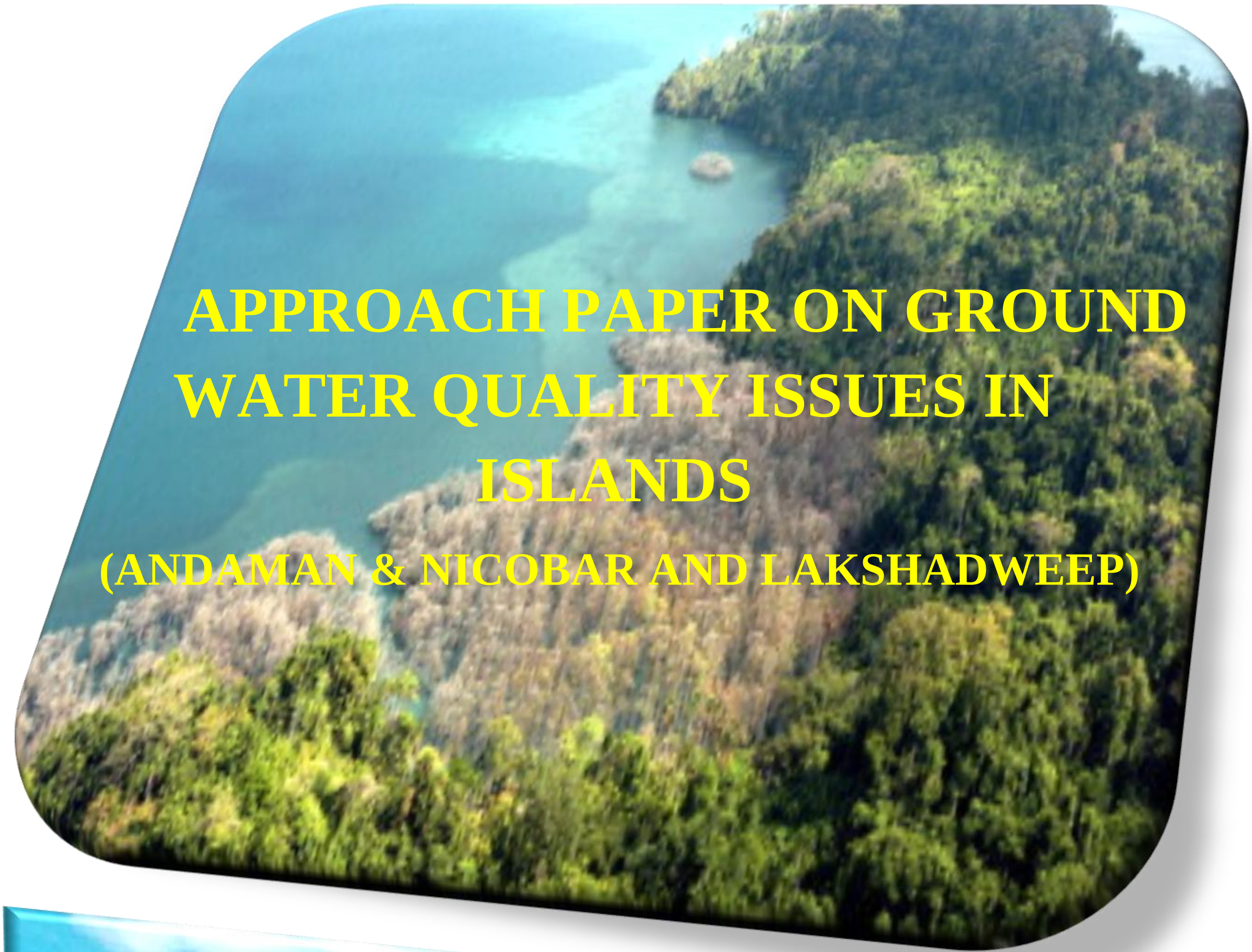

APPROACH PAPER ON GROUND WATER QUALITY ISSUES IN ISLANDS

(ANDAMAN & NICOBAR AND LAKSHADWEEP)

Central Ground Water Board
Ministry of Water Resources

Government of India
June 2010

उमेश नारायण पंजियार
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FOREWORD

I am happy to know that Water Quality Assessment Authority (WQAA) has taken an initiative to get the water quality issues examined in respect of the Andaman & Nicobar and Lakshadweep islands through an Expert Group headed by Shri S. Kunar, Member (SAM), Central Ground Water Board (CGWB). The Group has done a commendable job looking into the various aspects of water quality in respect of these islands. The Group has particularly undertaken the study to examine the effect of 'Tsunami' on the quality of ground water in the Andaman & Nicobar islands. The conclusions and recommendations, as indicated in the report, are very exhaustive and this would serve as a guide to the Administrators of the Andaman & Nicobar and Lakshadweep islands to take remedial measures for improving the quality of water.

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PREFACE

Water is a prime natural resource, a basic human need and essential for the sustenance of all life forms on the planet. The ever increasing demand for water has made this once abundant resource into a scarcity commodity. The heavy dependence on groundwater coupled with its hidden and unseen nature has resulted in development initiatives that are unaware of the hydrodynamic limits of the resource and unable to regulate the patterns of abstraction. Anthropogenic activities have further limited it through pollution. Another part becomes unusable due to the geogenic contamination. Developing and managing this resource in a sustainable way indeed pose many challenges.

Water Quality Assessment Authority, Ministry of Water Resources has taken a right and timely step in this direction to address the water quality issues in the Andaman and Nicobar Islands located in the Bay of Bengal and the Lakshadweep Islands located in the Arabian Sea. A Working Group was constituted by the Ministry of Water Resources under the Chairmanship of Sh. S Kunar, Member, Central Ground Water Board (CGWB) to prepare an 'Approach Paper' on ground water quality issues and its mitigation plan in Andaman & Nicobar and Lakshadweep islands.

The report submitted by the working group includes a detailed and comprehensive account of the basic information pertaining to each group of islands separately such as administrative set-up, population, climate, and also the technical aspects like geomorphology, geological and hydrogeological conditions, etc. A number of valuable recommendations have been given which will be of immense help for taking measures for improving the ground water quality in the islands.

CGWB has been actively engaged in carrying out Hydrogeological and Geophysical studies in the Andaman and Nicobar Islands since the past few decades. Ground water exploration was also carried out in Andaman and Nicobar Islands during 1984-91 during which period 47 exploratory bore wells were drilled. Some of these wells proved to be a great success and are being extensively used to augment the domestic water supplies to Andaman even today. Presently CGWB is carrying out artificial recharge and conservation studies for sustainable water supply in the Islands. 76 such schemes have been demarcated. CGWB also has carried out intensive studies specially to solve the chronic water supply problem to Port Blair city which has the bulk of population and activities, through Inter-island transfer of spring water.

The quality of ground water in shallow aquifers is generally within the permissible limits with low mineralization and fit for drinking and domestic purposes. However, the quality deteriorates with depth probably due to mixing with saline water below.

An effort has been made by the working group to highlight the effects of the devastating earthquake and tsunami of 26th December 2004 on the ground water regime of the islands. While the immediate effects have been severe in the Andaman and Nicobar islands, the Lakshadweep islands do not show any marked effects. It has been studied that as an immediate effect of the tsunami, partial and temporary contamination of ground water occurred due to large scale intrusion and mixing of the saline sea water. The effects however, gradually got stabilized. Comparison of results of chemical analysis of water samples collected during pre-monsoon period of 2002 (pre tsunami period) does not show much variation in the chemical quality when compared with analytical data of ground water samples collected during pre-monsoon period of 2007 (post tsunami period).

Lakshadweep islands are physiographically much different from the Andaman and Nicobar group. The 10 inhabited islands do face acute water scarcity and ground water is very susceptible to anthropogenic contamination because of the inherent properties of the underlying formations.. It has been brought out that as a whole the ground water in the islands is alkaline with a few exceptions. Pollution has been indicated as a major threat to the ground water in these islands. To overcome these problems Low Temperature Thermal Desalination (LTTD) water treatment technology has been successfully implemented in Lakshadweep islands and similar technology is proposed by the working group to be replicated in the Andaman and Nicobar islands as well.

It is hoped that the report will be of immense help for the island development and would serve as a guide for taking necessary remedial measures for improving the water quality and availability in the islands. The commendable work done by Shri S Kunar, Member, CGWB and other members of the working group from Central Ground Water Board namely, Shri. D. S. Thambi, Regional Director, Kerala Region, Trivandrum, Shri. Abhijit Ray, Superintending Hydrogeologist, Eastern Region, Kolkata, Shri S Bhattacharya, Scientist 'D', Central Ground Water Authority, New Delhi and Dr. Rajaram Purohit, Scientist 'B', Delhi deserves excellent appreciation for the initiative and sincerity of purpose. Shri Ram Mohan Mishra, Joint Secretary (Administration) and Member Secretary (WQAA), Dr P. K. Mehrotra, Director (WQ) and their team of officers definitely deserves deep appreciation for taking the initiative and enterprise under the aegis of the Water Quality Assessment Authority.

S Manoharan 5/5/2010
Special Secretary (WR)

Place: New Delhi
Date: 05/05/2010

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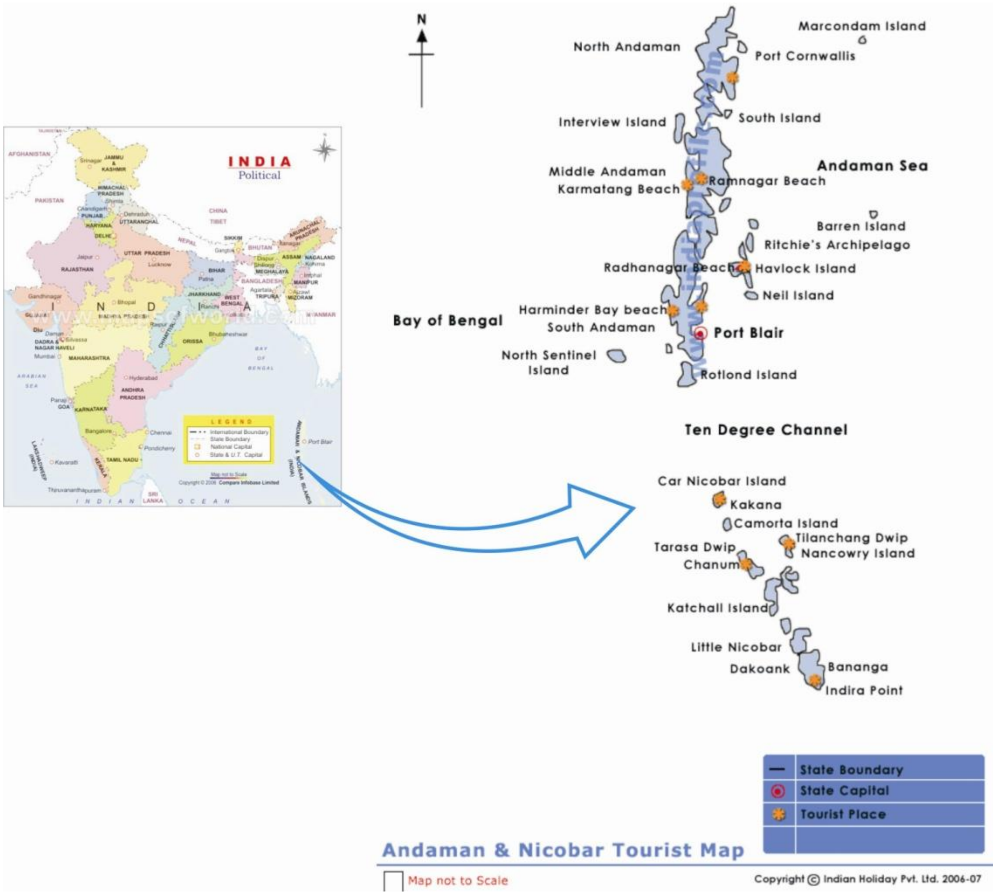
ANDAMAN AND NICOBAR ISLANDS

~at a glance~

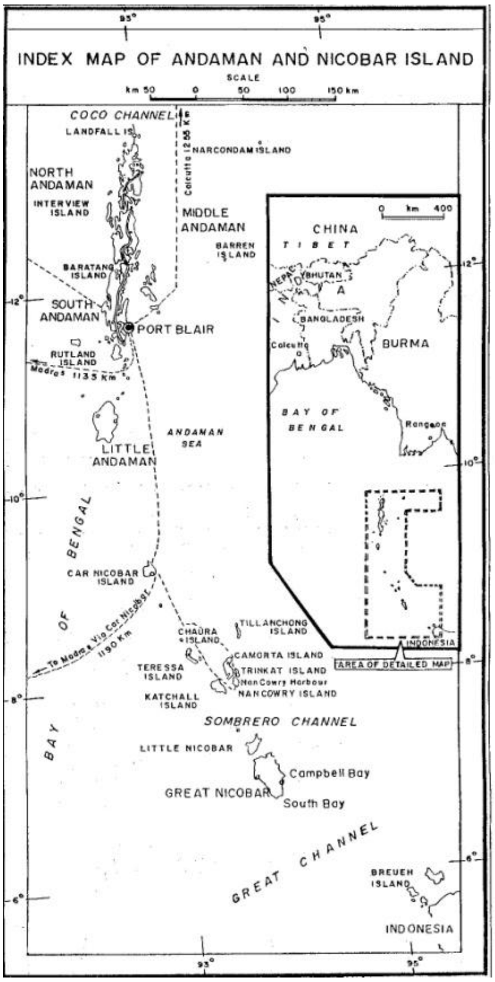


Location Bay of Bengal:	Long **92**^{0} to **94**^{0} E; Lat **6**^{0} to **14**^{0} N
Altitude (Highest Point):	Saddle Peak (N Andaman) **732 m**; Mt. Thullier (Great Nicobar) **642 m**
Coastline of A & N Islands:	1962 km.
Dimensions of Andaman Islands:	Total Length **467** km; Max. Width 52 km; Avg. Width 24 km.
Dimensions of Nicobar Islands:	Total Length **259** km; Max. Width 58 km;
Largest inhabited Island (Andaman Group):	Middle Andaman Islands 1536 sq km.
Largest inhabited Island (Nicobar Group):	Great Nicobar Island 1045 sq km.
Smallest inhabited Island (Andaman Group):	Curlew Island (2001 Census) 0.03 sq km.
Smallest inhabited Island (Nicobar Group):	Pillomillow Island (2001 Census) 1.3 sq km.

Distance by Sea:	Port Blair & Chennai -	1190 km.
	Port Blair & Kolkata -	1255 km.
	Port Blair & Visakhapatanam-	1200 km.
Distance by Air:	Port Blair & Chennai -	1330 km.
	Port Blair & Kolkata -	1303 km.

1.0 INTRODUCTION

Occurring to the east of the Indian mainland is an archipelago of over 500 islands, islets and rocks, covering an area of 8249 sq kms, known as the Andaman and Nicobar islands. Also referred to as the Bay Islands, these lie in the Bay of Bengal over 1200 kms east of the mainland. These islands form an arcuate chain, convex towards west having an approximate North-South trend over a length of 780 kms., within the geographical coordinates of 6^0 N to 14^0 N latitude and 88^0 E to 92^0 E longitude. These islands are the emergent peaks of submerged mountains extending from the Arakan Yoma ranges of Burma in the North to Java and Sumatra in the South-East.



The Union Territory of Andaman and Nicobar was a uni-district territory. The two districts of Andaman and Nicobar were formed by the Administration in the year 1974. Presently, the entire group of islands remains divided into three districts, namely, the North and Middle Andaman district, South Andaman district and the Nicobar district. The Andaman group of islands occur North of the 10^0 channel and has an area of 6408 sq kms., with 24 islands in them having human settlement. Five of the largest islands, of this group, Baratang, Rutland, and North, Middle, and South Andaman, lie close together and are known as the Great Andamans. Another main island, Little Andaman, is separated from the cluster by the waters of Duncan Passage. The Nicobar group of islands lie South of the 10^0 channel covering an area of 1841 sq kms., with 12 islands having human settlement. The two districts are separated by 160 kms of sea.

Baring a few islands in the Nicobar district, the terrain is mostly undulating with the main ridges running North-South. In between the main ridges deep inlets and creeks are formed by submerged valleys.

The islands have a large area under forest cover. The area under forest cover is 7171 sq kms., which accounts for nearly 87% of the total area of Andaman and Nicobar islands. The areas under the different categories are as follows:

Reserved Forests	25.43%
Protected Forests	31.41%
Tribal Reserves	28.10%
Sanctuaries and National Parks	1.21%
Other than Forest areas	13.85%

1.1 ADMINISTRATIVE SET UP

The Andaman and Nicobar group of islands is divided into three districts, each headed by a Deputy Commissioner, with the capital located at Port Blair, namely, a) North & Middle Andaman; b) South Andaman; and c) Nicobar

The North & Middle Andaman district has a geographical area of 3251.85 sq kms., with 2 sub-divisions (Mayabunder and South Andaman), 3 tehsils (Diglipur, Mayabunder and Rangat) and 100 revenue villages. Diglipur is one of 3 tehsils of North & Middle Andaman. It is the largest and farthest town of North Andamans, 290 km from Port Blair. Main attractions around Diglipur are Ross & Smith Island, Saddle peak national park, Rampur beach and mud volcanos. The tallest peak of the islands called the Saddle Peak (732 Metres) is located in Diglipur. Kalpong, the only river of Andaman flows from here.

South Andaman district has an area of 2980 sq km., with 2 tehsils namely "Port Blair"," Ferrargunj" and 99 revenue villages. Little Andaman island is the fourth largest of the Andaman Islands with an area of 739 sq km, lying at the southern end of the archipelago. It is separated from Rutland Island in Great Andaman by the Duncan Passage. It is home to the Onge tribe and has been a tribal reserve since 1957. "Little Andaman" which is sometimes considered as tehsil is yet to be notified. The capital of Andaman and Nicobar, Port Blair (since 1789. Originally, Port Cornwallis) is located in this district.

The Nicobar District is separated from Andaman group of Islands by 160 kms., wide channel, and has an area of 1841 kms., comprising 22 Islands, of which 12 are inhabited and 10 uninhabited (Table 1 a & b). The maximum length of Nicobars is 310 kms., and maximum width is 57.96 kms. The extreme Southern most ‘Pigmalion Point’ presently known as Indira Point is also southern most point of India, and is 310 kms., from Car Nicobar and barely 140 kms., from Sumatra Island (Indonesia). The head quarters are located at Car Nicobar.

Indian nationals do not require a permit to visit the Andamans. However, permits are required to visit Nicobar Islands and other tribal areas. Non-Indians need a *Restricted Area Permit* to visit the islands, but these are now issued on arrival at the Port Blair airport.

Table 1(a). Inhabited Islands

Sl. No	Geographical Name	Native Name	Area (sq kms.)	Population 1991	Population 2001
1.	Car Nicobar	Pu	126.9	19,252	20,292
2.	Chowra	Sanenyo	8.2	1,222	1,385
3.	Teressa	Luroo	101.4	1,777	2,026
4.	Bompuka	Poahat	13.3	53	55
5.	Katchal	Tihayu	174.4	5066	5,312
6.	Kamorta	Kamorta	188.2	2859	3,412
7.	Nancowry	Mout	66.9	944	927
8.	Trinket	Laful	86.3	350	432
9.	Little Nicobar	Long	159.1	171	348
10.	Pulomilo	-	1.3	90	150
11.	Kondul	Tamengshe	4.6	143	150
12.	Great Nicobar	Tokieong Long	1045.1	6,548	7,566

Table 1(b). Uninhabited Islands

Sl. No	Geographical Name	Native Name	Area (sq kms.)
1	Battimaly	Kuono	2.01
2	Tillangchong	La-uk	16.84
3	Meroe	Meroe	0.52
4	Teris	Tean	0.26
5	Menchal	Menchal	1.30
6	Tark	Fuya	0.26
7	Cubra	Konwana	0.52
8	Isle of Man	-	-
9	Megapod	-	-
10	Pigeon	-	-

1.1.1 Population

Population of Andaman and Nicobar islands take into account the inhabitants of about 38 of the 500 odd islands that comprise the entire Union territory. Given the total land area of the islands, the total population of Andaman and Nicobar islands taken together according to the 2001 census amounted to a shade above 350, 000. The tehsil wise division of the total population in Andaman and Nicobar islands are given in Table 2:

Table 2. Tehsil wise population of Andaman and Nicobar

Area	**Tehsil**	**Population**
North and Middle Andaman	Diglipur	42,877
North and Middle Andaman	Mayabander	23,912
North and Middle Andaman	Ranagat	38,324
South Andaman	Ferrargunj	48,628
South Andaman	Port Blair	159,845
Nicobar	Car Nicobar	20,292
Nicobar	Nancowry	21,776

The population of Andaman and Nicobar islands features a number of ethnicities. Given the small area, it is surprising to notice the sheer variety of ethnic groups that comprise Andaman and Nicobar islands population. The tribal communities of Andaman and Nicobar belong to both the African and Mongoloid groups. Some of them still continue with the primitive hunter-gatherer way of lives, some depend solely on fishing. There are also the descendants of the prisoners who were sent here as penal measures, and they also contribute largely to the population of the area. Some of the major proto-African Negroid tribes within the population at Andaman and Nicobar islands are the Jarawas, the Ongees and the Sentinelese.

The Shompen and the Nicobarese are the two main Mongoloid tribes of Andaman and Nicobar. Many of these tribes have fearfully low number of people left and are staring at extinctions. The many earthquakes and natural disasters including the tsunami, have made a lasting damage to the total demographic strengths of these tribes.

The islands have been witnessing a gradual growth in the population as will be evident from the table 3 & 4 below:

Table 3. Population growth

Year		1971	1981	1991	2001
Total Population		**115133**	**188741**	**280661**	**356265**
	Male	70027	107261	154369	192985
	Female	45106	81480	126292	163280
Rural Population		**88915**	**139107**	**205706**	
	Male	53195	78401	111986	
	Female	35720	60706	93720	
Urban Population		**26218**	**49634**	**74955**	
	Male	16832	28860	42383	
	Female	9386	20774	32572	

Table 4. Population as per Religion

Religion	1971	1981	1991
Hindu	70134	121793	189521
Christian	30342	48274	67211
Muslim	11655	16188	21354
Sikh	865	991	1350
Buddhist	103	127	322
Jain	14	11	17
Others	2020	1357	886

1.2 CLIMATE

The islands receive rainfall from both the south west and north east monsoons and maximum precipitation is between May & December. The islands enjoy tropical humid climate because of their location in equatorial zone surrounded by Andaman Sea. Because of paucity of climatic data from all along the islands, many of the meteorological parameters are described based upon the data collected from the IMD station at Port Blair. The relative humidity varies from 79% to 89%, wind speed varies from 7 km/hr to 10 km/hr while the maximum and minimum temperature fluctuate between 27 to 33^0 C and 21 to 25^0 C. Daily evaporation rate in the island is fairly high which cumulatively ranges from 1500-1800 mm per annum. Since the islands are mostly discrete and the topography and types of vegetarian, forestry as also the geographical localizations are varied, for being situated in a slender chain of nearly 740 km length, the rainfall distribution is highly varied and anomalous. These can be quite evident from the rainfall record in the islands. Prior to 1990 the rainfall used to commence from first week of May every year while now it is receded to first week of June as happened in 2001, 2002 and 2003. In 2002 the situation worsened and Dhanikhari dam got dried up and the Port Blair town water supply was totally shattered. Fortunately in 2004 the rainfall in Andaman District has been close to normal. However, the Tsunami devastated Southern group of Islands is not receiving appreciable rainfall. The normal rainfall of Port Blair is 3180 mm where as the mean annual rainfall of Andaman District is and Nicobar Districts are 2629.0 and 2624.0 mm respectively. In southern group of islands the rainfall pattern is important for large scale rainwater harvesting as also artificial recharge of ground water in specific areas. The rainfall in Andaman and Nicobar islands during the period 2004 to 2009 is given in Table 5 & 6.

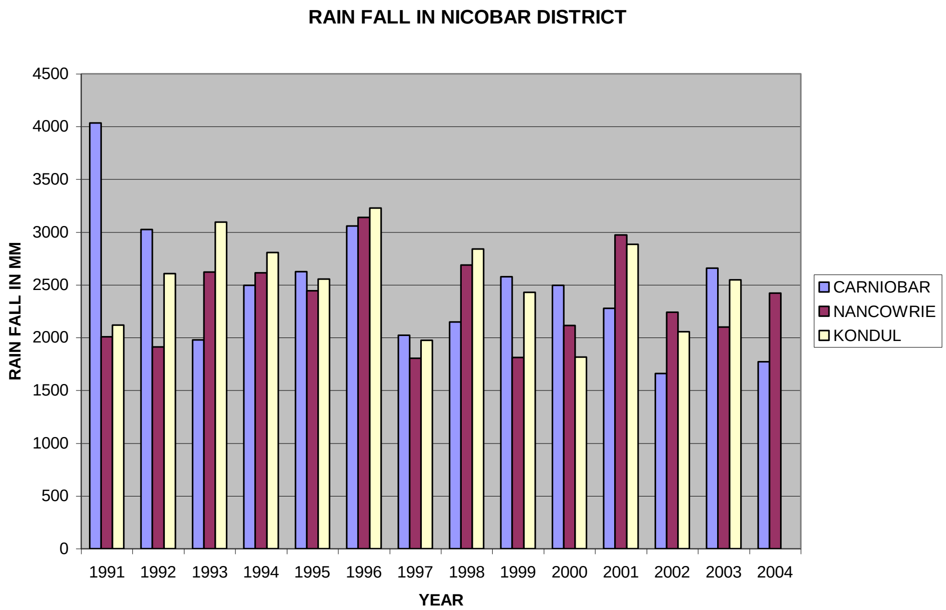


Table 5. Rainfall (in mm) during the period 2004 to 2009 (Andaman)

Year	2004		2005		2006		2007		2008		2009	
	RF	Dep	RF	Dep	RF	Dep	RF	Dep	RF	Dep	RF	Dep
Jan	59.1	49	2.7	-93	6.9	-83	0.0	-100	11.8	-70	0.0	-100
Feb	109.0	453	0.0	-100	0.4	-98	0.0	-100	67.7	244	0.0	-100
Mar	26.0	177	3.6	-62	14.0	49	0.0	-100	97.3	935	23.8	153
Apr	30.2	-47	36.7	-35	133.6	136	56.8	0	194.7	243	131.9	133
May	546.8	46	220.0	-41	336.1	-10	338.4	-10	650.4	74	274.4	-27
Jun	456.6	-14	482.7	-9	374.1	-29	390.7	-26	503.9	-5	758.2	43
Jul	313.9	-32	400.5	-13	200.5	-56	469.2	2	595.6	30	345.5	-25
Aug	336.1	-27	337.6	-26	243.4	-47	455.0	-1	498.9	9	447.6	-2
Sep	270.8	-42	506.4	9	599.6	28	546.6	17	399.8	-14	421.1	-10
Oct	239.0	-20	329.2	10	369.4	24	241.7	-19	243.1	-19	319.6	7
Nov	177.3	-16	296.6	41	57.1	-73	199.4	-5	303.1	44		
Dec	2.2	-98	215.8	71	66.5	-47	34.2	-73	47.4	-62		

Note: RF =Rainfall in mm; Dep = % departure from normal Rainfall

Table 6. Rainfall (in mm) during the period 2004 to 2009 (Nicobar)

Year	2004		2005		2006		2007		2008		2009	
	RF	Dep	RF	Dep	RF	Dep	RF	Dep	RF	Dep	RF	Dep
Jan	25.5	-77	75.5	-33	49.4	-56	21.5	-81	33.2	-71	67.9	-40
Feb	113.4	84	0.0	-100	61.6	0	7.0	-89	14.0	-77	27.9	-55
Mar	93.5	78	83.6	59	169.2	222	60.4	15	182.3	247	86.6	65
Apr	83.4	-26	66.8	-40	305.5	173	51.1	-54	235.9	111	161.1	44
May	390.9	6	262.8	-29	364.7	-1	433.8	18	187.0	-49	465.2	26
Jun	324.9	4	430.1	38	344.3	10	343.7	10	282.3	-10	139.0	-56
Jul	293.7	6	166.9	-40	141.4	-49	180.8	-35	214.3	-23	152.7	-45
Aug	206.2	-24	174.2	-36	137.1	-49	347.6	28	302.6	11	169.1	-38
Sep	323.6	-5	183.9	-46	378.5	11	277.2	-18	96.4	-72	164.9	-51
Oct	207.8	-36	226.0	-31	409.8	26	232.8	-29	252.3	-23	122.6	-62
Nov	164.7	-49	323.4	0	144.0	-56	315.1	-3	404.1	25		
Dec	102.5	-63	528.3	92	103.4	-62	123.7	-55	161.3	-41		

Note: RF =Rainfall in mm; Dep = % departure from normal Rainfall

1.3 GEOMORPHOLOGY

The Andaman & Nicobar islands have varied topographical features. The Andaman group of islands generally features a mountainous terrain with long ranges of hills and narrow valleys. The maximum altitude of these islands is at Saddle Peak, which is about 730 m above mean sea level. The peak is formed of sandstone, limestone and clay. There are no great elevations and the slopes are also moderate.

The Nicobar Islands are surrounded by the shallow seas and coral reef. The topography of Nicobar Islands features long, sandy beaches. Katchal and Car Nicobar have almost flat terrain. In Great Nicobar and Little Nicobar, the land is very irregular, having steep hills and valleys.

Car Nicobar is remarkably flat except for some cliffs in the north and small hilly areas in the interior. It is bordered by a silvery beach and areas of flat ground consisting of coraline diluvium.

Nancowry and Kamorta, have a hilly terrain covered with grass, forming undulating meadows. Empress Peak is about 1,420 feet (432.8 m) high and is the highest in Kamorta. The Nancowry harbour, with two entrances towards the east and west, is one of the finest and safest harbours in the world. Katchal is one of the largest islands in the central group. It is about 156 sq km in area. It is slightly hilly in the centre but has a remarkable flat area, like Car Nicobar. Katchal has the most suitable soil for paddy cultivation. Trinket is another small flat island. It is located at the eastern entrance to Nancowry harbour. Chowra is almost flat, except for a hill which is located at its southern tip. Like Car Nicobar it has no safe berthing and the coral formation around the island is reported to be a great impediment to anchoring vessels.

Teressa and Bompoka are also hilly. The former has a considerable flat area, while the latter has a few flat spaces around the western coast. Tillangchong has hills of elevations above 1,000 feet.

Great Nicobar is the southernmost land mass of the Nicobar group of Islands. Most of this island is hilly and undulating. The main hill range runs from north to south. Mount Thullier which is about 2,105 feet (641.6 m) high is the highest peak. Galathea, Alexandra and Dagmar are the major rivers. Kondul and Little Nicobar are also hilly and undulating.

As the Nicobars apparently lie directly in the local line of greatest weakness, severe earthquakes are to be expected, and have occurred many times. Stocks of great violence were recorded in 1847, 1881 (with tidal waves), and many times during 20th century. The tidal waves caused by the explosion of Krakatoa in the Straits of Sunda in 1883, were severely felt.

An earthquake epicenters off the west coast of Sumatra measuring 8.6 on the Richter scale caused a severe tsunami to strike parts of South-east Asia, India, Sri Lanka on 26 December 2004. Sea water inundated several coastal towns and villages taken over 2,50,000 human lives and affecting close to five million people.

In general, barring a few small Islands in the Nicobar group, all the others have undulating terrain with main ridges running North-South. There are also spurs running East – West in between the main ridges. Deep inlets and creeks are formed by the submerged valleys. Flatlands are few and perennial streams non – existent in most of the Islands except in Great Nicobar where there are 5 perennial rivers. Coral reefs surround most of the Islands.

1.4 GEOLOGY

The Islands are composed mainly of thick Eocene sediments deposited on Pre-Tertiary sandstone, silt stone and shale with intrusions of basic and ultra – basic igneous rocks. In the geologically Younger Richie's archipelago, calcareous sand stones are more common. The available geological evidence leads us to assume the possibility of geological period when the Andaman and Nicobar Islands formed a range between Burma and Sumatra. The Andaman and Nicobar Islands with Preparis and Cocos formed one continuous hill connecting this with Burma (Myanmar) through Cape Negrais.

This range was separated from Nicobar, the other continuous Island, by a strait of about 400 fathoms depth and 160 km width. Further in South the Nicobar Island was separated from Sumatra by yet another strait of 600 fathoms depth and about 48 km width. Thus Andaman and Nicobar formed 1120 km stretch part of Aracan Yoma Range of Burma, on the East of which, occur curious Islands like Narcondum and Barren.

It is believed that the dormant Barren Island Volcano belongs to the immediate Sunda group of Volcanoes, while the long extant Narcondum Volcano belongs to the Pegu group, both belonging to the general Sunda group. These Volcanic Islands in line with Nicobars form one of the principal lines of weakness in the earth's surface. It is noteworthy that the Andamans are just off this and escape the violent earthquakes to which the others are liable.

It is possible that the reason for Andamans escaping violent earthquakes while Nicobars are subject to them is that they are just off the line of greatest weakness which may run from Sumatra through Great Nicobar, Car Nicobar, Barren and Narcondum Islands to Aracan Yoma.

The Andaman Basin extends 1200 km from Burma to Sumatra and 650 km from the Malay Peninsula to the Andaman and Nicobar islands. The eastern portion of the basin is the Malay continental margin, a 250 km wide shelf which was cut into Malayan Paleozoic and Mesozoic rocks during the Early and Middle Tertiary. Subsequent folding and faulting modified the shelf, forming at least two major terraces, the Sumatra Shelf-basin and a 650 km long continental slope. Only a discontinuous veneer of Cenozoic sediments covers the continental margin, except for the Sumatra Shelf-basin, in which over 1 km of sediment has collected.

The Andaman-Nicobar Ridge, western boundary of the basin, consists of an Upper Cretaceous serpentinite-ophiolite-radiolarite core overlain by Paleocene to Miocene graywackes and shales at least 3000 m thick. Between the ridge and the Malay continental margin lies the Central Andaman Trough, two elongate basaltic seamounts 220 km long, and a complex system of rift valleys and associated smaller volcanic seamounts. Maximum depths of 4400 m in the Andaman Basin are located in the major branch of the rift system, the 700 km long Nicobar Rift Valley which is the proper boundary between the Andaman-Nicobar Ridge and the Central Andaman Trough.

Sediments in the Central Trough are 1.5 km thick, surprisingly thin in view of the huge Irrawaddy River sediment load which enters the north end of the basin and is trapped in the basin by surface currents. Large volumes of detritus which must have been produced during the Tertiary plantation of the Malay shelf also cannot be accounted for by the minor Andaman Basin fill. The great thicknesses of pre-Late Miocene Tertiary sediments in the Andaman-Nicobar Ridge were derived from the northeast, an area now occupied by submerged youthful rift topography. It is concluded that the sediments derived from planation of the Malay shelf were shed into an adjacent Tertiary trough which was subsequently molded into the Andaman-Nicobar Ridge during Oligocene to Miocene time. The continental margin and the Andaman-Nicobar Ridge were then rifted apart by Late Miocene to Recent movements which formed the Andaman Basin as a rhombochasm. Geophysical data support this interpretation.

The entire southeast Asian margin is marked by evidences of south-southeastward movement. Dextral strike-slip along Sumatra and sinistral strike-slip along the Philippine Rift are documented in the literature. The Java Trench along the front of the block has been interpreted as a product of thrusting.

Late Cretaceous igneous rocks – the “ophiolite suite”, marine sedimentary rocks of Paleocene to Oligocene age and Recent to sub-Recent beach sands, mangrove clay, alluvium and coral rags are exposed in the islands.

The ophiolite suite comprises ultrabasic rocks mainly serpentinite, peridolite with harzburzite, dunite, basic to intermediate lava, chert and jasper with radiolaria. They are exposed in South, Middle and North Andaman and in Great Nicobar. They are underlain by older sedimentaries comprising quartzite, slate, phyllite and schists.

The Tertiary sediments classified as the Mithakhari and Andaman Flysh Group comprises thinly bedded alternations of sandstones and siltstones, grit, conglomerate, limestones, shales, etc., are of Upper Cretaceous to Upper Eocene age.

The Tertiary Group is overlain successively by the Archipelago Group, Nicobar Group and the Quaternary Holocene Group, intervening with unconformity. The generalized succession is given in table 7 below:

Table 7. Geological Succession of Andaman District

Age	Group	Formation
Recent to sub-Recent	Quaternary Holocene Group	Beach sands, Mangrove clay, Alluvium, Coral rags and Shell limestone, loosely consolidated pebble beds
~~unconformity~~~~~~~~~~~~~~~~~~~		
Pleistocene to Late Pliocene	Nicobar Group	Shell limestone, Sandstone, Claystone, etc.
Miocene	Archipelago Group	Upper white claystone Melville Limestone
~~unconformity~~~~~~~~~~~~~~~~~~~		
Oligocene to Paleocene	Andaman Flysh Mithakhari Group	Thinly bedded alternations of sandstones and siltstones, grit, conglomerate, limestones, black shales, thinly bedded chert, pillow lava, etc.
~~unconformity~~~~~~~~~~~~~~~~~~~		
Late Cretaceous	Ophiolite Suite	Dyke swarms, acidic suite, with related effusive, mafic suite, ultramafic suite, etc.

1.5 PEDOLOGY

The Soils of the Andaman and Nicobar Islands have been classified into 3 orders Entisols, Inceptisols and Alfisols. The main agricultural soils are found in the valleys and are of alluvial and colluvial origin. The coastal areas prone to tidal floods may have acid sulphate soils. On the whole soils of these Islands are nutritionally poor and their organic matter content is on decline.

The soils of the islands vary in depth, texture and chemical composition and are acidic in nature. These are medium textured on the surface and medium to heavy textured in the sub-soil. Humus is generally lacking in the forest soils as it is generally washed away due to copious rainfall and steep slopes. These are clayey, partially drained and have poor water retention capacity. The depth of the soils is very shallow in the hill slopes and rarely exceeding 3 m in the valleys.

1.6 HYDROGEOLOGICAL CONDITIONS

Hydrogeologically, there are three major formations constituting the water table aquifer:

1. The porous formation consist of beach sand with coral rags and shells,
2. The thin cover of alluvium in the valleys and foot hills adjacent to valleys, and
3. The moderately thick pebbly valley fills deposits (colluvium) in the narrow intermontane valleys.

The thickness of the beach sands and alluvial deposits ranges from 3 to 6 m and sometimes up to 9 m. In Great Nicobar the thickness is thinner, only 2 to 2.5 m. The colluvial deposits in narrow intermontane valleys e.g., Beadonabad valley have much higher potentiality. One bore well of 152 mm diameter was drilled by Central Ground Water Board down to 16.50 mbgl tapping the total thickness of the saturated colluvial deposits and yielded 72 m^3/hr. and pumping for 500 minutes did not show any deterioration in chemical quality. The drawdown was recorded as **5.67 m** and Transmissivity was **127 m^2/day**. The well could cater to the domestic need of 10000 rural population. The fissured formation consists of the upper Cretaceous Ophiolite Suite of rocks including the basic volcanics, the ultrabasic and intermediate to acid plutonic rocks. Based on the compactness and fracturing of these rocks as revealed by exploratory drilling carried out in parts of the island the rocks are again classified as consolidated group and semi consolidated group. The fractured upper Cretaceous igneous rocks and the Lower Tertiary conglomerate, grits, graded sandstone (greywacke) and their weathered upper mantle form the aquifers, the weathered mantle is seldom 3 to 4 meter thick but adjacent to the valleys it is about 6 meters.

The saturated thickness of the weathered mantle and the immediately underlying shallow fracture zones form the water table aquifer. Deeper fracture zones within 60 mbgl form semi confined to confined aquifer. It is apparent from the study that the weathered sandstones are poor aquifers whereas the weathered volcanic rocks act as moderate to good aquifers at suitable locales. Results of 18 exploratory bore wells in South Andaman show that the deeper fractures imparting secondary porosity and permeability are restricted within 60 mbgl in sedimentary rocks and within 52.7 m in the volcanics and the intermediate plutonic rocks. The most productive fracture zones are in the volcanic rocks as noticed at Calicut in the depth range of 14 to 20 m, and 45 to 52 m where an intrusion of ultrabasic rock (Serpentinites) was noticed. The yield of the bore well was recorded as **44.67 m^3/hr**, drawdown was **8.23 m** after 500 minutes of pumping and Transmissivity was calculated to be **139.6 m^2/ day**.

The fractured volcanic rocks elsewhere are not productive eg. Brichganj and Hamfreyganj where the yield of the tube wells were in the order of 1.18 m^3/hr and 0.52 m^3/hr respectively. It appears that the fractured volcanic rocks are most productive where they are intruded by the ultrabasics. In the area covered by the fractured sedimentary rocks, 13 exploratory bore holes were drilled and 2 boreholes were found successful i.e., at Potheropore and Dilthaman Tank. At both the places Mithakari Sandstones and Shales were encountered. The productive fracture zones at Prothrapore occur between 25 to 60 meter, and yielded was 17 m^3/hr. However, the water which is brackish. The borehole at Dilthaman Tank yielded very less but the water was potable and EC values were within limits. The boreholes drilled at other places in the sedimentary rocks through dark grey shale of Mithakari Group were found dry.

The area covered with semi consolidated Lower Tertiary sedimentary rocks in the Great Nicobar Island were also explored. The thin bedded fine grained sand stone – clay stone alternation cannot be properly termed as aquifers. The maximum discharge obtained by tapping 31 m thick fine grained, soft argillaceous sand stone between 20 -92 mbgl, was 187 lit/hr and quality of water was found good. Slightly better discharge was found in the same Island but, the water was brackish (EC 4503 µs/cm at 25 ^{0}C). In sedimentary rock in valleys and adjacent to Bays, depth of dug wells are restricted to 3.5 to 4 mbgl, depth to water level in the dug wells in valleys range from 2.5 to 2.75 m, and in the igneous rock in same physiographic unit depth to water level generally is less than 3 mbgl, with a seasonal fluctuation around 1.5 to 2.5 m. Specific capacity of lower Tertiary Sandstone, was found very low in the range of 1.12 to 0.261 lpm/m, in the weathered volcanic rocks. Specfic Capacity values was in the order of 0.79 and 9.55 lpm/m.

A number of springs originate from the forests clad hills in both the igneous and sedimentary terrain and most of them are being utilized for rural water supply by APWD. Many of the spring fed streams have been bunded at higher altitudes to create a small reservoir from which water flows down by gravity through pipe lines to the villages located at lower altitudes or foot hills. With the decline of ground water table during dry season, the discharge from the spring decreases and majority of them dry up.

1.6.1 Ground Water Monitoring

In order to study the behaviour of ground water regime with time and space in Andaman group of islands 63 ground monitoring stations were established, and periodic water level measurements are being taken 2 times in the year, for pre-monsoon period during May and for the post-monsoon period during December. Depth to water level in majority of the monitoring stations ranges between 2- 5 m bgl (66%) and within 2 m bgl (25%) in rest of the stations during May. The minimum water level 0.9 m bgl was recorded during May at Maya Bunder in North Andaman, and maximum 10.55 m bgl at Calicut, in South Andaman. The water level trend has been analysed for all measurements which shows that there is a rising trend of water level in majority of the wells during 1998 to 2007 to the tune of 0.021 to 1.19 m/yr. However during the same period the pre monsoon trend shows falling trend in most of the wells.

1.6.2 Ground Water Resources

As per the GEC 1997 norm the watershed or administrative unit could not be applied here since the islands are generally separated. There are 36 Islands which are inhabited, hence the water resources of these Islands are taken into consideration. During computation the intermontane valleys and relatively flat topographical areas were considered as recharge areas. The hilly areas having slope more than 20% are deducted from the geographical area available in the inhabited islands. The water level data of all 36 islands are not available; the Rainfall Infiltration Method was adopted for resource estimation. Base flow of ground water through springs was also noticed, and the discharge was computed and added to ground water draft. The estimated resources are as follows:

- Area considered for Resource Estimation : 7860.51 sq km.
- Ground water Assessment year & Unit : 2001 & 36 inhabited Islands
- Gross Ground water Recharge : 326.273 MCM
- Tentative Base Flow : 5.475 MCM
- Net Ground water Recharge : 320.798 MCM
- Current Annual Gross Ground water Draft for drinking purpose : 11.978 MCM
- Annual allocation of groundwater for domestic and industrial water supply for next 25 yrs : 7.907 MCM
- Available ground water for future use : 302.772 MCM
- Stage of Ground water development : 3.73 %
- Categorisation : Safe

1.6.3 Ground Water Exploration

Central Ground Water Board carried out ground water exploration in Andaman and Nicobar islands from 1985 to 1994 during which 47 exploratory wells had been drilled. Of these, 18 wells have been constructed in South Andaman, 11 in Middle Andaman, 2 in North Andaman, 9 in Nicobar, 3 in Nancowry and 4 in Katchal. It is concluded from the exploration data that, in general, productive aquifers exists down to a depth of 60 m bgl. The quality of water in deeper aquifer deteriorates, probably due to contamination with the saline water below. The productive aquifer occur s within 60 m bgl in fractured volcanic and 30 m bgl in valley fill deposits with discharge varying from 10 to 45 m^3/hr. However, no productive granular zones were encountered down to the drilled depth of 160 m bgl in the semi-consolidated sedimentary formation. The valley fill deposits comprising of assorted pebbles, cobbles and gravels of volcanic, ultramafics and cherts in sand clay matrix in certain valleys are proved to be productive. Ground water quality in these shallow aquifers is suitable for drinking and domestic purposes. In Middle and South Andaman the discharges from the bore wells ranges from 10 to 25 m^3/hr, and 0.2 to 44.67 m^3/hr respectively. In Kamorta island the discharge varies from 0.5 to 1.0 m^3/hr.

The wells drilled by Central Ground Water Board at Beadonabad and Calicut, in South Andaman, are presently being used for water supply by Andaman PWD. The well at Beadonabad has a maximum discharge of 72 m^3/hr by air compressor and the productive granular zone is from 7 to 16.6 m bgl. The aquifer comprises pebbles, cobbles and gravels of radiolarian chert, basalt and serpentine in a sandy clay matrix. The well at Calicut has a maximum discharge of 45 m^3/hr by air compressor and the productive granular zone is from 14.6 to 20.6 m bgl and 45 to 54.6 m bgl. The aquifer comprises highly jointed and crushed vescicular ultrabasic rocks.

1.6.4 Geophysical Resistivity Survey

Vertical Electrical Soundings (VES), using the conventional Schlumberger configuration of electrodes were done at 14 sites in South Andaman. Of these, 4 were located in volcanic and ultramafic group of rocks, 4 in marginal zone of volcanic and Andaman Flysch sediments and 6 sites in Andaman Flysch sediments. In Great Nicobar island 9 VES were taken at 6 sites. The results are given in tables 8 a and b.

Table 8 (a). VES data in South Andaman

Location	Layer Resistivity (ohm-m)					Layer Thickness (m)			
	ρ_1	ρ_2	ρ_3	ρ_4	ρ_5	h_1	h_2	h_3	h_4
Beadonabad	7	17.5	VH	-	-	4	8	-	-
Rangachang	23	11.5	65	500	-	1	3	12.3	-
Brooksabad	22	11	65	VH	-	0.85	2.6	4.4	-
Birchganj	12.8	38.4	256	-	-	4.2	21	-	-
Protheropore	145	10.2	27	4	-	2.8	2.5	35	-
Bumlitan	34	1.7	VH	-	-	3	24	-	-
Bambooflat	60	VH	-	-	-	3	-	-	-
Tusnabad- Manpur	50	17	6.8	42.5	-	0.84	4.2	32.2	-
Stewartganj	89	17.8	2	6.1	0.98	0.92	2.02	4	60
Mannerghat I	280	57.5	37	2	VH	1.1	0.7	5.9	66
Mannerghat II	400	133	7.6	2.5	-	1.5	3.6	15.4	-
Caddleganj	6.6	2.6	0.7	-	-	4.9	49	-	-
Homfreyganj									
Eastern I	150	30	6.4	VH	-	1.17	5.3	15.5	-
Western II	12	6	18.9	VL	-	5.4	27	30	-
Manglutan	86	9.6	4.8	6.2	-	1.01	8.1	33.6	-
Air Field area	82	4.1	8.3	-	-	3	40	-	-

Table 8 (b). VES data in Nicobar

Location	Layer Resistivity (ohm-m)				Layer Thickness (m)			Depth to resistive stratum (m)
	ρ_1	ρ_2	ρ_3	ρ_4	h_1	h_2	h_3	
Magarnala	2350	123.7	7.9	H	1.8	3.6	8.6	14.0
Govindnagar	29	3.2	29	-	7.1	35.5	-	42.6
Army land	21	84	L	-	2.3	11.5	-	13.8
Navy Air Field	35	23.3	L		1.65	8.25	-	9.9
Gandhinagar	26	92	558	VH	1.7	3.4	25.6	30.7
Sastrinagar	2.15	5	1.6	H	2.1	6.3	30.9	39.3

L = Low: H = High: VH = Very High:

1.6.5 Ground Water Quality

The quality of ground water throughout the island is neutral to alkaline as envisaged from the analytical results of water samples collected from the existing monitoring stations and reference wells (all dug wells). It is generally of the calcium bicarbonate type, and the bicarbonate content varying from 91 to 427 ppm greatly predominates over the chloride content varying between 14 to 202 ppm. Computation of the chloride-bicarbonate ratio of groundwater from the islands show that the ratio varies between 0.1 to 0.2 which indicates that there has been no large scale saline water intrusion anywhere in the islands.

In general, the ground water is fresh with low mineralization having **Electrical Conductance** (EC) ranging from 292 to 1120 µs/ cm. at 25 ^{0}C, baring a few cases like 1340 µS/cm at 25 ^{0}C at Mirina Park, (South Andaman) and at Sitanagar, (North Andaman), > 2000 µs/ cm at Saitankhari (South Andaman).

Iron concentration in groundwater are mostly within the permissible limit, except at Namunanagar (1.36 ppm), Light house (2.15 ppm) and at Annicut (2.59 ppm).

Calcium, Magnessium, and Sodium concentration are well within the permissible limit. The chemical analysis results of water samples collected from spring show that the quality of water is good and fit for domestic and agricultural use.

Analysis of water samples from the 15 exploratory wells (maximum of 60 meter depth), majority of which fall in South Andaman area, indicates that the water is dominated by alkalies and strong acids – classified as non carbonate alkalies or primary salinity which is probably due to sea water contamination. Generally, groundwater from the deeper aquifer both in South Andaman and Campbell Bay areas are slightly alkaline with pH ranging from 7.1 to 7.8, except at Protherapore. At Power House, quality of water other than with respect to iron content is good with Specific Conductance and chloride within permissible range. The water quality at Calicut (depth 52 m) and Beadonabad (depth 16 m), are excellent with Specific conductance and Chloride in the ranges of 452 to 600 µs/cm and 12 to 37 ppm respectively. Chemical analysis results of selected water samples are given in tables 9 a & b.

Table 9 a. Results of Chemical Analysis of Water Samples from Surface water and Springs in Andaman Dist.

Sample No.	Location	pH	EC (µs/ cm. at 25 ^{0}C)	Constituents (parts per million)													
				TDS	TH as $CaCO_3$	Fe	SiO_2	Ca	Mg	Na	K	CO_3	HCO_3	SO_4	Cl	NO_3	F
1	Calicut Spring I	7.3	200	145	85	1.44	46	22	7.3	10	Trace	Nil	116	2.5	11	Nil	0.24
2	Calicut Spring II	7.8	360	240	165	1.52	64	44	12	12	Trace	Nil	213	Trace	12	3	0.17
3	Nayashahar Spring	7.8	526	349	250	Trace	46	68	19	19	Trace	Nil	329	Nil	18	Nil	0.16
4	Birchgang Spring	7.3	202	144	92	Nil	40	20	10	6.9	Trace	Nil	113	Nil	11	Nil	0.12
5	Hamphrygunj Nala	7.4	460	296	215	Nil	54	46	24	17	0.78	Nil	262	Trace	18	Nil	0.18
6	Bathu Basti Nala	8.1	67	40	17	0.72	9	2	3	7.6	0.78	Nil	24	Trace	11	Nil	Nil

Table 9 b. Results of Chemical Analysis of Water Samples from Dug Wells in South Andaman and Neil Islands.

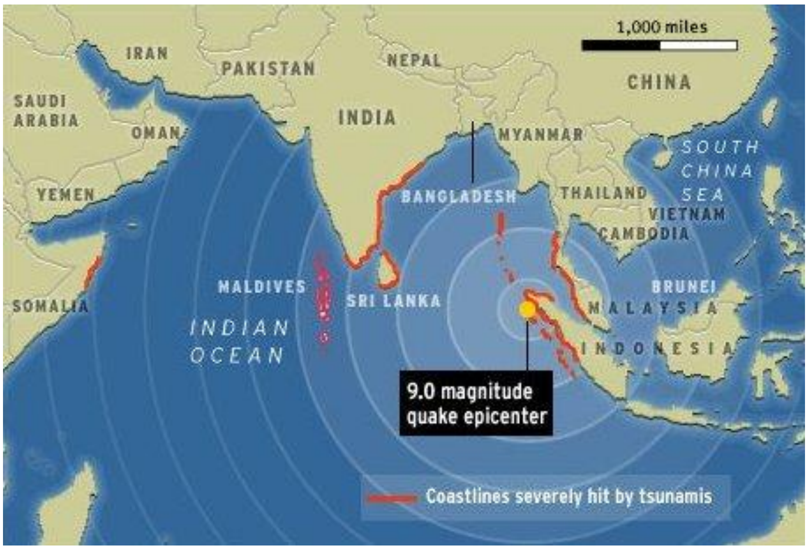
Sample No.	Location	pH	EC (µs/ cm at 25 ^{0}C)	Constituents in parts per million													
				TDS	TH as $CaCO_3$	Fe	SiO_2	Ca	Mg	Na	K	CO3	HCO_3	SO_4	Cl	NO_3	F
1	Calicut-I	7.4	568	340	272	0.63	60	68	25	17	Trace	Nil	335	Trace	18	Nil	0.24
2	Calicut-II	7.2	339	192	142	1.44	46	44	7.9	13	1.2	Nil	152	5	28	Nil	0.24
3	Austinabad	6.4	104	62	30	2.24	140	8	2.4	7.8	1.9	Nil	40	5	14	Nil	0.12
4	Port Blair-I	7.5	867	446	280	0.15	52	92	12	30	Trace	Nil	378	48	53	Nil	0.3
5	Port Blair-II	7.6	676	357	225	0.24	50	76	8.5	59	Trace	Nil	287	58	23	Nil	0.24
6	Neil Guest House	7.3	620	334	275	0.08	16	102	4.9	17	2.7	Nil	281	9.6	32	30	0.88
7	Neil Camp III	7.3	688	380	300	Nil	16	96	16	21	8.6	Nil	311	20	50	3	0.58
8	Neil Camp-V	7.4	1036	6.2	400	Nil	39	136	15	60	3	Nil	421	50	89	17	0.24
9	Neil Camp-IV	7.2	656	387	255	Nil	40	88	8.5	34	5.1	Nil	293	20	46	3	0.4
10	Neil Camp-IV Kucha	7.6	829	498	350	Nil	38	120	12	44	5.3	Nil	427	10	57	Nil	0.36
11	Neil Camp I	7.4	518	284	230	0.3	14	86	3.6	12	4.7	Nil	281	5	18	6.8	0.24
12	Garacherma	7.6	336	190	110	Nil	23	28	9.7	32	1.2	Nil	128	12	21	8.8	0.58
13	Beadonabad	7.05	440	275	230	Nil	40	50	25	14	0.98	Nil	256	Trace	18	Nil	0.12
14	Wandur School-1	7.2	535	287	205	Nil	16	40	25	36	1.6	Nil	226	10	46	Nil	0.4
15	Wandur	7.2	803	426	245	Nil	Trace	76	13	76	1.9	Nil	256	7.5	124	3	0.54
16	Manglutan School	7.2	1122	682	330	1.1	14	66	40	98	36	Nil	152	150	202	5	0.06

17	South Point	7.5	460	250	200	Nil	13	54	16	17	1.2	Nil	226	7.5	28	Nil	0.24
18	Junglighat	7.5	236	179	70	0.8	43	18	6	24	1.6	Nil	122	3.7	21	Nil	0.24
19	Dollygunj	7.3	283	197	120	0.54	37	32	9.7	16	0.78	Nil	159	5	18	Nil	0.3
20	Dollygunj AIR	7.6	127	92	50	Trace	24	12	4.9	6.4	1.4	Nil	61	2.5	11	2.5	0.06
21	Bumblioon	7.5	789	477	345	0.18	34	96	25	42	2.3	Nil	427	10	57	Nil	0.3
22	Birchgunj-I	7.2	384	243	175	0.34	48	38	19	7.3	Trace	Nil	183	5	35	3.5	0.3
23	Brooksabad AIR	7.6	577	344	240	Trace	28	62	21	40	Trace	Nil	323	5	28	2.5	0.24
24	Brooksabad Village	7.5	620	402	265	Trace	66	82	15	28	Trace	Nil	348	Trace	39	Nil	0.24
25	North Bay Jappan Dighi	7.9	365	209	135	Nil	18	34	12	33	0.78	Nil	165	3.7	39	Nil	0.12
26	School Line	7.8	204	122	65	Trace	15	16	6	16	3.1	Nil	91	2.5	25	Nil	0.12
27	Carbin Cove	7.8	319	191	105	Trace	4.4	30	7	29	2.3	Nil	171	5	21	Nil	0.18
28	Tylerabad-II	7.9	266	147	100	Trace	21	30	6.1	19	1.9	Nil	134	3.7	21	Nil	0.18
29	Chauldari-I	7.5	647	388	340	Trace	44	38	59	18	Trace	Nil	409	3.7	21	Nil	0.06
30	Chouldari Block Well	7	2305	1383	495	Trace	42	20	108	299	13	Nil	317	100	568	Nil	0.12
31	Manpur	7.4	603	361	260	Trace	19	88	9.7	28	1.5	Nil	355	2.5	35	Nil	0.3
32	Herbertabad	7.3	514	308	190	Trace	42	46	18	41	1.9	Nil	268	3.7	35	Nil	0.3
33	Tusanabad	7.2	191	114	60	Trace	30	14	6.1	18	Trace	Nil	98	Trace	18	Nil	0.12
34	North Bay Kutcha	7.6	124	74	32	Trace	13	5	4.9	11	Trace	Nil	98	Trace	18	Nil	0.12

35	Sabari	7.1	372	223	150	Trace	20	44	9.7	22	1.2	Nil	189	5	27	Nil	0.12
36	Kausalanagar	7.2	638	382	85	1	26	26	4.9	86	3.9	Nil	67	150	43	Nil	0.18
37	Barmannalla	7.7	358	214	145	Trace	54	32	16	18	Trace	Nil	183	55	32	Nil	0.12
38	Rangachang	8.5	306	183	127	Trace	66	24	16	17	Trace	30	152	Nil	18	Nil	0.12
39	Kodiakadi kutcha	8.5	297	178	137	Trace	56	22	20	14	Trace	18	165	Nil	14	Nil	0.12
40	Chidiatapu AFD	8.3	498	298	255	Trace	45	32	42	12	Trace	15	265	Nil	356	Nil	0.12
41	Cgrabraij Masjid	7.5	796	477	315	Trace	39	97	18	49	1.6	Nil	311	10	96	1.9	0.18
42	Cgrabraij kutcha	7.3	114	68	30	Trace	17	4	4.9	14	Trace	Nil	43	Nil	14	Nil	Nil
43	Haddo	7.4	871	522	220	Trace	22	50	23	85	8.1	Nil	207	2.5	163	34	0.18
44	Namunghar I	7	479	287	190	Trace	17	6	9.7	14	15	Nil	159	50	35	Nil	0.12
45	Dandas Point	7	313	187	92	Trace	42	16	13	23	2.3	Nil	79	50	28	Nil	0.24
46	Saitankadi	7.5	1393	834	197	Trace	25	34	27	207	10	Nil	70	150	337	5.3	0.12
47	Bambooflat jetty	7.2	740	444	210	Trace	31	65	11	78	13	Nil	378	Nil	60	Nil	0.24
48	Ferarganj	8.1	424	254	160	Trace	44	30	21	23	Trace	Nil	171	7.5	50	Nil	0.12
49	Uttara Village Pond	8.2	1550	930	480	Trace	50	79	69	47	14	Nil	Nil	687	35	Nil	0.24
50	Port Blair Airport	6.8	610	-	200	0.67		64	7.8	51	7.9	Nil	250	34	53	-	0.64
51	Chidiyatapu	7.5	681	-	290	Trace		86	18	23	Trace	Nil	287	28	53	-	0.045
52	Bombooflat	7.5	522	-	200	Trace		46	21	25	Trace	Nil	201	9	60	-	0.09
53	Guptapara	7.5	254	-	80	Trace		28	2	15	1.8	Nil	92	14	25	-	0.045

The water quality from the deeper fractured ophiolite suites as well as in the colluvial deposits are high in iron concentration varying from 0.6 to 7.65 ppm. This creates problem for drinking use.

1.6.6 Seismicity



The earthquake and resulting tsunami in the Indian Ocean on December 26th, 2004 had a devastating effect on Andaman and Nicobar Islands and also on the mainland. According to the Indian government, almost 11,000 people died in the tsunami and over 5,000 are missing and feared dead. It is estimated that 380,000 Indians have been displaced by the disaster. The areas hardest hit by the tsunami were the southeastern coast and the Andaman and Nicobar Islands.

The Andaman and Nicobar Islands are located near the epicenter of the original 9.0 earthquake. Both island groups were not only devastated by the tsunami, but also by the earthquake and several aftershocks that occurred near the islands in the following days.

The Nicobar Islands were particularly affected by the tsunami. The islands of Great Nicobar and Car Nicobar experienced widespread devastation because of their general flatness. Some smaller islands in the Nicobars have completely vanished and others have changed shape, such as Trinket, which split into two parts after the tsunami hit. Saltwater intrusion has also occurred on many islands, destroying farmland and sources of freshwater. Chowra Island (population 1,500) lost two- thirds of its people in the aftermath of the tsunami.

An effort has been made to study the effect of tsunami on the quality of ground water in the island chain. The immediate effect of tsunami might have resulted in partial and temporary contamination of ground water due to mixing with saline water. The effect stabilized subsequently and analysis of ground water samples collected during 2007 (post tsunami) does not show much variation in quality when compared with the results of analysis of ground water samples collected during 2002 (pre tsunami). However, in some localities the value of Iron concentration in ground water during 2007 was observed to be lower than the concentration observed during 2002. The results of chemical analysis of few ground water samples of monitoring wells in Andaman and Nicobar Islands are tabulated in Table 10.

Table 10. Pre and post tsunami ground water quality

1. Ground water sample from Hydrograph Network Station at Wimberleyganj		
Chemical parameter	April 2002	April 2007
Fe (mg/l)	**4.8**	**0.02**
Ca (mg/l)	30	20
Mg (mg/l)	19	18
Na (mg/l)	33	36
K (mg/l)	1.7	0.60
HCO_3 (mg/l)	207	207
Cl (mg/l)	35	14
SO_4 (mg/l)	1	7.48
NO_3 (mg/l)	---	----
F (mg/l)	0.67	0.57
Total Hardness (mg/l)	155	125
EC (µ mhos/cm at 25^0C)	495	337
pH	8.2	7.60
2. Ground water sample from Hydrograph Network Station at Bambooflat		
Chemical parameter	April, 2002	April, 2007
Fe (mg/l)	**6.1**	**0.33**
Ca (mg/l)	20	20
Mg (mg/l)	32	12
Na (mg/l)	46	72
K (mg/l)	6.3	1.90
HCO_3 (mg/l)	207	232
Cl (mg/l)	78	35
SO_4 (mg/l)	--	1.26
NO_3 (mg/l)	1.4	4.0
F (mg/l)	0.36	0.37
Total Hardness (mg/l)	180	100
EC (µ mhos/cm at 25^0C)	697	439
pH	7.8	7.80

3. Ground water sample from Hydrograph Network Station at Dandaspoint		
Chemical parameter	April, 2002	April, 2007
Fe (mg/l)	**7.4**	**0.20**
Ca (mg/l)	32	46
Mg (mg/l)	16	6
Na (mg/l)	17	26
K (mg/l)	3.4	1.8
HCO_3 (mg/l)	134	116
Cl (mg/l)	35	32
SO_4 (mg/l)	17	33
NO_3 (mg/l)	---	3.4
F (mg/l)	0.41	0.28
Total Hardness (mg/l)	145	90
EC (µ mhos/cm at 25^0C)	409	333
pH	8.0	7.60
4. Ground water sample from Hydrograph Network Station at Ranghat		
Chemical parameter	April, 2002	April, 2007
Fe (mg/l)	**1.6**	**0.03**
Ca (mg/l)	36	48
Mg (mg/l)	58	74
Na (mg/l)	19	36
K (mg/l)	1.7	2.20
HCO_3 (mg/l)	360	464
Cl (mg/l)	53	89
SO_4 (mg/l)	Nd	19
NO_3 (mg/l)	Nd	0.07
F (mg/l)	0.3	0.21
Total Hardness (mg/l)	330	425
EC (µ mhos/cm at 25^0C)	696	882
pH	7.4	7.85

5. Ground water sample from Hydrograph Network Station at Bakultala		
Chemical parameter	April, 2002	April, 2007
Fe (mg/l)	**0.65**	**1.05**
Ca (mg/l)	20	64
Mg (mg/l)	12	24
Na (mg/l)	23	47
K (mg/l)	1.7	3.9
HCO_3 (mg/l)	128	305
Cl (mg/l)	35	64
SO_4 (mg/l)	Nd	10
NO_3 (mg/l)	0.1	3
F (mg/l)	0.1	0.17
Total Hardness (mg/l)	100	260
EC (µ mhos/cm at 25^0C)	312	642
pH	8	7.28
6. Ground water sample from Hydrograph Network Station at Nimbutala		
Chemical parameter	April, 2002	April, 2007
Fe (mg/l)	**5.17**	**0.07**
Ca (mg/l)	44	60
Mg (mg/l)	15	29
Na (mg/l)	43	24
K (mg/l)	1.7	1.10
HCO_3 (mg/l)	207	305
Cl (mg/l)	64	50
SO_4 (mg/l)	Nd	6
NO_3 (mg/l)	Nd	-
F (mg/l)	0.5	0.6
Total Hardness (mg/l)	170	270
EC (µ mhos/cm at 25^0C)	592	615
pH	7.1	7.58

7. Ground water sample from Hydrograph Network Station at Rest Camp		
Chemical parameter	April, 2002	April, 2007
Fe (mg/l)	**13**	**-**
Ca (mg/l)	52	54
Mg (mg/l)	15	2.43
Na (mg/l)	33	17
K (mg/l)	2.2	1.3
HCO_3 (mg/l)	220	134
Cl (mg/l)	53	39
SO_4 (mg/l)	-	26
NO_3 (mg/l)	2	-
F (mg/l)	0.8	0.11
Total Hardness (mg/l)	190	145
EC (µ mhos/cm at 25^0C)	562	331
pH	7.2	7.7
8. Ground water sample from Hydrograph Network Station at Mayabundar		
Chemical parameter	April, 2002	April, 2007
Fe (mg/l)	**0.78**	**0.04**
Ca (mg/l)	16	74
Mg (mg/l)	24	21
Na (mg/l)	77	74
K (mg/l)	5.1	1.3
HCO_3 (mg/l)	152	403
Cl (mg/l)	124	64
SO_4 (mg/l)	8.6	22
NO_3 (mg/l)	-	-
F (mg/l)	0.3	0.18
Total Hardness (mg/l)	140	270
EC (µ mhos/cm at 25^0C)	693	697
pH	7.7	7.82

1.7 ACTIVITIES OF CENTRAL GROUND WATER BOARD IN ANDAMAN & NICOBAR ISLANDS

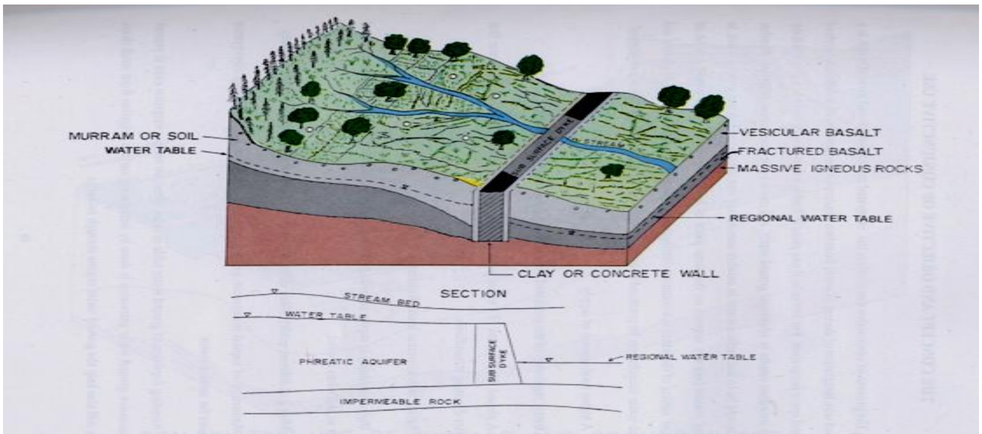
- Since its inception in 1972 CGWB is carrying out systemetic hydrogeological surveys and geophysical studies in the Islands.
- Ground water exploration was carried out in Andaman & Nicobar Islands during 1984-91 and during that period 47 exploratory bore wells were drilled.
- Short term water supply investigation is carried out in the Islands as per the request from various Andaman & Nicobar Administrative Departments, Central Departments and Defence (MES).
- Recently from 1997 CGWB is carrying out artificial recharge and conservation studies for sustainable water supply in the Islands. 76 such schemes have been demarcated. 3 schemes of these schemes are being funded from Central Sector Funds through CGWB and 20 ongoing schemes are being funded by A & N Administration.
- CGWB also has carried out surveys to monitor environmental degradation in Carnicobar Islands following request from Andaman Harbour Works, Govt. of India as per the directive of Ministry of Environment & Forest.
- CGWB also has carried out intensive studies specially to solve the permanent water supply problem to Port Blair city through Interisland transfer of spring water from Rutland as also the study in Port Blair Municipal Council area as per the request of Hon'ble Member of Parliament, Andaman & Nicobar Isalnds has been carried out.
- CGWB has surveyed all the streams in North, Middle and South Andaman to find out the suitable measures to conserve surface ground water and surplus monsoon run off for development of irrigated agriculture.
- CGWB also has carried out studies in remote Kamorta, Nancowry and Katehal Islands of Nicobar district to find out the drinking water sources.
- CGWB is financing in a big way to Andaman & Nicobar Administration during Xth 5 year plan period to develop artificial recharge and conservation practice including rain water harvesting from Central Sector Funds.
- The studies carried out by CGWB in the find of artificial recharge and conservation and rain water harvesting to solve the water supply problems and to develop minor irrigation have been proved highly feasible and successful and being implemented by Andaman and Nicobar Administration.
- To solve the water supply problem in Port Blair town the study by CGWB in Rutland Islands has proved that everyday 180 lakh litres of spring water is lost into the sea, which may be conserved and brought to Port Blair crossing sea. This may from a dependable basis of solution of drinking water crisis of Portblair. The detailed feasibility work is in progress. This was done at the behest of Hon'ble Lt. Governor of A & B Islands in peak crisis period of 2002.
- The marine sedimentaries are devoid of water in the subsurface where as the bore wells in igneous suit of rocks may be successful upto 60 m depth. However, there fractured aquifers are to be developed construction as recent drilling of private bore hole have significantly brought down the available water sources with an alarming cut down of discharge of the supply well drilled by CGWB.

1.7.1 Findings of CGWB in Andaman and Nicobar Islands

Formation	District	Findings
Marine sedimentary	Andaman and Nicobar Districts	Marine sedimentaries are devoid of water in the deeper horizon. Borewells are not feasible. Dugwells in shallow horizon having 4.5-5 m dia & 6 m depth may yeild 3000-5000 lpd.
Ophiolite igneous suite		Ophiolite igneous suites are moderately potential. Farctures available upto 60 m depth. Borewells, dugwells and dug cum borewells are feasible. Yeild of borewell may reach to the tune of 45000 ltr/hr.
Coralline Formations.		Coralline formations are highly potential and may be developed through dugwells of 4.5-5 m dia & 6 m depth. Yeild may vary from 15000-1lakh lpd. In Neil & Hutbay Island the irrigation is monthly done from dugwells trapping this formation.

Water scarcity in the islands exists in spite of the fact that the area receives good rainfall. Abundant scope exists for tapping sizeable portion of this rainfall, major part of which is lost either as surface fun-off or through sub-surface flows to the sea. Construction of artificial recharge and conservation structures can provide decentralized, point source of fresh water locally. The structures best suited for the terrain are contour bunding along hill slopes, small check dams on nullahs, roof top rain water harvesting, sub-surface dykes, spring development, etc. While most of the structures are utilized for arresting or conserving the rainfall run-off from surface, sub-surface dykes arrests the sub-surface flows which is lost to the sea unseen. The technical designs of the recharge and conservation structures are widely available and known, though modifications are often required in the structures depending on the site specific conditions. However, a sub-surface dyke is a specialized structure and like ground water, remains invisible after construction is completed. One such sub-surface dyke constructed at Guptapara in South Andaman under technical guidance from Central Ground Water Board, have yielded positive results. The typical design and technical aspects of a sub-surface dyke, is hence, detailed here.

Sub-Surface Dykes or Ground Water Dams or Underground ‘Bandharas’ is a sub-surface barrier constructed across a stream channel for arresting/retarding the ground water flow and increase the ground water storage. At favorable locations, such dams can also be constructed not only across streams, but in large areas of the valley as well for conserving ground water. Site Characteristics and Design Guidelines



ARTIFICIAL RECHARGE THROUGH UNDERGROUND BANDHARA

i) The primary objective of a sub-surface dyke is the creation of a subsurface storage reservoir with suitable recharge conditions and low seepage losses. Valley shapes and gradients are important considerations for site identification.

ii) Optimally, a valley should be well defined and wide with a very narrow outlet (bottle necked). This reduces the cost of the structure and makes it possible to have a comparatively large storage volume. This implies that the gradient of the valley floor should not be steep since that would reduce the storage volumes behind a dam of given height.

iii) The limitations on depth of underground construction deem that the unconfined aquifer should be within a shallow to moderate depth (down to 10 m bgl) and has a well-defined impermeable base layer. Such situations occur in hard rock areas and shallow alluvial riverine deposits.

iv) The limitations on depth of underground construction deem that the unconfined aquifer should be within a shallow to moderate depth (down to 10 m bgl) and has a well-defined impermeable base layer. Such situations occur in hard rock areas and shallow alluvial riverine deposits.

v) The drainage valley across which the subsurface dyke is constructed should carry a seasonal stream that goes dry in winter and summer and the water table should be located well below the riverbed, preferably throughout the year The valley section should preferably have a moderate gradient (less than 1%) so that the benefit spreads sufficiently in the up-gradient direction.

vi) The thickness of aquifer underlying the site should be adequate (more than 5 m) so that the quantity of ground water stored is commensurate with the effort and investment. Normally, in hard rock watersheds, the drainage courses have a limited thickness of alluvial deposits underlain by a weathered rock or fractured aquifer, which in turn passes into consolidated unaltered aquitard. This forms an ideal situation.

vii) The sub-surface dyke directly benefits the up-gradient area and hence should be located at a sufficient distance below the storage zone and areas benefiting from such recharge.

viii) A sub-surface dyke may potentially deprive the downstream users the benefit of ground water seepage, which they received under a natural flow regime. Care should therefore be taken to see that a large number of users are not located immediately downstream and those affected are duly compensated through sharing of benefits.

ix) For construction of ground water dam/ sub-surface dykes, a trench should be dug out across the ground water depression (streambed) from one bank to the other. In case of hilly terrain in hard rocks, the length of the trench generally may be less than 50 m. In more open terrain, the length may be usually less than 200 m but occasionally even more. It should be wide enough at the bottom to provide space for construction activity. In case of shallow trenches down to 5 m depth, the width at the bottom should be 2 m. For deeper trenches down to 15-20 m, deployment of mechanical equipment may be required. In such cases, width of 5 m at the bottom is recommended. The side slopes within alluvial strata should be 2:1 to make them stable. In case of more consolidated substrata, the slope could be steeper.

x) The cut-out dyke could be either of stone or brick masonry or an impermeable clay barrier. In the case of relatively shallow trenches within 5 m depth, the cut-out dyke could be entirely be made of clay. In case good impermeable clay is not available, a stone masonry wall of 0.45 metre thickness or a brick wall of 0.25 m thickness may be constructed on a bed of concrete. Cement mortar of 1: 5 proportion and cement pointing on both faces is considered adequate. In the case of very long trenches, for economic considerations, it may be necessary to provide masonry wall only in the central part of dyke and clay dyke suitably augmented by tar felting, PVC sheet etc. on the sides.

xi) In case of clay dykes, the width should be between 1.5 and 2m depending on the quality of clay used. The construction should be in layers and each fresh layer should be watered and compacted by plain sheet or sheep foot rollers of 1 to 2 ton capacity. In absence of roller, the clay should be manually compacted by hand ramets. Where the core wall is a masonry structure, the remaining open trench should be back-filled by impermeable clay. The underground structures should be keyed into both the flanks of stream for one meter length to prevent leakage from sides.

xii) The top of the underground structures should be located between 1 to 1.5 m below the streambed to permit overflow in high water table stage for flushing of salinity of ground water stored behind the dyke. The alignment of the dyke should be shown by fixing marker stones on the banks and whenever there is change of alignment in between. Before back-filling the sub-surface trench, piezometric tubes should be installed on both the faces of the dyke for measuring water levels. Such piezometers should be located in the central part, and in case of wider dykes at additional one or two locations.

The structures are low cost, easy to construct and can be made with locally available materials. Considering the physiography, geology and hydrogeology of the area, such structures are suitable for augmenting the water supply to small villages.

1.7.2 Coastal Regulatory Zones

This Union Territory has a coastline of 1962 km. which is ¼th of mainland India. The provisions of Coastal Regulation Zone Notification, 1991 as amended from time to time are being implemented by various designated authorities as stipulated in the Government of India approved Coastal Zone Management Plan for these islands. In this Union Territory of Andaman and Nicobar Islands, the Coastal Regulation Zone (CRZ) have been categorized into three zones-CRZ-I, CRZ-II and CRZ-IV. CRZ-I forms the major part which includes reserved forests, protected forests, mangroves, Wildlife Sanctuaries, National Parks, ecologically sensitive areas etc. The entire rural/revenue area is under CRZ-IV except a very small area which is under CRZ-II. No new construction is permissible with 500 m of the High Tide Line in CRZ-I and within 200 m of the High Tide Line in CRZ-IV areas. Thus, it helps in protection of the coastal area and hence the environment to a considerable extent.

1.8 CONCLUSIONS

- These islands form an arcuate chain, convex towards west having an approximate North-South trend over a length of 780 kms., within the geographical coordinates of 6^0 N to 14^0 N latitude and 88^0 E to 92^0 E longitude. These islands are the emergent peaks of submerged mountains extending from the Arakan Yoma ranges of Burma in the North to Java and Sumatra in the South-East**.**
- Baring a few islands in the Nicobar district, the terrain is mostly undulating with the main ridges running North-South. In between the main ridges deep inlets and creeks are formed by submerged valleys.
- The islands receive rainfall from both the south west and north east monsoons and maximum precipitation is between May & December.
- The normal rainfall of Port Blair is 3180 mm where as the mean annual rainfall of Andaman District and Nicobar District are 2629.0 and 2624.0 mm respectively.
- The Andaman group of islands generally features a mountainous terrain with long ranges of hills and narrow valleys.
- The Nicobar Islands are surrounded by the shallow seas and coral reef. The topography of Nicobar Islands features long, sandy beaches.
- The Islands are composed mainly of thick Eocene sediments deposited on Pre-Tertiary sandstone, silt stone and shale with intrusions of basic and ultra – basic igneous rocks.
- The soils of the islands vary in depth, texure and chemical composition and are acidic in nature. These are medium texured on the surface and medium to heavy textured in the sub-soil. Humus is generally lacking in the forest soils as it is generally washed away due to copious rainfall and steep slopes.
- Three major formations constitutes the water table aquifer –
    - The porous formation consist of beach sand with coral rags and shells;
    - The thin cover of alluvium in the valleys and foot hills adjacent to valleys, and

- The moderately thick pebbly valley fills deposits in the narrow intermontane valleys.

- A number of springs originate from the forests clad hills in both the igneous and sedimentary terrain and most of them are being utilized for rural water supply by APWD.
- In order to study the behaviour of ground water regime with time and space in Andaman group of islands, 63 ground monitoring stations are being monitored and periodic water level measurements are being taken for pre-monsoon period during May and for the post-monsoon period during December.
- Depth to water level in the monitoring stations lies within 5 m bgl generally.
- The ground water resource estimation as per GEC 1997 norm reveals that the islands have a stage of development of 3.73 % and has been categorized as SAFE.
- Productive aquifers exists down to a depth of 60 m bgl.
- The quality of water in deeper aquifer deteriorates, probably due to contamination with the saline water below. The productive aquifer occurs within 60 m bgl in fractured volcanic and 30 m bgl in valley fill deposits with discharge varying from 10 to 45 m^3/hr.
- The valley fill deposits comprising of assorted pebbles, cobbles and gravels of volcanic, ultramafics and cherts in sand clay matrix in certain valleys are proved to be productive.
- Ground water quality in these shallow aquifers is suitable for drinking and domestic purposes.
- In Middle and South Andaman, the discharges from the bore wells range from 10 to 25 m^3/hr., and 0.2 to 44.67 m^3/hr respectively. In Kamorta island the discharge varies from 0.5 to 1.0 m^3/hr.
- The quality of ground water throughout the island is neutral to alkaline. It is generally of the calcium bicarbonate type and the bicarbonate content varying from 91 to 427 ppm greatly predominates over the chloride content varying between 14 to 202 ppm.
- In general, the ground water is fresh with low mineralization having EC ranging from 292 to 1120 µs/ cm. at 25 ^{0}C.
- Marine sedimentaries are devoid of water in the deeper horizon. Borewells are not feasible.
- Ophiolite igneous suites are moderately potential. Farctures available upto 60 m depth.
- Coralline formations are highly potential and may be developed through dugwells of 4.5-5 m dia & 6 m depth.
- This Union Territory has a coastline of 1962 km. which is ¼th of mainland India. The Coastal Regulation Zone (CRZ) have been categorized into three zones-CRZ-I, CRZ-II and CRZ-IV in Andaman and Nicobar islands. CRZ-I forms the major part which includes reserved forests, protected forests, mangroves, Wildlife Sanctuaries, National Parks, ecologically sensitive areas etc. The entire rural/revenue area is under CRZ-IV except a very small area which is under CRZ-II. No new construction is permissible with 500 mtrs. Of the High Tide Line in CRZ-I and within 200 mtrs.

of the High Tide Line in CRZ-IV areas. Thus, it helps in protection of the coastal area and hence the environment to a considerable extent.

1.9 RECOMMENDATIONS

- Currently about 15,000 m^3 of drinking water is supplied every day. Owing to population growth demand for drinking water is expected to grow to 37,000 m^3 by 2025. For meeting the growing demand for drinking water, supply needs to be substantially augmented. This would require expeditious completion of ongoing schemes and identification of new commercially viable schemes. The ongoing schemes include - revival of Dilthaman tank, Nayagaon- Chakragaon Diggi Project, Chouldhari scheme and Artificial Recharge Schemes recommended by Central Ground Water Board.
- Two proposed new schemes: (a) raising the height of Dhanikhari Dam, and, (b) Indira Nullah Project may be undertaken to meet medium term requirement of the urban areas.
- In order to meet the long term demand of drinking water, the feasibility studies initiated in respect of tapping of water from Ruthland Island should be finalized early.
- The proposal of conversion of a part of sea at Flat Bay into a fresh water lake may also be considered.
- The Low Temperature Thermal Desalination (LTTD) water treatment technology successfully implemented in Lakshadweep Island can be replicated in Andaman and Nicobar. A pilot plant on LTTD process of capacity 0.1 million litres per day (say 100 m^3/day) is in operation at Kavaratti in Lakshadweep generating fresh water from the sea water to meet the drinking water needs of people. In LTTD method the energy requirement for the evaporation of water are taken from sea which makes the process eco- friendly and uses renewable source of energy. LTTD uses the temperature difference which exists between the surface layer water (28 -30 ^{0}C) and deep sea layer water (7 -1O ^{0}C) in an ocean to produce potable water.
- Capacity to treat raw water also needs to be augmented. Existing distribution system designed by Central Public Health & Environmental Organisation (CPHEEO) is considered to be adequate to cope with the projected water supply till 2011. Additional clear water reservoirs would need to be constructed to cope with the supply load for subsequent years.
- As per the Census 2001, out of 502 villages only about 340 are fully covered by the public provision of water. Proper water treatment plants are available only in a few places such as Diglipur, Rangat, Mayabunder, Bakultala, Bambooflat and Kamorta. Treatment plants need to be constructed, preferably using locally available technology, to supply clean drinking water to other villages.
- Composting toilets (Eco-San) should be promoted in places where water table is shallow to safeguard against ground water contamination from sewage, etc. A composting toilet is an aerobic processing system that treats excreta, typically with no water or small volumes of flush water, via composting or managed aerobic

decomposition. This is usually a faster process than the anaerobic decomposition at work in most wastewater systems, such as septic systems. Composting toilets are often used as an alternative to central wastewater treatment plants (sewers) or septic systems. Typically they are chosen to:-

- alleviate the need for water to flush toilets,
- avoid discharging nutrients and/or potential pathogens into environmentally sensitive areas, or
- capture nutrients in human excreta.

These should not be confused with pit latrines all of which are forms of less controlled decomposition, and may not protect ground water from nutrient or pathogen contamination or provide optimal nutrient recycling.

- Generating awareness and capacity building of community towards healthy living conditions by promoting eco-sanitation, Rain Water Harvesting, Water Conservation, recycling and re-use should be done on a large scale.
- Stereotype approach may not solve the water problems faced in the islands. A conjunctive development of catchments areas, groundwater and surface water and complimentary use of same should be the approach.
- The PWD proposal to build decentralized rainwater reservoir that will supply raw water to villages should be expedited with priority.
- Bore wells in North and Middle Andaman have not been very successful. Large diameter dug wells would be effective in augmenting the water supply locally.
- Appropriate investment need to be made in treatment plants as very often existing treatment plants fail to handle the supply demand.
- Proper sanitation is not possible without adequate water and improper sanitation runs risk of contaminating water sources. Therefore the government and NGOs should work to promote both aspects by initiating dialogue and frequent interaction.
- The current water supply system needs to be decentralized for augmentation taking into consideration the seismic risks, scattered and increasing population and climate change. This would also ensure that large portions of the population are not left without drinking water in the case of a natural disaster.
- Since the area under forest cover is close to 90%, integrated water resource management is possible only through active involvement of Forest Department.
- Formation of ‘Water User Association’ should be promoted to manage and maintain water resources.
- As of date Andaman does not have an effective water quality monitoring system in place. PWD should put a robust water quality and monitoring system in place to monitor surface and ground water quality.
- Andaman and Nicobar receive good rains. In the absence of any concrete policy for Rain Water Harvesting, the Union Territory has not been able to turn this huge advantage to its benefit. Holistic approach on Water Harvesting is therefore a must.
- Individual and community roof top rain water harvesting is an ideal decentralised system of providing safe drinking water. Full advantage to be made of the good rainfall the islands receive.

- Sub-surface dykes have proved to be helpful in conservation of ground water which otherwise would escape to the sea. One such structure has been constructed in Guptapara in South Andaman across a local nala. Wells constructed upstream of the dyke are benefitted from the conserved water. The structures being simple and requiring less scientific input can easily be constructed at local level. Physiography of the islands favours construction of these structures at many places. However, the selection of these sites does require scientific input and a few has already been identified by Central Ground Water Board.
- Springs are a good source of fresh water for the islanders. A number of springs originate from the forests clad hills in both the igneous and sedimentary terrain and most of them are being utilized for rural water supply by APWD. Detailed investigations of the springs are required and suitable structures, either in the form of contour bundings, small embankments, etc., as feasible from the hydrogeological point of view may be developed for sustainability of these point sources.
- Due to increasing population and developmental activities the waste generated is being released into the adjoining coastal environment affecting its quality. In absence of a proper sewerage system in the islands, the sewage goes to sea through the natural courses, drains and gutters. Proper sewerage treatment is an absolute necessity for disposal of waste water into the sea and ensuring that the quality of waste water meets the norms prescribed for such purpose. Sewage treatment plants should be installed at all localities having sizeable population.

LAKSHADWEEP ISLANDS

~at a glance~

Population (2001):	60,595
Density of Population:	500-2500 people per sq km.
Administrative HQ:	KAVARATTI.
Access:	by Air and Sea from India, South-west coast.
Location:	8º - 12º 13" North Lat. and 71º - 74º East Long.
Total islands:	36
Distance to Malabar coast:	200-400 kms
Total geographical Area:	32 sq kms
Major islands:	Minicoy, Kalpeni, Androth, Agatti, Kavaratti, Amini, Kadmat, Kiltan, Chetlat, Bitra, Bangaram & Pitti
Temparature:	32 ºC (Max.) to 28 ºC (Min.)
Humidity:	70-75%
Highest Rainfall:	241.8 mm (in 24 hours)
Unique feature:	The only coral reef island in India, rich flora and fauna. Virgin, Fragile eco-system. A unique and quiet getaway destination.

2.0 INTRODUCTION

The tiniest Union Territory of India, Lakshadweep is an archipelago consisting of 12 atolls, three reefs and five submerged banks. The reefs are in fact also atolls, although mostly submerged, with only small unvegetated sand cays above the high water mark. The submerged banks are sunken atolls. Almost all the atolls have a northeast-southwest orientation with the islands lying on the eastern rim, and a mostly submerged reef on the western rim, enclosing a lagoon.

It is a uni-district Union Territory with an area of 32 sq km., and comprise of 10 inhabited islands, 17 uninhabited islands attached islets, 4 newly formed islets and 5 submerged reefs. The inhabited islands are Kavaratti, Agatti, Amini, Kadmat, Kiltan, Chetlat, Bitra, Andrott, Kalpeni and Minicoy. Bitra is the smallest of all. Considering its lagoon area of about 4,200 sq km., 20,000 sq km., of territorial waters and about 4 lakhs sq km., of economic zone, Lakshadweep is a large territory. According to the 1991 Census, Lakshadweep had a population of 51707 persons. (It is 60,595 as per the Census -2001, provisional population Data sheet). More than 93% of the population who are indigenous, are Muslims and majority of them belong to the Shafi School of the Sunni Sect.

Malayalam is spoken in all the islands except Minicoy where people speak Mahl which is written in Divehi script and is spoken in Maldives also. The entire indigenous population has been classified as Scheduled Tribes because of their economic and social backwardness. According to the Scheduled Castes and Scheduled Tribes list (modification orders), 1956, the inhabitants of Lakshadweep who and both of whose parents were born in these islands are treated as Scheduled Tribes. There are no Scheduled Castes in this Union Territory. The main occupation of the people is fishing, coconut cultivation and coir twisting. Tourism is an emerging industry.

Kavaratti is the Administrative Headquarters of the Union Territory. The islands are restricted area and permit from the Administration is required to visit the islands.

The main islands are Kavaratti (where the capital city, Kavaratti, is located), Agatti, Minicoy, and Amini. The total population of the territory was 60,595 according to the 2001 census. The name of the archipelago literally translates as "hundred thousand islands" (laksha = "one hundred thousand", dweep = "island"). Lakka (Lacca) is the Malayalam equivalent of Laksha. Until 1973, the island group was known by the Anglicised name Laccadives although the term Laccadives strictly only applies to central Lakshdweep with the northern Amindivi Islands and Minicoy to the south considered separate. This is reflected in the pre-1973 name of the union territory, Laccadive, Minicoy, and Amindivi Islands. The Laccadive Islands and Minicoy Island are known as the Cannanore Islands.

2.1 ADMINISTRATIVE SET UP

The islands are a uni-district territory with 4 tehsils (Amini, Andrott, Kavaratti & Minicoy) and 9 sub-divisions (Agatti, Amini, Andrott, Chetlat (Bitra), Kadmat, Kalpeni, Kavaratti, Kiltan & Minicoy). There are 5 C.D. Blocks namely, Amini-(Amini & Kadmat), Andrott-(Andrott &Kalpeni), Kavaratti-(Agatti & Kavaratti), Kiltan-(Bitra, Chetlat & Kiltan) & Minicoy.

The Lakshadweep Island Councils Regulation, 1988 and the Lakshadweep (Administration) Regulation, 1988 under which the Island Councils and Pradesh Councils were set up have been repealed under Section 88 of Lakshadweep Panchayat Regulation,1994 promulgated by the President of India on 23 April 1994 consequent on the Constitution (73rd amendment) Act, 1992. The Island Councils came to an end after the expiry of its terms on 5.4.95. According to the new Panchayati Regulation there will be two tire system of Panchayats in Lakshaweep. There will be Dweep Panchayat and a District Panchayat. There will be no intermidiary panchayat in this territory. Ten inhabited Islands have the 10 Dweep Panchayats. The District Panchayat will have its Headquarter at Kavaratti. There are 79 seats in the Dweep Panchayat; out of which 75 seats are reserved for Scheduled Tribes candidates and 30 seats are reserved for women including women belonging to Scheduled Tribes. There will be a Chairperson and a Vice Chairperson in the Dweep Panchayat.

There will be 22 seats in the District Panchayats. Out of this 20 seats are reserved for Scheduled Tribes including 7 seats reserved for women belonging to ST’s. There will be one President-cum-Chief Counsellor and two Vice Presidents-cum-Counsellors in the District Panchayats.

The members of the Dweep Panchayat and District Panchayats will be directly elected. The Chair person of the Dweep Panchayats will be members of the District Panchayats by virtue of their position as Chairperson.

The Panchayat will discharge their functions as provided in the Lakshadweep Panchayat Regulation 1994 and schedule III & IV of the said regulations. So far the Dweep Panchayat and the District Panchayats have not been constituted in the U.T. of Lakshadweep.

2.1.1 Location, Boundaries, Area and Population

The islands are irregularly scattered in the Arabian Sea and consists of a number of sunken banks, open reefs and sand banks. Only eleven islands are inhabited (including the Bangaram island which is newly inhabited). Other islands are small and exist as satellites of the inhabited islands, which are away from Kozhikode by about 200 to 400 kilometers.

According to the Survey of India, the geographical area of Lakshadweep is 32 sq km. As per revenue records the area is only 28.5 sq km., which represents only the land use area. As per the 2001 census, the total population is 60650, with males constituting 31131 and female 29519. The Rural Population is 33683, with male constituting 17191 and females 16492. The Urban Population is 26967, with male constituting 13940 and females 13027. The density of population is high and stands at 1895 per sq km. The names of the inhabited islands, reefs and submerged sand banks indicating the area are given in Table 2.1. a, b, c.

Table 2.1.a. Lakshadweep Island

Sl No	Name	Population	Area (sq km.)		Total	Location	
			Island	Lagoon		Latitude	Longitude
1	Minicoy	9495	4.80	30.60	35.40	8º 16´	73º 03´
2	Kalpeni	4319	2.79	25.60	28.20	10º 04´	73º 36´
3	Andrott	10720	4.90	-	4.90	10º 48´.5	73º 40´
4	Agatti	7072	3.84	17.50	20.10	10º 51´	72º 11´
5	Kavaratti	10113	4.22	4.96	8.66	10º 35´.5	72º 30´
6	Amini	7340	2.60	1.50	4.10	11º 07´	72º 44´
7	Kadmat	5319	3.20	37.50	40.71	11º 13´	72º 46´
8	Kiltan	3664	2.20	1.76	3.96	11º 29´	73º 00´
9	Chetlat	2289	1.40	1.60	3.00	11º 41´	72º 41´
10	Bitra	264	0.10	45.61	45.71	11º 35´.5	72º 09´.5

Table 2.1.b. Reefs

Sl No	Name	Area (sq km.)		Total	Location	
		land	Lagoon		Latitude	Longitude
1	Beliapani	-	57.46`	57.46	12º17´	71º52´
2	Cheriapani	-	172.59	172.59	11º49´	71º43´´
3	Perumalpar	-	83.02	83.02	11º7´	71º59´

Table 2.1.c. Submerged Sand Banks

Sl No	Name	Area (sq km.)		Total	Location	
		land	Lagoon		Latitude	Longitude
1	Bassas de Pedro	-	2474.33	2474.33	12º 30´	72º 14´
2	Sesostris	-	388.53	388.53	13º 00´	71º 51
3	Corahdiv	-	339.45	339.45	13º 34´	72º 04´
4	Amini-Pitti	-	155.09	155.09	10º 44´	72º 28´
5	Elikalpeni	-	95.91	95.91	11º 7´	73º 59´
6	Investigator Bank	-	141.78	141.78	8º 33´	73º 25´

Apart from the above there are 17 uninhabited islands located in the close vicinity of the inhabited islands. They are namely: Pitti (Birds Island), Viringili, Cheriyam, Kodithala, Tilakkam (i), Thilakkam (ii), Thilakkam (iii), Pitti (i), Pitti (ii), Bangaram, Thinnakara, Parali(i), Parali (ii), Parali (iii), Kalpitti, Suheli Valiya Kara, Suheli Cheriya Kara

2.2 CLIMATE

Lying well within the tropics and extending to the equatorial belt, these islands have a tropical humid, warm and generally pleasant climate, becoming more equatorial in the southern islands of the territory. The climate is equable and no distinct and well marked seasons are experienced. Southwest monsoon period is the chief rainy season which lasts from late May to early October. The mean daily temperatures ranges between 22 to 33^{0}C while the humidity ranges between 72 to 85%. The vagaries of rainfall in the islands are given in tables 2.2, 2.3, 2.4, and 2.5.

Table.2.2

Station	Highest Annual % of Normal & Year (mm)	Lowest Annual % of Normal & Year (mm)	Heaviest in 24 hrs	
			Amount (mm)	Date
Minicoy	127 (1902)	64 (1939)	224.9	8.12.1965
Amini	169 (1933)	60 (1934)	241.8	27.8.1909

Table.2.3. Frequency of Annual Rainfall

Range in mm	No. of Years	Range in mm	No. of Years
Minicoy (Data 1901 - 1950)			
1001 - 1100	1	1601 -1700	11
1101 - 1200	1	1701 - 1800	1
1201 -1300	3	1801 -1900	5
1301 -1400	2	1901 - 2000	3
1401 - 1500	6	2001 - 2100	3
1501 - 1600	6		
Amini (1902 - 1950)			
901 - 1000	2	1801 - 1900	1
1001 - 1100	1	1901 - 2000	5
1101 - 1200	4	2001 - 2100	1
1201 - 1300	5	2101 - 2200	0
1301 - 1400	8	2201 - 2300	1
1401 - 1500	4	2301 -2400	0
1501 - 1600	8	2401 - 2500	0
1601 - 1700	4	2501 - 2600	1
1701 - 1800	4		

Table.2.4. Normal and Extremes of Rainfall

Station	No of Years (Data)		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Minicoy	50	a	43.2	22.3	20.8	51.3	179.6	309.1	238.3	209.3	158.2	179.1	143.3	85.9	1640.4
		b	2.6	1.3	1.4	2.9	8.7	17.4	13.9	12.4	10.1	10.6	8.1	4.7	94.1
Amini	50	a	20.6	2.0	4.3	25.4	125.2	380.7	311.9	217.2	149.6	141.1	85.6	40.9	1504.5
		b	1.3	0.3	0.3	1.4	5.2	17.3	16.5	12.3	10.2	8.4	5.0	2.2	80.4

Normal Rain Fall in mm (b) Average no. of Rainy days (days with rain of 2.5 mm or more) - based on all available data up to 1965

Table.2.5. Rainfall during the period 2004 to 2009

Year	2004		2005		2006		2007		2008		2009	
	RF	Dep	RF	Dep	RF	Dep	RF	Dep	RF	Dep	RF	Dep
Jan	7.2	-65	17.6	-14	23.1	13	9.8	-52	5.5	-73	4.7	-77
Feb	1.5	-91	11.0	-33	0.0	-100	4.7	-72	19.9	21	1.4	-92
Mar	1.9	-84	0.0	-100	44.0	252	0.0	-100	120.4	863	0.1	-99
Apr	7.6	-82	37.1	-14	0.3	-99	16.9	-61	15.7	-63	18.2	-58
May	874.0	392	92.7	-48	411.3	131	147.3	-17	180.4	1	162.0	-9
Jun	251.3	-23	248.8	-24	286.5	-12	555.6	71	254.5	-22	401.6	23
Jul	280.9	0	381.9	35	172.6	-39	298.3	6	364.0	29	266.4	-6
Aug	169.4	-20	102.4	-52	150.7	-29	267.2	26	206.5	-3	185.0	-13
Sep	200.0	22	277.9	69	318.2	94	346.0	110	108.9	-34	144.9	-12
Oct	193.3	26	164.2	7	119.2	-22	213.6	40	253.0	65	89.2	-42
Nov	107.5	-8	218.1	87	158.7	36	52.1	-55	67.5	-42		
Dec	2.2	-96	27.3	-54	10.8	-82	126.4	114	130.1	121		

Note: RF =Rainfall in mm; Dep = % departure from normal Rainfall

2.2.1 Special weather phenomena

A few cyclonic depressions and storms, which form in the south Arabian Sea during April and May, affect the weather over the territory. During the post monsoon months of October to December also, a few of such systems originating in the Bay of Bengal and travelling westwards emerge into the south Arabian sea, and occasionally affect these islands. In association with these, strong winds and heavy rains are common. Table 2.6 gives the number of storms and depressions which affected the region in the above mentioned months during the 80 years ending 1970. During the rest of the months, the territory was not affected by such systems. The cyclonic storms are believed to be responsible for the disposition of coral debris around the islands forming coral beach and the lagoons.

Table.2.6.

Month	Arabian Sea Storms/ Depression	Bay of Bangal Storms/ Depression
April	4	
May	1	
October	8	
November	9	7
December	3	3
Total	25	10

Surrounded by the vast ocean, the islands are open to storms and cyclones. One of the earliest natural calamities recorded was the great storm that struck the islands in April, 1847. It commenced in Kalpeni about 8 p.m. on 15th April, passed on to Androt and finally reached Kiltan after devastating these two islands. All the houses in Kalpeni were damaged and many were entirely washed away. The plantations in the island were completely destroyed. In Androth, the population before the storm was 2576. Many people perished in the storm and large numbers of the survivors migrated to other islands. Those left in the island numbered only 900. The coconut trees were almost completely destroyed.

In 1891, a violent storm burst upon Kavaratti island causing considerable damage to coconut trees. Large remissions of rent upon the cowle lands were necessitated during the next few years. The storm did a great deal of damage in Agatti and its attached islets and the Amindivi group of islands. But the damage done by the storm was not so great in these islands as in Kavaratti.

Kalpeni island was hit by a severe cyclone on 1st December, 1922. The waves washed completely over the narrow northern end and the sea poured across the island into the lagoon. The people in the northern part of the island had to flee for safety and all rushed to the mosque to pray. Fortunately the storm subsided without doing any serious damage beyond blowing down a few trees. The cyclone was scarcely felt in any other island except Suheli and to a slight extent Androth.

Another major storm which hit the islands occurred in 1941. Kavaratti was the island most affected by this storm. In 1963, a cyclone of mild intensity struck Androth island and

540 coconut trees were uprooted. The major calamity in recent times was the storm that hit the territory in December, 1965 causing considerable damage in Androth and Kalpeni islands. About 11,500 coconut trees were uprooted in Androth and about 9,500 trees in Kalpeni. Though the storm was felt in Kavaratti, Agatti and Kiltan, it was not so vehement in these islands.

2.3 GEOMORPHOLOGY

The islands are flat, rarely rising more than two meters, and consist of fine coral sand and boulders compacted into sandstone. Most atolls have a northeast, southwest orientation with an island on the east, a broad well developed reef on the west and a lagoon in between. All Lakshadweep islands are of coral origin and some of them like Minicoy, Kalpeni, Kadmat, Kiltan and Chetlat are typical atolls. The coral reefs of the islands are mainly atolls except one platform reef of Androth. The height of the land above the sea level is about 1-2 metres.

The islands on these atolls are invariably situated on the eastern reef margin except Bangaram and Cheriyakara which lie in the centre of the lagoon. On Bitra, the island is on the northern edge of the lagoon. The atolls Show various stages of development of the islands, the reefs at Cheriya panniyam, Perumalpar and Suheli represent, the earliest stage while Kalpeni, Kavaratti, Agatti and Kadmat are in intermediate stage and Chetlat and Kiltan are in an advanced or mature stage of development. The development and growth of the islands on eastern reef margin has been controlled by a number of factors. The cyclones from the east have piled up coral debris on the eastern reef while the very high waves generated annually during the southwest monsoon have pounded the reef and broken this into coarse and subsequently to fine sediments which was then transported and deposited on the eastern side behind the coral boulders and pebbles on the eastern reef. A gradual accretion of sediments by this process has led to the growth of the islands. Even the atolls where the islands are not yet fully developed (Suheli, Valiyapanniyam and Bitra) sandy cays occur on the eastern reef margin. In some of the lagoons like Kiltan and Chetlat the islands are growing at a very fast rate and during the next decade the lagoon itself may be filled up with sediments. In such atolls where openings occur in the reef or where the lagoon is too wide for the sand to be transported across its entire width. sand banks usually develop and enlarge towards the centre of the lagoon leading to the formation of the island in the centre such as in Bangaram and Suheli etc.

The islands do not have any rivers or creeks but some brackish water ponds occur at Bangaram and Minicoy. At Bangaram the pond has been formed during the process of growth of the Islands where the outlet of the bay has been blocked by sand. At Minicoy, a similar pond was being formed at the southern edge but a bund has been constructed and this has created an artificial brackish water pond.

Land use pattern

Total reporting area	3200 hects
Area not available for cultivation	650 hects
Total cropped area	2570 hects
Net sown area	2570 hects
Area sown more than once	1565 hects
Coconut harvested	280.18 lakh Nuts

2.4 GEOLOGY

There are no conclusive theories about the formation of these coral atolls. The most accepted theory is given by the English Evolutionist Sir Charles Darwin. He concluded in 1842 that the subsidence of a volcanic island resulted in the formation of a fringing reef and the continual subsidence allowed this to grow upwards.

When the volcanic island became completely submerged the atoll was formed encircling the lagoon where, with the action of the wind, waves, reef to currents and temperature, the coral islands were formed.

2.5 HYDROGEOLOGICAL CONDITIONS

The Union Territory of Lakshadweep is an archipelago on the western coast of Peninsular India in the Arabian sea spread over a distance of 300 km and comprising of small islands having area between 0.1 and 4.8 sq km. The growing population and raised standard of living has imparted stress on the available fresh water resources. The lack of surface and ground water storage capacity in these islands, inspite of high rainfall, makes freshwater resources a dear commodity.

Ground water occurs under phreatic conditions in these islands occurring as a thin lens floating over the seawater and is tapped by open wells. Majority of the wells included under participatory monitoring tap coral sands and in almost all the wells hard coral limestone is exposed near the bottom. The depth to water level in these islands vary from a few centimetres to 5 m below ground level and depth of the wells vary from less than a meter to about 6 m. The depth to water level is highly influenced by the tides.

The hydrogeology of Agatti, Amini, Androth, Chetlat, Minicoy,Kavaratti and Kalpeni are shown in annexures 1a to 1 g respectively.

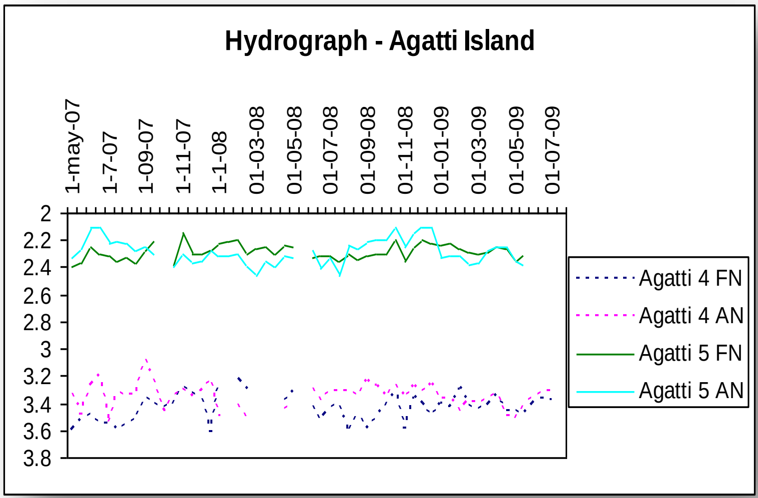
2.5.1 Water Level Scenario of Lakshadweep Islands

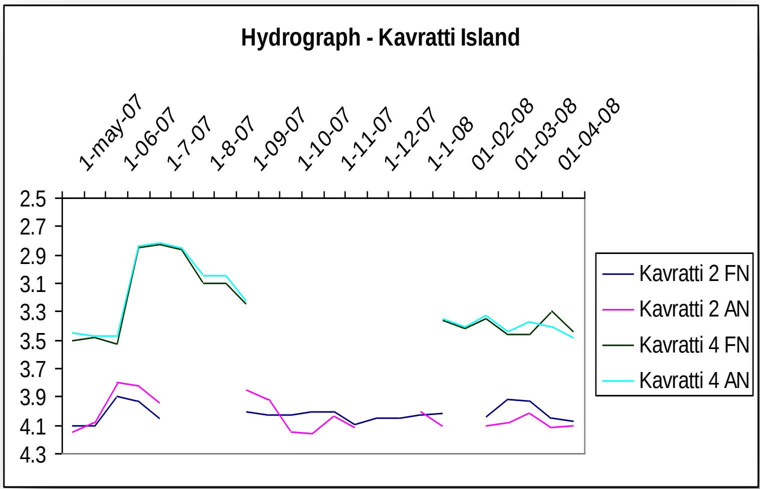
To assess the real groundwater situation, it is very essential to monitor the groundwater quantity and quality both spatially and temporally. CGWB has established monitoring wells in 2 phases. In the initial phase, 20 monitoring wells were established in 5 islands (Agatti, Kavratti, Amini, Kadamath and Kalpeni) for monitoring of water level during May 07. These wells were included under participatory monitoring programme by involving local people as observers. The observers were instructed to measure water level. All the observers were given a measuring tape, a register for data entry and addressed post - cards for communication of data to CHQ and proper training was given. Since the water level depends on tide, the observers were instructed to measure water level 2 times a day at specific timing of 8:00 hrs and 14:00 hrs on 1st and 15th of every month. In the second phase i.e., during January 2009, monitoring was increased to 4 more islands (Minicoy, Chetlat, Kiltan and Androth) by establishing 10 more wells. The number of monitoring wells identified in various islands is given table 2.7 below. The water level data of monitoring wells in different islands are tabulated in table 2.8, 2.9 and 2.10.

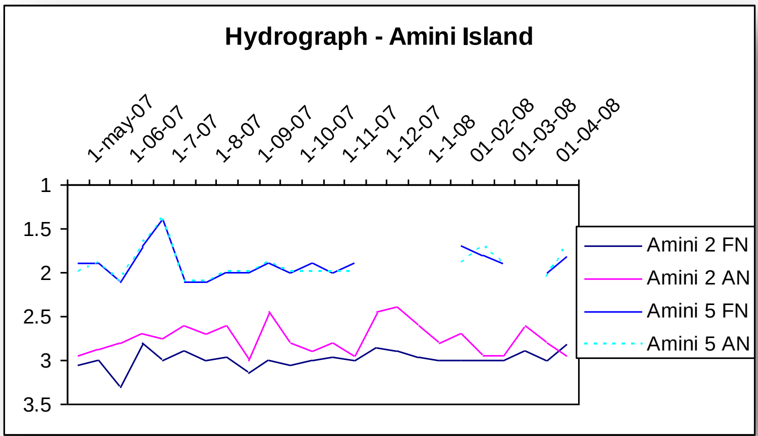
Table 2.7.

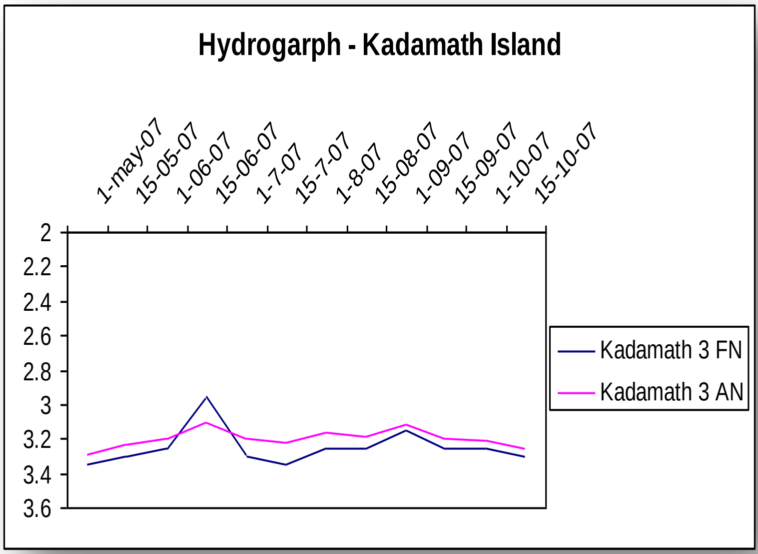
Sl No	Island	No of wells	Water level behaviour
1	Agatti	5	Area 2.70 sq km. Data from 2 wells for the period May 07 to July 09 shows that depth to water level ranges between 2.1 to 3.6 m bgl. The diurnal fluctuation in water level due to tides is in the range of 20 to 40 cms.
2	Kavratti	4	Area 3.63 sq km. Data from 2 wells shows that depth to water level ranges between 2.82 to 4.09 m bgl. The diurnal fluctuation in water level due to tides is 10 cms.
3	Amini	5	Area 2.50 sq km. The depth to water level ranges between 1.09 to 3.3 m bgl. The diurnal fluctuation in water level due to tides is more significant in well Amini 5. The diurnal fluctuation is in the range of 0 to 60 cms.
4	Kadamath	3	Area 3.13 sq km. Data available for one well indicates the depth to water level to range between 2.95 to 3.29 m bgl. The diurnal fluctuation in water level due to tides is in the range of 20 to 30 cms.
5	Kalpeni	3	Area 2.28 sq km. Data available for two wells shows the depth to water level to range between 1.79 to 2.9 m bgl. The diurnal fluctuation in water level due to tides is in the range of 0 to 80 cms.
6	Minicoy	2	
7	Chetlat	2	
8	Kiltan	3	
9	Androth	3	
	Total	**30**	

Hydrographs of selected wells in Lakshadweep








Hydrogarph - Kadamath Island
1-may-07
15-05-07
1-06-07
15-06-07
1-7-07
15-7-07
1-8-07
15-08-07
1-09-07
15-09-07
1-10-07
15-10-07
2
2.2
2.4
2.6
2.8
3
3.2
3.4
3.6
Kadamath 3 FN
Kadamath 3 AN

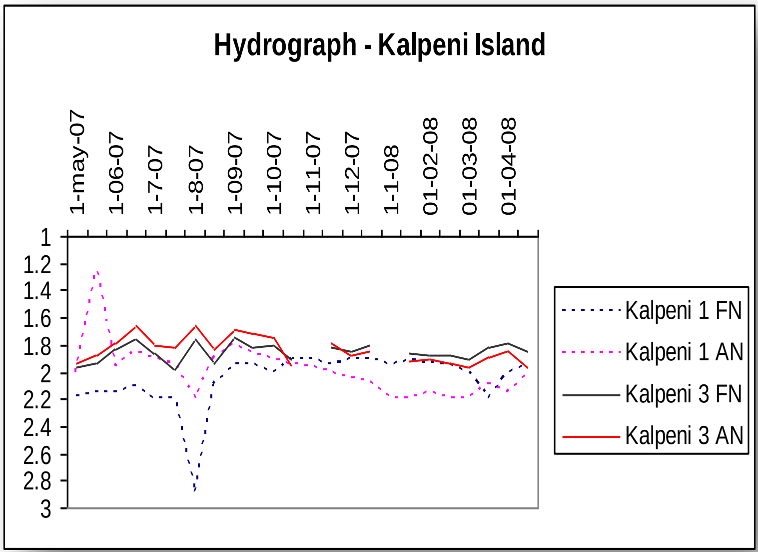

Hydrograph - Kalpeni Island
1-may-07
1-06-07
1-7-07
1-8-07
1-09-07
1-10-07
1-11-07
1-12-07
1-1-08
01-02-08
01-03-08
01-04-08
1
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8
3
Kalpeni 1 FN
Kalpeni 1 AN
Kalpeni 3 FN
Kalpeni 3 AN

Table. 2.8 Water Level Data of Monitoring wells in Agatti Island (May 07- July09)

	Agatti 4		Agatti 5	
	FN	AN	FN	AN
01-05-07	3.6	3.33	2.4	2.33
15-05-07	3.52	3.48	2.37	2.26
01-06-07	3.48	3.27	2.25	2.11
15-06-07	3.55	3.2	2.3	2.1
01-07-07	3.55	3.55	2.32	2.22
15-07-07	3.6	3.33	2.36	2.21
01-08-07	3.57	3.34	2.33	2.22
15-08-07	3.52	3.34	2.37	2.27
01-09-07	3.35	3.08	2.28	2.25
15-09-07	3.4	3.26	2.2	2.3
01-10-07	3.43	3.46		
15-10-07	3.4	3.35	2.38	2.4
01-11-07	3.27	3.3	2.15	2.3
15-11-07	3.33	3.35	2.3	2.37
01-12-07	3.37	3.32	2.3	2.35
15-12-07	3.62	3.22	2.28	2.28
01-01-08	3.28	3.5	2.22	2.32
15-01-08			2.21	2.31
01-02-08	3.22	3.4	2.2	2.3
15-02-08	3.3	3.52	2.3	2.4
01-03-08			2.26	2.46
15-03-08			2.25	2.36
01-04-08			2.3	2.4
15-04-08	3.38	3.45	2.24	2.32
01-05-08	3.32	3.4	2.25	2.33
15-05-08				

	Agatti 4		Agatti 5	
01-06-08	3.42	3.29	2.33	2.27
15-06-08	3.52	3.38	2.32	2.41
01-07-08	3.448	3.31	2.31	2.33
15-07-08	3.4	3.31	2.36	2.46
01-08-08	3.62	3.32	2.3	2.24
15-08-08	3.49	3.34	2.34	2.26
01-09-08	3.59	3.23	2.31	2.21
15-09-08	3.5	3.28	2.3	2.2
01-10-08	3.42	3.35	2.3	2.2
15-10-08	3.31	3.26	2.2	2.1
01-11-08	3.59	3.36	2.35	2.25
15-11-08	3.35	3.27	2.25	2.15
01-12-08	3.4	3.31	2.2	2.1
15-12-08	3.5	3.26	2.22	2.1
01-01-09	3.4	3.36	2.23	2.33
15-01-09	3.43	3.37	2.22	2.32
01-02-09	3.29	3.46	2.26	2.32
15-02-09	3.42	3.38	2.29	2.38
01-03-09	3.44	3.40	2.3	2.37
15-03-09	3.42	3.36	2.29	2.28
01-04-09	3.34	3.33	2.25	2.25
15-04-09	3.46	3.50	2.26	2.25
01-05-09	3.46	3.51	2.35	2.35
15-05-09	3.48	3.42	2.32	2.38
01-06-09	3.40	3.35		
15-06-09	3.37	3.33		
01-07-09	3.38	3.31		

Table 2.9. Water Level Data of Monitoring wells at Kavratti & Amini

	Kavratti 2		Kavratti 4	
	FN	AN	FN	AN
01-05-07	4.1	4.15	3.5	3.45
15-05-07	4.1	4.08	3.48	3.47
01-06-07	3.9	3.8	3.52	3.47
15-06-07	3.93	3.82	2.85	2.84
01-07-07	4.05	3.94	2.83	2.82
15-07-07			2.86	2.85
01-08-07	4.02	3.9	3.1	3.05
15-08-07			3.1	3.05
01-09-07	4	3.85	3.25	3.23
15-09-07	4.03	3.92		
01-10-07	4.03	4.15		
15-10-07	4	4.16		
01-11-07	4.01	4.04		
15-11-07	4.09	4.11		
01-12-07	4.05			
15-12-07	4.05			
01-01-08	4.03	4		
15-01-08	4.02	4.1	3.36	3.35
01-02-08			3.42	3.4
15-02-08	4.04	4.1	3.35	3.33
01-03-08	3.92	4.08	3.46	3.44
15-03-08	3.93	4.02	3.46	3.37
01-04-08	4.05	4.11	3.3	3.4
15-04-08	4.07	4.1	3.45	3.48

	Amini 2		Amini 5	
	FN	AN	FN	AN
01-05-07	3.05	2.95	1.9	2
15-05-07	3	2.87	1.9	1.9
01-06-07	3.3	2.8	2.1	2.1
15-06-07	2.8	2.7	1.7	1.7
01-07-07	3	2.75	1.4	1.4
15-07-07	2.9	2.6	2.1	2.1
01-08-07	3	2.7	2.1	2.1
15-08-07	2.97	2.6	2	2
01-09-07	3.15	3	2	2
15-09-07	3	2.45	1.9	1.9
01-10-07	3.05	2.8	2	2
15-10-07	3	2.9	1.9	2
01-11-07	2.97	2.8	2	2
15-11-07	3	2.95	1.9	2
01-12-07	2.85	2.45		
15-12-07	2.9	2.4		
01-01-08	2.97	2.6		
15-01-08	3	2.8		
01-02-08	3	2.7	1.7	1.9
15-02-08	3	2.95	1.8	1.7
01-03-08	3	2.95	1.9	1.9
15-03-08	2.9	2.6		
01-04-08	3	2.8	2	2.06
15-04-08	2.8	2.95	1.8	1.7

Table. 2.10. Water Level Data of Monitoring wells in Kadamath &Kalpeni Island

	Kadamath 3	
	FN	AN
01-05-07	3.35	3.29
15-05-07	3.3	3.23
01-06-07	3.25	3.2
15-06-07	2.95	3.1
01-07-07	3.3	3.2
15-07-07	3.35	3.22
01-08-07	3.25	3.16
15-08-07	3.25	3.18
01-09-07	3.15	3.12
15-09-07	3.25	3.2
01-10-07	3.25	3.21
15-10-07	3.3	3.25
01-11-07		
15-11-07	3.27	3.26
01-12-07	3.25	3.3
15-12-07	3.2	3.25
01-01-08	3.25	3.3
15-01-08	3.17	3.27
01-02-08	3.17	3.25
15-02-08	3.2	3.3
01-03-08	3.22	3.3
15-03-08	3.15	3.25
01-04-08	3.23	3.3
15-04-08	3.2	3.25

	Kalpeni 1		Kalpeni 3	
	FN	AN	FN	AN
01-05-07	2.18	2	1.97	1.94
15-05-07	2.15	1.25	1.93	1.88
01-06-07	2.15	1.96	1.83	1.79
15-06-07	2.11	1.85	1.76	1.66
01-07-07	2.2	1.9	1.86	1.81
15-7-07	2.2	1.95	1.98	1.82
01-08-07	2.9	2.2	1.76	1.65
15-08-07	2.1	1.9	1.94	1.83
01-09-07	1.95	1.8	1.75	1.69
15-09-07	1.95	1.86	1.82	1.71
01-10-07	2	1.9	1.8	1.75
15-10-07	1.91	1.95	1.9	1.96
01-11-07	1.9	1.96		
15-11-07	1.95	2	1.82	1.79
1-12-07	1.9	2.05	1.84	1.87
15-12-07	1.91	2.08	1.8	1.85
01-01-08	1.95	2.2		
15-01-08	1.92	2.2	1.86	1.92
01-02-08	1.93	2.16	1.87	1.91
15-02-08	1.95	2.2	1.88	1.93
01-03-08	2	2.2	1.91	1.97
15-03-08	2.2	2.1	1.82	1.89
01-04-08	2	2.15	1.79	1.85
15-04-08	1.95	2	1.85	1.96

2.6 GROUND WATER RESOURCES

Because of the inherent geomorphological, hydrogeological and physical characteristics of the islands, precise estimation of the ground water resources is difficult. Water level fluctuation method is not applicable as it does not reflect the change in storage. Water balance and chloride techniques also have their limitations. Hence, water budgeting combined with other factors were utilized for arriving at a realistic estimate of the resource. The bulk of the ground water draft is utilized in the domestic sector. Irrigation draft is minimum and industrial draft is negligible. However, due to the large population and the limited resource some areas are not able to cater even to the domestic requirements. The growing use of pump sets for domestic requirements has accelerated the ground water draft in the islands.

As per the methodology recommended by GEC 1997, the ground water resource of Lakshadweep is as follows:

- Total Ground Water Recharge : 12.08 mcm
- Natural Discharge during non-monsoon : 8.58 mcm
- Net Ground Water Availability : 3.50 mcm
- Draft for domestic uses : 2.20 mcm
- Stage of development : 63 %

The stages of development for the different islands are given in table 2.11.

Table. 2.11. Water Level Data of Monitoring wells in Kadamath &Kalpeni Island

Island	Stage of development (%)	Island	Stage of development (%)	Island	Stage of development (%)
Agatti	74	Chetlat	57	Kiltan	59
Amini	73	Kadmat	44	Kavaratti	86
Androth	57	Kalpeni	52	Minicoy	63

2.7 WATER SUPPLY

All the inhabited islands are problem areas so far as the drinking water supply is concerned. A central team consisting of Advisor (TM), Department of Rural Development along with experts from Central Ground Water Board, CSMCRI Bavanager, NEERI Nagpur, CESS Thiruvananthapuram, after their visit to Lakshadweep, came to the conclusion that no single system or approach to provide water supply to Lakshadweep islands would be sufficient due to typical geological and hydrogeological nature of these islands. They suggested tapping of ground water to the extent of its sustainable yield and supplement it with additional activities such as installation of Desalination Plants, Rain Water Harvesting etc. Accordingly, the Water Supply scheme was modified to have a combination of ground water, Reverse Osmosis Desalination Plants and rain water harvesting. In all islands water supply system is in existence partially. Now more attention has given to construction of individual rain water harvesting stuctures, since the system is more adoptable to these areas.

Population pressure placed an enormous strain on the quantity of fresh water available, leading to saline water intrusion. One desalination plant set up by the National Institute of Ocean Technology (NIOT) under the Ministry of Earth Sciences, GOI, which is based on pressure and temperature differential in the seawater and not on membrane (RO) technology. The plant was the sole source of drinking water being piped free of cost to every household in the island. The concept of the variation in the ocean water temperature with an increase in depth is used in the Low Temperature Thermal Desalination (LTTD) to flash evaporate the warm water at low pressure and condense the resulting vapour with the deep sea cold water. NIOT has already successfully commissioned a 100 m^3/day desalination plant at Kavaratti Island and a 1000 m^3/day capacity floating barge based desalination plant off the coast of Chennai.

2.8 MANAGEMENT OF LIQUID AND SOLID WASTES

Changing life style and the increasing population pressure have led to increased generation of sewage and solid wastes. The untreated domestic wastes are discharged into the sea directly without any treatment. The solid wastes are dumped on the narrow shore line, behind each house-hold, both at Agatti and Kavaratti, There is therefore an urgent need of proper solid waste management plan/system in the Islands. It is estimated that about 1.2 million litres of waste per day is generated at Kavaratti alone. Major issue concerning the disposal of solid waste is the absence of systematic sewerage system. Most households have constructed soak pits for disposal of latrine waste. Owing to acute pressure on the land, the soak pits have been constructed very close to the open wells. The soil being sandy and porous and the soak pits have been constructed rather unscientifically, faecal matter from the soak pits finds its way into the water in the open wells. The non-degradable solid wastes are dumped at one end of each island by the local bodies.

2.9 QUALITY OF GROUND WATER

The ground water in the islands is generally alkaline with a few exceptions. The Electrical Conductivity (EC) ranges from 500 to 15,000 µmhos /cm at 25 ^{0}C. Higher concentrations of dissolved solids are generally seen along the periphery of the island and also close to pumping centres. The quality variation is vertical, temporal and also lateral. The quality is highly variable and reversible. It is also observed that the quality improves with rainfall. Other factors affecting the quality are tides, ground water recharge and draft. There is a vertical variation of quality due to the zone of interface and underlying sea water. Perforation created due to drilling or otherwise also affects the quality as it acts as a conduit for flow of sea water. The Electrical Conductivity of ground water in the islands Agatti, Amini, Androth, Chetlat, Kalpeni, Kavarattiand Minicoy are shown in Annexures 2 a, to 2 g.

Wells manually operated retain more or less the same quality of ground water over longer time periods as compared to mechanized wells where, quality deterioration is observed in the form of increasing EC. Brackish water is present along topographic lows and in places where coarse pebbles and corals are present.

Another major threat to ground water in the islands is the pollution. The human and livestock wastes, oil spills and fertilizers are the main polluting agents with sewerage and other biological wastes contributing most.

2.10 CONCLUSIONS

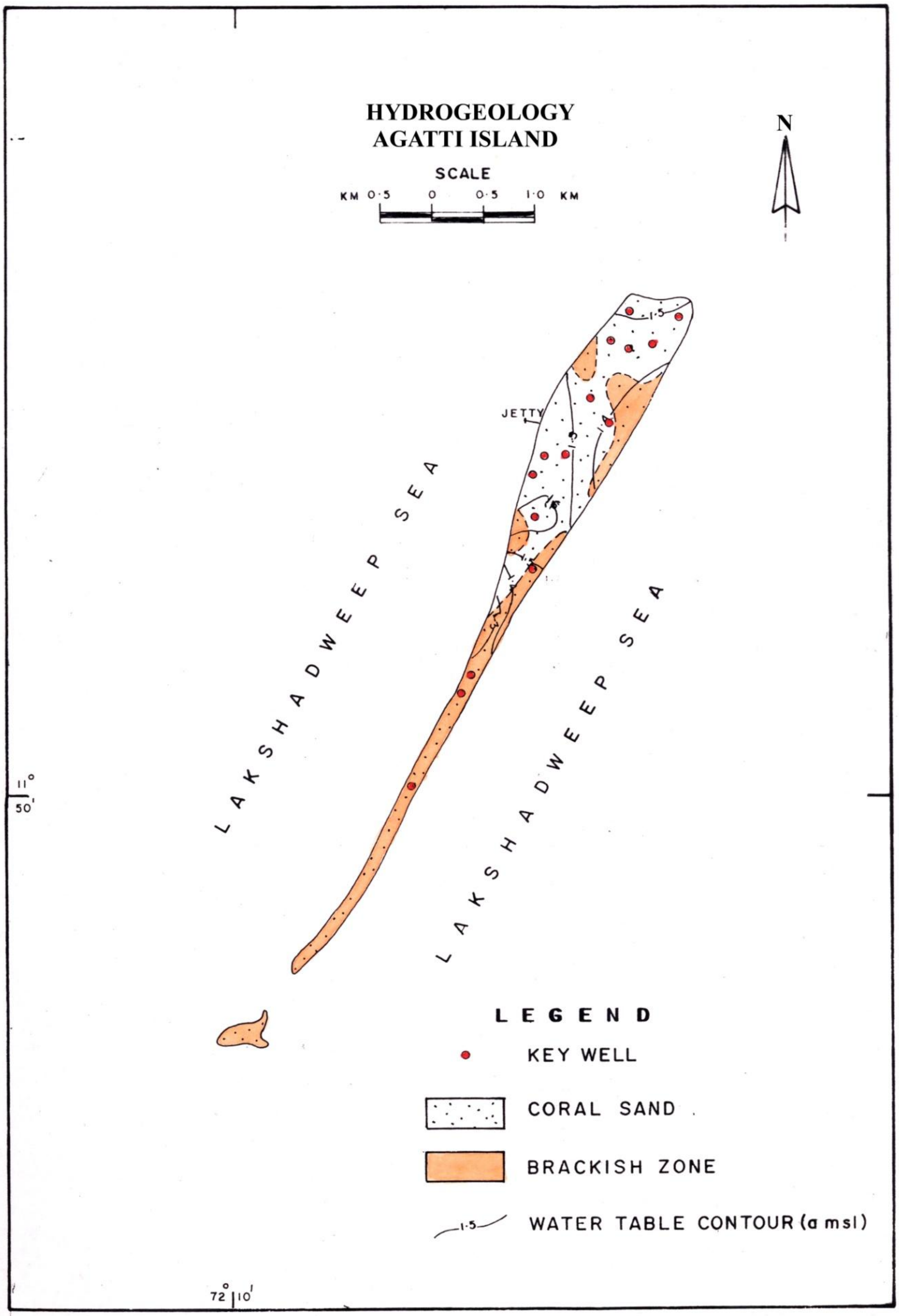
- Lakshadweep is a uni-district Union Territory with an area of 32 sq km., and comprise of 10 inhabited islands, 17 uninhabited islands attached islets, 4 newly formed islets and 5 submerged reefs.
- Lying well within the tropics and extending to the equatorial belt, these islands have a tropical humid, warm climate, becoming more equatorial in the southern islands of the territory.
- The islands are flat, rarely rising more than two meters, and consist of fine coral sand and boulders compacted into sandstone.
- All Lakshadweep islands are of coral origin and some of them like Minicoy, Kalpeni, Kadmat, Kiltan and Chetlat are typical atolls.
- The islands do not have any rivers or creeks but some brackish water ponds occur at Bangaram and Minicoy.
- Ground water occurs under phreatic conditions in these islands occurring as a thin lens floating over the seawater and is tapped by open wells. The depth to water level in these islands vary from a few centimetres to 5 m below ground level and depth of the wells vary from less than a meter to about 6 m.
- The depth to water level is influenced by the tides. The water level fluctuation in these islands is significantly controlled by tides when compared to the groundwater recharge and draft. The diurnal fluctuation of water level due to tides is in the range of negligible to 80 cms.
- The fresh water resources in the islands are limited.
- The stage of ground water development ranges from 44 to 86 %. Overall stage of development of the islands as a whole stands at 63 %.
- The water level suddenly rises to fraction of metres immediately after the rainfall and again falls down to the original level within hours. Hence the magnitude of seasonal fluctuation in water level due to ground water recharge is not so significant when compared to tidal fluctuations.
- Population pressure placed an enormous strain on the quantity of fresh water available, leading to saline water intrusion.
- The untreated domestic wastes are discharged into the sea directly without any treatment.
- Major issue concerning the disposal of solid waste is the absence of systematic sewerage system.

- Households have constructed soak pits for disposal of latrine waste. Owing to acute pressure on the land, the soak pits have been constructed very close to the open wells. The soil being sandy and porous and the soak pits have been constructed rather unscientifically, faecal matter from the soak pits finds its way into the water in the open wells and contaminate the ground water.
- The non-degradable solid wastes are dumped at one end of each island by the local bodies.
- The Electrical Conductivity of ground water ranges from 500 to 15,000 µmhos /cm at 25 0C. The quality variation is vertical, temporal and also lateral.
- Brackish water is present along topographic lows and in places where coarse pebbles and corals are present.
- The human and livestock wastes, oil spills and fertilizers are the main polluting agents with sewerage and other biological wastes contributing most.
- Unlike the mainland seasonal or perennial streams, lakes, ponds or wetlands do not exist in Lakshadweep. Overall climate is of humid, tropical monsoon type. The topography is almost flat, soils are sandy, highly permeable and even local surface run-off marks are not seen. The islands are so small that water run-off, if any, cannot attain critical concentration to render even a small stream. It is all in situ infiltration of rain water into the ground. Thus recharging potential is extremely good.
- Infiltrated rain water being of good quality, floats on the relatively denser saline water in the aquifer. However, the fresh water zone is of limited thickness. Almost every household has one or two shallow dug wells for extraction of this floating fresh water for washing, bathing, livestock and even drinking during critical periods of the year. This water is limited in quantity and its salinity level increases as a function of time during withdrawal in the dry periods.
- Contamination of ground water, anthropogenically is a serious threat in almost all the islands.
- In the islands, most of the latrines are based on soak pits since sewerage treatment system is not provided. Even defecation and urination made on the ground in the open has high probability of contaminating very shallow ground water especially during the rainy season because of high infiltration rate. Hence extraction of shallow ground water for drinking is full of health hazards.
- Desalination of saline water is quite expensive and energy demanding.
- The mean annual rainfall ranges from 1715 mm in Amini to 1934 mm in Minicoy. Howevcer, 80 % of the rainfall is received from May to November when roof top rain water harvesting would be sufficient to meet domestic requirements.
- December to April are the rainless months critical for water consumption.

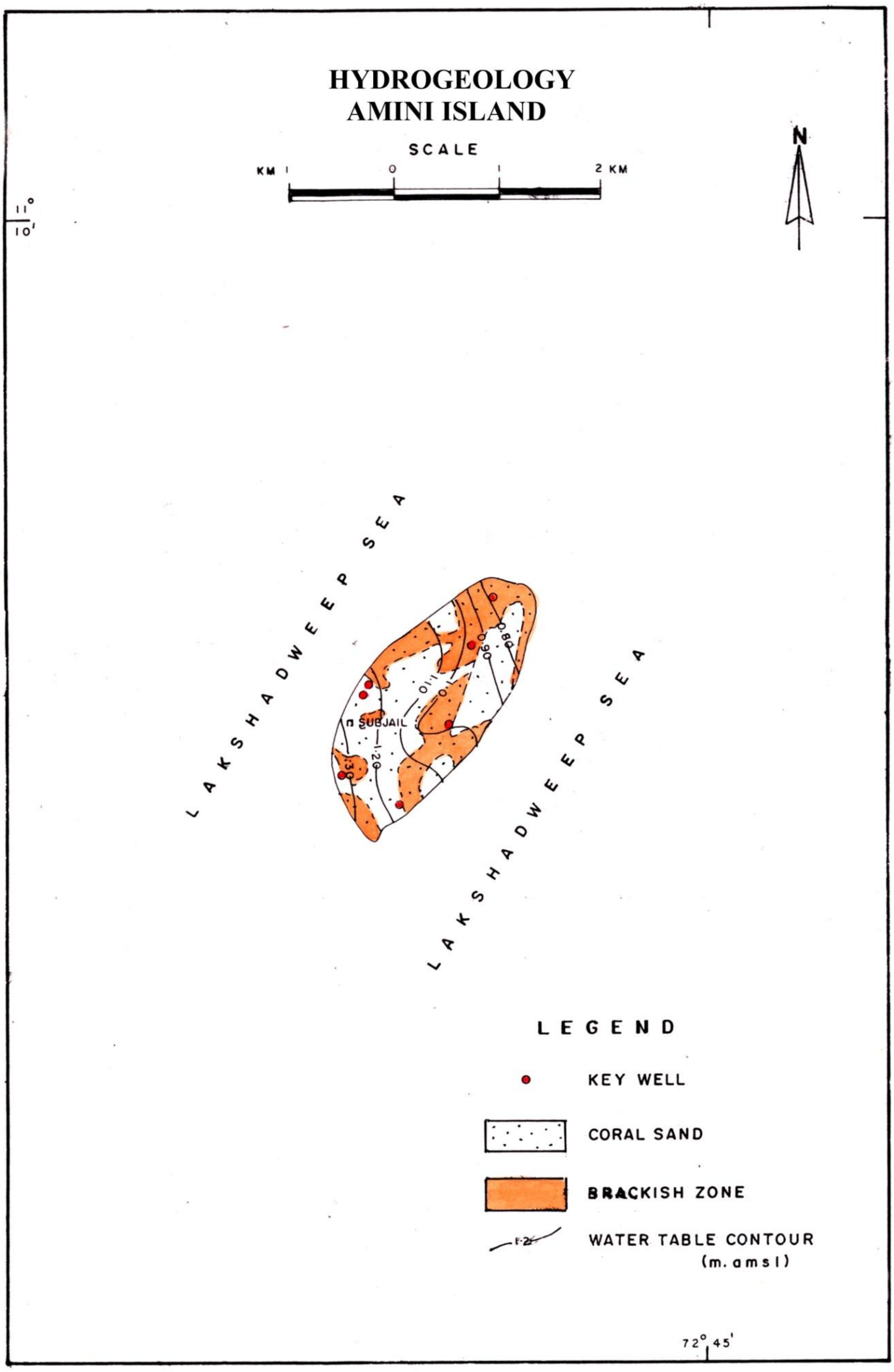
2.11 RECOMMENDATIONS

- Detailed hydrogeological and geophysical studies are required for proper understanding of the saline-fresh water interface behavior and management of the ground water resource.
- The need for harvesting and extraction of rain water on a scientific basis is very essential.
- Roof top rain water harvesting can provide reliable fresh water during major part of the year. Sloping roofs of GI sheets are common throughout the islands. The rain fall on the roof top can be channelized and stored in tanks for use. The advantage is that the tanks would get filled and re-filled a number of times during the rainy season.
- Rain Water Harvesting should be mandatory for all future civil constructions.
- Individual and community roof top rain water harvesting is an ideal decentralised system of providing safe drinking water. Full advantage to be made of the good rainfall the islands receive.
- Generating awareness and capacity building of community towards healthy living conditions by promoting eco-sanitation, Rain Water Harvesting, Water Conservation, recycling and re-use should be done on a large scale.
- The traditional open wells can be modified to increase the yield and also ensure its sustainability. Yield can be enhanced by laying filter pipes (collector pipes) horizontally into the fresh water layers and connecting it to the wells. In this way fresh water from 50 to 60 m horizontal distances can be collected in the open wells constructed with RCC rings.
- As the shallow, thin floating lens of ground water is easily prone to contamination, efforts for proper sewage disposal are to be given top priority.
- Composting toilets should be promoted particularly in places where water table is shallow to safeguard against ground water contamination from sewage, etc.
- The Low Temperature Thermal Desalination (LTTD) water treatment technology successfully implemented at Kavaratti in Lakshadweep island can be replicated in other islands.
- Land area being scarce, it would not be in larger interest to construct surface structures for harvesting rain water such as percolation tanks and ponds.
- Absence of nallas and streams in the islands rules out constructions of check dams and nullah bunds.
- A detailed liquid and solid waste management plan should be evolved. A pilot study on disposal of waste water and also non-biodegradable solid wastes could be undertaken in any one of the inhabited islands. The efficacy and reliability of the available waste management and treatment options are to be examined under the prevailing local conditions to prevent the environmental degradation and to protect and conserve the critical coastal habitats and their resources.

Annexure 1 a

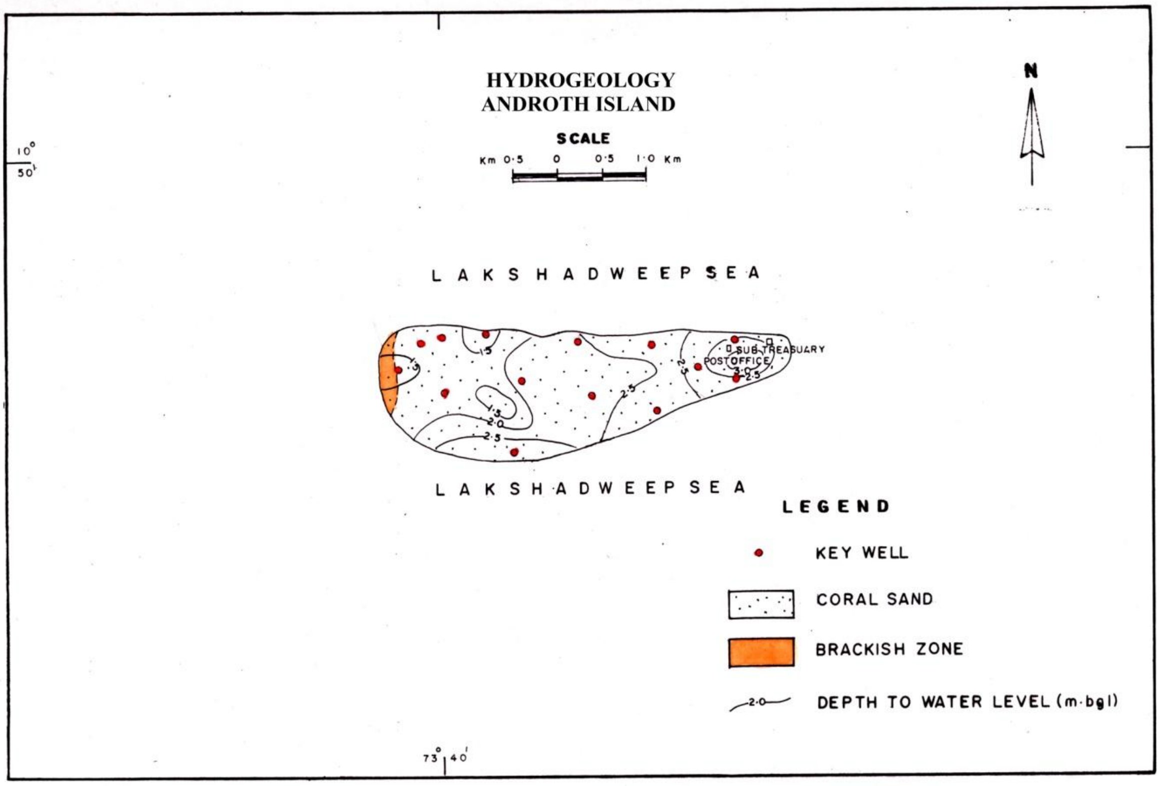

HYDROGEOLOGY
AGATTI ISLAND
SCALE
KM 0·5 0 0·5 1·0 KM
N
JETTY
LAKSHADWEEP SEA
LAKSHADWEEP SEA
11°
50'
72° 10'
LEGEND
KEY WELL
CORAL SAND
BRACKISH ZONE
1·5
WATER TABLE CONTOUR (a msl)

Annexure 1 b

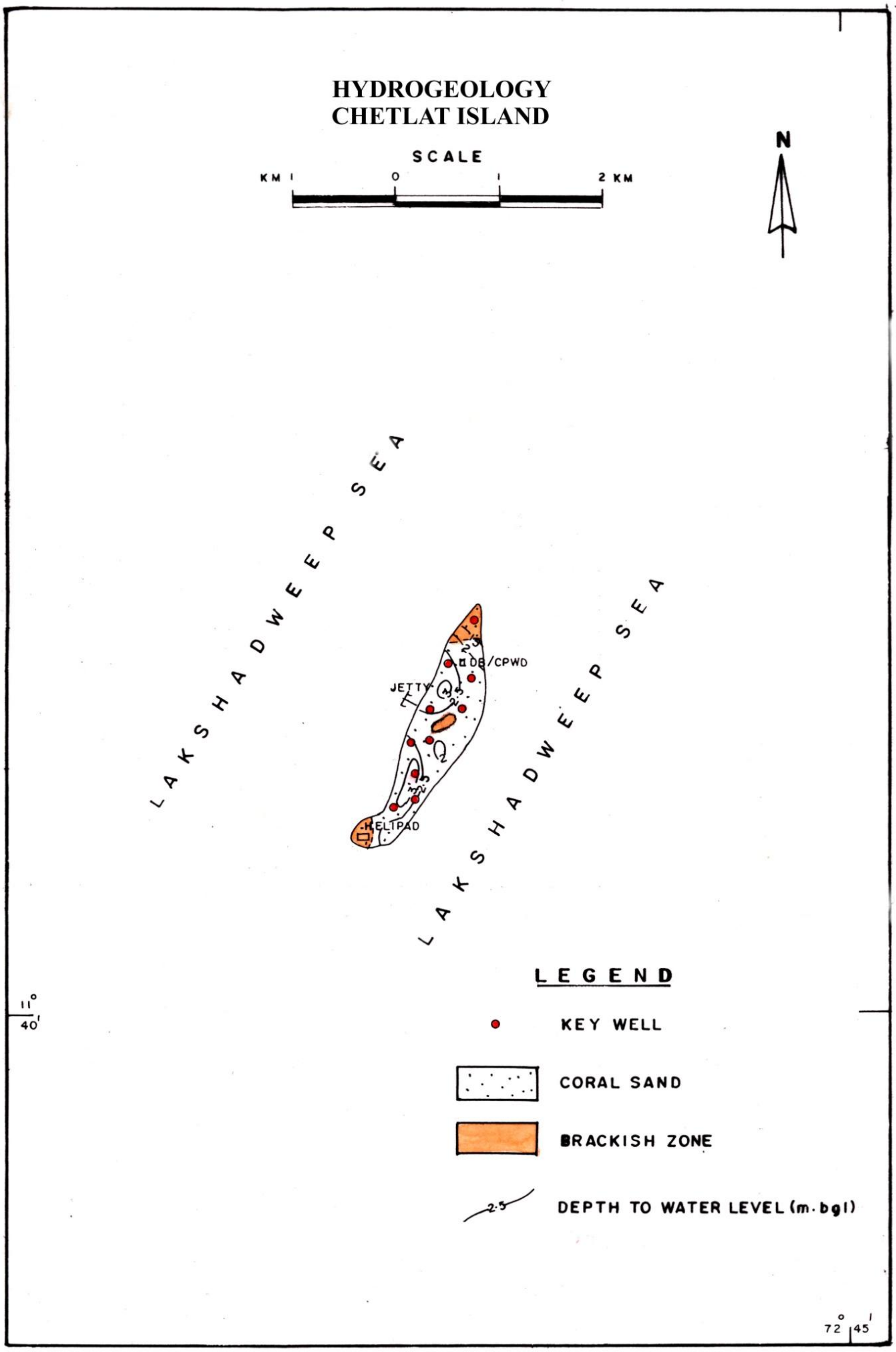


HYDROGEOLOGY
AMINI ISLAND
SCALE
KM 1
0
1
2 KM
N
11°
10'
LAKSHADWEEP SEA
LAKSHADWEEP SEA
SUBJAIL
0.80
0.90
1.10
1.10
1.20
1.30
LEGEND
KEY WELL
CORAL SAND
BRACKISH ZONE
WATER TABLE CONTOUR
(m. amsl)
72° 45'

Annexure 1 c

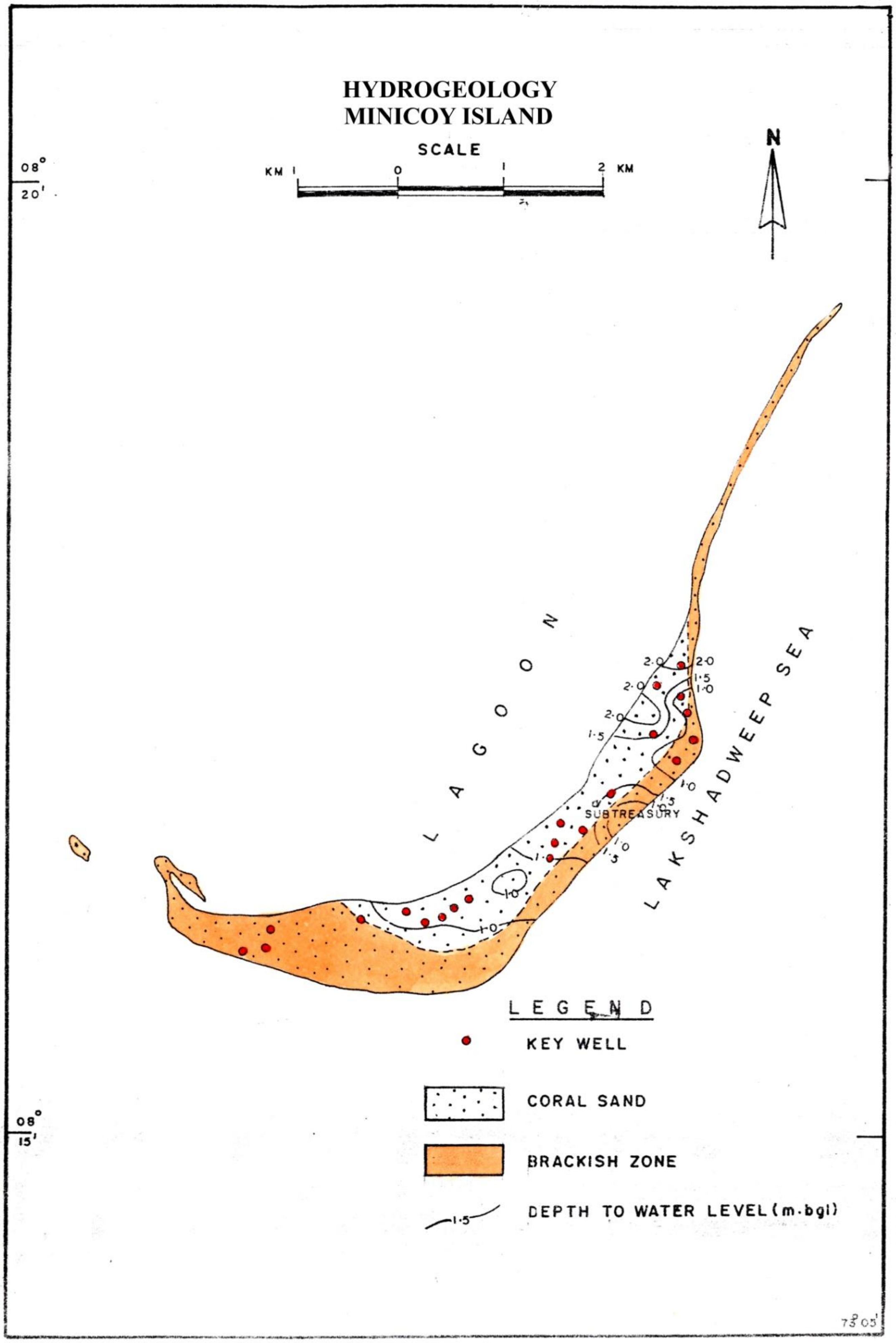

HYDROGEOLOGY
ANDROTH ISLAND
SCALE
Km 0·5 0 0·5 1·0 Km
N
10°
50'
LAKSHADWEEP SEA
SUB TREASUARY
POST OFFICE
LAKSHADWEEP SEA
LEGEND
KEY WELL
CORAL SAND
BRACKISH ZONE
DEPTH TO WATER LEVEL (m·bgl)
73° 40'

Annexure 1 d



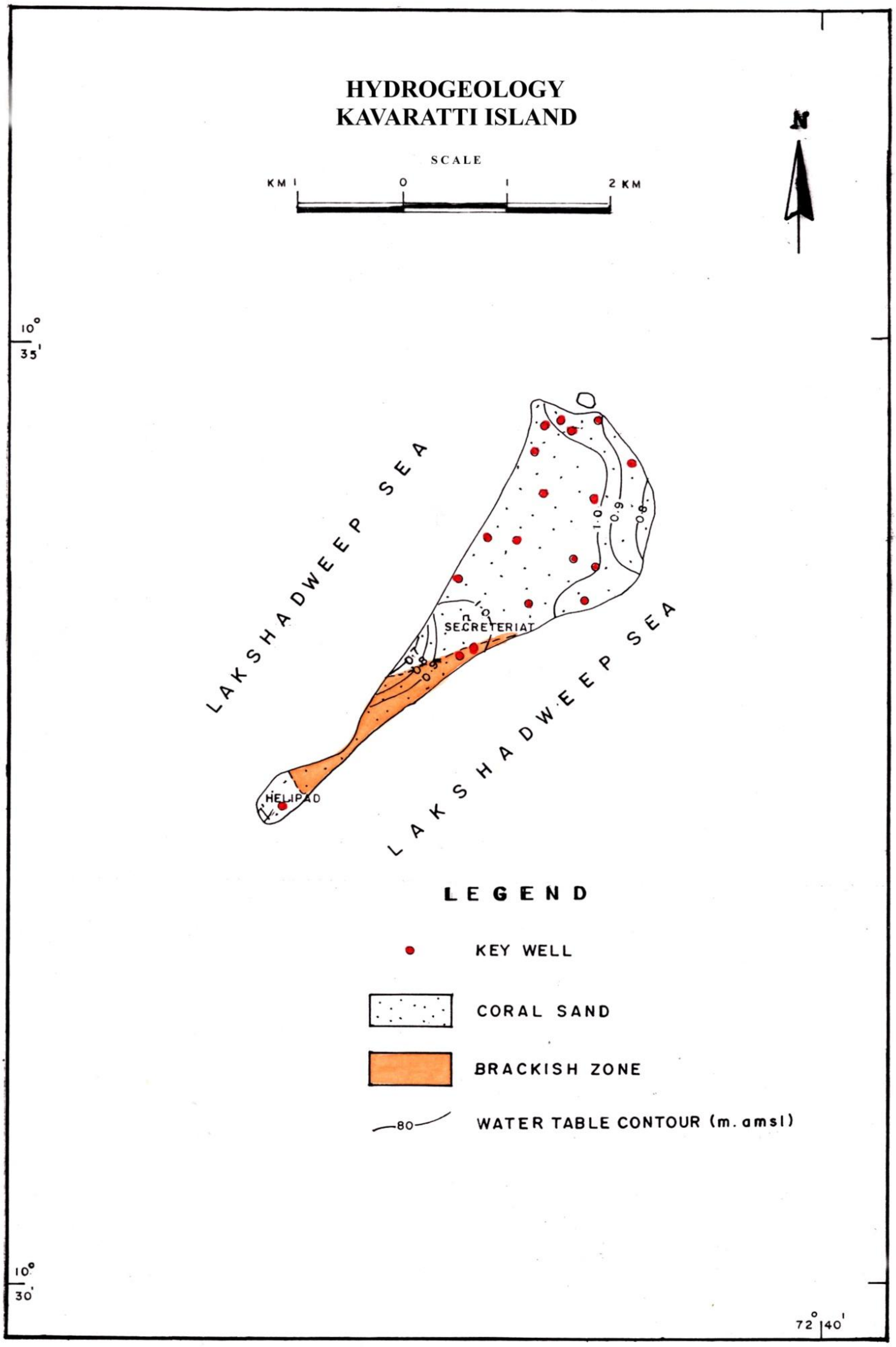
HYDROGEOLOGY
CHETLAT ISLAND
SCALE
KM 1
0
1
2 KM
N
LAKSHADWEEP SEA
LAKSHADWEEP SEA
DB/CPWD
JETTY
HELIPAD
LEGEND
KEY WELL
CORAL SAND
BRACKISH ZONE
DEPTH TO WATER LEVEL (m.bgl)
2·5
11°
40'
72° 45'

Annexure 1 e

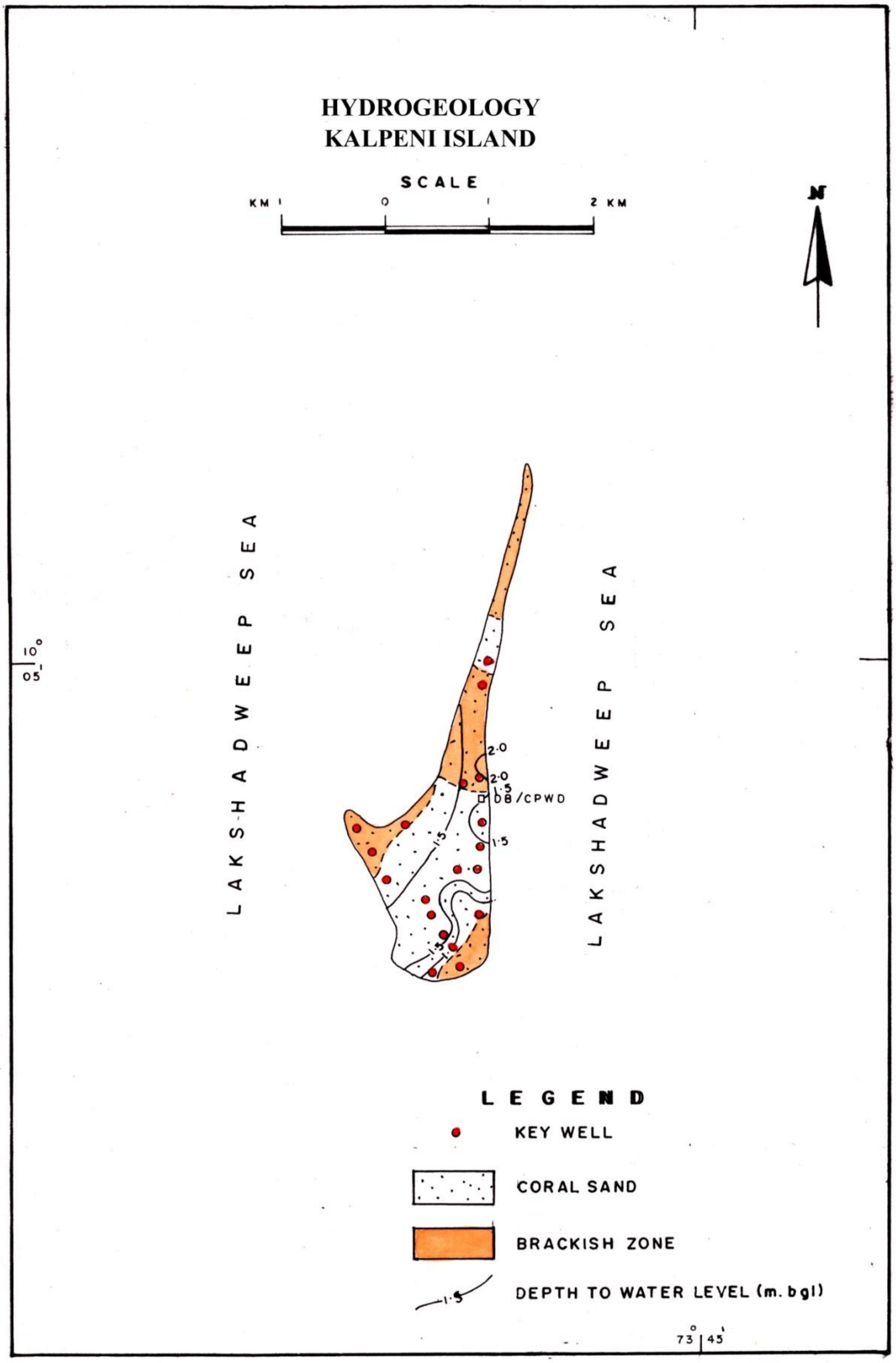


HYDROGEOLOGY
MINICOY ISLAND
SCALE
KM 1 0 1 2 KM
N
08°
20'
08°
15'
LAGOON
LAKSHADWEEP SEA
SUBTREASURY
LEGEND
KEY WELL
CORAL SAND
BRACKISH ZONE
DEPTH TO WATER LEVEL (m.bgl)

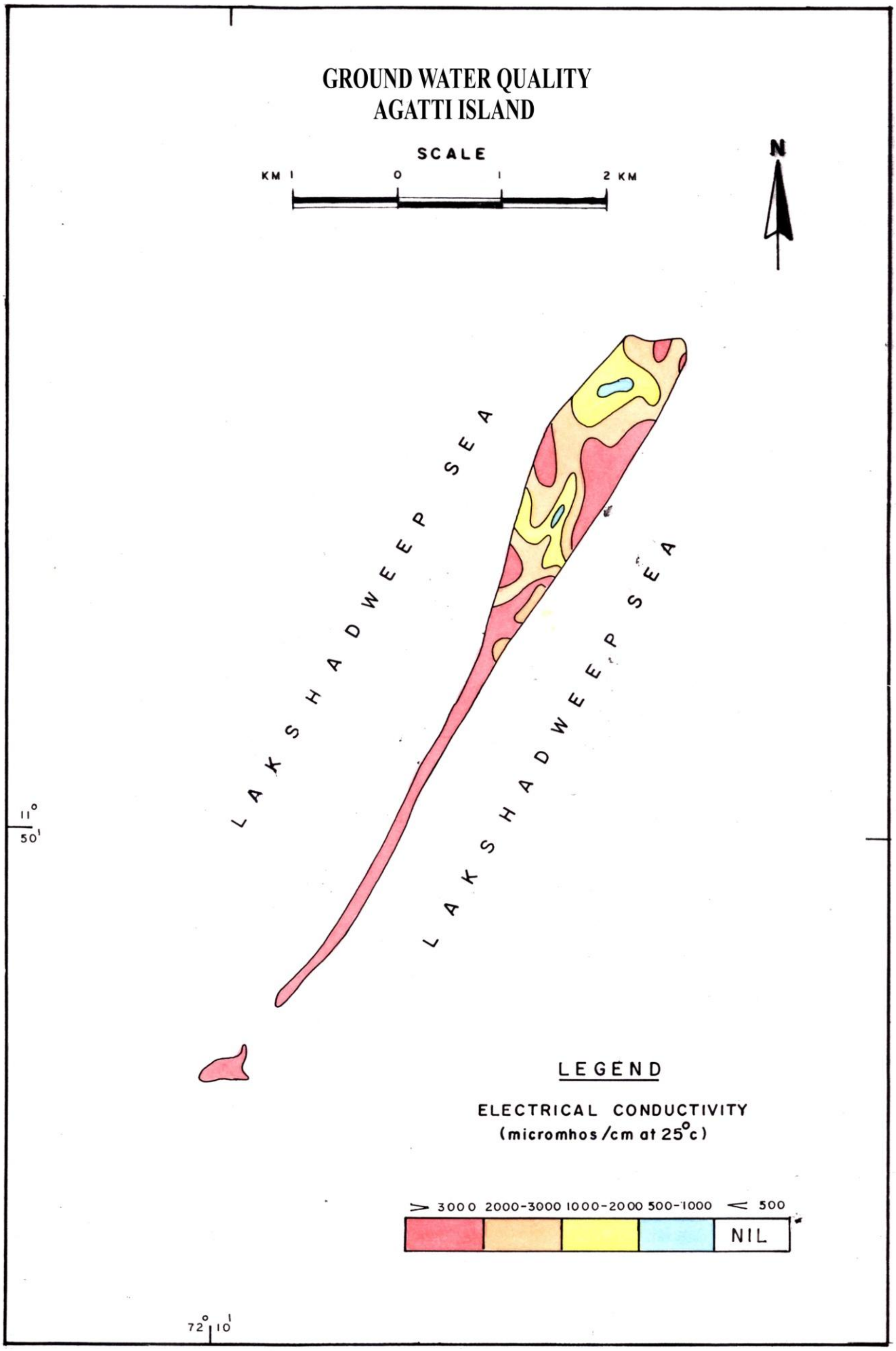
Annexure 1 f


HYDROGEOLOGY
KAVARATTI ISLAND
SCALE
KM 1
0
1
2 KM
N
10°
35'
LAKSHADWEEP SEA
SECRETERIAT
HELIPAD
1.0
0.9
0.8
LAKSHADWEEP SEA
LEGEND
KEY WELL
CORAL SAND
BRACKISH ZONE
80
WATER TABLE CONTOUR (m.amsl)
10°
30'
72° 40'

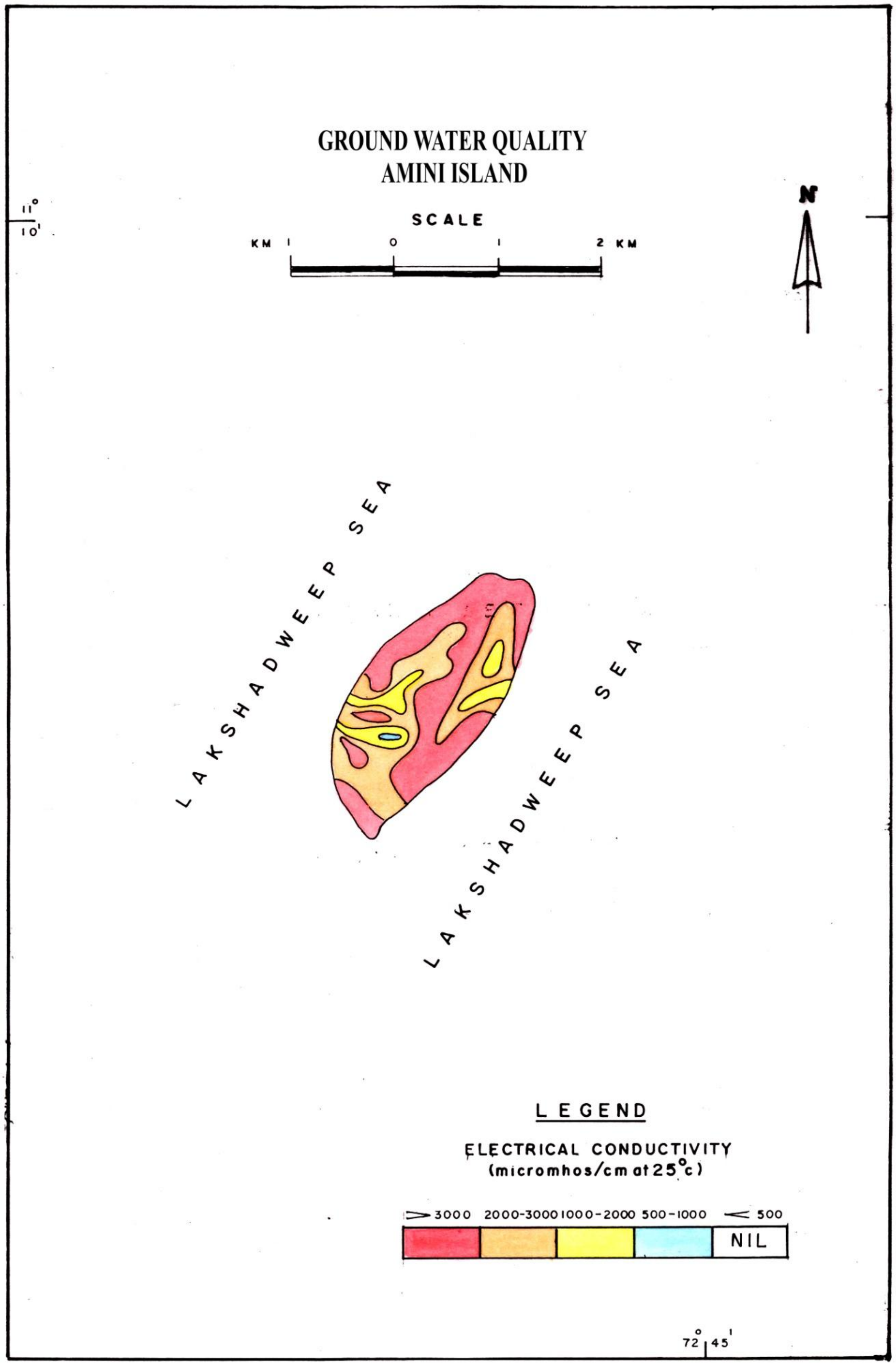
Annexure 1 g


HYDROGEOLOGY
KALPENI ISLAND
SCALE
KM 1
0
1
2 KM
N
LAKSHADWEEP SEA
LAKSHADWEEP SEA
10°
05'
2·0
2·0
1·5
DB/CPWD
1·5
1·5
LEGEND
KEY WELL
CORAL SAND
BRACKISH ZONE
1·5
DEPTH TO WATER LEVEL (m. bgl)
73° 45'

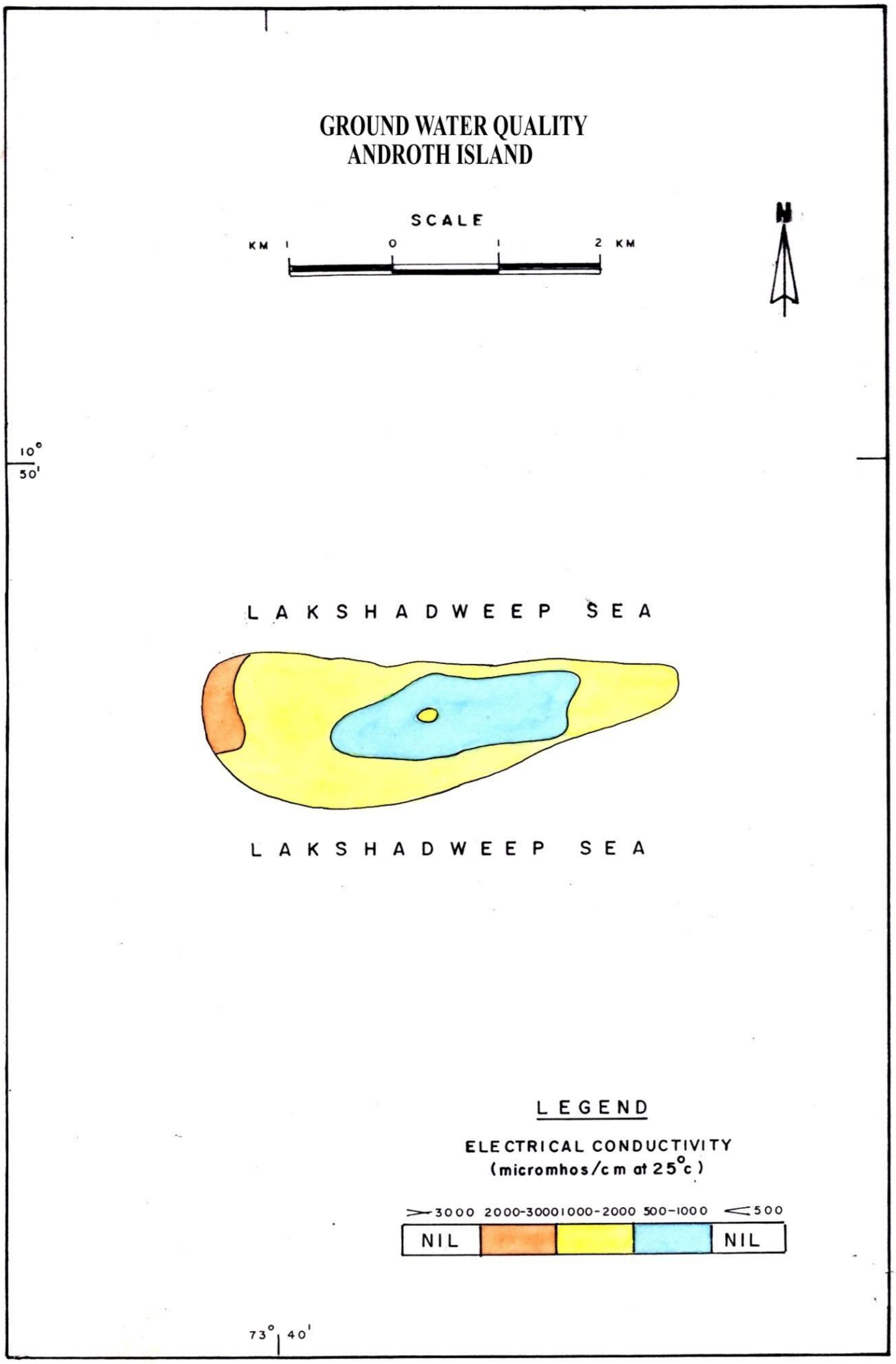
Annexure 2 a


GROUND WATER QUALITY
AGATTI ISLAND
SCALE
KM 1 0 1 2 KM
N
LAKSHADWEEP SEA
LAKSHADWEEP SEA
11°
50'
72° 10'
LEGEND
ELECTRICAL CONDUCTIVITY
(micromhos /cm at 25°c)
> 3000
2000-3000
1000-2000
500-1000
< 500
NIL

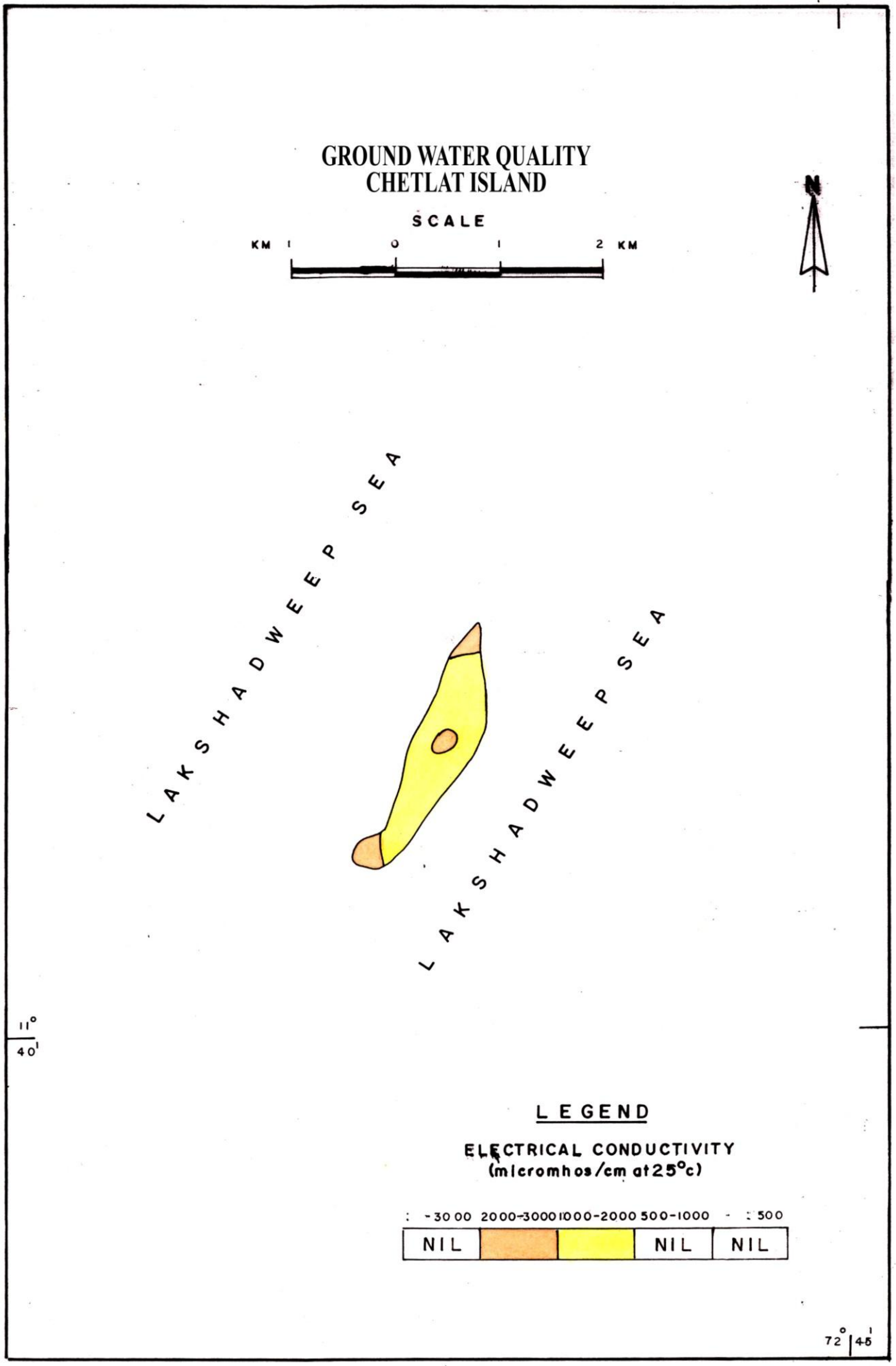
Annexure 2 b



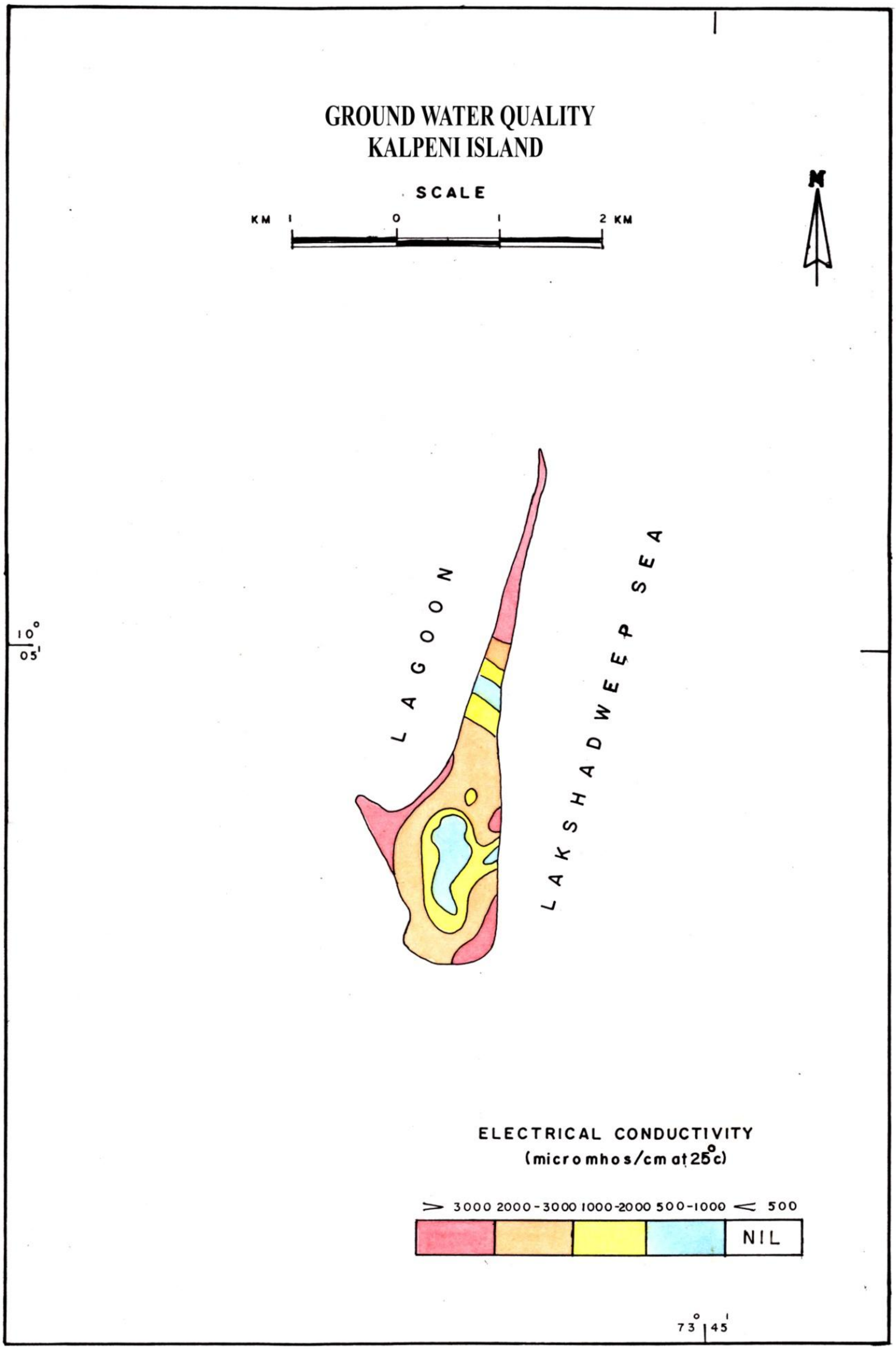
GROUND WATER QUALITY
AMINI ISLAND
SCALE
KM 1 0 1 2 KM
N
11°
10'
LAKSHADWEEP SEA
LAKSHADWEEP SEA
LEGEND
ELECTRICAL CONDUCTIVITY
(micromhos/cm at 25°c)
> 3000
2000-3000
1000-2000
500-1000
< 500
NIL
72° 45'


GROUND WATER QUALITY
ANDROTH ISLAND
SCALE
KM 1 0 1 2 KM
N
10°
50'
LAKSHADWEEP SEA
LAKSHADWEEP SEA
LEGEND
ELECTRICAL CONDUCTIVITY
(micromhos/cm at 25°c)
>3000 2000-3000 1000-2000 500-1000 <500
NIL
NIL
73° 40'

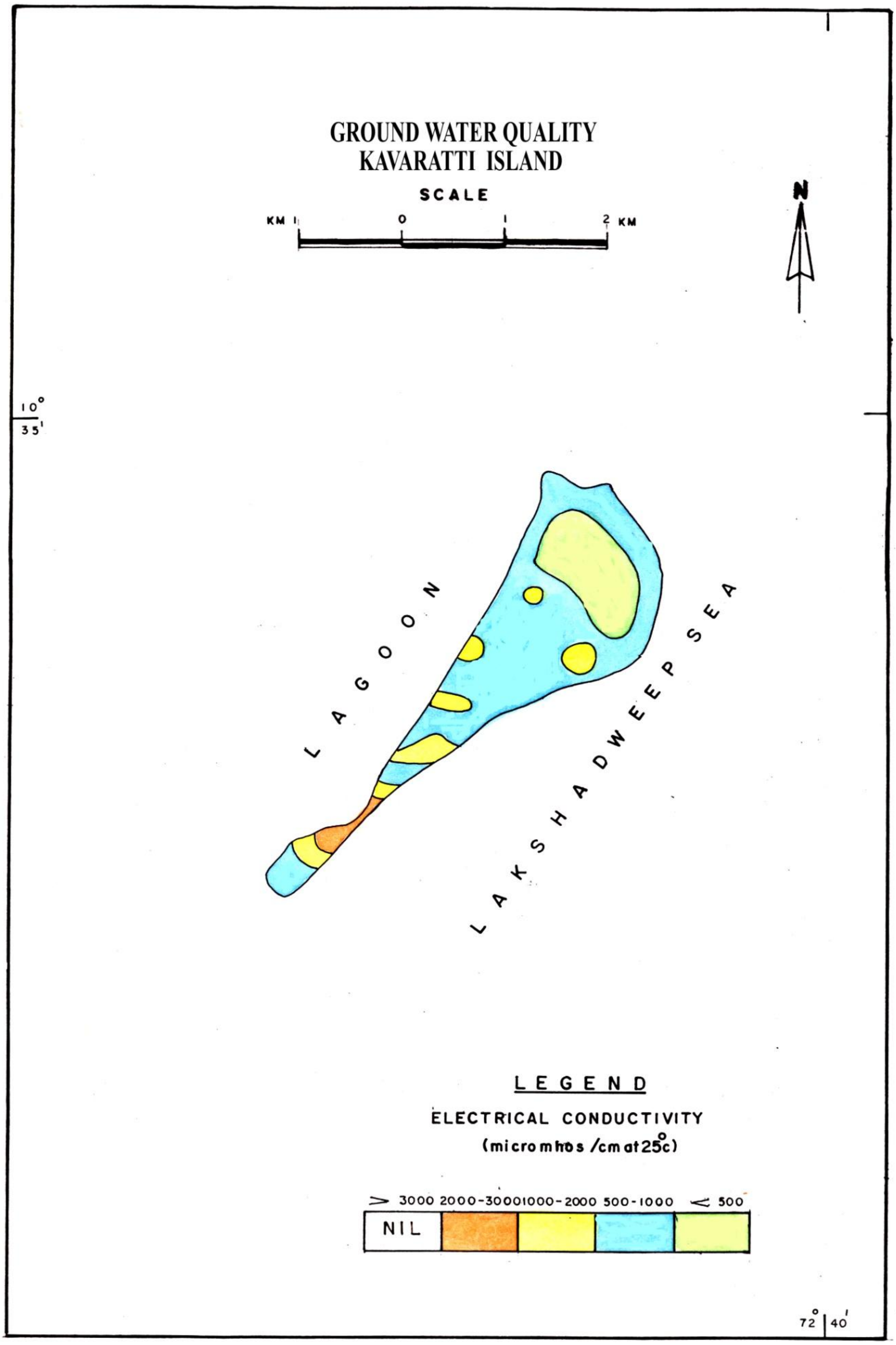
Annexure 2 d


GROUND WATER QUALITY
CHETLAT ISLAND
SCALE
KM 1 0 1 2 KM
N
LAKSHADWEEP SEA
LAKSHADWEEP SEA
11°
40'
72°
45'
LEGEND
ELECTRICAL CONDUCTIVITY
(micromhos/cm at 25°c)
-3000
2000-3000
1000-2000
500-1000
500
NIL
NIL
NIL

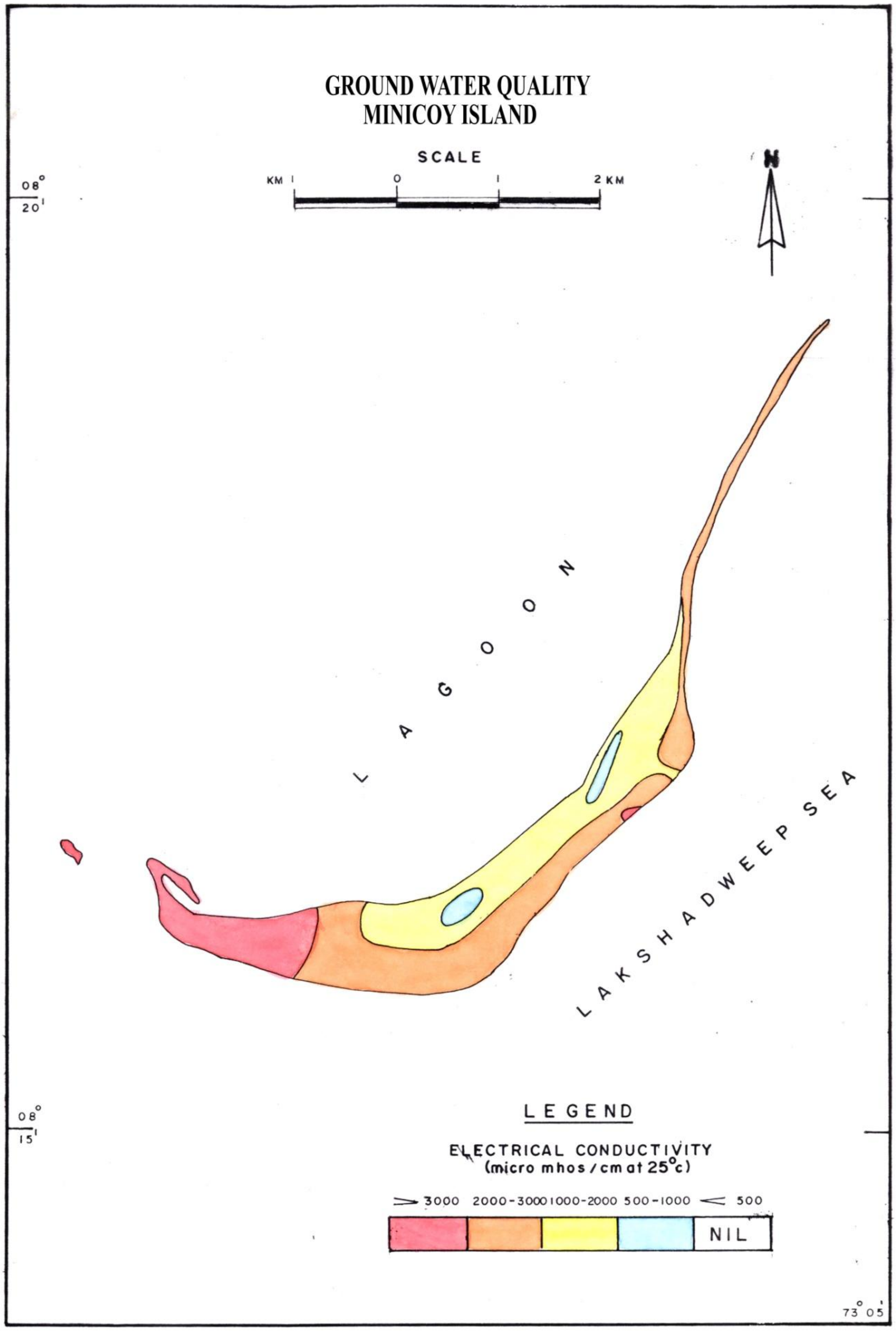
Annexure 2 e


GROUND WATER QUALITY
KALPENI ISLAND
SCALE
KM 1 0 1 2 KM
N
LAGOON
LAKSHADWEEP SEA
10°
05'
ELECTRICAL CONDUCTIVITY
(micromhos/cm at 25°c)
> 3000 2000-3000 1000-2000 500-1000 < 500
NIL
73° 45'

Annexure 2 f


GROUND WATER QUALITY
KAVARATTI ISLAND
SCALE
KM 1 0 1 2 KM
N
10°
35'
LAGOON
LAKSHADWEEP SEA
LEGEND
ELECTRICAL CONDUCTIVITY
(micromhos /cm at 25°c)
> 3000 2000-3000 1000-2000 500-1000 < 500
NIL
72° 40'

Annexure 2 g


GROUND WATER QUALITY
MINICOY ISLAND
SCALE
KM 1 0 1 2 KM
N
08° 20'
08° 15'
73° 05'
LAGOON
LAKSHADWEEP SEA
LEGEND
ELECTRICAL CONDUCTIVITY
(micro mhos / cm at 25°c)
> 3000
2000-3000
1000-2000
500-1000
< 500
NIL