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Preface

While planning for the coastal zone management, the groundwater component of the vulnerable zone is invariably ignored or neglected, as it is invisible from the surface and needs indirect as well as modern scientific technologies to understand. It is needless to say that the Mahanadi deltaic region is very thickly populated and people depend on the groundwater for their domestic use, as surface water is insufficient particularly during summer, very often polluted, and many areas are submerged by saline water. Frequent floods and cyclones also contaminate the surface water. The groundwater of the area is contaminated both vertically and laterally by the ingress of seawater in various degrees.

Many organisations work independently in this area without any coordination with each other. Everybody withdraws water from the subsurface on his or her own will, assuming that the resource is unlimited and without realising the consequences of such abuse to the precious resource. Over the years, the population, industrialisation, demand for non-monsoon irrigation and wastage have increased manifold. This has led to the installation of a good number of high discharge pumping wells, which has put more pressure on the limited fresh groundwater resource. Lack of awareness and management, poor understanding of the aquifer system, absence of proper legislation or its disregard and poor enactment have multiplied the problem.

In this book, the nature and extent of the different aquifer systems in the coastal part of the Mahanadi Delta have been delineated by geological, geophysical, hydro-geochemical and remote sensing techniques and methods. Geophysical logs and lithological samples of more than 150 boreholes of the area were analysed and interpreted to understand the subsurface condition. The aquifers are found to be extensive and often interconnected. There is a vertical as well as lateral variation in the salinity of groundwater. Basing on the mode of occurrence, aquifer properties, interconnectivity, etc., seven aquifer systems have been identified and named according to their positions from the top. The characteristics of the individual aquifer have been discussed in the book. In the shallow aquifer, which is named as A0, fresh groundwater is controlled by the geomorphology of the area and restricted to certain geomorphic features such as beach ridges, natural levees and some palaeo-channels in shallow zone of the coastal area, under unconfined condition, which need to be understood and protected. The deep aquifers are confined in nature and further classified into A1–A6. The A1 and A2 aquifers do not contain freshwater except very small brackish patch in the western part. The top surface of A3 aquifer is found at a depth of 78–104 metres and fresh in the north-western part with saline ingression from the northeast and southern sides. The top surface of A4 aquifer occurs at a depth of 120–140 metres with saline ingression from northeast and southeast sides. There is also a small patch of saline water in the west central part encircled by freshwater. The top surface of A5 aquifer is found at a depth of 173–220 metres in which freshwater extends from western side to the north-eastern part through the central part of the area. The A6 aquifer is found at about 285 metres and very little information is available for the understanding of its nature and disposition.

Chemical characteristics along with the usability of the groundwater from different locations and from different depths for drinking and irrigation analysis of the samples have been also discussed in the book. The freshwater is under hydrodynamic condition and with a delicate balance of saline–fresh interface. Ignorance, improper well construction and unregulated withdrawal may disturb the delicate balance and ultimately may cause the whole aquifer to turn saline. The available freshwater is precious and limited, and needs good groundwater management practice with different protective and corrective measures. Rearrangement of the pumping pattern, safe withdrawal of freshwater, scientific well design and adequate measures for artificial recharge should be taken up in the zone to protect the aquifers from saline ingression. Awareness among the people can also help in better management of this valuable resource.

As far as possible, the metric system of unit has been adopted, except in rare cases where the original units of expressions of the authors and the result of some of the instruments are maintained. I have endeavoured to acknowledge all sources of information and views of the original authors and the workers. Though care has been taken to incorporate correct information, some errors or omissions might have crept in inadvertently. I welcome pointing out of such omission, so that it can be rectified in the future edition.

I gratefully acknowledge the guidance and inspiration of Prof. R.N. Hota, Dr. K. A.S. Mani and Dr. D.K. Dutt. The contributions of Dr. Nihar Ranjan Das, Dr. Subash Ch Mahala and Shri Sanjaya Kumar Mishra deserve special mention. I am also indebted to Shri Samarendra Mohanty for his help in conducting the geophysical logs and sharing his knowledge about the area. I would remain obliged to scientists of CGWB, GWSI and RWSS for the help received from them at different stages.

Bhubaneswar, India Dr. Prakash Chandra Naik

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Chapter 1
Introduction

Abstract The coastal deltaic regions are areas of dense population and centre for economic growth. The socio-economic development in these regions also depends on the availability of the water resources. In these regions, there is a complex heterogeneous subsurface built up and groundwater is contaminated by various degrees of seawater intrusion with a delicate balance of saline-freshwater interface. The coastal aquifers of the Mahanadi Delta have a similar geo-environmental condition, where the groundwater has been subjected to sea-water intrusion, making it unsuitable for domestic and agricultural use. The available usable fresh water resource is limited here. The frequent cyclones and floods directly contaminate the surface water and the intrusion of the seawater has contaminated the groundwater in many places. Industrialisation and other human activities have put more pressure into this limited groundwater resource. The nature and extent of the different aquifer systems of the area have been delineated by geological, geophysical, hydrogeochemical and remote sensing techniques.

Keywords Coast · Mahanadi delta · Groundwater · Sea-water intrusion

1.1 General

Worldwide, population, economic production and social activities are mostly concentrated in deltas, coastal areas and riverbanks. Geologically, these areas are characterized by dynamic geo-environmental processes and as a result, exhibit highly variable environmental settings and a complex heterogeneous subsurface build-up. To some extent, socio-economic activities depend on the availability of water resources, raw material and manpower. The different geo-environmental hazards like flooding, sub-soil instability, coastal erosion and salt-water intrusion are the main constraints for the development in these areas. Moreover, human activities can lead to progressive environmental degradation and resource depletion. Therefore, proper information and understanding of the natural processes and

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subsurface conditions of these areas are prerequisites for the sound and sustainable socio-economic development.

It is also well known that groundwater is the principal source of drinking water in the rural habitations of the country and almost 85% of the rural water supply is dependent on groundwater. In many such habitations, sources are getting dry and the system becomes defunct because of excessive drawl of groundwater, environmental degradation and poor recharge. In many areas this leads to the emergence of quality related problems like excess fluoride, iron and arsenic contamination and salinity ingress into the drinking water sources.

Many people still believe that India's irrigation water mainly comes from canal irrigation systems. This might have been true in the past; recent research shows that groundwater irrigation has overtaken surface-water irrigation as the main supplier of water for Indian crop. Even more importantly, groundwater now contributes more to the agricultural wealth creation than any other irrigation source. Groundwater use is now so extensive that we can no longer afford to overlook it. Supplying to 27 million hectares of farmland, groundwater now irrigates a larger area than surface water (21 million hectares). This means it sustains almost 60% of the country's irrigated land. At the local level, an increasing number of districts today have larger shares of irrigated land under groundwater irrigation than surface water irrigation. A count of mechanized wells and tube wells also illustrates how quickly groundwater irrigation has spread. The number of wells has rocketed in the last 40 years, from less than one million in 1960 to more than 19 million in the year 2000 (IWMI-TATA 2002).

In the coastal plain where usable surface water is not enough and groundwater is limited, increasing water demand for tourism sector in addition to the irrigation and domestic water supply are threats for groundwater. Finally, if groundwater is overexploited, seawater moves into the aquifer and quality of groundwater starts to deteriorate. The salt concentration in it also increases.

The Mahanadi basin extends over states of Chhattisgarh and Odisha with a smaller area of Jharkhand, Maharashtra and Madhya Pradesh, draining an area of over 141 thousand sq. km and lies between east longitudes 80°28′ and 86°50′ and north latitudes 19°08′ and 23°32′. The basin has maximum length and width of 587 and 400 km. It is bounded by the Central India hills on the north, by the Eastern Ghats on the south and east and by the Maikal range on the west. The Mahanadi is one of the major rivers of the country and among the peninsular rivers it ranks second to the Godavari in water potential and flood producing capacity, It originates from a pool, 6 km from Farsiya village of Dhamtari district of Chhattisgarh and empties into the Bay of Bengal near False point about 16 km below the confluence of the Chitartala and the Mahanadi. The total length of the river from origin to its outfall into the Bay of Bengal is 851 km. The Seonath, the Hasdeo, the Mand and the Ib joins Mahanadi from left whereas the Ong, the Tel and the Jonk joins it from right. Six other small streams between the Mahanadi and the Rushikulya also form the part of the basin. The major part of basin is covered with agricultural land accounting to 54.27% of the total area and 4.45% of the basin is covered by water bodies. The river has been considerably tamed and the pattern of use of different stretches has undergone considerable change with the development of the multi-purpose river valley projects. Although rain fed, the river's water wealth is quite substantial, because of the occurrence of heavy rainfall in the catchment area.

The Mahanadi delta is formed at the mouth of the river Mahanadi. It is a classical arcuate type delta with an aerial spread of about 9000 sq km, associated with dense human settlement. It lies between 85°40′ and 86°45′ east longitudes and 19°40′–20° 35′ north latitudes. The depositional history in the geological past and the recent has shaped the hydrogeological set up in the delta. The oscillating depositional environments, fluviatile to marine, have given rise to a wide variety of sediments. The coarser clastic layers form the repository of groundwater, but tidal incursion, salt-water ingress from sea and seawater entrapped in the sediments, contaminate the groundwater and restrict the scope of its exploitation. This has created a complex hydro-chemical situation with saline water underlying or overlying the fresh water and fresh water bodies alternating with the saline water bodies. Groundwater occurs under water table and confined conditions, with auto-flowing conditions at many places. There is no uniformity in the quality variation of groundwater both laterally and vertically. Frequent cyclone and flood in this area contaminates surface and near surface water and makes it unsuitable for human consumption.

To understand the complexity of the hydrogeological condition as well as nature and extent of seawater intrusion in part of the Mahanadi delta close to the sea between river Devi and river Mahanadi, attempt has been made in the present work to collect all the hydrogeological data, analyse them systematically and draw meaningful inferences. The present work will help to understand the interrelationship of fresh and saline water, geometry of the different aquifers and the role played by geomorphological, lithological, climatological, hydrological, geophysical and hydro-geochemical factors in the occurrence, distribution, movement, recharge-discharge and quality of groundwater in the study area. In course of the present work information from various departments working in the area has also been collected and compiled systematically.

1.2 Location

The area selected for the detailed study is located in the lower part of the Mahanadi delta in the south of river Mahanadi between longitudes 86°17′–86°40′ east and latitudes 20°03′–20°20′ north.

It encompasses the major part of Kujang and Ersama blocks and a small area of Tirtol and Balikuda blocks of Jagatsinghpur district, Odisha, India. It is bounded by Mahanadi in the north; Balikuda block in the south, Bay of Bengal in the east and Tirtol block in the west (Fig. 1.1).