end regulators on the minor drains.

The tail end regulators to be fully functional may also require some sea side bunds to protect the farms from higher tides and storm surges; effective drainage through the bunds would have to be incorporated into the planning.

The regulators would have some environmental impacts especially for water users taking water below the regulator. The river would effectively become saline with possible impacts on the coastal communities.

Tail end Regulators with Diaphragm wall

This type of structure is being proposed in major rivers such as Kollidam and Palar of Tamil Nadu State. Apart from preventing surface sea water ingress these structures will help in long way to prevent sub-surface intrusion. These structures are helpful in creating significant storages in upstream side and will play a major role in the last mile irrigation and storage of water for drinking purposes.

Regulator cum Bridge

The Regulator Cum Bridge acts as a saline water intrusion barrier which is constructed across the river. It is a gated structure having a Bridge on top providing access to the people for moving around. The water stored behind the regulator can be used for drinking water, agricultural uses and industrial use.

This acts as a flood control structure by leading entire flood discharge into the sea during the monsoon season. This also protects against the tidal affects. During the summer months it acts as a barrier to protect the sea water intrusion into the land.

A typical section of Regulator cum Bridge provided by Kerala is enclosed as Plate-2.

Lock cum Regulator

The Lock cum Regulator is a gated structure having a special arrangement for closing the gates.

Inlet Sluice/Control Sluice

Control sluice are being constructed at mouth of the creeks or sub creeks to control the saline ingress due tidal effect in to the command area. The layout plan and section of a sluice as provided by Odisha is enclosed at Plate-3.

Bandharas

The river beds have flat slopes near the mouth and tides are running into the land for considerable distance due to which the village wells surrounding the estuaries have turned saline due to the constant process of tidal ingress into the land. As a result of over drawl of sweet water from these wells process of contamination is increasing year by year and more and more number of wells are turning saline which are affecting agricultural lands and production there from. Besides, direct infiltration of sea water takes places through river beds and contaminates ground water. It is therefore necessary to stop the tidal ingress into the land by sealing the mouths of these rivers by way of constructing suitable structures near their mouths.

The height of these structures would be kept as to keep submergence of land to the minimum and yet the projects remain economically viable.

The Structures constructed on small rivers without gates as solid barriers/concrete walls on rivers are called Bandharas. No gate will be installed on these Bandharas as submergence is not likely to pose problems in this case.

As a normal practice, the top of the Bandharas shall be kept 1 meter above the highest tide level so that the waves from the sea side will not splash above Bandharas and pollute sweet water reservoirs behind them. In case where submergence does not become a problem, the Bandharas shall be raised even highest to store more sweet water. Individual case shall be examined on this line to take maximum benefits of the sweet water reservoirs for the purpose of irrigation.

The irrigation may also be proposed three to four times during monsoon from the reservoirs behind Bandharas also. This will facilitate to protect Kharif irrigation and at the same time increase recharge from larger areas by spreading reservoir water in the command areas through lift. The surrounding villages will get benefit through the probable improvement of their well water.

Bandhara will be constructed with impervious cut off below the foundation. Such cut off will be taken down to relatively impervious strata and will enable to prevent tidal ingress through foundation strata directly to contaminate ground water.
A typical layout plan and section of Somnath Bandhara as received from Gujarat is enclosed at Plate-4(A) to 4(C).

Kharland Schemes
The Kharland Schemes consists of embankments along the banks of the creeks to restrict the tidal waters to enter into agricultural lands.

In Maharashtra, the flood waters are allowed to go into the sea through the cross drainage works constructed in the embankments. One way gates are provided to the cross drainage works in order to restrict the saline water from the sea to enter into the agricultural lands.

In Karnataka, these are schemes have earthen bunds with stone revetment to the slopes and sluices with wooden needles (wooden plank shutters filled with puddle earth in between the planks) are constructed along the banks of rivers/ and streams which will be kept open during the rainy season and floods and are closed thereafter to prevent ingress of sea water into cultivable lands. These structures are being constructed and are in existence since past.

The Kharland Schemes would
- Protect the agricultural land from salinity ingress
- Provide Fresh water recharge
- Protect property and population from cyclones & Tsunamis
- Provide approach for villagers

A typical layout & section of Kharland scheme executed by Karnataka is given in Plate 5(A) & 5(B).

Salt Water Exclusion Dam

The Salt Water Exclusion dams (SWED) are vented dams constructed across rivers/streams at the confluence of the sea up to high tide level. Such structures are kept open during rainy season to mitigate floods in the river and later closed to prevent the ingress of sea water into the rivers.

A typical layout/ section of SWED scheme executed by Karnataka is given in Plate-6.

Bunds/Embankments

The bunds are constructed in the coastal areas to collect and surface water run off and protect the saline water ingress. These are the most common techniques and have been in use since old days. The bund is mainly constructed on the contour lines. The bunds are constructed with either soil or stones.
A typical section of the Bund executed by Goa is given in Plate-7.

Vented Cross Bar

Vented cross Bars are generally designed in discharge areas where direct irrigation is not feasible from the streams. Vented Cross Bars are constructed across the steams with reinforced cement concrete on an average height of 2.5 m above bed level, a minimum of 2 vents and provision of wooden shutters to discharge the flood water and silt load carried during the monsoon seasons. During the lean sea season it protects the sea water from entering inland. Earthen canals are constructed for distribution of the raised up water behind the VCB flowing by gravity to the fields. Protection works upstream of the VCB and along the canals are also provided to protect earthen canals the since earthen canals are often found to get damaged, resulting in deposition of large quantities of sand and silt in the paddy fields. The cost of these structures varies depending on the width of the streams, bed profile and length of protection works and canals.
A typical layout plan/ section of VCB executed by Kerala is given in Plate-8.

Nalla Plugs
In the area where rainfall in not low, but continuous heavy drawl of ground water has resulted in lowering of the water table on account of extremely limited facility of irrigation water through irrigation projects and also no proper method employed for harvesting. This has permitted the ingress of sea water. Under the above situation it is therefore an imperative need to undertake different measures to harvest all available run-offs at different locations which will induce ground water recharge. In addition to the suggested recharge techniques for the proposed area, through construction of check dams, recharge tanks, recharge wells, spreading channels and afforestation, it is proposed that a series of nalla plugs may be constructed in upper reaches in the catchment areas of the river system met within the problematic areas and adjacent to this area. This system of nalla plug will further help in

arresting the surface run-off and impounding it at intervals in nalla ponds. This will accelerate infiltration rate and subsequent recharge efficiency to built up ground water resources at an enhanced rate.

As series of construction of nalla plugs will also help in reducing soil erosion and silt load which will be carried to the proposed nalla plugs on downstream. Since there are no sufficient irrigation projects available in these areas, other modes of water harvesting will have to be given a serious thought under which nalla plugs will be one of the very important measures in the river basins. In addition, it may be stated that the part of the run-off which does not percolate will be made available as a supplemental irrigation, which can also reduce the demand of underground water to some extent.

Gully plugging in Forest Areas: may be taken up for assisting retention percolation of rain water by the impounding.

5.2.2 Recharge Techniques

Check Dams

Check dams are constructed in the beds of rivers with regulation device to check the monsoon flow, which otherwise passes away to the sea. The stored water contributes towards ground water recharge and utilisation by farmers for lift irrigation in nearby fields.

This is a simple and quick method for increasing recharge to ground water in areas of increasing salinity and lowering of water table. Construction of as many check dams as possible on all streams is required to be done wherever site conditions are favourable. Besides, if more numbers of suitable sites are available on one stream, then these are also to be considered for construction of check dams. Thus the construction of check dams need not be restricted to certain proposed sites only. If additional prospective sites area available these should also be considered.

The good system of recharge can be built up if a series of check dams are constructed downstream of all reservoirs sites and arrangements made in the concerned project, for release of stored water into the stream, to fill up check dams. Where ever the bridges or culverts are located on the coastal highway, these may be combined with check dams wherever feasible.

The check dams are a key element in the overall recharge plan. The structure utilizes flap gates to store water at the recession of each flood. During prolonged stream-flow periods, gates remain open so that the flood waters flow down the stream channel unrestricted. Through the repeated filling of the pool behind the gates, the water will percolate through the wetted lake area into the ground, some water will also be available for supplementary irrigation to kharif crops by lift and for the essential early watering for the planting and establishing rabi crops.
A typical layout plan/ section of Check dam executed by Gujarat is given in Plate-9.

Recharge Tanks

Check dams usually being of low height and having small water spread area. They are proposed to be used for diverting surplus water to recharge tanks in the nearby area.

Recharge tanks, will not only help in increasing the rate of recharge but will also improve the quality of ground water. The intake of water of recharge tanks without feeding device will be restricted to its local catchment. This is however not considered to be sufficient to serve the purpose. It is, therefore, necessary to connect such recharge tanks to existing or proposed check dams by constructing regulators and feeder channels. During monsoon, flood waters from check dams, fitted with flap gates, can be diverted to recharge tanks, through regulators and feeder channels.

In monsoon, the flap gates of the check dams will store part of monsoon flow in the river and divert a flow to feed the recharge tanks.

Recharge Wells

The recharge wells will be dug like open wells with 3 to 4 m in diameter (the dimensions depend on the locations of the well). They will then be filled with rubble and with sand filter at the top. These wells will be useful to recharge pervious aquifers located at some depths below the ground level. Such conditions prevail in this area, where the limestones are highly cavernous at different levels. Recharge wells can be constructed in the beds of rivers. During the monsoon surplus flood waters in river will cater these wells through top filler and clear water will enter through aquifers. Recharge wells can also be constructed inside the recharge percolation tanks or feeder channels. If they are constructed in river beds, no feeding arrangements will be necessary and if properly located they will not be silted and will require less maintenance. In cases where they are constructed inside recharge of percolation tanks, there will be some problem of silting at top every year. This problem of silting can be solved to some extent by constructing conical top for such recharge wells.

A typical layout plan/ section of Recharge well executed by Tamil Nadu is given in Plate 10(A) to 10(C).

Recharge Reservoirs/Spreading Channel

Spreading Channel is one of the acceptable devices, when recharge is desired along a narrow but a continuously long area. The sweet water impounded through induced recharge acts as a barrier, to check the movement of saline water from sea side. Therefore, if spreading channels are provided near the coastal line they would act as a good recharge cum salinity control device.

The section and length of spreading channel would depend on the quantum of the supply of fresh water. A Channel of considerable length would definitely be advantageous but, the dimensions would have to be restricted depending upon the availability of quantum of fresh water. The channel should be constructed in small lengths at different locations in the reach depending upon availability of water from proposed recharge reservoirs.

The benefits can be achieved by making optimum use of waters of all the big rivers and the small rivers of corresponding locations.

For effective planning of getting maximum benefit of available storage the waters of all schemes, the reservoirs of medium and minor capacities may be constructed on all big and small rivers depending upon condition and feasibility of sites.

A typical layout plan/ section of Und Recharge Reservoir executed by Gujarat is given in Plate 11(A) & 11(B).

Recharge Shaft

Recharge Shafts are the most efficient and cost effective structures to recharge the aquifer directly. These can be constructed in areas where source of water is available either for some time or perennially. Following are the site characteristics and design guidelines:

i. To be dug manually if the strata is of non-caving nature.
ii. If the stratum is caving, proper permeable lining in the form of open work, boulder lining should be provided.
iii. The diameter of shaft should normally be more than 2 m to accommodate more water and to avoid eddies in the well.
iv. In the areas where source water is having silt, the shaft should be filled with boulder, gravel and sand to form an inverted filter. The upper-most sandy layer has to be removed and cleaned periodically. A filter should also be provided before the source water enters the shaft.
v. When water is put into the recharge shaft directly through pipes, air bubbles are also sucked into the shaft through the pipe, which can choke the aquifer. The injection pipe should therefore be lowered below the water level.

The main advantages of this technique are as follows:

i. It does not require acquisition of large piece of land as in case of percolation tanks.
ii. There are practically no losses of water in the form of soil moisture and evaporation, which normally occur when the source water has to traverse the vadose zone.
iii. Disused or even operational dug wells can be converted into recharge shafts, which do not involve additional investment for recharge structure.
iv. Technology and design of the recharge shaft is simple and can be applied even where base flow is available for a limited period.
v. The recharge is fast and immediately delivers the benefit. In highly permeable formations, the recharge shafts are comparable to percolation tanks. The recharge shafts can be constructed in two different ways viz. vertical and lateral. The details of each are given in the following paragraphs.

The construction procedure of recharge shaft is illustrated below:

i. Drilling of bore hole of diameter 0.200 m to a various depth of 35m, 55m and 70 m.
ii. Reaming of bore hole of diameter 0.200 m to 0.35 m to a various depth of 35m, 55m and 70m.
iii. Necessary PVC casing (plain & ribbed screen) pipes are to be erected up to the total depth. End caps on both ends of the bore holes are to be provided.
iv. Compressor development for bore hole has to be done.

v. After completing the bore hole, filter trench is to be constructed by erecting the RCC Hume Pipe of 600 mm Dia and top of the Hume pipe with RCC circular slab.
vi. The Gap between the bore hole and the filter trench is to be filled to 0.30 depth of 40mm broken stone jelly and then with 0.15 m coarse sand.
vii. Top of the recharge trench is to be covered with RCC circular slab with holes.

Necessary display boards explaining the details of the recharge structure are to be displayed to have good exposure about ground water recharge.
A typical layout plan/ section of Recharge Shaft executed by Tamil Nadu is given in Plate 12(A) to 12(C).

Afforestation
Vegetation is known to improve the rate of infiltration and thereby step up the irrigation rate in three ways given below:

- Formation of root channels
- Increase in detention time of rain water
- Reduction in evaporation from land

Formation of Root Channels
When the root system gets old either in a living tree or a dead tree by a process of decay and decomposition they leave behind a network of channels which constitute path ways for movement of water into substrata.

Increase in detention time of rainwater
The total amount of water entering the soil is governed to a suitable degree by the time available for infiltration. It therefore follows that if water can be made to move slowly rather than rapidly across the land or, if it is impounded on the surface the percolation of water in the sub-soil is greatly increased. Increase in the detention time is obtained by fixing obstruction of trees to surface flow as well as presence of vegetative cover.
Soil under vegetative cover contains twigs and leaf litter in vapour states of deterioration which act like a sponge and absorb and holds larger quantity of water which then percolates into the soil.

As against this on an open area when rain drops hit the ground each drop explode like a miniature bomb on the ground. This explosion brings to the surface the fine clay particles, being the lightest in the soil structure. These clay particles block the capillaries and make soil more impervious to water.

Reduction in Evaporation from land
Tree belts are known to have salutary effects on evaporation. Evaporation reduces considerably under the influence of the shelter belt. Though the maximum benefits of shelter belt can be on its vicinity, its beneficial effects are discernible to the extent of a strip land 30 to 35 times the height of the trees.

Evaporation of soil moisture is governed by velocity of the wind and the moisture content. As the moisture from the upper layers evaporated and is swept by strong and continuing wind, as in the Saurashtra Coastal region, ground water from deeper layers of soil is drawn up by capillary action, which again evaporates in a continuous cycle of drawl of water from the sub soil and its evaporation by wind action. Tree belts at regular intervals would act as barriers and reduce velocity of the wind and effectively protect the areas.

Shelterbelt Plantation

Shelterbelt plantation along the coastline is a viable technique for significantly reducing both the direct and indirect adverse impacts of salinity on plants and water resources. Shelterbelts act as barriers that diminish damage from salt-laden winds in coastal areas and provide shelter to coastal life. The 'bio-shield' formed by planting a vegetation belt along coastlines besides other such soft measures also help in absorbing/ dissipating the force of severe coastal storms and cyclones.

5.2.3 Management Techniques

Cropping pattern

The problem of salinity has been created due to the change in rainfall pattern and injudicious use of irrigation water by cultivators. Substantial hectares of land has come under the effect both due to inherent salinity and the encroachment of sea water along the coastal belt The present cropping pattern should be changed to suit the changed situation from the view point of soil climatological and agro economical conditions. The cropping pattern of an area depend upon mainly soil types, prevailing climate and the irrigation facilities available

The soil climate and the quality of irrigation water have been affected. The present cropping pattern may be reviewed keeping in view the existing position in respect of all the factors. As such, a single cropping system can be suggested in the coastal area of coastal states/UTs.

A change in existing crop pattern as a sequel to increase in salinity in soils and water, can be adopted in a three-fold manner as follows

1. Introducing crops with lower water requirements
2. Introducing salt tolerant and semi salt tolerant crops
3. Incorporating Boron-resistant crops

New crops like date palm, Bor, Bamboo, Eucalyptus, Guava, Coconut, may be grown if they are not grown by the cultivators at present. These all are moderately to highly salt tolerant crops. Among field crops Wheat, Bajra, Jowar, Mustard, Safflower, Cotton and Castor are some of the field crops which have been found to withstand the salinity upto some extent.

The cultivation of Date Palm, Guava, Pomegranate, Ber, Eucalyptus, Subabul (Luceon Leucocaophela) etc is also suggested wherever feasible because these crops are tolerant to salinity and can be grown even where the limited irrigation facilities are available.

During the hot weather, the total salt content in water would be too high to permit a summer crop and therefore it would not be advisable to take any crop.

The following table gives the crop selection in respect to the quality of irrigation water.

Crop selection in respect to the quality of irrigation water

Tolerance class	Soil type	E.C. of water (m.mhos/cm)	Field Crops	Orchard Crops	Forest Crops
Highly tolerant	Light to medium Texture	More than 10	Sugarbeet and Dhaincha	Date Palm	Babul shrub
	Heavy Texture	5-10			
Tolerant	Light to medium Texture	5-10	Safflower, Mustard, Barley, Wheat, Bajri, Jowar, Cotton, Castor	Ber, Coconut and Guava	Eucalyptus hybrid, Saru
	Heavy Texture	3-5			
Semi Tolerant	Light to medium Texture	3-5	Rice, Sugarcane, Maize, Sunflower, Sesamum, Gram and Groundnut	Cauliflower, Onion and Potato	Mango and Pomegranate
	Heavy Texture	1.5-3			

The following table gives the crops which are Tolerant to Boron (B).

Tolerance of Different Crops to Boron (B)

Tolerant		Semi-Tolerant		Sensitive	
More than 1-2 ppm of Boron		1-2 ppm of Boron		Upto 1 ppm of Boron	
Date palm Sugarbeat Lucerne	Onion Cabbage Carrot	Sunflower Cotton Tomato Potato Pumpkin Sweet Potato	Radish Barley Wheat Oat Maize	Maize Potato Beans	Grape Orange Lemon

The following table gives the suggested cropping pattern.

Suggested Cropping Pattern

Field Crops				Orchard Crops	Forest Crops
Kharif		Rabi			
Bajri **Jowar** **Cotton** **Castor**	Groundnut Math Rice	Barley Wheat Sunflower Mustard	Onion Isabgul Cumin	Date Palm Ber Coconut Guava Pomegranate	Babul Shrub Eucalyptus hybrid Saru Subabul

Minimum Flow in Rivers

River operations and flow management can have a significant effect on salinity. With greater volumes of environmental water available there is greater potential to improve river salinity through increased dilution. Environmental watering can also, in some circumstances, increase salinity. Those circumstances need active management to minimise salinity impacts. The salinity risks associated with flow management therefore need to be identified and managed within the context of broader flow management objectives.

Regulation of Ground Water Extraction

The uncontrolled development of ground water in the area, without adequate provisions for recharging, has resulted generally in overdrawal and resultant ingress of salinity in ground water.

There is a need to

1. Enforce ground water legislation for future expansion of construction of wells and putting engineer, electrification etc.,
2. To take steps to educate the farmers to reduce their present withdrawal to achieve ground water balance.

Regulating the use of land and water is very sensitive matter. In a country like India which is predominantly rural, the farmers would have natural resistance to any regulation, controlling basic requirement like water for agriculture purpose. Moreover, the Government machinery required to effectively enforce such regulations on thousands of farmers would present practical problems of management and administration. Nevertheless, a certain balance needs to be established. This aspect needs to be carefully studied from all above angles by the Government so that an effective solution is found. While extending the jurisdiction of the Act, the validity may be extended as per the requirements, from time to time.

Along with enactment of the regulation it would also be essential to educate the farmers by various means and use of all available media so as to obtain maximum co-operation from them.

Reclamation of Land

The coastal saline areas are located quite adjacent to the sea extending for a few kilometres into land. It would therefore, be technically possible to utilise the sweet water from certain reservoirs for reclaiming these coastal saline soil for agricultural development.

The soils in these coastal are at many places affected by the sea water inundations and are rendered saline. This land can be brought under cultivation through the process of reclamation after preventing the tidal water ingress along coastal lands.

(Remove Phase-1, Phase-II and Phase III)

During the process of leaching and reclamation, the selection of crops at various stages of desalinisation plays a very important role. These techniques involve adoption of suitable varieties of crops depending upon their salt-tolerance. The crop of paddy has been found to be one of the most suitable crops during early stages of reclamation.

Anti Sea Erosion Works

The structures constructed on the beach (seawalls, groynes, breakwaters/artificial headlands) or further offshore (offshore breakwaters) influence coastal processes to stop or reduce the rate of coastal erosion which in turn will reduce the salinity ingress.

Groyne

A coastal structure constructed perpendicular to the coastline from the shore into the sea to trap long shore sediment transport or control long shore currents. This type of structure is easy to construct from a variety of materials such as wood, rock or bamboo and is normally used on sandy coasts.

Seawall

A seawall is a structure constructed parallel to the coastline that shelters the shore from wave action. This structure has many different designs; it can be used to protect a cliff from wave attack and improve slope stability and it can also dissipate wave energy on sandy coasts.

Offshore breakwater

An offshore breakwater is a structure that parallels the shore (in the near shore zone) and serves as a wave absorber. It reduces wave energy in its lee and creates a salient or tombolo behind the structure that influences long shore transport of sediment. More recently, most offshore breakwaters have been of the submerged type; they become multipurpose artificial reefs where fish habitats develop and enhance surf breaking for water sport activities. These structures are appropriate for all coastlines.

Artificial headland

This structure is constructed to promote natural beaches because it acts as an artificial headland. It is relatively easy to construct and little maintenance is required.

De-siltation of Lakes

The Lakes present along the coastal areas may be desilted to ensure that it is filled in by the fresh rainwater.

Brief about measures adopted in the states has been discussed in Table 5.4, Table 5.5 and Table 5.6.

Table 5.4 Salinity Control Techniques Adopted

Sl no	Structure	Purpose	Definition	States
1	Bandhara	Structures constructed near the mouths of rivers to stop tidal ingress into the land by sealing the mouths of the rivers.	Structures with solid masonry/concrete walls with impervious cut off below the foundation	Gujarat

2	Regulators	Structures constructed near the mouths of rivers to stop tidal ingress into the land by sealing the mouths of the rivers.		
	Tidal regulator		Gated structures on large rivers constructed with impervious cut off below the foundation, such that the cut off taken down to relatively impervious strata.	Gujarat
	Tail end Regulator		Gated Structures constructed just at the tail end of the river	Kerala, Tamil Nadu
	Regulator Cum Bridge		Gated Structure having bridge on the top	Kerala
	Lock cum Regulator		Gated structure with a lock arrangement	Kerala
	Inlet Sluice/Control Sluice		Sluices constructed at the mouth of a creek or a sub creek	Odisha
3	Kharland	These are kept open during the rainy season and floods and are closed thereafter to prevent ingress of sea water into cultivable lands	Earthen bunds with stone revetment to the slopes and sluices with wooden needles (wooden plank shutters filled with puddle earth in between planks) are constructed along the banks of rivers/ and streams	Maharashtra, Karnataka
4	Salt water Exclusion dams	Allows flood waters to enter into the sea during rainy season and later closed to prevent ingress of sea water in to the rivers	These are vented dams constructed across rivers/streams at the confluence of the sea upto the high tide	Karnataka
5	Bunds/Embankments	To restrict the flow of sea water inland	An embankment constructed with enough cut off	Kerala, Goa, West Bengal
6	Vented Cross Bars	To restrict the flow of sea water inland	Constructed across the stream with vents and wooden shutters to discharge flood water and protect saline water ingress	Kerala
7	Nalla Plugs	Help in arresting the	Very small earthen bunds	Gujarat

		surface run off and impounding at intervals	constructed	

Table 5.5 Recharge Techniques Adopted

Sl No	Structure	Purpose	Definition	State
1	Check dams/ In stream structures	Water is stored, which contributed towards ground water recharge and utilisation by farmers for lift irrigation in nearby fields	Constructed in the beds of rivers with regulation device to check the monsoon flow, which otherwise passes away to the sea	Gujarat, Tamil Nadu, Odisha
2	Recharge tanks	Tanks to store water	Recharge tanks area constructed by making use of local depressions near the river banks. These recharge tanks area filled by diverting surplus water of river through linking channels.	Gujarat
3	Recharge wells	To recharge pervious aquifers located at some depths below the ground level	Like open wells with 3 to 4 m in diameter, filled with rubble and sand filter at the top.	Gujarat Tamil Nadu
4	Recharge Reservoirs/ Spreading channel	Recharge desired along the narrow but continuously long area	The sweet water impounded through induced recharge acts as a barrier to check the movement of saline water from sea side	Gujarat
5	Recharge shaft	To recharge pervious aquifers located below the ground level		Tamil Nadu
6	Afforestation	To retain the ground water	Planting may be taken up along the coast.	Gujarat

Table 5.6 Management Techniques/Land Reclamation Techniques Adopted

Sl No	Measure	Purpose	Definition	State
1	Cropping Pattern	To help proper vegetation	Crops suitable to the saline affected area have been provided	Gujarat
2	Minimum Flow in Rivers	Not to let in the saline water inland	Small quantities of fresh water are let into the sea to create a fresh water barrier	Andhra Pradesh
3	Regulation of Ground Water Extraction	To help retention of fresh water aquifers		Gujarat
4	Reclamation of Land	To retain the land		Gujarat
5	Anti-Sea Erosion Works			Odisha
6	Desiltation of lakes			

5.3 SUMMARY OF THE PROPOSALS RECEIVED FROM THE STATE GOVERNMENT:

The State governments have submitted the proposals which have already been adopted in their states and those works they propose to take up in the future.

A total of approximately 22473 structures are completed/ ongoing with a cost of Rs 1599 cr incurred. These have been taken up the state government funds except the state of Maharashtra which has carried out a few schemes using the Funds from NABAARD and Tamil Nadu State which has carried out a few schemes using the World Bank aided IAMWARM

It is proposed to take up further 2927 structures with a total cost of 5467.61 cr. Tamil Nadu has proposed to take up a scheme using the assistance from Asian Development Bank funds. The table 5.7 gives the details of the state wise schemes completed/ongoing along with the future proposals.

Table 5.7 Summary of the Proposals from the State Governments

Sl No	State	Saline land in th ha	No of Structures completed/ongoing	Area benefitted (Ha)	Cost incurred (Rs in cr)	Proposed Structures	Area to be benefitted (Ha)	Proposed cost (Rs in cr)
1	Gujarat	714	10829	281260	1072	2412		1090.19
2	Maharashtra	64	421	42192	64.65	148	5635	108.53
3	Goa	18			40.55	57		159.00
4	Karnataka	86	143	15836.45	55	326	15058	780.60
5	Kerala	26	91+bunds		294.58	26		344.20
6	Tamil Nadu	100	4			53		1255.63
7	Andhra Pradesh	276	Pilot studies conducted			Survey Proposed		14.29*
8	Orrissa	400	30	42252	88.51	20	20858	90.17
9	West Bengal	820	Drinking water purification		1667.69	For drinking water Purification		1500.00#
10	Puducherry	1	368 (approx)		130.71			125.00
11	Daman & Diu		No Data Received					*
	Total		22473		1599	2927		5467.61

* No specific demand has been indicated by the UT/ State Government.
# The salinity ingress component has not been separately indicated by the State Government.

5.4 SALINITY INTRUSION MANAGEMENT – INTERNATIONAL EXPERIENCES

The wetlands have been manipulated for different purposes since time immemorial. For instance, in Europe, the use of dikes and tide gates to convert estuarine wetlands into agricultural lands and to allow urban development on low-lying coastal zones began in the seventh century and was common practice by the eleventh and twelfth centuries (Daiber 1986). This type of land conversion has occurred in other continents as well and is the single greatest reason for the destruction of wetlands worldwide (Middleton 1999). Along the coast of northwestern North America during the past two hundred years, dikes and levees have been built to drain tidal wetlands, both to convert them into agricultural land and to protect flood-prone areas (Gianico et al, 2005).

Coastal areas all over the world have been affected adversely by the problem of salinity ingress. Saline water intrusion has affected surface water as well as ground water resources. In the case of surface water, intrusion may be detectable and accordingly situation may be improved by adopting suitable protection measure; but in the case of ground water salination, the monitoring as well as protection measures are not so straightforward.

5.4.1 Salinity Intrusion Management in Coastal regions of North America

In the continent of North America, this problem persists in coastal regions with different degree of extent at different places. The variable hydrologic characteristics and the different history of ground water withdrawals have contributed to the different patterns of salinity intrusion in the continent. Communities residing in the coastal belts of North America are taking initiative to manage and prevent saltwater intrusion to ensure a sustainable source of groundwater for the future.

Scientific monitoring of ground water resources has been given significant importance in those areas by establishing numerous water level and water quality monitoring network all along the Atlantic and Pacific coasts of USA. As it gives the clear picture of the ground water resources from time to time, this helps in adopting suitable protection measure for the particular scenario. Moreover, water quality/ level monitoring networks, hence developed, may also act as early warning system for the worsening situation beneath the ground due to intrusion of saline water as well as on the rate of saltwater encroachment. Sampling wells have been excavated at regular intervals within an aquifer, which provide three-dimensional characterization of the extent of saltwater.

The traditional approach for monitoring the location or movement of saltwater contamination is to collect groundwater samples at periodic intervals for analysis of the chloride or dissolved solids concentration of water. With advancement in technology, innovative sampling and monitoring approaches have been developed. Electro-magnetic logs have been maintained at different locations in Ventura County, California, which give a detailed vertical profile of conductivity with change in depth. As conductivity is the direct measure of salt concentration in water, these logs are used to assess the salinity ingression at different location at regular time interval. Automated sampling systems, which use satellite telemetry for monitoring of water levels and specific conductance, have also been developed in the Upper Floridan aquifer in the Brunswick Georgia area to provide real-time monitoring of saltwater intrusion. Numerical modelling has become very useful in exploring the pattern of ground water flow and salinity intrusion in many regions of North America. With development of more powerful computers and other technologies, numerical modelling may become more popular in the future.

Monitoring of saltwater intrusion is not the solution of the problem. Monitoring provides the necessary inputs to be required while taking steps to control this problem of salination. In North America, numerous engineering and regulatory approaches have been adopted to counter the problem of ground water salination. Most common approach is to reduce the rate of pumping in the coastal areas or to move the location of withdrawal wells further inland. Reductions in coastal withdrawals allow groundwater levels to recover from their stressed levels, and fresh groundwater to displace the intruded saltwater. An example of a successful water-level recovery program is provided from central New Jersey, where water levels in four confined aquifers of the Northern Atlantic Coastal Plain have rebounded as a result of mandated reductions in groundwater withdrawals (and a shift to surface-water supply sources), begun in the late 1980s (Spitz et al. 2008).

Another commonly adopted measure is to recharge the coastal aquifer with fresh water artificially. Artificial recharge can be executed with the help of injection wells; and, thus created network of injection wells filled with fresh water acts as a hydraulic barrier to saltwater intrusion. On the Atlantic Coast in southeastern Florida, artificial recharge technique is extensively used. Artificial recharge can be accomplished through injection wells or by infiltration of freshwater at land surface. In either case, the recharged water creates hydraulic barriers to saltwater intrusion. Perhaps the most prominent example of the use of artificial recharge to control saltwater intrusion on the Atlantic Coast is in southeastern Florida. The extensive network of surface-water canals is used during the dry season to convey freshwater from inland storage areas to coastal areas, where the water is recharged through the canals to slow saltwater intrusion in the underlying Biscayne aquifer (Barlow, 2010).

In addition to these conventional methods, some innovative approaches are also used. ASR (aquifer storage recovery) systems have been developed, which store additional imported water during wet years and extract the additional groundwater during dry periods to fulfill the demand of fresh water. These systems are developed in New Jersey, Virginia, South Carolina, Florida and California. Desalination systems, which use reverse osmosis membrane to remove salts from the water, are being used at some places, viz. City of Cape May, New Jersey etc, in North America. Desalinated water is further blended with the fresh water, and hence, increasing the fresh water availability in the region.

At some places, multi-component strategies have been used to manage salinity intrusion; which includes implementation of various engineering and regulatory techniques simultaneously to combat this problem. Efforts made in the direction of prevention of salinity, have been supplemented with the implementation of water-conservation & water reuse strategies and regular monitoring of groundwater levels/ quality to assess the response of the hydrologic system to management actions. The State of Georgia provides an example in which a multi-component strategy has been used to manage saltwater intrusion.

Multi-component strategy in the State of Georgia*

'In response to the saltwater contamination and related water-supply issues, the State of Georgia has developed a comprehensive plan to stabilize or halt saltwater intrusion into the Upper Florida aquifer (Georgia Environmental Protection Division 2006). The basis of the plan is the establishment of three management subregions within the state's coastal zones, with each subregion having a varying degree of vulnerability to saltwater intrusion. Within the area closest to Hilton Head Island, the plan includes restricting withdrawals from the Upper Floridan aquifer to 2004 pumping rates and eventually reducing withdrawal rates within the area by $2.2\times10^{-1} m^3/s$ (5 Mgal/day). The plan also encourages blending of groundwater and surface-water sources to meet increased demands within this area. In the Brunswick area, the plan prohibits new wells within the area of saltwater contamination and management of existing withdrawals to avoid further expansion of the saltwater plume. The plan also calls for the implementation of water-conservation, water-efficiency, and water-reuse strategies within the entire coastal zone of the state, and continued monitoring of groundwater levels, chloride concentrations, and streamflow within the coastal zone to determine how the hydrologic system responds to management actions.'

* Paul M. Barlow & Eric G. Reichard, Saltwater intrusion in coastal regions of North America, Hydrogeology Journal · February 2010.

5.4.2 Israel's Experiment in Desalination

Israel, with a coastline length of around 270 km, is leading in the world to combat the fresh groundwater shortage crisis using advanced technologies. Israel's water demand outstrips available water from conventional resources that are provided by the natural replenishment.

Tremendous pressure on fresh water supply forced the Israel government to choose a different water management plan.
Sea water and the coastal / mountain aquifers being the main source of supply of water, Israel has achieved a sustainable water consumption level, providing for all the water needs of the country via innovations that have involved overcoming extensive engineering, biological and logistical challenges. Instead of using various measures for preventing salt water intrusion in ground water, they focussed instead on the desalination of the salt water to meet their fresh water demand. In fact, they have adopted a multistage approach to fight salinity in the country, and have simultaneously used various approaches to avoid salinisation and its negative effects, such as reduction of salt in supplied water, reduction of salts added during domestic and industrial use of water, proper water resource management such as release of part of water resources to sea, first-flush release etc, proper drainage system, soil conditioning, pioneering work in drilling, exceptionally deep wells, reaching 1500 meters and pump settings as high as 500 meters, etc.
Driven by necessity, Israel is learning to squeeze more out of a drop of water than any country on Earth, and subsequently, Israeli researchers have pioneered new techniques in drip irrigation, such as moisture sensitive automated drip irrigation directly to plant roots, and development of new crop strains that provide 10 times higher yield with the same amount of water. They have developed resilient well systems for African villages and biological digesters than can halve the water usage of most homes. They have developed a nationwide water conveyance system to deliver water throughout the country from the natural reserve in the north. Almost all the domestic waste water is being treated and reused for irrigation in the agriculture sector.
Israel experimented with seawater desalination almost 50 years ago, building a pilot plant on the Tel Aviv beach. More recently, the world's largest seawater reverse osmosis plant was commissioned at Hadera in 2009. Three large scale seawater desalination plants and some smaller brackish water desalination facilities desalinating brackish water from ground water wells rather than sea water provide about 320 MCM of Israel's potable water requirements to all sectors (Tenne, 2010). This volume is approximately 42% of the country's domestic water requirement.
Israel's water management approach has been supported by a vigorous R&D programme, which has been responsible for close to 250 water technology companies in Israel. Worldwide, Israeli companies have installed more than 350 desalination plants in nearly 40 countries, which is a testament to the country's leadership in this field (Ogden, 2013). Israel now fulfils around half of its domestic water demand from desalination, and that has helped to turn one of the world's driest countries into the region which has more water than it needs.

5.5 SOURCE OF FUNDING FOR THE SCHEMES

The Ministry of Water Resources funds some of the schemes implemented by the State Governments by providing the central assistance in terms of grant/aid. The following schemes are run by the Ministry of Water Resources for providing the central assistance

1. Pradhan Mantri Krishi Sinchayee Yojana (PMKSY)
    a. Accelerated Irrigation Benefits Programme (AIBP)
    b. Command Area Development and Water Management Programme(CADWM)
2. Repair, Renovation and Restoration of Water Bodies (RRR)
3. Flood Management Programme (FMP)

The various salinity measures taken up by the State governments have been classified into different methods discussed under Section 5.1. The methods discussed can be funded under either PMSKY (AIBP, CADWM), FMP or RRR. The table 5.8 gives the details of how these techniques can be funded.

Table 5.8 Classification of Schemes for Funding

Sl No	Measure Adopted	Classification	Funding clasification
1	Regulators (Tidal regulator, Tail end Regulator, Regulator cum Bridge, Lock cum Regulator, Inlet Sluice/Control Sluice)	Salinity Control Techniques	AIBP/FMP
2	Bandharas	Salinity Control Techniques	AIBP/FMP
3	Kharland Schemes	Salinity Control Techniques	AIBP/FMP
4	Salt Water Exclusion Dams	Salinity Control Techniques	AIBP/FMP
5	Bunds/Embankments	Salinity Control Techniques	AIBP/FMP
6	Vented Cross Bar	Salinity Control Techniques	FMP
7	Nalla Plugs	Salinity Control Techniques	CADWM
8	Check Dams / Instream Structure	Recharge Techniques	AIBP
9	Recharge Tanks	Recharge Techniques	RRR
10	Recharge Wells	Recharge Techniques	RRR
11	Recharge Reservoirs/ Spreading Channel	Recharge Techniques	RRR/ CADWM
12	Afforestation	Recharge Techniques	
13	Cropping Pattern	Management Techniques	
14	Minimum flow in rivers	Management Techniques	
15	Regulation of Ground Water Extraction	Management Techniques	
16	Reclamation of Land	Management Techniques	
17	Anti Sea Erosion Works	Management Techniques	
18	Desiltation of lakes	Management Techniques	

The Schemes in Sl no 12 to 18 cannot be funded under any of the existing Centrally Sponsored Schemes. However, a separate scheme may be created and necessary central assistance may be provided for execution of such projects.

5.6 CONCLUSIONS

This study has been taken up on the Prime Minister's intervention that the Water Resource Ministry may examine the issues of salination of land along the coast in a scientific manner and suggest suitable remedial measures. It was also stressed that the state of Gujarat has already implemented the projects which needs thorough study. The committee has made a thorough study of the proposals submitted by the state governments on the protection measures taken up to prevent the salinity intrusion in coastal regions of India. The study revealed that there is significant difference in the prevention measures carried out on the east coast and on the west coast. The summary of the study taken up for different states is provided below.

- India has a long coastline of about 7500 km of which about 5400 km covers the peninsular India while the remaining coastline belongs to the Andaman, Nicobar and Lakshadweep Islands. The problem of coastal saline soils occurs in varying degree in the states of Gujarat, Maharashtra, Goa, Karnataka, Kerala, Tamil Nadu, Andhra Pradesh, Odisha, West Bengal and the union territories of Daman & Diu and Puducherry. In most of the areas, lack of drainage system has been the main contributing factor; in some areas, overdraft of groundwater, ingress of saline sea water and unscientific agricultural practices are adding to the problem in a big way.
- The coastal plain of Saurashtra and Kachchh of Gujarat has a low reliability of the monsoon rainfall. Lack of adequate surface water irrigation system and excessive pumping of ground water deteriorated the quality of water. The 0.848 Mha of coastal strip of Gujarat is badly affected by salinity. Gujarat is the only state where a number of different types of structural measures such as check dams, regulator, bandharas, recharge wells, recharge tanks, nalla plugs, afforestation etc., are taken up to arrest the salinity intrusion which is described in the section 3.1. The committee opined that such works should continue in future.
- The state of Maharashtra receives plentiful rainfall from the south west monsoon. An area of 0.06 Mha of land is affected by salinity. During the high tides, sea water enters the inland agricultural lands which damages the fertile soils. Thus, to protect the inland agricultural lands, the bunds known as kharland schemes are constructed along the river not to allow the saline water to enter inland during high tides. The committee asked Maharashtra state to continue its activities and complete all the schemes envisaged in the Master Plan at the earliest.
- The rainfall pattern in the coastal belt of Karnataka is similar to that of Maharashtra and similar kinds of protection measures such as Kharland Schemes, Salt Water Exclusion Dams and river protection works are carried out. The salinity is not noticed during the monsoon season, however the saline water interface is observed from the months of October onwards. Karnataka may continue the schemes as per the design recommendations of the subcommittee formed for the study of Salt Water Exclusion Dams.

- In the state of Goa, protective bunds are constructed along the river to protect the agricultural lands getting inundated by the sea water during the high tides.
- The state of Kerala is very narrow and all the districts of this state are affected by salinity intrusion problem. Due to the abundant rainfall during the monsoon season, the problem of salinity is only experienced from the months of October onwards. The state of Kerala has a number of industries along the coast. A number of measures such as construction of regulators, bunds, check dams etc are taken up to protect the coastal lands from salinity intrusion. Such schemes may be continued.
- On the east coast, Tamil Nadu is the worst affected state having maximum salinity intrusion. In this state, problem of salinity exists in coastal and inland areas. This region receives rainfall from the north east monsoon during the months of October, November and December. The excessive usage of ground water for irrigation, drinking and for industrial sector has depleted the fresh water reserves and increased the salinity intrusion. Mainly check dams are constructed to arrest the salinity intrusion in this state.
- The soils along the coast of Andhra Pradesh state are mostly sandy in nature and of marine origin. Only pilot studies are initiated to protect salinity intrusion at certain places. This state receives rainfall from both southwest and northeast monsoon. No arrangement for any systematic soil surveys have been taken up. The committee urged that the solutions for tackling the problems of salinity can be possible only when the state identifies the areas of high, medium and low saline conditions and seek remedial measures. The state of Andhra Pradesh has agreed to take up the survey works to find out the extent of salinity. Further, a National Centre for Sustainable Development of Deltaic Regions, as suggested by Government of Andhra Pradesh, may be setup under Member (River Management), Central Water Commission. The Centre may provide technical support for planning and designing measures for prevention of salinity ingress in delta regions of the country and for undertaking necessary survey and investigation for this purpose.
- In the State of Orissa an area of about 0.253 Mha of land is completely affected by salinity and an area of 0.286 Mha is partially affected. Orissa has proposed creek irrigation projects to protect against the salinity intrusion.
- In West Bengal the ground water salinity at different depths in the coastal districts is found over an area of about 1.0 Mha. The transgression of saline water along estuaries and its sedimentation has lead to the presence of brackish saline water in the coastal tract. In this state many saline water treatment plants are adopted to provide safe drinking water. The committee opined that the West Bengal state is one of the worst affected by salinity and requires careful attention. The State of West Bengal may take up soil surveys, identify the critical locations of salinity and then suitable remedial measures may be taken up.
- The union territory of Puducherry has an area of 0.492Mha, and consists of four unconnected districts, Puducherry, Karaikal, and Yanam on the east coast and Mahe on the West Coast. Check dams, irrigation tanks, coastal tail end regulators, tube wells and ponds are constructed to prevent salinity intrusion in the coastal areas.

- The Daman & Diu union territory is located near to the state of Gujarat. This state has not provided any remedial measures to be taken up to prevent the salinity intrusion.

5.7 RECOMMENDATIONS

The committee makes following recommendations for implementing the proposed plan to deal with the salinity ingress problems in the coastal states:

- The committee opined that there is an immediate need to protect the coastal lands which are most vulnerable to the problem of salinity intrusion. This is of much significance in order to provide a better life to the people residing in the coastal areas that are well populated and are also marked by important cities.
- The committee viewed that the state of Gujarat has carried out extensive studies and implemented different protection measures along the coast to prevent salinity intrusion which may be replicated by other states.
- The states where rainfall is abundant may provide minimum flows in rivers to ensure that sea water is prevented from entering inland. The possibility of utilising the major rivers situated in the states for providing irrigation water in the region and for creating fresh water barrier should be explored on a high priority basis.
- The coastal protection works requires clearance from the State Coastal Zone Management Authority and such clearances may be obtained at the earliest for taking up the works.
- The people situated near the coastal areas need to be educated on the problems faced by excessive drilling and usage of ground water. They should be enlightened on the measures taken to tackle the salinity such as crop rotation, salt resistant crops, afforestation etc., which needs more local attention.
- There is a need to develop an effective mechanism to scientifically monitor salinity level in the ground water that helps adopting suitable protection measure for the particular location and scenario. In addition, water managers will need to consider how saltwater intrusion may be affected by potential rises in sea level due to climate change. The efforts in this direction have so far been minimal in India. The potential impacts of sea level rise could be serious but manageable if appropriate actions are taken. However, many of the adverse consequences can be avoided by taking timely measures in anticipation of sea level rise. There is also a need to explore the innovative and multi-component strategies for control of seawater salinisation, which could be relaligned as per the severity of the problem and need in different coastal areas.
- The committee viewed that the best salinity management outcomes require the involvement and engagement of a diverse range of stakeholders and communities. Effective engagement can leave a lasting legacy of informed, involved and confident communities who understand the value of salinity management. This will also help to ensure that organisations who are involved in environmental water management, river

management, waterway management and land management will contribute towards improvement of salinity management.

- The committee observed that the salinity risks have been reduced by the measures taken up by the state governments, which has been a major factor for the success of prevention of salinity intrusion landwards. The States have to continue work on the desired measures as the salinity risks remain and this still requires careful management to ensure that the problem of salinity intrusion is minimized.
- Improving knowledge about salinity risks will inform and potentially delay, or reduce the need, future investment in salinity mitigation. Improving knowledge and predictive capability will also enable more efficient coastal salinity management with a higher degree of confidence. With this objective in view, a National Center for Scientific Study of Salinity Ingress in Delta Regions may be setup by CWC/ Ministry of Water Resource, River Development & Ganga Rejuvenation.
- Long term regular monitoring especially of groundwater level and salinity in coastal regions is essential for successful coastal salinity management. It helps in understanding the type of preventive measures to be undertaken to prevent the salinity intrusion. The committee further recommends that the activities (including setting up of observation network) should be taken up in a time bound manner and be completed with effective planning. For this each state may set up an inter disciplinary committee for taking up the works on salinity intrusion measures and such committee may have a Director monitoring of the regional offices as the member to monitor the progress of such works.
- The committee viewed that proper surveys need to be taken up for effective implementation of the measures. These surveys have to be taken up on regular basis.
- The total cost of the proposed works to be taken up in coastal regions of India is about Rs 5467 crore. The state-wise break-up of the cost may be seen at Table 5.7. The funding for the scheme can be provided from the existing schemes of MoWR, RD & GR or a separate scheme may be created and necessary central assistance may be provided for execution of such projects. For this purpose, necessary guidelines/ modalities etc. may be framed by CWC in consultation with CWPRS, CGWB and any other technical agency, as required.
- The committee recommends that Detailed Project Reports (DPRs) would be prepared by the State Government / agency identified by the State Government, and works would be implemented by a government agency identified by the State Government. A Technical Advisory Committee (TAC) will be constituted by the State to techno-economically appraise and approve the DPR. TAC shall also include representative from Regional offices of Central Water Commission (CWC) and Central Ground Water Board (CGWB) /National Centre for Salinity Ingress.
- Committee is of the view that MoWR, RD & GR will coordinate the programme at the central level through Central Water Commission. After approval of the DPR by the State TAC, the State will submit the proposal for funding of the schemes to the CWC (HQ), which will examine the proposal and make appropriate recommendation to MoWR, RD & GR for release of funds. The existing Coastal Erosion Dte at CWC (HQ) may be suitably strengthened and renamed as Coastal Protection Dte to look

after the work related to preparation of detailed guidelines for funding of Salinity Ingress Management Projects, funding pattern and eligibility criteria for funding, criteria for selection, procedure for submission of proposals from the State Government, mechanism for monitoring and evaluation of the schemes funded under the programme, etc.

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Appendix-I

File No. CWC/3/5(A)/Hyd(C)/2014/141-175
Government of India
Central Water Commission

Hydrology (Central) Directorate
Sewa Bhawan, R K Puram
New Delhi 110066
Date: 03.09.2014

Order

Adoption of suitable protection measures for prevention of salinity ingress depends upon various factors including site specific conditions, hydrology or availability of water resources; geology / hydro- geology of area; suitability of site for construction of barrage or weir for storing surface water and for subsequently using them for maintaining the hydrological gradient towards sea side etc. It has, therefore, been decided to prepare a broad outline report in consultation with State Governments / Union Territories and specialized organizations of State Government / Government of India in the related field. The scope of the report will be to provide broad outline of the measures to be taken to arrest or minimize the salinity ingress in the coastal States / Union Territories.

2. For this purpose, it has been decided to constitute a Technical Committee under the chairmanship of Chairman, Central Water Commission. The composition of the Technical Committee is as under.

i.	Chairman, Central Water Commission & Ex-officio Secretary to Government of India	Chairman
ii.	Chairman, Central Ground Water Board	Member
iii.	Ground Water experts / Engineer- in -Chief / Chief Engineer of Coastal States / UTs	Member
iv.	Chief Engineer, Designs (NW&S), CWC	Member
v.	Engineering Geologist from Geological Survey of India	Member
vi.	Director, National Institute of Hydrology	Member
vii.	Chief Engineer, HSO, CWC	Member-Secretary

3. The Committee will prepare broad outline of the measures to be undertaken in the coastal States / UTs for prevention of salinity ingress in coastal areas. The Committee will give its report in a period of 3 months.

4. The Committee may co-opt any expert as special invitee and TA / DA of the members will be borne by the organizations to which the members belong or their concerned States / UTs.

5. Secretariat support will be provided by the Director, Hydrology (Central), Central Water Commission.

6. This issues with the approval of Chairman, Central Water Commission.

Director
Hydrology (Central)
Tele: 011-26106432 Fax: 011- 26106369
E-mail: hydcent@nic.in

To

i. Engineer - in - Chief, Irrigation & CAD Department, Govt. of Andhra Pradesh / Water Resources Organisation, Govt. of Tamil Nadu / Department of Water Resources, Govt. of Odisha.
ii. Chief Engineer (Saurashtra) & Additional Secretary, Government of Gujarat.
iii. Chief Engineer (WRDO), Water Resources Department, Government of Karnataka / Irrigation & Administration, Water Resources Department, Govt. of Kerala / South West, Irrigation & Waterways Directorate, Govt of West Bengal / Water Resources, Govt of Goa / PWD, Govt of Pondicherry.
iv. Chairman, Central Ground Water Board, New Delhi.
v. Director General, Geological Survey of India, Kolkata / Camp Office at New Delhi with a request to nominate an Engineering Geologist from Geological Survey of India.
vi. Director, National Institute of Hydrology, Roorkee
vii. Chief Engineer, Designs (NW&S), CWC

Copy to:

viii. PPS to Secretary to the Government of India, Ministry of Water Resources, Shram Shakti Bhawan, New Delhi 110001
ix PPS to Chairman, Central Water Commission, Sewa Bhawan, R K Puram, New Delhi-110066
x. PPS to Member (D&R), Central Water Commission, Sewa Bhawan, R K Puram, New Delhi 110066
xi. Joint Secretary, Policy Planning, Ministry of Water Resources, Shram Shakti Bhawan, New Delhi 110001

Copy also to:

xii. Principal Secretary, Water Resources Department, Govt. of Maharashtra / Irrigation & CAD Department, Government of Andhra Pradesh / Water Resources Department, Govt. of Karnataka / Department of Water Resources, Govt. of Odisha / Water Resources, Govt. of Goa with a request to nominate an officer from State Ground Water organization.

xiii. Secretary, Narmada (Water Resources), Water Supply & Kalpasar Department, Govt of Gujarat / PWD, Govt of Tamil Nadu with a request to nominate an officer from State Ground Water organization

xiv. Additional Chief Secretary, Water Resources, Govt of Kerala / Irrigation & Waterways Department, Govt of West Bengal with a request to nominate an officer from State Ground Water organization.

xv. Development Commissioner & Secretary(PWD), Govt of UT of Daman & Diu and DNH / Commissioner cum Secretary (PWD), Govt of UT of Pondicherry with a request to nominate an officer from Water Resources Organization.

xvi. Chief Engineer, Central Water Commission, Gandhinagar, Nagpur, Coimbatore, Hyderabad, Bhubaneswar and Siliguri for co-ordinating with concerned States / UTs.

Director
Hydrology (Central)

Appendix-II

Summary Record of Discussions of the 1st Meeting of Technical Committee for adopting suitable protection measures for prevention of salinity ingress in the coastal States / Union Territories held on 30th September, 2014 at CWC, New Delhi

The 1st Meeting of Technical Committee for adopting suitable protection measures for prevention of salinity ingress in the coastal States / Union Territories was held at Sewa Bhawan, CWC, New Delhi on 30th September, 2014 under the chairmanship of Shri A.B. Pandya, Chairman, Central Water Commission, New Delhi.

At the outset of the meeting, the Chairman of the committee welcomed all the participants and briefly explained the background and scope of the present committee. He mentioned that the saline water ingress problem is multi disciplinary in nature involving hydrology, geology, ground water aquifer system, hydrogeology etc. The problem needs to be tackled in surface and ground water front also. He further mentioned that the present multi disciplinary committee can study all aspects of the problem in a scientific manner and suggest remedial measures. He also indicated that this first meeting can be utilised to interact with the State Governments and relevant departments to understand the present problem. Chairman requested Member Secretary to take up further agenda items.

Chief Engineer, HSO, CWC & Member Secretary of the Committee, explained the background of formulation of the committee and made a presentation on "**Salinity Ingress in Coastal Areas of India"** highlighting the various aspects of the problem such as – extent of the area affected, reasons of the problem, state wise status of the problem, measures taken up by Gujarat State, general salinity control measures etc. Through the presentation, the following points have been identified for further deliberations:

- ❖ Details of the coastal areas affected by soil salinity and saline water intrusion;
- ❖ Impact of the problem on various aspects in the area;
- ❖ Studies by research institutions / specialized organizations namely, Geological Survey of India, Central Ground Water Board, and National Institute of Hydrology etc.;
- ❖ Studies by academic and research institutions;
- ❖ The details of remedial measures adopted / initiated by other countries;
- ❖ The details of remedial measures adopted / initiated by States / Union Territories and their effects;
- ❖ Formulation of plans / schemes to address the problem.

The Chairman of the Committee requested all Members/representatives of the Members to express their views on the subject.

At first, Gujarat State representative Shri M. K. Dixit, M.D., GWRDC, NWRWS&K made a presentation on "**Salinity Ingress for Coastal Zone Management of Gujarat"**. The status of the problem, reasons associated with it, measures undertaken by the State Government and the results achieved have been brought out in the presentation. The representative informed that the forest clearance and fund requirement as the major difficulties being faced in the execution of the remedial measures in the state. Further it has been mentioned that Gujarat government is getting the funds from NABARD and he would provide the relevant rules and regulations of NABARD after obtaining them from the concerned Departments.

Chairman enquired about the implication of the Coastal Zone Regulation Act in execution of the remedial measures in the coastal area. Shri J. Chandrashekhar Iyer, Chief Engineer (CSRO), CWC, Coimbatore informed that execution of any coastal protection works requires clearance from the State Coastal Management Authority and similar action may be necessary in the remedial measures also. Shri A. K. Kharya, Director, CC & IAD Dte., CWC mentioned that restriction of sand mining and its transportation creates main problem in such works. The state representative promised to provide the relevant information after discussing with the concerned State Departments.

Shri B. K. Suresh Babu, Superintending Engineer, Minor Irrigation, Mysore, representative of Govt of Karnataka, informed that the saline ingress problem is mainly present in North and South Kannada as well as Udipi districts of the state due to high tidal waves. It was informed that the problem is of seasonal in nature as the area receives good amount of rainfall during the monsoon which dilutes the salinity of the sea water. State Government constructed 148 salt water exclusion dams in north and south Kannada districts of the state to reduce the salinity ingress problem in the state. As per the information provided, out of existing 148 salt water exclusion dams around 24 dams are not functioning and few more are facing different maintenance problems. The State Government has constituted a sub committee to examine the problems being encountered in these dams and to suggest the measures. The committee identified the following reasons for non functioning of the dams:

- Leakage through the foundation due to high tide level
- Leakage through the dam structure due to improper design/ construction/ maintenance
- Improper maintenance/ operation of gates

After examination of the condition of various dams, the committee of the State Government came out with necessary norms to be followed in construction of new such dams and repairing of the existing dams. The representative highlighted few difficulties being faced in the construction/repair of the dams such as usage of sulphite resistance cement, corrosion problem of steel in saline environment, fixing of the height of the structure based on the tide height and land acquisition problems. He also mentioned that a master plan had been prepared in this regard and promised to provide the same to the committee. Further, it has been requested to bring the works related to salinity remedial measures under the ambit of AIBP for funding purpose.

Shri A. Chinnappan, Technical Expert (Geo-Physics), Tamil Nadu PWD, State Ground & Surface Water Resource Data Centre informed that the saline ground water is present in 13 districts of the State all along the coast line. However, the nature and reasons of the problem vary from place to place. In Mouthambedu – Minjur and Besant Nagar – Thiruvanmiyur areas of Chennai city falling in Thiruvallur district, central and Southern parts of Thoothukudi district, Valliyur block of Tirunelveli district and some areas of Kanyakumari district, the problem surfaced mainly due to excess pumping of ground water for industrial and domestic purpose while in Pudukkottai and Ramanathapuram districts the marine depositional formation has been the main cause. The effluents and seepage from the brackish water aqua farms present in Nagapattinam district area is the major reason for poor quality of ground water in Narayanapuram and Mahendrapalli of Sirkali Blocks of the district. State Government initiated construction of recharging structures to contain the problem and restrictions are being imposed on the excess ground water withdrawal wherever the problem is due to excess withdrawal of ground water. State Government established 284 observation points (viz. open wells /piezometers) along the coast line and the pre and post monsoon water levels are being observed to analyse and monitor the sea water ingress problem. The state requested the committee for technical guidance and providing necessary fund for implementation of remedial measures.

Shri Subhash. V, Chief Engineer, Projects- II, representative of Govt. of Kerala informed the following points:

- ❖ Kerala, a coastal State with 560 km long coastal line is broadly divided into three natural zones based on the diversity of physical features viz. the low-land, mid-land and high-land. The low-land coastal stretch including the inland water bodies are prone to salinity intrusion due to the nature of soil and tidal effect. Intrusion of saline water through rivers is already crossed more than 30 kms towards inland in a number of rivers. However, the micro level data is not available.
- ❖ The salinity problems persist for few months when the rainfall is less in the area. Hence, the problem can be considered as seasonal nature in the state.
- ❖ Salinity intrusion has already affected the drinking water schemes along the river sides and water abstraction from rivers for industrial purpose. It also affected the fresh water fish habitats thereby reducing the fish catch. The soil salinity has affected the paddy cultivation and other agricultural activities in low-land areas adjacent estuaries and lakes.
- ❖ The Irrigation Department has already taken initiative to construct regulators, check-dams, saline intrusion structures etc. Traditionally the Oorumuttu (temporary in nature) are constructed to prevent the salt water intrusion. Apart from this, river water flow is also regulated through dam operation to maintain minimum flow during summer months so as to reduce tidal intrusion into the creeks and rivers.
- ❖ As part of increasing the water availability in rivers, thrust is given to renovate ponds to enhance the storage capacity on a watershed basis.

The Chairman enquired about the Kuttanadu Project which also involves salinity remedial measures. Shri Subhash. V informed the progress of the project and mentioned various difficulties being faced in the execution of the project due to harsh and remote location of the project .

Shri J .B. Mohapatra, Engineer-in-Chief (WR), Govt. of Odisha informed the committee about the status of the problem in the state. The important points are as follows:

- ❖ Odisha has a vast track of coastal plains with a coast length of 480 Km. A considerable area (about 5.40 Lakh Hectares) of the coastal area is beset with salinity hazard due to sea water ingression into the multiple aquifer systems. Ground water salinity in this region is purely a geogenic phenomenon. This saline tract extends from Chandaneswar (Baleswar District) to Brahmagiri (Puri District). Width Of the tract varies from 10-55 Km in different coastal Districts. The depths or occurrence of saline and fresh water bearing aquifers are also not uniform along the entire tract. The State Government had conducted a hydro geological and hydro chemical profiling survey of this area to assess the saline zone. According to the findings, parts of 7 coastal districts covering 42 blocks, suffer from salinity problem in different magnitudes.
- ❖ In the event of large scale drilling of wells without proper cement sealing and technical supervisions, the alternating fresh and saline aquifers of the region are likely to be interconnected, resulting in conversion of fresh aquifers to saline aquifers. More over the coastal sand dunes, which are the repositories of fresh ground water in saline affected areas, need to be protected from encroachment and manipulations as they are the only sources of drinking water.
- ❖ Storage of large volumes rainwater/ runoff along the coastline by constructing Coastal Embankments can induce artificial recharge and maintain a positive hydrostatic environment to minimize seawater ingressions.

Shri Ashok P. Avhad, Project Director & Superintending Engineer, Govt. of Maharashtra informed the committee about the Khar land (coastal saline soils) problem in the state. The important points are as follows:

- ❖ The Khar land problem prevalent in Konkan region of the state spread over four districts viz. Thane, Raigad, Ratnagiri and Sindhudhurg and around 63184 ha land has been affected. Tidal water inundation is the main cause of the problem.
- ❖ The State Government has initiated remedial measures such as construction of saline embankments along the banks of 58 creeks in the area to restrict the tidal water entering into the agriculture lands. These saline embankments have been provided with cross drainage works with one way gates to discharge the flood water into the sea.
- ❖ The State Government prepared plans to construct 575 schemes to reclaim around 49120 ha of the land. Till now 395 schemes have been completed and another 69 schemes are in progress in the state. Around 40793 ha of the khar land has been reclaimed in the state.

Shri K. C. Naik, Member, Central Ground Water Board informed that the main factors affecting the coastal aquifers are sea water intrusion, up coning of saline water and geogenic salinity. The eastern and western coasts of the country are quite different in nature. The edge of the continental coastline is remarkably straight in the western coast and is mainly consisting of hard rock formation except in parts of Kerala and Gujarat where as the eastern coast is generally characterized by wide coast with deltaic alluvial formation. Due to this basic difference, the nature of the problem and remedial measures to arrest the problem would be different. Further, he informed that in the eastern coast the occurrence of saline zones are very complex. At many places the saline aquifers overlie the fresh water aquifers and construction of tube wells in these areas needs expertise. Referring to Odisha, he mentioned that construction of sluice gates across the creeks have arrested salinity ingress and successfully reclaimed saline land which otherwise was inundated by sea water during high tides in parts of Chandbali and Basidevpur blocks. For better ground water management in the coastal areas there is need to closely monitor the ground water scenario, ground water abstraction rate and scientific design of well so as to prevent saline water to enter in to the fresh aquifer. Further augmentation of ground water through rain water harvesting and increasing water use efficiency will also reduce the salinity ingress in the aquifer. For preparation of proposals / plans the State Govt. Organization may obtain the necessary relevant data available with their regional offices. A report **"Coastal Aquifer Systems of India**" prepared by CGWB will be very much useful in understanding the problem and the soft copy of the report can be made available.

Dr. J. S. Mehta, Director, Geological Survey of India, informed that GSI has carried out coastal geomorphology mapping under "National Geomorphologic & Lineament Mapping Program (NGLM)". These maps would be useful to understand the geology of the coast line and will be helpful in deciding the nature of the strata. The maps are available with the Department and can be obtained from the regional offices of GSI. Further the coastal geomorphology and quaternary geological maps are available in the respective State units and the local GSI offices can be contacted for any guidance in this regard.

Shri Mehta also informed that Shri Dinesh Gupta, Deputy Director General, GSI had carried out the saline water and fresh water 3D modeling in the Naveli area of Tamil Nadu. GSI can be consulted for this purpose also.

Dr (Ms.) Anupma Sharma, Scientist -D, N.I.H., Roorkee (representing Director, National Institute of Hydrology) made a presentation on a study carried out in Minsar basin "Coastal Groundwater Dynamics and Management in the Saurashtra Region, Gujarat". She highlighted the topography, geology and hydrological conditions of the study area and brought out effectiveness of various remedial measures implemented in the area.

Shri J. Chandrashekhar Iyer, Chief Engineer (CSRO), CWC, Coimbatore informed that Coastal Protection and Development Advisory Committee (CPDAC) finalized the coastal lengths of the country and all the coastal states and the same statistics can be used to maintain the uniformity. Further, it was suggested to classify the salinity problem as severe/ critical/ normal taking the all the relevant factors into account with the help of CGWB / State Ground Water Department. He suggested carrying out scientific studies to understand the effects/ impacts of the proposed measures on the coastal and river system so as to reduce the negative impacts.

Shri A.K. Kharya, Director, CC & IAD dte, CWC mentioned that the rise of sea levels due to climate change may have implications on saline water ingress. It was advised to take climate change effects while preparing and finalizing long term plans for remedial measures.

The Chairman requested all the coastal State Governments to identify the problematic areas in the respective states through investigations and to prepare necessary plans for remedial measures to reduce the saline water ingress problem as well as to reclaim the already affected areas systematically. It was suggested that different types of remedial measures followed/implemented in different States in this regard can be pooled together and based on the conditions of the specific area the relevant measures can be adopted and experience of all the coastal states can be effectively utilized. Regarding funding, it was felt that the different components of the remedial schemes can be funded under AIBP/ RRR/ Flood Management schemes based on the nature of structure and its utility. However, the benefit cost ratio can be computed combinedly as a single scheme.

In the end, after deliberations, it was decided that all the State Governments would prepare the proposals along with the cost component of the remedial measures covering the following aspects:

a. Delineation of the coastal areas affected by soil salinity and saline water intrusion
b. Causes of the problems
c. Impact of the problem on various aspects in the area
d. The details of remedial measures initiated
e. Present physical and financial progress of such remedial measures
f. Effectiveness / impacts of the implemented remedial measures
g. Future plans / schemes required to reduce the problem with cost estimate

GSI and CGWB would also provide information available with them on the subject to Central Water Commission / concerned State Governments

The meeting ended with vote of thanks to the Chair.

Appendix-III

Summary Record of Discussions of the 2nd Meeting of Technical Committee for adopting suitable protection measures for prevention of salinity ingress in the coastal States / Union Territories held on 27th November, 2014 at CWC, New Delhi

The 2nd Meeting of Technical Committee for adopting suitable protection measures for prevention of salinity ingress in the coastal States / Union Territories was held at Sewa Bhawan, CWC, New Delhi on 27th November 2014 under the chairmanship of Shri A.B. Pandya, Chairman, Central Water Commission, New Delhi.

At the outset, Chairman of the committee welcomed the members and representatives of States and Union Territory of Daman & Diu. While discussing the adverse effects of salinity and experience gained during implementation of some of the measures to control the salinity ingress, particularly in Gujarat, Chairman, Technical Committee underlined the need for expeditious action by States / UTs so that the work could be completed by scheduled time. Chairman requested the Member Secretary to take up further agenda items.

The first meeting of the Committee was held on 30th September, 2014 and summary records of discussions have been sent to all members / representatives vide letter no.CWC/3/53 (A)/ Hyd.(C)/2014/285 dated 17th October, 2014. No comments have been received from any of the Members. Minutes were confirmed.

Chief Engineer, HSO, CWC & Member Secretary of the Committee, made a brief presentation on background and present status of the work. He explained the background of formulation of the technical committee and present status of the proposals received from different states which is as under.

- Proposals have been received from Gujarat, Maharashtra, Kerala and Andhra Pradesh states.
- A list of district wise identified structures (Salt Water Exclusion Dams) with cost has been received from Karnataka state
- A note on Salinity problems in coastal areas in India has been received from CGWB.
- A team of officers from CWC visited few anti saline structures of Gujarat state during 18th to 20th November, 2014 and held discussions with the state government authorities.

Chief Engineer, HSO, CWC requested for formulation of a time frame for furnishing of information and for this purpose he proposed that a separate meeting of state officers with CWC can be organized if States wish so.

The Chairman of the Committee requested all the Members / representatives of the States and UTs to indicate action taken by them on the subject.

At first, Andhra Pradesh State representative made a presentation on "**Sea Water Intrusion - a Case Study in Andhra Pradesh"** wherein three pilot studies taken up in Krishna Delta, Visakhapatnam and Srikakulam of the State have been discussed. In the discussion it emerged that no systematic survey had been conducted so far in the state, hence the extent of affected area data has not been systematically delineated. Further, the state desired to have a multi disciplinary technical committee under the Chairmanship of Member, CWC involving members from state, CWC, NIH, CGWB to prepare plan for investigation, and for suggesting necessary measures in this regard.

It was indicated by the State representative that some pockets in coastal Andhra Pradesh have fresh water reserves in deeper aquifer which are overlain by salty strata. It was noted that such geogenic salinity, though not covered within the scope of the Committee, can be addressed after detailed study. In this regard, NIH has developed technique of identification of source of recharge zone by use of isotope. State Government may take up the matter with NIH. The State representative also requested for setting up Delta Region Research Centre in the State.

In addition, the State representative also stated that being a new State, financial assistance may be provided to them for such works. Commissioner (SPR) stated about possibility of funding under the Ministry's Scheme on RRR of Water Bodies or under Minor Irrigation. He indicated that on the basis of their experience in implementation of salinity prevention works, States may suggest any modification in the guidelines for inclusion of such schemes under RRR of Water Bodies or Minor Irrigation works. For this purpose, a reference from the States may be sent to CWC / Commissioner (SPR), MoWR.

Chairman, CWC assured to provide needed technical assistance to the States in addressing the problem of salinity ingress. Regarding constitution of the multi-disciplinary Committee under the Chairmanship of Member, CWC was suggested that an officer from Gujarat may be included in the Committee. A formal request for constitution of the Committee may be sent to Chairman, CWC by the Government of Andhra Pradesh.

The Committee suggested that for the present, the state may indicate fund requirement for conducting the studies including investigation for delineating affected areas due to salinity ingress in the coastal areas.

In the presentation by Government of Gujarat, progress on different measures being implemented in Saurashtra region was explained. He listed measures taken so far and proposed measures to be taken in the coming few years. Director, Hydrology (Central), CWC mentioned that as per the report of High Level Expert Committee the total affected area in Gujarat was 7,00,000 hectare while the State Government has proposed to treat only 1,37,000 ha and therefore, the State representative may check the statistics.

The representative of Karnataka State indicated that the State is facing problems due to spilling over of tidal waves in to adjoining sea shore and near banks of creeks, rivulets directly draining in to the Arabian Sea. Maharashtra and Goa state representativesin their presentation also explained the problem faced by them which are identical to that of

Karnataka. During the presentations, the details of the affected areas, remedial measures adopted and their impacts, future proposals and bottlenecks faced in the execution of the reclamation measures were discussed.

The representative from West Bengal explained that the state is facing salinity ingress problem all along the coast line due tides as well as excessive ground water withdrawal. He mentioned about adoption of different approaches in coastal area adjoining Odisha and in Sunderbans delta. He requested for a detailed study particularly in respect of Sunderbans in view of very large network of embankments in the area. After deliberation, the committee requested him to formulate necessary proposal involving relevant state departments and furnish the same at the earliest.

The representative from Diu & Daman informed that rain water harvesting structures are being constructed as the remedial measure and requested for guidance in this regard. The Chairman mentioned that local office of CGWB can be contacted for details of rain water harvesting structures and assured needed help from the Committee. The Committee requested him to furnish the proposal at the earliest and if required, help can be taken from CWC/ CGWB / NIH.

The representative from Kerala informed that the observations of CWC on the proposal submitted by the State will be attended and necessary consolidated proposal will be furnished at the earliest.

The representative from Tamil Nadu informed that the proposal is under preparation and would be furnished at the earliest.

Considering close association of NIH in this task, NIH was requested to formulate the first draft of the Introduction chapter of the report bringing out the climatic conditions, geology, hydrogeology of coastal areas, general problems faced, structural and non structural remedial measures available to tackle the problems etc.

After detailed deliberation during the meeting, it was decided that the following information would be furnished by State Governments and Union Territories.

a) Demarcation of areas affected by salinity ingress on a map;
b) Description of Problem in the State / UT and their environmental and socio-economic impacts;
c) Steps taken by States / UTs for tackling the problem;
d) Effectiveness and benefits of the remedial measures;
e) Typical design of various structural measures adopted by States / UTs;
f) Recommendations by the Committee, if any, constituted by the States / UTs;
g) Future Programmes formulated by States / UTs in order to tackle the problem;
h) Expenditure incurred so far and fund required for implementation of the proposed measures along with phasing.

The meeting ended with vote of thanks to the Chair.

Appendix-IV

Summary record of Discussions of the 3rd Meeting of Technical Committee for Adopting Suitable Protection Measures for Prevention of Salinity Ingress in the Coastal States/Union Territories held on 29th April, 2016 at CWC, New Delhi

The 3rd Meeting of Technical Committee for adopting suitable protection measures for prevention of salinity ingress in the coastal States/Union Territories was held at Sewa Bhawan, CWC, New Delhi on 29th April 2016 under the Chairmanship of Shri G S Jha, Chairman, Central Water Commission, New Delhi.
At the outset of the meeting, the Chairman of the committee welcomed all the participants and briefly explained the background and scope of the present committee. Chairman requested the Member Secretary to take up further agenda items.

The Chief Engineer HSO & Member Secretary of the Committee informed that the second meeting of the committee was held on 27th November, 2014 and the summary records of discussions have been circulated to all the members/representatives vide letter no CWC/3/53(A)/Hyd.(C)/2014/ 373 dated 03.12.2014. Since no comments have been received from any of the members, the minutes are confirmed.

The Chief Engineer HSO& Member Secretary of the Committee, informed the committee that based on the information obtained from the state governments/ UTs a draft report on "The Salinity Problems in Coastal States/Union Territories of India" was prepared and circulated during January 2016 for the comments of states/UTs comments and updating/ inclusion of information. The reminder has been sent during February 2016. The comments in this regard have been received from the states of Gujarat, Maharashtra and Andhra Pradesh and the rest of the states/UTs are yet to respond. All the states/UTs are requested to furnish necessary information so as to complete the report at an early date.

The Member Secretary of the Committee requested Dr. (Ms) Anupama Sharma, Scientist D, National Institute of Hydrology (NIH) to make a brief presentation on the over view of the problem of salinity and its remedial measures. The presentation brought out general problems faced in the coastal India, reasons thereof and various remedial measures available to tackle the salinity ingress problem.

Smt K.Rekha Rani, Deputy Director, Hydrology (C) gave a presentation on the status of the proposals received from the state/UT governments. The state wise status has been explained and the information which is yet to be received has been highlighted during the presentation.

The Chairman observed that some of the information is yet to be received from the State Governments. He said that since the matter is being monitored at the highest level, the report needs to be completed at the earliest. He requested the state governments to provide all the information in a fortnight time. However, certain states have requested for more time and accordingly it is decided that the necessary information will be furnished within three weeks.

The chairman observed that different types of structures have been constructed in different states depending upon their local and geological conditions. The typical design and cost estimate of such structures will help in arriving at fund requirement of the states and inclusion in the report. Accordingly, the states/ UTs are requested to furnish typical designs and cost estimates of recent time for the different structures executed in this regard.

The discussions were held with the representatives from each of the state government on the proposals received by them.

Gujarat:
Shri A.D.Kanani, Superintending Engineer from the government of Gujarat said that they would be proposing scheme of transferring 3 MAF of water from Narmada river to the Bandharas for treating the saline affected lands in the region of Saurashtra and Kachchh. This scheme is in pipe line and certain works are already in execution. The government of Gujarat would be submitting revised proposal, maps, typical design and recent cost estimates of different structures undertaken in the state within the time frame.

Maharashtra:
Shri Ashok P. Avhad, Superintending Engineer of Kharland Development Circle has said that the proposals submitted earlier would be revised as works of earlier proposals had already been executed. He furnished the revised proposal in the meeting.The government of Maharashtra would be submitting maps, typical design and recent cost estimates of different structures undertaken in the state within the time frame.

Goa:
Shri Anant G. Bhagwat, Superintending Engineer, representative from Water resources Department, Government of Goa has said that all the information pertaining to the Goa state will be provided in time.

Karnataka:
Shri S.Krishna, Superintending Engineer, Minor Irrigation said that the maps, additional information, the typical design and cost estimates will be provided in three weeks. He also said that certain information requested during the circulation of the draft report has been prepared and provided in both soft and hard copies.

Kerala:
Shri Joshy KA Superintending Engineer said that they are in the process of acquiring information and then grouping them in systematic order. A total of 9 districts were affected by salinity. He assured that the new proposal will be sent along with the typical design and cost estimate of structures within three weeks.

Tamil Nadu:
Shri S.Raja, representative from the Tamil Nadu state said they will stick to the time line and will provide the necessary information requested at the earliest.

Andhra Pradesh:
Shri M.John Satya Raju, Deputy Director, Ground Water Department, Government of Andhra Pradesh said that no remedial measures have been taken up in the state in a bigger scale. Only the pilot studies have been taken up. For scientific study of the affected area by salinity ingress the state is proposing certain survey works. Depending upon the outcome of survey works necessary remedial measures would be taken up.

Orrissa:
Shri Jatindra Kumar Pattnaik, Superintending Engineer from the Government of Orrissa said that apart from the creek irrigation projects, number of sluices had been provided to tackle the salinity ingress. The maps, information on sluices, along with the typical designs and cost estimates will be provided in three weeks.

West Bengal:
Shri Amit Roy, Director, River Research Institute, representative from the West Bengal said that in the state of west Bengal a number of organisations are dealing with the similar kind of works and that the gathering of information will take some time.
The drinking water scheme which they have submitted earlier, has now been revised and certain structural measures in tackling the salinity ingress has been provided. The other information will be submitted at the earliest.
A proposal for setting up an internal committee consisting of various organisations will be thought of. However SE, NTBO said that setting up such a committee would take time and information in a short span will not be provided.

The Director, RRI, West Bengal said that they will try to provide the information at the earliest along with the problems associated with the land acquisition.

Puducherry:
Shri P.Arivazhagan, Executive Engineer, representative from the Union Territory of Puducherry has said the information in the format requested will be provided in the three weeks time. They said that the problems associated in regard to funding will also be sent.

Shri D.K.Tiwary, SE, NTBO explained that the clearance from the Coastal Regulatory Authority is essential to carry out such schemes in the coastal areas. This has to be obtained from the Ministry of Environment and Forests. Shri M.Raghuram, Director, Hyd (C) informed that the government of Maharashtra has already obtained such a clearance. Representative from Government of Maharashtra Shri Ashok P.Avhad, SE, explained that the Kharland Development Circle received such approval for around 575 Kharland schemes. The committee opined that it is imperative that all the states need to take such as approval before taking up the works in the coastal area.

Shri Rajesh Kumar, Director, Coastal Erosion Directorate, informed that the coast line of peninsular portion is finalized and is 7516.6 km, based on the survey carried out jointly by NHO, Dehradun and Survey of India in 1970. This length may be adopted until new length has been finalized.

Shri, Sanjay Kumar Singh, Director, CC & IAD said that climate change needs to be taken in effect and the recommendations provided under IPCC may be incorporated in the report. He stressed for inclusion of non-structural measures in the report.

State representatives enquired about funding pattern for such schemes and criteria for introducing such projects under AIBP. The Chairman informed that the PMKSY scheme has been launched recently and providing financial assistance to the areas affected with the salinity ingress can be covered in that provided the scheme qualifies for it. Since the scheme is in initial stages, necessary modification can be incorporated in the scheme. Apart from PMKSY, the FMP and RRR are the schemes of Ministry of Water Resources through which the feasibility of central assistance can be explored for such schemes.

Shri Arivazhagan, representative from Government of Puducherry informed that state is getting financial assistance from NDMA under cyclone protection scheme. Chairman informed that the works proposed under other schemes should not be included in the present proposals so as to avoid duplication. He stressed to provide the financial expenditure incurred and proposed along with necessary cost estimate in detail to help in finalising the report.

The Chairman and Member Secretary of the committee urged the state/UT governments to provide the information within three weeks' time so as to finalise the report at an early date.

The meeting ended with vote of thanks to the Chair.

Annexure 2.1

Floodgate Opening Devices*

Device	Operation	Water level Control	Advantages/ Disadvantages
Tidal floodgate	Various designs exist. Usually consists of an aperture within the existing floodgate with another smaller floodgate attached. A floating arm opens the gate and allows water exchange with each tide. The gate opens on the low tide and closes with the rising tide.	Control is very good as the float arm can be adjusted to stop inflow at the desired water level.	Advantages: Automatic operation of the gate by the tide. Excellent water level control. The amount of exchange and maximum height of tidal influence on the inside water level can be adjusted. This design is flood secure and automatically closes as outside water level rises. Disadvantages: There is a minor risk of being jammed open. In some cases, a new gate may be required.
Sluice gates	Sluice gates consist of an aperture within existing floodgate with a sliding plate cover that can be opened to varying degrees. This opening can be vertical, horizontal or rotational in design.	The aperture size can be adjusted to vary the amount of inflow to suit site conditions so water level control is good. The position of the aperture in the floodgate can also be varied and will affect water level control.	Advantages: The variable aperture size means sluice gates provide excellent water level control. The simple design is low cost and low maintenance. Disadvantages: Requires manual operation and manual closure during floods.
Winch gates	Various designs exist including, a) winch and cable mechanism which allows the existing floodgate to be lifted open either horizontally or vertically and b) a worm drive mechanism that opens the gates vertically.	Depends on the design. Horizontal winch gates have limited water level control and are either fully open or closed. Vertical lift gates have good water level control and can be set in any position, from fully closed to fully open.	Advantages: Winch gates can allow large, rapid inflows of river water and can be fully raised to assist outflow after flooding. Disadvantages: These gates require intensive manual operation and manual closure in the event of flooding. Horizontal winch gates have a greater risk of causing overtopping when open. Vertical winch gates can experience closing difficulties due to friction.

Retention Structures*

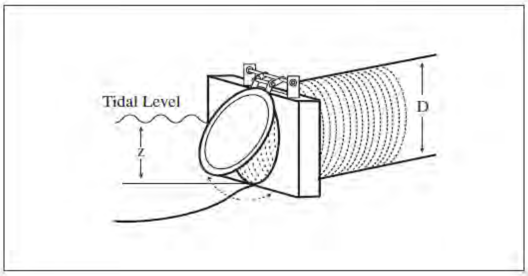
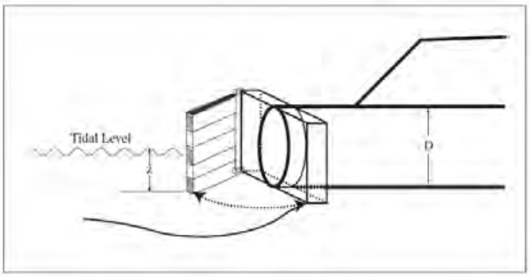
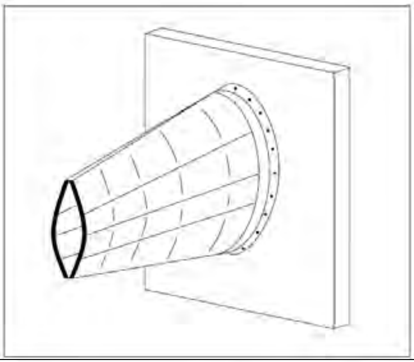
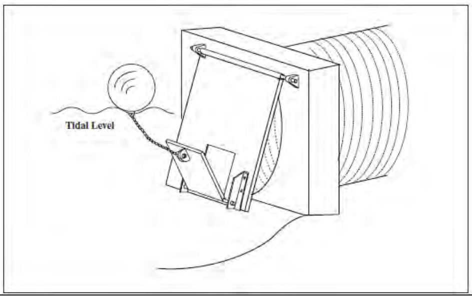
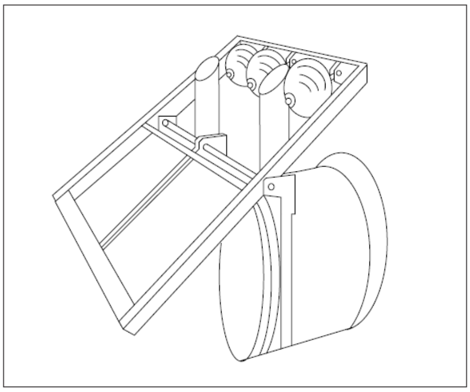
Device	Operation	Advantages	Disadvantages
Weirs / fixed sill	Weirs and fixed sills consist of a partial block in the drain. A variety of designs exist and many	Weirs and sills provide an ability to retain a guaranteed minimum water level. There is potential to	It may be difficult to vary the minimum water level once installed, depending upon the design. They can be difficult to

	materials can be used (i.e. sandbags, rock/fill, concrete, steel).	vary the depth of water retention depending on the design (i.e. to retain only groundwater or to retain shallow surface water). These structures are generally low maintenance and low cost, depending on materials.	remove from drain, again depending on design and materials.
Penstocks	These are a sluice gate or vertical lift gate placed on the landward side of a culvert.	Penstocks provide a good seal, good water level control and rarely fail. They are low maintenance if made from stainless steel.	Can be expensive. They are manually operated and can remain jam open during outflow periods if they are the vertical winch type design. A screw thread design prevents this.
Dropboard culverts	Design consists of boards placed in slots in front of any culvert on the landward side.	Water level depth can be adjusted to a desired level. Low cost.	Manually operated and the boards can be difficult to remove under a significant head of water. They are suitable only for low volume drains. They often have some leakage between the boards.

*Adapted from: http://www.dpi.nsw.gov.au/agriculture/resources/soils

Annexure 2.2

Examples of Types of Tidal Flood Gates

S.N.	Type of gate	Schematic design
1.	**Top-hinged**, round, cast iron or steel tide gate attached to cylindrical culvert.	
2	**Side-hinged**, rectangular tide gate made of aluminum or stainless steel attached to square or rectangular concrete culverts.	
3.	**Rubber duckbill** made of flexible rubber; the opening is a vertical slot in a single molded piece of rubber that fits over the end of a culvert.	
4.	**Bottom-hinged pet door**. The pet door gates comprise a small area, i.e. the pet door, within the larger area of a top-hinged tide gate that opens with very low hydraulic head differential to improve water flow and fish passage. Pet doors may be top-hinged, bottom-hinged or side-hinged.	
5.	**Self-regulating or buoyant tide gate**. Because of its buoyancy, the lid of the gate remains open, floating above water, most of the time (in other gates, default position of lid is closed position). The only time this type of gate closes is when flood tides reach a level that is high enough to cause upstream flooding. Adjustments can be made to fit site-specific conditions so the gate is closed during daily tides or only during extreme tides associated with storm events. Improves fish passage.	

Source: Giannico and Souder (2005)

Annexure 2.3

COASTAL REGULATION ZONE NOTIFICATION 2011

The Ministry of Environment and Forests (MoEF) issued the Coastal Regulation Zone (CRZ) Notification on February 19, 1991, under the Environment (Protection) Act, 1986, with the aim to provide comprehensive measures for the protection and conservation of the coastal environment. The 1991 Notification has been amended several times in consideration of requests made by various State Governments, Central Ministries, NGOs etc. Office orders have also been issued by MoEF from time to time clarifying certain provisions. The recent CRZ Notification 2011 is a consolidation of the frequent changes to the 1991 Notification.

The main objectives of the CRZ Notification 2011 are:

- To ensure livelihood security to the fishing communities and other local communities living in the coastal areas;
- To conserve and protect coastal stretches, its unique environment and its marine area, and;
- To promote development in a sustainable manner based on scientific principles, taking into account the dangers of natural hazards in the coastal areas and sea level rise due to global warming.

The notification restricts the setting up and expansion of any industry, operations or processes and manufacture or handling or storage or disposal of hazardous substances in the CRZ area. For the purpose of conserving and protecting the coastal areas and marine waters, the CRZ area is classified as follows:

(1) **CRZ I** – the ecologically sensitive areas and the geomorphological features that play a primary role in maintaining the integrity of the coast such as mangroves, coral reefs and associated biodiversity, sand dunes, mudflats which are biologically active; national parks, marine parks, sanctuaries, reserve forests, wildlife habitats and other protected areas under the provisions of Wild Life (Protection) Act, 1972 (53 of 1972), the Forest (Conservation) Act, 1980 (69 of 1980) or Environment (Protection) Act, 1986 (29 of 1986) including biosphere reserves encompassing salt marshes, turtle nesting grounds, horse shoe crabs habitats, sea grass beds, nesting grounds of birds; areas or structures of archaeological importance and heritage sites; and, the area between Low Tide Line (LTL) and High Tide Line (HTL) i.e. the inter-tidal zone.

(2) **CRZ II** – The areas which are developed upto or close to the shoreline and falling within municipal limits.

(3) **CRZ III** – The areas that are relatively undisturbed and those do not belong to either CRZ-I or II which include coastal zone in the rural areas (developed and undeveloped) and also areas within municipal limits or in other legally designated urban areas, which are not substantially built up.

(4) **CRZ IV** – (a) the water area from LTL to the limit of territorial waters of India (12 nautical miles on the seaward side), and (b) the water area of the tidal influenced water body from the mouth of the water body at the sea to the distance upto which the tidal effects are experienced which shall be determined based on salinity concentration of five parts per thousand (ppt) measured during the driest period of the year (here the term 'tidal influenced water bodies' implies the water bodies influenced by tidal effects from sea, in the bays, estuaries, rivers, creeks, backwaters, lagoons, ponds connected to the sea or creeks and the like).

(5) Areas requiring special consideration for the purpose of protecting the critical coastal environment and difficulties faced by local communities:

(a) (i) CRZ area falling within municipal limits of Greater Mumbai; (ii) the CRZ areas of Kerala including the backwaters and backwater islands; (iii) CRZ areas of Goa.

(b) Critically Vulnerable Coastal Areas (CVCA) such as Sundarbans region of West Bengal and other ecologically sensitive areas identified as under Environment (Protection) Act, 1986 and managed with the involvement of coastal communities including fisherfolk.

A separate Island Protection Zone Notification has been issued for protection of the islands of Andaman & Nicobar, and Lakshadweep under Environment (Protection) Act, 1986.

The CRZ notification brings out the activities permissible under the above mentioned classes (for details refer MoEF, 2011). Besides a detailed list of prohibited activities within CRZ (for details refer MoEF, 2011), the following are declared as prohibited activities within the CRZ pertaining to water resources etc.:

(i) Land reclamation, bunding or disturbing the natural course of seawater except those:

- required for setting up, construction or modernisation or expansion of foreshore facilities like ports, harbours, jetties, wharves, quays, slipways, bridges, sealink, road on stilts, and such as meant for defence and security purpose and for other facilities that are essential for activities permissible under the notification;
- measures for control of erosion, based on scientific including Environmental Impact Assessment (EIA) studies
- maintenance or clearing of waterways, channels and ports, based on EIA studies;
- measures to prevent sand bars, installation of tidal regulators, laying of storm water drains or for structures for prevention of salinity ingress and freshwater recharge based on studies carried out by any agency to be specified by MoEF.

(ii) Mining of sand, rocks and other sub-strata materials except,

- those rare minerals not available outside the CRZ area,
- exploration and exploitation of Oil and Natural Gas.

(iii) Withdrawal of groundwater and construction related thereto, within 200 m of HTL; except the following:

- in the areas which are inhabited by the local communities and only for their use.
- in the area between 200-500 m zone, withdrawal of groundwater shall be permitted only when done manually through ordinary wells for drinking, horticulture, agriculture and fisheries and where no other source of water is available. Restrictions for such withdrawals may be imposed by the authority designated by the State Government and Union territory Administration in the areas affected by sea water intrusion.

Annexure 3.1A

List of Completed Bandhara/T.R in the Region of Kachchh (KIC Bhuj)

Sr. No	Year of Investig-aton by Committe	Reach	Taluka	Salinity Afected area in Hact.	Constructed Bandhara / T.R Name	Storage in Mcft	Benifited Area in Ha.	Year of Completion
1	2	3	4	5	6	7	8	9
1	1982-83	Maliya-Lakhpat	Bhachau	63500	Lakhapar	77.69	475	2008-09
2					Bhachau	6.00	490	2008-09
3					Nani Chirai	4.60	460	2007-08
4					Chhadwada	83.34	480	2010-11
5					Amaliyara	14.13	470	2007-08
6					Jangi	14.13	480	2008-09
7					Moti Chirai	17.66	950	2007-08
8					Wandhiya	24.72	470	2007-08
			Total	**63500**		**242.27**	**4275**	
9	1981-82		Anjar	24300	Vira	12.71	480	**(Under const.)**
10					Modavadsar	4.24	900	2007-08
11					Sanghad	56.50	560	1998
			Total	**24300**		**73.45**	**1940**	
12	1980-81		Mundra	54470	Mundra	95.70	500	2008-09
13					Bhadreshwar T.R.	42.38	1000	2010-11
14					Jarpara	16.60	990	2007-08
15					Kukadsar	27.55	475	2006-07
16					Bhadreshwar	10.59	485	2006-07
17					Gundala (Luni)	10.59	120	2013-14
18					Navinal	70.63	490	2006-07
19					Wandh	11.30	250	2007-08
20					Kandagara	24.37	980	2007-08
21					Luni	10.59	490	2008-09
22					Dhrab	7.06	495	2007-08
			Total	**54470**		**327.36**	**6275**	
23	1979-80		Mandvi	62390	Bharapar	4.94	490	2008-09
24					Mota Layja	202.00	950	2007-08
25					Bambhadai	5.30	950	2006-07
26					Modkuba	15.19	480	2006-07
27					Pachotiya	25.78	960	2008-09
28					Bhadia Nana	4.23	475	2007-08
29					Gundiyali	9.54	470	2008-09
30					Mapar	124.30	400	2009-10
31					Bada	10.24	970	2008-09
32					Layja-2	21.90	750	2012-13
33					Rukmavati TR	8.48	48	1991
34					Changdai	6.00	210	2012-13
			Total	**62390**		**437.90**	**7153**	
35	1980-81	Maliya-Lakhpat	Abdasa	107780	Belawandh	98.88	180	2000
36					Gunay	38.85	900	2008-09
37					Golay	84.76	700	2009-10
38					Moti Sindhodi	75.93	600	2009-10

39					Khirsara	113.00	490	2010-11
40					Kosa Vadsar T.R.	653.33	3000	2010-11
41					Dhuvai T.R.	122.90	2000	2008-09
42					Khuada	15.89	475	2006-07
43					Kadoli	5.30	200	2007-08
44					Charopari	94.29	940	2008-09
45					Lathedi	16.95	930	2007-08
46					Budiya	81.93	455	2007-08
47					Suthari (Akri)	34.96	410	2014-15
			Total	**107780**		**1436.97**	**11280**	
48	1981-82		Lakhpat	37590	Narayan Sarovar	98.18	500	2007-08
49					Kori Creek (Guneri)	11.65	485	2007-08
50					Koriyani	45.20	930	2009-10
51					Nani Chher	14.12	800	2011-12
52					Zara	18.01	800	2012-13
			Total	**37590**		**187.16**	**3515**	
53	1982-83		Rapar	21100	Navagam (Manaba)	38.85	900	2008-09
54					Lakdawandh	496.88	1732	2000
			Total	**21100**		**535.73**	**2632**	
dfs								

Annexure 3.1B

List of Completed work in Saurashtra Region

SR. No.	NAME OF SCHEME	Taluka	Completed Year	Storage Mcum	Benifited Area (Ha.)
1	2	3	4	5	6
A	**Tidal Regulator**				
1	Vadodara Zala T.R.	Sutrapada	1982	7.93	1560.00
2	Vasoj T.R.	Una	1984	2.69	500.00
3	Meghal T.R.	Maliya (H)	1989	6.00	1198.00
4	Mul Dwarka T.R.	Kodinar	1991	1.70	373.00
5	Somanath T.R.	Veraval	2010	1.85	300.00
6	Panch Pipalava T.R.	Kodinar	1998	11.07	1600.00
	H.L.C.-1 Total			**31.24**	**5531.00**
A	**Tidal Regulator**				
7	Malan T.R.	Mahuva	2012	18.42	3300.00
8	Kerly T.R.	Porbandar	1992	67.88	1012.00
9	Visavada T.R.	Porbandar	1978	2.12	25.00
10	Medha Krick T.R.	Porbandar	1993	49.00	4048.00
11	Bhogat T.R.	Kalyanpur	1998	6.00	3179.00
12	Khiri T.R.	Jodia	1998	0.16	75.00
13	Bed T.R.	Jamnagar	2012	3.34	2250.00
14	Alang T.R.(Check Dam)	Talaja	2014	0.42	550.00
	H.L.C.-2 Total			**147.34**	**14439.00**
	Total H.L.C. 1 &2			**178.58**	**19970.00**
B	**Bandhara**				
1	Sangawada Bandhara	Mangrol	1979	0.11	40.00
2	Sheriyaj Bandhara	Mangrol	1980	0.10	28.00
3	Jankhravada Bandhara	Una	1982	0.11	45.00
4	Lati Bandhara	Sutrapada	1982	0.06	11.00
5	Barda Bandhara	Kodinar	1985	4.82	900.00
6	Badlapur Bandhara	Veraval	1985	0.13	44.00
7	Sill Bandhara	Mangrol	1987	0.86	145.00
8	Sodam Bandhara	Kodinar	1991	11.07	508.00
9	Sardagram Bandhara	Mangrol	1993	2.92	510.00
10	Somanath Bandhara	Veraval	1995	0.29	35.00
11	Aadri Bandhara	Veraval	1995	0.18	35.00
12	Khada Bandhara	Una	1996	8.85	1764.00
	H.L.C.-1 Total			**29.50**	**4065.00**
B	**Bandhara**				
13	Jambuda Bandhara	Jamnagar	1998	0.39	384.00
14	Akvada Bandhara	Bhavnagar	1999	0.04	78.00
15	Kalsar Bandhara	Mahuva	1999	0.27	34.00
16	Samdhiyala Bandhara	Rajula	2000	1.76	300.00
17	Bherai Bandhara	Rajula	2007	0.08	60.00
18	Visaliya Bandhara	Rajula	2009	2.00	1400.00
19	Kadiayali Bandhara	Jafrabad	2009	0.03	146.00
20	Nikol Bandhara	Mahuva	2001	24.08	5000.00
21	Gopanath Bandhara	Talaja	2011	0.18	500.00
22	Khandhera Bandhara	Talaja	2008	0.14	227.00

SR. No.	NAME OF SCHEME	Taluka	Completed Year	Storage Mcum	Benifited Area (Ha.)
1	2	3	4	5	6
24	Hamusar Bandhara	Okha Mandal	2011	0.04	57.00
25	Hadiayan Bandhara	Jodia	2011	2.31	1750.00
26	Sarmat Khara Beraja Bandhara	Jamnagar	2002	2.58	891.00
27	Bhalambha Bandhara	Jodia	2005	3.70	825.00
28	Hathab Bandhara	Bhavnagar	2012	0.03	350.00
29	Khatrivada Bandhara(Check Dam)	Jafrabad	2013	0.04	150.00
30	Pindhara Bandhara	Kalyanpur	2014	1.57	345.00
31	Jashpara Bandhara	Talaja	2014	0.33	520.00
	H.L.C.-2 Total			**39.68**	**13118.00**
	Total H.L.C. 1 &2			**69.18**	**17183.00**
C	**Recharge Reservoir**				
1	Vrajmi Recharge Reservoir	Maliya (H)	1987	10.35	1070.00
2	Noli Recharge Reservoir	Mangrol	1995	3.03	2360.00
	H.L.C.-1 Total			**13.38**	**3430.00**
C	**Recharge Reservoir**				
3	Kerly Recharge Reservoir	Porbandar	2002	21.27	1220.00
4	Garibpura Recharge Reservoir	Ghogha	2003	0.20	58.00
5	Samdhiyala Recharge Reservoir	Talaja	2007	0.11	40.00
6	Mobhiyana Recharge Reservoir	Rajula	2007	0.09	120.00
7	Moti Jagdhar Recharge Reservoir	Mahuva	2007	0.23	80.00
8	Sihan Recharge Reservoir	Khambhaliya	2007	5.10	202.00
9	Dadhiyari Recharge Reservoir	Jodia	2007	0.04	25.00
10	Bhavanipura Recharge Reservoir	Talaja	2008	0.20	120.00
11	Jinjuda Recharge Reservoir	Maliya (M.)	2008	1.70	570.00
12	Adhevada Recharge Reservoir	Bhavnagar	2009	1.84	625.00
13	Und Recharge Reservoir	Jodia	2010	0.90	300.00
14	Habukvad Recharge Reservoir	Talaja	2011	0.06	220.00
15	Machchhu Recharge Reservoir	Maliya (M.)	2012	0.60	400.00
16	Sarod Recharge Reservoir	Rajula	2014	0.10	150.00
17	Taveda Recharge Reservoir	Mahuva	2014	0.12	130.00
18	Aebhalvad Recharge Reservoir	Rajula	2014	0.02	80.00
	H.L.C.-2 Total			**32.58**	**4340.00**
	Total H.L.C. 1 &2			**45.96**	**7770.00**
D	**Recharge Tank**				
1	Ghogham Recharge Tank	Kodinar	1979	0.04	10.00
2	Aajak Recharge Tank	Magrol	1979	0.02	30.00
3	Kadaya Recharge Tank	Maliya (H)	1981	0.06	30.00
4	Mangrol Recharge Tank	Mangrol	1981	0.18	60.00
5	Shil Recharge Tank	Mangrol	1983	0.01	10.00
	H.L.C.-1 Total			**0.31**	**140.00**
D	**Recharge Tank**				
6	Sanodar Recharge Tank	Ghogha	2009	0.02	118.00
7	Tansa Recharge Tank	Ghogha	2009	0.03	150.00
8	Nani Babriyat Recharge Tank	Talaja	2009	0.08	200.00
9	Manar Recharge Tank	Talaja	2009	0.15	300.00
10	Bapada Recharge Tank	Talaja	2009	0.03	55.00
11	Ishor - 1 Recharge Tank	Talaja	2009	0.02	110.00
12	Bela Recharge Tank	Talaja	2009	0.08	220.00
13	Neshiya Recharge Tank	Talaja	2010	0.08	220.00

SR. No.	NAME OF SCHEME	Taluka	Completed Year	Storage Mcum	Benifited Area (Ha.)
1	2	3	4	5	6
15	Ishor - 2 Recharge Tank	Talaja	2009	0.02	110.00
16	Dihor Recharge Tank	Talaja	2010	0.08	220.00
17	Sankhada Recharge Tank	Una	2011	0.02	60.00
18	Bardiya Recharge Tank	OKha Mandal	2011	0.11	140.00
19	Padva Recharge Tank	Ghogha	2011	0.07	150.00
20	Manar-2 Recharge Tank	Talaja	2012	0.07	250.00
21	Timana Recharge Tank	Talaja	2011	0.04	80.00
22	Gagava Recharge Tank	Jamnagar	1998	0.14	30.00
23	Nageshree Recharge Tank	Rajula	2012	0.03	80.00
24	Malnaka Recharge Tank	Bhavnagar	2012	0.04	120.00
25	Gurgadh-2 Recharge Tank	Kalyanpur	2012	0.46	35.00
26	Moti Kheradi Recharge Tank	Rajula	2012	0.06	150.00
27	Dhatravada Recharge Tank	Talaja	2012	0.02	150.00
28	Bhakhal Recharge Tank	Bhavnagar	2013	0.04	120.00
29	Gara-2 Recharge Tank	Kalyanpur	2013	0.39	20.00
30	Gurgadh-1 Recharge Tank	Kalyanpur	2014	0.20	41.00
31	Sondardi Recharge Tank	Una	2014	0.02	50.00
32	Nageshwar-2 Recharge Tank	OKha Mandal	2014	0.16	80.00
	H.L.C.-2 Total			**2.51**	**3319.00**
	Total H.L.C. 1 &2			**2.82**	**3459.00**
E	**Spreading Channel**				
1	Sabli netravati Spreding Channel (7.30 k.m.)	Mangrol	1996	0.05	1566.00
2	Goma -Chara Spreding Channel (0.90 k.m.)	Kodinar	1998	0.22	160.00
3	Medhal -Aadri Spreding Channel(4.56 k.m.)	Maliya (H)	2000	0.03	457.00
4	Mul dwarka sodam Spreding Channel (7.29 k.m.)	Kodinar	2007	0.02	560.00
5	PPTR Sodam Spreding Channel (4.45 k.m.)	Kodinar	2007	0.05	270.00
6	Arnej C- block Spreding Channel (3.12 k.m.)	Kodinar	2007	0.01	270.00
7	Noli - netravati Spreding Channel (18.99 km)	Malia(H)	2008	0.19	3015.00
8	Sara Link Canal (3.24 k.m.)	Sutrapada	2009	0.02	400.00
9	Noli- meghal Spreding Channel (10.34 k.m.)	Mangrol	2010	0.09	1000.00
10	Devaka - Kahri Spreding Channel (4.92 k.m.)	Veraval	2010	0.05	1020.00
11	Netravati -Mdhuvanti -1 Spreding Channel (6.60 k.m.)	Mangrol	2010	0.06	1100.00
12	Netravati -Mdhuvanti -2 Spreding Channel(2.58 k.m.)	Mangrol	2012	0.01	350.00
	H.L.C.-1 Total			**0.79**	**10168.00**
E	**Spreading Channel**				
13	Kerly- Kindri Spreding Channel (21.06 k.m.)	Porbandar	2006	0.20	2550.00
14	Khijadiya-Jambuda Spreding Channel (7.35 k.m.)	Jamnagar	2009	0.03	627.00
15	Medha - kindri Spreding Channel (7.00 k.m.)	Porbandar	2012	0.07	1524.00
16	Khiri - Hadiayan Spreding Channel (6.90 k.m.)	Jodia	2010	0.11	960.00
17	Jambuda - Khiri Spreding Channel (5.43 k.m.)	Jodia	2013	0.08	1000.00
18	Nikol- Klasar Spreding Channel(3.51 k.m.)	Mahuva	2011	0.06	560.00

SR. No.	NAME OF SCHEME	Taluka	Completed Year	Storage Mcum	Benifited Area (Ha.)
1	2	3	4	5	6
20	Bed - Sarmat Spreding Channel (1.55 k.m.)	Jamnagar	2012	0.01	150.00
21	Und -Balmbha Spreding Channel (5.71 k.m.)	Jodia	2010	0.08	910.00
22	Kerly-Tukada Spreding Channel (2.28 k.m.)	Porbandar	2012	0.02	160.00
23	Bed-Sikka Spreding Channel (3.44 k.m.)	Jamnagar	2013	0.02	549.00
24	Blamabha - Sampar Spreading Channel (9.21 k.m.)	Jodia	2013	0.08	1470.00
25	Pachhatar Kolikhada-2 Spreading Channel (7.92 k.m.)	Porbandar	2013	0.03	1180.00
26	Pacchatar Kolikada - 1 Spreading Channel (15.70 k.m.)	Porbandar	2014	0.38	2295.00
27	Vasoj P.P.T.R. Spreading Channel (9.75 k.m.)	Una	2014	0.09	334.00
28	Visaliya Samdhiyala Spreading Channel (2.78 k.m.)	Rajula	2014	0.02	180.00
29	Ozat Maduvanti Spreading Channel (19.23 k.m.)	Porbandar	2014	0.19	2855.00
30	Hadiayana - Und Spreading Channel (9.18 k.m.)	Jodia	2014	0.05	1370.00
31	Ozat Madhuvanti Spreading Channel (5.20 k.m.)	Porbandar	2015	0.04	745.00
	H.L.C.-2 Total			**1.75**	**19829.00**
	Total H.L.C. 1 &2			**2.54**	**29997.00**

No	Check Dam	Total Number	Storage Mcum	Benifited Area(Ha.)
1	Bhavanagar District	174	3.48	2102.00
2	Amreli District	38	0.88	642.00
3	Junagadh District	181	7.43	1805.00
4	Jamanagar District	202	9.33	2841.00
5	Porbandar District	39	1.82	867.00
6	Rajkot District	38	1.83	404.00
	Total	**672**	**24.77**	**8661.00**

Annexure 3.2A

District wise completed Kharland Schemes in Maharashtra

397 Kharland Development Completed Schemes			
S. N.	Name of Scheme	Taluka	Area reclaimed (ha)
1	2	3	4
Dist- Thane			
1	Uttan Dongari	Thane	31
2	Dongri	Thane	43
3	Raimurde	Thane	162
4	Bhainder 'A'	Thane	717
5	Owale Bhayanderpada	Thane	81
6	Owale	Thane	190
7	Deokhar	Thane	199
8	Kolshet Kawesar *	Thane	120
9	Kharigaon	Thane	178
10	Agasan	Thane	147
11	Chorkhar Annapurna	Bhiwandi	262
12	Vakilacha Kopara	Bhiwandi	34
13	Karbhari	Bhiwandi	45
14	Kalkhar	Bhiwandi	67
15	Khaleri Kasheri	Bhiwandi	152
16	Kambe Katai	Bhiwandi	49
17	Talikhar	Bhiwandi	102
18	Gaonkhar Junadurkhi	Bhiwandi	86
19	Malki	Bhiwandi	112
20	Ganephirangipada	Bhiwandi	122
21	Wadukhar	Bhiwandi	73
22	Demkhar Wadunavghar	Bhiwandi	230
23	Kolyacha Kopara	Bhiwandi	41
24	Navikhar Dunge	Bhiwandi	128
25	Gaonkhar Kewani	Bhiwandi	61
26	Kalher Kevani Moti Diva (P)	Bhiwandi	152
27	Anjur Diva	Bhiwandi	318
28	Manjare Diva *	Bhiwandi	35
29	Pura Bolinj	Vasai	145
30	Vathar	Vasai	91
31	Kaular	Vasai	78
32	Sandor	Vasai	24
33	Dhovali Sandor	Vasai	20
34	Mulgaon Killa	Vasai	95
35	Vadvali Kirvali	Vasai	127
36	Umelman	Vasai	82
37	Wanyachi Barachi	Vasai	122
38	Navison	Vasai	145
39	Kol	Vasai	78
40	Panju (Island)	Vasai	43
41	Dhanagari Karpe *	Vasai	72
42	Bapane	Vasai	143
43	Dongar Masuri	Vasai	178
44	Sarja More	Vasai	74
45	Kalamb *	Vasai	250
46	Sasunavaghar	Vasai	454
47	Dhankopri Paynagale	Vasai	91
48	Western Vaitarna	Vasai	51
49	Phanaspada Khardi Koshimbe	Vasai	433
50	Rangaon Bhaigaon	Vasai	264
51	Juli	Vasai	98
52	Kashid Kopar	Vasai	96
53	Mukkam	Vasai	34
54	Agashi	Vasai	190

55	Tembhipada	Vasai	55
56	Pura-Bolinj	Vasai	109
57	Narangi Chikhal Dongari	Vasai	936
58	Chandansar Ghaskopari	Vasai	22
59	Amarshi Ghaskopari	Vasai	51
60	Dandekar	Vasai	149
61	Shirgaon Kothe	Vasai	71
62	Shirgaon Son	Vasai	117
63	Masoli	Dahanu	30
64	Asangaon	Dahanu	180
65	Dedale kolavli	Dahanu	32
66	Umroli	Palghar	75
67	Ucheli	Palghar	66
68	Mahim-Kelwa	Palghar	60
69	Allyali	Palghar	77
70	Kora	Palghar	26
71	Khatali-Wilangi & Khatali-Wilangi (Part)	Palghar	75
72	Purandare	Palghar	66
73	Tondale	Palghar	72
74	Datiware	Palghar	120
75	Lingi	Palghar	142
76	Juibet Datiware	Palghar	140
77	Tembhi Khodave	Palghar	159
78	Darughatim	Palghar	125
79	Vadhiv	Palghar	330
80	Saphale	Palghar	416
81	Navghar	Palghar	82
82	Darshet Umberpada	Palghar	29
		Total	**11227 ha**
Dist-Raigad			
83	Masad	Pen	545
84	Vadav Borge	Pen	277
85	Jambhultep	Pen	159
86	Kokeri	Pen	62
87	Rave(East)	Pen	76
88	Rave(West)	Pen	240
89	Patkhar	Pen	19
90	Nagdi Sapoli	Pen	130
91	Vashi Odhangi	Pen	457
92	Mora Kotha	Pen	35
93	Ghandhe	Pen	48
94	Shirki Vashi	Pen	310
95	Vave Odhangi	Pen	321
96	Machela Charbi	Pen	345
97	Juhi Abbas	Pen	331
98	Palkhar	Pen	92
99	Talekhar	Pen	61
100	Jite	Pen	48
101	Patnoli	Pen	23
102	Burdi	Pen	83
103	Owali	Pen	72
104	Koleti	Pen	96
105	Chowle	Pen	40
106	Dutarfa Kopar	Pen	206
107	Sonkhar Urnoli	Pen	594
108	Narvel Benawale	Pen	1388
109	Kane Koproli	Pen	246
110	Kalai	Pen	36
111	Vadhavpada Motha Bhal	Pen	101
112	Dhondpada	Pen	132
113	Sai	Panvel	224
114	Pargaon Dungi	Panvel	127

115	Aware	Uran	145
116	Kopta Koproli	Uran	672
117	Borkhar	Uran	430
118	Jui Dhamkadi	Uran	307
119	Sonkhar Mandave	Alibag	67
120	Medhekhar	Alibag	176
121	Poferi	Alibag	183
122	Navin Milkat	Alibag	201
123	Manoranjan	Alibag	186
124	Dhaktapada Shahapur	Alibag	345
125	Rayende Pezare	Alibag	99
126	Narangi	Alibag	195
127	Tajpur	Alibag	51
128	Fansapur Kurdus	Alibag	156
129	Kopari Chikali	Alibag	52
130	Dhenkoni	Alibag	169
131	Dherend	Alibag	149
132	Kavade	Alibag	274
133	Kachli Pitkari	Alibag	334
134	Belhar Lebhi	Alibag	118
135	Varasgaon	Alibag	221
136	Navedar Beli	Alibag	47
137	Dhivan	Alibag	139
138	Mankule	Alibag	532
139	Varsoli	Alibag	40
140	Palav Bagmala	Alibag	103
141	Chaul Aacharya	Alibag	58
142	Shahabaj	Alibag	498
143	Bapale	Alibag	101
144	Bhonang	Alibag	162
145	Kude Surkoli	Alibag	202
146	Akshi Savargaon	Alibag	40
147	Sonkota Hashivare	Alibag	265
148	Pale Nageshwari	Alibag	82
149	Revdanda Theronda	Alibag	32
150	Khidki	Alibag	17
151	Kamalpada Dhamanpada	Alibag	350
152	Waghran	Alibag	221
153	Chaul Agrav	Alibag	50
154	Kharhaon	Roha	29
155	Borkosbkotha	Roha	61
156	Palas	Roha	67
157	Zolambe	Roha	129
158	Nave Navkhar	Roha	95
159	Divkhar	Roha	202
160	Karnjveera	Roha	64
161	Dhondkhar	Roha	95
162	Shenvai panbal	Roha	44
163	Kharkhardi	Roha	26
164	Uchel Virjoli	Roha	122
165	Vavepotgi	Roha	44
166	Annapurna	Roha	196
167	Cheher Mithekhar	Murud	211
168	Hafizkhar	Murud	27
169	Murud Yeshwanti	Murud	106
170	Vande	Murud	37
171	Sonkhar Jaffer	Murud	136
172	Mazgaon Adaste	Murud	60
173	Jamurtkhar	Murud	18
174	Shirgaon Yesde	Murud	167
175	Murud Amboli	Murud	165
176	Walke Satarde & vistar	Murud	518
177	Salav (A+B)	Murud	83
178	Tokekhar	Murud	14

179	Savli Mitheghar	Murud	151
180	Mazgaon	Tala	54
181	Tamhane Tarfe	Tala	12
182	Girane Nanivali	Tala	140
183	Vashi Haveli	Tala	56
184	Walvati	Shrivardhan	57
185	Yeshwanti	Shrivardhan	217
186	Bag Mandala	Shrivardhan	27
187	Saigaon Nigdi	Shrivardhan	89
188	Dighi Karlas	Shrivardhan	90
189	Galsure	Shrivardhan	100
190	Velas Vadavali	Shrivardhan	117
191	Kudgaon Harvit	Shrivardhan	67
192	Kandalwada old	Mhasala	51
193	Kharsai Old	Mhasala	24
194	Waral Old	Mhasala	322
195	Khargaon Budruk	Mhasala	30
196	Sanderi	Mhasala	23
197	Banumarium	Mhasala	36
198	Ambet	Mhasala	97
199	Tondsure Khargaon	Mhasala	91
200	Kalsuri Old	Mhasala	46
201	Waral New	Mhasala	438
202	Amshet	Mhasala	48
203	Pangloli	Mhasala	27
204	Devli Moor	Mangaon	65
205	Mendhi	Mahad	70
206	Veer	Mahad	37
207	Tudil	Mahad	23
208	Gomendi	Mahad	53
209	Telange	Mahad	45
210	Varathi	Mahad	20
211	Sape	Mahad	48
212	Jui	Mahad	42
213	Are Khurd Are Budra	Roha	11
214	Kumbhoshi	Roha	14
215	Sanegaon	Roha	18
		Total	**19965 ha**
		Dist-Ratnagiri	
216	Velas	Mandangad	25
217	Shipole	Mandangad	21
218	Vesavi Kante	Mandangad	60
219	Panderi	Mandangad	64
220	Kelshi	Dapoli	27
221	Ade	Dapoli	35
222	Malvi	Dapoli	16
223	Anjarle	Dapoli	27
224	Shivvganwadi	Dapoli	30
225	Danbhil	Dapoli	9
226	Govindshetwadi	Dapoli	32
227	Hedavi Narvan	Guhagar	45
228	Narwan	Guhagar	59
229	Palshet	Guhagar	26
230	Chiveli	Chiplun	45
231	Pedhe Parshuram	Chiplun	43
232	Govalkot	Chiplun	84
233	Shiral	Chiplun	40
234	Jambhut Kond	Chiplun	27
235	Kaluste Bhile	Chiplun	128
236	Karambavane	Chiplun	58
237	Musalmanwadi No.2	Chiplun	48
238	Gangrai	Chiplun	42
239	Bahiravali	Khed	45

240	Randale	Khed	15
241	Savanas Tumbad	Khed	57
242	Remjevadi	Khed	39
243	Kotawali	Khed	41
244	Songaon	Khed	42
245	Fadake	Khed	34
246	Dhamandevi	Khed	30
247	Nandiwade	Ratnagiri	38
248	Warawade	Ratnagiri	49
249	Malgund	Ratnagiri	99
250	Kunage	Ratnagiri	11
251	Nivendi	Ratnagiri	30
252	Kajarwadi	Ratnagiri	22
253	Murugwadi	Ratnagiri	23
254	Kalbadevi	Ratnagiri	23
255	Kasarweli	Ratnagiri	22
256	Kelye	Ratnagiri	10
257	Wadamirya	Ratnagiri	146
258	Zadgaon	Ratnagiri	9
259	Umbarwadi	Ratnagiri	24
260	Sadye	Ratnagiri	24
261	Basni	Ratnagiri	42
262	Nevare - Chinchvane	Ratnagiri	26
263	Majgaon	Ratnagiri	54
264	Ganesh Gule	Ratnagiri	12
265	Gavade Ambere	Ratnagiri	165
266	Wada Dabhil	Ratnagiri	32
267	Dorle	Ratnagiri	21
268	Gaonkhadi	Ratnagiri	55
269	Gauravwadi No.1	Ratnagiri	16
270	Chapheri Kasari	Ratnagiri	235
271	Karla	Ratnagiri	75
272	Chinchkhari	Ratnagiri	45
273	Kolambe	Ratnagiri	34
274	Golap Ranpar	Ratnagiri	31
275	Pawas (A+B)	Ratnagiri	28
276	Bhatiwadi	Ratnagiri	49
277	Pawas -B	Ratnagiri	29
278	Ranpar	Ratnagiri	7
279	Wadavaitye	Rajapur	24
280	Amboigad	Rajapur	20
281	Nate	Rajapur	94
282	Kondsar (Khurd)	Rajapur	34
283	Kondsar (Budruk)	Rajapur	128
284	Madban	Rajapur	54
285	Holi	Rajapur	14
286	Kuveshi	Rajapur	17
287	Ansure Bakale	Rajapur	166
288	Sagve	Rajapur	51
289	Padave	Rajapur	17
290	Chinchad	Rajapur	53
291	Hamdaremala	Rajapur	10
292	Wadapale	Rajapur	16
293	Bharadewadi	Rajapur	19
294	Harche	Lanja	26
		Total	**3523 ha**
		Dist-Sindhudurg	
295	Thakurwada	Deogad	17
296	Damlemala	Deogad	25
297	Girye Kholwadi	Deogad	19
298	Palekarwadi	Deogad	71
299	Manche	Deogad	46
300	Kelye	Deogad	72

301	Puralkhothar	Deogad	75
302	Phanasewadi	Deogad	71
303	Hurshi	Deogad	34
304	Padel no. 1	Deogad	39
305	Padel no. 2	Deogad	42
306	wada	Deogad	29
307	Mutat	Deogad	29
308	Mutat bhatwadi	Deogad	27
309	Waghotan Soundale .	Deogad	55
310	Mond	Deogad	79
311	Talawade Tembhawali	Deogad	60
312	Puralgaon	Deogad	35
313	Baparde	Deogad	35
314	Tirloat Dalviwadi	Deogad	15
315	Halye Wadatar	Deogad	34
316	Bagmala	Deogad	29
317	Mithbava	Deogad	225
318		Deogad	16
319	Taramumbri	Deogad	15
320	Bhatvadi Jamsande	Deogad	40
321	Kunkeshwar	Deogad	33
322	Naringre	Deogad	41
323	Mithamumbri Bagwadi	Deogad	35
324	Naringre Giraval	Deogad	18
325	Elaye Bhaskarwadi No.2	Deogad	10
326	Munge Karivane wadi	Deogad	53
327	Hirle Shivapur	Malwan	55
328	Shivagar	Malwan	34
329	Wayari	Malwan	33
330	Dukhande	Malwan	14
331	Masure	Malwan	225
332	Wayangani	Malwan	41
333	Achara Deulwada	Malwan	47
334	Tondavali	Malwan	52
335	Bhagwatgad Terai	Malwan	18
336	Hadi	Malwan	90
337	Achara Dongar wadi	Malwan	47
338	Achra Paar wadi	Malwan	57
339	Achara Bade Khajan	Malwan	18
340	Malwan Dhuriwada	Malwan	179
341	Hadi Kanlgaon	Malwan	225
342	Adari Nive	Malwan	70
343	Bandivade	Malwan	120
344	Amberi	Malwan	75
345	Varchi Devali	Malwan	133
346	Kalethar Devali	Malwan	168
347	Pendur	Malwan	130
348	Chippiwadi	Vengurla	33
349	Gadedhavwadi	Vengurla	33
350	Kavthi Chippi Bharni	Vengurla	26
351	Bhatimali	Vengurla	45
352	Redi Saudagarwadi	Vengurla	19
353	Aravali	Vengurla	41
354	Asolipal	Vengurla	33
355	Ambekhan Ubhadanda	Vengurla	38
356	Ajgaon Shiroda Tiroda	Vengurla	26
357	Mochemad	Vengurla	32
358	Vengurla	Vengurla	54
359	Aravali Tak	Vengurla	106
360	Devaswadi	Vengurla	25
361	Ansurwadi	Vengurla	8
362	Tulas	Vengurla	5
363	Mithagarwadi	Vengurla	189
364	Shiroda	Vengurla	67

365	Khalche Ansur	Vengurla	62
366	Redi	Vengurla	147
367	Aravli Asoli Naichead	Vengurla	73
368	Varche Ansur	Vengurla	55
369	Nawabag Ubhadanda	Vengurla	34
370	Asolipal No.1	Vengurla	66
371	Mhapan Kochara	Vengurla	29
372	Ganesh Kochara	Vengurla	119
373	Kelus	Vengurla	59
374	Karli Dutondwadi	Vengurla	107
375	Waingani	Vengurla	26
376	Nivti Kochara	Vengurla	26
377	Dabholi Khanoli	Vengurla	49
378	Kavathi Chendvan	Kudal	50
379	Walawal	Kudal	46
380	Chendvan No.1	Kudal	46
381	Nerur	Kudal	62
382	Kavathi Gavkaarwadi	Kudal	24
383	Sarambal	Kudal	19
384	Tiroda No.1	Sawantwadi	18
385	Tiroda No.2	Sawantwadi	27
386	Nanos	Sawantwadi	25
387	Aronda No.2	Sawantwadi	192
388	Dhakle Khajan	Sawantwadi	53
389	Talvane Velve	Sawantwadi	83
390	Talavane	Sawantwadi	12
391	Kinale	Sawantwadi	29
392	Juva Kinale	Sawantwadi	21
393	Kavathani Muthewadi	Sawantwadi	25
394	Kavathani	Sawantwadi	12
395	Satarda No.2	Sawantwadi	13
396	Satarda No.1	Sawantwadi	20
397	Satosa	Sawantwadi	18
		Total	**5682 ha**
397		**Grand Total**	**40397 ha**

Annexure 3.2B

Ongoing Kharland Schemes in Maharashtra

Sr. No.	Name of Scheme	District	Cost		Reclaimed Area (ha)	Expenditure upto end of March 2015 (Rs in Lakhs)
			Total cost (Rs in Lakhs)	Work Cost (Rs lakhs)		
1	2		3	4		5
1	Vehale pimplas	Thane	282.01	224.71	455.00	251.22
2	Bharodi	Thane	208.66	166.27	225.00	42.59
3	Chikhalpada	Thane	101.90	92.64	20.00	85.29
4	Kalsuri Turumwadi	Raigad	81.73	65.51	45.00	23.64
5	Varathi Chimbav Bebelghar	Raigad	131.03	119.12	93.00	27.33
6	Jambhuwadi	Ratnagiri	92.93	74.06	84.00	51.14
7	Shirgaon	Ratnagiri	64.38	51.37	74.00	49.60
8	Vagholi	Ratnagiri	103.03	82.11	35.60	69.88
9	Juve Jaitapur	Ratnagiri	188.81	150.50	168.00	183.68
10	Dale Jaitapur	Ratnagiri	118.01	94.07	54.00	84.72
11	Mirvane	Ratnagiri	67.75	54.20	69.00	0.05
12	Manjare	Ratnagiri	126.62	115.11	80.00	82.99
13	Devud - A	Ratnagiri	48.68	44.25	25.00	47.57
14	Kumbhavade	Ratnagiri	88.60	80.54	47.00	20.83
15	Shirvane Dabhil	Ratnagiri	43.52	39.57	23.00	29.25
16	Padave Banewadi	Ratnagiri	19.68	19.68	11.00	0.00
17	Ganapati Pule	Ratnagiri	23.90	23.90	12.37	0.00
18	Shirgaon Shetewadi	Ratnagiri	22.73	22.73	12.27	0.00
19	Villey Kondwadi	Ratnagiri	29.51	26.83	16.00	0.00
20	Mondpar	Sindhudurg	156.46	142.24	88.00	77.77
21	Belavle Jamsande	Sindhudurg	109.85	99.87	59.00	50.95
22	Kanyalwadi	Sindhudurg	37.17	33.79	20.00	22.15
23	Kelus Dimwadi	Sindhudurg	88.71	80.65	62.00	72.65
24	Tembivali Kalviwadi	Sindhudurg	23.52	23.52	18.00	3.62
	Total		**2259.19**	**1927.24**	**1796.24**	**1276.92**

Annexure 3.3A

Design considerations of SWED

- The height of dam (storage) is fixed considering the high flood level and high tide level (HTL). Top level of dam is fixed at a height of 0.30 m above HTL.
- The soil met with usually being sandy in coastal regions, the foundations are designed based on Khosla's theory of design of weirs on permeable foundations. The total length of upstream and downstream aprons provided will be 8 to 10 times the gross head on the structure, so that exit gradient shall be well within the critical gradient.
- Cut of walls are provided up to the hard strata or impervious strata as per scour depth calculations. The minimum depth of upstream cut off wall is the difference between the HTL and the lowest nala bed level.
- The downstream cement concrete apron is provided at about 0.60 to 0.90 m below stream bed level with toe walls for effective dissipation of energy.
- One meter thick clay puddle filling will be provided in front of cut off walls to arrest seepage.
- RCC Piers are provided at 2m interval. They are provided with grooves to facilitate fixing of wooden shutters for storage of water. Foot slab is generally provided over Piers for the operation of shutters.
- For R.C.C.works sulphate resistant cement should be used as per I.S. Specifications.
- Fibre glass shutter is recommended for gates instead of steel or wood shutters.

Annexure 3.3B

Details of Existing Salt Water Exclusion Dam Works in Karnataka

Sl.N	District	Taluk	Name of work	Year of Construction	Cost of Construction (Rs in lakhs)	Areabenefitted (Ha.)
1	2	3		5	6	7
1	DK	Mangalore	Pavanve in Cheliyar village	1965-66	Since these dams are very old, the cost details are not available.	89.07
2	DK	Mangalore	Manampadi in Hejamadi village	1961-62		104.00
3	DK	Mangalore	Nanthodi in Bangrakuloor village	1967-68		86.64
4	DK	Mangalore	Ullalabailu in Ullala village	1969-70		50.32
5	DK	Mangalore	Chithrapu	1968-69		44.55
6	DK	Mangalore	Kolachekambla	1962-63		80.94
7	DK	Mangalore	Hoigegudda in Padupanambur	1969-70		55.00
8	DK	Mangalore	Adyapadi	2004-05	400.00	660.00
9	DK	Mangalore	Chelyaru	2006-07	179.55	141.64
10	DK	Mangalore	Aranda Aggadakaliya	2007-08	49.50	53.34
11	DK	Mangalore	Bandasale in bappanadu village	2008-09	30.00	42.50
12	DK	Mangalore	Uppudakatta in Chelyaru village	2009-10	30.00	44.53
13	DK	Mangalore	Angadithota in Athikaribettu village	2012-13	49.00	30.00
14	DK	Mangalore	Gajani in Chitrapu village	2012-13	49.00	35.00
15	DK	Mangalore	Golidadi in Pavanje village	2012-13	45.00	35.00
16	DK	Mangalore	Shedikatta in Chithrapu village	2012-13	48.00	35.00
17	DK	Mangalore	Babbarsegundi in Athikaribettu village	2012-13	48.00	20.00
18	DK	Mangalore	Koppala byakarukodi in Karnire village	2012-13	30.00	20.00
				Total	**958.05**	**1,627.53**
1	Udupi	Udupi	Palimaru	1956-57	Since these dams are very old, the cost details are not available.	291.60
2	Udupi	Udupi	Aroor	1956-57		186.80
3	Udupi	Udupi	Manipurakatta	1962-23		201.20
4	Udupi	Udupi	Kalmadi bobbaryakatte	2011-12	223.10	60.00
5	Udupi	Udupi	Nadsalu in Paduvari village	1967-68	Since these dams are very old, the cost details are not available.	102.00
6	Udupi	Udupi	Avaralumattu	1967-68		89.93
7	Udupi	Udupi	Kurkal	1978-79		239.00
8	Udupi	Udupi	Bolja	1987-88	16.88	70.20
9	Udupi	Udupi	Kalmadi in Kodavoor village	1998-99	101.00	72.53
10	Udupi	Udupi	Bannadi	1996-97	55.00	161.00
11	Udupi	Udupi	Udyavara(Ankundru)	1992-93	3.90	89.00
12	Udupi	Udupi	Neelavara	2001-02	249.00	340.20
13	Udupi	Udupi	Balatta Katapadi	2004-05	9.00	52.25
14	Udupi	Udupi	Nagaramata in Hosala village	2004-05	55.00	87.00
15	Udupi	Udupi	Padubaikadi in Haradi village	2005-06	14.00	40.48
16	Udupi	Udupi	Harpinabailu in Parampalli village	2005-06	18.00	40.46
17	Udupi	Udupi	Sasithota in Kutpadi village	2005-06	30.00	41.70
18	Udupi	Udupi	Manoor in Kota village	2005-06	20.00	40.00
19	Udupi	Udupi	Kambalagaddejaddu in Manoor village	2006-07	28.00	74.00
20	Udupi	Udupi	Kemthoor in Kemthoor village	2008-09	104.26	101.00
21	Udupi	Udupi	Kumerigudda in haradi village	2009-10	12.63	40.00
22	Udupi	Udupi	Maddalkatta in Marne village	2008-09	40.00	42.50
23	Udupi	Udupi	Koukrani in Hejamadi village	2009-10	44.67	41.00
24	Udupi	Udupi	Uggelbettu in Aroor village	2011-12	140.64	50.00
25	Udupi	Udupi	Nadiyooru in Palimaru village	2010-11	32.82	41.00
26	Udupi	Udupi	Sampigenagara in Udyavara village	2012-13	42.46	10.00
27	Udupi	Udupi	Suvarna river in Bellamballi village	2012-13	56.73	12.00
28	Udupi	Udupi	majalubail Sasithota seaview resort in Kadekaru village	2011-12	34.60	25.00

29	Udupi	Udupi	Kidiyoor Ambalapadi	2008-09	137.41	85.00
30	Udupi	Udupi	Padu avaralmattu in Hejamadi village	2012-13	23.13	10.00
31	Udupi	Udupi	Kalthatta in Moodabettu village	2011-12	49.50	15.00
32	Udupi	Udupi	Chennangadi in Kodavoor Village	2012-13	40.97	16.00
33	Udupi	Udupi	Abbanna Kudru in Nayyamballi	2012-13	114.45	28.00
34	Udupi	Udupi	Peli luis in Padubaikadi village	2012-13	30.74	13.00
35	Udupi	Kundapura	Kambadakone	1963-64	Since these dams are very old, the cost details are not available.	97.46
36	Udupi	Kundapura	Sankadabagilu in Yadtare village	1969-70		46.58
37	Udupi	Kundapura	Bijooru	1982-83		50.63
38	Udupi	Kundapura	Kattebelthuru	2005-06	480.00	635.00
39	Udupi	Kundapura	Senapura	2005-06	450.00	495.00
40	Udupi	Kundapura	Yedamavinahole	2006-07	175.00	337.00
41	Udupi	Kundapura	Surendrapatila in Uppinakudru	2009-10	57.20	41.00
42	Udupi	Kundapura	Frank Demellow in Beejadi village	2010-11	19.38	25.00
43	Udupi	Kundapura	Komayya in Tekkatte village	2009-10	15.91	32.38
44	Udupi	Kundapura	Marror in Koni village	2010-11	34.70	41.00
				Total	**2,960.08**	**4,609.90**
1	U.K	Ankola	Aversa Kharland Scheme	As these dams are very old the details regarding year of construction & cost are not available.		66.00
2	U.K	Ankola	Bhavikeri Kharland Scheme			77.00
3	U.K	Ankola	Shiroor Chandmath Kharland Scheme			122.00
4	U.K	Ankola	Belegonge Kharland Scheme			153.00
5	U.K	Ankola	Nadumastikeri Kharland Scheme			180.00
6	U.K	Ankola	Babruwada Kharland Scheme			49.00
7	U.K	Ankola	Hitckad Kharland Scheme			42.00
8	U.K	Ankola	Amberagi Kharland Scheme	2009-10	30.00	40.46
9	U.K	Ankola	Chandumath at Belase tank Kharland Scheme in	2011-12	50.00	71.00
10	U.K	Ankola	Vasarkudrage Kharland Scheme	2011-12	50.00	49.00
11	U.K	Ankola	Bilihonge Kharland Scheme	2011-12	50.00	61.00
12	U.K	Ankola	Juga Kharland Scheme	2011-12	50.00	45.00
13	U.K	Ankola	Construction of kharland across karehalla near Karebail	2012-13	50.00	50.00
14	U.K	Ankola	Costruction of Kharland Scheme (SWED) Chandumath near Belse Tank in	As these dams are very old the details regarding year of construction & cost are not available.		
15	U.K	Bhatkal	Sharadahole (Belke) Kharland Scheme		9.15	50.00
16	U.K	Bhatkal	Hebale Kharland Scheme		7.71	352.00
17	U.K	Bhatkal	Chatrakurve Kharland Scheme		45.00	121.00
18	U.K	Bhatkal	Mankangundi Kharland Scheme		30.00	16.19
19	U.K	Bhatkal	Ullan Tannir katte Kharland Scheme	2011-12	50.00	23.00
20	U.K	Bhatkal	Construction of Kharland near Belke pinnupal		50.00	41.00
21	U.K	Bhatkal	Costruction of Kharland Scheme in Kundarebirappa Benli)	As these dams are very old the details regarding year of construction & cost are not available.		
22	U.K	Honnavar	Haldipur Kharland Scheme			220.00
23	U.K	Honnavar	Navilgon to Holangodde Kharland Scheme			308.00
24	U.K	Honnavar	Constn. of Kharland near Kasarkod bridge across Sharaviti revir este side of L.Bank	2011-12	40.00	30.00
25	U.K	Honnavar	Constn. of Kharland near Kasarkod bridge across Sharaviti revir este side of R.Bank	2011-12	45.00	20.23
26	U.K	Honnavar	Constn. of Kharland near Haldipur Tarebagil	2011-12	30.00	41.00
27	U.K	Honnavar	Construction of kharland from Haldipur Horbhag to Irappan Hittalu	2012-13	25.00	40.47
28	U.K	Honnavar	Manki KLS	As these dams are very old the details regarding year of construction & cost are not available.		120.00
29	U.K	Honnavar	Mavinkurve K.L.S			61.50
30	U.K	Honnavar	Balkur-Idagunji K.L.S			148.00
31	U.K	Honnavar	Berolli K.L.S			154.00
32	U.K	Honnavar	Costruction of Kharland Scheme to Yalamakki Halla in Manki Panchayat			
33	U.K	Karwar	Ghadasai Kharland Scheme	1986	7.00	304.00
34	U.K	Karwar	Kinner Kharland Scheme	1970	7.16	307.00
35	U.K	Karwar	Mavinhalla Kharland Scheme	1970	3.82	256.00
36	U.K	Karwar	Sunkeri Kharland Scheme	1964	6.80	304.00
37	U.K	Karwar	Honkon Hotegali Kharland Scheme	1991	8.43	250.00

38	U.K	Karwar	Honkon Hotegali Kharland Scheme	1971	5.93	250.00
39	U.K	Karwar	Chittakul Kanasageri (Extn) Kharland Scheme	2012-13	50.00	134.00
40	U.K	Karwar	Amadalli Kharland Scheme	2012-13	50.00	179.00
41	U.K	Karwar	Mavinhalla Kharland Scheme	As these dams are very old the details regarding year of construction & cost are not available.		250.00
42	U.K	Karwar	Nakadmulla Kharland Scheme	2005-06	10.00	218.22
43	U.K	Karwar	Benge-Bogri K.L.S	2007-08	27.00	47.00
44	U.K	Karwar	Reconstruction of Kinnar KLS	2011-12	90.00	299.00
45	U.K	Karwar	ReConstruction of Kharland & Sluice from Sadashivagad to devabhag bridge (near Mannewad urdu school)	2012-13	50.00	80.94
46	U.K	Karwar	Construction of Hotegali kharland	2012-13	50.00	95.00
47	U.K	Karwar	Construction of kharaland at Mavin halla (Sadashivgad) chittakul gram panchayat	2012-13	50.00	80.84
48	U.K	Kumta	Betkuli Bargi Kharland Scheme	1983	16.69	324.00
49	U.K	Kumta	betkuli Bargi (Extn) Kharland Scheme	As these dams are very old the details regarding year of construction & cost are not available.	23.79	284.00
50	U.K	Kumta	Hosakatta Kharland Scheme	1974	20.34	1113.00
51	U.K	Kumta	Manikatta Kharland Scheme	1974	7.50	351.00
52	U.K	Kumta	Kalbhag Major Kharland Scheme	As these dams are very old the details regarding year of construction & cost are not available.		123.00
53	U.K	Kumta	Kalbhag Major Kharland Scheme			90.00
54	U.K	Kumta	Baggon Kharland Scheme			53.00
55	U.K	Kumta	Bandekatta Kharland Scheme			120.00
56	U.K	Kumta	Kalkatta Kharland Scheme			81.00
57	U.K	Kumta	Manikatta Kharland Scheme			59.00
58	U.K	Kumta	Hagde Kharland Scheme			154.00
59	U.K	Kumta	Kagal Kharland Scheme			95.00
60	U.K	Kumta	Kodkani Kharland Scheme			118.00
61	U.K	Kumta	Masarkurve Kharland Scheme			117.00
62	U.K	Kumta	Torke Kharland Scheme			53.00
63	U.K	Kumta	Hegde Naribole KLS	2009-10	50.00	30.00
64	U.K	Kumta	Construction of KLS at Salukatta	2011-12	26.00	81.00
65	U.K	Kumta	Construction of KLS at Ghazni	2011-12	20.00	101.00
66	U.K	Kumta	Manikatta Ghazani Kharland Scheme	2011-12	35.00	51.00
67	U.K	Kumta	Construction of kharland at Hegde masarkurve gazani	2012-13	35.00	28.00
68	U.K	Kumta	Bargi Panchayat Kimmani Ghazani Kharland Scheme	2012-13	35.00	41.00
69	U.K	Kumta	Kyakankodi Jantradi Kharland Scheme	2011-12	35.00	25.00
70	U.K	Kumta	Kodkani Aramanekoppa Kharland Scheme	2011-12	35.00	49.00
71	U.K	Kumta	Construction of Kharland at hittal makki mulekeri	2012-13	25.00	36.42
72	U.K	Kumta	Construction of kharland from house of hini harikartavadi lakxmi harikantra to house of Govind harikantra	2012-13	25.00	40.47
73	U.K	Kumta	Construction of Mirjan Taribagilu kharland	2012-13	35.00	25.00
74	U.K	Kumta	Construction of kharaland across Mudangi Aganashini hole	2012-13	30.00	24.28
75	U.K	Kumta	Construction of Alve kodi Gazani kharland	2012-13	35.00	53.00
76	U.K	Kumta	Construction of mirjan kalmatte kharland	2012-13	30.00	31.00
77	U.K	Kumta	Construction of Jantradi at near Karki kodi gazani	2012-13	35.00	41.00
78	U.K	Kumta	Costruction of Kharland Scheme from Betkuli Azizaumar land to Ganpati Shivu patgar land	As these dams are very old the details regarding year of construction & cost are not available.		
79	U.K	Kumta	Costruction of Kharland Scheme from Gangekolla kattin bogari			
80	U.K	Kumta	Costruction of Kharland Scheme (SWED) Lukkeri (Manikatta) Halla			
81	U.K	Kumta	Costruction of Kharland Scheme Hosakatta			
		Total			**1582.32**	**9599.02**

Annexure 3.4A

Details of district wise remedial measures taken up in Kerala

Sl No	District	Project	Place	Remarks
1	Thiruvanathapuram	salinity intrusion barrier	on river Vamanapuram in Parakadavu	
2	Thiruvanathapuram	Permanent VCB (Vented cross bar)	u/s of river on Kannukalichal	Feeder of all Vellayani Padashekarams
3	Kollam	Paravur-Pozhikkara regulator		
4	Kollam	Temporary bund	Velayiparambu	
5	Kollam	Temporary bund	Vettiyathodu	
6	Kollam	Temporary bund	Mukkannikkara	
7	Kollam	Temporary bund	Kizhakkumbhagam	
8	Kollam	Regulator Cum Bridge	Moozhy in East Kallada	
9	Alapuzha	Thaneermukkom bund		
10	Alapuzha	Thottapally regulators		
11	Alapuzha	Temporary Bund	Pulikeezhu, north of Pulikeezhu bridge	
12	Alapuzha	Large no of temporary bunds constructed every year		
13	Kottayam	Large no of temporary bunds constructed every year	In panchayats T.V.Puram, Thalayazham, Kallara, Udayanapuram and Thalayolaparambu	No Major Structures Constructed
14	Ernakulam	Lock-Cum-Regulator	Pathalam	
15	Ernakulam	Lock–Cum Regulator	Anjimmal	
16	Ernakulam	Temporary tidal bunds	Across Kadamprayar temporary thodu (72m), Challanam bund (55 m, 2 no)	
17	Thrissur	Lock-Cum-Regulator	Orumanayoor	
18	Thrissur	Many Temporary Bunds		
19	Malapurram	73 No of Salt Water Exclusion Structure (SWES) and Salt water Exclusion Vented Cross Bar (SWEVCB)		Major ones are Kavannakallu, Biyyam and Chamravattom
20	Kozhikkode	Salt Water Exclusion Works	Kallai river at Kunnathupalam	
21	Kozhikkode	Salt Water Exclusion Vented Cross Bar	Cherukulam	
22	Kannur	Regulator Cum Bridge	Kattampally	
23	Kannur	Regulator Cum Bridge	Cherupuzha	
24	Kasargode	Uppala Anicut	Upala River	
25	Kasargode	Bambrana Anicut	Shiriya River	
26	Kasargode	Salt Water Exclusion cum bridge	Kottkunje across Morgal River	
27	Kasargode	Chithari Regulator Cum Bridge	Chithari River	
28	Kasargode	Nambiarkkal anicut	Nileshwaram River	
29	Kasargode	Thalachal anicut	Kavvai River	

Annexure 3.5A

Details of Recharge Wells constructed in Tamilnadu

S.No	Name of Work	Sub- Basin	No. of ARS	Tank Name	Expenditure (Rs.)
1	Construction of Artificial Recharge Well Structures in Nallavur Sub basin (4 tanks - Nallavur, Kiliyanur, T.Parangani, Ulagapuram in Villupuram District)	Nallavur	4	Nallavur	4351453
				Kiliyanur	4322702
				T.Parangani	4476773
				Ulagapuram	4472900
2	Construction of Artificial Recharge Well Structures in Gomukhi Sub basin (3 tanks - Nagalur, Ogaiyur, Kurur in Villupuram District)	Gomukhi	3	Nagalur	4233098
				Ogaiyur	4237007
				Kurur	4582138
3	Construction of Artificial Recharge Well Structures in VarahanadhiSub basin (6 tanks -Adanur, S.Kunnathur, Melkaranai, Sathyamangalam, Valathi, Semmedu in Villupuram District)	Varahanadhi	6	Adanur	4105532
				S.Kunnathur	4092711
				Melkaranai	4090276
				Sathyamangalam	4184651
				Valathi	4242048
				Semmedu	4275903
4	Construction of Artificial Recharge Well Structures in Cheyyar - Kiliyar Sub basin (6 tanks - Thirupanamur,Namandi,Perungattur, in Thiruvannamalai district and Perunagar,Visoor,Serpakkam, in Kancheepuram District)	Cheyyar - Kiliyar - Thiruvann	3	Thirupanamur	4336947
				Namandi	4349919
				Perungattur	4371293
		Cheyyar - Kiliyar - Kancheep	3	Perunagar	4518206
				Visoor	4325861
				Serpakkam	4389123
5	Construction of Artificial Recharge Well Structures in Koundanyanadhi Sub -Basin (2 tanks - Katpadi,	Koundanyanadhi	2	Katpadi	4626011
				Karigiri	4645266
6	Construction of Artificial Recharge Well Structures in kosathalayar Sub - Basin (5 tanks - Bagavaeli,Maruderi, Sumaithangi,Valluvambakkam,Nagaleri in Vellore district)	Kosathalayar	5	Bagaveli	4713722
				Marudheri	4754868
				Sumaithangi	4912615
				Valluvambakkam	4515078
				Nagaleri	4568809
7	Construction of Artificial Recharge Well Structures in ThurinjalarSub - Basin (7 tanks - Aradapattu,Su.Andapattu, Pavithram,Mallavadi,Mathulambadi, Nookambadi,Somasipadi in Thiruvannamalai district)	Thurinjalar	7	Aradapattu	4947097
				Su.Andapattu	4947097
				Pavithram	4947097
				Mallavadi	5005047
				Mathulambadi	4965458
				Nookambadi	4950472
				Somasipadi	4954053
8	Construction of Artificial Recharge Well Structures in Upper Vellar Sub	Upper	11	Puthiragoundampal	4658673
				Erammasamudhira	4863404

	-Basin (11 tanks - Puthiragoundampalayam,Erammasa muthiram,Chinnamasamuthiram,Sar voy,Deviyakurichi, Thalaivasal, Puthur,Thiyaganur,Aragalur,Periyeri, Sitteri in Salem District)	Vellar		Chinnasamuthiram	4863275
				Sarvoy	4630161
				Deviyakuruchi	4879429
				Thalaivasal	4898154
				Puthur	4639108
				Thiyaganur	4667837
				Aragalur	4661700
				Periyeri	4905318
				Sitteri	4640812
9	Construction of Artificial Recharge Well Structures in South Vellar Sub - Basin (3 tanks - Valanadu, Pannai Periyakulam, Nellikulam, in Trichy	South vellar	3	Valanadu	4669092
				Pannai Periyakulam	4700753
				Nellikulam	4691085
10	Construction of Artificial Recharge Well Structures in Chinnar Sub - Basin (3 tanks - Annamangalam, Keelapuliyur, Elumoor in	Chinnar	3	Annamangalam	4884494
				Keelapuliyur	4878550
				Elumoor	4888191
11	Construction of Artificial Recharge Well Structures in Coouam Sub basin (4 tanks - Coouam Tank, Kadambattur Tank, Kesavanallathur Tank and Satharai tank of Thiruvallur District)	Coouam	7	Coovam	3336660
				Kadambattur	3336042
				Kesavanallathur	1664640
				Satharai	3339175
		Total	**57**		**242107780**

Annexure 3.5 B

Recharge Structures constructed under MPRAS Scheme in Tamilnadu from 2008-15

S.No	District	Check Dam	Recharge Shaft	Sub Surface Dyke	Percolation Pond	Bed dam	Weir	Diaphragm Wall	Gully Plugging	Contour Bund	Nulla Bunds	Village Pond/Village Tank	Farm Pond	Total
1	Ariyalur	51	5	-	-	-	-	-	-	-	-	2	146	204
2	Coimbatore	153	49	-	46	-	-	-	-	-	-	34	24	306
3	Cuddalore	317	21	-	15	-	-	-	-	-	-	7	108	468
4	Dharmapuri	284	17	-	47	-	-	-	-	-	-	36	15	399
5	Dindugal	626	1	-	39	-	-	-	1	-	-	3	40	710
6	Erode	137	-	-	39	-	-	-	-	-	-	0	46	222
7	Kanchipuram	109	241	-	34	-	-	-	-	-	-	62	8	454
8	Kanyakumari	67	-	-	-	-	-	-	-	-	-	-	-	67
9	Karur	144	-	-	12	-	-	-	-	-	-	31	346	533
10	Krishnagiri	254	2	-	57	-	-	-	37	-	-	62	33	445
11	Madurai	279	33	-	5	1	-	-	-	-	-	9	24	351
12	Nagappattinam	52	28	-	-	1	-	-	-	-	-	23	147	251
13	Namakkal	268	64	-	38	-	-	-	-	-	-	8	162	540
14	Nilgiris	59	-	-	-	-	-	-	-	-	-	-	-	59
15	Perambalur	116	-	-	-	-	-	-	-	-	-	-	70	186
16	Pudukkottai	119	11	-	2	-	-	-	-	-	-	6	141	279
17	Ramnad	19	-	-	1	-	-	-	-	-	-	3	189	212
18	Salem	275	5	-	47	-	-	-	-	-	-	10	24	361
19	Sivagangai	21	132	-	-	-	-	-	-	-	-	1	89	243
20	Thanjavur	38	172	-	-	-	-	-	-	-	-	10	343	563
21	Theni	573	7	-	25	-	-	-	-	6	8	10	19	648
22	Thiruvallur	136	26	-	12	-	1	-	-	-	-	38	29	242
23	Thiruvannamalai	495	116	7	9	-	-	-	-	-	-	25	125	777
24	Thiruvarur'	44	10	-	-	4	-	-	-	-	-	21	677	756
25	Thoothukkudi	239	10	-	18	-	-	-	-	-	-	6	19	292
26	Tiruchy	181	8	-	28	-	-	-	-	-	-	17	238	472
27	Tirunelveli	276	63	-	13	-	-	-	-	-	-	18	101	471
28	Tiruppur	76	25	-	29	-	-	-	-	-	-	1	11	142
29	Vellore	337	185	-	50	-	-	2	-	-	-	40	133	747
30	Villupuram	236	116	-	66	-	-	-	-	-	-	35	151	604
31	Virudunagar	329	55	-	6	-	-	-	-	-	-	14	31	435
	TOTAL	**6310**	**1402**	**7**	**638**	**6**	**1**	**2**	**38**	**6**	**8**	**532**	**3489**	**12439**

Annexure 3.7A

Details of completed schemes in Odisha

Sl no	Name of project	Name of drain	District	Project cost (Rs lakhs)	Area Irrigated in Ha
1	Excavation of creek & Sub creek for arresting alinity and ground water recharge in part of Aul Block in Kendrapara District Package No I,II, III	Sunamuhi areikana, Chunabandha, Anuko to Aul. Bada Anko to Alka, Anko to Gopinathpur Anko Koladiha, Brahmanijodi, Kaladia	Kendrapara	923.33	3500
2	Renovation to creek Irrigation project of Rajjkanika Block	Bagi nallaha, Pettanalha, Similimahara, Ujanga Mahara, Mirzapur nallaha, Kathapainallaha, Gopalpurnallaha	Kendrapara	545.22	1790
3	Providing Harishpur creek Irrigation project in Rajnagar block package No I,II	Mahulia to Harishpur	Kendrapara	253.64	924
4	Providing creek Irrigation and recharging ground water through kuhali boupokhori nallah, Kalidaspur Gadala Nallah, Para creek, Gomei creek, Napata nallah, Chhatara to Ricket Channel and Balinagar creek	Kuhali boupokhori nallah, kalidaspur gadala mnallah, para creek, gomei creek, napata nallah, Chhatara to Ricket Channel and Balinagar Creek	Bhadrak	150.54	1800
5	Providing creek irrigation and recharging ground water through Anadola Jore (Main) and Sub Creeks, Naya Kanidhi Jore, Purusottam Pur Jore, Kashipur Nallah, Karanjadia creek, Balarampur nallah, Gaham nallah and Rahimpur sub-creek	Anadola Jore (main) and sub creeks, naya kanidhi Jore, Purusottam Pur Jore, Kasipur Nallah, Karanjadia creek, Balarampur nallah, Gaham Nallah and Rashimpur Sub-Creek	Bhadrak	151.35	1240
6	Providing Creek Irrigation and recharging ground water through baliapada creek, narahari creek, kasimila nallah, bideipur nallah, godi creek, anandapur creek, shasiskadeipur creek, tentuliadia sub-creek and karanapali nallah	Baliapada creek, narahari creek, kasimila nallah, bideipur nallah, godi creek, anandapur creek, shasiskadeipur creek, tentulidia sub creek and karanapali nallah	Bhadrak	184.29	2460
7	Renovation of Kani drain along with link drain under AIBP	Kani	Bhadrak	62.88	400
8	Renovation of Salia jore falling to river salandi in Chandabali block under AIBP	Salia	Bhadrak	43.77	500
9	Renovation of Natiajore Creek Irrigation Project in Chandabali Block of Bhadrak District under NABARD Assistance (RIDF-XV)	Natiajore	Bhadrak	349.5	2500
10	Renovation of Basant creek irrigation project	Baruan	Jagatsinghpur	200	500
11	Renovation of Kathagadi creek irrigation project	Baruan	Jagatsinghpur	300	1000
12	Japa Creek Irrigation Project	Tigiria	Jagatsinghpur	100	1255
13	Pachera Creek Irrigation Project	Basulei Nai	Jagatsinghpur	105	1245
14	Nagarighat Creek Irrigation Project	Saunlia	Jagatsinghpur	175.2	1950
15	Guneimuhan Creek Irrigation Project	Alaka	Jagatsinghpur	131.61	1800
16	Haladi Pani Creek Irrigation Project	Mahanga	Jagatsinghpur	103	1145
17	Bagadi Creek Irrigation Project	Sankha	Jagatsinghpur	95	1040
18	Construction of Instream structure near village Sribantapur over Sribantapur Nallah	Sribantapur Nallah	Puri	8	18
19	Construction of Instream structure near village Nanapur over Kopajore Nallah	Kopajore Nallah	Puri	19	15
20	Construction of Instream structure near village Birabaranpada over Maliatutha Nallah	Maliatutha Nallah	Puri	12.8	20
21	Talsuan Creek	Kadua	Puri	22.5	250
22	Tikerpara Creek	Kadua	Puri	190	1050

Annexure 3.7B

Details of on-going schemes in Odisha

Sl no	Name of project	Name of drain	District	Project cost (Rs lakhs)	Area Irrigated in Ha
1	Creek Irrigation to Aul Block and construction of sluice on K.K right embankment	Sahupada, Atala, Kundakhia, Gopalpur to bank, Arjunpur, Digochhia, Saliancha to Mahasahani, Digochhia to Mahasani, Panchanapada to Mahadipata etc	Kendrapara	726.51	3500
2	Akhadasahi Creek Irrigation Project in Mahakalapada Block	Akhadasahi Creek	Kendrapara	565	2500
3	Creek Irrigation for Dasamouzi Island (Karamkul to Patparia) construction of inlet sluice at Ashramabalikuda	Nuna	kendrapara	86.37	750
4	Weikhia Creek Irrigation Project	Weikhia	Khruda & Puri	1415.37	1700
5	Kathilagotha Creek Irrigation Project	Kathilagotha	Jagatsinghpur	360.75	1070
6	Patua Creek Irrigation Project	Sankha	Puri	1250	2050
7	Construction of Check Dam-Cum-VRB on Drain No.II near village Hansapada	D.C.No 11	Puri	38.37	20
8	Khadanga jore Irrigation Project with sluice under NABARD Assistance (RIDF-XIX)	Khadanga	Bhadrak	284.86	4260

Annexure -4.1A

Works proposed in Kachchh region of Gujarat

Taluka Wise List					
Sr. No.	**Name of Work**	**Nos.**	**District/Taluka**	**Estimated Amount (Rs. Lakh)**	**Proposed Benefited Area(Ha)**
1	**2**		**3**	**4**	**5**
	Bandharas				
1	Jodhapur Wandh	1	Rapar	1760	650
2	Palasava (Gaun)	1	Rapar	1230	600
3	Moti Rav	1	Rapar	718	480
4	Bela - Mauvana Bandhara	1	Rapar	1450	550
	Total	**4**		**5158**	**2280**
5	Amarapar Bandhara	1	Bhachau	1600	450
6	Bambhanaka Bandhara	1	Bhachau	450	150
7	Dholavira(Rankandhi) Bandhara	1	Bhachau	3024	500
	Total	**3**		**5074**	**1100**
8	Vang - Dador	1	Nakhatrana	923	450
	Total	**1**		**923**	**450**
9	Kadhwandh	1	Bhuj	564	450
10	Nana Dinara Bandhara	1	Bhuj	720	550
11	Mota Dinara Bandhara	1	Bhuj	830	600
12	Kuran Bandhara	1	Bhuj	725	560
		4		**2839**	**2160**
8	Gugariyana Bandhara	1	Lakhapat	1200	650
	Total	**1**		**1200**	**650**
	Total	**13**		**15194**	**6640**

Taluka Wise List					
Sr. No.	**Name of Work**	**Nos.**	**District/Taluka**	**Estimated Amount (Rs. Lakh)**	**Proposed Benefited Area(Ha)**
1	**2**		**3**	**4**	**5**
	Small Checkdam				
1	Pkg No- 1	54	Rapar	372.75	270.00
2	Pkg No- 2	50	Rapar	344.00	250.00
3	Pkg No- 3	25	Rapar	227.92	125.00
4	Pkg No- 4	61	Rapar	478.50	365.00
5	Pkg No- 5	40	Rapar	320.00	240.00
6	Pkg No- 6	51	Rapar	515.13	263.00
7	Pkg No- 7	48	Rapar	432.00	288.00
	Total	**329**		**2690.30**	**1801.00**
1	Pkg No- 8	40	Bhachau	956.96	585.00

2	Pkg No- 9	45	Bhachau	387.00	247.50
3	Pkg No- 10	40	Bhachau	344.00	220.00
4	Pkg No- 11	45	Bhachau	387.00	247.50
	Total	**170**		**2074.96**	**1300**
1	Pkg No- 12	17	Bhuj	360.18	130.00
2	Pkg No- 13	11	Bhuj	100.00	100.00
3	Pkg No- 14	25	Bhuj	105.00	100.00
4	Pkg No- 15	20	Bhuj	95.00	80.00
5	Pkg No- 16	40	Bhuj	705.00	350.00
6	Pkg No- 17	50	Bhuj	750.00	375.00
7	Pkg No- 18	50	Bhuj	425.00	275.00
8	Pkg No- 19	60	Bhuj	510.00	330.00
	Total	**273**		**3050.18**	**1740**
1	Pkg No- 20	10	Mundra	85.00	55.00
2	Pkg No- 21	15	Mundra	127.50	82.50
3	Pkg No- 22	15	Mundra	127.50	82.50
4	Pkg No- 23	16	Mundra	136.00	88.00
5	Pkg No- 24	10	Mundra	85.00	55.00
6	Pkg No- 25	10	Mundra	85.00	55.00
	Total	**76**		**646**	**418**
1	Pkg No- 26	22	Anjar	189.20	121.00
2	Pkg No- 27	25	Anjar	215.00	137.50
3	Pkg No- 28	30	Anjar	258.00	165.00
4	Pkg No- 29	25	Anjar	215.00	137.50
	Total	**102**		**877.2**	**561**
1	Pkg No- 30	35	Nakhatrana	301.00	192.50
2	Pkg No- 31	40	Nakhatrana	344.00	220.00
3	Pkg No- 32	45	Nakhatrana	387.00	247.50
4	Pkg No- 33	35	Nakhatrana	301.00	192.50
5	Pkg No- 34	50	Nakhatrana	430.00	275.00
6	Pkg No- 35	55	Nakhatrana	473.00	302.50
7	Pkg No- 36	44	Nakhatrana	378.40	242.00
	Total	**304**		**2614.40**	**1672.00**
1	Pkg No- 37	45	Abdasa	387.00	247.50
2	Pkg No- 38	40	Abdasa	344.00	220.00
3	Pkg No- 39	45	Abdasa	387.00	247.50
4	Pkg No- 40	50	Abdasa	430.00	275.00
5	Pkg No- 41	60	Abdasa	516.00	330.00
6	Pkg No- 42	60	Abdasa	516.00	330.00
	Total	**300**		**2580**	**1650**
1	Pkg No- 43	25	Mandavi	215.00	137.50
2	Pkg No- 44	30	Mandavi	258.00	165.00
3	Pkg No- 45	32	Mandavi	275.20	176.00
4	Pkg No- 46	35	Mandavi	301.00	192.50
5	Pkg No- 47	34	Mandavi	292.40	187.00
	Total	**156**		**1341.6**	**858.0**

1	Pkg No- 48	50	Lakhapat	430.00	275.00
2	Pkg No- 49	45	Lakhapat	387.00	247.50
3	Pkg No- 50	50	Lakhapat	430.00	275.00
4	Pkg No- 51	45	Lakhapat	387.00	247.50
5	Pkg No- 52	45	Lakhapat	387.00	247.50
6	Pkg No- 53	55	Lakhapat	473.00	302.50
	Total	**290**		**2021.00**	**1292.50**
	Total	**2000**		**17895.64**	**11292.50**

Sr. no.	Name of Work	District/ Taluka	Estimated cost (Rs. in lac)	Benefited area (in Ha)
1	2	3	4	5
	Big Checkdam			
1	Vamoti-1	Abdasa	55.00	40.00
2	Vamoti-2	Abdasa	65.00	45.00
3	Vamoti-3	Abdasa	50.00	35.00
4	Vamoti-4	Abdasa	50.00	35.00
5	Vamoti-5	Abdasa	75.00	55.00
6	Vamoti-6	Abdasa	45.00	30.00
7	Vamoti-7	Abdasa	60.00	40.00
8	Vamoti-8	Abdasa	60.00	40.00
9	Vamoti-9	Abdasa	60.00	40.00
10	Sudhdhro	Abdasa	55.00	38.00
11	Balachor Nani	Abdasa	60.00	42.00
12	Lathedi-2	Abdasa	90.00	70.00
13	Lathedi-3	Abdasa	80.00	60.00
14	Naranpar-1	Abdasa	85.00	63.00
15	Bhanada-1	Abdasa	60.00	40.00
16	Tera	Abdasa	70.00	30.00
17	Butta	Abdasa	80.00	60.00
18	Lakhaniya-3	Abdasa	90.00	70.00
19	Lakhaniya-4	Abdasa	90.00	70.00
20	Kuvapaddhar-1	Abdasa	70.00	55.00
21	Khanay	Abdasa	100.00	70.00
22	Vagoth-1	Abdasa	70.00	55.00
23	Vagoth-2	Abdasa	50.00	35.00
24	Motiber-1	Abdasa	70.00	55.00
25	Motiber-2	Abdasa	60.00	40.00
26	Khakhra	Abdasa	70.00	55.00
27	Navavas	Abdasa	50.00	35.00
28	Budha-Chapari-1	Abdasa	90.00	60.00
29	Galo	Abdasa	200.00	150.00
30	Langai	Abdasa	80.00	60.00
31	Bitto Choro	Abdasa	90.00	75.00
32	Mitti-1	Abdasa	120.00	95.00
33	Mitti-2	Abdasa	135.00	115.00
34	Khanmora	Abdasa	100.00	85.00
35	Pasivalo	Abdasa	80.00	60.00
36	Vaghapadhar-1	Abdasa	65.00	40.00

37	Vaghapadhar-2	Abdasa	70.00	50.00
38	Vaghapadhar-3	Abdasa	75.00	65.00
39	Vaghapadhar-4	Abdasa	98.00	65.00
40	Fulay	Abdasa	55.00	40.00
41	Bitta -1	Abdasa	80.00	60.00
42	Laiyari-1	Abdasa	80.00	40.00
43	Laiyari-2	Abdasa	80.00	40.00
44	Balachod Nani-2	Abdasa	72.00	45.50
45	Balachod Nani-3	Abdasa	36.00	35.00
46	Balachod Moti-1	Abdasa	52.00	42.00
47	Balachod Moti-2	Abdasa	40.00	35.00
48	Bhimpar	Abdasa	48.00	42.00
49	Sanosara-2	Abdasa	112.00	52.50
50	Nandra-4	Abdasa	64.00	45.50
51	Kandhai-1	Abdasa	60.00	45.50
52	Vamoti Moti-2	Abdasa	56.00	45.50
53	Samanda-1	Abdasa	40.00	35.00
54	Bhedi-1	Abdasa	100.00	56.00
55	Bhedi-2	Abdasa	64.00	45.50
55		**Total**	**4062.00**	**2928.00**
1	Kundhanvalo	Mandvi	190.00	135.00
2	Samsanvalo	Mandvi	275.00	195.00
3	Dhokda	Mandvi	140.00	110.00
4	Momaymora	Mandvi	150.00	115.00
5	Vekra	Mandvi	140.00	100.00
6	Sherdi	Mandvi	150.00	110.00
7	Nana Asambiya	Mandvi	160.00	115.00
8	Makada-2	Mandvi	20.00	18.00
9	Makada-3	Mandvi	25.00	18.00
10	Makada-4	Mandvi	20.00	18.00
11	Vengdi-1	Mandvi	95.00	75.00
12	Undoth-2	Mandvi	80.00	65.00
13	Jagmalvalo	Mandvi	95.00	75.00
14	Poladia-2	Mandvi	60.00	40.00
15	Sambharai-1	Mandvi	95.00	75.00
16	Modkuba-2	Mandvi	95.00	75.00
17	Mota Ratadiya-2	Mandvi	80.00	65.00
18	Hamla-Manjal-1	Mandvi	90.00	70.00
19	Hamla-Manjal-2	Mandvi	75.00	55.00
19		**Total**	**2106.23**	**1529.00**
1	Nagor-1	Bhuj	98.00	75.00
2	Nagor-2	Bhuj	82.00	74.00
3	Nagor-3	Bhuj	60.00	68.00
4	Nagor-4	Bhuj	83.00	74.00
5	Zikadi-3	Bhuj	90.00	90.00
6	Zikadi-4	Bhuj	56.00	68.00
7	Zikadi-5	Bhuj	62.00	71.00
8	Trambo-1	Bhuj	70.00	78.00
9	Habay	Bhuj	90.00	60.00
10	Dhrang-1	Bhuj	62.00	62.00
11	Dhrang-2	Bhuj	49.00	60.00
12	Kunaria-2	Bhuj	185.00	120.00

<table>
<tr><td>13</td><td>Kera-1</td><td>Bhuj</td><td>117.00</td><td>125.00</td></tr>
<tr><td>14</td><td>Sedata-1</td><td>Bhuj</td><td>76.00</td><td>66.00</td></tr>
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<tr><td>20</td><td>Modasar</td><td>Bhuj</td><td>90.00</td><td>75.00</td></tr>
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<tr><td>27</td><td>Zura-3</td><td>Bhuj</td><td>71.25</td></tr>
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<tr><td>33</td><td>Hariparvaro</td><td>Bhuj</td><td>75.00</td></tr>
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<tr><td>43</td><td>Kurbai</td><td>Bhuj</td><td>71.25</td></tr>
<tr><td>44</td><td>Nana Dinara-3</td><td>Bhuj</td><td rowspan="8">485.42</td><td>67.50</td></tr>
<tr><td>45</td><td>Simarivalo</td><td>Bhuj</td><td>71.25</td></tr>
<tr><td>46</td><td>Jhuna (berdivaro)</td><td>Bhuj</td><td>60.00</td></tr>
<tr><td>47</td><td>Sumarapor</td><td>Bhuj</td><td>67.50</td></tr>
<tr><td>48</td><td>Dhoravar</td><td>Bhuj</td><td>67.50</td></tr>
<tr><td>49</td><td>Juna-2</td><td>Bhuj</td><td>75.00</td></tr>
<tr><td>50</td><td>Tuga</td><td>Bhuj</td><td>71.25</td></tr>
<tr><td>51</td><td>Nana Dinara(Alayvandh)</td><td>Bhuj</td><td>67.50</td></tr>
<tr><td>52</td><td>Mindhiyaro</td><td>Bhuj</td><td rowspan="8">557.87</td><td>60.00</td></tr>
<tr><td>53</td><td>Ludia-1</td><td>Bhuj</td><td>69.00</td></tr>
<tr><td>54</td><td>Kuran-3</td><td>Bhuj</td><td>70.50</td></tr>
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<tr><td>56</td><td>Zuna-3</td><td>Bhuj</td><td>75.00</td></tr>
<tr><td>57</td><td>Mota Dinara (Bhanuvandh)</td><td>Bhuj</td><td>56.25</td></tr>
<tr><td>58</td><td>Mota Dinara Vadi Vistar</td><td>Bhuj</td><td>56.25</td></tr>
<tr><td>59</td><td>Godpar</td><td>Bhuj</td><td>52.50</td></tr>
<tr><td>60</td><td>Bhaukha -1 CD</td><td>Bhuj</td><td>75.00</td><td>12.00</td></tr>
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66	Godapar -3 CD	Bhuj	71.00	15.00
67	Jamkunaraiya -1 CD	Bhuj	98.00	15.00
68	Khari -1 CD	Bhuj	80.00	14.00
69	Kuran -1 CD	Bhuj	95.00	15.00
70	Kuran -2 CD	Bhuj	76.00	12.00
71	Kuran -3 CD	Bhuj	70.00	13.00
72	Kuran -4 CD	Bhuj	60.00	14.00
73	Kuran -5 CD	Bhuj	65.00	12.00
74	Tankanasar -1 CD	Bhuj	90.00	15.00
75	Tuga -1 CD	Bhuj	88.00	15.00
76	Vandhsim -1 CD	Bhuj	80.00	14.00
77	Dhrobana -1 CD	Bhuj	80.00	14.00
78	Dhrobana -2 CD	Bhuj	66.00	12.00
79	Paiya CD	Bhuj	76.00	13.00
80	Dhoravar CD	Bhuj	77.00	14.00
80		**Total**	**6040.14**	**4336.25**
1	Vadala Checkdam	Mundra	85.50	50.00
2	Pavadiyara Checkdam	Mundra	136.50	75.00
3	Vanki-1 Checkdam	Mundra	98.40	65.00
4	Vanki-2 Checkdam	Mundra	125.00	65.00
5	Bhadreshwar Checkdam	Mundra	100.00	55.00
6	Zarapara Checkdam	Mundra	110.00	60.00
7	Vaghura-1 Checkdam	Mundra	69.70	50.00
8	Kundrodi Checkdam	Mundra	75.00	55.00
9	Beraja Checkdam	Mundra	111.64	80.00
10	Vaghura-2 Checkdam	Mundra	40.56	70.00
11	Tappar Checkdam	Mundra	40.00	50.00
12	Toda Checkdam	Mundra	164.00	75.00
13	Karaghogha Checkdam	Mundra	42.00	40.00
13		**Total**	**1198.30**	**790.00**
1	Makhiyan-4	Anjar	73.15	42.00
2	Makhiyan-5	Anjar	71.25	42.75
3	Makhiyan-6	Anjar	75.60	46.50
4	Makhiyan-7	Anjar	71.25	41.25
5	Bhalot-1	Anjar	61.75	37.50
6	Bhalot-2	Anjar	42.75	36.00
7	Chandroda-1	Anjar	53.30	36.75
8	Chandroda-2	Anjar	80.75	44.25
9	Chandroda-3	Anjar	76.00	45.00
10	Chandroda-4	Anjar	66.50	45.00
11	Chandroda-5	Anjar	85.50	46.50
12	Chandroda-6	Anjar	80.75	52.50
13	Chandroda-7	Anjar	90.25	53.25
14	Devliya-1	Anjar	75.60	46.50
15	Khedoi-1	Anjar	52.25	47.25
16	Khedoi-2	Anjar	57.00	47.25
17	Satapar-2	Anjar	77.08	45.00
18	Sarapar-3	Anjar	65.00	52.50
19	Satapar-4	Anjar	71.25	45.00
20	Satapar-5	Anjar	66.50	45.00
21	Zaru-1	Anjar	38.00	37.50

22	Zaru-2	Anjar	28.70	39.00
23	Mithapasavriya-1	Anjar	139.40	39.00
24	Khirsara-1	Anjar	52.00	66.75
25	Khirsara-2	Anjar	33.25	37.50
26	Chandrani-1	Anjar	64.80	56.25
27	Bhimasar-1	Anjar	66.50	42.00
28	Bhimasar-2	Anjar	42.75	37.50
28		**Total**	**1858.88**	**1253.25**
1	Gedi-1 Makwana Vokala	Rapar	50.00	40.00
2	Gedi-2 Odhavari Nadi	Rapar	50.00	35.00
3	Gedi-3 Naliavari Nadi	Rapar	35.00	30.00
4	Dabhiyavlo vokalo	Rapar	50.00	35.00
5	Anarvavalo vokalo	Rapar	70.00	60.00
6	Pirvalo vokalo	Rapar	52.00	35.00
7	Shankarvalo vokalo	Rapar	70.00	75.00
8	Parmeshwaro vokalo	Rapar	70.00	110.00
9	Checkdam near BSF Tower	Rapar	50.00	50.00
10	Meghasar	Rapar	55.00	45.00
11	Potiyavalo	Rapar	55.00	60.00
12	Kuda Jampar-1	Rapar	50.00	8.00
13	Kuda Jampar-2	Rapar	50.00	7.00
14	Kuda Jampar-3	Rapar	70.00	15.00
15	Kuda Jampar-4	Rapar	80.00	12.00
16	Kuda Jampar-5	Rapar	35.00	7.00
17	Kuda Jampar-6	Rapar	35.00	6.00
18	Balasari	Rapar	44.00	40.00
19	Hamirpar	Rapar	66.00	35.00
20	Badargadh	Rapar	105.60	30.00
21	Chitrod	Rapar	95.70	35.00
22	Dhadadhro	Rapar	123.20	235.00
23	Dorkiwandh	Rapar	71.50	35.00
24	Khedukaa	Rapar	94.60	40.00
25	Nagtar-1	Rapar	80.30	45.00
26	Saay	Rapar	107.80	35.00
27	Sanava	Rapar	67.10	45.00
27		**Total**	**1782.80**	**1205.00**
1	Bharudiya-3	Bhachau	50.00	35.00
2	Bharudiya-4	Bhachau	50.00	34.00
3	Vondh-3	Bhachau	45.00	37.00
4	Vondh-4	Bhachau	45.00	37.00
5	Kanthkot	Bhachau	45.00	37.00
6	Aadhoi-5	Bhachau	45.00	20.00
7	Aadhoi-6	Bhachau	30.00	12.00
8	Aadhoi-7	Bhachau	20.00	16.00
9	Aadhoi-8	Bhachau	45.00	20.00
10	Bharudiya-5	Bhachau	40.00	16.00
11	Bharudiya-6	Bhachau	20.00	7.00
12	Kandhelvandh-1 (Kakarva)	Bhachau	80.00	21.00
13	Kandhelvandh-2 (Kakarva)	Bhachau	60.00	16.00
14	Nara-1	Bhachau	47.00	16.00
15	Nara-2	Bhachau	21.00	8.00

16	Rampar (Halra)	Bhachau	21.00	8.00
17	Toraniya-1	Bhachau	15.00	5.00
18	Toraniya-2	Bhachau	15.00	5.00
19	Toraniya-3	Bhachau	15.00	5.00
20	Toraniya-4	Bhachau	17.00	6.00
21	Lakadiya	Bhachau	90.00	20.00
22	Katariya-1	Bhachau	55.00	14.00
23	Katariya-2	Bhachau	45.00	12.00
24	Katariya-3	Bhachau	60.00	17.00
25	Sikara-1	Bhachau	95.00	28.00
25		**Total**	**1071.00**	**452.00**
1	Shinapar-1	Lakhpat	87.00	55.00
2	Shinapar-2	Lakhpat	120.00	65.00
3	Shinapar-3	Lakhpat	113.00	70.00
4	Guneri (Atada-1)	Lakhpat	111.00	55.00
5	Bityari-1	Lakhpat	124.00	60.00
6	Bityari-2	Lakhpat	80.00	65.00
7	Meghpar-1	Lakhpat	39.00	23.00
8	Meghpar-2	Lakhpat	39.00	23.00
9	Lakhapar-1	Lakhpat	65.00	45.00
10	Lakhapar-2	Lakhpat	149.00	100.00
11	Pranpar(Atada-2)	Lakhpat	80.00	66.00
12	Sayara-1	Lakhpat	81.00	65.00
13	Sayara-2	Lakhpat	94.00	60.00
14	Khadak-1	Lakhpat	65.00	30.00
15	Khadak-2	Lakhpat	49.00	27.00
16	Khadak-3	Lakhpat	84.00	45.00
17	Julrai-1	Lakhpat	81.00	70.00
18	Julrai-2	Lakhpat	87.00	45.00
19	Julrai-3	Lakhpat	70.00	35.00
20	Budha-1	Lakhpat	59.00	30.00
21	Budha-2	Lakhpat	54.00	27.00
22	Budha-3	Lakhpat	55.00	27.00
23	Harudi(Paiya)	Lakhpat	70.00	35.00
24	Kharoi (Rakhadi)	Lakhpat	54.00	23.00
25	Kharoi (Mandir)	Lakhpat	60.00	38.00
26	Murchban	Lakhpat	80.00	60.00
27	Pipar-1	Lakhpat	60.00	30.00
28	Pipar-2	Lakhpat	75.00	37.00
29	Pipar-3	Lakhpat	50.00	25.00
30	Mori-1	Lakhpat	65.00	35.00
31	Mori-2	Lakhpat	65.00	32.00
32	Mori-3	Lakhpat	65.00	35.00
33	Sakatkhata-1	Lakhpat	60.00	30.00
34	Sakatkhata-2	Lakhpat	70.00	35.00
35	Nareda (Mandir)	Lakhpat	47.00	25.00
36	Nareda (Bhindia)	Lakhpat	65.00	35.00
37	Rodasar	Lakhpat	124.00	69.00
38	BelaValo (Laxmirani)	Lakhpat	54.00	28.00
39	BelaValo-1	Lakhpat	68.00	38.00
40	Bhadra-1	Lakhpat	60.00	30.00
41	Bhadra-2	Lakhpat	56.00	28.00

42	Pathada Vokalo- CD-1 , Sandhrowandh	Lakhpat	50.00	20.00
43	Pathada Vokalo- CD-2 , Sandhrowandh	Lakhpat	60.00	30.00
44	Pathada Vokalo- CD-3 , Sandhrowandh	Lakhpat	70.00	35.00
45	Ashay Vokalo CD , Vill. Chamara	Lakhpat	50.00	20.00
46	Gudh Vokalo CD, Vill. Chamara	Lakhpat	50.00	20.00
47	Karijar Vokalo CD, Chamara	Lakhpat	60.00	30.00
48	Nara CD on Bharavari River vill. Nara	Lakhpat	70.00	31.00
49	Zumara CD on local river , Viil. Zumara	Lakhpat	60.00	30.00
50	Lakhapat-3 CD on local River, Lakhapat	Lakhpat	50.00	26.00
51	Lakhapat-4 CD on local River, Lakhapat	Lakhpat	60.00	28.00
52	Atada CD on local River , Vill. Atada	Lakhpat	70.00	34.00
53	Pranpar CD on Local River, Vill Pranpar	Lakhpat	60.00	26.00
53		**Total**	**3744.00**	**2086.00**
1	Dhamay	Nakhtrana	174.00	55.00
2	Deshalpar(Gu)	Nakhtrana	149.00	50.00
3	Jinjay	Nakhtrana	124.00	80.00
4	Muru-1	Nakhtrana	118.00	80.00
5	Muru-2	Nakhtrana	140.00	75.00
6	Moti Aral	Nakhtrana	124.00	50.00
7	Vang	Nakhtrana	100.00	65.00
8	Dador	Nakhtrana	71.00	40.00
9	Bibar	Nakhtrana	65.00	35.00
10	Nirona	Nakhtrana	87.00	50.00
11	Kharadiya	Nakhtrana	76.00	40.00
12	Amara-1	Nakhtrana	87.00	40.00
13	Amara-2	Nakhtrana	150.00	60.00
14	Lakhiyavira	Nakhtrana	124.00	40.00
15	Akadana	Nakhtrana	124.00	80.00
16	Kotada(Tharavada)	Nakhtrana	68.00	45.00
17	Tharavada	Nakhtrana	150.00	80.00
18	Vamrapdar	Nakhtrana	120.00	70.00
19	Tharavada(Kotada)	Nakhtrana	135.00	65.00
20	Tal(Fulay)	Nakhtrana	153.00	50.00
21	Tal(Chhari)	Nakhtrana	130.00	70.00
22	Paiya	Nakhtrana	148.00	72.00
23	Tal(Laiyari))	Nakhtrana	297.00	90.00
24	Mathal-2	Nakhtrana	95.00	50.00
25	Mathal-3	Nakhtrana	98.00	45.00
26	Vyar-1	Nakhtrana	150.00	60.00
27	Vyar-2	Nakhtrana	43.00	20.00
28	Vyar-3	Nakhtrana	95.00	50.00
29	Naranpar-3	Nakhtrana	255.00	90.00
30	Naranpar-5	Nakhtrana	45.00	20.00
31	Sukhsan-1	Nakhtrana	53.00	25.00
32	Sukhsan-2	Nakhtrana	53.00	25.00
33	Sukhsan-3	Nakhtrana	53.00	25.00

34	Vadva(Kaya)-1	Nakhtrana	60.00	22.00
35	Vadva(Kaya)-2	Nakhtrana	40.00	18.00
36	Vibhapar	Nakhtrana	55.00	22.00
37	Danana	Nakhtrana	45.00	20.00
38	Kotada(Roha)-1	Nakhtrana	60.00	22.00
39	Kotada(Roha)-2	Nakhtrana	65.00	23.00
40	Jarjok	Nakhtrana	65.00	24.00
41	Rampar(Roha)-1	Nakhtrana	50.00	21.00
42	Rampar(Roha)-2	Nakhtrana	135.00	75.00
43	Rampar(Roha)-3	Nakhtrana	53.00	25.00
44	Rampar(Roha)-4	Nakhtrana	40.00	18.00
45	Rampar(Roha)-5	Nakhtrana	45.00	20.00
46	Khirasara (Roha) Checkam	Nakhtrana	104.00	50.00
47	Tharavada -2 Checkam	Nakhtrana	130.00	60.00
48	Muru -3 Checkam	Nakhtrana	117.00	55.00
49	Kotada (Tharavada-2) Checkam	Nakhtrana	104.00	50.00
50	Dhoro Checkam	Nakhtrana	130.00	60.00
51	Lakhiyarvira -2 Checkam	Nakhtrana	130.00	70.00
52	Vedhar Checkam	Nakhtrana	76.00	40.00
53	Ranara Checkam	Nakhtrana	104.00	50.00
54	Chandra Nagar Checkdam	Nakhtrana	200.00	80.00
54			**5860.17**	**2708.60**
	Total	**354**	**27723.52**	**17288.1**

Annexure 4.1B

Works proposed in Saurastra region of Gujarat

Sr.No.	Name Of Work	District	Estimated Amount (Rs. Lakh)	Proposed Benefited Area (ha)
(A) Tidal Regulator & Bandharas				
1	Jodiya T.R. 1 & 2	Jamnagar	6000	1600
2	Maleshri T.R.	Bhavnagar	1000	633
3	Setrunji T.R. 1 & 2	Bhavnagar	7500	7500
4	Machhundri T.R.	Gir – Somnath	2000	1000
5	Saiyad Rajpara T.R.	Gir – Somnath	2500	1500
6	Aathamanabara Bandhara	Devbhumi Dawarka	2536	8875
7	Virpur Bandhara	Devbhumi Dawarka	100	1500
8	Mota Aambla Bandhara	Devbhumi Dawarka	2735	2500
9	Bhimrana Bandhara	Devbhumi Dawarka	150	150
10	Bhimpura Bandhara	Devbhumi Dawarka	150	150
11	Vrajnala Bandhara	Devbhumi Dawarka	200	60
12	Suraka Bandhara	Bhavnagar	445	500
13	Kuda Bandara	Bhavnagar	300	300
14	Methala Bandhara	Bhavnagar	5000	5000
15	Gatarvadi Bandhara	Amreli	1400	1000
16	MItiyala Bandhara	Amreli	800	500
(B) Spreading Channel				
17	Sampar to Bela checkdam Sp.ch. (24.00 km.)	Jamnagar	750	2400
18	Bela checkdam to Zinzuda R.R. Sp.ch. (7.0 km.)	Jamnagar	350	1120
19	Und to Balmbha Sp.CH. (4.25 k.m.)	Jamnagar	470	90
20	Construction of Sp.Ch. from barada bandhara to Vadodara Zala T.R. (6.41 k.m.)	Gir Somnath	268.58	400
21	Netravati Madhuvanti Sp.ch. Phase – 3 (2.50 k.m.)	Junagadh	400	350
22	Machhu R.R. to zinzuda R.R. sp.ch.(36.30 K.m.)	Morbi	5000	3600
23	Machhu R.R. to Rapar checkdam Sp.Ch. (10.0 k.m.)	Morbi	800	1600
24	Methal – Kalsar Sp.Ch. (12.0 k.m.)	Bhavnagar	1000	1000
25	Alang – Jashpara Sp.ch. (3.0 k.m.)	Bhavnagar	300	100
26	Vasoj P.P.T.R. Sp. Ch. (13.80 k.m.)	Gir – Somnath	1000	1500
(C) Anti sea Erosion Works				
27	Kharvavad Anti Sea Erosion work	Porbandar	400	0
28	Navibandar Anti Sea Erosion work	Porbandar	400	0
(D) Recharge Tank & Other Salinity Control Work				
29	Kenedi Recharge Tank	Devbhumi Dawarka	35	60
30	Lovarli Recharge Tank	Devbhumi Dawarka	350	100
31	Gorinja Recharge Tank	Devbhumi Dawarka	100	200
32	Dabla – 1 Recharge Tank	Devbhumi Dawarka	35	90
33	Ran Recharge Tank	Devbhumi Dawarka	50	90
34	Shivrajpur Recharge Tank	Devbhumi Dawarka	200	150
35	Noli Lambora Radial Canal	Junagadh	200	300
36	Hadiyana Radial Canal-2	Jamnagar	54	155
37	Meghal T.R. Radial Canal Kanek Vokalo	Junagadh	200	100
38	Bodaki T.R.Radial canal	Morbi	278	800
39	Kunnad Check Dam (Jodiya T.R. 3)	Jamnagar	48.53	90
40	15 Checkdam	Morbi	750	300
41	Sanganiya checkdam	Bhavnagar	150	200
42	Devaka checkdam	Amreli	100	100
43	5- Checkdam	Jamnagar	250	100
44	Going – 2 reclamation	Devbhumi Dawarka	450	90
45	Jodiya reclamation bund renovation(20 km.)	Jamnagar	1000	4000
		Total	**48205**	**51853**

Annexure- 4.2A

Schemes proposed in Maharashtra

Sr. No.	Name Of scheme	Taluka	Praposed Reclaimed Area (ha)
	District Thane		
1	Khari	Thane	16
2	Diva	Thane	32
3	Sabe	Thane	136
4	Sonkhar Davale Desai	Thane	175
4	**Thane District Total**		**359**
	Palghar District		
1	Dahisar kasarle	Vasai	77
2	Chimne hedavde	Vasai	15
3	Kofrad	Vasai	27
4	Shirgaon Son to Kothe	Vasai	202
5	Shirgaon	Vasai	101
6	Bordi	Dahanu	30
7	Chandigaon	Dahanu	97
8	Vadkun	Dahanu	138
9	Bada Pokharan	Dahanu	162
10	Aagvan	Dahanu	121
11	Dehane	Dahanu	20
12	Vangaon	Dahanu	10
13	Tarapur	Palghar	81
14	Kharekuran	Palghar	71
15	Kharmendri	Palghar	28
16	Makunsar	Palghar	101
17	Agarwadi	Palghar	21
18	Jalsar	Palghar	12
18	**Palghar District Total**		**1314**
22	**Total**		**1673**
	District Raigad		
1	Borli Mandala Surai	Murud	44
2	Virjoli	Roha	0
3	Kandhane (Khurd)	Roha	12
4	Mahadev Mhalunge	Roha	91
5	Gophanwadi	Roha	24
6	Bhalgaon Mumroli	Roha	124
7	Juibet	Roha	280
8	Rovale	Tala	39
9	Waral	Tala	5
10	Rahatad	Tala	77
11	Kude	Tala	86
12	Madand	Tala	70
13	Dabhol	Mahad	60
14	Sanderi Mathachi Wadi	Mhasala	40
15	Palekhar	Mhasala	16

1	2	3	4
16	Pabhare	Mhasala	16
17	Palsap	Mhasala	24
18	Kudgaon	Mhasala	12
19	Toradi	Mhasala	36
20	Kozare	Mhasala	10
21	Talwade	Mhasala	10
22	Nigdi	Mhasala	12
23	Mendadi	Mhasala	14
24	Kole	Mhasala	21
25	Kolmandala	Shrivardhan	12
26	Kandalwada New	Shrivardhan	200
27	Nandgaon Mazgaon	Murud	36
27	**Total**		**1371**
	District Ratnagiri		
1	Jawali	Mandangad	60
2	Peve	Mandangad	55
3	Borkhat	Mandangad	17
4	Gothe	Mandangad	13
5	Kudewadi	Mandangad	48
6	Umroli	Mandangad	81
7	Mhapral	Mandangad	59
8	Padwe	Mandangad	23
9	Aadi	Mandangad	38
10	Aambavne	Mandangad	36
11	Shivgaon	Mandangad	10
12	Kingatghar	Mandangad	24
13	Nigadi	Mandangad	21
14	Bhatghar	Mandangad	11
15	Veral	Mandangad	41
16	Kolisare	Ratnagiri	25
17	Ganeshgule	Ratnagiri	45
18	Pomendi khurd	Ratnagiri	40
19	Someshwar	Ratnagiri	104
20	Kharviwadi	Ratnagiri	28
21	Kasarveli	Ratnagiri	38
22	Shirgaon Gangurde	Ratnagiri	10
23	Wada Dabhil	Ratnagiri	32
24	Guravwadi No.2	Ratnagiri	30
25	Takale	Ratnagiri	25
26	Hatis	Ratnagiri	20
27	Musalmanwadi No.1	Chiplun	39
28	Ugawate Wadi	Chiplun	20
29	Ketaki	Chiplun	23
30	Bramhanwadi	Chiplun	15
31	Waghivar No.2	Chiplun	15
32	Waghivar No.1	Chiplun	13
33	Bhoiwadi	Chiplun	26
34	Aambavane	Dapoli	44
35	Ladghar	Dapoli	26
36	Kotya	Dapoli	44
37	Uttambar	Dapoli	18
38	Padale	Dapoli	5

39	Talwadi	Dapoli	10
40	Musalmanwadi	Dapoli	25
41	Dabhol	Dapoli	70
42	Usagaon	Dapoli	35
43	Umberghar	Dapoli	13
44	Salwadi	Dapoli	10
45	Panchnadi	Dapoli	22
46	Kongale	Dapoli	24
47	Karijure	Sangameshwar	25
48	Makhajan	Sangameshwar	20
49	Sogamwadi	Rajapur	15
50	Upale	Rajapur	10
51	Wada Tivre	Rajapur	25
52	Danda Adiwade	Rajapur	60
53	Karla	Rajapur	22
54	Wada Vaghran	Rajapur	12
55	Vaki	Rajapur	15
56	Nanarwadib(Nanurgaon	Rajapur	15
57	Tavasala	Guhaghar	5
58	Katvanwadi	Guhaghar	5
59	Bundel Bader	Guhaghar	19
60	Madala Mohala	Guhaghar	75
61	Musalmanwadi	Guhaghar	4
62	Tetlas	Guhaghar	50
63	Veldur	Guhaghar	35
64	Anjanvel	Guhaghar	35
65	Bhandarwadi	Guhaghar	10
66	Dafalewadi	Guhaghar	41
67	Kurul	Guhaghar	34
68	Bhandar Rohile	Guhaghar	10
69	Kararut Wadi	Guhaghar	10
70	Ozarwadi	Guhaghar	13
71	Kavatewadi	Guhaghar	48
72	Bhatgaon	Guhaghar	141
73	Dugwadi	Guhaghar	16
74	Samberwadi	Guhaghar	28
75	Khotwadi	Khed	41
		Total	**2270**
	District Sindhudurg		
1	Trilot Dalviwadi	Devgad	15
2	Vanivade	Devgad	26
3	Mohulgaon	Devgad	13
4	Elaye Joshiwada	Devgad	19
5	Vada Kerpoe	Devgad	10
6	Hindale	Devgad	15
7	Kunkeshwar Valkewadi	Devgad	51
8	Kelkarmala	Devgad	4
9	Dhaboli	Devgad	7
10	Virwadi	Devgad	3
11	Amberi	Devgad	6
12	Katwanwadi	Devgad	12
13	Mutat Ranewadi	Devgad	7
14	Morve Wadi	Devgad	7

15	Elaye Jambhiche Khajan	Devgad	5
16	Juva Pankhol	Malvan	16
17	Talani Masure	Malvan	5
18	Varad	Malvan	5
19	Kalse	Malvan	4
20	Talasu	Malvan	5
21	Khavanewadi	Vengurla	10
22	Ambrewadi	Vengurla	10
23	Aaveriwdai	Vengurla	21
24	Terekhol Mansiwadi	Savantwadi	45
	Total		**321.00**
138	**Total**		**5635.00**

Annexure 4.3A

Proposed Salt Water Exclusion Dams (SWED) across West Flowing Rivers in Dakshina Kannada & Udupi Districts of Karnataka

Sl. No	District	Taluk	Name of work	River/ basin	Type of work	Prposed area (ha)	Amount (Rs. In lakhs)
1	2	3	4	5	6	7	8
1	DK	Mangalore	SWED at Kowkrani in Manampady village	WFR	Anicut	84.00	120.00
2	DK	Mangalore	SWED at Padubailu in Chitrapu village	WFR	Anicut	84.00	120.00
3	DK	Mangalore	SWED near Koppalakudru Shashindra's house in Haleyangady village.	WFR	Anicut	21.00	30.00
4	DK	Mangalore	SWED near Neharu Bridge in Manampady village.	WFR	Anicut	84.00	120.00
5	DK	Mangalore	SWED near bridge in Talapady village.	WFR	Anicut	56.00	80.00
6	DK	Mangalore	SWED at Darkas in Athikaribettu village	WFR	Anicut	35.00	50.00
7	DK	Mangalore	SWED near Rukmayya Moolya's house in Pavanje village.	WFR	Anicut	49.00	70.00
8	DK	Mangalore	SWED at Uliya in Ullala village.	WFR	Anicut	35.00	50.00
9	DK	Mangalore	SWED at Guddekopla in Idya village.	WFR	Anicut	42.00	60.00
10	DK	Mangalore	SWED to thodu at Kariya in Surathkal village.	WFR	Anicut	49.00	70.00
11	DK	Mangalore	SWED to Kadatabbu thodu in Munnuru village.	WFR	Anicut	35.00	50.00
12	DK	Mangalore	SWED to Shambhavi and Pavanje river in Chitrapu village.	WFR	Anicut	84.00	120.00
13	DK	Mangalore	SWED at Mattu in Atikaribettu village.	WFR	Anicut	400.00	2500.00
14	DK	Mangalore	SWED near Somanatha Temple in Munnuru village.	WFR	Anicut	20.00	60.00
15	DK	Bantwal	SWED at Kumpanamajalu in Pudu village.	WFR	Anicut	15.00	50.00
16	DK	Mangalore	SWED at Aranda in Aggadakaliya village.	WFR	Anicut	50.00	100.00
17	DK	Mangalore	SWED at Gattikudru in Harekala village.	WFR	Anicut	25.00	50.00
18	DK	Mangalore	SWED at Paryala in Amblamogaru village.	WFR	Anicut	30.00	90.00
			Total Dakshina Kannada District			**1,198.00**	**3,790.00**
19	Udupi	Kundapur	SWED across Sankadagundi river in Yadthare village.	WFR	Anicut	120.00	460.00
20	Udupi	Kundapur	SWED across Gundanavady thodu at Moovattumudi in Hemmady village.	WFR	Anicut	40.25	57.50
21	Udupi	Kundapur	SWED at Andearipala in Hosadu village.	WFR	Anicut	40.25	57.50
22	Udupi	Kundapur	SWED at Tarapaty in Uppunda village.	WFR	Anicut	644.00	920.00
23	Udupi	Udupi	SWED at Kurkalu in Kurkalu village.	WFR	Anicut	241.50	345.00
24	Udupi	Udupi	SWED at Kuriyapatna in Nadsalu village.	WFR	Anicut	32.20	46.00
25	Udupi	Udupi	SWED across Pangala river in Pangala village.	WFR	Anicut	241.50	345.00
26	Udupi	Udupi	SWED near Kolalagiri in Uppoor village.	WFR	Anicut	966.00	1380.00
27	Udupi	Udupi	Reconstruction of SWED at Palimaru in Palimaru	WFR	Anicut	80.00	400.00
28	Udupi	Udupi	SWED across Kamini river near Paduhithilu Jarandaya Daivastana in Padubidri village.	WFR	Anicut	60.00	300.00
29	Udupi	Udupi	Reconstruction of SWED at Mattu in Kote village	WFR	Anicut	150.00	300.00
30	Udupi	Udupi	Reconstruction of Bolja SWED in Udyavara village.	WFR	Anicut	50.00	200.00
31	Udupi	Udupi	SWED near Siddhi Vinayaka Temple in Perampalli	WFR	Anicut	500.00	1,000.00
32	Udupi	Udupi	SWED cum bridge near Indira Mohan's house in Kadekaru village.	WFR	Anicut	85.00	200.00
33	Udupi	Udupi	SWED at Kallusanka in Harady village	WFR	Anicut	15.00	40.00
34	Udupi	Udupi	SWED near Timmannakudru Hanging bridge in Kemmannu village	WFR	Anicut	15.00	40.00
35	Udupi	Udupi	SWED at Kudrungodu of Handady Gramapanchayath	WFR	Anicut	15.00	0.00
36	Udupi	Kundapur	SWED at Sankady between Pandeshwara and Hosadu	WFR	Anicut	45.00	200.00
37	Udupi	Kundapur	SWED cum barrage near Sourabha Factory at Hangaluru village.	WFR	Anicut	25.00	100.00
38	Udupi	Kundapur	SWED near Kalavinabagilu in Thalluru village.	WFR	Anicut	70.00	250.00

39	Udupi	Kundapur	Improvement of SWED near Kattebelthuru in Kattebelthuru village.	WFR	Anicut	400.00	1,100.00
40	Udupi	Kundapur	SWED at Arekallu in Bijuru village.	WFR	Anicut	80.00	300.00
41	Udupi	Kundapur	Improvement of SWED at Bantwady in Senapur	WFR	Anicut	350.00	1,100.00
42	Udupi	Kundapur	SWED cum barrage at Alivegadde in Shirooru village.	WFR	Anicut	50.00	175.00
43	Udupi	Kundapur	SWED cum barrage at Sarpinagadde in Shiroorur	WFR	Anicut	40.00	150.00
44	Udupi	Kundapur	SWED cum barrage at Benageri in Gujjady village.	WFR	Anicut	28.00	40.00
45	Udupi	Udupi	SWED near Kaipunjalu bridge in Uliyargoli village.	WFR	Anicut	21.00	30.00
46	Udupi	Udupi	SWED at Baggumunda in Kalmady village.	WFR	Anicut	21.00	30.00
47	Udupi	Udupi	SWED near Baikady river in Harady village.	WFR	Anicut	21.00	30.00
48	Udupi	Kundapur	SWED at Sankadabagilu in Yedthare village.	WFR	Anicut	70.00	100.00
			Total Udupi District			**2,191.00**	**6,115.00**
			Total Dakshina Kannada & Udupi District			**3,389.00**	**9,905.00**

Annexure 4.3 B

Proposed Salt Water Exclusion Dams (SWED) across West Flowing Rivers in Uttara Kannada District of Karnataka

Sl.No.	Village	Name of the Work	Basin	Sib Basin	Name of Local Nala	Proposed Area to be benefitted (in ha)	Cost (Rs in lakhs)
Karwar Taluka							
1	Chittakula	At L/B of Kali river sadashivgad Mavinhalla to Honnagajani	WFR	Kali river	Kali Back water	200.00	1,500.00
2	Chittakula	At L/B of Kali river near Devbag to Rampur	WFR	Kali river	Kali Back water	100.00	900.00
3	Chittakula	At L/B of Kali river near Alvewada to Rampur	WFR	Kali river	Kali river	50.00	300.00
4	Kinner	At L/B of Kali river from zadki to Boribag.	WFR	Kali river	Kali Back water	100.00	900.00
5	Kinner	At L/B of Kali river from Ambejog to Gunasubha	WFR	Kali river	Kali Back water	60.00	450.00
6	Wailwada	At L/B of Kali river from Siddar to Bagjug	WFR	Kali river	Kali Back water	150.00	900.00
7	Wailwada	At L/B of Kali river from Naite to madibhale	WFR	Kali river	Kali Back water	50.00	300.00
8	Kerwadi	At L/B of Kali river from Kadye to Khandali	WFR	Kali river	Kali Back water	125.00	300.00
9	Hankon	At L/B of Kali river from Hankon bridge to Halgejug	WFR	Kali river	Kali Back water	900.00	900.00
10	Ghadsai	At L/B of Kali river from Ulga harijan keri to Dholmath	WFR	Kali river	Kali Back water	225.00	450.00
11	Kadwad	At L/B of Kali river from kadwad Madibag to karwar	WFR	Kali river	Kali r water	100.00	1,200.00
12	Kadwad	At Kadwad sunkeri	WFR	Kali river	Siddapur Nala	350.00	800.00
13	Hankon	At Hankon - Hotegali	WFR	Kali river	Kali river	300.00	400.00
14	Hankon	From Hotegali to Hankon	WFR	Kali river	Kali Back water	200.00	200.00
15	Ghadsai	At Ghadsai	WFR	Kali river	Kali Back water	150.00	200.00

16	Majali	From Mudegeri to Kothar Halebag Sadashivgad.	WFR	Kali river	Aravhalla	100.00	1,500.00
17	Chitakula	From Chittakula Seabird collony to Sadashivgad.	WFR	Kali river	Devbag halla	300.00	600.00
18	Chendia	At Chandia Halla	WFR	Kali river	Doddahalla	200.00	500.00
			Total			**3,660.00**	**12,300.00**
Ankola Taluka							
19	Mudrani	Construction of SWED near Mudrani Village	WFR	Gangavali River	Pujageri River	210.00	210.00
20	Hattikeri	Construction of SWED near mavinkeri Village	WFR	Gangavali River	Hattikeri Halla	120.00	300.00
21	Heggare	Construction of KLS near Heggare village	WFR	Gangavali River	Heggar river	60.00	100.00
22	Harwada	Construction of KLS near Harwada village	WFR	Gangavali River	Hattikeri Halla	40.00	50.00
23	Balale	Construction of KLS near Balale	WFR	Gangavali River	Balale Halla	40.00	50.00
24	Gabitkeni	Construction of KLS near Gabitkeni	WFR	Gangavali River	Keni Halla	50.00	100.00
25	Bhavikeri	Construction of KLS near Bhavikeri village Mastisalu (Moggarsalu)	WFR	Gangavali River	Bhavikeri Halla	50.00	100.00
26	Belekeri	Construction of KLS near Belekeri - Kodisalu	WFR	Gangavali River	Kodisalu	30.00	50.00
27	Mogata	Construction of KLS near Mogata	WFR	Gangavali River	Gangavali River	30.00	50.00
28	Aggragona	Construction of Aggragona Halla R/B KLS	WFR	Gangavali River	Aggragona Halla	60.00	100.00
29	Chandumath	Construction of Chandumath near Belse Halla KLS	WFR	Gangavali River	Belse	60.00	30.00
30	Sagadgeri	Construction of Sagadgeri gummanhonda Halla KLS	WFR	Gangavali River	Gumman honda Nala	40.00	50.00
31	Sagadgeri	Construction of Sagadgeri Tari to Pharakhitlu KLS	WFR	Gangavali River	Sagadgeri Nala	40.00	50.00
32	Balale	Construction of Balale KLS	WFR	Gangavali River	Balale Halla	30.00	50.00
			Total			**860.00**	**1,290.00**
Kumta Taluka							
33	Hiregutti	Construction of Hosakatta KLS from Morab	WFR	Aghanashini	Aghanashini	800.00	500.00

		to Mudangi		River	Back water		
34	Tumble katta	Construction of Manikatta KLS	WFR	Aghanashini River	Aghanashini Back water	725.00	350.00
35	Chatra kurve	Construction of SWED near Chatrakurve	WFR	Aghanashini River	Aghanashini Back water	210.00	1,500.00
36	Hittala makki	Construction of KLS at Hittalamakki	WFR	Aghanashini River	Aghanashini Back water	400.00	600.00
37	Kumta Town	Construction of KLS at R/B of Handihalla Shashihittlu upto Service Station.	WFR	Aghanashini River	Handihalla Nala	136.00	80.00
38	Muroor	Construction of KLS at R/B of Sankaragadda at Ch. 500 to 750m	WFR	Aghanashini River	Sankangadda nala	142.00	60.00
39	Muroor	Construction of KLS at L/B of Aghanashini near Muroor	WFR	Aghanashini River	Aghnashini river	105.00	60.00
40	Divagi	Construction of KLS near Ambekeri in Divgi Gram Panchayat	WFR	Aghanashini River	Aghnashini river	142.00	50.00
41	Divagai	Construction of KLS at R/B of Divagi bridge in Aghanashini river.	WFR	Aghanashini River	Aghnashini river	117.00	100.00
42	Divagai	Construction of KLS from Aghnashini Bridge to 500 M	WFR	Aghanashini River	Aghnashini river	142.00	50.00
43	Hiregutti	Construction of KLS at Hosakatta	WFR	Aghanashini River	Aghnashini river	50.00	100.00
44	Bargi	Construction of KLS at Betkuli Bargi	WFR	Aghanashini River	Aghnashini river	60.00	100.00
45	Bargi	Construction of KLS at Betkuli Bargi Extension	WFR	Aghanashini River	Aghnashini river	50..	80.00
46	Nadu maskeri	Construction of KLS at Torke (selected streches 500 m)	WFR	Aghanashini	Aghnashini river	40.00	100.00
47	Kagal	Construction of KLS at Kagal (selected streches 500 m)	WFR	Aghanashini	Aghnashini river	40.00	80.00
48	Hegde	Construction of KLS at Hegde (selected streches 500 m)	WFR	Aghanashini	Aghnashini river	34.00	100.00
49	Manikatta	Construction of KLS at Manikatta I (selected streches)	WFR	Aghanashini	Aghnashini river	50.00	200.00
50	Manikatta	Construction of KLS at Manikatta II (selected streches 500 m)	WFR	Aghanashini	Aghnashini river	60.00	100.00
51	Manikatta	Construction of KLS at Manikatta I (selected stretches 500 m)	WFR	Aghanashini	Aghnashini river	50.00	100.00
52	Bada	Construction of KLS at KaikattaI (selected streches 500 m)	WFR	Aghanashini	Aghnashini river	40.00	80.00

53	Kodkani	Construction of KLS at Kodkani (selected streches 500 m)	WFR	Aghanashini	Aghnashini river	30.00	100.00
54	Mirjan	Construction of KLS at Masurkurve (selected streches 500 m)	WFR	Aghanashini	Aghnashini river	20.00	100.00
55	Baggon	Construction of KLS at Baggon (selected streches 500 m)	WFR	Aghanashini	Aghnashini river	10.00	100.00
56	Kalbagh	Construction of KLS at Kalbagh major-I(selected streches 500 m)	WFR	Aghanashini	Aghnashini river	10.00	80.00
57	Kalbagh	Construction of KLS at Kalbagh major-II(selected streches 500 m)	WFR	Aghanashini	Aghnashini river	50.00	80.00
						3,463.00	**4,850.00**
Honnavar Taluka							
58	Gudanakattu	Construction of SWED near Gudanakattu across Badagani River	WFR	Badgani River	Badgani Back Water	250.00	750.00
59	Navilgon	Construction of Bund from Veranakeri to Kokanta of Navilgon village	WFR	Badgani River	Navilgon Nala	25.00	80.00
60	Navilgon	Construction of Kharland Bund near Kakurve railway bridge to Jadkan Temple of Navilgon village	WFR	Badgani River	Navilgon Nala	30.00	80.00
61	Manki	Construction of KLS near Manki-kumbarkeri village	WFR	Sharavati River	kumbarkeri Nala	200.00	150.00
62	Pavin kurva	Construction of KLS near Pavinkurva village	WFR	Badagani River	Pavinkurva Nala	120.00	120.00
63	Manki	Construction of KLS from kirubail to Taribagil	WFR	Badagani River	Kirubail Nala	100.00	100.00
64	Shashihitlu	Construction of KLS L/B Shashihitlu	WFR	Sharavati River	Sharavati Back water	100.00	120.00
65	Chikkanakod	Construction of KLS from Kudla to Gundbal	WFR	Sharavati River	Bhaskeri Back water	300.00	750.00
66	Haldipur	Construction of KLSnear konkar Bridge	WFR	Badagani River	Konkar Nala	120.00	100.00
67	Mavinkurva	Construction of KLS near Gulibeli	WFR	Sharavati River	Sharavati Back water	50.00	50.00
68	Hosad	Construction of KLS near Hosad	WFR	Sharavati River	Sharavati Back water	40.00	50.00
69	Padukuli	Construction of KLS near Jalavalli Neeruhonda	WFR	Sharavati River	Sharavati Back water	40.00	50.00
70	Kha rva	Construction of KLS near Kharva Sindhur	WFR	Sharavati River	Sharavati Back water	50.00	50.00

						1,425.00	**2,450.00**
Bhatkal Taluka							
71	Mavalli	Construction of KLS at Sarasvati halla	WFR	Sarasvati halla	Sea Back Water	80.00	100.00
72	Tannir Ghatta	Construction of KLS at Tannirughatta	WFR	Tanniru Ghatta Halla	Sea Back Water	100.00	120.00
73	Bengre	Construction of KLS at Bengre-Shashihitlu	WFR	Venkatapur Halla	Sea Back Water	100.00	120.00
74	Tattihitlu	Construction of KLS Tattihitlu	WFR	Venkatapur River	Tattihitlu Nala	76.00	150.00
75	Gudihitlu	Construction of KLS at Gudihitlu	WFR	Venkatapur River	Back water	80.00	100.00
76	Alvekodi	Construction of KLS at Alvekodi	WFR	Venkatapur River	Back water	70.00	100.00
77	Kaikini	Construction of KLS at Kaikini	WFR	Kaikini Nala	Back water	60.00	100.00
78	Belke	Construction of KLS at Belke	WFR	Belke Nala	Back water	50.00	100.00
79	Gorate	Construction of KLS at Gorate	WFR	Gorate Nala	Back water	90.00	100.00
80	Bailur	Construction of KLS at Bailur	WFR	Bailur Nala	Back water	80.00	100.00
81	Shirali	Construction of Shardahole KLS R/BCh. 2.50M to 3.00 Mtrs.	WFR	Venkatapur	Shardahole	50.00	100.00
82	Hebale	Construction of Hebale KLS L/B at Ch. 0.500M to 1.50 Mtrs.	WFR	Venkatapur	Hebale Halla	45.00	100.00
83	Hebale	Construction of Hebale KLS R/B at Ch. 0.500M to 1.50 Mtrs.	WFR	Venkatapur	Hebale Halla	35.00	80.00
84	Kaikini	Construction of Haradi KLS L/B at Ch. 0.500M to 1.00 Mtrs.	WFR	Venkatapur	Arabian Sea	50.00	100.00
85	Kaikini	Construction of Haradi KLS R/B at Ch. 0.500M to 1.00 Mtrs.	WFR	Venkatapur	Arabian Sea	55.00	80.00
86	Bailur	Construction of Saraswati KLS L/B at Ch. 0.500M to 1.00 Mtrs.	WFR	Venkatapur	Saraswati river	55.00	70.00
87	Bailur	Construction of KLS L/B Beleke Halla Pinnupada (500 Mtrs)	WFR	Venkatapur	Saraswati river	55.00	100.00
88	Belke	Construction of KLS L/B at Belke Halla PinnupadaCh. (0.500M)	WFR	Venkatapur	Belke Nala	40.00	100.00
89	Belke	Construction of KLS R/B at Belke Halla Pinnupada Ch. (500Mtrs)	WFR	Venkatapur	Belke Nala	45.00	50.00
90	Jali	Construction of Battaramone Doddamane Halla R/B KLS Ch. 500Mtrs)	WFR	Venkatapur	Doddamane Halla	40.00	80.00

91	Jali	Construction of Battaramone Doddamane Halla L/B KLS Ch. 500Mtrs)	WFR	Venkatapur	Doddamane Halla	45.00	80.00
92	Mundalli	Construction of /sharabi KLS Ch. 1.50 to 2.20 Km	WFR	Venkatapur	Sharabi river	75.00	100.00
93	Shirali	Construction of Alvekodi KLS L/B Ch. 0 to 500 m	WFR	Venkatapur	Arabian Sea	45.00	90.00
94	Shirali	Construction of Alvekodi KLS R/B Ch. 0 to 500 m	WFR	Venkatapur	Arabian Sea	45.00	90.00
95	Bemgre	Construction of Doddahalla KLS R/B Ch. 400 m trs	WFR	Venkatapur	Doddamane Halla	55.00	80.00
96	Bemgre	Construction of Doddahalla KLS R/B Ch. 400 m trs	WFR	Venkatapur	Doddamane Halla	55.00	80.00
97	Mundalli	Construction of Mundalli KLS Ch. 0.500 m trs	WFR	Venkatapur	Mundalli river	40.00	80.00
98	Heble	Construction of Honnegajani KLS Ch. 0.500 m trs	WFR	Venkatapur	Honnegajani	45.00	80.00
99	Jali	Construction of Battarmane Doddamane KLS R/B	WFR	Venkatapur	Doddamane Halla	30.00	80.00
100	Mundalli	Construction of Sharabi. KLS	WFR	Venkatapur	Sharabi river	25.00	50.00
101	Shirali	Repairs to Mogerkeri KLS sluice (2 Nos.)	WFR	Venkatapur	Dodahalla	120.00	50.00
102	Shirali	Construction of Gudihittalu KLS & Sluice works	WFR	Venkatapur	Venkatapur	250.00	200.00
103	Shirali	Construction of Mogerkeri KLS	WFR	Venkatapur	Doddahalla	175.00	100.00
			Total			**2,261.00**	**3,110.00**
			Grand Total			**11,669.00**	**24,000.00**

Annexure-4.3 C

Proposed River protection works in Dakshina Kannada inWest Flowing River of Karnataka

Sl no	Taluk	Name of work	Amount Rs. In lakhs
1	Mangalore	River bank protection work at selected place of Nethravathi river. (ch. 0 - 1.00 Km.)	200.00
2	Mangalore	River bank protection work at selected place of Nethravathi river. (ch. 1.00 - 2.00 Km.)	200.00
3	Mangalore	River bank protection work at selected place of Nethravathi river. (ch. 2.00 -3.00 Km.)	200.00
4	Mangalore	River bank protection work at selected place of Nethravathi river. (ch. 3.00 -4.00 Km.)	200.00
5	Mangalore	River bank protection work at selected place of Nethravathi river. (ch. 4.00 -5.00 Km.)	200.00
6	Mangalore	River bank protection work at selected place of Nethravathi river. (ch. 5.00 -6.00 Km.)	200.00
7	Mangalore	River bank protection work at selected place of Nethravathi river. (ch. 6.00 -7.00 Km.)	200.00
8	Mangalore	River bank protection work at selected place of Nethravathi river. (ch. 7.00 -8.00 Km.)	200.00
9	Mangalore	River bank protection work at selected place of Nethravathi river. (ch. 8.00 -9.00 Km.)	200.00
10	Mangalore	River bank protection work selected place of Nethravathi river. (ch. 9.00 -00.00 Km.)	200.00
11	Mangalore	River bank protection work at selected place of Gurupura river. (ch. 0 - 1.00 Km.)	150.00
12	Mangalore	River bank protection work at selected place of Gurupura river. (ch. 1.00 - 2.00 Km.)	150.00
13	Mangalore	River bank protection work at selected place of Gurupura river. (ch. 2.00 -3.00 Km.)	150.00
14	Mangalore	River bank protection work at selected place of Gurupura river. (ch. 3.00 -4.00 Km.)	150.00
15	Mangalore	River bank protection work at selected place of Gurupura river. (ch. 4.00 -5.00 Km.)	150.00
16	Mangalore	River bank protection work at selected place of Gurupura river. (ch. 5.00 -6.00 Km.)	150.00
17	Mangalore	River bank protection work at selected place of Gurupura river. (ch. 6.00 -7.00 Km.)	150.00
18	Mangalore	River bank protection work at selected place of Gurupura river. (ch. 7.00 -8.00 Km.)	150.00
19	Mangalore	River bank protection work at selected place of Gurupura river. (ch. 8.00 -9.00 Km.)	150.00
20	Mangalore	River bank protection work at selected place of Gurupura river. (ch. 9.00 -00.00 Km.)	150.00
21	Mangalore	River bank protection work at selected place of Nandini river. (ch. 0 - 1.00 Km.)	150.00
22	Mangalore	River bank protection work at selected place of Nandini river. (ch. 1.00 - 2.00 Km.)	150.00
23	Mangalore	River bank protection work at selected place of Nandini river. (ch. 2.00 -3.00 Km.)	150.00
24	Mangalore	River bank protection work at selected place of Nandini river. (ch. 3.00 -4.00 Km.)	150.00
25	Mangalore	River bank protection work at selected place of Nandini river. (ch. 4.00 -5.00 Km.)	150.00
26	Mangalore	River bank protection work at selected place of Nandini river. (ch. 5.00 -6.00 Km.)	150.00
27	Mangalore	River bank protection work at selected place of Nandini river. (ch. 6.00 -7.00 Km.)	150.00
28	Mangalore	River bank protection work at selected place of Nandini river. (ch. 7.00 -8.00 Km.)	150.00
29	Mangalore	River bank protection work at selected place of Nandini river. (ch. 8.00 -9.00 Km.)	150.00
30	Mangalore	River bank protection work at selected place of Nandini river. (ch. 9.00 -00.00 Km.)	150.00
		Total	5000

Proposed River protection works in Udupi inWest Flowing River of Karnataka

Sl No	Taluk	Name of work	Amount Rs. In lakhs
1	Udupi	Protection work to thodu near Kode Khandige of Kote Gramapanchayath	30.00
2	Udupi	River bank protection work at left bank of down stream side of Kote Mattu bridge.	50.00
3	Udupi	River bank protection work at right bank of upstream side of Kote Mattu bridge.	50.00
4	Udupi	River bank protection work at left bank of downstream side of Pangala Mattu bridge.	30.00
5	Udupi	River bank protection work at left bank of upstream side of Pangala Mattu bridge.	50.00
6	Udupi	River bank Protection work at Parapatna in Hejamady village.	30.00
7	Udupi	River bank Protection work at Nadikudru in Hejamady village.	30.00

8	Udupi	Bank Protection work near Sankuthota Bhoja Poojary's house in Uliyaragoli Panchayath.	30.00
9	Udupi	River bank Protection work at Kaipunjalu in Uliyaragoli Panchayath.	50.00
10	Udupi	Bank Protection work to Kamini river near Jarandaya Temple in Padubidru Panchayath.	50.00
11	Udupi	River bank Protection work near Chandithota in Bada Grama Panchayath.	50.00
12	Udupi	River bank Protection work near Yenegudde Chikkady.	50.00
13	Udupi	River bank Protection work near Udyavara Sampige.	50.00
14	Udupi	River bank Protection work near Udyavara Railway Bridge.	50.00
15	Udupi	Improvements to thodu at Kakkedaru Indubailu in Udyavara village.	50.00
16	Udupi	River bank Protection work behind Sri. Mahalingeshwara Temple in Hejamady village.	40.00
17	Udupi	River bank Protection work near Garady Adve in Palimaru village.	25.00
18	Udupi	River bank Protection work at Pithrody Kaduvinabagilu in Udyavara village.	30.00
19	Udupi	Bank Protection work near Bankerakatta Punjadady Burma Poojarthi's house in Ambalpady	30.00
20	Udupi	River bank Protection work to Kalsanka thodu near Saibaba Mandir in Kodavoor village.	50.00
21	Udupi	River bank Protection work to both sides of Bavalikudru bridge in Neelavara village.	35.00
22	Udupi	Bank Protection work to right bank of Kalyanapura bridge (Sasithota) in Mooduthonse vill.	50.00
23	Udupi	River bank Protection work at Honnale Kalavinabagilu to Masjid in Harady village.	50.00
24	Udupi	River bank Protection work to Kalmady river near Chennangady in Kodavoor village.	25.00
25	Udupi	Bank Protection work East side of Bankerukatta bridge to Acharigundy of Ambalpady Pancha	30.00
26	Udupi	Flood Protection work to river in Sasithota in Kadekaru village.	30.00
27	Udupi	River bank Protection work to thodu flowing through Bobbarya Jeddu Janatha Colony in Kuthpady village.	20.00
28	Udupi	River bank Protection work to Seetha river in Kumerugudda in Harady village.	50.00
29	Udupi	River bank Protection work to Swarna river in Paskudru in Perampalli village.	50.00
30	Udupi	River bank Protection work to Seetha river in Sashihithlu of Kumragodu village.	40.00
31	Udupi	Bank Protection work in North side of Kumragodu Ganapathy temple in Kumragodu village.	20.00
32	Udupi	Flood Protection work to Baikady Old Ferry area.	50.00
33	Udupi	Flood Protection work near Heranje Hanging Bridge in Heruru vilalge.	50.00
34	Udupi	Flood protection work near Uggelbettu SWED in Uppoor village.	50.00
35	Udupi	Flood protection work to Madisalu river near Nadubettu Hirebettu in Uppoor village.	50.00
36	Udupi	River bank Protection work in Kemmannu Padukudru.	20.00
37	Udupi	River bank Protection work near Rehamathulla Sadik Saheb's land in Kemmannu village.	20.00
38	Udupi	River bank Protection work near Hoode Guderi Kambala in Kemmannu village.	20.00
39	Udupi	River bank Protection work near Arooru bridge in Uppoor village.	30.00
40	Udupi	Flood protection work in Kola area of Kadekaru village.	40.00
41	Udupi	Flood protection work in Kuthpady Kadekaru village.	50.00
42	Udupi	River bank Protection work near Padukere Jyanodaya Bhajana Mandira in Kadekar village.	20.00
43	Udupi	River bank Protection work near Vinayaka Temple in Perampalli village.	50.00
44	Udupi	Flood protection work to Seetha river near Mahishamardhini Temple in Neelavara village.	50.00
45	Udupi	River bank Protection work to thodu in Kemmannu Gajanana road of Paduthonse Gramapanchayath.	40.00
46	Udupi	Flood protection work at Malpe Koppalthota in Kodavoor village.	30.00
47	Udupi	River bank Protection work at Majjigepade in Kidiyuru village.	20.00
48	Udupi	River bank Protection work of left bank at Adjeel in Aroor village.	20.00
49	Udupi	River bank Protection work at Padukukkake side of river in Honnala Nandikeshwara	50.00

		Temple to Akki Poojarthy's house of Harady village.	
50	Udupi	River bank Protection work near Irmady Sri. Subrahmanya and Sri. Brahmalingeshwara Temple in Havanje village.	50.00
51	Udupi	Improvements to Yellampalli thodu in Neelavara Panchayath.	20.00
52	Udupi	River bank Protection work near Darussalam English Medium School in Paduthonse village.	5.00
53	Udupi	River bank Protection work to Swarna river left bank near Padukudru Smt. Lilli D'souza w/o. Siman D'souza's land Paduthonse village.	20.00
54	Udupi	River bank Protection work to Swarna river left bank near Padukudru Sri. Abdul Khadar S/o. Ismail Saheb's land Paduthonse village.	15.00
55	Udupi	River bank Protection work to Swarna river near Mayady in Uppoor village.	25.00
56	Udupi	River bank Protection work to Seetha river near Perlakadi in Paduthonse village.	20.00
57	Udupi	River bank Protection work near Kemmannu bridge in Paduthonse village.	50.00
58	Udupi	River bank Protection work to river near Kalmady Bobbaryapade Nagabana in Hosakatta village.	20.00
59	Udupi	River bank Protection work to Udyavara river near Baputhota in Malpe village.	30.00
60	Udupi	Bank Protection work to Nagabana downstream of Baputhota Kalmady bridge in Malpe village.	30.00
61	Udupi	Bank Protection work at right bank of Padikudru Baligarakudru bridge in Paduthonse village.	50.00
62	Udupi	River bank Protection work near Shekar Poojary's house in Moodabettu village.	25.00
63	Udupi	River bank Protection work near Kodavoor bridge in Kodavoor village.	50.00
64	Udupi	River bank Protection work near Kuduru Compound in Paduthonse village.	20.00
65	Udupi	River bank Protection work to Indrani river in Moodabettu village.	30.00
66	Udupi	River bank Protection work to Swarna river near Mudakudru Kakkethota in Kalyanapura village.	30.00
67	Kundapur	River bank Protection work near Nyany Revellow's house in Anagalli village.	20.00
68	Kundapur	River bank Protection work near Renny Furtado's house and Stany Rebellow's house in Anagalli village.	20.00
69	Kundapur	River bank Protection work near Gretta's house in Anagalli village.	20.00
70	Kundapur	River bank Protection work near Halekody Dayananda Poojary and David D'souza's house in Hosala village.	40.00
71	Kundapur	River bank Protection work to Nagamata river in Seethanadi between agricultural land of Karkada and hosala in Hosala village	50.00
72	Kundapur	River bank Protection work near Kudrudaddy in Balkuru village.	25.00
73	Kundapur	River bank Protection work near Smt. Mery D Almeda's agricultural land in Anagalli village.	30.00
74	Kundapur	River bank Protection work near Vilaskeri in Basruru village.	75.00
75	Kundapur	River bank Protection work to North side of Tenkakeri Kodi bridge in Gundmimat in Saligram Town Panchayath	50.00
76	Kundapur	River bank Protection work to Bachalu thodu in Moodugiliyaru at Kota Gramapanchayath	20.00
77	Kundapur	Bank Protection work to Sannahole near Laxmi Marakalthi's house in Giliyaru village.	20.00
78	Kundapur	Bank Protection work near Handattu Danagundu road in Kotathattu Gramapanchayath.	20.00
79	Kundapur	Bank Protection work near Kamastarakudru Herikudru Stella D Almeda's land in Anagalli village.	25.00
80	Kundapur	River bank Protection work near Manooru bridge in Manoor village.	30.00
81	Kundapur	River bank Protection work near Nagaramata SWED in Barkuru village.	50.00
82	Kundapur	River bank Protection work near Herikudru Manasa Mandira in Anagalli village.	20.00
83	Kundapur	River bank Protection work near Moodabettu in Uppinakudru village.	100.00
84	Kundapur	River bank Protection work near Laxmi Poojarthy's house in Hemmady village.	30.00
85	Kundapur	River bank Protection work near Marana house in Talluru village.	200.00

86	Kundapur	River bank Protection work near Tenkabailu in Hosadu village.	50.00
87	Kundapur	River bank Protection work near Beskuru in Paduvari village.	200.00
88	Kundapur	River bank Protection work near Sankadabagilu Vented Dam in Yadthare village.	5.00
89	Kundapur	River bank Protection work behind Mangali's house in Yadthare village.	5.00
90	Kundapur	River bank Protection work near Kudrisalu in Yadthare village.	10.00
91	Kundapur	River bank Protection work near Naikanakatte in Yadthare village.	50.00
92	Kundapur	River bank Protection work near Jalady in Kattebelthuru village.	30.00
93	Kundapur	River bank Protection work near Aratejanthrabagilu in Hosadu village.	30.00
94	Kundapur	River bank Protection work near Moovattumudi in Hemmady village.	50.00
95	Kundapur	River bank Protection work near Samsarakatte to Marana house in Talluru village.	50.00
96	Kundapur	River bank Protection work near National Highway to Marana house in Talluru village.	50.00
97	Kundapur	River bank Protection work near Somayya Padavayi's house in Kambadakone village.	30.00
98	Kundapur	River bank Protection work near Manki in Gujjady village.	50.00
99	Kundapur	River bank Protection work near Nandanavana Kamini's house in Kergal village.	50.00
100	Kundapur	River bank Protection work near Bayarihithlu in Uppunda vilalge.	50.00
101	Kundapur	River bank Protection work at Kalavinabagilu in Hadavu village.	125.00
102	Kundapur	River bank Protection work at Molakodu in Teggarse village.	50.00
103	Kundapur	River bank Protection work at Alivekody Tarapaty in Paduvari village.	50.00
104	Kundapur	River bank Protection work at Nakatte in Yadthare village.	40.00
105	Kundapur	River bank Protection work at Balikeri in Devalkunda village.	100.00
106	Kundapur	River bank Protection work at Battekudru in Haklady village.	50.00
107	Kundapur	River bank Protection work at Sankadabagilu in Yadthare village.	30.00
108	Kundapur	River bank Protection work at Nagadde in Padukone village.	100.00
109	Kundapur	River bank Protection work at Chungigudde Chikkalli in Nada village.	100.00
110	Kundapur	River bank Protection work at Guddamady in Senapura village.	50.00
111	Kundapur	River bank Protection work at Parankali Tenginagundi in Senapura village.	50.00
112	Kundapur	River bank Protection work at Parankali Tenginagundibettu in Amparu village.	50.00
113	Kundapur	River bank Protection work at Thonavalli Kalavinabagilu in Haklady village.	50.00
114	Kundapur	River bank Protection work at Arate Tenkabailu in Hosadu village.	50.00
115	Kundapur	River bank Protection work at Yelluru in Vandse village.	30.00
116	Kundapur	River bank Protection work at upstream Bantwady Vented dam in Senapura village.	100.00
117	Kundapur	River bank Protection work near Maraswamy Temple in Trasi village.	50.00
118	Kundapur	River bank Protection work near Sulse in Kattebelthuru village.	50.00
		Total Udupi	5055

Annexure-4.3D

Proposed River protection works in Uttara Kannada district of Karnataka

Sl No	Name Of Work	Taluk	Amount (in lakhs)
1	Protection to bank of Kali river from ch 0.00 to 10.00	karwar	1730.00
2	Protection to bank of kolage honne gajani from ch 0.00 to 10	karwar	1700.00
3	Protection to bank ofmajali nachakan bag from ch 0.00 to 2.00	karwar	400.00
4	Protection to bank of amadalli manjil Hole from ch 0.00 to 2.00	karwar	1500.00
5	Protection to bank of chendia Hole from ch 0.00 to 2.00	karwar	1200.00
	Total		**6530.00**
6	Protection to bank of gangavalli River from ch 0.00 to 5.00	Ankola	1800.00
7	Protection to bank of Hattikeri Hole from ch 0.00 to 5.00	Ankola	1100.00
8	Protection to bank of belekeri kodisala hole from ch 0.00 to 5.00	Ankola	1100.00
9	Protection to bank of pujageri hole from ch 0.00 to 6.00	Ankola	1500.00
10	Protection to bank of Baleguli Hole from ch 0.00 to 4.00	Ankola	1100.00
11	Protection to bank of keni Hole from ch 0.00 to 4.	Ankola	925.00
12	Protection to bank of madanamadi hole from ch 0.00 to 5.00	Ankola	800.00
	Total		**8325.00**
13	Protection to bank of Aganashini River from ch 0.00 to 10.00	Kumta	3600.00
14	Protection to bank of Hoskatta Mudangi from ch 0.00 to 5.00	Kumta	1800.00
15	Protection to bank of gokaran temple Halla from ch 0.00 to 5.00	Kumta	1600.00
16	Protection to bank of Kalbag Alvedande Holee from ch 0.00 to 6.00	Kumta	1800.00
17	Protection to bank of dareshwar hole from ch 0.00 to 3.00	Kumta	920.00
	Total		**9720.00**
18	Protection to bank of Badagani River from ch 0.00 to 9.00	Honnavar	1000.00
19	Protection to bank of karaki kodi Hole from ch 0.00 to 5.00	Honnavar	1100.00
20	Protection to bank of apsarakonda holefrom ch 0.00 to 3.00	Honnavar	555.00
21	Protection to bank of manki kumbarkatta halla from ch 0.00 to 6.00	Honnavar	900.00
	Total		**3555.00**
22	Protection to bank of bailur sarsvathi halla from ch 0.00 to 5.00	Bhatkal	1100.00
23	Protection to bank of honne madi halla from ch 0.00 to 4.00	Bhatkal	900.00
24	Protection to bank of belake halla from ch 0.00 to 3.00	Bhatkal	600.00
25	Protection to bank of sarabhi halla from ch 0.00 to 8.00	Bhatkal	1500.00
26	Protection to bank of bailur karehalla hole from ch 0.00 to 3.00	Bhatkal	770.00
27	Protection to bank ofvenkatapur hole from ch 0.00 to 3.00	Bhatkal	1100.00
	Total		5970.00
	Grand Total		**34100.00**

Annexure 4.4A

Proposed schemes in Kerala

District	Sl. No.	Name of work	Project cost expected (` in Crores)
Kasaragod	1	RCB at Palayivalavu	65.00
	2	Renovation of Chittari anicut cum bridge	3.00
		Total	68.00
Kannur	1	Reformation of Marginal bund on U/s side of Kattampally RCB	3.00
	2	Permanent earthern bund at Thattumpuram	1.00
	3	Permanent earthern bund around Thekkumpad island	9.20
	4	Permanent earthern bund around Chirakkal and Madakkara island	14.95
	5	Permanent earthern bund between Irinavu RCB and Mungom	8.00
		Total	36.15
Kozhikode	1	RCB at Perincheri kadavu	35.00
		Total	35.00
Malappuram	1	Veliyancode lock cum bridge	22.00
	2	SWEVCB at Para in Parappanangadi	1.00
	3	Tanur lock	6.00
	4	SWEVCB at Vettom	0.75
		Total	29.75
Thrissur	1	Construction of RCB at Munayam.	36.00
	2	Renovation and improvements of regulator at Enamakkal.	40.00
	3	Renovation and improvements of regulator at Idiyanchira.	5.00
	4	Construction of permanent vented cross bar with anti corrosive	6.00
		Total	87.00
Kottayam	1	SWE Barrage across KV Canal and Vadayar	8.00
	2	Construction of 48 Nos. of Sluices	15.00
		Total	23.50
Ernakulam	1	Lock cum regulator across Kadamprayar at Kozhithodu.	30.00
		Total	30.00
Alappuzha	1	Construction of permanent SWE vented cross bar with anti corrosive shutters (40 Nos.)	10.00
		Total	10.00
Kollam	1	Construction of check dam (RCB) across Ithikkara river to prevent salt water instrusion for Kurungal-Adichanalloor L.I. Schemes in Chathannoor Panchayath.	8.00
	2	Construction of check dam and sluice cum bridge to prevent salt water intrusion and other allied works in Pavoor vayal to	0.60

		Vattakayal in Ward No. 8 in Thrikkadavoor Panchayath.	
	3	Construction of check dam to prevent salt water intrusion and other allied works in Pattathilkadavu kayalvaram in Ward No. 14 of Thrikkaruva Panchayath.	0.30
	4	Construction of check dam to prevent salt water intrusion and other allied works in Palakkassery kayalvaram in Ward No. 10 of Thrikkaruva Panchayath.	0.30
	5	Construction of check dam to prevent salt water intrusion and other allied works in Melemukku kayalvaram in Ward No. 10 of Thrikkaruva Panchayath.	0.30
	6	Construction of check dam to prevent salt water intrusion and other allied works in Manalikkadavu Charuvil Planthodathu in Ward No. 15 of Thrikkaruva Panchayath.	0.30
	7	Construction of regulator at Ithikara on the downstream of Ithikkara Bridge.	15.00
		Total	24.80
		GRAND TOTAL	344.20

Annexure 4.7A

Proposed schemes in Orissa

<table>
<tr><th>Sl no</th><th>Name of project</th><th>Name of drain</th><th>District</th><th>Project cost (Rs lakhs)</th><th>Area Irrigated in Ha</th></tr>
<tr><td>1</td><td>Creek irrigation to kanika block (West) including construction of sluice and renovation of creeks</td><td>Chadesh Nallaha, Banki nallaha, taladia, Jokadandi-II, Chhinchinadia nallah, lunia nallaha, kandanalli</td><td>kendrapara</td><td>1267.22</td><td>1200</td></tr>
<tr><td>2</td><td>Renovation to sunity Drainage creek along with it linek drain in mahakalapada block in kendrapara district</td><td>Sunity drainage creek</td><td>kendrapara</td><td>470.21</td><td>900</td></tr>
<tr><td>3</td><td>Construction of creek Irrigation Project at Village Khalagaon</td><td>Muguranallah</td><td>Jagatsinghpur</td><td>500</td><td>1000</td></tr>
<tr><td>4</td><td>Construction of creek Irrigation Project at Village Balipatna</td><td>Gaon Nai</td><td>Jagatsinghpur</td><td>500</td><td>1000</td></tr>
<tr><td>5</td><td>Construction of creek Irrigation Project at Mururanallah at village nuagaon (left)</td><td>Muguranallah</td><td>Jagatsinghpur</td><td>400</td><td>500</td></tr>
<tr><td>6</td><td>Construction of creek Irrigation Project at Mururanallah at village nuagaon (Right)</td><td>Muguranallah</td><td>Jagatsinghpur</td><td>400</td><td>500</td></tr>
<tr><td>7</td><td>Construction of creek Irrigation Project at Village Fullapatna</td><td>Gaon Nai</td><td>Jagatsinghpur</td><td>300</td><td>500</td></tr>
<tr><td>8</td><td>Construction of creek Irrigation Project at Village Prasannapur</td><td>Muguranallah</td><td>Jagatsinghpur</td><td>400</td><td>500</td></tr>
<tr><td>9</td><td>Construction of creek Irrigation Project at Village Barunabedi</td><td>Gaon Nai</td><td>Jagatsinghpur</td><td>300</td><td>500</td></tr>
<tr><td>10</td><td>Construction of creek Irrigation Project at Village Pbahakana-Baramundali</td><td>Muguranallah</td><td>Jagatsinghpur</td><td>400</td><td>500</td></tr>
<tr><td>11</td><td>Construction of creek Irrigation Project at Village Rasakanti</td><td>Gaon Nai</td><td>Jagatsinghpur</td><td>400</td><td>500</td></tr>
<tr><td>12</td><td>Construction of creek Irrigation Project at Village Ranigadia-Kathagadi Muhan</td><td></td><td>Jagatsinghpur</td><td>500</td><td>700</td></tr>
<tr><td>13</td><td>Construction of creek Irrigation Project near nalakana thakurani of Village Baradia</td><td>Muguranallah</td><td>Jagatsinghpur</td><td>400</td><td>500</td></tr>
<tr><td>14</td><td>construction of inlet sluice at benakanda</td><td>malibasa drain</td><td>kendrapara</td><td>500</td><td>3700</td></tr>
<tr><td>15</td><td>Mahanga creek</td><td>mahanga</td><td>Jagatsinghpur</td><td>1300</td><td>2050</td></tr>
<tr><td>16</td><td>Construction of Instream structure near village Satakabad/Bilimuhani over Dhanua</td><td>Dhanua</td><td>Puri</td><td colspan="2" rowspan="2">Survey & Soil investigation completed</td></tr>
<tr><td>17</td><td>Construction of Instream structure near village Sunugoradi over Dhanua</td><td>Dhanua</td><td>Puri</td></tr>
<tr><td>18</td><td>Construction of Instream structure near village Badhei Sahi over Dhanua</td><td>Dhanua</td><td>Puri</td><td colspan="2">Survey & Soil investigation to be taken up</td></tr>
<tr><td>19</td><td>Renovation of Nunajore Haladiganda creek and its system</td><td>Nunajore</td><td>Bhadrak</td><td>400</td><td>3655</td></tr>
<tr><td>20</td><td>Renovation of Saya & Karanji Creek and its links with sluice</td><td>Karanji</td><td>Bhadrak</td><td>200</td><td>600</td></tr>
<tr><td>21</td><td>Renovation of Deula drain and its sub-tributaries</td><td>Deula</td><td>Bhadrak</td><td>80</td><td>300</td></tr>
<tr><td>22</td><td>Renovation of Badaharipur creek with its sub-creeks</td><td>Badaharipur</td><td>Bhadrak</td><td>150</td><td>1200</td></tr>
<tr><td>23</td><td>Renovation of Terzodia creek and its link from Haladiganda creek to Manteri</td><td>Terzodia</td><td>Bhadrak</td><td>150</td><td>553</td></tr>
</table>

Annexure 4.10 A

Works Proposed by government of Goa

1. New works approved by the government

Sr. No	Name of work	Length in Mts.	Area Protected in Ha.	Estimated Cost (Appx) in Lac
1	Strengthening to the bund "Cantor Khazan" at Amona in Bicholim Taluka.	1930	100	438.74
2	Strengthening to the bund "Palni" at St. Estevam in Tiswadi Taluka.	1380	46	314.51
3	Strengthening to the bund "Candle Khazan" at charao in Tiswadi Taluka.	2100	80	464.67
4	Desilting and Renovation of ponds, Tember Tollem at Curlim Cansaulim			49.39
5	Improvement to the "kantor (Bailo Cantor)"	725	13	83.58
	Total	6135	239	1350.89

2. List of works submitted to WRD for accord of Technical Sanction

Sr. No	Name of work	Length in Mts.	Area Protected in Ha.	Estimated Cost (Appx) in Lac
1	Reconstruction of sluice gate and improvement to the bund "Goltim-Diver in Tiswadi Taluka	2800	170	497.00
2	Construction of retaining wall protecting the "Parashte field" at Parashte in Pernemn Taluka	900	4	495.00
3	Reconstruction of sluice and strengthening to the bund "Donxi Khazan "at Narao in Bicholim Taluka.	430	40	261.00
4	Strengthening to the bund "Asnoi Khasan'' at Corjuem, Bardez Taluka.	960	19	303.00
5	Improvement to the bund "Salem Khazan" at Salvador-de-Mundo, Bardez Taluka	2000	50	246.00
6	Reconstruction of Sluice gate in the bund "Vai Casan"at jua St.Estevam in Tiswadi Taluka.	2000	45	25
7	Stregthening to the bund "Zuva Khazan"at Aldona, Bardez Taluka.	600	56	267
8	Closure of breaches and repairs to the bund Ofla & Dongo"at Carambolim, Tiswadi Taluka	3700	350	78
9	Closure of breaches and strengthening to the bund "Maha Khazan"at Marra Pilerne in Bardez Taluka	2000	200	52
10	Strengthening to the internal bund "Kaste Khazan"at Madapai, ponda Taluka	180	21	31
11	Strengthening to the internal bund "Zuva Khazan"at Aldona, Bardez Taluka	60	56	93
12	Strengthening to the internal bund (Bitorlo) of Irlem Bhailem Khazan"At Sancoale, Maramgoa Taluka.	681	100	83
13	Improvement to the bund "Novar Khazan"at Rai-Rachol in Salcete Taluka	1290	80	261
		17601	1191	2692.00

3. List of Estimates under Preparation

Sr No	Name of Work	Length in mts	Area protected in Ha	Estimated Cost (Appx) in Lakhs
1	Strengthening to the bund "Cave khazan" at Chodan of Tiswadi Taluka	1500	55	300.00
2	Strengthening to the bund "Neura khazan" at Neura of Tiswadi Taluka	4000	400	800.00
3	Strengthening to the bund "Hindlem khazan" at Narva of Bicholim Taluka	900	20	180.00
4	Strengthening to the bund "Diggi khazan" at Narva of Bicholim Taluka	800	11	160.00
5	Strengthening to the bund "Dosco" at Corjuem. of Bardez Taluka	750	23	150.00
6	Strengthening to the bund "Udatto Vavtoli khazan " at Amona of Bicholim Taluka	1700	100	340.00
7	Strengthening to the bund "Unvem khazan" at Amona of Bicholim Taluka	900	20	180.00
8	Strengthening to the bund "Bhailem Xeth Khazan" at Amona of Bicholim Taluka	2200	200	440.00
9	Strengthening to the bund "Mulakh Khazan" at Mayem of Bicholim Taluka	1740	40	348.00
10	Strengthening to the bund "Bhavkai Khazan" at Mayem of Bicholim Taluka	1800	50	360.00
11	Reconstruction of "Cono" sluice gate at Divar of Tiswadi Taluka	2000	40	25.00
12	Strengthening to the bund "Navclim Khazan" at Navelim of Tiswadi Taluka	4500	300	1000.00
13	Strengthening to the bund "Dubcnem Khazan" at Charao of Taluka	500	6	100.00
14	Strengthening to the bund "Bodiem Cummanem Khazan" at Tivim of Bardez Taluka	3000	75	600.00
15	Strengthening to the bund "Bar Amre Khazan " at Madkai of Ponda Taluka	1700	400	340.00
16	Strengthening to the bund "Shirdottem" at Shiroda of Ponda Taluka	1500	60	300.00
17	Strengthening to the bund "socrem Khazan" at Shiroda of Ponda Taluka	1000	40	200.00
18	Strengthening to the bund at "Vajem Shirodaof Ponda Taluka	500	10	100.00
19	Strengthening to the bund "Ponolem Khazan" at Ponolem, Aldona of Bardez Taluka	3500	100	700.00
20	Strengthening to the bund "Katrache Khazan (Cantorlacho Bund)" at Moira of Bardez Taluka	200	20	40.00
21	Strengthening to the bund "Dutone Khazan at Bastora of Bardez Taluka	300	150	60.00
22	Strengthening to the bund ""Kantra" at Pomburpa of Bardez Taluka	1200	125	240.00
23	Strengthening to the bund "Sancoalc Tikhajan" at Tikhajan Mayem of Bicholim Taluka	1400	50	280.00
24	Strengthening to the bund "Vainginim" at Mayem of Bicholim Taluka	1200	50	280.00
25	Strengthening to the bund "Thorli Devkadil" at Amona of Bicholim Taluka	1700	80	340.00
26	Strengthening to the bund "Rumod cantorla" at Amona of Bicholim Taluka	300	0.88	60.00
27	Strengthening to the bund " Dabem" at Virdi- Sanquelim of Bicholim Taluka	1200	22	240.00
28	Strengthening to the bund "Hindlem Khazan" at Naroa in Bicholim Taluka	900	20	180.00
29	Strengthening to the bund "unve Khazan at Amona in Bicholim Taluka	930	20	186.00
30	Strengthening to the bund "vatalim" at Lotulim in Salcete Taluka	400	2 direct 50 indirect	80.00
31	Strengthening to the bund "Oldicho Agor" at Carmona, Salcete Goa	300	2	60.00
32	Internal bund of Socolfond Condalem at Rassaimm Loutulim Goa	1380	25	276.00
33	Internal bund of Nocasama Tenents at Vanxem Loutulim Goa	2000	150	400.00
34	Replacement of wooden structure to the sluice gates and repairs to the bund "Vadoli" at Loutulim in Salcete taluka	5000	150	1000.00
35	Solvecho Guddi situated at Maina Curtorim Salcete Goa	500	5 direct 50 indirect	100.00
36	Repairs to the bund "Chirbhath "(Tolleabund) at Chinchinim	800	5 ha direct	160.00
37	Strengthening of the bund Carai and Macazana khazan at charao is Tiswadi	3000	150	600.00

	Taluk			
38	Strengthening of the bund calizo at tafordem khazan at Moira is Bardez Taluk	2000	50	400.00
39	Strengthening of bund olaulim khazan at olaulim is Bardez Taluk	2000	50	400.00
	Total	61200	3076.88	11665.00
	Cost of work listed at Annexure -I	6135	239	1351
	Cost of work listed at Annexure -II	17601	1191	2692
	Total	84936	4506.88	15708
	Add provision for Technical staff and mobility@1%			157.08
	total			Say 15900