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Government of India

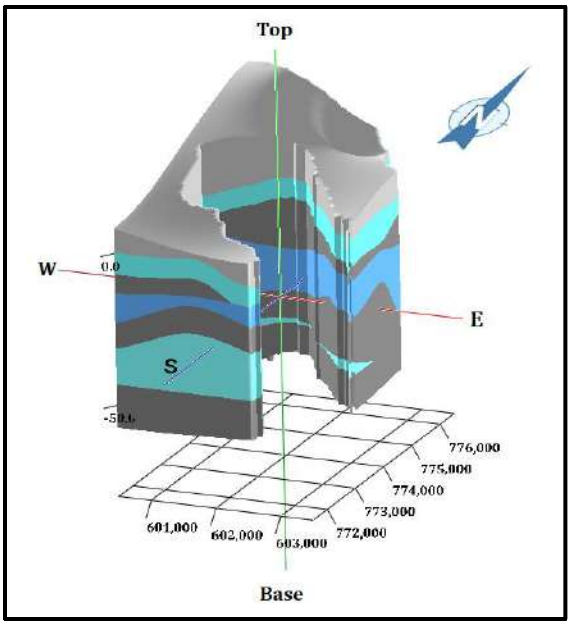
MINISTRY OF JAL SHAKTI

Department of Water Resources, River Development & Ganga Rejuvenation

Report On

NATIONAL AQUIFER MAPPING & MANAGEMENT PLAN

NICOBAR DISTRICT, A & N Islands



Central Ground Water Board

Eastern Region, Kolkata

2023

केंद्रीय भूमि जल बोर्ड
जल संसाधन, नदी विकास और गंगा संरक्षण विभाग
जल शक्ति मंत्रालय
भारत सरकार

Central Ground Water Board
Department of Water Resources,
River Development & Ganga Rejuvenation
Ministry of Jal Shakti
Government of India

Report on
NATIONAL AQUIFER MAPPING AND MANAGEMENT PLAN

NICOBAR DISTRICT
Andaman & Nicobar Islands

पूर्वी क्षेत्र, कोलकाता

Eastern Region, Kolkata

2023

FOREWORD

To understand the nature and occurrences of groundwater, Aquifer geometry, dispositions & characteristics and management of groundwater resource, National Aquifer Mapping & Management Programme (NAQUIM) has been taken up by CGWB under XIIth Plan. Under this program, Aquifer Mapping studies & Management plan preparation is taken up in Nicobar District, A & N Islands.

Present attempt to understand subsurface aquifer behavior under aegis of NAQUIM broadly includes four major components namely Data gap analysis, Data generation, Data collection & compilation and preparation of Aquifer maps and Aquifer Management Plan. Finally evaluation of data and prepared maps and 3D models of aquifers along with prepared aquifer management plans are compiled in the present report.

Preparation of this report in its present form is outcome of the efforts of Dr. Indranil Roy, Scientist 'D' (HG), Sujit Sarkar, Scientist 'D' (GP), Dr. Nilamoni Barman, Scientist 'B' (HM), Atalanta Narayan Chowdhury, Assistant Chemist, Suparna Dutta, Assistant Chemist and Awadhesh Kumar, STA (HG).

It is much anticipated that, this report will become an important tool not only for various User Agencies, Engineers, Scientists, Administrators, Planners and others involved in groundwater planning, development and management but also to the common people to make them aware of local groundwater issues and its sustainable management.

Dr. Anadi Gayen

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Executive Summary

Nicobar District is studied by Central Ground Water Board (CGWB) for its hydrogeology under over all scope of NAQUIM project. Specifically, aim of the study is to understand ground water condition of Nicobar district, identify ground water sustainability issues, vulnerability of aquifer from sea-water ingress, assess the scenario with the perspective of Demand – Supply Management in view of development plans and ultimately to come up with a suggestion for mitigation measures based on conceived hydrogeological model.

Andaman and Nicobar group of islands is a Union Territory of India located in Indian Ocean. The Nicobar District lies in the southern part of this Union Territory. At present, Nicobar district consists of 3 tehsils viz. Car Nicobar, Nancowry and Great Nicobar. Demographic profile of Nicobar district presents mostly a tribal dominated picture. Population peaked in 2001 where after a decline is observed. Analysis shows that about 98% of reported area of these islands is under forest cover and the remaining only 2% is available for other land uses including agriculture.

Recently, Niti Aayog identified that development of Great Nicobar Island is significant from the point of view of national security as well as country's economic prosperity. In current geopolitical situation, Indian Ocean Region (IOR) in general and the Indian Ocean in particular have turned into a strategic hotspot. Hence development in the Andaman & Nicobar Islands is necessary for strengthening India's regional presence. Niti Aayog proposed construction of both sea-port and airport with associated township and ancillaries in the island. Demand from the economic drivers would translate into change to a water demand of 388 KLD.

The district being entirely rural, under ***Jal Jeevan Mission*** (JJM) of Govt of India, the entire district is covered with Functional Household Tap Connection (FHTC) in every rural home. As per Jal Jeevan Mission Dashboard, the work is complete (https://ejalshakti.gov.in /jjmreport/JJMIndia.aspx accessed on 31st Oct, 2022). Groundwater is the main source with 89.9% of all structures. Surface water contributes in 8.6% structures and Rain water collection systems 1.5% structures.

Results show that, per-capita Fresh Water Resource availability declined from about 39000 m^3 in 1901 to 6800 m^3 in 2011 and approaching water scarcity. In view of proposed development of Great Nicobar Island with proposed 6.5 lakh population it will further dwindle to a meager 392 m^3 and reach "absolute" water scarcity (< 500 m^3 per year per capita, as per FAO classification).

Climate modeling results show that Southern group of islands received maximum rainfall, while middle group of islands received lowest rainfall during 2001-2020. Forecasting model shows that the rainfall will increase in the upcoming years in the Southern group of islands, while in the other islands groups rainfall will further decrease.

Several drillings were carried out by CGWB in Great Nicobar Island during 1987-88 in search of groundwater. Exploratory wells were constructed to locate potential fresh water aquifer in Tertiary sandstone. Lithologs reveal that Tertiary consolidated formations are mostly composed of argillaceous material devoid of any significant granular zone. Down to maximum explored depth of 101 m.

Presently Surface Geophysical Investigations are carried out at Great Nicobar Island. The aim of the geophysical investigation was to determine the lithological variation with depth from sea shore to inland part of the island along with saturated water quality variation at the eastern coast of the island.

Exploratory data and geophysical investigation data are compiled and correlated to understand aquifer disposition. In Nicobar district, mainly two broad hydrogeological units are present.

Fractured Consolidated Formation: Lithologically, marine sedimentary group of rocks comprising shale, sandstone, grit and conglomerate and extrusive, intrusive igneous rocks (volcanics and ultramafics) and coralline limestone contributes towards this hydrogeological unit. Occurrence and movement of ground water in this formation is controlled mainly by the zone of secondary porosity and along the contact plane of various litho-units. Weathered Mantle and Saprolitic Zone plays important role in recharging the zone of secondary porosity. Because of active tectonism, this group of rocks is highly deformed. However, the nature of deformation is expected to be brittle in nature at shallow depth and ductile at deeper part. In case of coralline limestone, solution cavity forms the main pathway for movement of ground water. However, formation of marl over coralline limestone as weathering product impedes ground water movement.

As per the very limited exploration records, this has limited yield potential of 5 – 10 m3/day. Exploratory borehole yielded meager discharge. Large diameter (4 – 6 m) dugwells may be constructed down to 4 – 6 m depth. However, several springs across the islands emerge from this unit. This indicates that its actual yield potential may not be properly understood.

Unconsolidated formation: Lithologically, mainly Coralline sand horizon constitutes this aquifer. Recent beach sand, coral rags, alluvium, colluvium and valley-fills also contributes to the formation. Weathered mantle and saprolitic zone over consolidated formation is in hydrological continuity with this aquifer system in general. The unit occurs mainly at the coastal parts of the island and thins out towards island interior with increase in elevation.

Present population of the islands mainly depends on this formation for water supply. In every habitation, several dugwells are constructed tapping this one. However the aquifer horizons are isolated and discontinuous in nature and getting their replenishment from connected weathered mantle at higher elevation. Except in exposed sand horizons, very low infiltration rate due to high clay content of valley-wash at top horizon shows direct rainfall recharge is not significant. This unit has yield potential of 10 – 20 m3/day. Large diameter (3 – 5 m) dugwells may be constructed down to 3 – 5 m depth.

As such all the islands are under *Safe* category with overall Stage of Groundwater Extraction (SGWE) of the district 0.28 % with the exception of Chowra Island, which has been categorized as *Saline.*

On an average groundwater quality of various islands are under acceptable limits of BIS, 2012 except iron, which is under permissible limits. Hence, groundwater quality of various islands is suitable for domestic use as per BIS standards and potable in nature. Quality-wise it is also suitable for irrigational and industrial use.

For irrigational demand management, suitable crop planning and intensification is proposed. Suggested crop alignment, if implemented along with Drip Irrigation System, is expected to reduce water consumption by about 40% by reducing area as well as increasing cropping intensity. Hence, annual agricultural water demand in 2050 will be reduce to the tune of 1.58 mcm, thereby reducing a demand of 1.05 mcm of irrigation water need.

In order to harness the water already used in domestic and drinking sector, extensive water recovery through STP and recycling it to industrial need, will lead to maximum utilization of scarce water resource and may fulfill industrial demand.

Ground water based Water Supply should be in low-key considering fragility of groundwater system in these islands. During pumping of freshwater from an aquifer having both fresh and brackish/saline water, the pressure head in the vicinity of well is lowered which ultimately leads to the rise of brackish/saline water.

Suggested structure for groundwater abstraction

Type of Structure	Depth	Topographic Feature Type	Elevation Class
Skimming Wells	Very Shallow	Coastal plains	3 – 10 m
Large diameter Dug well	Shallow (< 8m)	Foot Slope	10 – 20 m
Shallow Tube well	Moderately Shallow (< 15m)	Upland	20 – 50 m
Deep Tube well	Deep (< 30m)	Highland	> 50 m

Considering Island setup, geomorphological context, land-use pattern and relative groundwater potentialities of underground aquifer system, only a few types of artificial recharge / conservation structures are possible for augmentation & conservation of ground water resources. However if implemented and maintained properly, will help immensely towards protection of precious groundwater resource of the Islands.

Most importantly, it’s the People’s participation that matters in water security in these islands. There is a need to start educating the communities on how to use water and integrate positive practices. In future scenario of developing prospect of these islands. Hence awareness generation should be the prime aim for successful implementation of all suggested management interventions.

Projected and Modified Freshwater Requirement by 2050

Need	Projected Fresh Water Resource Requirement	Management Intervention	Modified Fresh Water Resource Requirement after Management Intervention
	mcm		mcm
Drinking & Domestic	33	Augmentation of SW + GW	33
Irrigation	2.63	Crop Modification	1.58
Industrial	26.5	Waste Water Recycling	-Nil-
Total	**62.13**		**34.58**

Quantitative Impact on Water Resource

Intervention	Demand Class	Impact on Water Resource			Major Impact on
		Augmented	Load Reduced	Depleted	
		mcm	mcm	mcm	
Reservoir Creation	Drinking & Domestic	20	–	–	SW + GW
Check Dam Creation	Drinking & Domestic	10	–	–	SW + GW
Groundwater Pumping	Drinking & Domestic	–	–	3	GW
Desalination Plant	Drinking & Domestic	Strategic	–	–	SW
Wastewater Recycling	Industrial & Infrastructure	–	26.5	–	SW + GW
Rainwater Harvesting	Drinking & Domestic + Agriculture	0.23	–	–	GW
Other Recharge Initiatives	Drinking & Domestic + Agriculture	0.01	–	–	GW
Crop Orientation and Drip irrigation	Agriculture	–	1.05	1.58	GW

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Chapter I

Introduction

Aquifer mapping can be defined as a scientific process, wherein a combination of geologic, geophysical, hydrologic and chemical field and laboratory analyses are applied to characterize the quantity, quality and sustainability of ground water in aquifers. The process is expected to improve our understanding of the geologic framework of aquifers, their hydrologic characteristics, water levels in the aquifers and how they change over time. Results of these studies contribute significantly to groundwater resource management by planners, policy makers and other stakeholders. In this context, National Aquifer Mapping & Management Programme (NAQUIM) has been taken up by CGWB under XIIth Plan. Details about the project are available at https://www.aims-cgwb.org/general-background.php. As per the annual action plan, groundwater management studies of Nicobar District of Union Territory of Andaman and Nicobar have been taken up by CGWB, ER, Kolkata during **AAP 2022-23**.

Nicobar District is studied by Central Ground Water Board (CGWB) for its hydrogeology under over all scope of National aquifer Mapping (NAQUIM) project. Specifically, aim of the present study is to understand ground water condition of Nicobar district, identify ground water sustainability issues, vulnerability of aquifer from sea-water ingress, assess the scenario with the perspective of Demand – Supply Management in view of development plans and ultimately to come up with suggestions for groundwater management based on conceived hydrogeological model.

Andaman and Nicobar group of islands is a Union Territory of India located in Indian Ocean. The island group forms an arcuate shaped island chain with Bay of Bengal on the West and the Andaman Sea on the East. There are 572 islands in the island group having a total area of 8,249 km^2. Of these, only 38 are permanently inhabited. The islands extend broadly from 6° to 14° North latitudes and from 92° to 94° East longitudes. Entire chain of islands is divided into two sub-groups namely Andaman group in north and Nicobar group in south separated by 10° latitude (also known as 10° Channel which is about 150 km wide). Extreme southern-most 'Pygmalion Point' presently known as Indira Point (6°45'10" N and

93°49′36″ E) located in Great Nicobar Island, is the southernmost landmass of India and lies only 150 km from Sumatra Peninsula (Indonesia).

The capital of the union territory, *Port Blair*, is located about 1,255 km from Kolkata, about 1,200 km from Visakhapatnam and about 1,190 km from Chennai and is connected by regular air and ship services. Nicobar Group of Islands is connected with Port Blair through ships ferrying bi-weekly as well as helicopter service.

The existence of the Nicobar Islands is known from the time of Ptolemy onwards. It is mentioned in few ancient Chinese texts. As the islands are located on sea route from Sumatra to Mainland India, they were source of fresh rations and drinking water for ancient mariners. The tribal inhabitants were in touch with the outer world through the trade of '*copra'* (Dried coconut meat) and '*cowri'* (Conch shell). From 17th century onwards Portuguese and French tried to colonize the islands through missionary activities. In 1756, the Danes took control of these islands with base at Kamorta Island, but later abandoned in 1848. In 1869 the British formally took possession of these islands and included within the territory of A & N Islands in 1871. This Administrative arrangement continued till Independence of India. Prior to 1974, the Union Territory of Andaman and Nicobar Islands was a uni-district territory. Two districts viz. Andaman and Nicobar were formed in the year 1974 vide Andaman & Nicobar Administration's notification dated 19-7-1974. Erstwhile part of District of Andaman, District of Nicobar came into existence on 1st of August, 1974.

The Nicobar District lies in the southern part of this Union Territory. At present, Nicobar district consists of 3 tehsils viz. Car Nicobar, Nancowry and Great Nicobar. The tehsil of Nancowry was bifurcated into 2 tehsils, Nancowry and Great Nicobar, vide Notification No. 149/2006 F.No.3-195/2002-LSG (Rev) dated 17th August, 2006, of the Andaman & Nicobar Administration. The island group can be located in SOI Toposheets 87C/15, 87C/12, 87C/16, 87D/13, 87H/3, 87H/4, 87H/8, 87H/10, 87H/3, 87H/11, 87H/12, 88E/5, 88E/9, 88E/10, 88E/11, 88E/12, 88E/15, 88E/16, 88F/9, and 88E/13.

Nicobar Group island chain has an overall length of 310 km and 58 km width. Google map of the island chain with main study area is given in **Fig. 1.1.** Detailed map of the island chain is given in **Fig 1.2.** Car Nicobar is the district headquarter of Nicobar district. The island is located about 275 km south of UT capital Port Blair. There are three CD Blocks in this district viz., Car Nicobar comprising only 16 inhabited villages, Nancowry comprising of 44 inhabited villages and Campbell Bay comprising of 30 inhabited villages, which are placed under respective Tehsils *i.e.,* Car Nicobar, Nancowry and Great Nicobar. Administrative divisions are given in **Table 1.1 a**.

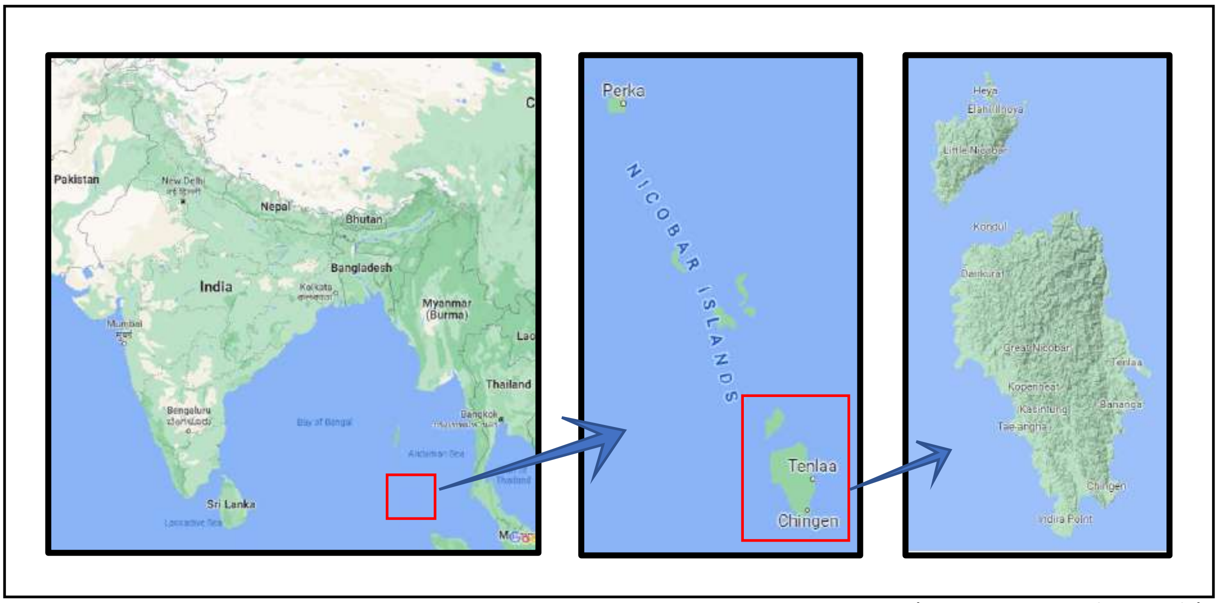
Nicobar group of islands comprise of twenty-two (22) islands with a total area of 1,841 km^2 of which only 10 islands are inhabited (Census, 2011). Car Nicobar and Pulomilo are the most and least populated Islands respectively in the Nicobar District (Census, 2011). Bampooka, Trinket and Kondul Islands were shown inhabited in 2001 Census but became uninhabited during the last decade as no population is reported in 2011 Census (Census, 2011). Island-wise and population details are given in **Table 1.1 b**.

Car Nicobar Island represented by the single inhabited island represents the administrative sub-division. On the other hand, Nancowry refers to a single island, and act as administrative sub-division for rest of the adjoining islands. The island is approximately 160 km south-southeast of Car Nicobar. Great Nicobar sub-division is represented by Campbell Bay block covering Great Nicobar Island and adjoining islands. The Great Nicobar Island is separated from rest of the Nicobar Islands by the six-degree channel (aka Sombrero channel). Campbell Bay area is the administrative headquarters of Great Nicobar Island. It is about 600 km south of Port Blair. District population growth pattern, Island-wise demographic details and occupational profile is given **Table 2a, 2b and 2c** respectively. Population variation graph is given in **Fig. 1.3**.

All the Islands are declared **Tribal Reserve Area** under Andaman and Nicobar Islands (Protection of Aboriginal Tribes) Regulation, 1956 Act with the exception of the eastern coast of Great Nicobar, comprising 7 villages, which is a non-reserve area. In that area initial settlement of 330 Ex-servicemen families were done in 1969-72 under Accelerated Development Program of Ministry of Labour and Rehabilitation, GOI.

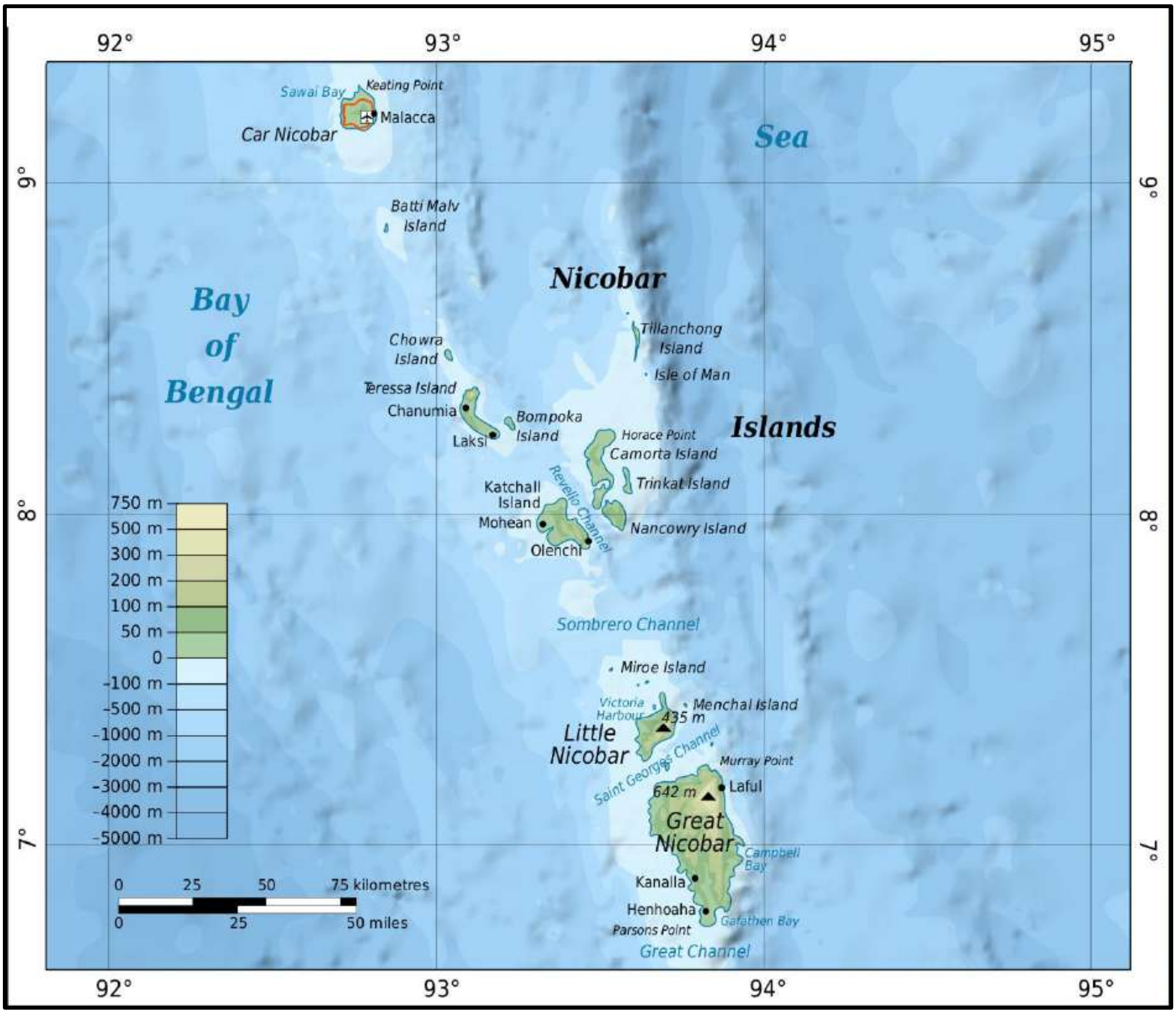
Table 1.1a Administrative divisions of Nicobar group of islands

District	Sub-Division / Tehsil	CD block
Nicobar	Car Nicobar	Car Nicobar
	Nancowry	Nancowry
	Great Nicobar	Campbell Bay



(Source: Google Earth)

Fig. 1.1 Location of Nicobar Group of Islands with main study area



(Source: Wikipedia)

Fig. 1.2 Detailed map of Nicobar Group of Islands

Table 1.1b Habitation Status of Nicobar group of islands

Sl.	Island Name	Native Name	Block	Status	Area	Population	
					sq. km.	2001	2011
1	Car Nicobar	Pu	Car Nicobar	Inhabited	126.9	20292	17841
2	Chowra	Sanenyo	Nancowry	Inhabited	8.2	1385	1270
3	Teressa	Luroo	Nancowry	Inhabited	101.4	2026	1934
4	Katchal	Tihayu	Nancowry	Inhabited	174.4	5312	2685
5	Kamorta	Kamorta	Nancowry	Inhabited	188.2	3412	3688
6	Nancowry	Mout	Nancowry	Inhabited	66.9	927	1019
7	Little Nicobar	Long	Campbell Bay	Inhabited	159.1	348	278
8	Great Nicobar	Tokieong Long	Campbell Bay	Inhabited	1045.1	7566	8069
9	Tillang Chong Island	La-ukg	Nancowry	Inhabited	16.84	13	38
10	Pulomillow Island	–	Campbell Bay	Inhabited	1.3	145	20
11	Battimaly	Kuono	Car Nicobar	Uninhabited	2.01	–	–
12	Meroe	Meroe	Campbell Bay	Uninhabited	0.52	–	–
13	Treis	Tean / Albatai	Campbell Bay	Uninhabited	0.26	–	–
14	Menchal	Menchal	Campbell Bay	Uninhabited	1.3	–	–
15	Trak	Fuya /Mafuya	Campbell Bay	Uninhabited	0.26	–	–
16	Cubra	Konwana	Campbell Bay	Uninhabited	0.52	–	–
17	Bompuka	Poahat	Nancowry	Uninhabited	13.3	55	–
18	Kondul	–	Campbell Bay	Uninhabited	4.6	150	–
19	Trinket	Laful	Nancowry	Uninhabited	86.3	432	–
20	Isle of Man	Laouk	Nancowry	Uninhabited	–	–	–
21	Megapod	–	Campbell Bay	Uninhabited	–	–	–
22	Pigeon	–	Campbell Bay	Uninhabited	–	–	–

(Source: Area and Population figures are from Census 2001 & 2011)

1.1 Demographic Profile

Demographic profile of Nicobar district presents mostly a tribal dominated picture. Salient information is tabulated in **Table 1.2a, 1.2b, and 1.2c**. Population peaked in 2001 where after a decline is observed.

Table 1.2a Population Growth Pattern in Nicobar District

Census Year	Population	% Decadal Growth
1901	6511	-
1911	8818	35.43
1921	9272	5.15
1931	10240	10.44
1941	12452	21.6
1951	12009	-3.56
1961	14563	21.27
1971	21665	48.77
1981	30454	40.57
1991	39208	28.74
2001	42068	7.29
2011	36842	-12.42

Table 1.2b Demographic Profile of Inhabited Island in Nicobar group of islands

	Island	Area	Census Villages (2011)			Population 2011			ST Population	
		sq. km	Inhabited	Uninhabited	Total	Male	Female	Household	Male	Female
1	Car Nicobar	126.91	16	0	16	9735	8106	4250	7659	7368
2	Great Nicobar	1044.54	19	26	45	4849	3197	2180	506	392
3	Chowra	8.28	5	0	5	656	614	367	610	611
4	Teressa	101.26	8	3	11	1059	875	551	938	845
5	Katchal	174.3	6	33	39	1538	1147	715	652	587
6	Nancowry	66.82	10	9	19	530	489	238	522	484
7	Kamorta	188.03	15	16	31	2146	1542	915	1135	1051
8	Pilomillo	1.29	1	0	1	15	5	5	15	5
9	Little Nicobar	159.02	10	15	25	161	140	63	156	140
10	Tillangchong	16.83	1	0	1	38	0	4	5	0

(Source: Census, 2011)

Table 1.2c Occupational Profile of Inhabited Island in Nicobar group of islands

Sl.	Island	Occupation				Farmers	Agriculture Farm
		Main	Marginal	Total	Non workers		
1	Car Nicobar	3664	5180	8844	8997	2723	1
2	Great Nicobar	3337	491	3828	4218	392	2
3	Chowra	89	249	338	932	198	0
4	Teressa	205	394	599	1335	140	0
5	Katchal	1080	278	1361	1324	178	1
6	Nancowry	80	306	386	633	184	0
7	Kamorta	1145	573	1718	1970	240	1
8	Pilomillo	0	0	0	20	0	0
9	Little Nicobar	13	0	13	288	0	0
10	Tilongchang	38	0	38	0	0	0

(Source: Census, 2011 and District Irrigation Plan for Nicobar District, 2015)

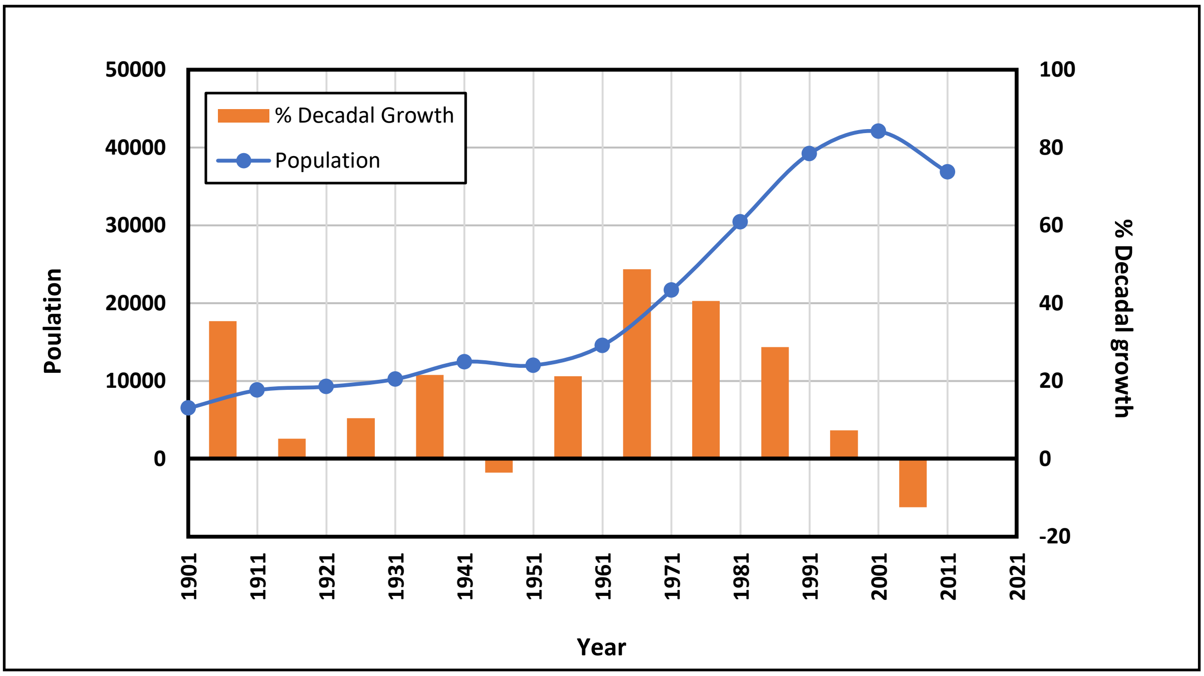


Fig. 1.3 Decadal Variation in Population and Growth rate

1.2 Land-Use and Forest Cover

Nicobar group of islands are covered by lush green tropical vegetation backed by copious rainfall almost throughout the year. As these islands are till date mostly untouched, they maintain their natural state. Details of land-uses statistics for Nicobar District are given in **Table 1.3**. Graphical representation of the Land use statistics is given in **Fig. 1.4**. Details of forest cover in Nicobar group of islands are given in **Table 1.4**.

Table 1.3 Land-use in Nicobar District

Sl.	Land-use Category	2008-09	2009-10
		Area (ha)	Area (ha)
1.	Total Geographical area	184100.00	184100.00
2.	Reporting area for land utilization	157746.32	157794.50
3.	Forest area	154207.00	154207.00
4.	Not available for Cultivation	1625.61	1670.61
5.	Other uncultivated land excluding fallow land	444.16	444.16
7.	Current fallow	467.37	472.98
8.	Fallow land other than current fallow	731.88	731.88
9.	Net area sown	270.37	270.87
10.	Area sown more than once	151.00	110.00
11.	Total cropped area	421.37	377.87

(Source: District Statistical Handbook, 2011)

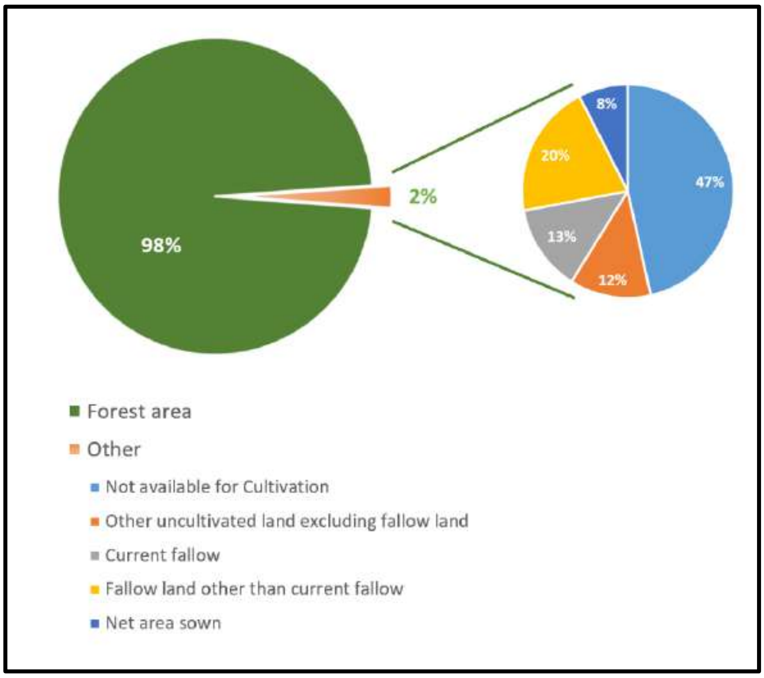


Fig. 1.4 Pie Diagram of Components of Land-Use

Table 1.4 Details of forest cover in Nicobar group of islands

Sl.	Island Name	Total Area (ha)	Declared Forest Area (ha)	% Area	Remarks
1	Car Nicobar	12691	12691	100	Tribal Reserve
2	Chowra	828	828	100	Tribal Reserve
3	Teressa	10126	6000	59.3	Tribal Reserve
4	Katchal	17430	12000	68.8	Tribal Reserve
5	Kamorta	18803	14000	74.5	Wild Life Sanctuary
6	Nancowry	6682	4000	59.9	Tribal Reserve
7	Little Nicobar	15902	15500	97.5	Tribal Reserve
8	Great Nicobar	104454	96040	91.9	02 National Park & 01 Biosphere Reserve *
9	Tillang Chong Island	1683	1683	100	W.L Sanctuary / Tribal Reserve
10	Pulomillow Island	129	129	100	Tribal Reserve
11	Battimaly	207	207	100	Wild Life Sanctuary
12	Meroe	51	51	100	Tribal Reserve
13	Teris	26	26	100	Tribal Reserve
14	Menchal	129	129	100	Tribal Reserve
15	Trak	26	26	100	Tribal Reserve
16	Cubra	51	51	100	Wild Life Sanctuary
17	Bompuka	1346	1346	100	Tribal Reserve
18	Kondul	466	466	100	Tribal Reserve
19	Trinket	3626	2000	55.2	Tribal Reserve
20	Megapod	12	12	100	Wild Life Sanctuary

*Galathea National Park (11000 ha), Campbell Bay National Park (42623 ha), & Great Nicobar Biosphere Reserve (88500 ha) declared on 28th Nov 1996, 18th March 1992 and 06th Jan 1989 respectively. National Parks are part of Biosphere Reserve. All the forests in the district have legal status of Protected Forest.

Source: Forest Statistics, DEF (2019)

Analysis shows that about 98% of reported area of these islands is under forest cover and the remaining only 2% is available for other land uses including agriculture. Land-Use / Land Cover Map of Nicobar District is given in **Fig. 1.5**

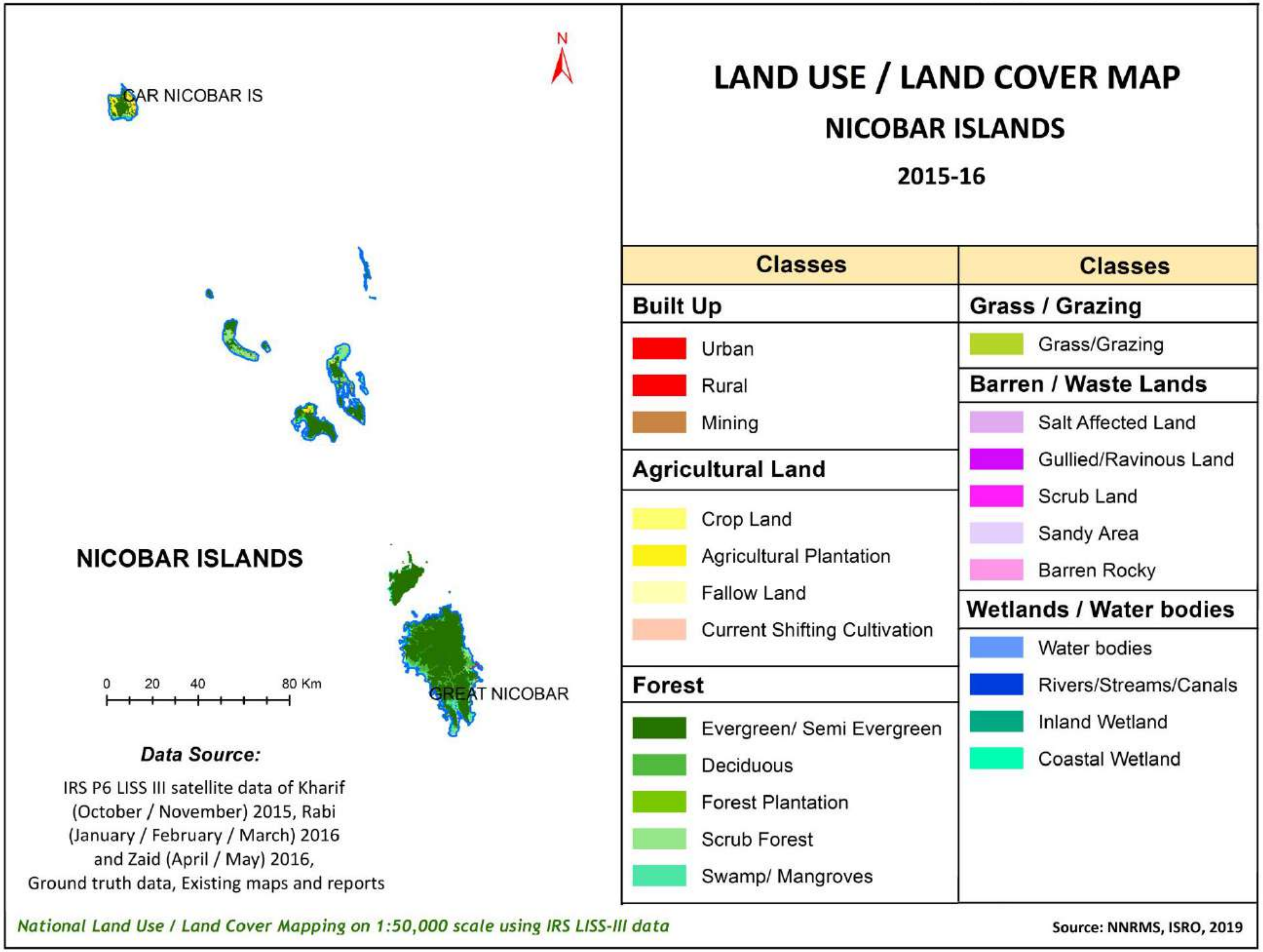


Fig. 1.5 Land-Use / Land Cover Map of Nicobar District

1.3 Agriculture and Irrigation

As per land-use data, about 98% of reported area of these islands is under forest cover and the remaining only 2% is available for other land uses including agriculture. Of this only 8 % is net sown area. Hence, only in 0.16 % of reported area is under agriculture. Only Teressa, Katchal, Kamorta, Nancowry, Little Nicobar, Great Nicobar and Trinket islands have agricultural land. Proportion of agricultural land to total area varies significantly from island to island.

The central group of islands shows signs of human influence in the form of extensive grassland introduced by the European colonizers. Similarly, rubber plantation was introduced into Katchal islands after independence. However, coconut plantation is the main plantation crop followed by Areca Nut and Cashew Nut. Major agricultural crops grown in Nicobar Islands are given in **Table 1.5**. Agricultural land-use in Nicobar District is given in **Table 1.6**.

Table 1.5 Major agricultural crops grown in Nicobar Islands

Sl.	Island	
1	Car Nicobar	Coconut, Arecanut, Fruits, Tuber Cops, Vegetables
2	Chowra	Coconut, Tuber Crops
3	Teressa	Coconut, Arecanut, Cashew, Fruits, Tuber Crops
4	Bampooka	Coconut, Tuber Crops
5	Katchal	Paddy, Red Oil Palm, Vegetables, Coconut, Arecanut, Spices
6	Nancowry	Coconut, Arecanut, Fruits, Tuber Crops
7	Kamorta	Coconut, Arecanut, Cashew, Banana
8	Trinket	Coconut
9	Little Nicobar	Coconut, Arecanut, Colocasia, Dioscorea
10	Pilomilo	Coconut, Colocasia
11	Kondul	Dioscorea
12	Great Nicobar	Paddy, Vegetables, Coconut, Arecanut, Fruits

Source: Srivastava and Ambast (2009)

Agricultural practice is mostly rain-fed. Broad bed-Furrow system is used for water conservation. Agriculture Contingency Plan for Nicobar District (2015) shows that irrigation in the islands is dug well and pond based (**Table 1.7**). No bore-well is used for the purpose. Irrigation is given to sugar cane, banana, papaya and chilies only. Field-crop production and

Horticulture & Plantation Crop production in Nicobar District is given in **Table 1.8a and 1.8b** respectively.

Table 1.6 Agricultural land-uses in Nicobar District

Agricultural land use	Area (ha)	Cropping intensity
Net sown area	267.9 ha	141.06 %
Area sown more than once	110 ha	
Gross cropped area	377.9 ha	
Net irrigated area	110 ha	
Sources of Irrigation	**Number**	
Open wells	170	
Ponds	45	
Machinery for Irrigation	**Number**	
Pump Set	405	

(Source: Agriculture Contingency Plan for Nicobar District, 2015)

Table 1.7 Island-wise Irrigation Sources

Sl.	Island	Farmers	Agriculture Farm	Sources of irrigation	
				Pond	Well
1	Car Nicobar	2723	1	1	87
2	Great Nicobar	392	2	27	44
3	Chowra	198	0	0	0
4	Teressa	140	0	3	9
5	Katchal	178	1	6	5
6	Nancowry	184	0	0	11
7	Kamorta	240	1	8	14

(Source: District Irrigation Plan for Nicobar District, 2015)

Table 1.8a Field-crop production in Nicobar District

Major Field Crops Cultivated	Area (ha)						
	Kharif			*Rabi*			Summer
	Irrigated	Rainfed	Total	Irrigated	Rainfed	Total	Grand Total
Paddy	-	2.65	2.65	-	-	-	2.65
Maize	-	-	-	-	9.66	9.66	9.66
Black gram	-	-	-	-	6.32	6.32	6.32
Sugarcane	11.00	-	11.00	-	-	-	11.00
Root crops	-	241.03	241.03	-	-	-	241.03

(Source: Agriculture Contingency Plan for Nicobar District, 2015)

Table 1.8b Horticulture & Plantation Crop production in Nicobar District

Horticulture / Plantation	Area (ha)		
	Total	Irrigated	Rain-fed
Horticulture Crops – Fruits			
Banana	170.0	170.0	-
Papaya	149.9	149.9	-
Pineapple	51.5	-	51.5
Citrus fruits	32.3	-	32.3
Mango	26.0	-	26.0
Other minor fruits	101.3	-	101.3
Horticulture Crops - Vegetables			
Chilies	5.70	5.70	-
Sweet Potato	8.51	-	8.51
Tapioca	21.99	-	21.99
Root crops	210.53	-	210.53
Plantation Crops			
Coconut	14655		14655
Areca nut	890.5		890.5
Cashew nut	1036.9		1036.9
Rubber	645.03	-	645.03

(Source: Agriculture Contingency Plan for Nicobar District, 2015)

1.4 Drinking Water Supply

The district being entirely rural, under ***Jal Jeevan Mission*** (JJM) of Govt of India, the entire district is covered with Functional Household Tap Connection (FHTC) in every rural home. As per Jal Jeevan Mission Dashboard, the work is complete (https://ejalshakti.gov.in /jjmreport/JJMIndia.aspx accessed on 31st Oct, 2022). As on date the daily supply of potable water to households in the entire district is 4512 m^3. Details of habitation-wise drinking water supply in various islands are given in **Annexure 8**. Summary of Island-wise planned capacity of water supply in Nicobar district is given in **Table 1.9a**. However, outside the coastal stretches of the islands water wells are absent as in most of the islands, habitation is limited to the coastal part only. In the central part of the islands, springs or spring fed perennial streams are present. They are sustainable moderately yielding sources.

Groundwater is the main source with 89.9% of all structures. Surface water contributes in 8.6% structures and Rain water collection systems 1.5% structures (**Table 1.9b**). Various components of drinking water supply by source types in shown in **Fig. 1.6**. Initially all the groundwater abstraction structures were dug wells, however from 2012-13 onwards, in the most water scarce tehsil *i.e.,* Nancowri tehsil, implementation of skimming wells / infiltration wells took place to tackle the problem. Altogether, these wells are planned to provide 575 m^3 of water in various islands in the tehsil. Photo of few groundwater source in Car Nicobar Island is given in **Fig. 1.7a** and **1.7b**.

Table 1.9 a Summary of Island-wise planned capacity of Water Supply in Nicobar district

Island	No. of Habitation	Water Supply Capacity (m^3)
Car Nicobar	16	2781
Kamorta	12	575
Katchal	1	125
Nancowry	6	100
Theresa	8	15
Chowra	5	9
Great Nicobar	9	875
Little Nicobar	6	32
Total	**63**	**4512**

Table 1.9 b Summary of water abstraction structures in Nicobar group of islands

	Source Type	Number	%
Groundwater	Open Dug well	52	26.3
	Infiltration Well	126	63.6
Surface Water	Nallah	10	5.1
	Spring	6	3.0
	Pond	1	0.5
Rain Water	Rain Water	3	1.5
	Total	**195**	100

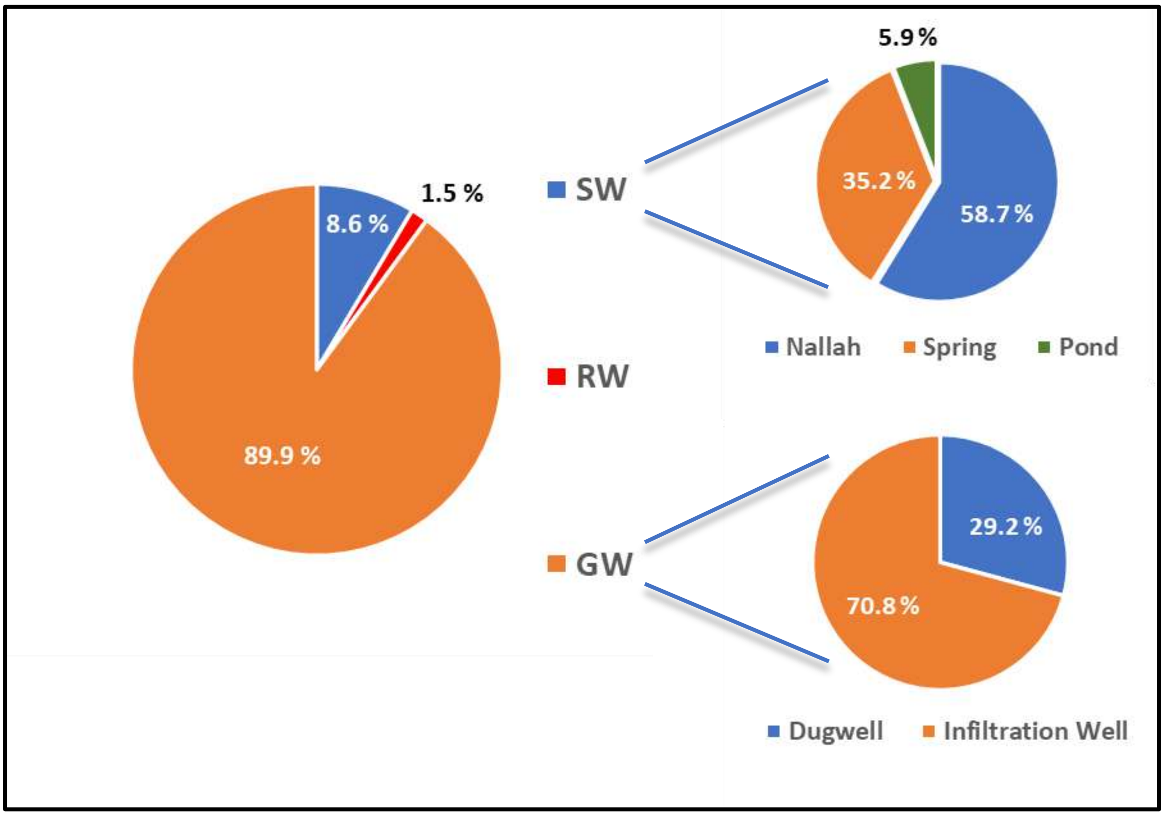


Fig. 1.6 Pie Diagram of Components of Drinking Water Supply by Source Type

Earlier, Chowra Island had not any drinking water sources (Kar, 2004). From 2006-07 onwards, five (05) infiltration wells and one (01) pond is created as viable drinking water source. Rain water collection systems are also implemented in three (03) habitations of Chowra Island and are planned to augment groundwater-based sources.

Fig. 1.7a Water Supply Dugwell at Arong, Car Nicobar

Fig. 1.7b Water Supply Dugwell at Kimious, Car Nicobar

1.5 Traditional Water Collection – Storage - Management System in Nicobar

Jackwell

Shompen tribe of Great Nicobar Island has indigenous rainwater harvesting technique. Taking benefit of undulating terrain, in small catchments, bunds of hard bullet wood were built in the lower parts of the catchment with pits constructed in the upstream side of the bund. Rainwater is collected in those pits. These pits are called "*Jackwell*". Split bamboos are also extensively used in the water harvesting systems. A full length of split bamboo was placed along the slope. Rainwater flow through it and get collected in the pits. Splitted bamboo pipes are also placed under trees to collect the dripping water from the leaves. A series of increasingly bigger jackwells were connected by such bamboo pipes to make sure that overflow from one is conserved by the next. This series ultimately leads to the biggest jackwell, with an approximate diameter of 6 m and depth of 7 m.

However, during field visit no such structure could be located. This may be due to the restriction in movement in Tribal land. Interaction with locals also could not shed light on the matter.

Use of Coconut Shells as Primitive Water Collection System

A very primitive rainwater collection system using coconut shells is in practice in Chowra island. This age-old rainwater collection system is practiced by the islanders where hollow coconut shells are hung at the sides of hutments to collect roof-top rainwater. At times of great crisis, islanders also collect water from contiguous Teressa Island with canoes.

1.6 Present Perspective

Recently, Niti Aayog identified that development of Great Nicobar Island is significant from the point of view of national security as well as country's economic prosperity. In current geopolitical situation, Indian Ocean Region (IOR) in general and the Indian Ocean in particular have turned into a strategic hotspot. Hence development in the Andaman & Nicobar Islands is necessary for strengthening India's regional presence.

Additionally, Great Nicobar Island represents a significant economic development opportunity. The main east-west shipping route that links East Asian exports with the Indian Ocean, Suez Canal and Europe runs just to the south of Great Nicobar Island. Niti Aayog proposed construction of both sea-port and airport with associated township and ancillaries in the island so that India can participate more fully in the global shipping trade, creating employment opportunities for its citizens and improving quality of life for current and future residents of the island.

Demand for workers from the economic drivers would translate into change in residing population for the region. Pre-Feasibility Report (2021) of survey carried out by AECOM for Niti Aayog projects population density of 27 person /hectare for the region with a total population of 6.5 lakh by 2050. As per the said report, this translates to a water demand of 388 KLD.

Chapter 2

HYDROMETEOROLOGY

2.1 Climate Pattern in Nicobar District

Lying well within the tropics and controlled by the equatorial belt, climate of the Nicobar Group of Islands can be defined as humid, tropical, coastal climate. Proximity to the equator and the sea ensures a hot-humid uniform climate. The climate is equable and no distinct and well-marked seasons are experienced. The Islands have rainfall from both the Southwest and Northeast monsoons and the maximum rainfall is between May to December (**Table 2.1)**. In Nicobar District the lowest annual rainfall was 1335.8 mm during 1982 and the highest annual rainfall was 3923.8 mm during 1975.

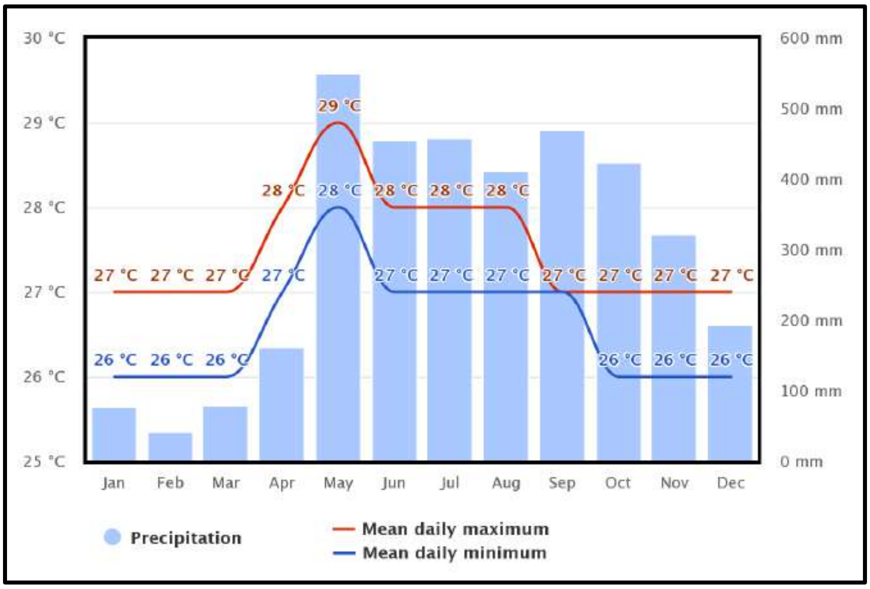
Table 2.1 Rainfall Pattern in Nicobar District

Rainfall	Average Rainfall (mm)	Average Rainy days	Normal Onset	Normal Cessation
Period	**2000-2021**	**2008 – 2015**		
SW monsoon (June-Sep)	1111.5	64	20th May	Last week of September
NE Monsoon (Oct-Dec)	760.5	41	First week of October	Last week of December
Winter (Jan- March)	265.0	16	First week of January	End of March
Summer (Apr-May)	413.2	26	Start of April	Mid May
Annual	2550.4	147	-	-

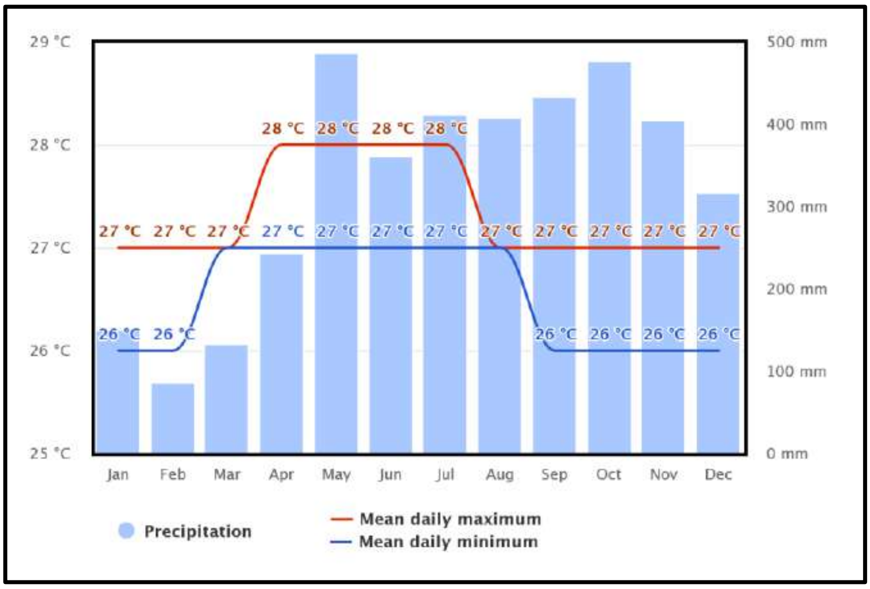
(Based on Car Nicobar IMD Station data)

However, the climate regimes of these small islands located in the Indian Ocean are predominantly influenced by the Asian monsoon. Seasonal alternation of atmospheric flow patterns results in two distinct climatic regimes summer monsoon and winter monsoon, with a clear association with ENSO events (Mimura et al., 2007). Monthly variability in precipitation and temperature at two extremities of Nicobar District (climate diagrams are based on 30 years of hourly weather model simulations) are given in **Fig. 2.1**. Annual and Monthly rainfall data of Car Nicobar IMD station is given in **Table 2.2**. Trend in annual rainfall is given in **Fig. 2.2**. It's correlation with ONI index (**Fig. 2.3**) may be clearly observed.

A. Car Nicobar Island



B. Great Nicobar Island



(Source: meteoblue, https://www.meteoblue.com/)

Fig. 2.1 Monthly variability in precipitation and temperature at two extremities of Nicobar District (climate diagrams are based on 30 years of hourly weather model simulations)

Table 2.2 Annual and Monthly rainfall data of Nicobar Subdivision of IMD

Month	January	February	March	April	May	June	July	August	September	October	November	December	Total
2000	108.9	26.0	227.3	116.5	333.2	313.8	99.2	382.9	177.9	420.0	175.9	116.0	**2497.6**
2001	100.8	43.0	83.5	87.5	409.8	154.3	204.8	216.6	202.2	214.8	421.2	139.5	**2278.0**
2002	0.0	0.2	39.2	16.8	329.0	205.3	44.4	245.4	321.0	90.7	253.2	115.9	**1661.1**
2003	34.0	20.6	211.4	18.8	203.5	57.7	421.0	416.8	192.0	408.0	276.4	211.5	**2471.7**
2004	62.4	113.1	32.2	43.1	363.7	311.5	101.7	160.0	182.3	200.4	193.8	8.0	**1772.2**
2005	34.0	0.0	160.5	51.4	208.9	373.2	131.4	199.5	280.1	232.5	244.7	544.2	**2460.4**
2006	44.2	61.6	147.8	251.6	365.4	277.2	95.4	149.5	516.2	498.8	83.2	52.4	**2543.3**
2007	0.8	0.0	0.0	56.4	543.1	402.7	187.1	441.5	390.6	237.2	446.4	55.0	**2760.8**
2008	38.5	32.2	159.0	233.3	177.2	354.5	204.3	421.0	108.0	426.3	424.7	210.1	**2789.1**
2009	8.0	43.6	81.4	259.6	599.8	167.8	90.8	125.4	183.3	141.9	156.6	129.2	**1987.4**
2010	79.0	26.0	1.7	28.3	229.3	501.9	447.8	318.9	234.8	249.1	583.2	355.7	**3055.7**
2011	322.2	163.1	270.5	158.6	187.9	348.8	346.4	184.8	347.6	203.0	218.2	350.9	**3102.0**
2012	328.0	50.8	103.3	115.8	472.3	145.2	325.8	205.5	518.8	114.4	282.9	272.9	**2935.7**
2013	209.5	110.4	101.2	35.7	268.7	666.7	377.9	224.1	351.2	307.9	183.9	164.4	**3001.6**
2014	176.9	30.5	0.0	35.1	388.1	276.9	198.6	220.9	331.3	269.9	264.2	228.6	**2421.0**
2015	118.2	20.2	2.7	157.9	163.3	376.3	205.0	138.4	481.6	221.8	401.4	175.5	**2462.3**
2016	164.3	69.4	0.0	5.0	136.0	495.9	117.6	204.8	532.0	285.6	190.8	696.2	**2897.6**
2017	643.1	20.1	69.7	144.2	344.2	199.5	170.2	253.2	290.5	233.7	277.2	488.4	**3134.0**
2018	209.4	94.7	17.9	201.7	300.7	377.8	133.4	126.1	229.2	215.4	173.0	321.8	**2401.1**
2019	174.6	24.4	23.8	56.3	255.6	379.0	184.3	263.8	297.2	181.1	229.3	103.8	**2173.2**
2020	15.2	10.0	0.4	44.3	252.0	553.9	183.1	222.8	435.2	252.2	235.5	229.1	**2433.7**
2021	104.0	42.0	119.0	163.8	277.1	227.0	372.1	473.1	444.7	333.6	248.3	63.9	**2868.6**
2022	135.3	45.5	84.2	103.7	309.5	325.8	211.0	254.3	320.4	260.8	271.1	228.8	**2550.4**
Mean	**108.9**	**26.0**	**227.3**	**116.5**	**333.2**	**313.8**	**99.2**	**382.9**	**177.9**	**420.0**	**175.9**	**116.0**	2497.6

(Source: IMD, Kolkata)

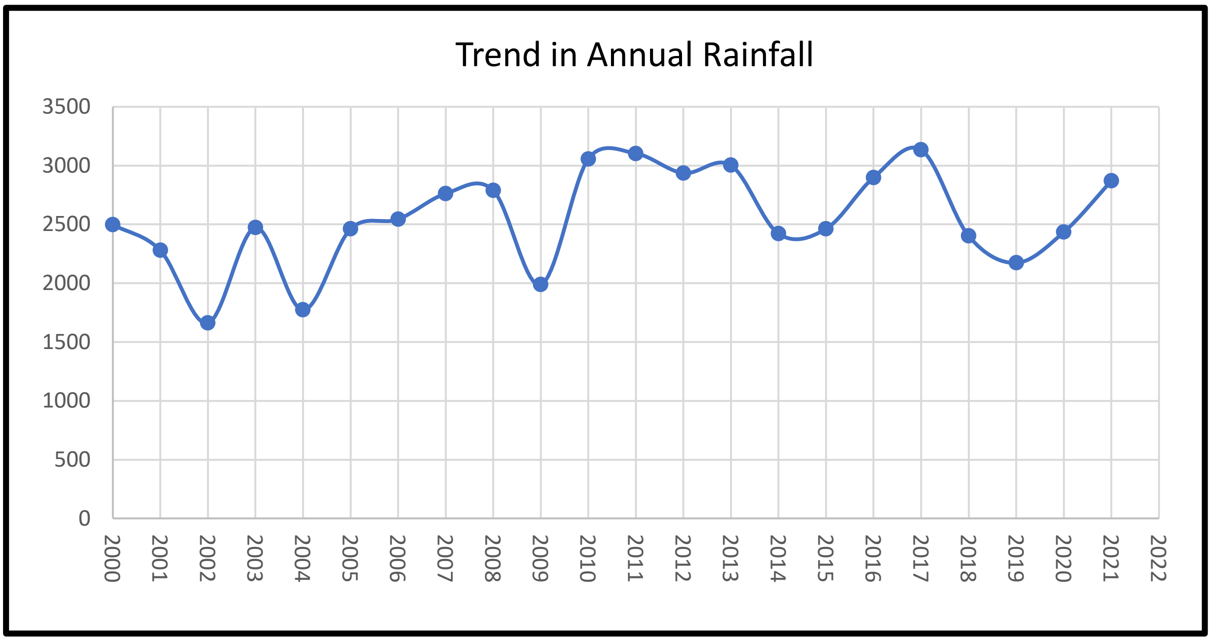


Fig. 2.2 Trend in Annual Precipitation

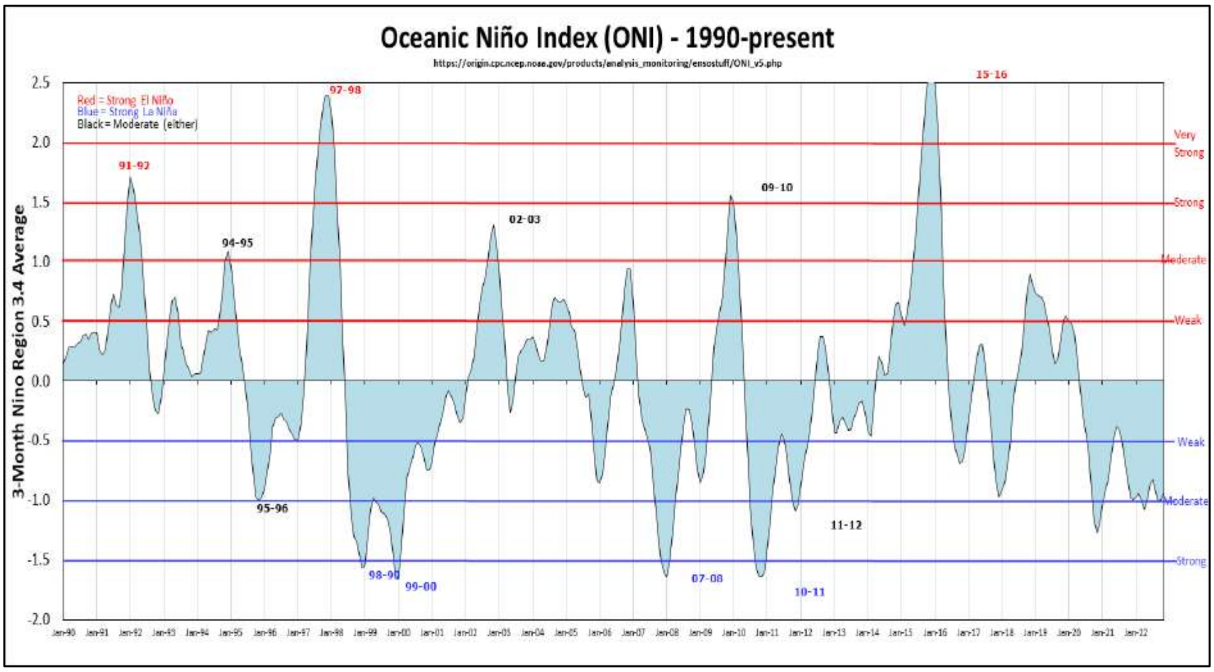


Fig. 2.3 ONI Index (Year 1990-Present)

2.2 Rainfall and Potential Evapotranspiration Trend Analysis

Two most significant climatological parameters, namely, Rainfall (RF) and Potential Evapotranspiration (PET) are studied and forecasting is done up to the year 2030. Forecasting modeling is done for the district as a whole and specifically for Great Nicobar Island in view of its development prospect.

Pre-whitening, Mann–Kendall test analysis, Sen-Slope and Exponential Triple Smoothing (ETS) Algorithm are utilized in the analysis of the climatic data. The RF and PET data are acquired from the Global Precipitation Measurement Satellite System (GPM IMERG Final Precipitation L3 1 month 0.1° x 0.1° V06) and Famine Early Warning Systems Network (FEWS NET) Land Data Assimilation System (FLDAS) (FLDAS Noah Land Surface Model L4 Global Monthly) with 0.1° x 0.1° spatial resolution from the year 2000 to 2020.

A) Nicobar District

Annual cumulative RF value and the forecasted RF value is plotted for the duration of 2000 to 2020 for the various islands of Nicobar district. RF varies from 2000 mm to 4300 mm over the islands. Average annual RF from 2001-2020 over various island groups in Nicobar district are given in **Table 2.3**. Southern group of islands received maximum RF, while middle group of islands received lowest RF during the period. Forecasting model (**Fig. 2.4**) shows that the RF will increase in the upcoming years in the Southern group of islands, while in the other islands groups RF will decrease.

Table 2.3 Average annual RF from 2001-2020 over Nicobar district

Islands	Mean RF (mm)	Std. Dev.
Car Nicobar	2972.2	±493.69
Katchal, Nancowri and Kamorta	2777.15	±486.26
Great Nicobar and Little Nicobar	3123.25	±452.59

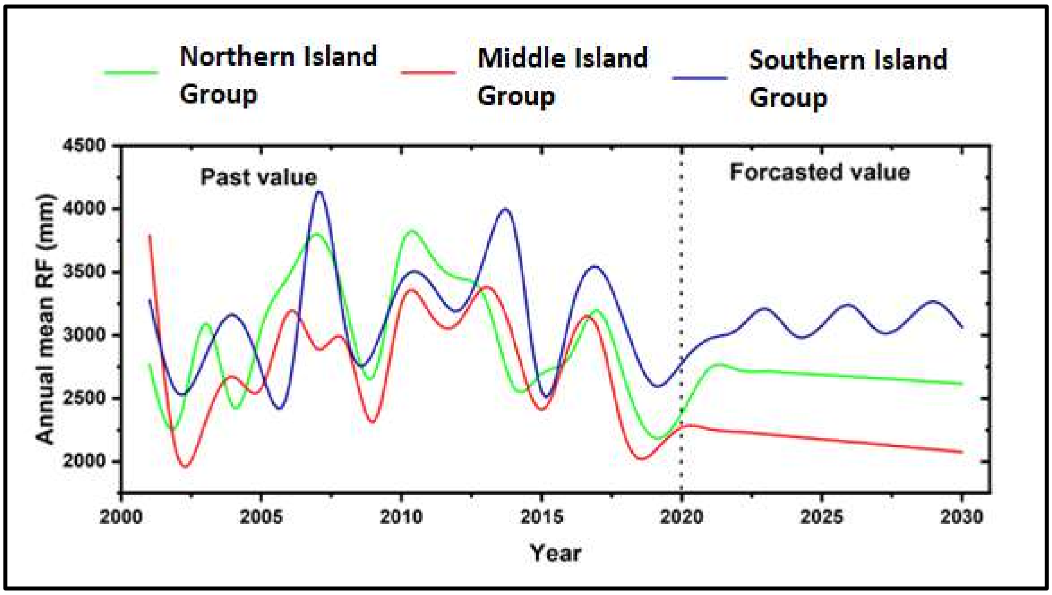


Fig. 2.4 Past and forecasted value of Nicobar island districts from 2001-2030

B) Great Nicobar Island

Study region is divided in to five different domains (D-1, D-2, D-3, D-4, and D-5) (**Table 2.4 and Fig 2.5**). This present model is generated mostly over the Island, hence the predictions are to be high influenced by the oceanic phenomena over the region.

Utilized twenty years (2000-2020) of RF and PET monthly dataset for M-K trend analysis and Sen-slope-estimator, over different domains do not show significant variability in the magnitude and direction of trends (**Table 2.5**). Season-wise analysis of RF indicates that the island receives RF in all seasons. It is noteworthy that the region is influenced by the south-west monsoon, north-east monsoon and pre-monsoon showers (**Fig. 2.6**). It is observed that north-east monsoon carried higher RF than the south-west monsoon. In the winter season, the forecasted RF is higher than the mean RF, whereas, in the other seasons forecasted RF is lesser than mean RF (except in post-monsoon season in D-3), which indicates that the RF will increase in winter season and decrease in the other seasons (**Fig. 2.6**). Season-wise predicted future trend of RF are given in **Fig. 2.7**.

Table 2.4 Domain details

S. No.	Domain	Latitude	Longitude
1	D-1	6.7°-7.3°	93.3°-94°
2	D-2	7.2°	93.7° -93.8°
3	D-3	7.1°	93.7° -93.9°
4	D-4	6.9° -7°	93.8°
5	D-5	6.9° -7°	93.9°

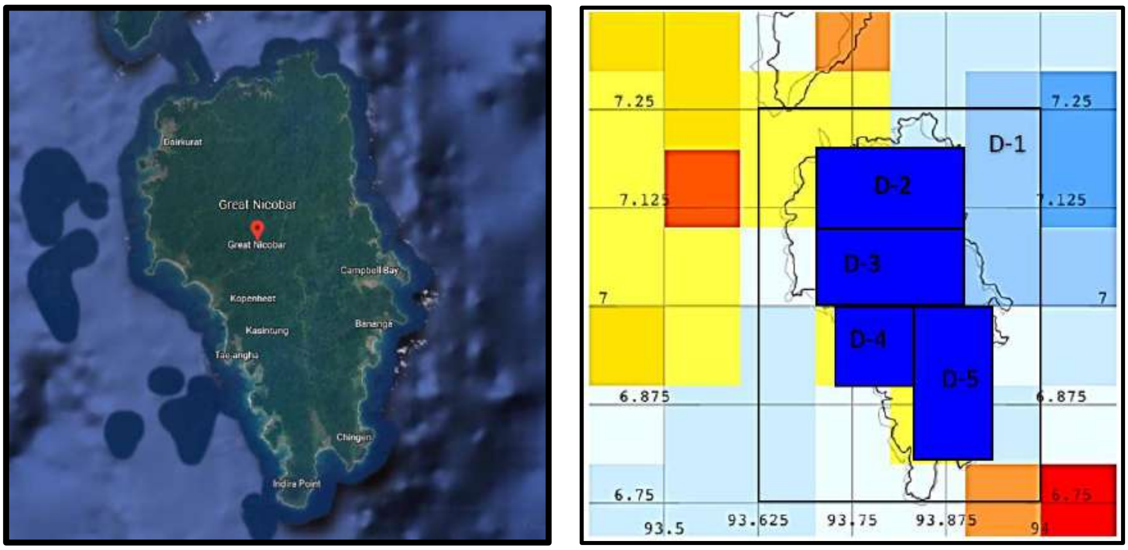


Fig. 2.5 Google earth image and different selected domains (blue box) over the Great Nicobar Island

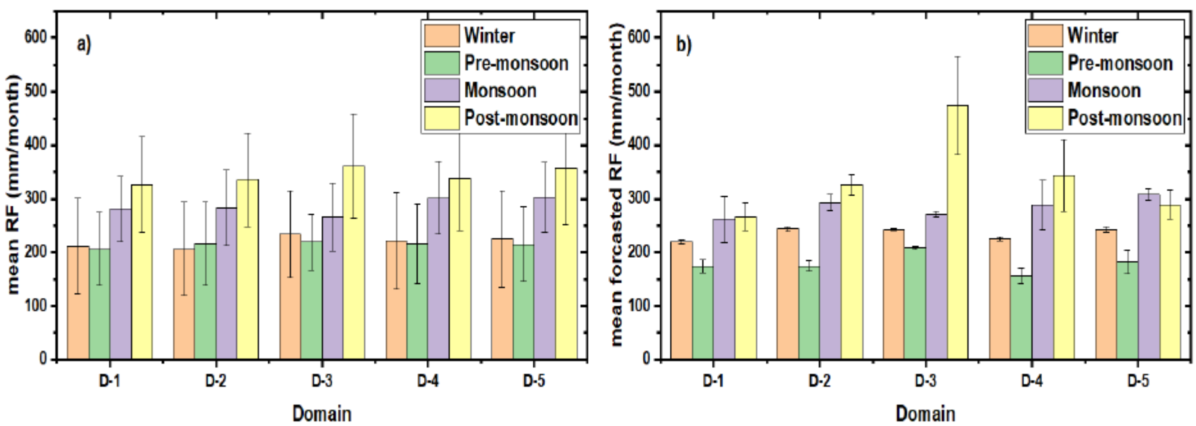


Fig. 2.6 Seasonal a) Mean RF and b) Forecasted RF over various domains

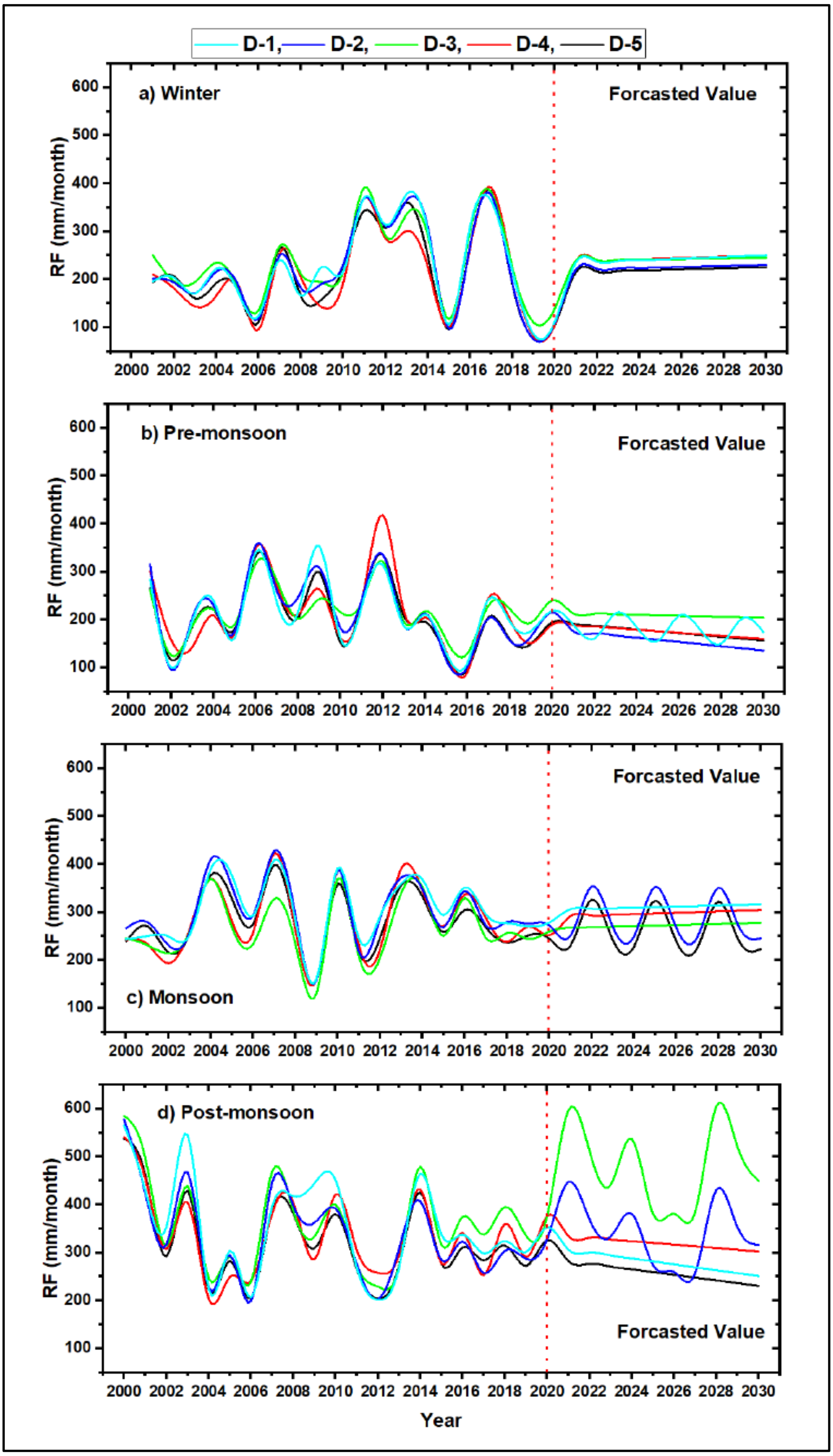


Fig. 2.7 Mean RF and Forecasted RF in different seasons in Great Nicobar

2.3 Seasonal Variation of RF and PET in Great Nicobar Island

Monthly RF and PET are plotted from 2000 to 2020 for the different selected domains of Great Nicobar (**Fig. 2.8**). More or less, RF occurs every month over the region. Simultaneously, PET is negligible in the rainy season (monsoon, post-monsoon and winter). Only in the pre-monsoon season, PET enhanced over the region. As the study region is an island with complex topography, the maximum RF leads to ocean as a surface runoff and some part lost as evapotranspiration.

Seasonal analysis of RF indicated that the island received RF in all the seasons. Though the region is influenced by the south-west monsoon, north-east monsoon and pre-monsoon showers, it is observed that the north-east monsoon carried higher RF than the south-west monsoon in the area. PET is negligible in the rainy season (monsoon, post-monsoon and winter). Only in the pre-monsoon season, PET enhanced over the region.

On monthly basis, RF starts rising in February and reached a peak in May which is considered pre-monsoon rain. South-west monsoon appears in the region in May. RF drops in August due to the southwest monsoon break and rise in September again. Owing to the south-west monsoon retreat RF drops in October and again rises in November and the winter season. The north-east monsoon appears in the island during winter season and RF is higher than the south-west monsoon. February receives the minimum RF of < 100 mm of the year and the rest of the months receive higher RF of > 100 mm.

On monthly basis, PET starts rising in January and reached the maximum value of 55 mm in April. After April, PET starts falling up to the minimum value of 2 mm in September. January to May is the period when maximum water is lost in terms of PET and less groundwater recharge takes place. For the rest of the months, PET is low owing to the higher RF and maximum groundwater recharge occurs during this period. Month-wise variation in RF and PET over Great Nicobar Island is given in **Fig. 2.9**.

Hence, it’s evident that recharge is taking place for the month of May to January as RF exceeds PET. Decline in water table will be observed during the months of February to April.

Table 2.5 M-K trend and Sen-slope for RF and PET
(Over different quadrant/domains in various seasons)

Parameters	Season	Quadrant	M-K trend	Sen-slope
Rainfall	Winter	D-1	No	0.8833
		D-2	No	1.987
		D-3	No	1.976
		D-4	No	1.156
		D-5	No	3.024
	Pre-monsoon	D-1	No	-3.993
		D-2	No	-3.285
		D-3	No	-0.197
		D-4	No	-4.515
		D-5	No	-2.308
	Monsoon	D-1	No	-0.8603
		D-2	No	0.9884
		D-3	No	0.726
		D-4	No	-0.3756
		D-5	No	1.0406
	Post-monsoon	D-1	No	-4.143
		D-2	No	-1.8903
		D-3	No	-2.487
		D-4	No	-6.46
		D-5	No	-6.048
Potential Evapotranspiration	Winter	D-1	No	Negligible
		D-2	No	Negligible
		D-3	No	Negligible
		D-4	No	Negligible
		D-5	No	Negligible
	Pre-monsoon	D-1	No	Negligible
		D-2	No	Negligible
		D-3	No	Negligible
		D-4	No	Negligible
		D-5	No	Negligible
	Monsoon	D-1	No	Negligible
		D-2	No	Negligible
		D-3	No	Negligible
		D-4	No	Negligible
		D-5	No	Negligible
	Post-monsoon	D-1	No	Negligible
		D-2	No	Negligible
		D-3	No	Negligible
		D-4	No	Negligible
		D-5	No	Negligible

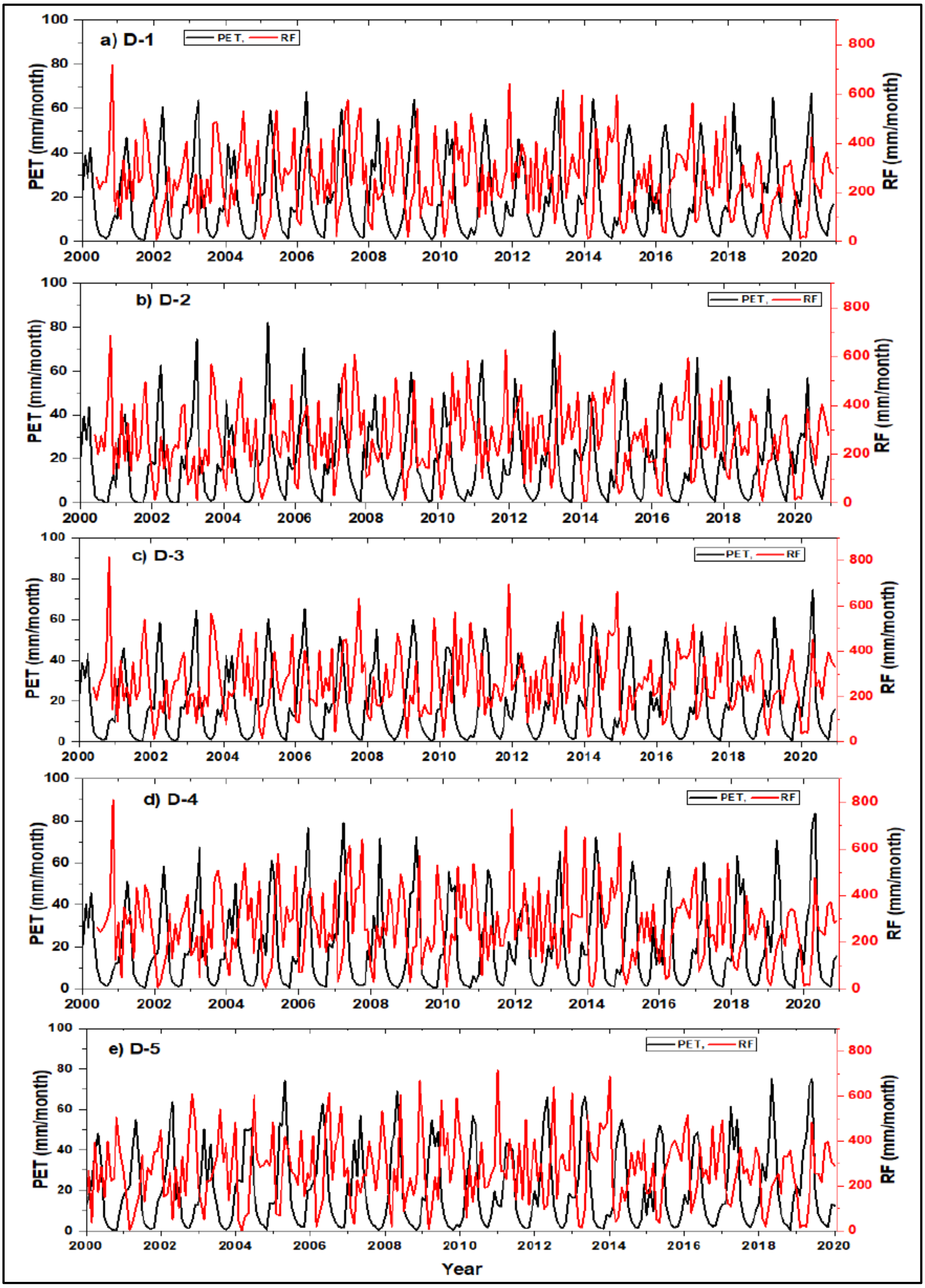


Fig. 2.8 Time series RF and PET variation over the selected domains in Great Nicobar

Table 2.6 Mean and forecasted RF over the different zones over Great Nicobar

Season	Domain	Avg. RF (mm/month) (2000-2020)	Avg. forecasted RF (mm/month) (2020-2030)	% Difference
Winter	D-1	211.6	220.2	3.9
	D-2	206.4	243.9	16.6
	D-3	233.4	242.3	3.7
	D-4	220.7	225.32	2
	D-5	224.7	242.5	7.5
Pre-monsoon	D-1	206.4	173.9	-17
	D-2	216.3	174.5	-21.4
	D-3	219.4	208.6	-5
	D-4	215.5	156.1	-31.9
	D-5	215.1	181.9	16.7
Monsoon	D-1	280.9	262	-6.9
	D-2	283.5	292.9	3.2
	D-3	265.9	270.9	1.8
	D-4	301.4	288.3	-4.4
	D-5	302.7	307.5	1.5
Post-monsoon	D-1	325.7	266	-20
	D-2	335.3	325.8	-2.8
	D-3	360.7	473.5	-27
	D-4	337.7	343.3	1.6
	D-5	357	288.8	-21

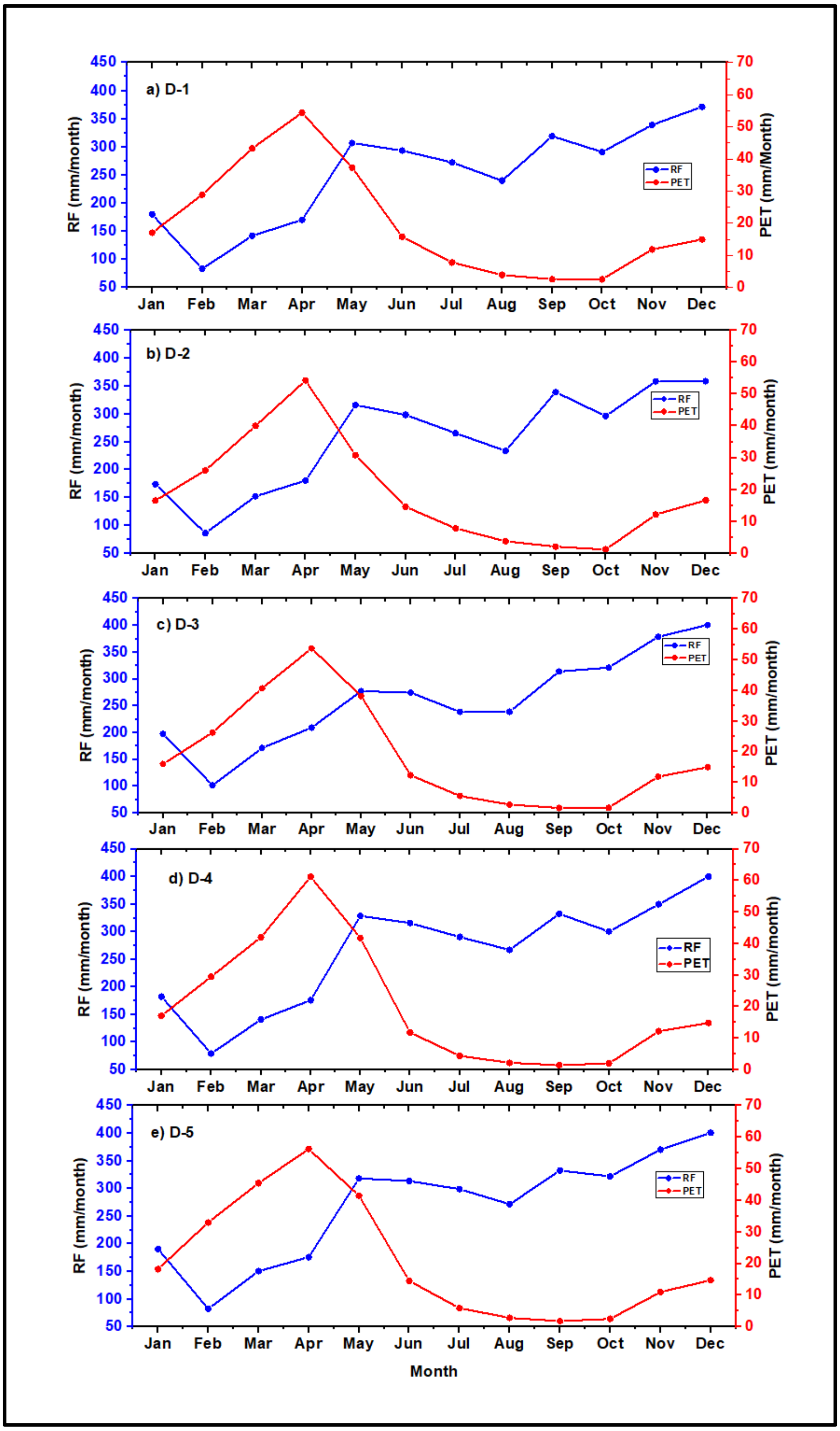


Fig. 2.9 Monthly RF and PET variation over the selected domains in Great Nicobar Island

Chapter 3

REGIONAL GEOLOGY

Tectonically, Andaman and Nicobar Group of Islands are located at the central part of Sunda-Java subduction complex. Along the subduction complex, Indian Plate is subducting along the geophysically traced Arakan-Yoma-Andaman-Java trench (Curray and Moore, 1974; Karig *et al*. 1979; Mukhopadhyay, 1988). Nicobar group of islands represent the tail part of the island chain. The predominance of sedimentary rocks and local thrust-emplaced ophiolite slices and olistoliths (Ray, 1982) are consistent with an outer arc setting for the Andaman and Nicobar Islands (Chakraborty and Pal, 2001). Major tectono-stratigraphic elements in these islands strike approximately parallel to the trend of the trench. Tectonic elements of the island chain of Andaman and Nicobar are: (a) Outer-arc comprised of oceanic crust (in the form of ophiolites) and trench sediments and (b) Fore-arc represented by siliciclastic to carbonate turbidites (Pal *et al*., 2003). Generalized Litho-Stratigraphy of Nicobar district is given in **Table 3.1**. Tectonic Setup of Andaman-Nicobar Island Area is given in **Fig. 3.1**. Schematic 3-D Block diagram of Andaman Subduction Zone (Singh and Moeremans, 2017) is given in **Fig. 3.3**.

In a broad sense, lithologically, marine sedimentary group of rocks comprising shale, sandstone, grit and conglomerate; extrusive and intrusive igneous rocks (volcanics and ultramafics) and Coralline limestone mainly occupy the area. Amongst these marine-sedimentary group is most pervasive and occupy nearly 70% of the entire area of the islands while the igneous group covers nearly 15% while the rest 15% by coralline and limestone formations. Because of tectonism the igneous and marine-sedimentary group of rocks are fractured and fissured. The geology of the islands is highly varied and even changes within a small distance. Island-wise occurrence of various litho-groups are summarized in **Table 3.2**. Geological Map of Nicobar group of Islands is given in **Fig. 3.4**. Detailed geological maps of Car Nicobar Island (**Fig. 3.5**), Chowra, Teressa and Bampooka Island (**Fig. 3.6**), Katchal, Kamorta, Nancowri, and Trinket Island (**Fig. 3.7**), Tillangchong Island (**Fig. 3.8**), Little Nicobar Island (**Fig. 3.9**), and Great Nicobar Island (**Fig. 3.10**) are prepared.

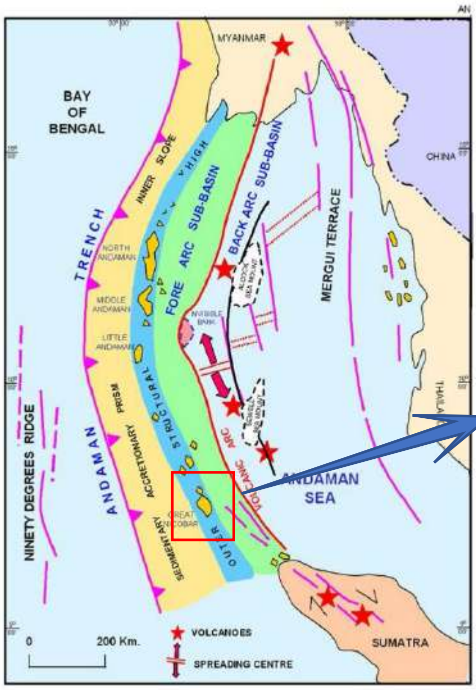
Table 3.1 Generalized Litho-Stratigraphy
(After Karunakaran, *et al*, 1967; Ray, 1982; Pal *et al*, 2003)

Tectonic Setting	Age	Stratigraphic Unit	Lithological Character
	Holocene to Recent	Recent	Beach sand, Swampy clay, raised beach shell limestone
Fore Arc	Pliocene (cf. Ray, 1982) Miocene (Chatterjee, 1964)	Archipelago Group (400m thick)	Interbedded sequence of tuff, limestone, sandstone and clay.
	Unconformity		
	Upper Eocene Oligocene (Pawde & Ray, 1963) Oligocene- Lower Miocene	Andaman Flysch Group (300m thick)	Interbedded sequence of sandstone, siltstone and shale
	Unconformity / transitional		
Trench Slope	Middle to Late Eocene (Karunakaran *et al*, 1967)	Mithakhari Group (1400m thick)	Conglomerate, sandstone and shale
	Tectonic / Unconformity		
Accretionary Slices	Late Cretaceous to Paleocene (Roy *et al*, 1988) Early Cretaceous (cf Jafri, 1990).	Ophiolite Group	Metamorphics, tectonites, cumulates, plagiogranite - diorite - andesite suite, basalt and pelagic sediments

Table 3.2 Island-wise occurrence of various litho-groups

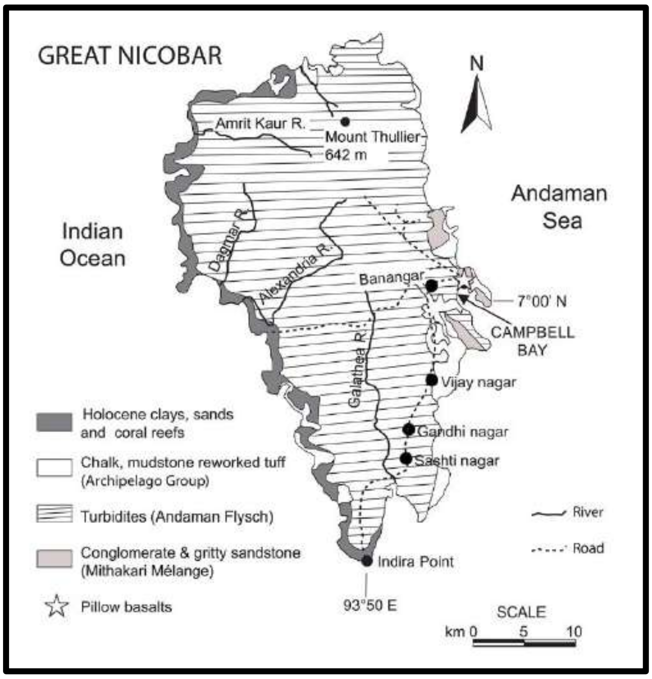
Stratigraphic Units	Islands												
	Car Nicobar	Chowra	Teressa	Bompoka	Katchal	Nancowri	Kamorta	Trinket	Tillangchong	Pulo milo	Little Nicobar	Kondul	Great Nicobar
Recent Sediments	P	P	P	P	P	P	P	P	P	P	P	P	P
Archipelago Group	N	P	P	N	N	P	P	N	N	N	N	N	P
Andaman Flysch Group	N	N	N	N	P	N	N	N	N	N	P	N	P
Mithakhari Group	N	N	N	N	P	N	N	N	N	N	N	N	P
Ophiolite Group	N	N	P	P	P	P	P	N	P	N	N	N	P

P: Present; N: Not Observed; (Compiled from GSI Map)



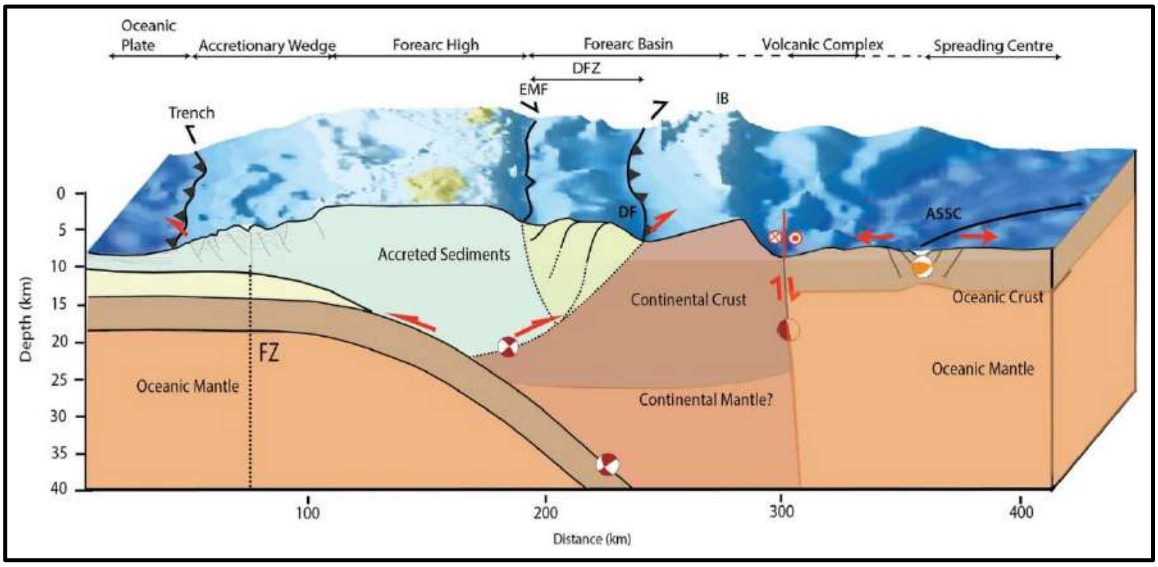
NDR, DGH, Min. of Pet and Nat. Gas, GoI

Fig. 3.1 Tectonic Setup of Andaman-Nicobar Island Area



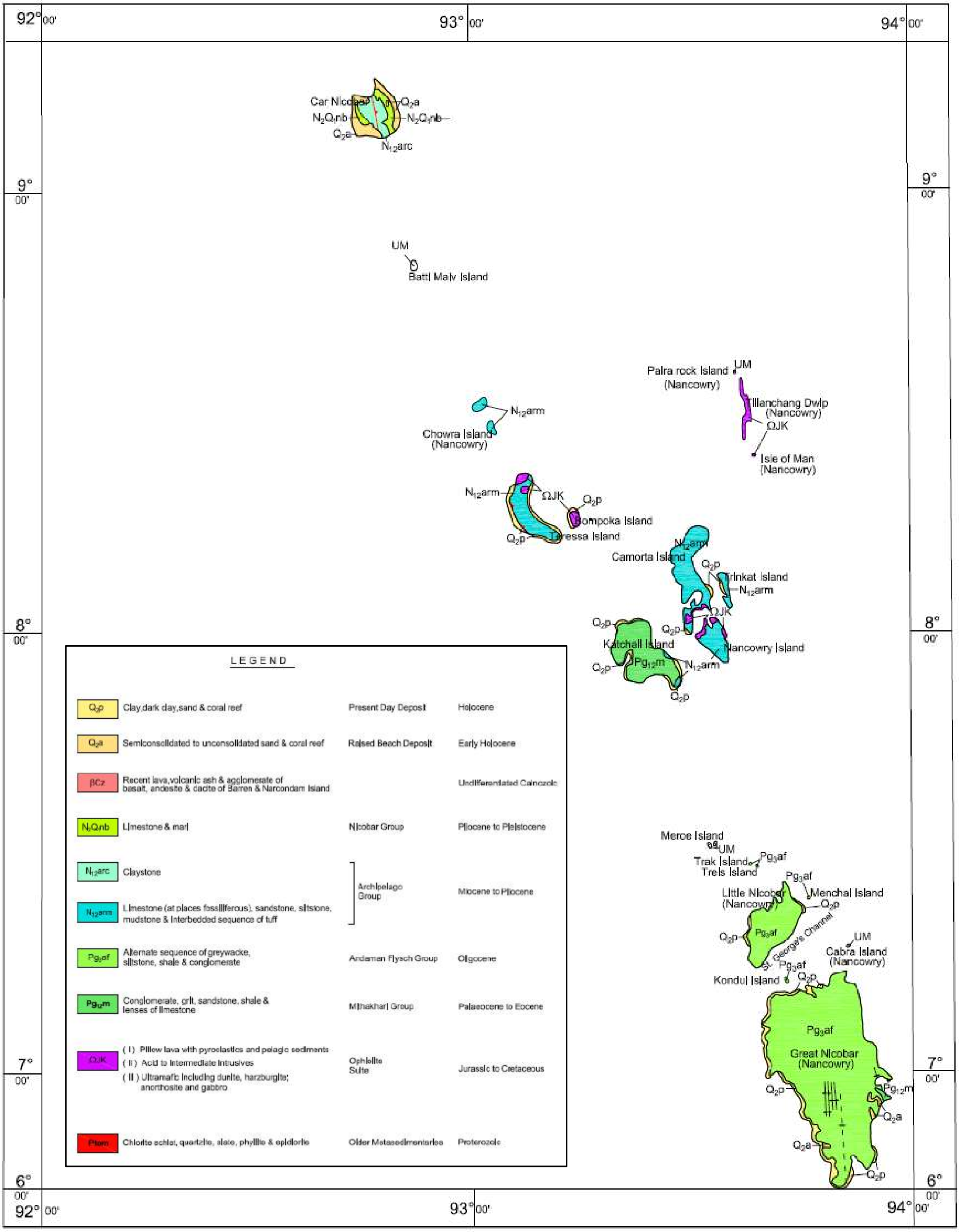
Bandopadhyay and Carter (2017)

Fig. 3.2 Geological map of Great Nicobar Island



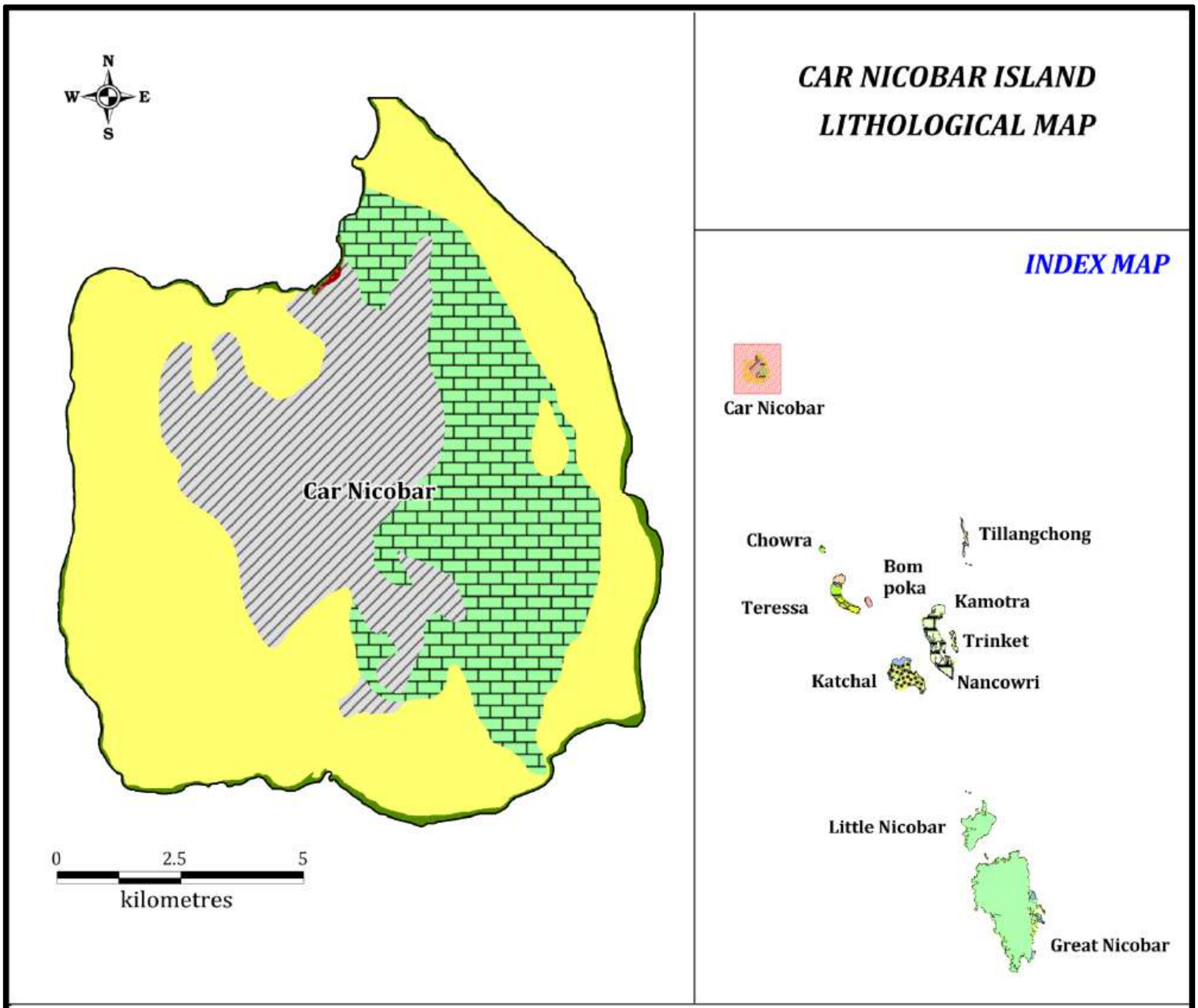
(Singh and Moeremans, 2017)

Fig. 3.3 Schematic 3-D Block diagram of Andaman Subduction Zone



Source: Geological Survey of India

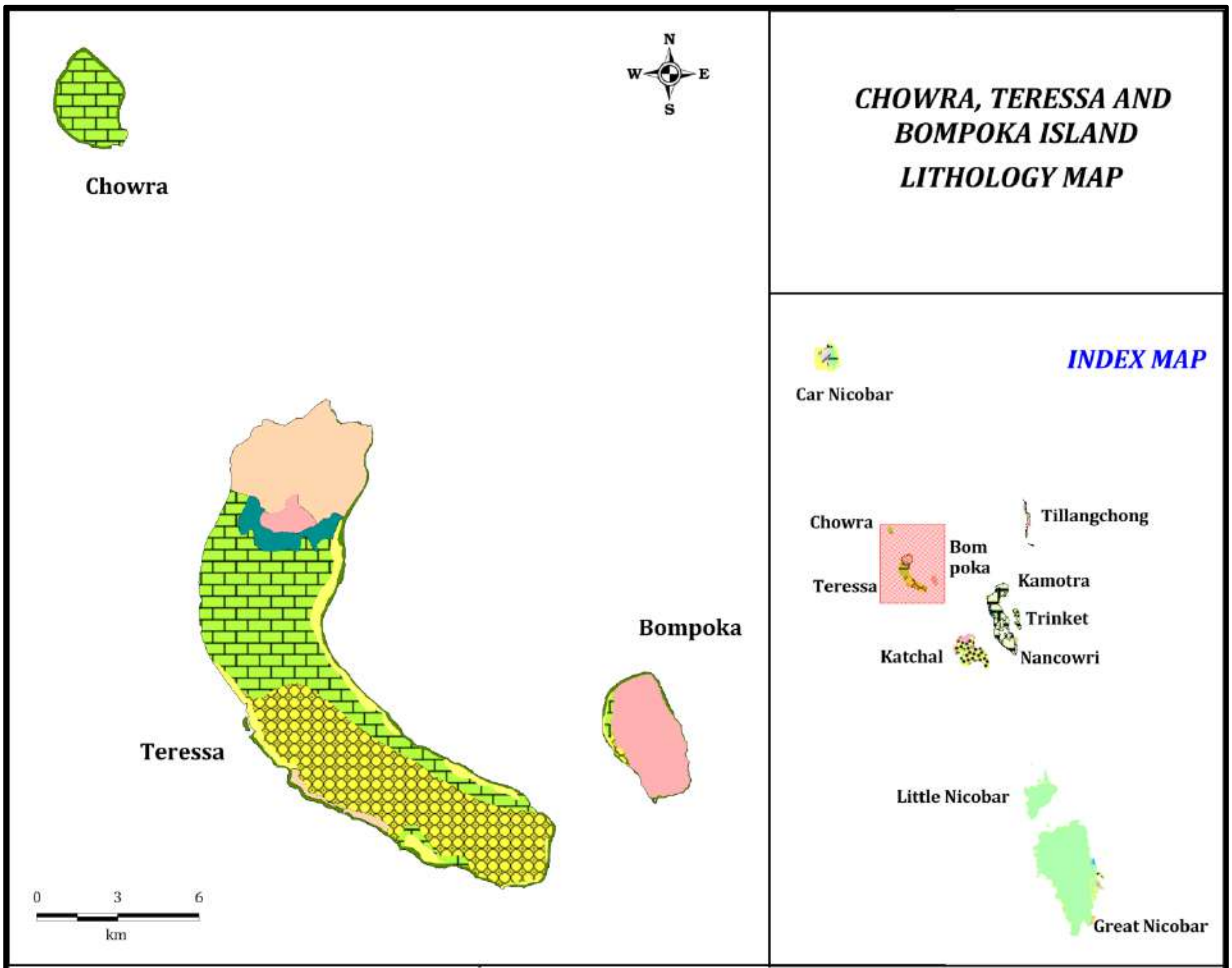
Fig. 3.4 Geological Map of Nicobar group of Islands



LEGEND

	Age	Group Name	Formation	Lithology
	Pliocene - Pleistocene	Nicobar	Abbeville Limestone	Limestone With Calcite Crystals & Fossil
	Early Miocene	Nicobar	Sawai-Bay Limestone	Bioclastic Limestone With Fossil & Shell Fragment
	Late Miocene	Nicobar	Nicobar Marl	Marl Beds With Calcareous Siltstone Bands
	Meghalayan	Newer Alluvium	Present Day Deposits	Clay, Dark Clay, Sand, Coral Reef
	Holocene	Newer Alluvium	Raised Beach Deposit	Semi To Unconsolidated Sand And Coral Reef

Fig 3.5 Geological Map of Car Nicobar Island (Source: GSI)

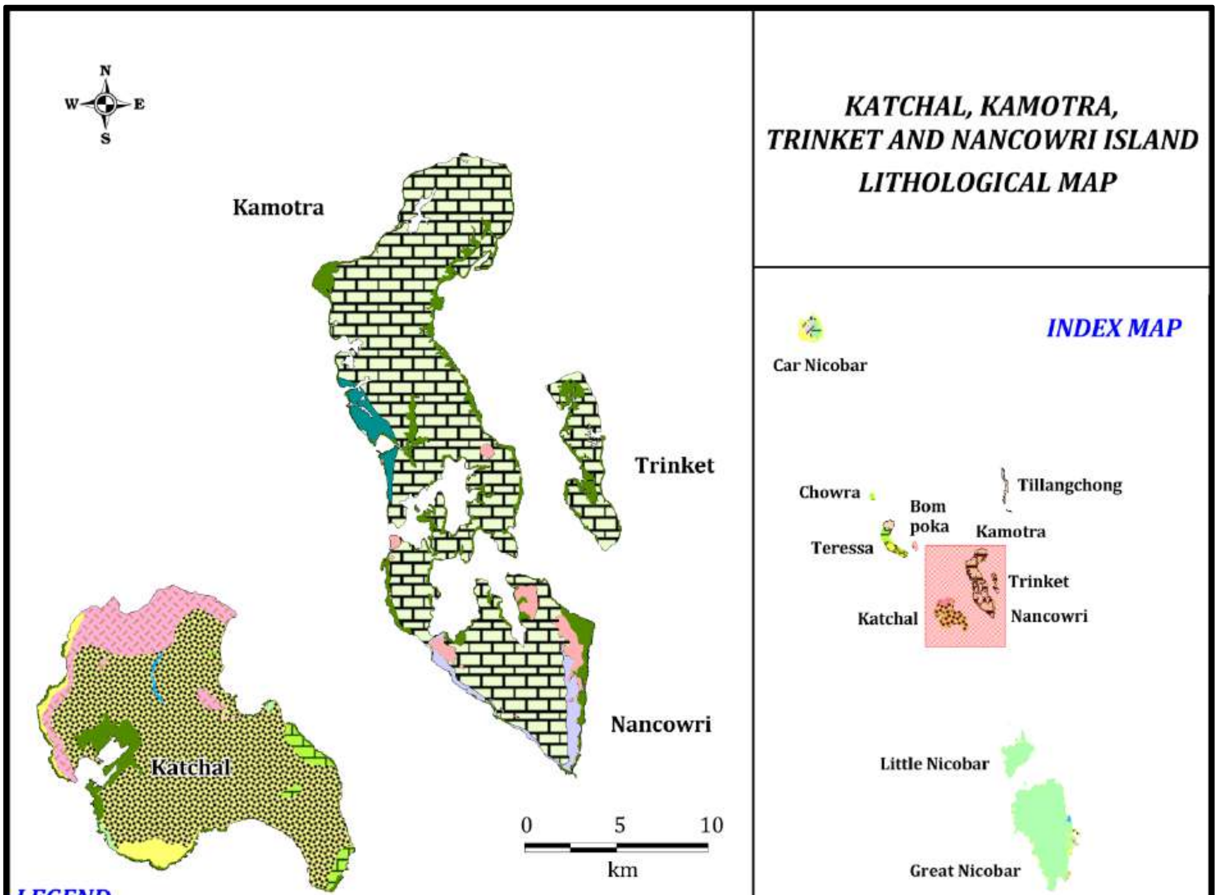


LEGEND

LITHOLOGY

	Age	Group Name	Formation	Lithology
	Meghalayan	Newer Alluvium	Present Day Deposits	Clay, Dark Clay, Sand, Coral Reef
	Holocene	Newer Alluvium	Raised Beach Deposit	Semi To Unconsolidated Sand And Coral Reef
	Miocene - Pliocene	Archipelago	Melville Conglomerate	Grit & Conglomerate
	Miocene - Pliocene	Archipelago	Strait	Fossiliferous Sandstone, Siltstone & Conglomerate
	Miocene - Pliocene	Archipelago	Melville Limestone	Fossiliferous Limestone
	Jurassic- Cretaceous		Ophiolite Suite	Pillow Lava, Tuff, Agglomerate, Pelagic Sediments
	Jurassic- Cretaceous		Ophiolite Suite	Peridotite, Serpentinite, Anorthosite & Gabbro With Basic/Ultrabasic Intrusive

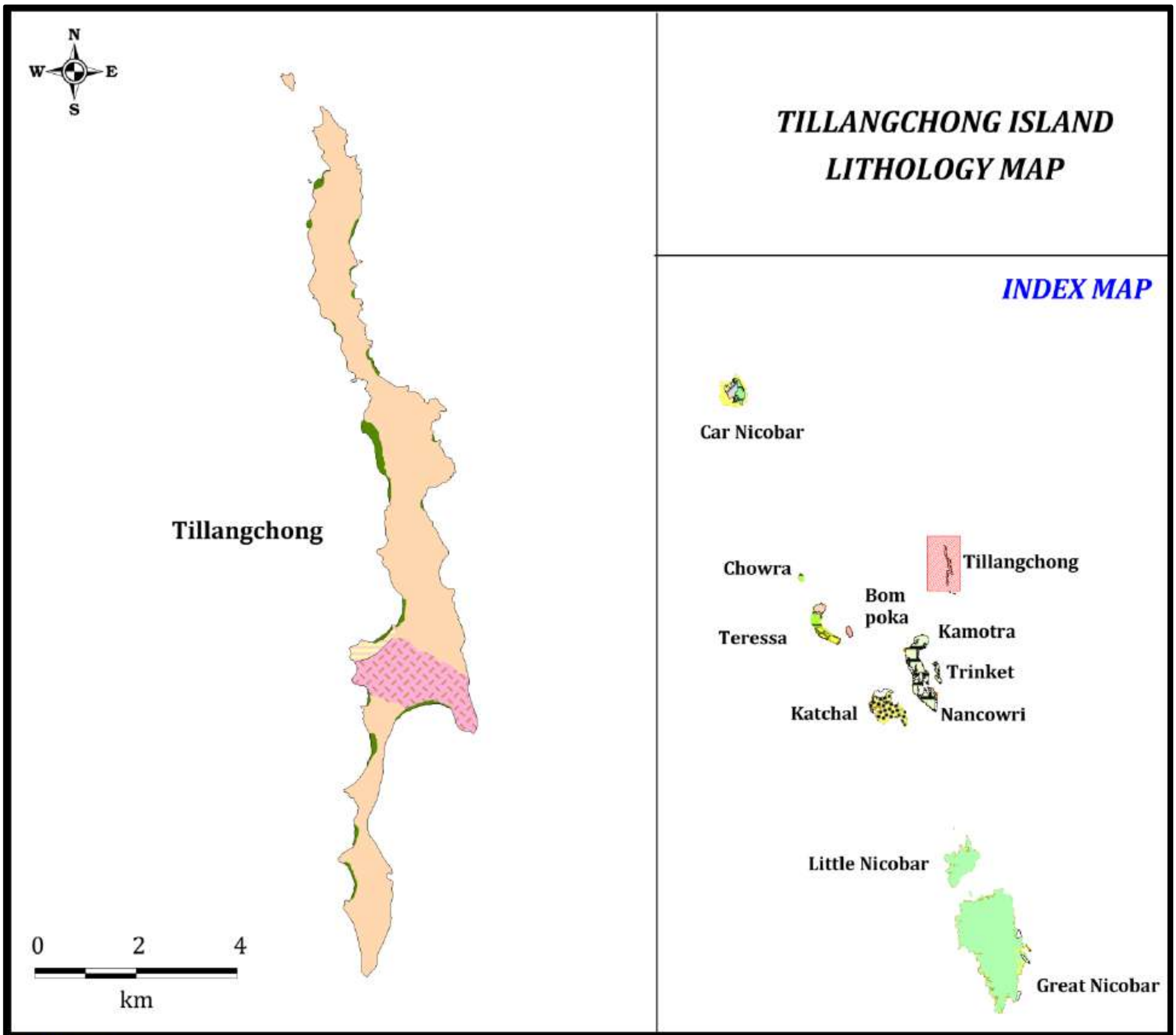
Fig 3.6 Geological Map of Chowra, Teressa and Bampooka Island (Source: GSI)



LEGEND

	Age	Group Name	Formation	Lithology
	Meghalayan	Newer Alluvium	Present Day Deposits	Clay, Dark Clay, Sand, Coral Reef
	Holocene	Newer Alluvium	Raised Beach Deposit	Semi To Unconsolidated Sand And Coral Reef
	Miocene - Pliocene	Archipelago	Round Chalk	Calcareous Mudstone With Siltstone & Sandstone
	Miocene - Pliocene	Archipelago	Strait	Fossiliferous Sandstone, Siltstone & Conglomerate
	Miocene - Pliocene	Archipelago	Undifferentiated Archipelago	Grit, Conglomerate ,Fossiliferous Limestone
	Miocene - Pliocene	Archipelago	Melville Limestone	Fossiliferous Limestone
	Oligocene	Andaman Flysch	Undifferentiated Flysch	Greywacke, Shale, Siltstone, Conglomerate
	Palaeocene - Eocene	Mithakhari	Namunagarh Grit	Gritty Sandstone
	Palaeocene - Eocene	Mithakhari	Undifferentiated Mithakari	Greywacke, Grit, Sandstone & Conglomerate
	Palaeocene - Eocene	Mithakhari	Hopetown Conglomerate	Conglomerate, Pebbly And Gritty Sandstone
	Jurassic- Cretaceous		Ophiolite Suite	Pillow Lava, Tuff, Agglomerate, Pelagic Sediments
	Jurassic- Cretaceous		Ophiolite Suite	Peridotite, Serpentinite, Anorthosite & Gabbro with Basic/Ultrabasic Intrusive

Fig 3.7 Geological Map of Katchal, Kamorta, Nancowri, and Trinket Island (Source: GSI)

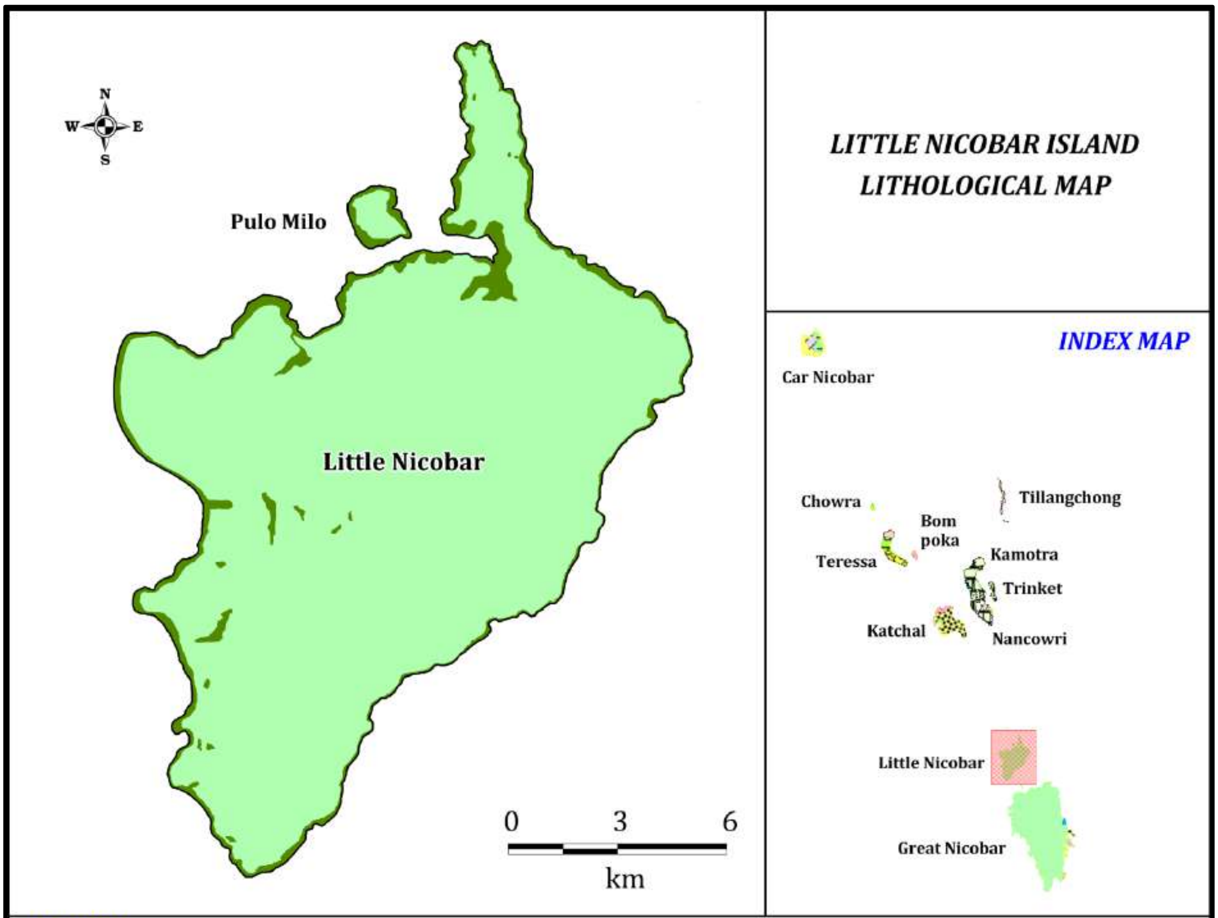


LEGEND

LITHOLOGY

	Age	Group_Name	Formation	Lithology
	Meghalayan	Newer Alluvium	Present Day Deposits	Clay, Dark Clay, Sand, Coral Reef
	Palaeocene - Eocene	Mithakhari	Undifferentiated Mithakari	Greywacke, Grit, Sandstone & Conglomerate
	Jurassic- Cretaceous		Ophiolite Suite	Pillow Lava, Tuff, Agglomerate, Pelagic Sediments
	Proterozoic	Older Metasedimentaries (Andaman)		Quartzite, Schist, Epidiorite, Slate, Phyllite

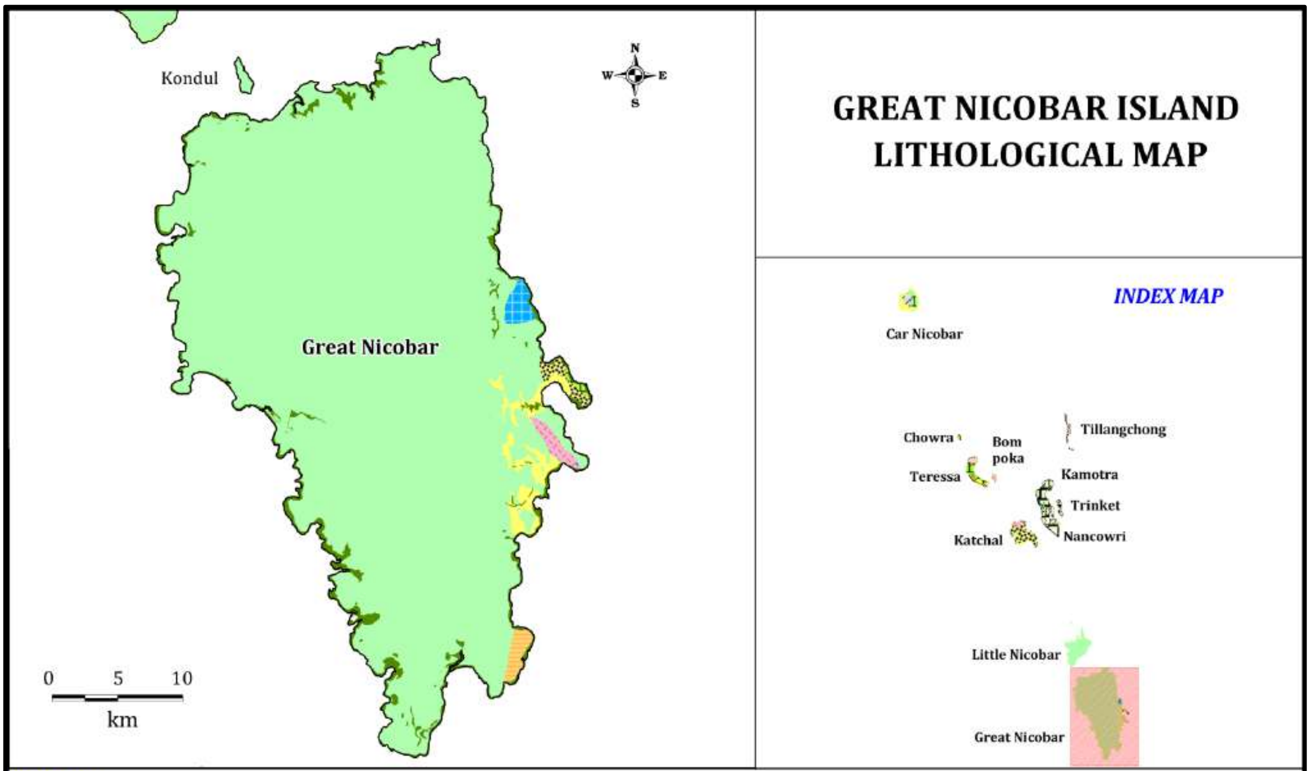
Fig 3.8 Geological Map of Tillangchong Island (Source: GSI)



LEGEND

Age	Group Name	Formation	Lithology
Meghalayan	Newer Alluvium	Present Day Deposits	Clay, Dark Clay, Sand, Coral Reef
Oligocene	Andaman Flysch	Undifferentiated Flysch	Greywacke, Shale, Siltstone, Conglomerate

Fig 3.9 Geological Map of Little Nicobar Island (Source: GSI)



LEGEND

	Age	Group Name	Formation	Lithology
	Meghalayan	Newer Alluvium	Present Day Deposits	Clay, Dark Clay, Sand, Coral Reef
	Holocene	Newer Alluvium	Raised Beach Deposit	Semi To Unconsolidated Sand And Coral Reef
	Miocene - Pliocene	Archipelago	Undifferentiated Archipelago	Grit, Conglomerate ,Fossiliferous Limestone
	Miocene - Pliocene	Archipelago	Melville Limestone	Fossiliferous Limestone
	Oligocene	Andaman Flysch	Undifferentiated Flysch	Greywacke, Shale, Siltstone, Conglomerate
	Palaeocene - Eocene	Mithakhari	Undifferentiated Mithakari	Greywacke, Grit, Sandstone & Conglomerate
	Palaeocene - Eocene	Mithakhari	Hopetown Conglomerate	Conglomerate, Pebbly And Gritty Sandstone
	Palaeocene - Eocene	Mithakhari	Namunagarh Grit	Gritty Sandstone
	Jurassic- Cretaceous		Ophiolite Suite	Peridotite, Serpentinite, Anorthosite & Gabbro With Basic/Ultrabasic Intrusive

Fig 3.10 Geological Map of Great Nicobar Island (Source: GSI)

Chapter 4

GEOMORPHOLOGY

4.1 Physiography

Physiography of the island group is controlled mainly by rock types (lithology) and associated geological structures. In general, hard competent rocks formed elevated ground where as argillaceous rocks generally eroded and formed depressional areas. This situation is accentuated where structural features such as fold hinges coincided with lithology to form the ridges. This clearly indicate that most of the ridges are represented by massive, thick bedded sandstone of Mithakhari and Andaman Flysch formations. The lithological control may sometimes override structural control through synclines occupying hills and anticlines the valley. Low coastal areas are mostly contributed by coralline formations.

Car Nicobar Island is remarkably flat except for some cliffs in the north and small hilly areas in the interior. Maximum elevation is 80 m.

Katchal Island has a central highland consisting of two main strike ridges in this island trending NNW-SSE direction. East Bay Range has the maximum elevation of 230 m and has a gentle westerly slope. On the other hand, Tapain-Olench Range has a gentle easterly slope. Northern part of the inland is characterized by almost flat topography.

Adjoining Kamorta Island shows a rolling topography with maximum elevation of 203 m. Nancowri Island has the highest elevation of 143 m.

Chowra Island is generally flat but has a 93 m high rocky upland at its southern end. Coral reefs extend about 1.5 miles from the northwestern side of the island.

In Teressa Island topography is generally flat. However, northern portion of the island has elevations reaching 263 meters.

Trinket Island shows a flat and low topography with maximum elevation of 32 m. The island is surrounded by shallow waters and coral reefs.

Little Nicobar Island has two peaks, Mt. Deoban (435 m) and Mt. Empress (432 m) in Sathabang Hill range located in the South-central part of the island.

Great Nicobar Island exhibits highly undulating topography. The general trend of the main hill ranges is N-S and act as water divides. Mt. Thullier with an elevation of 641.5 m is the highest peak of the island and is situated at the central part of the island. In general, lithological and structural controls seem to have played a major role in the formation of physiographic features. Island-wise topographic characteristics are summarized in **Table – 4.1**. Perimeter-Area (P/A) ratio indicates that larger islands have highly dissected coastline in contrast to smaller islands.

Table 4.1 Island-wise topographic characteristics

Sl.	Island Name	Area (A)	Coast Line Length (P)	Highest Elevation	Length (L)	Width (W)	Form Factor	Aspect Ratio	P/A Ratio	Elongation Direction	Shape
		(Km^2)	(Km)	(m)	(Km)	(Km)	A/L^2	L/W	P/A		
1	Great Nicobar	960.5	216.36	642	53.71	25.84	0.33	2.1	0.23	N-S	Inverted Tear Drop
2	Katchal	164.0	78.95	230	20.22	11.7	0.40	1.7	0.48	NE-SW	Irregular
3	Little Nicobar	149.5	71.31	420	18.31	11.74	0.45	1.6	0.48	NW-SE	Elongated
4	Kamorta	143.1	114.01	203	27.19	7.26	0.19	3.7	0.80	NNW-SSE	Arcuate
5	Car Nicobar	126.9	54.27	80	15.14	12.22	0.55	1.2	0.43	NNW-SSE	Tear Drop
6	Teressa	94.18	58.05	263	22.36	4.78	0.19	4.7	0.62	NNW-SSE	Arcuate
7	Nancowri	51.6	44.65	143	11.54	7.19	0.39	1.6	0.86	NNW-SSE	Inverted Tear Drop
8	Trinket	18.8	27.69	32	9.63	1.89	0.20	5.1	1.47	NNW-SSE	Elongated
9	Tillangchong	18.19	48.65	304	17.05	1.95	0.06	8.7	2.67	N-S	Elongated
10	Bompoka	11.1	14.19	206	4.32	2.56	0.59	1.7	1.28	NNW-SSE	Lozenge
11	Chowra	7.46	11.39	93	2.42	3.69	1.27	0.7	1.53	NNW-SSE	Lozenge
12	Kondul	2.2	7.59	147	2.89	0.99	0.26	2.9	3.48	NNW-SSE	Elongated
13	Batt Malv	2.06	5.68	53	1.95	1.12	0.54	1.7	2.76	NNE-SSW	Lozenge
14	Meroe	1.42	4.88	39	1.51	0.77	0.62	2.0	3.44	N-S	Tear Drop
15	Pulo milo	1.34	4.66	56	1.42	0.96	0.66	1.5	3.48	NE-SW	Arcuate
16	Menchal	0.92	3.77	74	0.98	0.98	0.96	1.0	4.10	NNW-SSE	Round
17	Isle of Man	0.75	4.17	106	1.34	0.41	0.42	3.3	5.56	WNW=ESE	Elongated
18	Trails	0.65	3.19	45	0.81	0.71	0.99	1.1	4.91	NE-SW	Oval
19	Trek	0.23	1.87	24	0.22	0.1	4.75	2.2	8.13	NNE-SSW	Elongated
20	Kabra	0.18	1.85	35	0.46	0.26	0.85	1.8	10.28	NE-SW	Elongated
21	Pigeon	0.12	1.42	54	0.36	0.22	0.93	1.6	11.83	NNW-SSE	Elongated
22	Megapod	0.09	1.36	55	0.45	0.29	0.44	1.6	15.11	NE-SW	Oval

Data Source: SRTM Plus 1-arc-sec DEM Ver. 3 (GCS: WGS 1984)

Prepared digital elevation model (DEM) using SRTM Data for the entire Nicobar group of islands is given in **Fig. 4.1**.

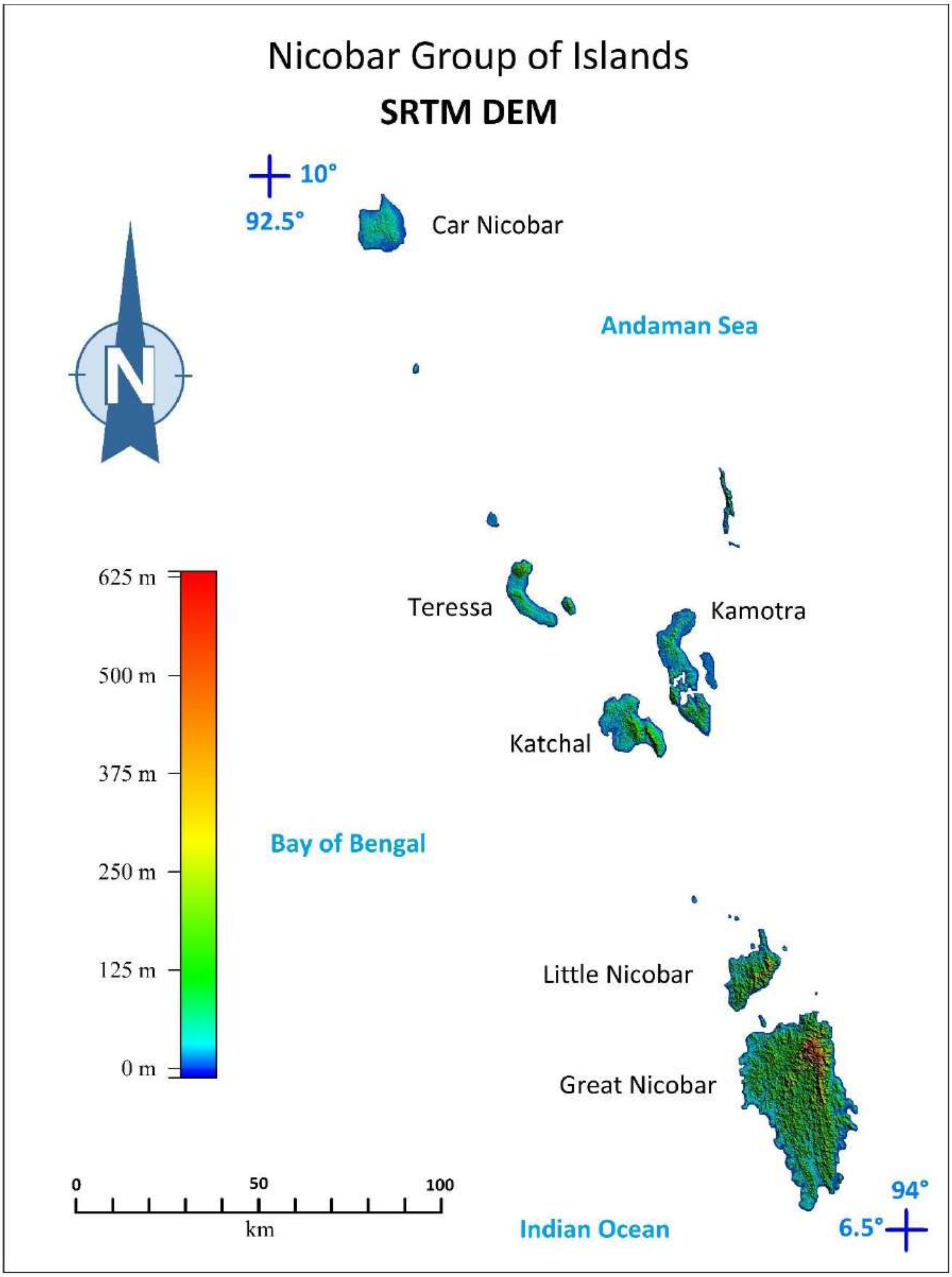
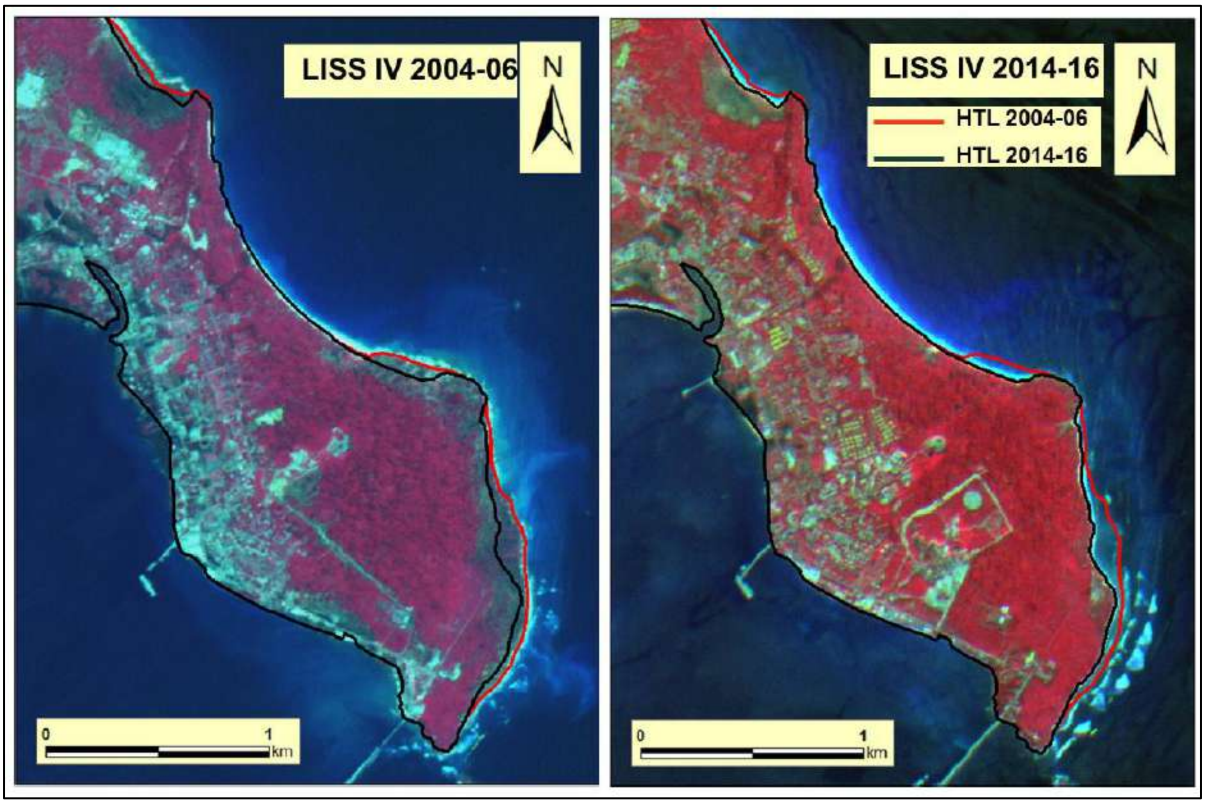


Fig. 4.1 Prepared DEM of the Nicobar group of Islands

Shoreline Change Atlas of India (Ratheesh *et al*, 2021) reported results of shoreline changes between 2004-06 and 2014-16. The main observations are

1. Large-scale changes in coastline in Nicobar group of islands happened due to the December 2004 tsunami and earthquake.
2. As on 2014-16, around 123 km of the coast is under erosion, along 112 km of the coast is under accretion and 455 km of the coast is under stable condition.
3. Deterioration of the shoreline is observed along east coast of Car Nicobar Island, Campbell Bay, and Trinket Island. A long stretch of coast at Pullo Ullo area in Little Nicobar Island is under erosion. Coastal erosions in Car Nicobar Island are observed along Mus, Sawal and Tamalo area.



Source: Shoreline Change Atlas of India (Ratheesh *et al*, 2021)

Fig. 4.2 Erosion at Campbell Bay area (Great Nicobar Island)

4.2 Elevation and Slope Characteristics

The Island group shows distinct elevation classes separated by sloppy plains representative of interplay in various energy conditions. District Irrigation Plan of Nicobar (2016) subdivided island physiography into (i) moderate to steep hill ranges, (ii) intermountain narrow valley, and (iii) coastal tracts including swamps. Island profile analyses show that the islands may be broadly classified in to the five elevation classes (**Table 4.2**). Schematics of observed elevation classes in Nicobar group of Islands are given in **Fig. 4.3**. Island-wise area under various elevation classes is tabulated in **Table 4.3**. Stacked column chart for percent area for main islands are given in **Fig. 4.4** for comparison among islands. The graph shows that Great Nicobar, Little Nicobar and Nancowri are dominated by highlands, Katchal, Kamorta, Teresa, and Car Nicobar is dominated by uplands. In Katchal and Car Nicobar significant coastal plain area is present.

Table 4.2 Identified Elevation Classes

Sl.	Topographic Feature Type	Elevation Class	Slope Characteristics
1.	Shore	0 - 3 m	0 - 3°
2.	Coastal plains	0 – 10 m	1° - 2°
3.	Foot Slope	10 – 20 m	3° - 5°
4.	Upland	20 – 50 m	2° - 10°
5.	Highland	> 50 m	> 20°

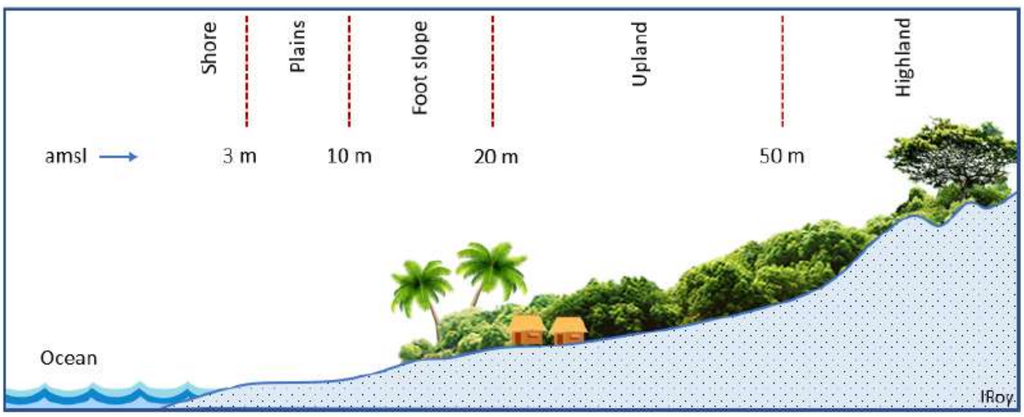


Fig. 4.3 Schematics of observed elevation classes in Nicobar group of Islands

Table 4.3 Island-wise Area under various elevation classes

Sl.	NAME	Total	0-3 m	% Area	3-10 m	% Area	10-20 m	% Area	20-50 m	% Area	> 50 m	% Area
1	Great Nicobar	960.47	**6.73**	0.70	**1.76**	0.18	**37.24**	3.88	**226.77**	23.61	**687.97**	71.63
2	Katchal	163.98	**2.21**	1.35	**1.00**	0.61	**11.90**	7.26	**82.77**	50.48	**66.10**	40.31
3	Little Nicobar	149.52	**2.33**	1.56	**2.14**	1.43	**4.98**	3.33	**39.34**	26.31	**100.73**	67.37
4	Kamorta	143.05	**3.92**	2.74	**1.51**	1.06	**42.75**	29.88	**68.71**	48.03	**26.16**	18.29
5	Car Nicobar	130.17	**2.11**	1.62	**7.86**	6.04	**33.57**	25.79	**69.12**	53.10	**17.51**	13.45
6	Teressa	94.18	**2.82**	2.99	**2.96**	3.14	**10.29**	10.93	**47.40**	50.33	**30.71**	32.61
7	Nancowri	51.63	**1.19**	2.30	**1.53**	2.96	**4.07**	7.88	**14.70**	28.47	**30.14**	58.38
8	Trinket	18.80	**1.05**	5.59	**1.35**	7.18	**14.99**	79.73	**1.41**	7.50	**0.00**	0.00
9	Tillangchong	18.19	**1.19**	6.54	**1.09**	5.99	**1.45**	7.97	**3.69**	20.29	**10.77**	59.21
10	Bompoka	11.07	**0.62**	5.60	**0.56**	5.06	**0.77**	6.96	**2.22**	20.05	**6.90**	62.33
11	Chowra	7.46	**0.56**	7.51	**0.54**	7.24	**5.76**	77.21	**0.44**	5.90	**0.16**	2.14
12	Kondul	2.18	**0.21**	9.63	**0.18**	8.26	**0.23**	10.55	**0.48**	22.02	**1.08**	49.54
13	Batt Malv	2.06	**0.18**	8.74	**0.24**	11.65	**0.28**	13.59	**1.35**	65.53	**0.01**	0.49
14	Meroe	1.42	**0.23**	16.20	**0.16**	11.27	**0.62**	43.66	**0.41**	28.87	**0.00**	0.00
15	Pulo milo	1.34	**0.13**	9.70	**0.15**	11.19	**0.56**	41.79	**0.49**	36.57	**0.01**	0.75
16	Menchal	0.92	**0.10**	10.87	**0.08**	8.70	**0.11**	11.96	**0.40**	43.48	**0.23**	25.00
17	Isle of Man	0.75	**0.15**	20.00	**0.14**	18.67	**0.12**	16.00	**0.13**	17.33	**0.21**	28.00
18	Trails	0.65	**0.10**	15.38	**0.10**	15.38	**0.20**	30.77	**0.25**	38.46	**0.00**	0.00
19	Trek	0.23	**0.07**	30.43	**0.06**	26.09	**0.10**	43.48	**0.00**	0.00	**0.00**	0.00
20	Kabra	0.18	**0.07**	38.89	**0.04**	22.22	**0.04**	22.22	**0.03**	16.67	**0.00**	0.00
21	Pigeon	0.12	**0.03**	25.00	**0.03**	25.00	**0.02**	16.67	**0.04**	33.33	**0.00**	0.00
22	Megapod	0.09	**0.01**	11.11	**0.02**	22.22	**0.06**	66.67	**0.00**	0.00	**0.00**	0.00
	Total	1758.46	**26.00**	1.48	**23.48**	1.34	**170.14**	9.68	**560.15**	31.85	**978.69**	55.66

(Area in Sq. Km.)

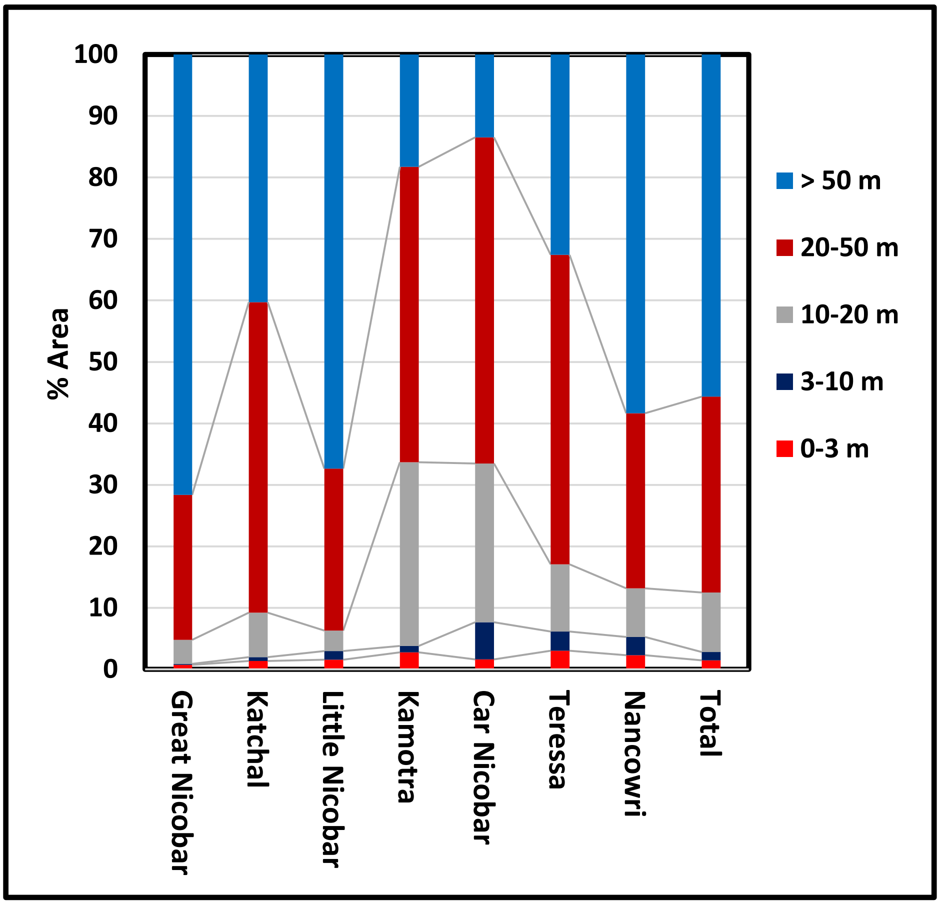


Fig. 4.4 Stacked column chart for % area in main islands

4.3 Drainage

Nicobar group of Islands are devoid of any big river system. Great Nicobar is the only Island having five perennial rivers viz., Alexandria, Amrit Kaur, Dagmar, Galathea and Danes. Each of these rivers originates from Mt. Thullier range (**Fig. 4.5**).

Galathea River flows southernly over faulted anticline is the most important river of Great Nicobar Island. This river is mostly used by Shompen tribes for various purposes, including drinking, fishing and transportation. Other important river is westward flowing Alexandria River which originate from central high land. South-westerly flowing Dagmar River is also counted as the major perennial river of the Great Nicobar. There are several Nallah (Small River) in Great Nicobar Island *e.g.,* Magar Nallah, Dhilon Nallah, Vijay Nagar Nallah etc. which are used for water supply in the island. In all other island, including Car Nicobar Island, there is no large stream / river system. The existing streams are small and mostly seasonal in nature.

Detailed drainage map of Great Nicobar Island is prepared along with drainage divide is prepared and given in **Fig. 4.6**. The prepared map shows dendritic, parallel and trellis pattern. This indicates about presence of cyclic lithology (*i.e.* alternate soft and hard rock-strata as in Shale-Sandstone) as well as structural control.

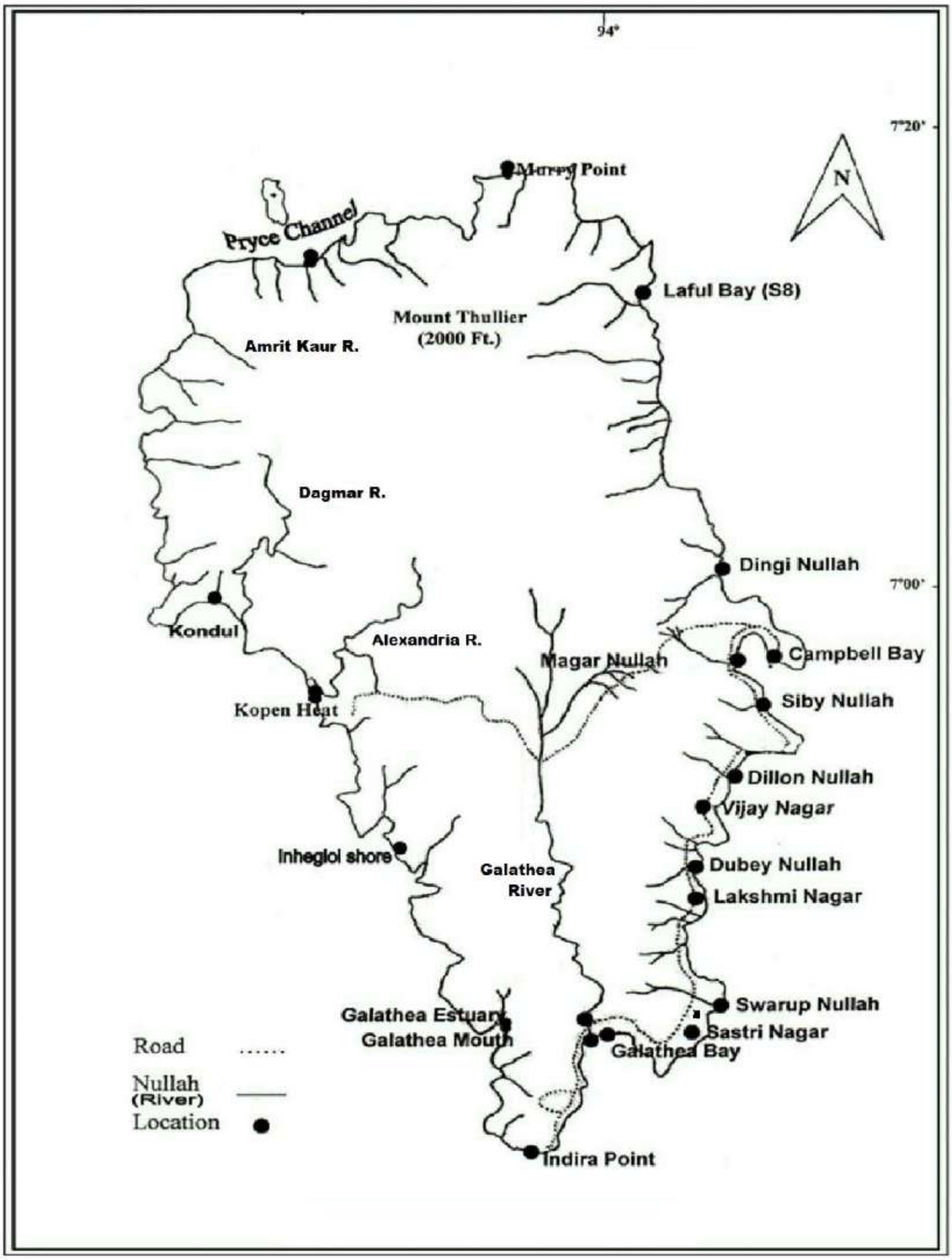


Fig. 4.5 Major River and Nallahs in Great Nicobar Island

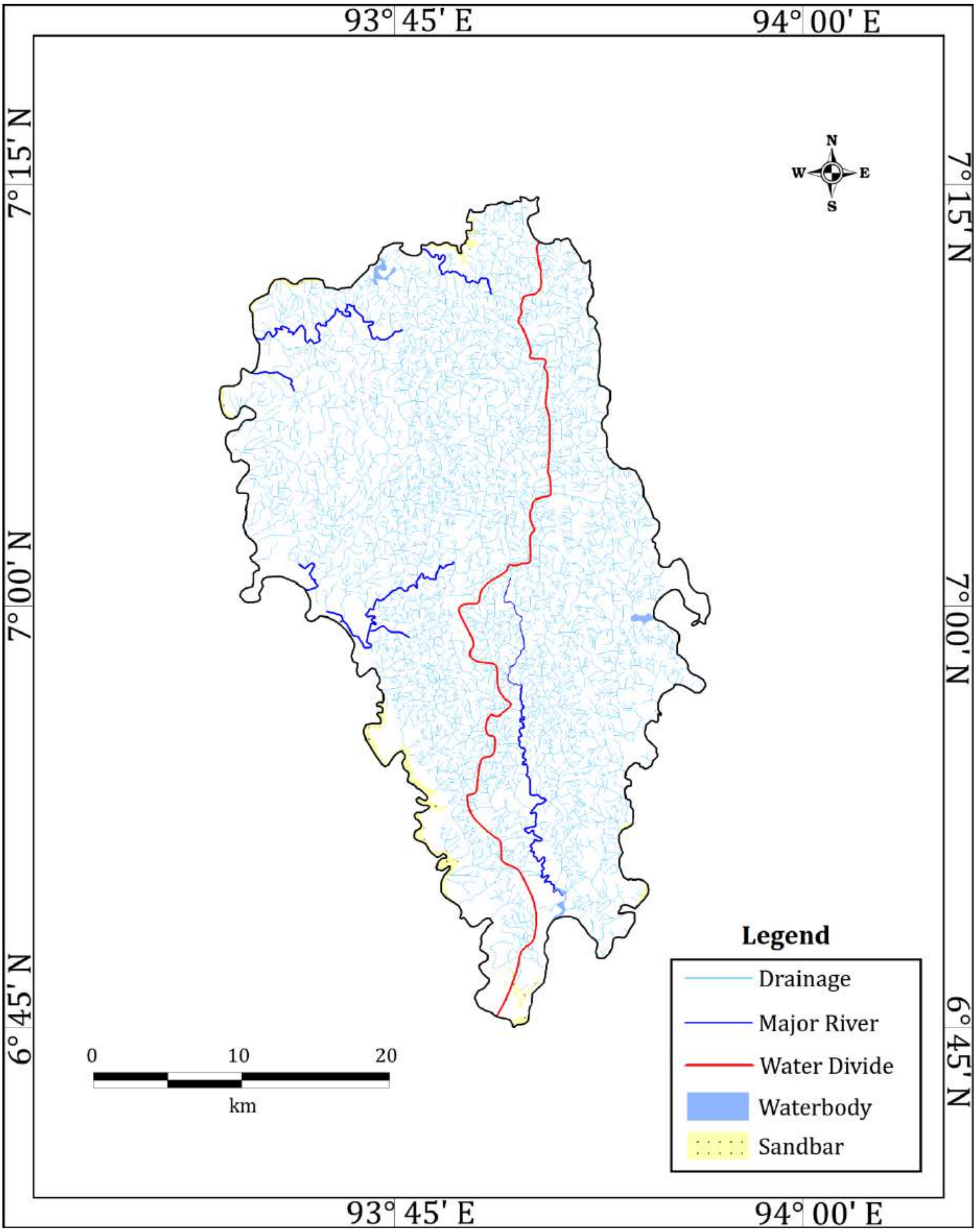


Fig. 4.6 Detailed drainage map of Great Nicobar Island

4.4 Soil Characteristics

Soils in islands of Nicobar district are of alluvial and colluvial origin and are mainly derived from sedimentary rocks like sandstone, lime stone, mud stone, and clay stone. However, in places, ophiolitic rocks also contributed to soil formation. Island soils vary in depth, texture and chemical composition and are generally acidic in nature except Car Nicobar and Katchal (Velmurugan *et al*., 2016). In general, sandy to clay loam mixed with coarse materials of coralline origin dominates the soil texture. They are partially drained and have poor water retention capacity. Depth of the soils is very shallow in the hill slopes moderately deep in table land (50-100 cm) to more than 1.5 m and rarely exceeding 2 m in the valleys. The coastal plains and beaches have sandy soil in most of the islands.

The soils of Nicobar Islands are classified into 3 orders Entisol, Inceptisol and Alfisol (**Table 4.4**) (Velmurugan et al., 2016). The soils of the islands vary in humus content and is generally lacking in the forest soils as it is generally washed away due to copious rainfall and steep slopes. The soils are low to moderate in nitrogen and phosphorus content and moderate in potassium content. Soils are generally acidic in nature except Car Nicobar and Katchal. The salinity is not a major concern as the EC values are well within the acceptable limits. Organic carbon is high with mean values more than 1.2% except in coastal sandy soils. Average chemical characteristic of soil is given in **Table 4.5**.

Table 4.4 Taxonomic position and limitations of soils in Nicobar Districts

Sl.	Order	Suborder	Great group	Limitations
1.	Entisol	Fluvent	Tropofluvent	Moderate erosion and Organic Carbon, low base status
		Orthent	Troporthent	Moderate erosion, loss of top soil, low nutrients
		Psamment	Fluventic	Coarse texture, low water holding and nutrient retention capacity
2.	Inceptisol	Ochrept	Typic dystrochrept	Sloppy land, moderate erosion, shallow depth of soil
3.	Alfisol	Ustalf	Haplustalf	Moderate erosion, low water holding and nutrient retention capacity

Source: Velmurugan *et al*., 2016

Table 4.5 Surface Soil Properties of Nicobar Islands

Island	pH	EC (dS m^{-1})	Organic Carbon (%)	Available macronutrients (kg/ha)		
				N	P	K
Car Nicobar	7.07 ± 0.67	0.06 ± 0.05	2.03 ± 0.39	261 ± 66	22 ± 7.32	230 ± 82
Nancowry	5.78 ± 0.80	0.10 ± 0.03	1.59 ± 0.68	250 ± 91	9.1 ± 5.44	309 ± 74
Great Nicobar	5.08 ± 0.35	0.05 ± 0.04	2.65 ± 0.83	346 ± 61	9.1 ± 1.99	228 ± 36
Critical limit (Medium fertility)	6.5-8.5	< 0.8	0.5 - 0.75	280 - 560	11 - 22	110 - 280

Soil depth: 0-20 cm; Statistical Parameter: Mean ± SD; Source: Velmurugan *et al*., 2016

Soil properties in natural condition influence the crop distribution and yield which in turn get influenced by the types of vegetation. Due to soil condition, the major land use in Car Nicobar and Nancowry group of Islands are plantations (coconut and arecanut) and homestead gardens where tuber crops, fruits and vegetables are grown. In Great Nicobar rice, pulses are grown in coastal plains and plantations in upper slopes. In the acidic soils of Katchal, rubber is grown.

Chapter 5

Hydrogeology

5.1 Oceanic Island Hydrogeological Setup

In oceanic islands, groundwater commonly occurs as freshwater lens over saline water at bottom. This freshwater lens in the islands is formed due to the radial movement of the freshwater from center of the island towards the coast, as a dynamic system in hydraulic continuity with seawater. The occurrence of freshwater lens over saline water in island conditions was independently studied by Ghyben (1888-89) and Herzberg (1901) (Ghassemi *et al.* 1990). The works established the relation between the freshwater head above mean sea level and the depth to freshwater - saltwater interface in unconfined aquifer system and is popularly known as the Ghyben-Herzberg (GH) relationship (**Fig. 6.1**).

Thickness of the freshwater zone above sea level is represented as h and that below sea level is represented as z. The two thicknesses h and z, are related by ρ*f* and ρ*s*, where ρ*f* is the density of freshwater and ρ*s* is the density of saltwater.

$$z = \frac{\rho f}{(\rho f - \rho s)} \times h$$

With the assumption of freshwater has a density of about 1.000 g/cm^3 at 20 °C, and that of seawater is about 1.025 g/cm^3, the equation can be further simplified to

$$z = 40\,h$$

Hence, Ghyben–Herzberg ratio states that, for every meter of fresh water in an unconfined aquifer above sea level, there will be forty meters of fresh water in the aquifer below sea level. The basic assumptions for the applicability of Ghyben-Herzberg relation are a) water table must lie above msl; and b) water-table slope downward towards the ocean.

However, studies in small islands indicate that the ratio of thickness of freshwater above and below msl is highly variable. In the Cayman Islands it is 1: 20 while it is 1: 30 in Tarawa and 1: 20 in Christmas Island (Falkland, 1984). In case of Lakshadweep islands, CGWB studies indicated the same (Najeeb, 2003).

Studies also indicated that a saline water-fresh water interface is not sharp and a transition zone is present through which the salinity increases with depth (Barker, 1984). Water-table fluctuation and change in sea level due to tidal action significantly introduce mixing of water of different salinities, creating the transition zone. Width of the transition zone depends on aquifer properties. However, in general, higher the fluctuation, thicker is the transition zone (**Fig. 5.2**).

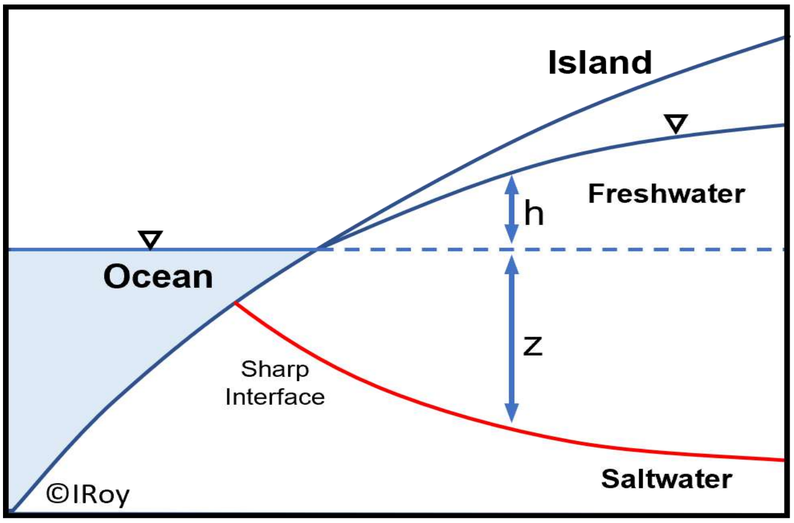


Fig 5.1 Ghyben-Herzberg relationship for oceanic islands

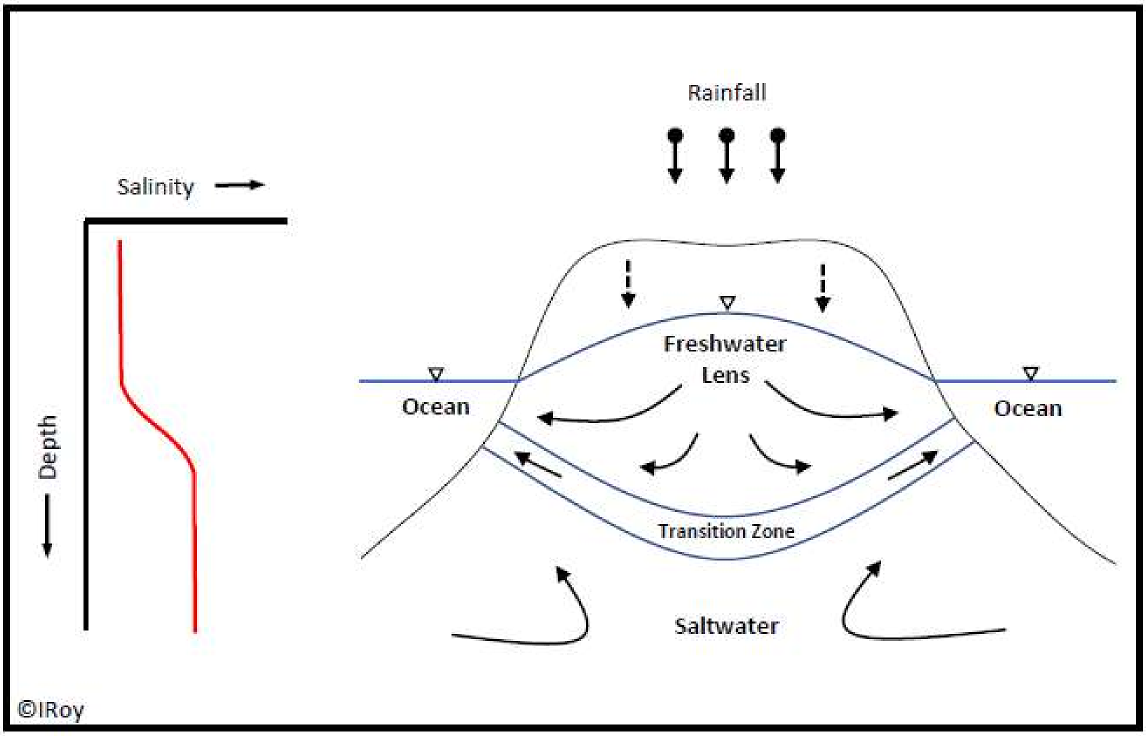


Fig. 5.2 Schematic Diagram of Freshwater lens in Oceanic Islands (after Barker, 1984)

In order to identify the role of the shape of the island in deciding the freshwater lens, aspect ratio parameter of the islands is used. The method has been advocated by several workers (Najeeb, 2003). In general, shape of the islands does not conform to any geometric form. Aspect ratio is computed taking into consideration the length and breadth area of the island. The island area is divided by ratio of its length to breadth to get the aspect ratio. This ratio is used to study the stability of the freshwater lens in these islands and the salient features are given in **Table 4.1**. It is observed that Islands with aspect ratio greater than 0.5 have stable fresh water lens, under identical geomorphological settings.

5.2 Exploratory Drilling

Several drillings were carried out by CGWB in Great Nicobar Island during 1987-88. Exploratory wells were constructed to locate potential fresh water aquifer in Tertiary sandstone. Lithologs reveal that Tertiary consolidated formations are mostly composed of argillaceous material devoid of any significant granular zone. Down to maximum explored depth of 101 m. Exploration data is compiled and summarized to understand aquifer disposition (**Table 5.1**). A typical lithological log is given in **Table 5.2**. Individual lithologs are given in **Annexure – 3**. Graphical representation of selected lithologs is given in **Fig 5.4**. Banerjee *et al.* (1988) concluded that as such, the Tertiaries have limited groundwater prospect. However, the results may be somewhat influenced by the limitation that small rotary rig was used for the drilling purpose.

Fig. 5.3 Exploratory well constructed at Powerhouse Campbell Bay during AAP 1987-88 (Photo: March-2023)

Table 5.1 Exploration details in Campbell Bay Area (AAP 1987-88), Great Nicobar Island

Sl. No	Location	Geo Reference	Geology	Lithology	Depth drilled	Productive Fracture Zones encountered	Discharge	EC	Remarks
					(in m bgl)	(in m bgl)	(m3/hr)		
1	Yatrik Officers' Mess Campbell Bay (EW)	7°00"00', 93°56"00'	Mithakhari Formation	Medium to fine soft sandstone & shale	60.23	8.5-11, 13-18, 20-23	0.5 (by air compressor)	636	Abandoned due to very poor yield. Converted into Piezometer
2	Powerhouse Campbell Bay (EW) 200 m North of 1st well)	7°00"10', 93°56"00'	Mithakhari Formation	Medium to fine soft sandstone & shale	60.6	15-29, 31-40	0.4 (by air compressor) Less than 400 lph	4503	Abandoned due to very poor yield. Converted into Piezometer
3	Magarnala	6°09"08', 93°54"00'	Andaman Flysch	Beach sand, Coral rags & sandstone & shale	60.65	-	-	-	Abandoned
4	Govindnagar-I (EW) (12 km from Campbell Bay on E-W Road	7°00"00', 93°54"00'	Andaman Flysch	Sandstone & shale	80.5	-	-	-	Abandoned due to low yield and poor quality
5	Army Land I (EW)	7°01"00', 93°54"05'	Andaman Flysch	Andaman Flysch and Sandstone & shale	101	20-40, 76-81, 86-92	0.2 (by air compressor)	-	Converted into Piezometer
6	Naval Air Strip	7°01"30', 93°54"15'	Mithakhari Formation	Shale & compact Sandstone	63.1	15.6-20.3	Poor Discharge	1200	Abandoned
7	Civil Hospital	7°01"15', 93°55"10'	Mithakhari Formation	Shale & compact Sandstone	63	39-43, 56-60	-	-	Very poor discharge; Converted into piezometer

Sl. No	Location	Geo Reference	Geology	Lithology	Depth drilled	Productive Fracture Zones encountered	Discharge	EC	Remarks
					(in m bgl)	(in m bgl)	(m3/hr)		
8	Armyland II	7°01"20', 93°54"45'	Andaman Flysch	Compact fine grained sandstone & shale	59.4	Nil	-Dry-	-	-
9	Govindnagar II	6°58"40', 93°55"05'	Mithakhari Formation	Argillaceous Sandstone, Siltstone and Claystone	27.36	Nil	-Dry-	-	-

Table 5.2 Typical litholog of Campbell Bay Area

Location: Officers' Mess, Yatrik, Campbell Bay Area, G.N.I

Lithology	Simplified Lithology	From	To	Thickness
Coral rags in soil and Silt, dirty white	Coraline Sand	0	3.7	3.7
Coralline limestone, dirty white, unconsolidated, with broken shells of coral in sand and soft, dark grey mudstone	Coraline Limestone	3.7	11	7.3
Shale, dark grey, soft with few fossils	Shale	11	13	2
Sandstone, grey, medium to coarse grained, angular to sub-angular with clastics of ultrabasic rock in an argillaceous matrix	Sandstone	13	17.65	4.65
Shale, dark grey, interbedded with thin sandstone, fine grained	Shale	17.65	20.3	2.65
Sandstone, dark grey, medium to coarse grained compact with ultrabasic rock fragments in the clastics	Sandstone	20.3	22.3	2
Shale-sandstone alternations in thin bedded sequence, Sandstone compact with ultrabasic rock fragments in the clastics	Shale	22.3	60.23	37.93

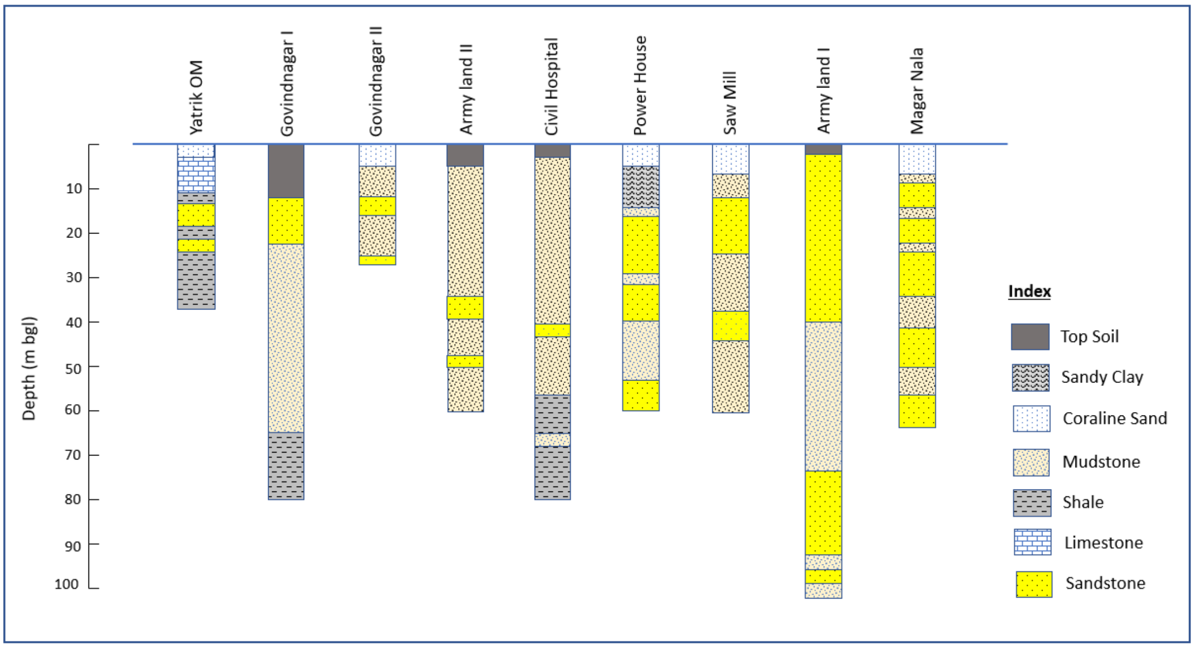


Fig 5.4 Graphical representation of selected lithologs

5.3 Geophysical Investigation

The Surface Geophysical Investigations (VES) were carried out at Great Nicobar Island during May, 2022 and March, 2023. A total of 32 VES were conducted at 32 different locations of the Island. Aim of the geophysical investigation was to determine the lithological variation with depth from sea shore to inland part of the island along with saturated water quality variation at the eastern coast of the island.

Geophysical investigations were conducted with maximum current electrodes spacing (AB) of 200 m deploying resistivity meter CRM-500 (Auto C). The typical resistivity sounding curve for the study area are of 'H' type, 'K' type and 'QH' type. The same were interpreted by 1D inversion technique using IPI2Win® software. Preliminary values of the model parameters are obtained by matching the VES field curves with the theoretical master curves and auxiliary point charts and these model parameters are subsequently used as input /starting model in software for further refinement of results. Resistivity of different layers and corresponding thicknesses are reproduced by a number of iterations until the model parameters of all VES curves are totally resolved with minimum RMS error. The results of VES are interpreted in terms of subsurface geology and aquifer characteristics under prevailing hydrodynamic conditions.

After interpretation of all the VES data it is envisaged that resistivity of the 1st geo-electric layers i.e. top soil of the study area are varied from 0.9 to 1024 ohm-m and thickness varies from 0.60 to 5.71 m. (except Army Land - 2 location where thick clay layer have been observed). The resistivity of the 2nd geo-electric layers of the study area varies from 1.4 to 622.0 ohm-m indicating saturated with brackish formation to gravelly weathered formation. The thickness varies from 1.1 to 19.2 m. The resistivity of the 3rd geo-electric layers of the study area varied from 0.02 ohm-m to 5177 ohm-m indicating saline saturated formation to compact formation. In between fresh saturated formation are identified where resistivity ranges varies from 23.3 to 152 ohm-m. The thicknesses of the 3rd geo-electric layer varied from 2.2 to 33.2 m. The resistivity of the 4th geo-electric layer varied from 0.4 ohm-m to 1898 ohm-m indicating saline saturated formation to compact formation. Again in between fresh saturated formation have been identified where resistivity ranges varied from 21.9 to 71.7 ohm-m and thickness varies from 5.7 to 26.3 m. The resistivity of the 5th layers varies from 0.13 to 33.6 ohm-m indicating saline saturated formation fresh saturated formation except Jogendernagar- 1 location where compact formation are identified. The thickness of the 4th layer varies from 12.3 to 26.3 m. The resistivity of the last layers are varies from 0.06 to 60.90 ohm-m indicating high saline saturated formation exists at Vijaynagar - 1 location, just below the fresh saturated formation and medium resistivity value is indicating fresh saturated formation identified at Gandhinagar -2 location.

From interpreted results and prepared geo-electric section, potential fresh ground water bearing zones have been identified down to the depth of 50 m at five (05) locations namely 1) Army Land -1, 2) Gobindanagar-2, 3) Laxminagar-1, 4) Gandhinagar-2, and 5) Gandhinagar-4. VES curves obtained in Great Nicobar Island are given in **Fig 5.3**. VES curves obtained in Car Nicobar Island are given in **Fig 5.5**. Based on standardized resistivity values fence diagram is prepared for east coast of Great Nicobar Island (**Fig 5.6**). Detailed Observations are given in **Annexure 9**.

In Car Nicobar Island, geophysical investigation was carried out during 2004-05 (Kar and Adhikari, 2005). A total 34 numbers of Vertical Electrical Sounding (VES) were carried out at different parts of the island to delineate the fresh water pockets. VES survey was carried out by deploying AC resistivity meter and ABEM Terrameter SAS 300 B. During the survey maximum current electrode separation was kept 400 m (AB). The field apparent resistivity values were plotted against half current electrode separation values and thus VES curves were generated for each VES station. The VES curves are found to be HKH, KQ, K, H, QKQ, QH, AA, Q & HK types. These curves were interpreted by partial curve matching technique with the help of standard master curves. Some VES were carried out near the open wells of known lithology and the interpreted resistivity values were standardized (**Table – 5.4**). VES curves obtained in Car Nicobar Island are given in **Fig 5.7**. Based on standardized resistivity values fence diagram and section were prepared at different places of Car Nicobar (**Fig 5.8a to d**). In general, the area is mostly represented by three to five subsurface geo-electric layers. Below the surface soil, freshwater lens is present. This zone continues within weathered zone. Below the weathered saturated fresh formation, brackish and saline water formations are present.

Table 5.3 Standardized Resistivity Values for various geo-electrical layers of Great Nicobar Island

Sl. No.	Formation Characteristics	Resistivity (ohm-m)
I	Top Soil	0.9 - 1024
II	Hard Coralline Limestone	1878 -5177
III	Saturated (Fresh) Semi-Weathered Coralline Limestone/Coralline Sand	146 - 622
IV	Saturated (Fresh) Semi-Weathered Coralline Limestone/ Sandstone or Cavernous Limestone	23 -152
V	Brackish to Fresh Formation in Coralline Limestone or Sand	12 - 20
VI	Brackish Formation	6 - 12
VII	Saline to Brackish Formation	2 - 6
VIII	Saline Formation	< 2

Table 5.4 Standardized Resistivity Values for various geo-electrical layers of Car Nicobar Island

Sl. No.	Formation	Resistivity (Ohm-m)
I	Top soil	5-5600
II	Hard Coralline Limestone	630-2800
III	Saturated (fresh) semi-weathered Coralline limestone/ Coralline sand.	175-8125
IV	Saturated (fresh) weathered Coralline limestone / sandstone or Cavernous limestone.	32-800
V	Nicobar marl	4-17
VI	Brackish to fresh formation in Coralline limestone or sand	18-29
VII	Brackish formation	9-18
VIII	Saline to brackish formation	6-9
IX	Saline	<6

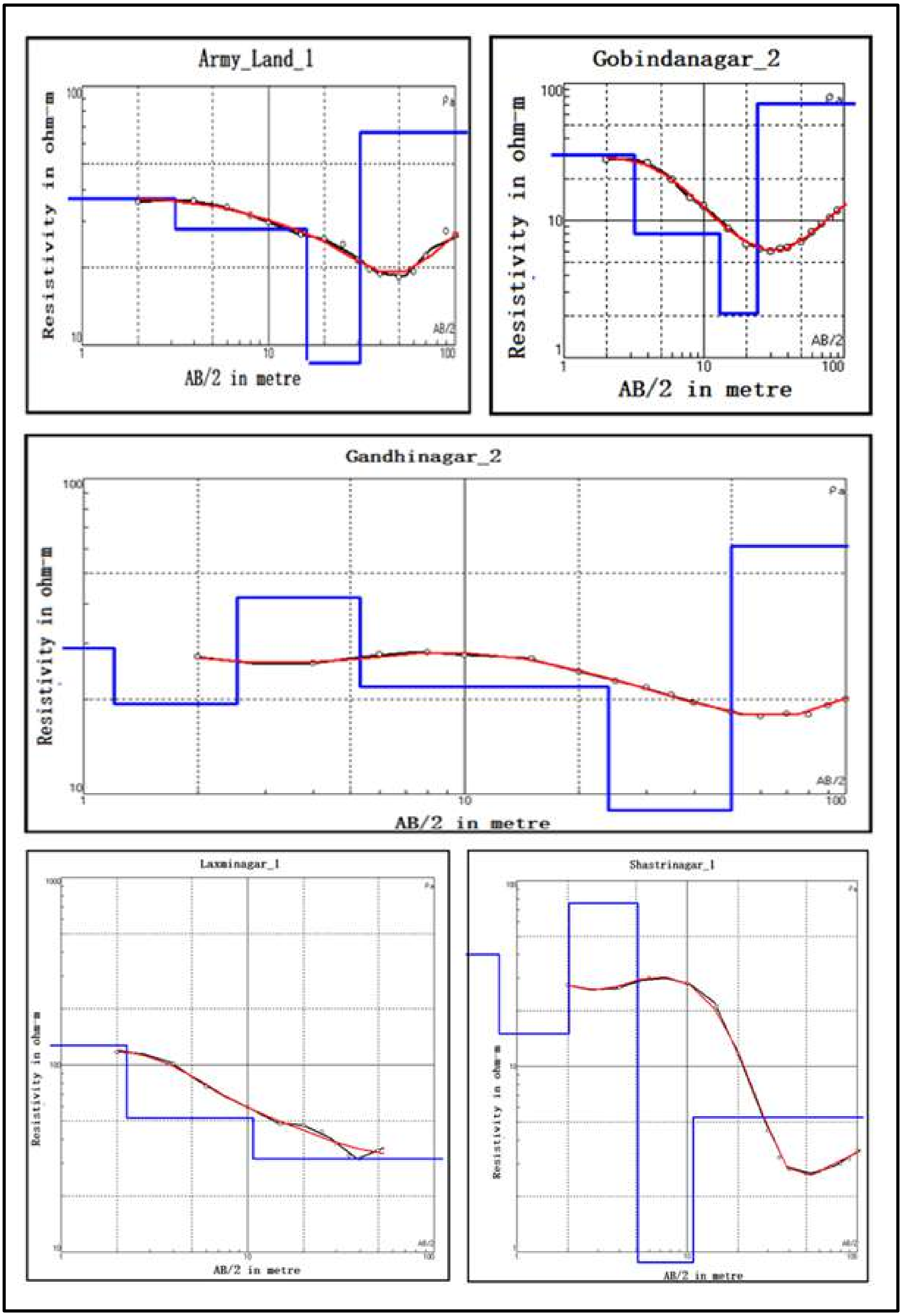


Fig. 5.5 VES curves obtained in Great Nicobar Island

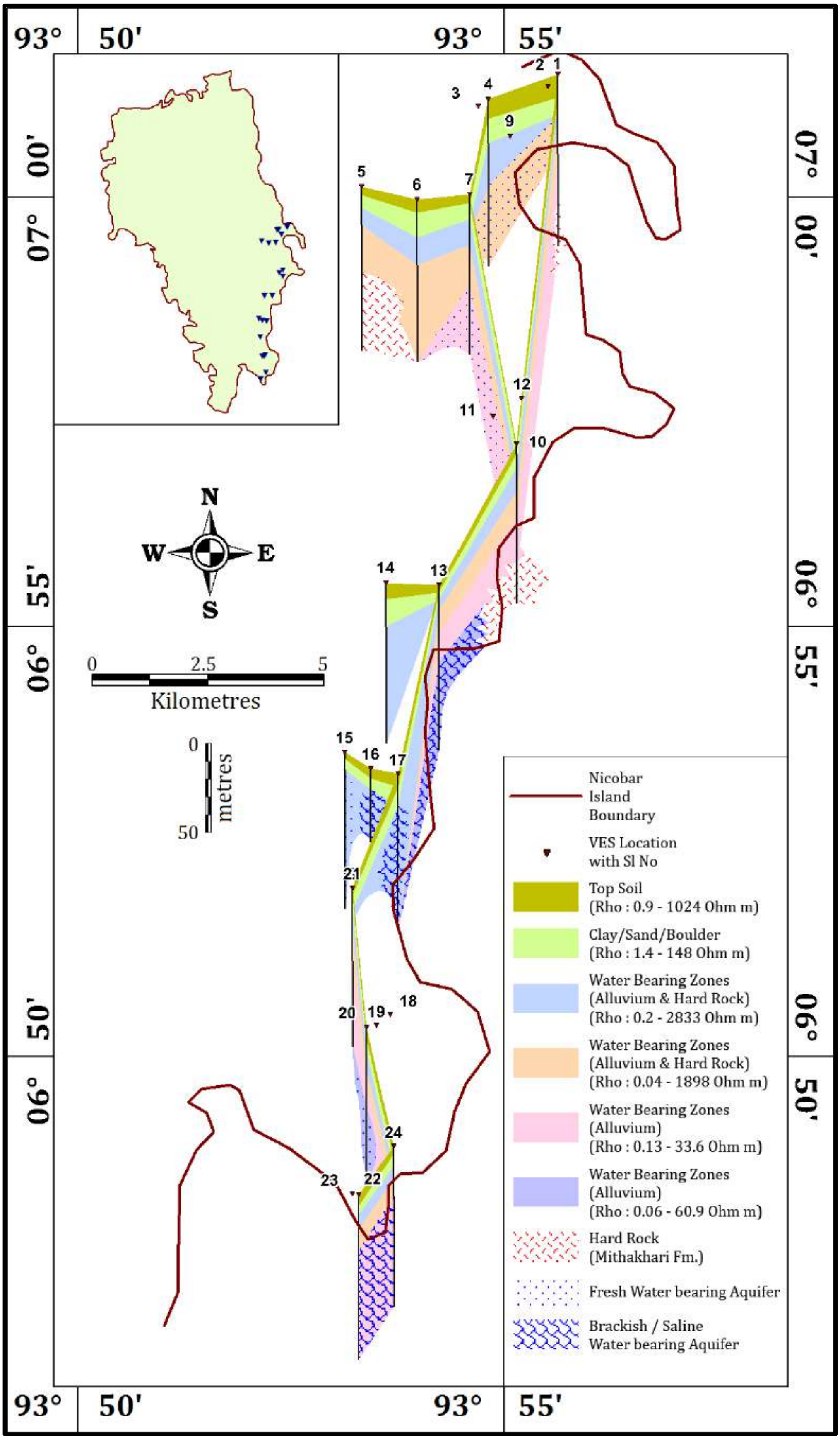
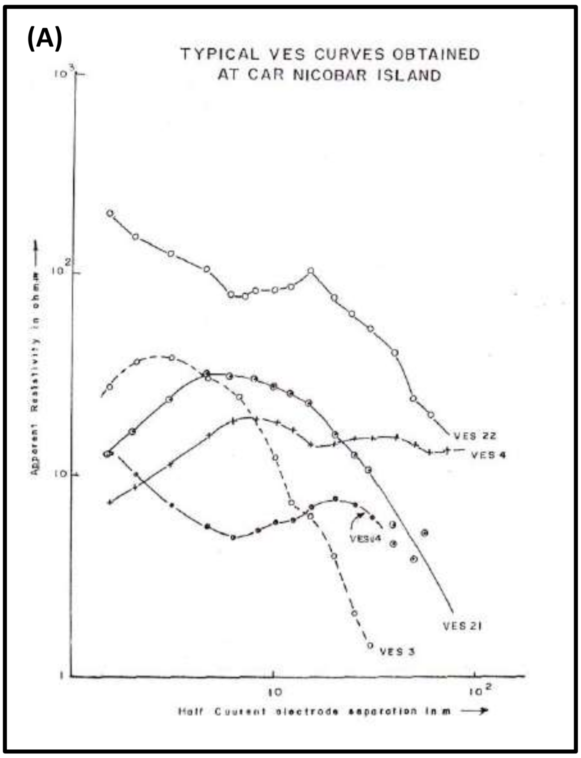
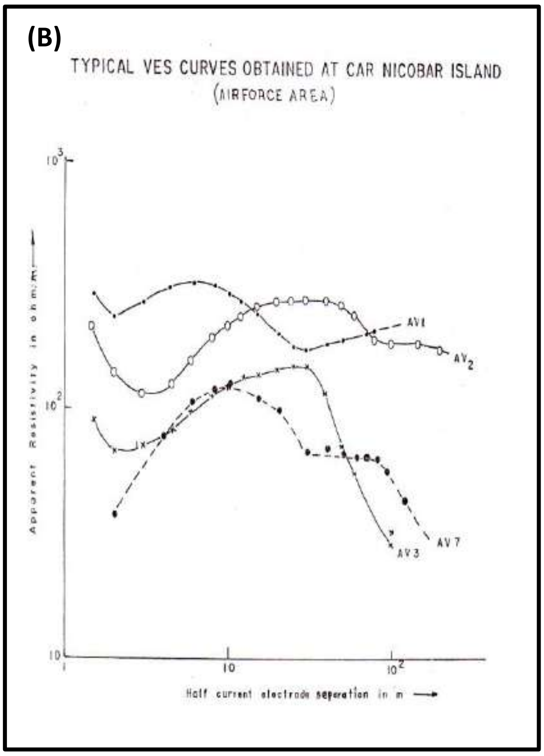


Fig. 5.6 VES based Fence diagram, East Coast, Great Nicobar Island





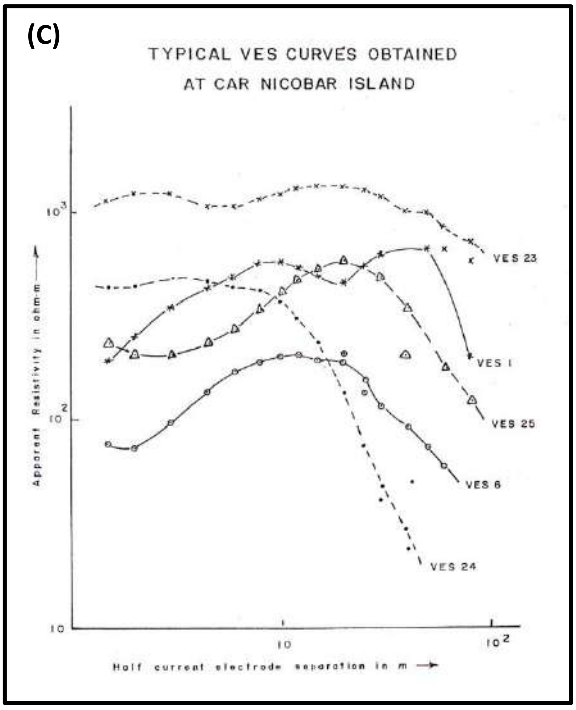


Fig. 5.7 VES curves obtained in Car Nicobar Island (Kar and Adhikari, 2005)

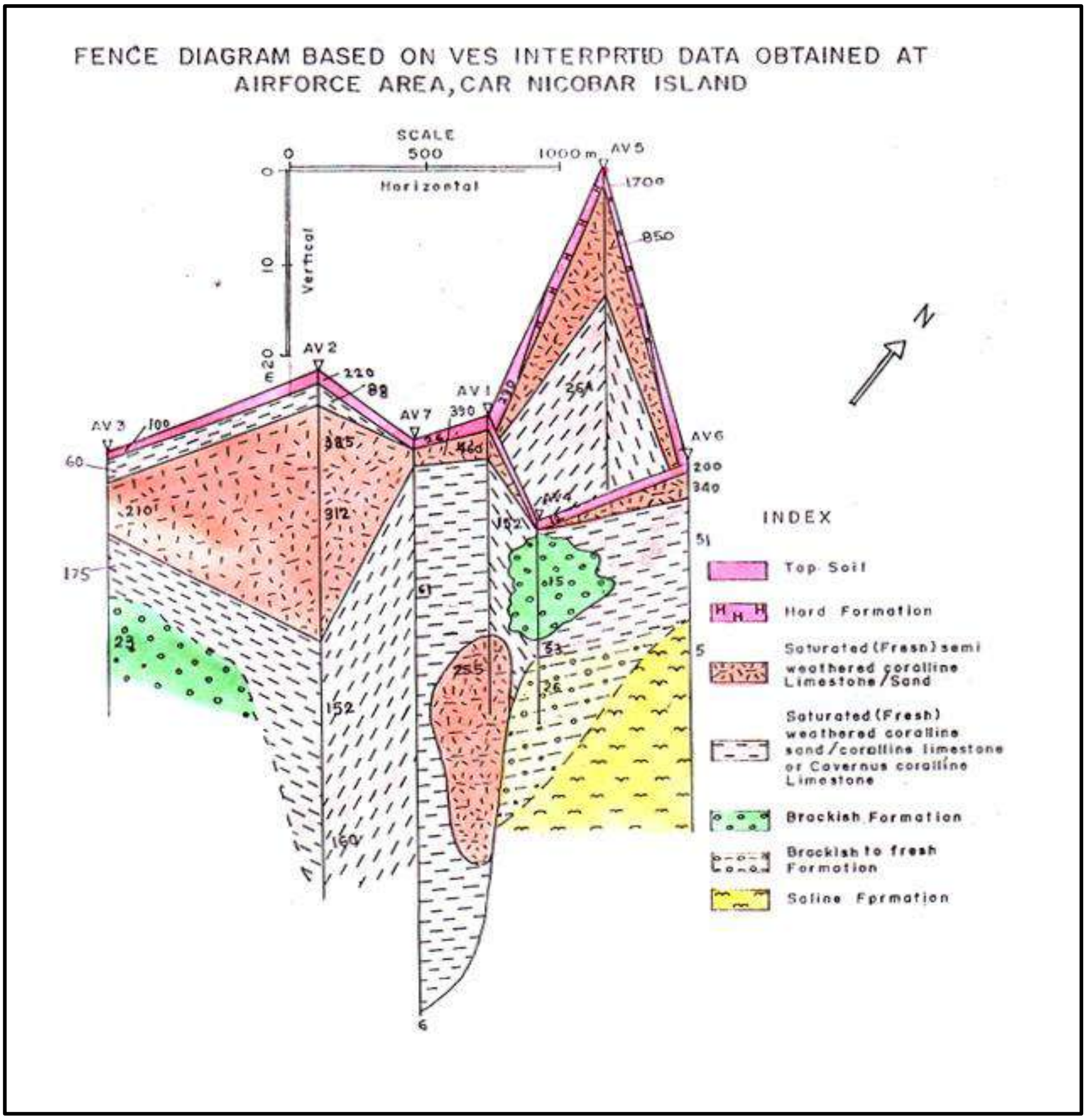


Fig. 5.8a VES based Fence diagram, Air Force Area, Car Nicobar Island (Kar and Adhikari, 2005)

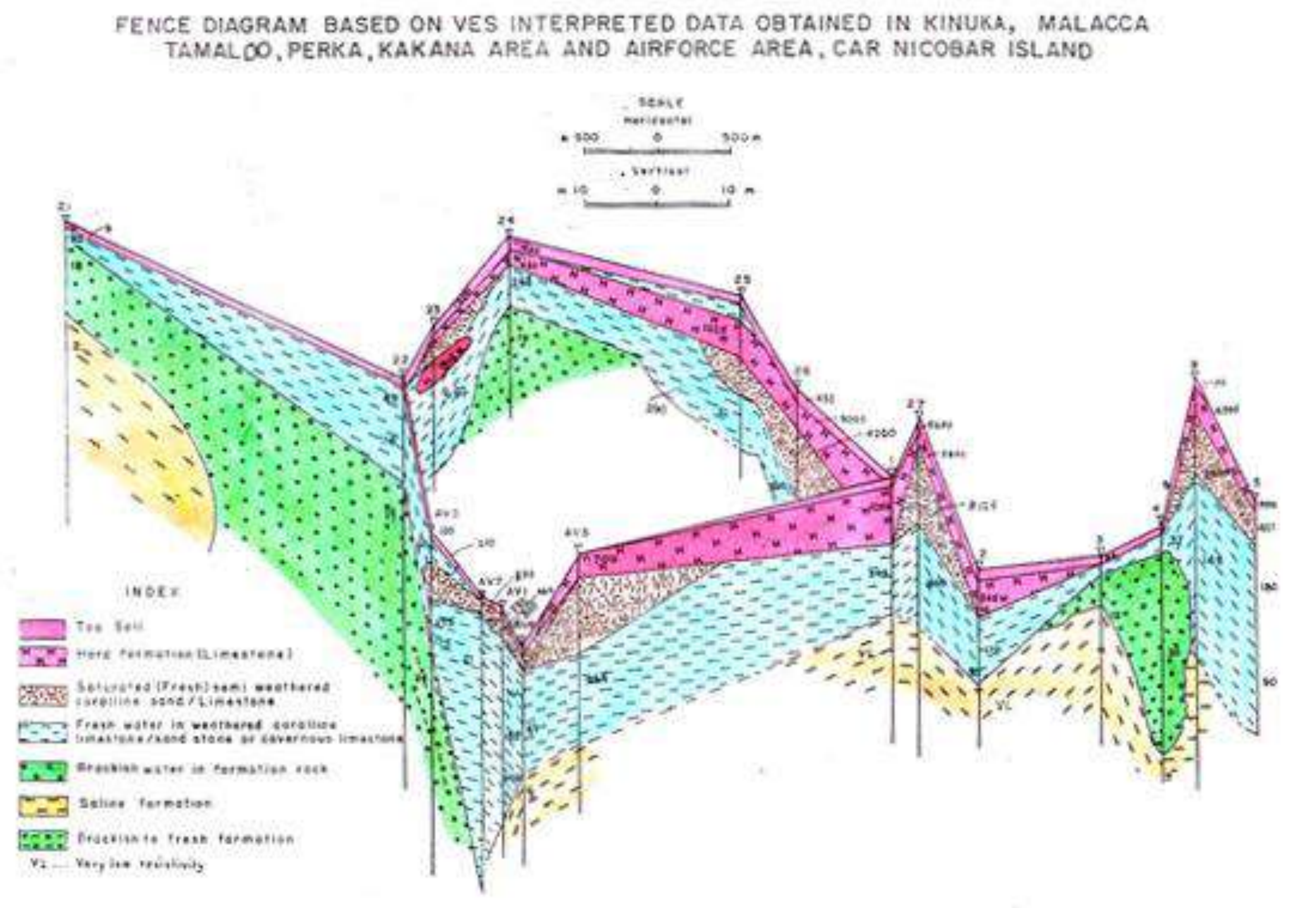


Fig. 5.8b VES based Fence diagram, Kinuka-Kanana, Car Nicobar Island (Kar and Adhikari, 2005)

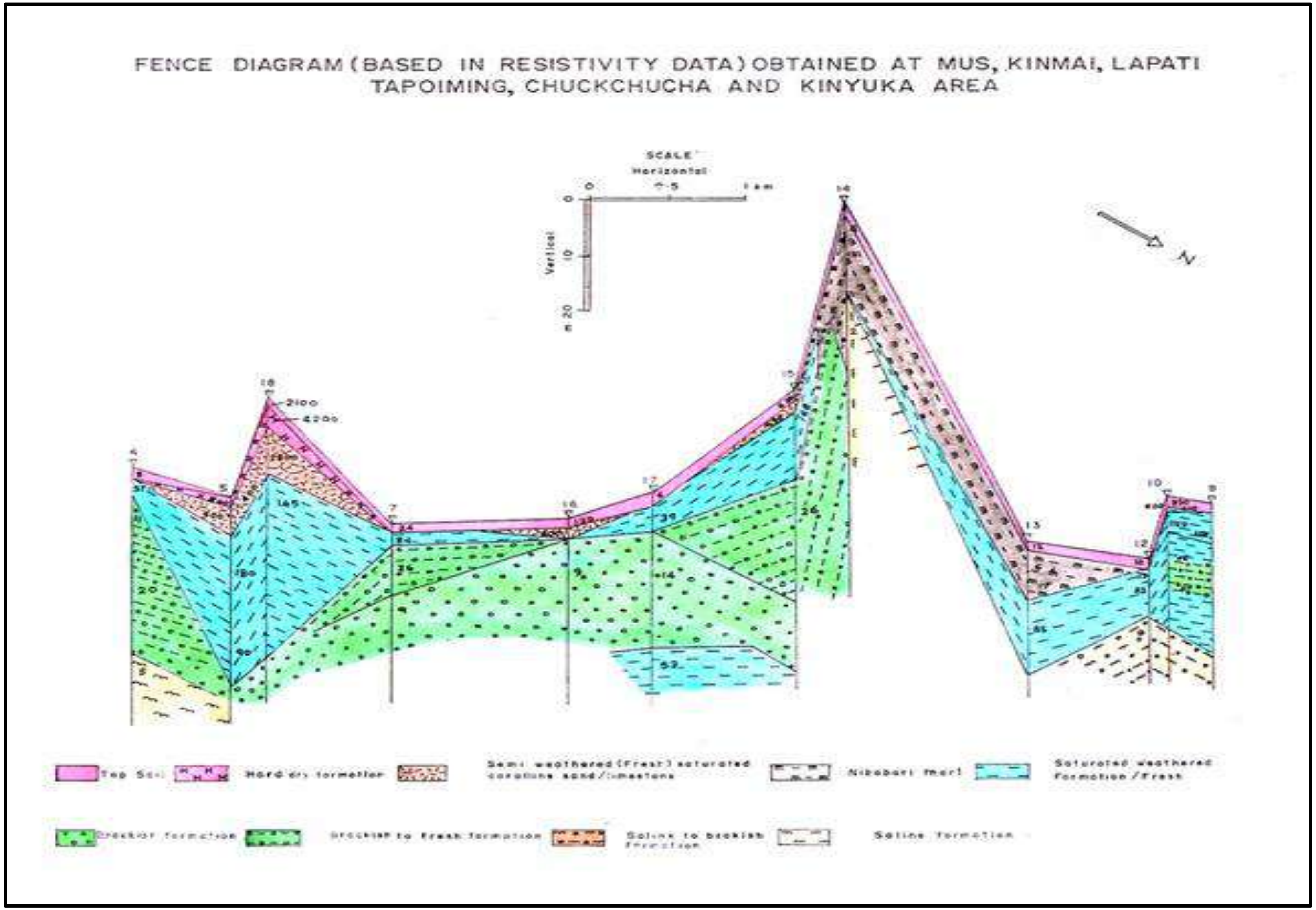


Fig. 5.8c VES based Fence diagram, MUS-Kinuyaka, Car Nicobar Island (Kar and Adhikari, 2005)

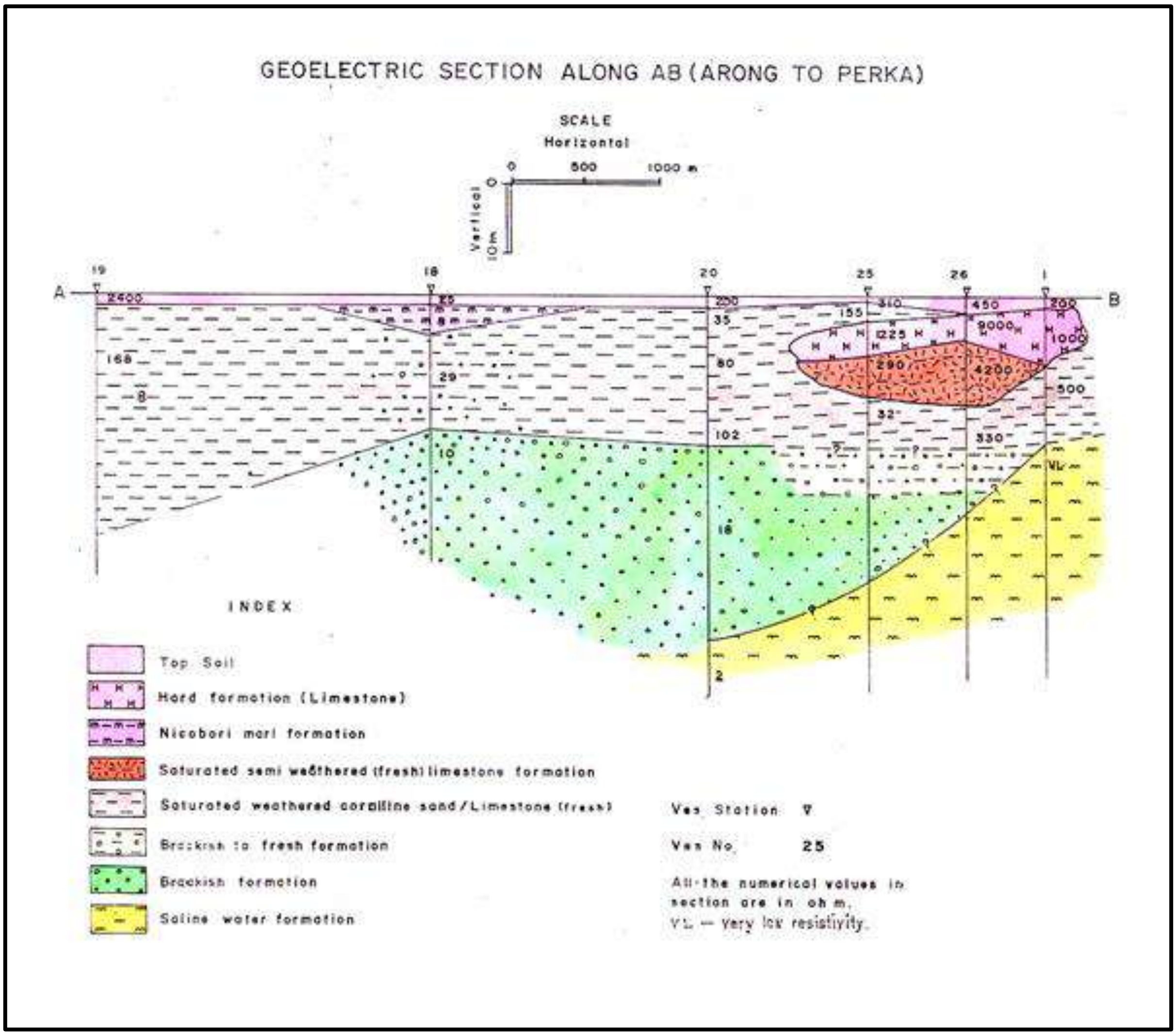


Fig. 5.8d VES based Fence diagram, Arong-Perka, Car Nicobar Island (Kar and Adhikari, 2005)

5.4 Water-Table Behavior

As indicated by climate modeling, the islands receive copious rainfall though out the year touching every month. Hence, in presence of thin freshwater lens, pre-monsoon and post-monsoon season water levels are not distinguishable from each other. Hence groundwater levels are measured across dry spell. Water levels are measured in Great Nicobar Island during May, 2022 and March, 2023. May, 2022 water levels though typically comes under pre-monsoon period shows shallow water level due to copious rainfall in preceding months in 2022. On the other hand, March, 2023 water levels though typically comes under early pre-monsoon season, shows deeper water level due to paucity of rainfall in preceding two months in 2023.

It is also to be noted that water-level monitoring in the Nicobar district is greatly influenced by its habitation distribution. Most of the islands are forested and mostly inaccessible. Groundwater abstraction structures, where water level measurement can be carried out, are only available in coastal region. Hence constructed water table represents only a minor fraction of the entirety.

For water level monitoring purpose, sixty (60) key observation wells are established in Great Nicobar Island in view of its future development prospect. All the key wells are dug well. Depth of these dug wells vary from 2.5 m in Gandhinagar area to 10 m depth in Joginder Nagar and Govind Nagar area. Details of established key observation wells are given in **Annexure – 1 & 2**. Key observation well location map is given in **Fig. 5.9.**

After dry season, observed depth to water level varies from 0.05 m bgl to 3.5 m bgl. Minimum depth to water level of 0.05 m bgl is observed at Govindnagar area and maximum depth to water level of 3.5 m bgl is observed at Shastrinagar area.

After wet season, observed depth to water level varies from 0.2 m bgl to 3.62 m bgl. Minimum depth to water level of 0.2 m bgl is observed at Govindnagar area and maximum depth to water level of 3.62 m bgl is observed at Vijaynagar area.

Prepared Depth-to-Water level maps for Dry- and Wet-seasons are given in **Fig. 5.10a** and **5.10b**.Statistical analysis of the water level data is carried out. Basic Statistics for DTW Variability is given in **Table. 5.5**. Histogram of Dry- Season DTW, Wet- Season DTW and their difference are given in **Fig. 5.11**.

Table 5.5 Basic Statistics for DTW Variability

	Dry Season DTW	Wet Season DTW	Fluctuation in DTW (Dry - Wet)
N of Cases	60	60	60
Minimum	0.05	0.05	-1.87
Maximum	3.5	3.62	1.1
Median	0.9	0.60	0.2
Arithmetic Mean	1.03	0.85	0.18
Standard Deviation	0.69	0.85	0.55

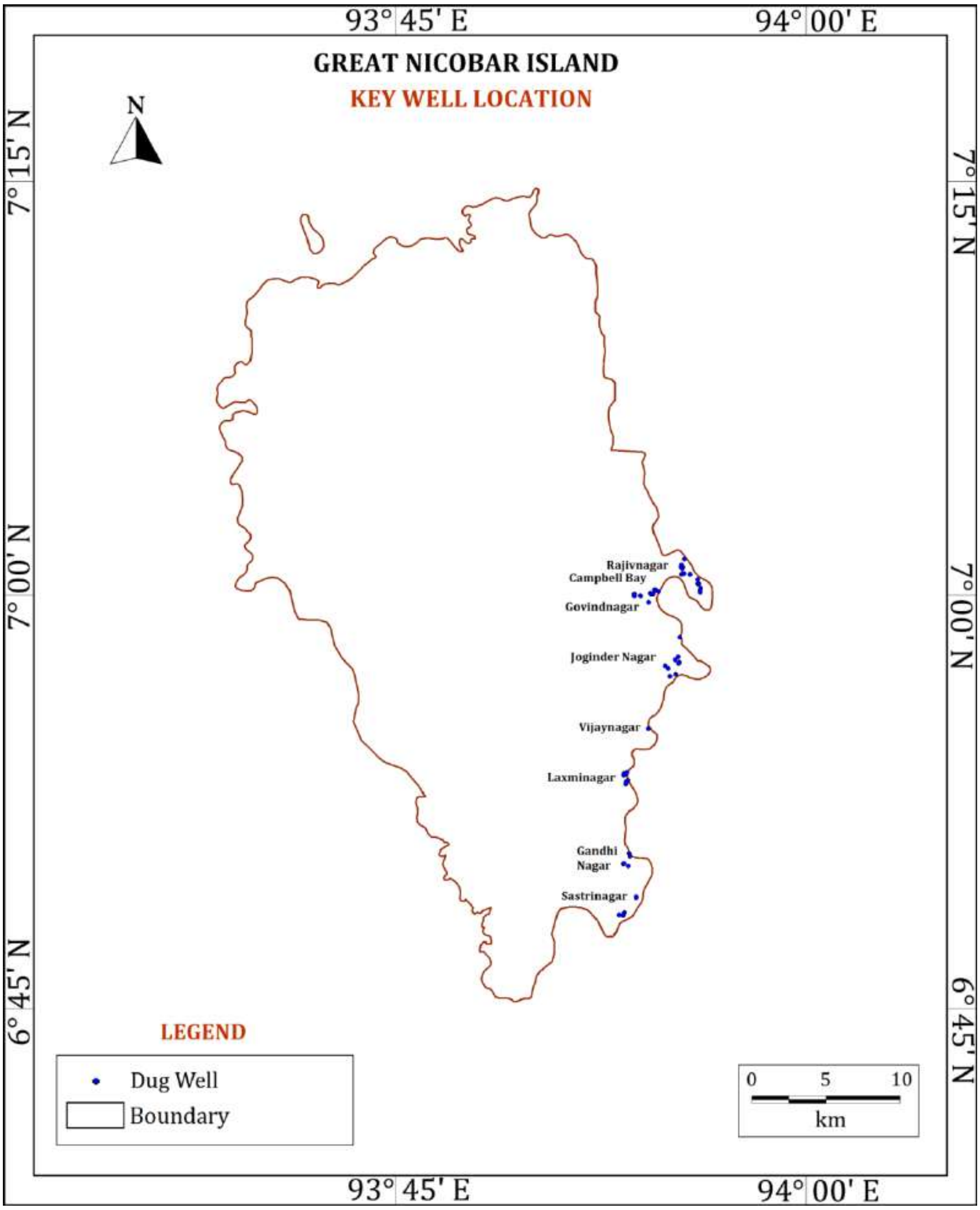


Fig. 5.9 Key-well locations in Great Nicobar Island

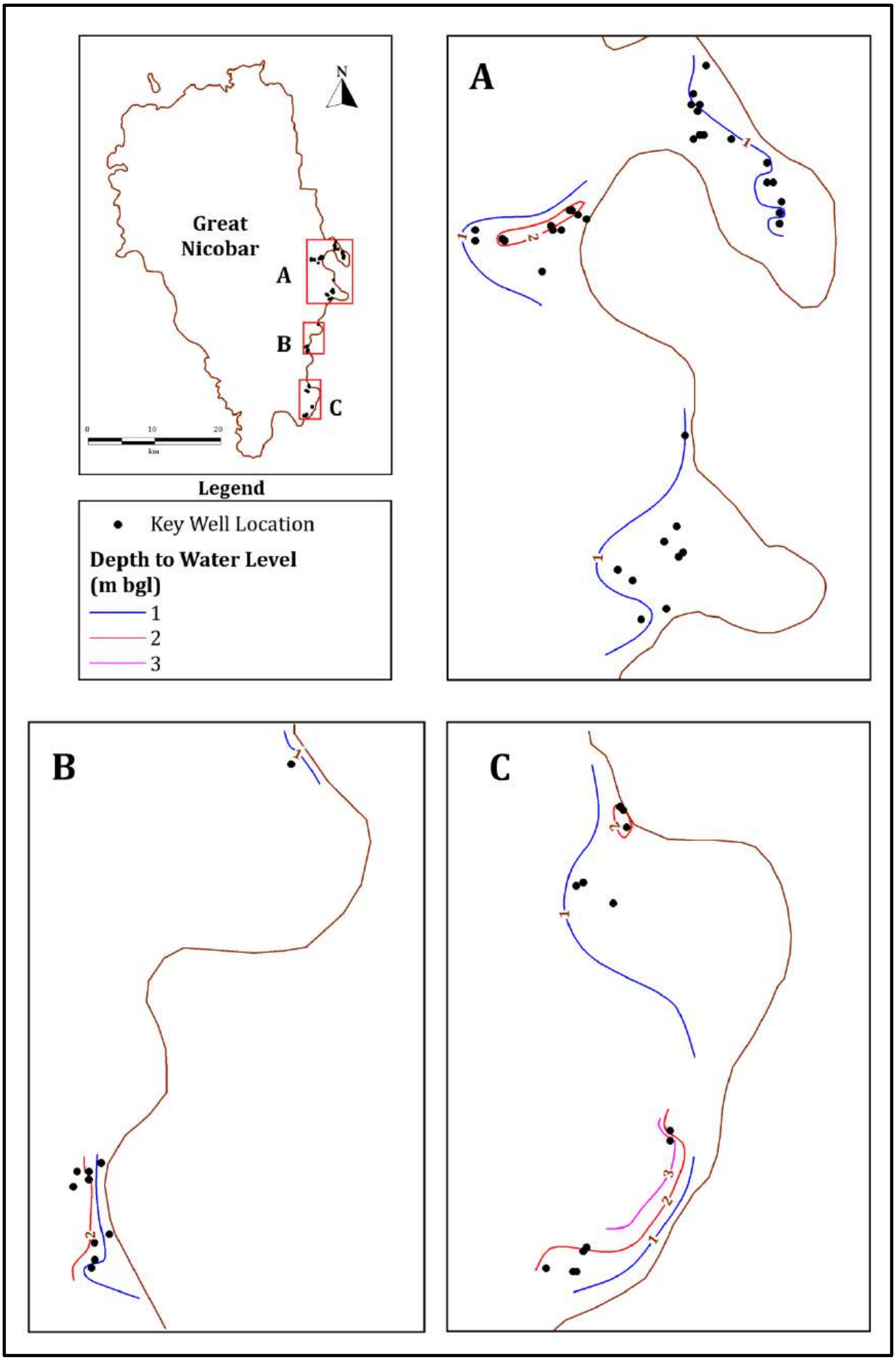


Fig. 5.10a Dry- Season Depth to Water Table Map of Great Nicobar Island

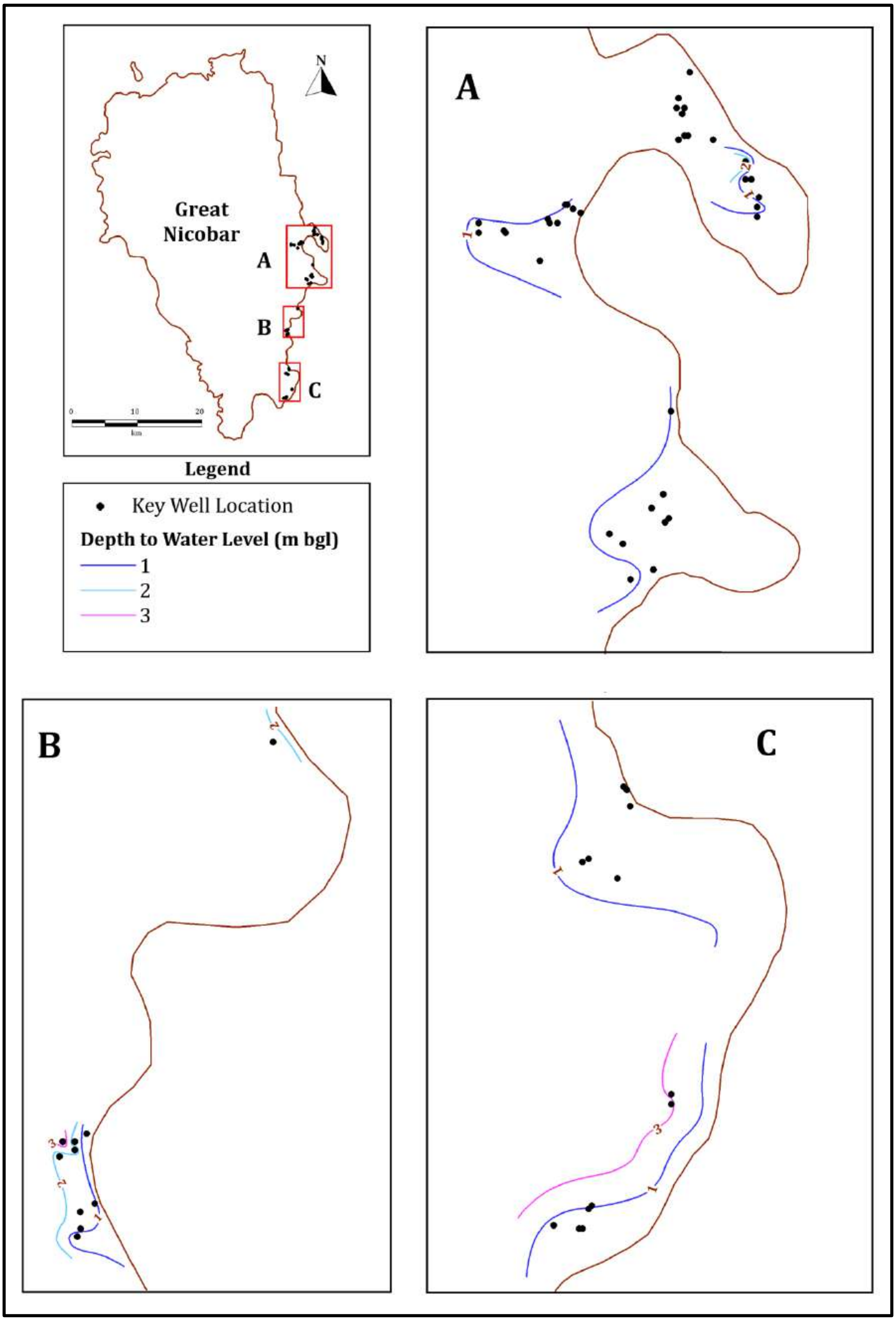


Fig. 5.10b Wet- Season Depth to Water Table Map of Great Nicobar Island

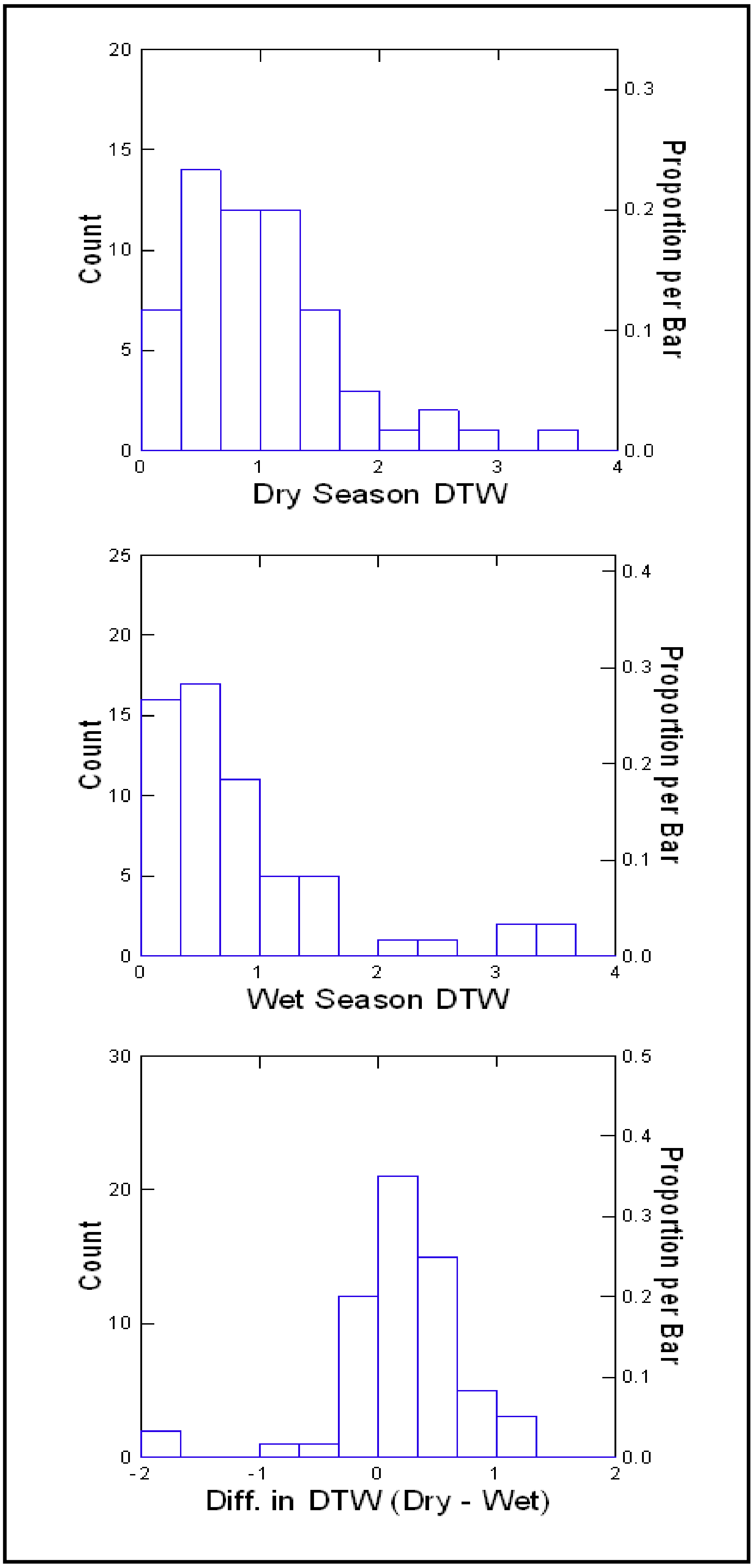


Fig. 5.11 Histogram of Dry-, Wet- Season DTW and their Difference

5.5 Groundwater Recharge Response

Groundwater recharge possibilities are estimated through soil infiltration test. Single ring infiltrometer is used for the purpose. Results and summarized observations are given in **Table 5.6.** Detailed Observations are given in **Annexure 6**. Soil infiltration test graphs of Great Nicobar Island are given in **Fig. 5.12**.

Results show that in Jogindernagar area, over valley-fill deposits in a more or less flat topographic setting, initial infiltration rate was 3.1 cm/hr which finally reduced to 0.4 cm/hr with an average infiltration rate of only 1 cm/hr. On the other hand, in Govindnagar area, over forested mountain slope, initial infiltration rate was 37.8 cm/hr which finally reduced to 2.4 cm/hr with an average infiltration rate of 11.6 cm/hr. This shows that in contrast to popular perception,

Table 5.6 Results and Summarized Observations of Soil Infiltration Test

Measurements Parameters	Unit	Observations	
Site Name	-	**Jogindernagar**	**Govindnagar**
Geo Reference	DD	6.999965° N 93.8901967°E	6.9622768° N 93.9226687°E
RL	m amsl	15m	60m
Geomorphology	-	**Valley-fill plain**	**Hill slope**
Slope	Degree	**1° - 3°**	**10° - 12°**
Soil Type	-	**Clayey soil**	**Forest Brown soil**
Land Use	-	**Coconut Orchard**	**Forest Land**
Vegetation	-	**Grass covered**	**Grass covered**
Nearby Water level	m bgl	**0.45**	**0.5**
Initial Head	cm	34	30
Head after 10 min	cm	33.49	23.7
Head 10 min last measurement	cm	33.11	7.3
Final Head	cm	33.05	6.9
Test duration	min	56	120
Initial Rate (First 10 min)	cm/hr	**3.1**	**37.8**
Final Rate (Last 10 min)	cm/hr	**0.4**	**2.4**
Average Rate	cm/hr	**1.0**	**11.6**

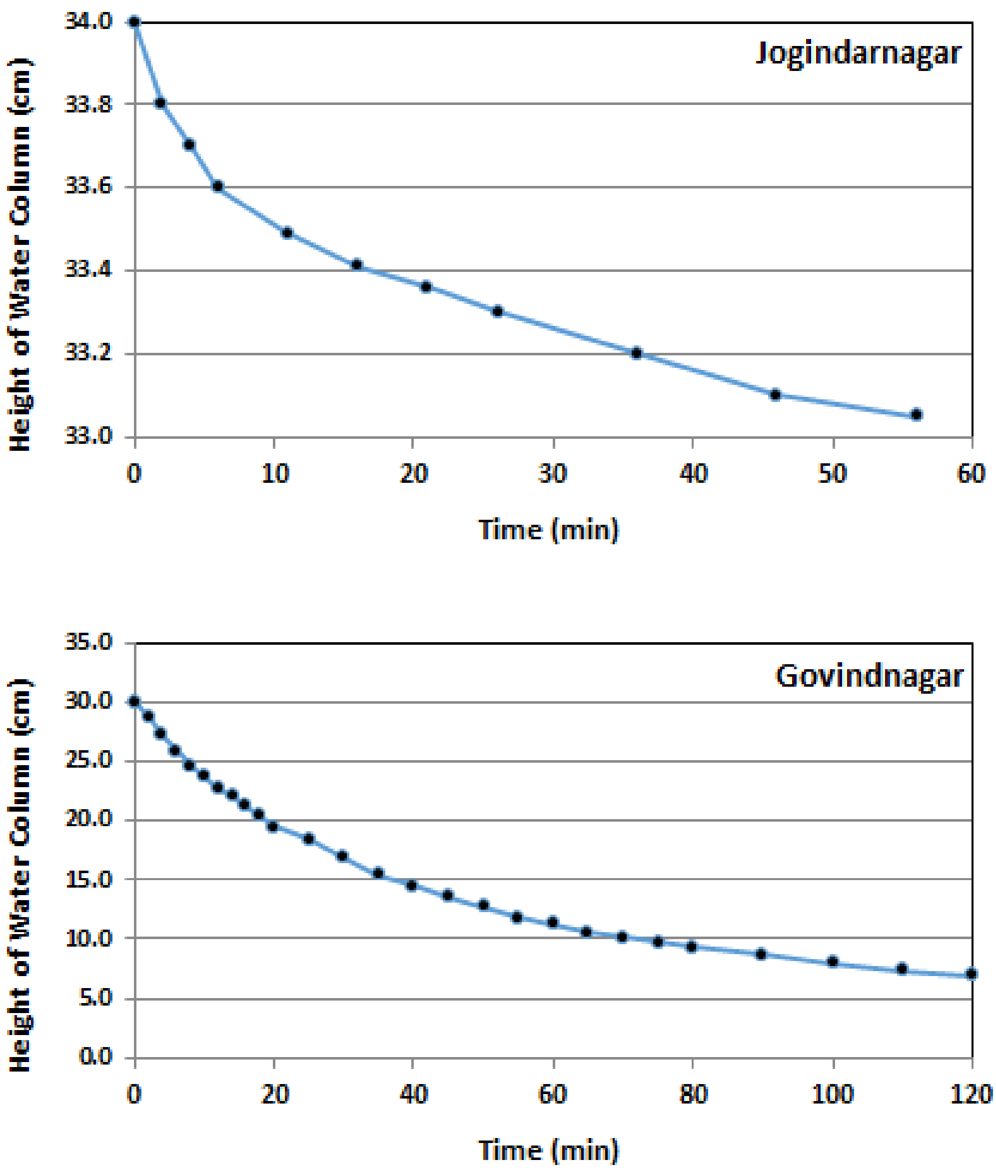


Fig. 5.12 Plots of Soil infiltration tests in Great Nicobar Island

5.6 Groundwater Draft Response

Main Objective of this study is to have an idea about aquifer parameters, well performance and yield characteristics of the wells. The islands do not have any borewell till date except those constructed by CGWB during 1987-88, which are defunct now. Islanders are dependent on large diameter Dugwells or spring/nallah based water supply system. Hence, to understand groundwater withdrawal response, two dugwells are analysed based on their recovery performance. Methods utilized for analyses of the data are summarized below.

Slichter's Method (1906) is used to determine the *Specific Capacity* (C) of the wells.

$$C' = 2.30\frac{A}{t'}\log\frac{S_1}{S_2}$$

Where, C is Specific Capacity; A is Cross sectional Area; S_1 is Drawdown when Pumping stopped and S_2 is Residual draw down at time t' after pumping stops with the assumption that flow is only from the bottom. Based on recovery performance wells are analysed.

Muskat's Method (1937) is used to determine the *Transmissivity* (T) of the aquifer. The method extends the use of Slichter's equation for estimation of Transmissivity by combining Theim's Solution for steady-state flow.

$$T = \frac{C'A}{2\,\pi\,t'}\log_e\frac{S_1}{S_2}$$

$$C' = \log_e\frac{r_0}{r_w}$$

Where, A is cross sectional area; r_0 is distance at which drawdown is negligible at the end of pumping; r_w is radius of the well; S_1 is Drawdown at the time pumping stops and S_2 is residual drawdown at time t' after pumping stops. The underlying assumptions are aquifer is confined with lateral flow into the well under steady-state.

However, the method is valid only for dug wells tapping confined aquifers with the well ending at the bottom of the confining layer. There is also serious practical limitation is to estimate the distance to a point of zero drawdown. Considering the dugwells are tapping the bottom portion of the aquifer horizon, the method is applied; however the aquifer horizon is essentially unconfined. Hence, this absolutely downgrades the estimation of T. However, no other value of T exists for the area.

Hvorslev Method (1951) is used to determine the *Permeability* (K) of the aquifer. The method is also based on Recovery Data and takes storage into consideration. Concept of Shape Factor is introduced which depends on the radius of the well and the nature of intake area.

$$K = \pi \frac{a^2}{S} \frac{\ln h_1 - \ln h_2}{t_2 - t_1}$$

Where, 'a' is well radius; S is shape factor; K is Permeability; h_1 and h_2 are drawdowns at time t_1 and t_2. If water enters through bottom only, value of *Shape Factor* is twice the diameter of the well.

Romani's Method (1973) is used to determine *Optimum Yield* (Y) of a well. Main aim is to have an idea of the maximum quantity of water which can be pumped out from a dug well either by continuous or intermittent pumping. It also reflects upon the yield characteristics of the aquifer tapped.

$$n = \frac{720 - t_1}{t_2 + t_3}$$

$$Y = Q\,(t_1 + nt_2)$$

Where, t_1 is the time at which the well is dry or the well reaches the optimum lifting capacity of the pump; t_2 is time to empty 50% of the well; t_3 time for 50% recovery of water level; and Y is the Optimum Yield of the well.

Detailed observations are given in **Annexure 7**. Estimated Well parameters, Aquifer parameters and Aquifer Yield are summarized in **Table 5.7**. Graphical plots of Slichter's Method and Romani's Method are given in **Fig. 5.13a to d**. Derived values of T and K agree with each other as expected saturated zone tapped by dugwell is 2m.

Table 5.7 Estimated Aquifer Parameters and Aquifer Yield

Parameter/Methods	Well 01	Well 02
Well Parameter		
Slichter's Method (1906)		
Diameter	9 m	7.75 m
A	254.6 m^2	188.8 m^2
t'	300 min	100 min
Log (S_1/S_2)	2.6	1.1
Specific Capacity (C)	**5.1 m^2/min**	**4.8 m^2/min**
Aquifer Parameters		
Muskat Method (1937)		
r_0	50 m	50 m
C'	1.71	1.86
S_1/S_2	2.843	1.129
t'	370 min	60 min
Transmissivity (T)	**20 x 10^{-2}**	**11 x 10^{-2}**
Hvorslev Method (1951)		
a	4.5 m	3.875 m
h_1	0.199 m	3.03 m
t_1	65 min	60 min
h_2	0.15 m	2.79 m
t_2	195 min	130 min
S	18 m	15.5 m
Hydraulic Permeability (K)	**11 m/day**	**5 m/day**
Aquifer Yield		
Romani Method (1973)		
t_1	90 min	215 min
t_2	46 min	100 min
t_3	340 min	265 min
Q	0.10 m^3/min	0.06 m^3/min
n	1.63	1.38
Optimum Yield (Y)	**17 m^3/day**	**21 m^3/day**

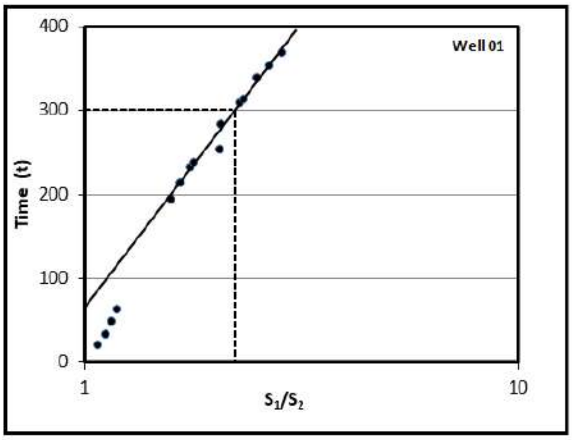


Fig. 5.13a Plot of Log S_1/S_2 vs. t (Slichter's Method)

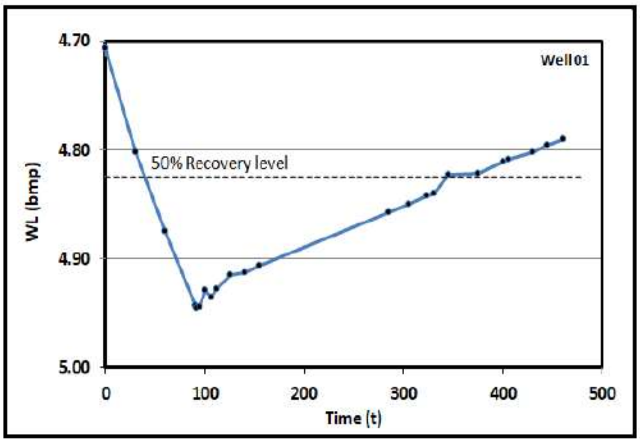


Fig. 5.13b Yield Test of Large Diameter Dugwell using Romani method

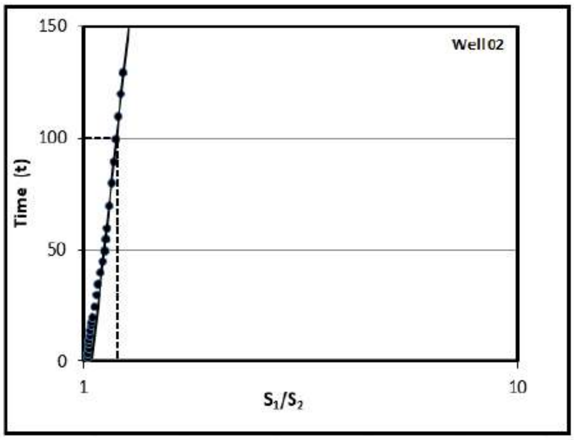


Fig. 5.13c Plot of Log S_1/S_2 vs. t (Slichter's Method)

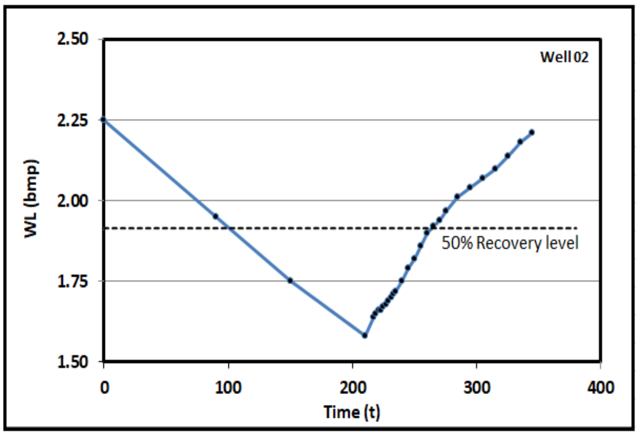


Fig. 5.13d Yield Test of Large Diameter Dugwell using Romani method

5.7 Aquifer Disposition and Properties

Exploratory data and geophysical investigation data are compiled and correlated to understand aquifer disposition. In Nicobar district, mainly two broad hydrogeological units are present. They are

a) Fractured Consolidated Formation

Lithologically, marine sedimentary group of rocks comprising shale, sandstone, grit and conglomerate and extrusive, intrusive igneous rocks (volcanics and ultramafics) and coralline limestone contributes towards this hydrogeological unit. Occurrence and movement of ground water in this formation is controlled mainly by the zone of secondary porosity and along the contact plane of various litho-units. Weathered Mantle and Saprolitic Zone plays important role in recharging the zone of secondary porosity. Because of active tectonism, this group of rocks is highly deformed. However, the nature of deformation is expected to be brittle in nature at shallow depth and ductile at deeper part. In case of coralline limestone, solution cavity forms the main pathway for movement of ground water. However, formation of marl over coralline limestone as weathering product impedes ground water movement.

As per the very limited exploration records, this has limited yield potential of 5 – 10 m^3/day. Exploratory borehole yielded meager discharge. Large diameter (4 – 6 m) dugwells may be constructed down to 4 – 6 m depth. However, several springs across the islands emerge from this unit. This indicates that its actual yield potential may not be properly understood.

b) Unconsolidated formation

Lithologically, mainly Coralline sand horizon constitutes this aquifer. Recent beach sand, coral rags, alluvium, colluvium and valley-fills also contributes to the formation. Weathered mantle and saprolitic zone over consolidated formation is in hydrological continuity with this aquifer system in general. The unit occurs mainly at the coastal parts of the island and thins out towards island interior with increase in elevation.

Present population of the islands mainly depends on this formation for water supply. In every habitation, several dugwells are constructed tapping this one. However the aquifer horizons are isolated and discontinuous in nature and getting their replenishment from connected weathered mantle at higher elevation. Except in exposed sand horizons, very low infiltration rate due to high clay content of valley-wash at top horizon shows direct rainfall recharge is not significant. This unit has yield potential of 10 – 20 m^3/day. Large diameter (3 – 5 m) dugwells may be constructed down to 3 – 5 m depth.

Aquifer Characteristics are summarized in **Table 5.8**. Summarized dugwell characteristics based on Land Classes are given in **Table 5.9**. Prepared 3-D disposition of aquifer in Campbell Bay Area is given in **Fig 5.14**. Island-wise prepared aquifer maps are given in **Fig 5.15 to 5.20**.

Table 5.8 Aquifer Characteristics

<table>
<tr><th colspan="2">Aquifer</th><th></th><th>Coastal Coralline Aquifer</th><th>Fractured Meta - Sedimentaries</th><th>Fractured Volcanics</th><th>Coralline Limestone</th></tr>
<tr><td colspan="2">Explored Depth ranges</td><td>m bgl</td><td>0-8</td><td>4-101</td><td>–</td><td>–</td></tr>
<tr><td colspan="2">Fracture Occurrence</td><td>m bgl</td><td>-NA-</td><td>8-10, 15-20, 23-28, 35-43, 56-60, 76-81, 86-92</td><td>30 – 50 (expected)</td><td>–</td></tr>
<tr><td colspan="2">Optimal Yield Range</td><td>m^3/day</td><td>15-20</td><td>5-10</td><td>–</td><td>–</td></tr>
<tr><td colspan="2">Fresh-Saline Interface</td><td>m bgl</td><td>6-8</td><td>20-30 (Deeper at island interior)</td><td>20-30 (Deeper at island interior)</td><td>6-8 (Deeper at island interior)</td></tr>
<tr><td rowspan="2">Aquifer parameter</td><td>Transmissivity (T)</td><td>m^2/day</td><td>10 to 20 x 10^{-2}</td><td>–</td><td>–</td><td>–</td></tr>
<tr><td>Permeability (K)</td><td>m/day</td><td>5 to 11</td><td>–</td><td>–</td><td>–</td></tr>
<tr><td colspan="3">Suitability for Drinking</td><td>Potable</td><td>Potable (Brackish at depth)</td><td>Potable (Brackish at depth)</td><td>Potable in Stored Reserve</td></tr>
</table>

Table 5.9 Summarized Dugwell Characteristics based on Land Class

Land Class	Depth of Well	Depth to water Table	Seasonal Fluctuation
Coastal Area	~ 2 m bgl	0.5 - 1 m bgl	~ 0.5 m bgl
Slope Area	2 - 3 m bgl	1 – 1.5 m bgl	~ 0.5 m bgl
Upland Area	~ 4 m bgl	1 – 1.5 m bgl	~ 0.5 m bgl

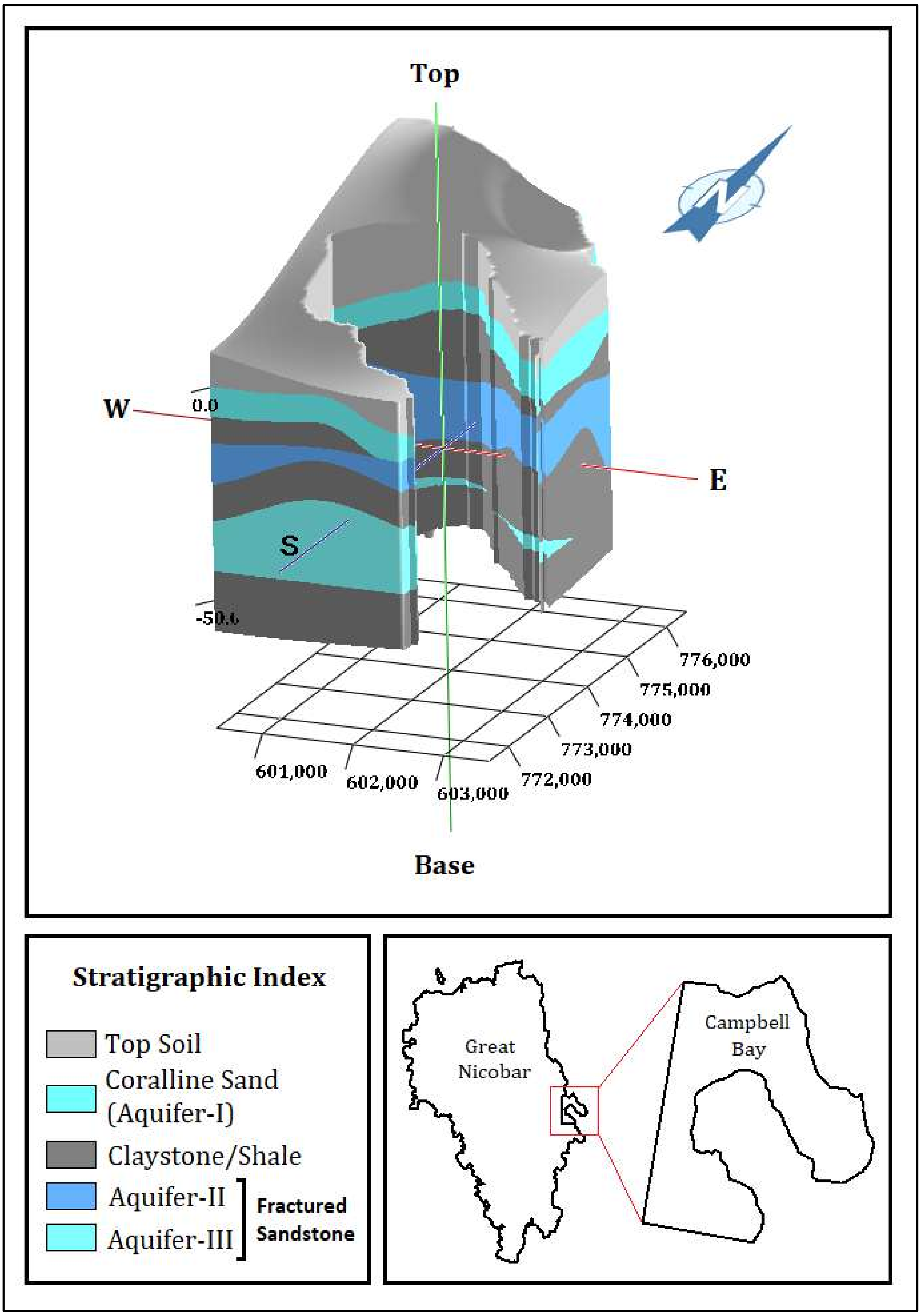


Fig 5.14 3-D Aquifer Disposition in Campbell Bay Area, Great Nicobar Island

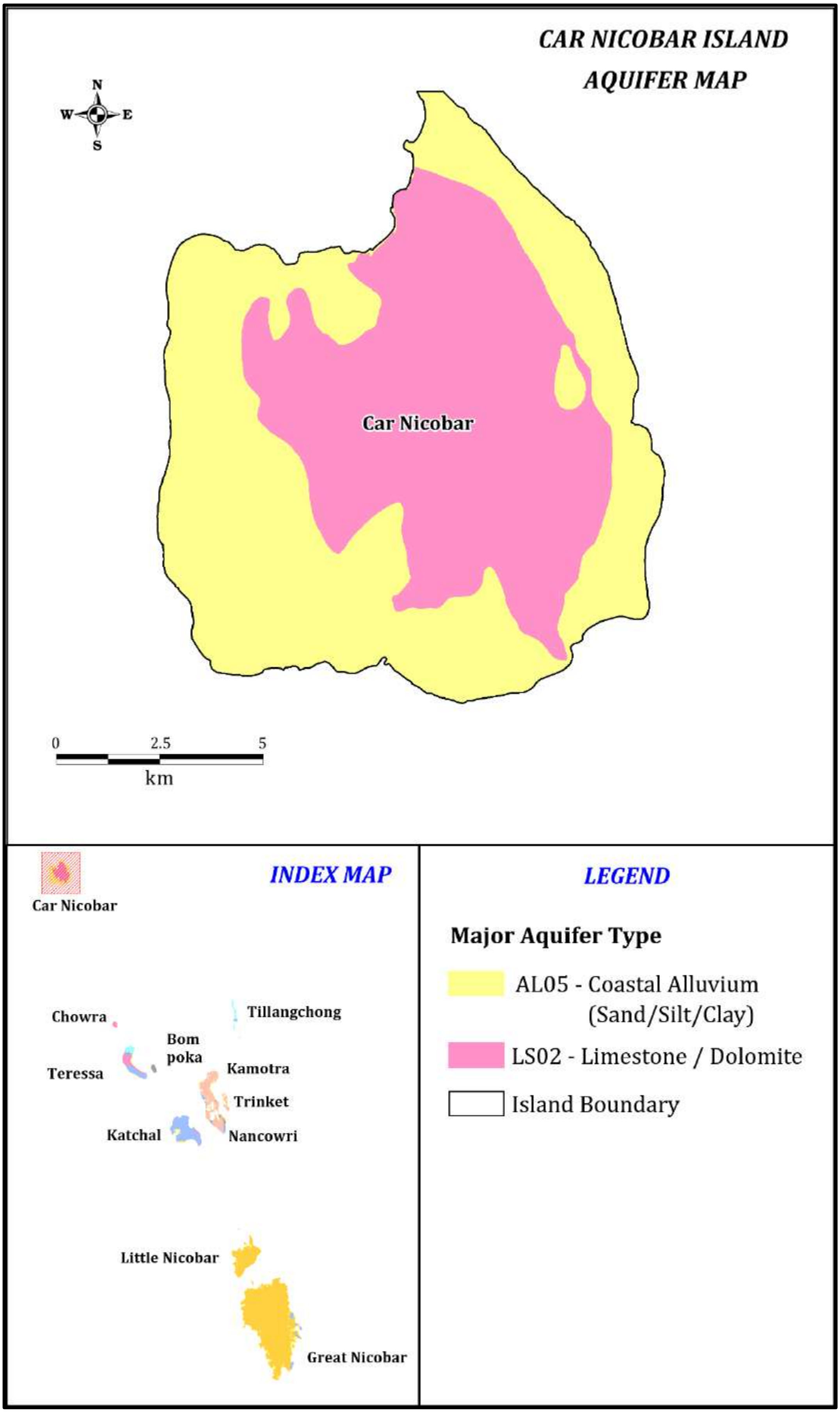


Fig 5.15 Aquifer Map of Car Nicobar Island

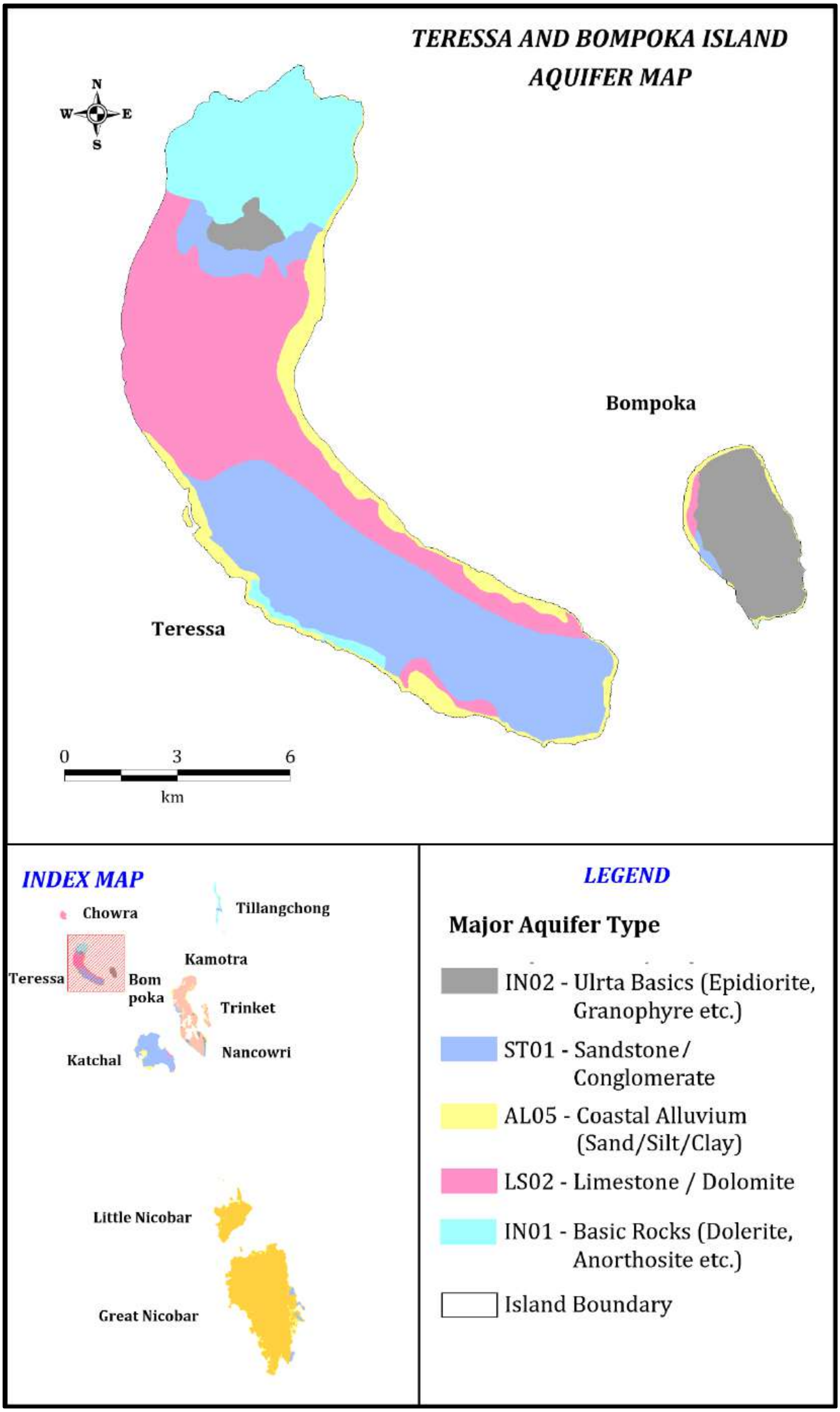


Fig 5.16 Aquifer Map of Chowra, Teressa and Bampooka Island

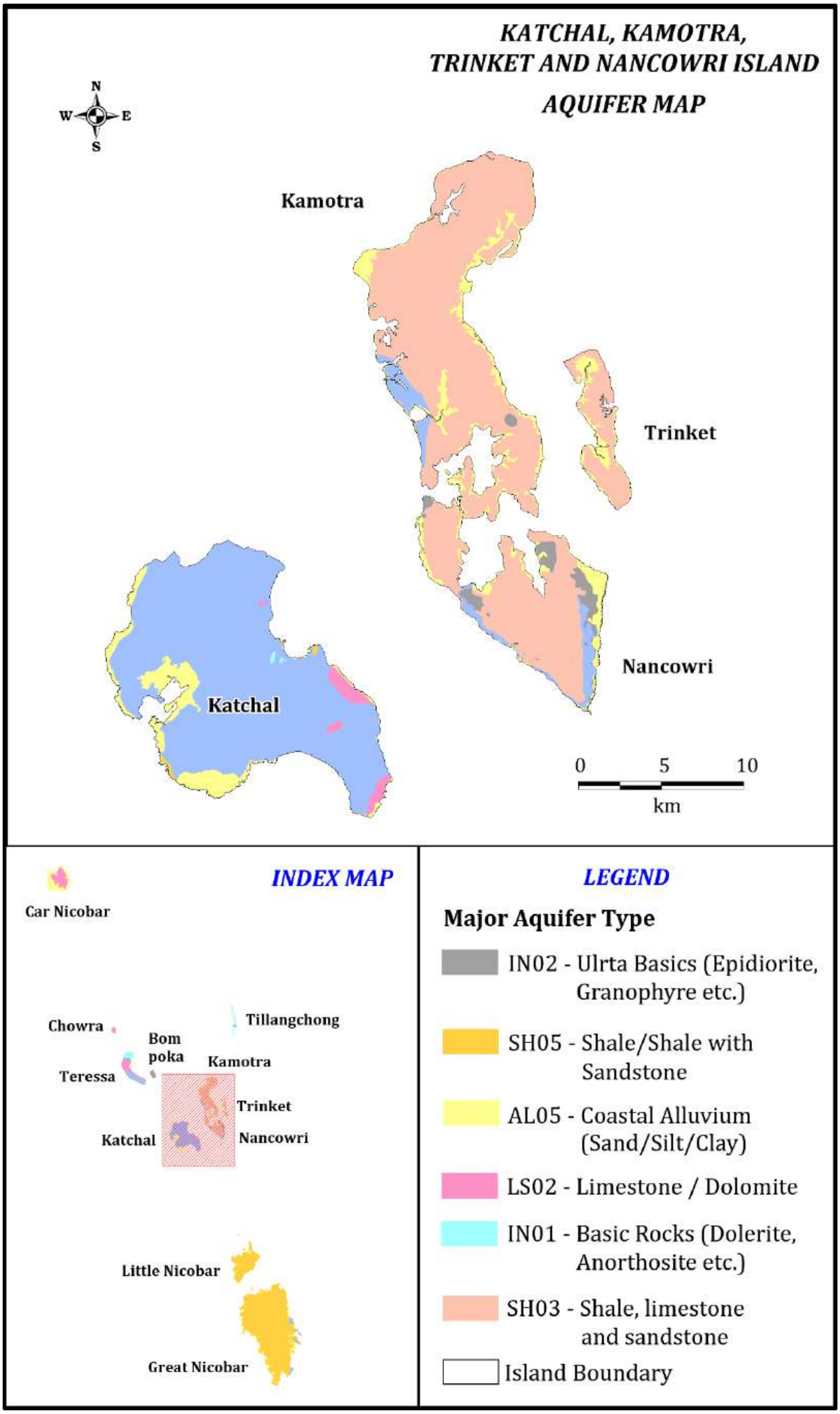


Fig 5.17 Aquifer Map of Katchal, Kamorta, Nancowri, and Trinket Island

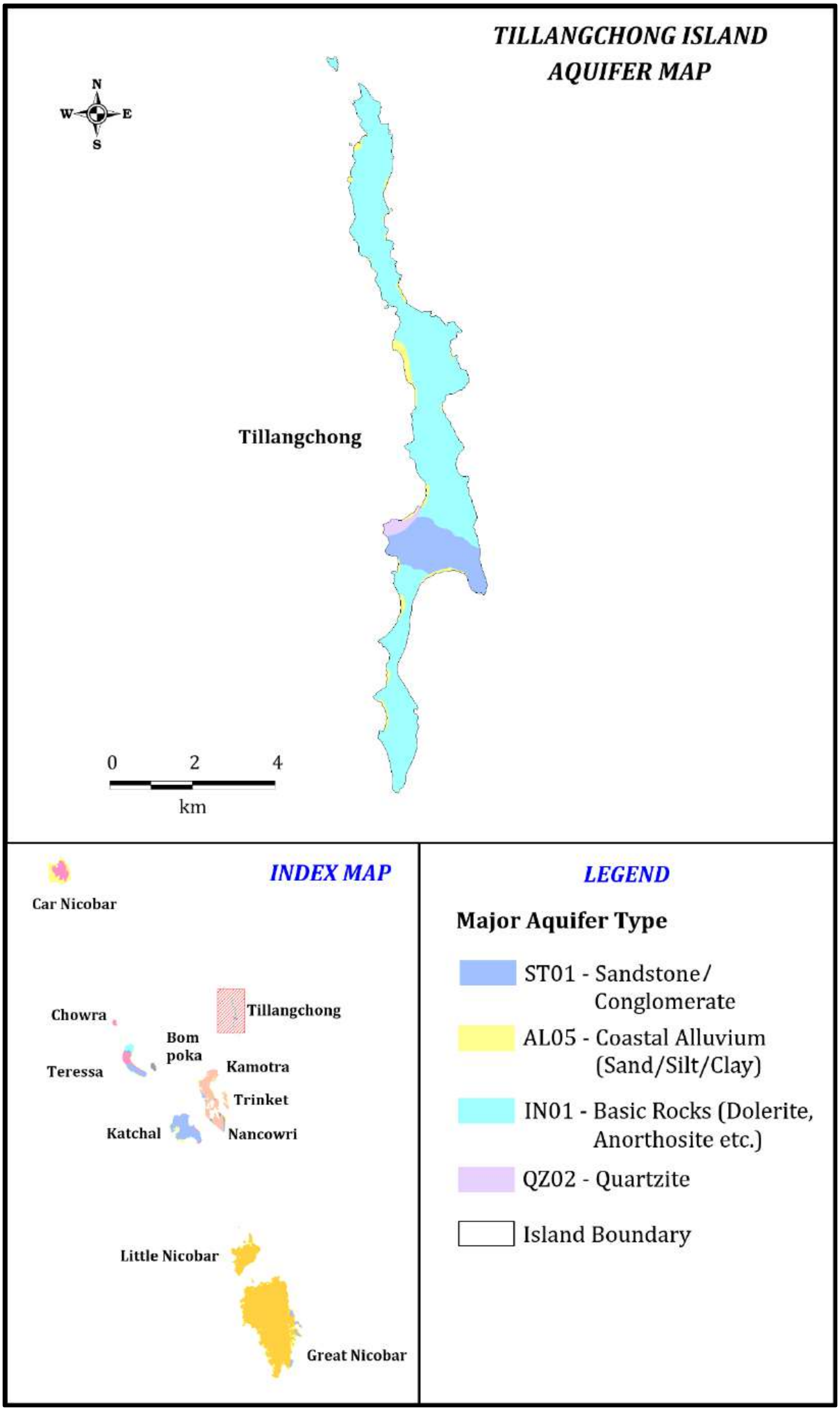


Fig 5.18 Aquifer Map of Tillangchong Island

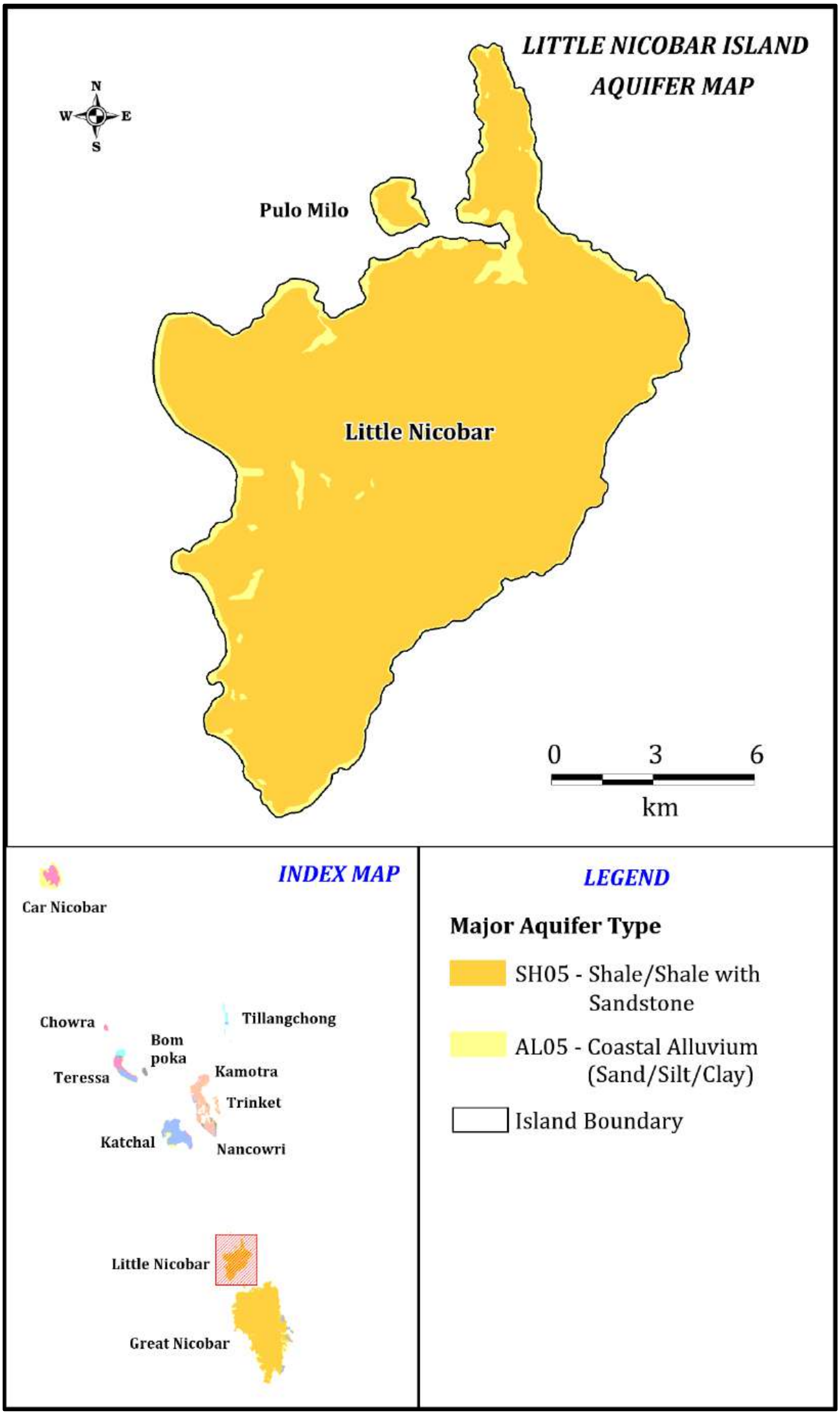


Fig 5.19 Aquifer Map of Little Nicobar Island

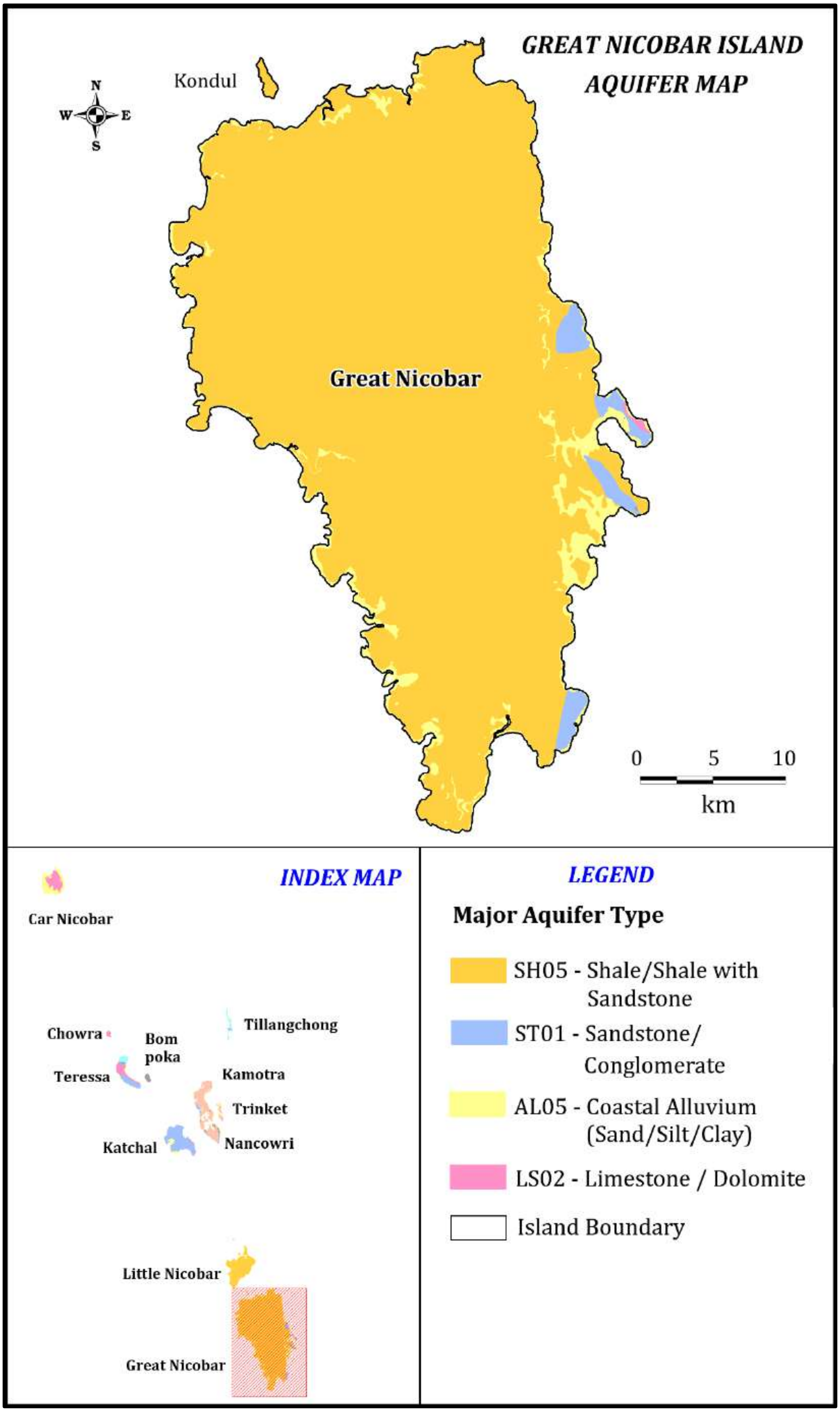


Fig 5.20 Aquifer Map of Great Nicobar Island

5.8 Groundwater Potential of Islands

Study reveals that individual islands show significant variability in groundwater potential based on their topography, ruggedness, shape factor, lithology and aquifer inter-connectivity. These factors in combination control thickness of freshwater lens, groundwater flow pattern and formation of springs. Groundwater prospect of individual Islands are summarized below based on present study and previous works (Kar, 2004; Kar and Adhikari, 2005; Banerjee *et al.*, 1988). Compilation of data clearly indicates that most of the tribal villages in the islands are came up beside perennial springs except where forcefully shifted due to natural calamity *e.g.* tsunami. Hence, it highlights importance of securing perennial water source for the village in traditional knowledge.

Bambooka Island: The Island is underlain by the volcanics and the coastal parts are occupied by Coralline formation. Number of springs oozes out from these volcanic rocks. In coastal areas coralline formation supports construction of open dug wells.

Chowra Island: The Island is underlain by Coralline and Foraminiferal limestone. Numerous caves are present in south-eastern elevated portion of the island. Sands overlie the limestone throughout the Island. Sand horizon is thicker along the coast than the central part. At places silty calcareous marl are developed through weathering of limestone. Sand being more porous and permeable than underlying limestone, percolating rain water flows laterally following topographic slope. This results insignificant groundwater recharge. Isolated fresh water lens thickness varies between 5 and 80 cm seasonally. During high tide the thickness of fresh water may increase further depending on location of well (Kar, 2004).

Great Nicobar Island: Being the largest, the Island is underlain by The Island is underlain by marine sedimentaries, volcanics and Coralline formations. Exploratory drilling carried out by CGWB in 1984-86 (Banerjee *et al.*, 1988) indicated poor ground water potential of sedimentaries. However, several perennial springs, spring-fed streams and rivers formed in this island. This is the only island where true river system exists. Galathea is most important river in the island which created its own flood plain. Coastal coralline formation supports construction of open large diameter dug wells.

Katchal Island: The Island is underlain by Sedimentaries and Coralline formations. There are number of perennial springs present in the island mainly located in the central part of the island, which may from sustainable sources. Spring sources at Mildera, Bichdera, Lalmuna, Lambabalu are perennial. In coastal areas coralline formation supports construction of open dug wells.

Kamorta Island: The Island is underlain by mostly marine sedimentary group of rocks barring small patches near Changua, Al-u-kheak, Ramjau and Munak villages. The coastal tracts are formed by potential coralline formation. Potential springs are present in the volcanic formation. Spring sources at Changua, Al-u-kheak, New Laful, new Pilpillow new Kakana Munak, Ramjaw and Payhiu Bunderkhari Bada Enak Chhota Enak are perennial in nature. In coastal areas coralline formation supports construction of open dug wells.

Kondul and Pulo Millo Islands: The islands are underlain by Mud Stone and Silt Stone formations flanked by coralline formations, which use to facilitate construction of water yielding wells.

Little Nicobar Island: The island is underlain by sedimentaries (*i.e.* Mud stone, Silt stone and Clay stone) and the coastal parts are occupied by Coralline formation. Number of springs oozes out at higher elevations. In coastal areas coralline formation supports construction of open dugwells.

Nancowry Island: The Island is mostly underlain by marine sedimentaries. In southern part volcanics are exposed. Akin to other islands the coast is underlain by coralline formation. There are several springs present in the island. Spring sources at Tapong, Altheak are perennial in nature. Spring sources at Champin, Hitui village area are non-perennial in nature. In coastal areas coralline formation supports construction of open dugwells.

Trinket Island: The Island is mainly underlain by sedimentaries (*i.e.* Mud stone, Silt stone and Clay stone). Sedimentaries have low groundwater potential while coastal coralline formation supports construction of open dugwells.

Teressa Island: The Island is underlain by volcanic pillow lava and Marine sedimentary flanked by Coralline formation. There are several springs present in the island. Spring sources at Bengali Village, Pipe Nala in the Ponda area, Alurong, Chukmachi, Luxi, Enam are perennial. In coastal areas coralline formation supports construction of open dug wells.

5.9 Tidal influence on Groundwater Regime

Geometric relationship of moon and Sun relative to Earth results in creation of different types of tides. In parts of the northern Gulf of Mexico and Southeast Asia, tides have one high and one low water per tidal day. These tides are called 'diurnal tides'. Groundwater in the islands is in hydraulic continuity with surrounding seawater. Hence, groundwater regime is highly influenced by the diurnal tidal fluctuations of the sea. The magnitude of the tidal fluctuation is dependent on several factors amongst which the permeability of the aquifer material, the proximity of the site to the sea and the magnitude of tidal variation in the sea play significant roles. The above factors may also impart a time lag between tidal fluctuation in the sea and observation variable.

A dug-well in coastal area of Campbell Bay, Great Nicobar Island is measured for its water level, temperature and electrical conductivity over a period of six (06) hours with sampling interval of 30 minutes. The results show strong correlation between tidal fluctuation in the sea and observation variable. Details of observations are given in **Table – 5.10a and 5.10b**. The results are given in **Fig. 5.21**. The graph shows a time-lag of 60 min between peak tide level and highest groundwater water table, however this is sampling frequency dependent and a higher resolution sampling will provide a precise estimate. EC and groundwater temperature maximizes and minimizes respectively with a time-lag of 90 min. However, these two maxima and minima coincide clearly indicating a mixing phenomenon related delay.

Hence, it's evident that in coastal areas, groundwater regime is tide dependent. It is observed that the fresh water area expands during high tide whereas it shrinks during low tide. This can be effectively used for scheduling of pumping of water wells, as high tide effectively creating groundwater mound in coastal areas.

Table 5.10a Site Details of Tidal Influence Test

Parameters	Well Details
Site Name / Date	Vijaynagar (Old) / 17-03-2023
Geo Reference / RL	06.93184° N; 93.9077517 °E / 5 m
Geomorphology / Slope	Coastal Plain / 1° - 3°
Well type	Dug well
Depth / MP / Dia.	2 m / 0.35 m / 0.54 m
Distance from Ocean	180 m

Table 5.10b Observational Details of Tidal Influence Test

Time	Time Interval Since Start	Depth to Water level	Water Table	EC	Temp	Tide level
IST	**Min**	**m bgl**	**m amsl**	**µS/cm**	**°C**	**m amsl**
13:10	0	1.75	1.25	525	28.3	0.79
13:40	30	1.72	1.28	526	28.3	0.86
14:10	60	1.67	1.33	527	28.3	0.92
14:40	90	1.64	1.36	527	27.9	0.97
15:10	120	1.63	1.37	529	27.9	1.01
15:40	150	1.55	1.45	531	27.4	1.04
16:10	180	1.49	1.51	542	27.2	**1.05**
16:40	210	1.35	1.65	550	27.3	1.04
17:10	240	1.33	**1.67**	555	27.3	1.03
17:40	270	1.34	1.66	**560**	**27.0**	1.00
18:10	300	1.4	1.6	550	27.2	0.95
18:40	330	1.42	1.58	546	27.2	0.90
19:10	360	1.46	1.54	540	27.3	0.85

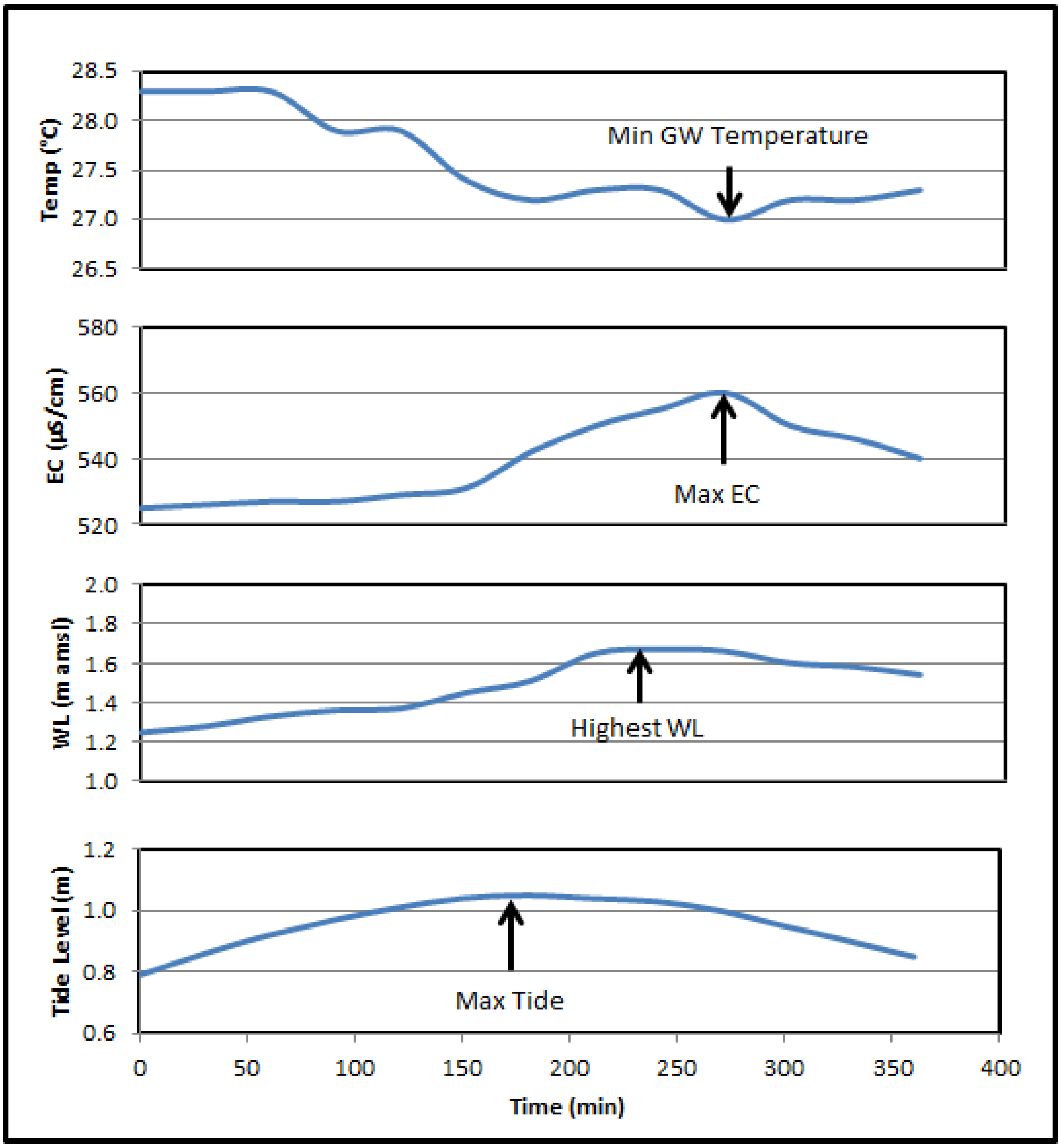


Fig. 5.21 Tidal influence on Groundwater Regime in Great Nicobar Island

Chapter 6

Groundwater Quality

To determine ground water quality and its suitability for various uses namely, domestic, industrial and irrigation purposes, groundwater samples are collected from different wells in Great Nicobar Island and natural springs located in the area during the study. Water samples are collected from 46 key wells for chemical analysis. Field values of EC and pH is also measured for all key wells. Collected samples are analyzed in the Regional Chemical Laboratory of Central Ground Water Board, Kolkata. Groundwater analysis data of other islands are compiled from previous studies of CGWB and ICAR.

6.1 Major Ion Chemistry

In Great Nicobar Island, ground water in general is alkaline with pH value ranging from 7.2 to 8.1 with an average of 7.8. Electrical Conductivity, which is a function of amount of total dissolved solids in ground water, as observed in dug well samples, ranges between 142 and 1081 µ mhos/cm (laboratory values) in ground water of the area. On the other hand Electrical Conductivity, of spring water samples ranges between 144 and 289 µ mhos/cm. This clearly indicates that springs being located at inner part of the island are less affected by salinity than coastal dug wells. Total hardness (as $CaCO_3$) of ground water in the area varies from 80 and 300 mg/l with an average of 178, which shows moderately hard nature of ground water. **Table 6.1** summarises the overall range and average values of common chemical constituents of ground water of the area. Major chemical constituents of ground water of the area from Dugwell samples are broadly described as below:

Cations: Calcium (Ca^{+2}), Magnesium (Mg^{+2}), Sodium (Na^{+}), and Potassium (K^{+}) are major cations present in ground water of the area. Calcium and Magnesium contents range from 10 to 66 mg/l and 2.4 to 37.6 mg/l, respectively. Sodium and Potassium contents range from 7.1 to 83.6 mg/l and 0.2 to 12.6 mg/l, respectively. Iron ($Fe^{+2/+3}$) content of ground water of the area is commonly lower than the permissible limit of 1 ppm but in places it may reach up to 2.25 mg/l.

Anions: Chloride (Cl^{-}), Sulphate (SO_4^{-2}), Nitrate (NO_3^{-}), and Bicarbonates (HCO_3^{-}) are major anions in ground water. Analysis results show that Chloride content varies between 14.2

and 99.3 mg/l, Bicarbonates between 122 and 366 mg/l, Sulphate between below detection limit and 53 mg/l, and Nitrates between below detection limit and 21.3 mg/l in the study area. Another important anion species is Fluoride (F^-), which ranges up to 0.89 mg/l.

Table 6.1 Range and average values of chemical constituents of ground water of Great Nicobar Island

		Dug well			Spring		
Parameters	**Unit**	**Max**	**Min**	**Average**	**Max**	**Min**	**Average**
pH (lab)	-	8.1	7.2	7.8	8.0	7.8	7.9
EC (lab)	µ mhos/cm	1081	142	462	289	144	217
TH	ppm (as $CaCO_3$)	300	80	178	210	85	136
Ca	mg/l	66	10	37	36	16	26
Mg	mg/l	37.6	2.4	20.6	30.3	10.9	17.6
Na	mg/l	83.6	7.1	33.1	29.8	10.0	16.0
K	mg/l	12.6	0.2	3.3	2.1	1.7	1.9
HCO_3	mg/l	366.0	122.0	219.4	189.1	103.7	144.9
Cl	mg/l	99.3	14.2	41.1	31.9	17.7	23.9
SO_4	mg/l	53	-BDL-	12	23	-BDL-	10
NO_3	mg/l	21.3	-BDL-	5.5	9.0	-BDL-	4.7
F	mg/l	0.89	-BDL-	0.16	0.53	-BDL-	0.14
Fe	mg/l	2.25	0.03	0.52	1.43	0.60	0.91
TDS	-	467	180	301	261	133	197

Groundwater chemistry of Great Nicobar island are analysed using Schoeller Diagram (**Fig. 6.1a**), Piper Plot (**Fig. 6.1b**), and Durov Plot (**Fig. 6.1c**). Piper Plot and Durov Plot suggest a mixing mechanism in place (Lloyd and Heathcote, 1985) which is shifting groundwater composition from island interior to coastal part from Mg^+ dominance to Na^+ dominance. Map showing EC variation of Great Nicobar Island is given in **Fig. 6.1e**. Detailed analysis results are given in **Annexure 4**.

Out of 09 wells drilled in Great Nicobar (during 1987-88) only four produced water, one with two zones. When plotted in Piper diagram (**Fig. 6.1d**), of these, one well (Near Power house) (sample E2) plots in extreme Cl^- zone and indicates primary salinity from sea water. One Well plots in opposite end and indicates free from primary salinity. Other three are in various stage of mixing with saline water.

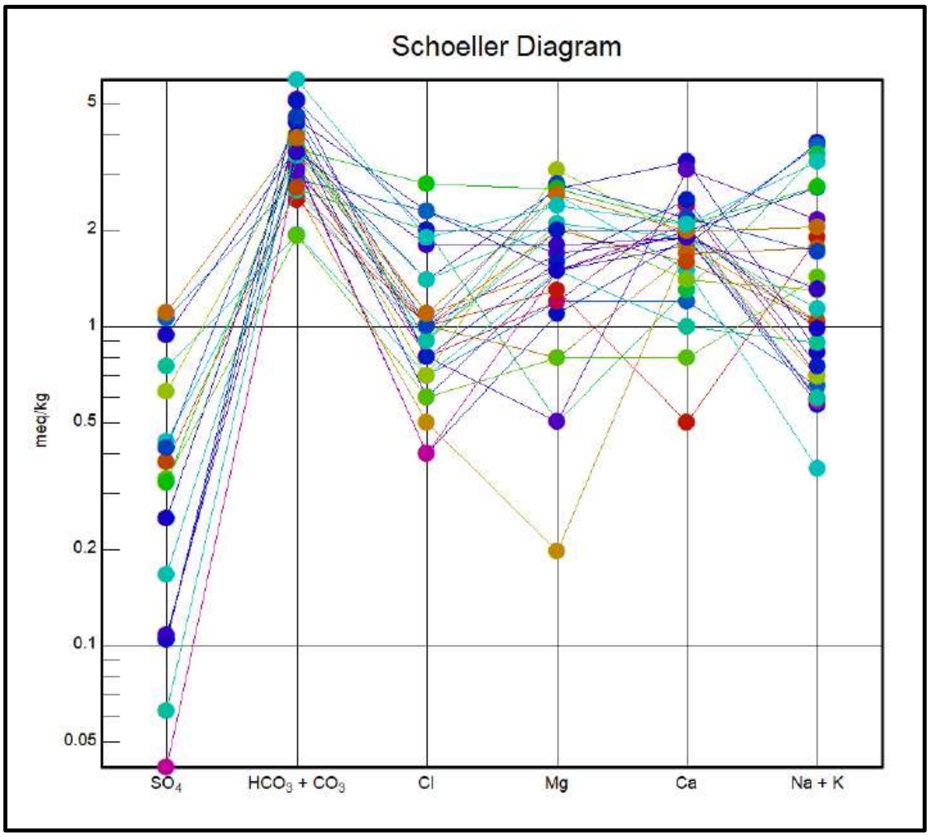


Fig. 6.1a Schoeller Diagram showing Great Nicobar GW chemistry

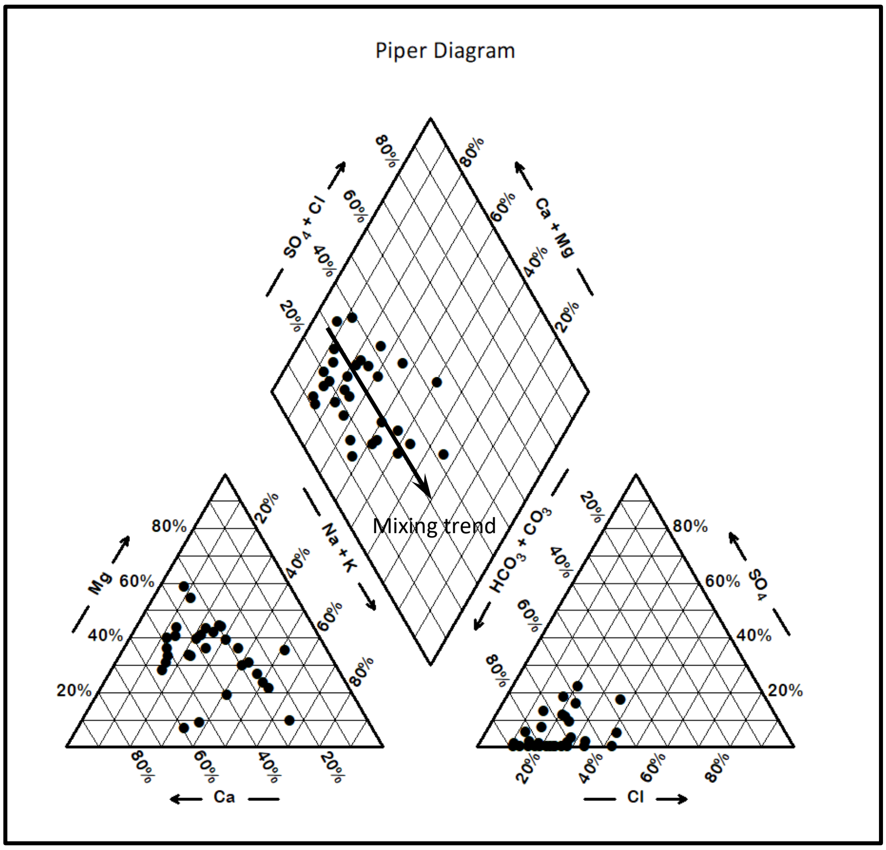


Fig. 6.1b Piper Diagram showing Great Nicobar GW chemistry

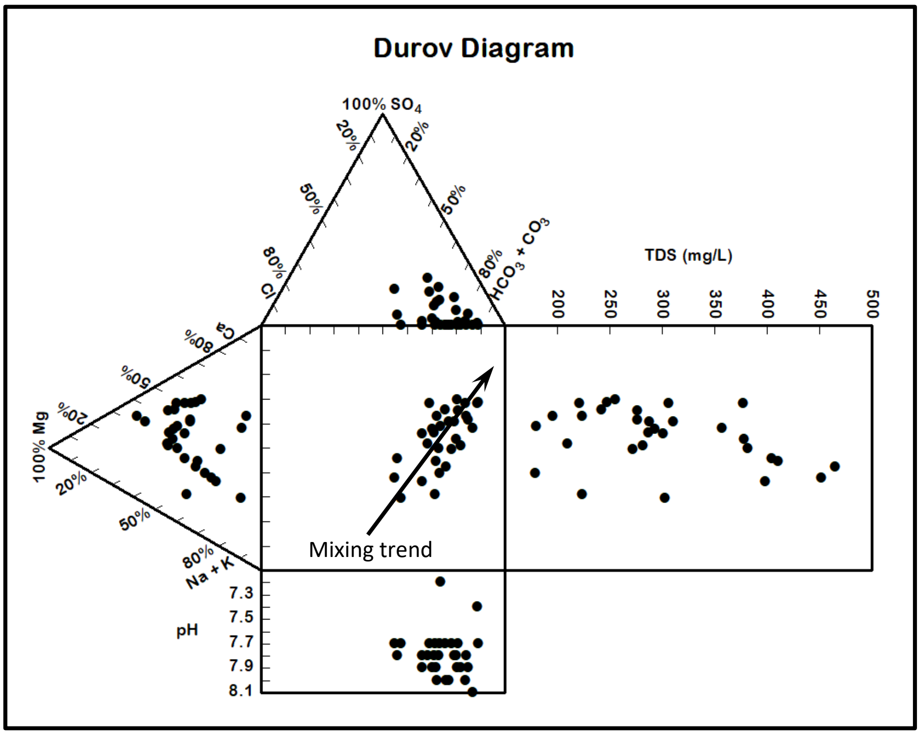


Fig. 6.1c Durov Diagram showing Great Nicobar GW chemistry

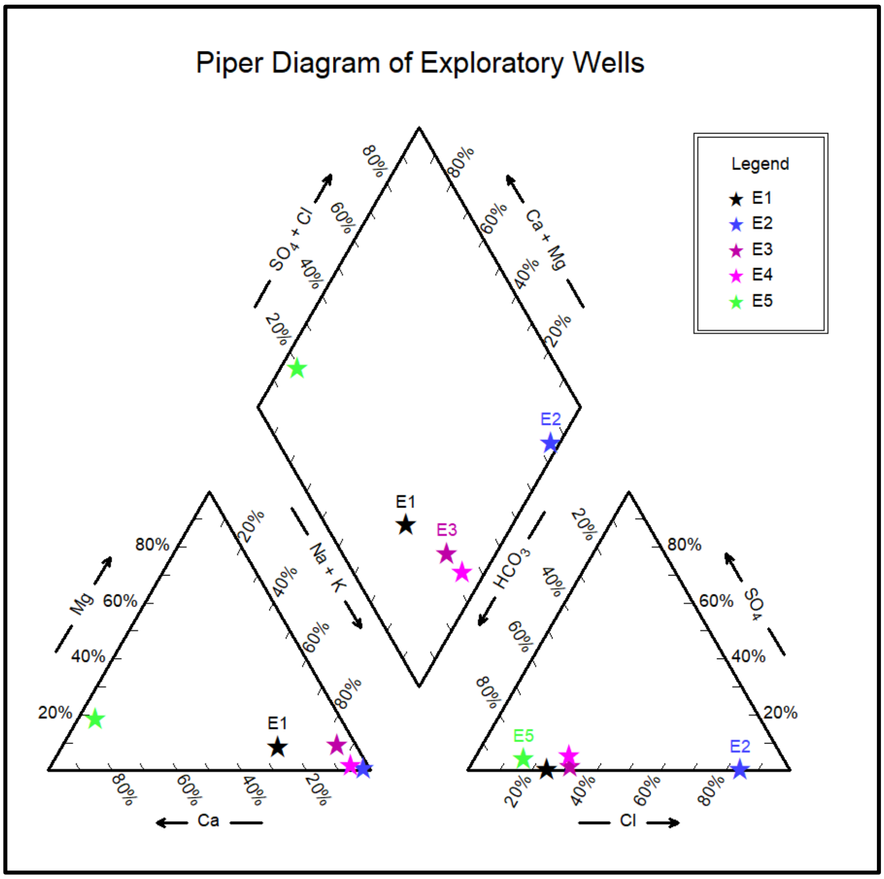


Fig. 6.1d Piper Diagram showing exploratory well water chemistry

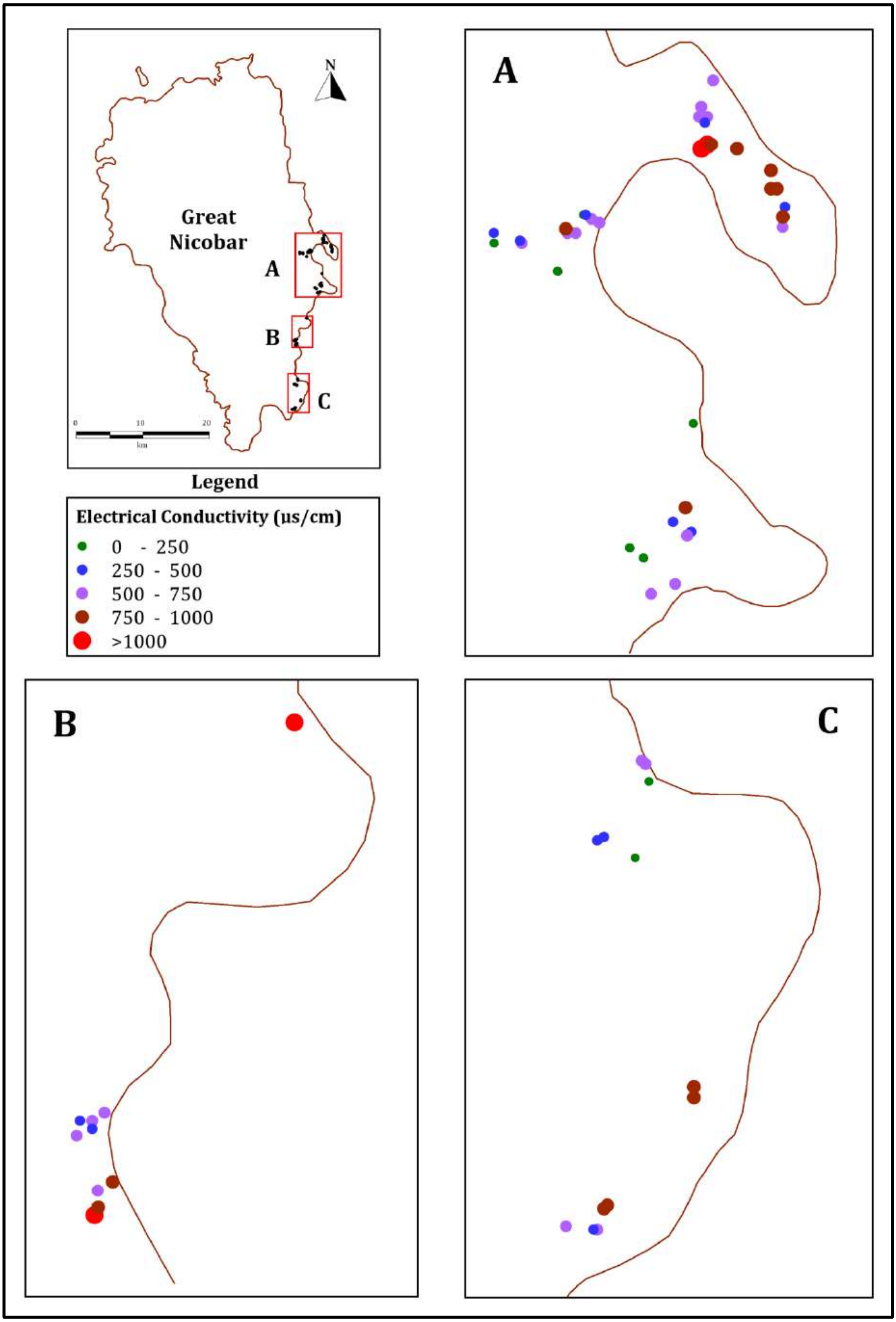


Fig. 6.1e Map showing EC variation in Great Nicobar Island

6.2. Seasonal fluctuation of Groundwater Quality

Seasonal fluctuation of groundwater quality is tested through EC variation and water sample analysis. Field measured Dry-season and Wet-Season EC are plotted as binary plot (**Fig. 6.2a**). The graph shows that wet season impart slight dilution in EC values. Statistical analysis results are given in **Table – 6.2** and histogram in **Fig. 6.2b.** Statistical analysis shows that except some outliers. It shows the EC values are more controlled by well draft *i.e.* directly related to fresh-saline interface depth.

Seasonal variations in average groundwater chemistry of Great Nicobar Island are compared using Schoeller Diagram (**Fig. 6.3a**) and Piper Plot (**Fig. 6.3b**). The plots also indicate that no significant change takes place in groundwater chemistry with the advent of rainy season.

Table 6.2 Basic Statistics for EC Variability

N of Cases	60
Minimum	-890
Maximum	932
Median	-7
Arithmetic Mean	16.55
Standard Deviation	267.75

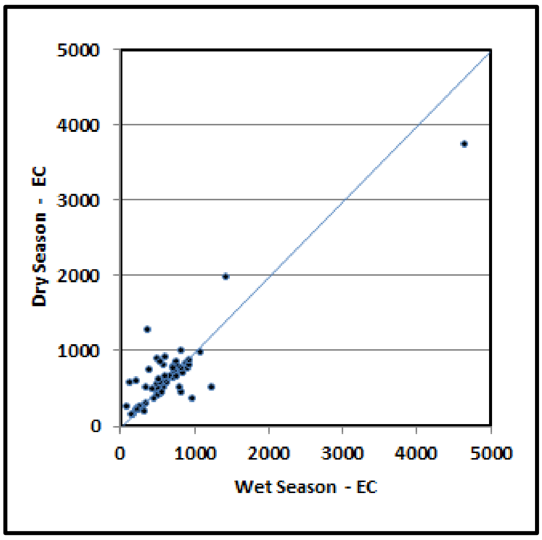


Fig. 6.2.a Binary plot of Dry-season vs. Wet-Season EC

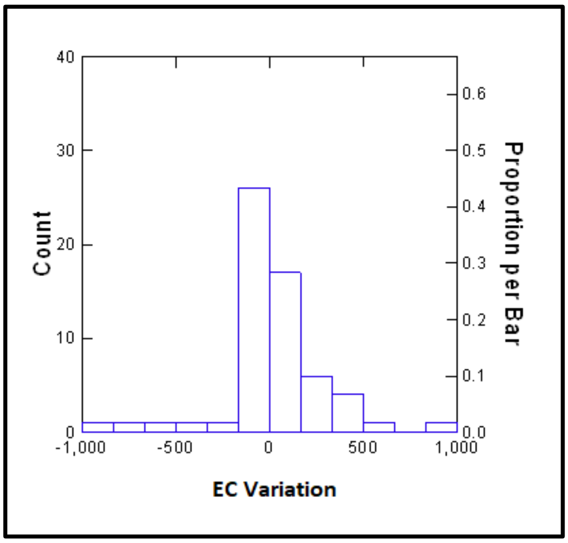


Fig. 6.2.b Histogram of EC variation

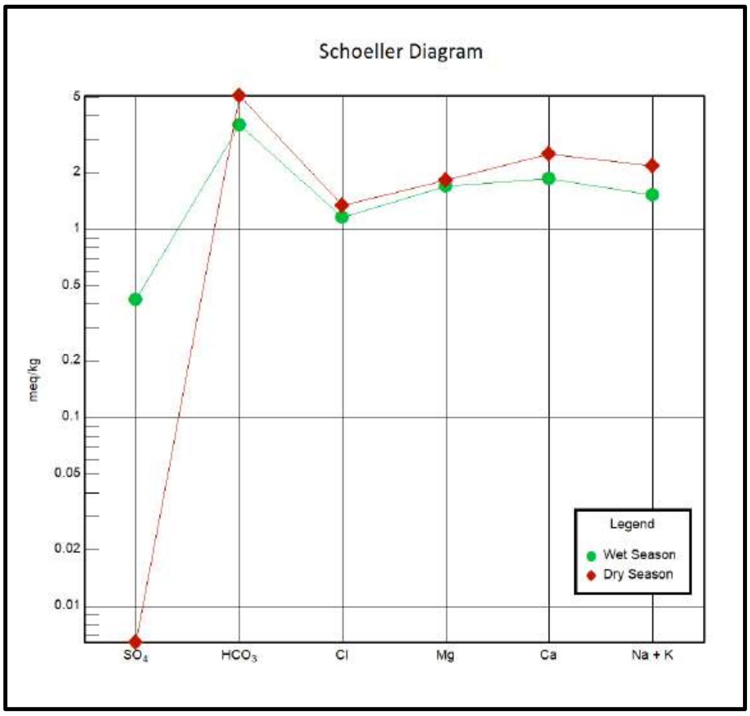


Fig. 6.3a Schoeller Diagram for major ions showing Season-wise Comparison

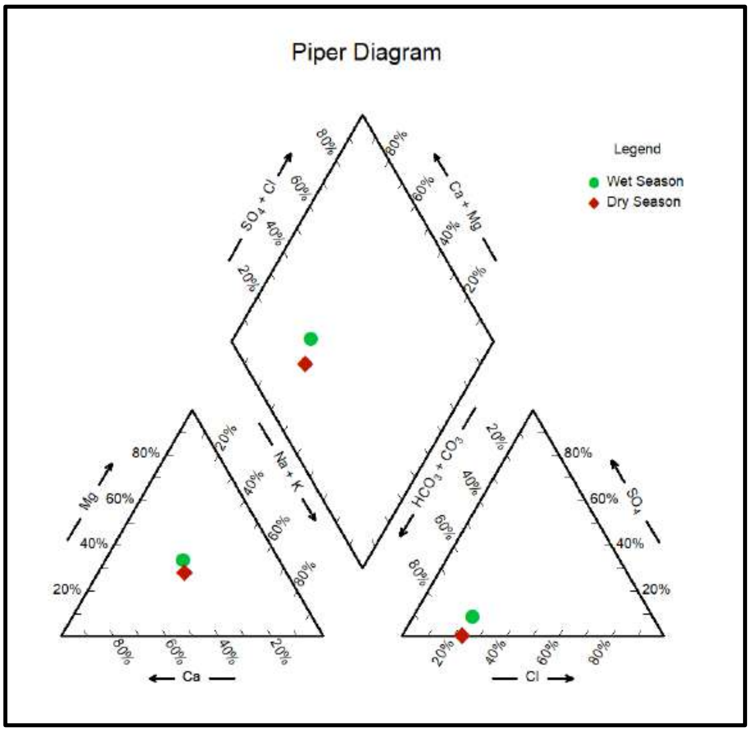


Fig. 6.3b Piper Diagram showing Season-wise Comparison

6.3 Island-wise Comparison of Groundwater Quality

Average major ion concentrations of groundwater from previous work of CIARI-ICAR in different Islands are presented in **Table 6.3**. The pH of the water samples varies from 7.3 to 7.9 with mean value of 7.6. Average EC value of various islands varies from 400 to 640 µS/cm. Average TDS value ranges from 256 to 409 ppm. Among the dissolved ions, Ca^{2+} and Mg^{2+} predominates the cation, while HCO_3^- and Cl^- dominates the anion concentration.

Average groundwater chemistry of various islands are compared using Schoeller Diagram (**Fig. 6.4a**), Piper Plot (**Fig. 6.4b**), and Durov Plot (**Fig. 6.4c**). EC and TH variation is plotted in **Fig. 6.4d**. Schoeller Diagram for major ions shows overall similarity in water chemistry for the all the islands. Departure in SO_4 values in Great Nicobar Island may be due to higher agricultural activity in Great Nicobar Island compared to other islands. The diagram also indicates similar type of geological material is responsible for water chemistry evolution. Comparison of TH and EC indicates that in Katchal Island in addition to calcium and magnesium other divalent cations are contributing to TH.

On the other hand, prepared Piper diagram and Durov diagram shows time dependent evolution of groundwater chemistry. Based on cationic composition islands are not much differentiated. On the other hand, in anionic composition, islands show a clear variability with Cl^- imparting strong variability. However, this may be result of sampling bias as Great Nicobar being the largest island has habitation more inland compared to other island where habitation is more concentrated in coastal area. Sampling points are restricted within the habitation. Over all, Piper diagram shows a saline water mixing trend with Great Nicobar showing least mixing and Katchal the most with other island in between. In term of TDS, Durov diagram shows Car Nicobar having highest average and Kamorta-Katchal the least.

Table 6.3 Status of Groundwater Quality of few Nicobar Group of Islands

Island	Average Ionic Concentration (ppm)												
	pH	EC	TDS	Ca^{2+}	Mg^{2+}	Na^+	K^+	CO_3^{2-}	HCO_3^-	SO_4^{2-}	Cl^-	NO_3^{2-}	TH ppm
Car Nicobar	7.9	640	409	37.0	18.2	14.2	7.1	0.4	85.8	2.1	74.2	1.8	165
Katchal	7.9	430	256	53.0	30.3	10.0	15.3	1.4	84.6	2.6	166.8	0.6	253
Kamorta	7.4	400	256	51.3	13.2	7.5	6.9	0.0	104.5	1.5	32.8	2.2	181
Nancowry	7.9	500	320	39.4	18.7	16.8	7.4	2.4	133.2	1.2	137.8	2.2	173

(Source: CIARI-ICAR) (Note: EC in µS /cm, TDS: Total Dissolved salts; TH: Total Hardness as $CaCO_3$)

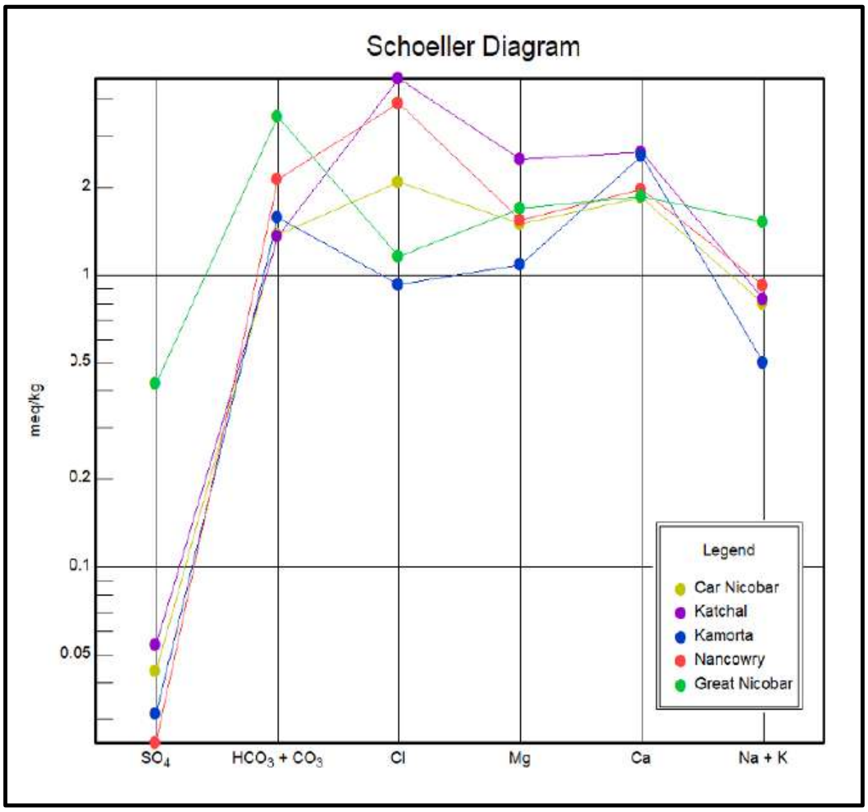


Fig. 6.4a Schoeller Diagram for major ions showing Island-wise Comparison

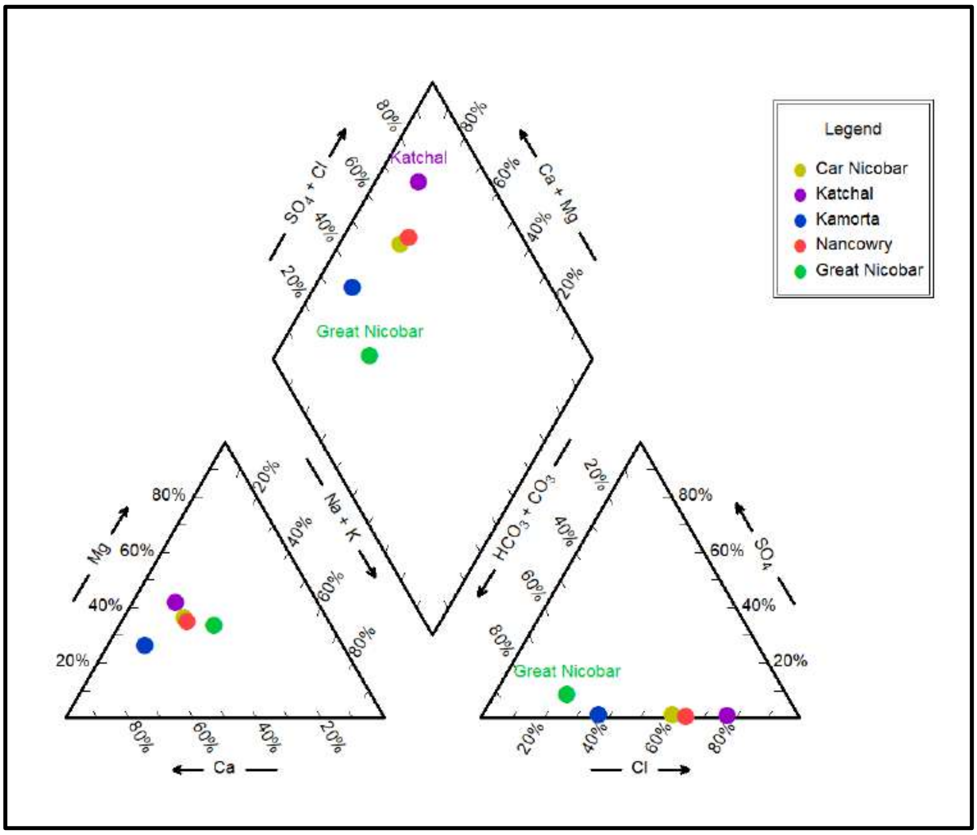


Fig. 6.4b Piper Diagram showing Island-wise Comparison

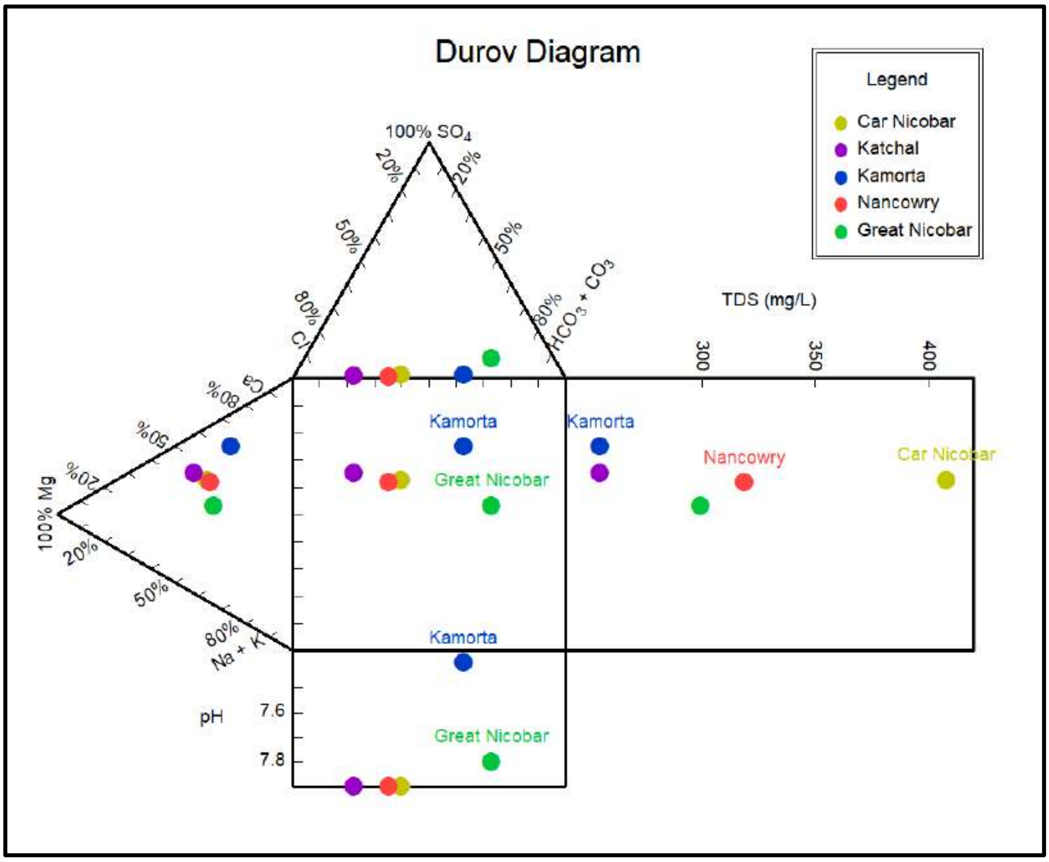


Fig. 6.4c Durov Diagram showing Island-wise Comparison

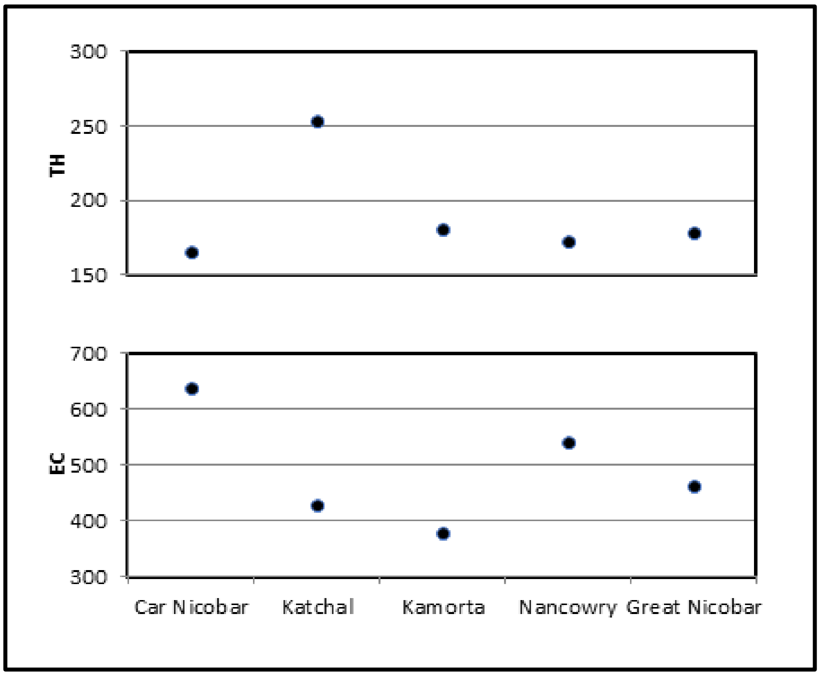


Fig. 6.4d Island-wise EC and TH variation

6.4 Hydro-geochemical Facies

Geochemical character of groundwater through hydro-geochemical facies analysis is done by plotting the concentrations of major cations and anions in Piper tri-linear diagram (Piper, 1954).

Island-wise average groundwater compositions plot in different areas of Piper diagram. The Piper diagram for island averages (**Fig. 6.4b**) for phreatic aquifer shows that Magnesium (Mg^{+}) is dominant the cation type. On the other hand, In Great Nicobar and Kamorta Islands, HCO_3^- is the dominant anionic species, whereas in Katchal, Car Nicobar, and Nancowri Islands, Cl^- is the dominant anionic species. Hence on an average, in Great Nicobar and Kamorta Islands, groundwater is **Ca-Mg-HCO_3** type and in Katchal, Car Nicobar, and Nancowri Islands, groundwater is **Ca-Mg-SO_4-Cl** type.

For Great Nicobar Island, well specific groundwater compositions plot little differently than average composition in Piper diagram. There is no single dominant cation type. All three types, Mg^{+} -dominant, Ca^{+} -dominant, and alkali (Na^{+} + K^{+}) –dominant type, are present. In the cation facies, about 40% of the samples plot into the Magnesium type, about 30% samples in Sodium and Potassium type about 25% samples in No dominant type and 05% in Calcium type. On the other hand, HCO_3 emerged as single dominant anionic species. Hence, groundwater facies is varying between **Ca-Mg-HCO_3** type and **Na-HCO_3** type.

This shows that in Great Nicobar and Kamorta Islands, groundwater is more influenced by rock composition where as in in Katchal, Car Nicobar, and Nancowri Islands, groundwater is more influenced by saline water mixing. Within island, as in case Great Nicobar, water composition is modified through saline water interaction and gets more Na^{+} dominated near coastal areas.

6.5 Evolution of Groundwater Quality

Comparison of groundwater samples from dug wells and natural springs clearly indicates that gradual evolution of groundwater and mixing process with saline water. Rock-water interaction is also assessed using Gibbs Diagram (Gibbs, 1970), which now-a-days a widely used method to establish the relationship of water composition and evolutionary mechanism. The diagram has three distinct fields of precipitation dominance, evaporation dominance and rock-water interaction dominance. However this diagram was initially developed for surface water and hence has some limitations (Marandi and Shand, 2018).

Analytical results for Island-average and for individual wells in Great Nicobar Island are plotted in Gibbs Diagram (**Fig. 6.5**). Distribution of samples in the rock dominance region of the plot in the Gibbs diagram suggests that the major ion chemistry of groundwater is controlled by chemical weathering of rock forming minerals.

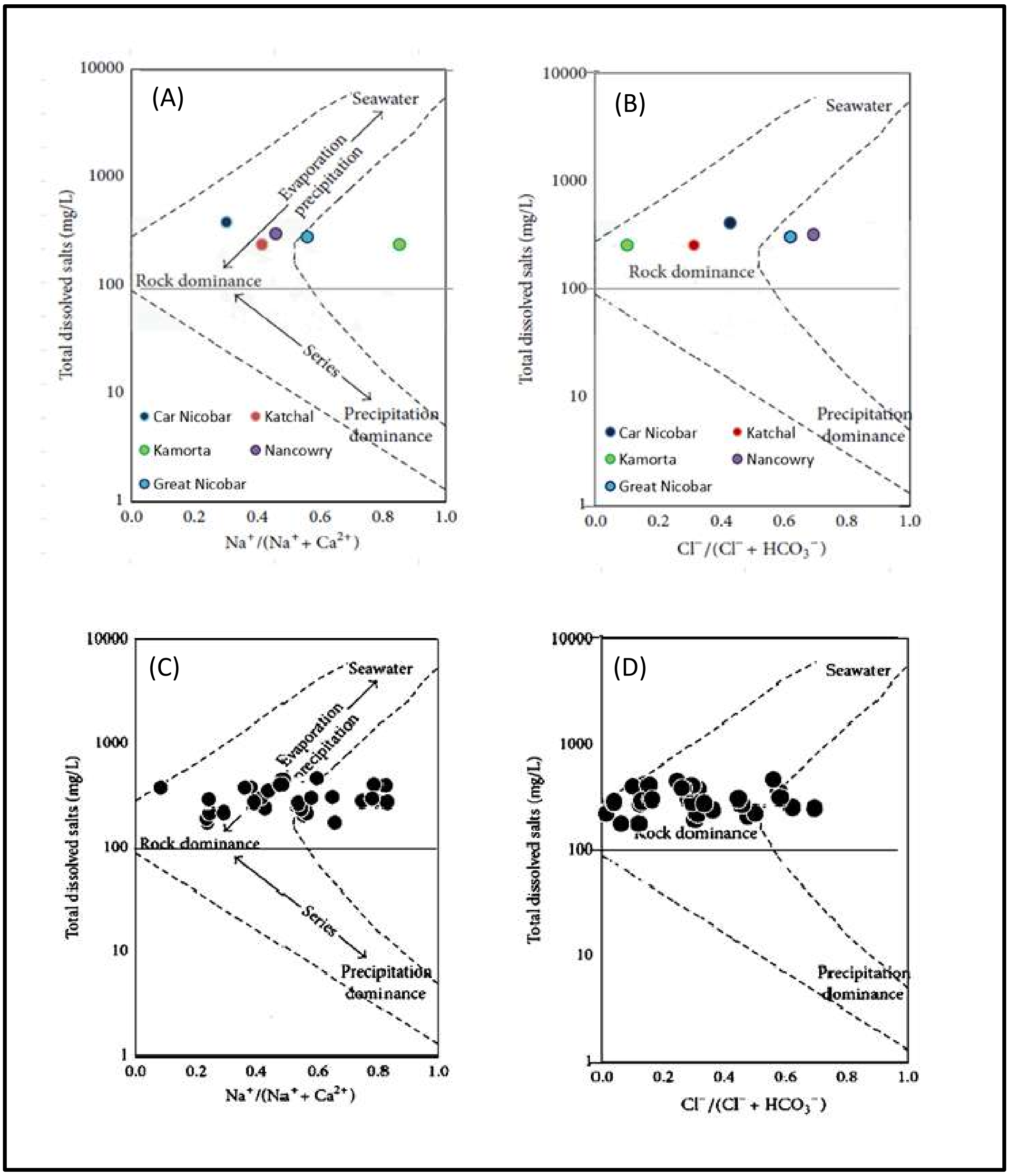


Fig. 6.5 Gibbs Diagram for Island-average (A & B) and for individual wells in Great Nicobar Island (C & D)

6.6 Suitability of Groundwater for various Uses

Each water use has specific quality need. Therefore, to set the quality standard, it is essential to identify the uses of water. Further, the quality of water required for a particular use depends on the specific application. Three main usage of groundwater is discussed below.

A. Domestic Use

The analytical results of physical and chemical parameters of groundwater were compared with the standard guideline values as recommended by Bureau of Indian Standard (BIS, 2012) for drinking and public health purposes (**Table 6.4**). It shows that on an average groundwater quality of various islands are way under ***acceptable*** limits of BIS, 2012 except iron, which is under ***permissible*** limits. Hence, groundwater quality of various islands is suitable for domestic use as per BIS standards and ***potable*** in nature.

Table 6.4 Comparison of Island Groundwater Quality with BIS Standard (2012)

Parameters	Units	BIS 2012 Limits		Island Average				
		Acceptable	Permissible	Car Nicobar	Katchal	Kamorta	Nancowry	Great Nicobar
pH		6.5 to 8.5		7.9	7.9	7.4	7.9	7.8
Total Hardness		300	600	165	253	181	173	178
Dissolved Solids	mg/l	500	2000	409	256	256	320	300.7
Calcium (as Ca)	mg/l	75	200	37	53	51.3	39.4	37.2
Magnesium (as Mg)	mg/l	30	100	18.2	30.3	13.2	18.7	20.6
Iron (as Fe)	mg/l	0.3	1.0	-	-	-	-	**0.5**
Chloride (as Cl)	mg/l	250	1000	74.2	166.8	32.8	137.8	41.1
Fluoride	mg/l	1.0	1.5	-	-	-	-	0.2
Sulphate	mg/l	200	400	2.1	2.6	1.5	1.2	20.4
Nitrate	mg/l	45	45	1.8	0.6	2.2	2.2	8.3

B. Irrigational Use

Knowledge of irrigation water quality is critical in understanding management for long-term productivity. Water for irrigation should be free of harmful contaminants and have a low salt content. In India, the Central Pollution Control Board (CPCB) has developed a concept of designated best use (CPCB, 2019). As per CPCB norm, irrigation water should have pH between 6.0 and 8.5; Electrical Conductivity at 25°C micro mhos/cm must be below 2250; Sodium absorption Ratio should be maximum 26 and maximum Boron content should be 2mg/l. As per this criteria, groundwater quality of various islands are suitable for irrigational use.

Island-wise average irrigation groundwater quality parameters and individual wells in Great Nicobar Island irrigation groundwater quality ranges are summarized in **Table 6.5** and **Table 6.6** respectively.

Table 6.5 Status of Average Irrigation Groundwater Quality of Islands

Name of the Island	pH	EC	Salinity Hazard	Sodium Adsorption Ratio	Exchangeable Sodium Ratio	Magnesium Hazard
		(μS /cm)	SH	SAR	ESR	MH
Car Nicobar	7.9	640	Medium	0.48	0.19	44.8
Katchal	7.9	430	Medium	0.27	0.09	48.5
Kamorta	7.4	400	Medium	0.24	0.09	29.8
Nancowry	7.9	500	Medium	0.55	0.21	43.9
Great Nicobar	7.9	640	Medium	1.08	0.41	47.7

Analytical results for Island-average and for individual wells in Great Nicobar Island are plotted in Wilcox Diagram and USSL Salinity diagram (**Fig. 6.6 a-d**). Island-averages behave very similarly and plot ***Excellent to Good*** class in Wilcox Diagram and ***C2-S1*** class representing **Medium salinity hazard - Low sodium hazard** in USSL diagram. On the other hand, individual wells in Great Nicobar Island, plot ***Excellent to Good*** class in Wilcox Diagram except only one sample and ***C1-S1*** to ***C3-S1*** class in. However, in USSL diagram modal class is ***C2-S1*** matching with island average. Further, observed nitrate concentration is very low as there is no contamination from agricultural sources as only natural farming is practiced without any chemical inputs. Hence, groundwater of the islands are suitable for irrigational purposes.

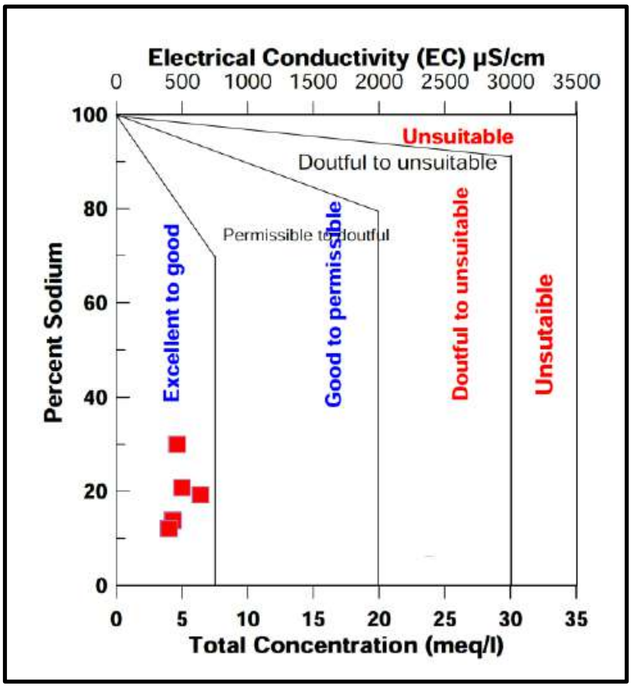


Fig. 6.6a Wilcox Diagram for Island – wise average

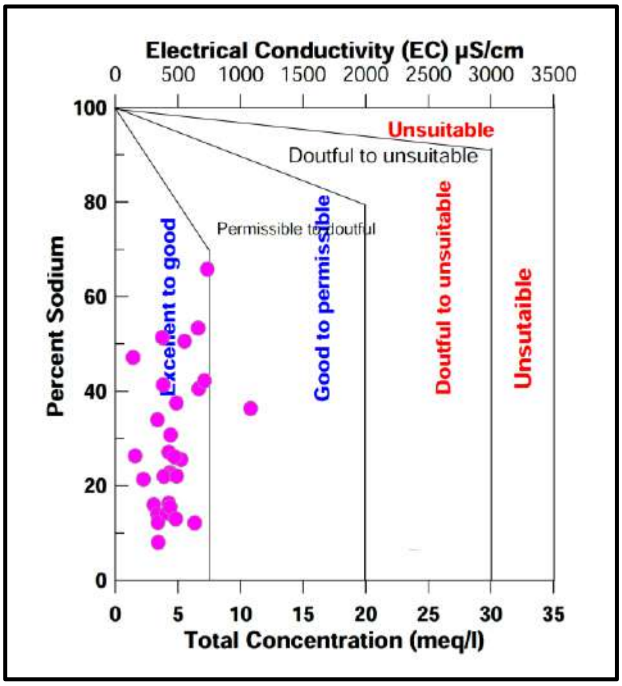


Fig. 6.6b Wilcox Diagram of for individual wells in Great Nicobar Island

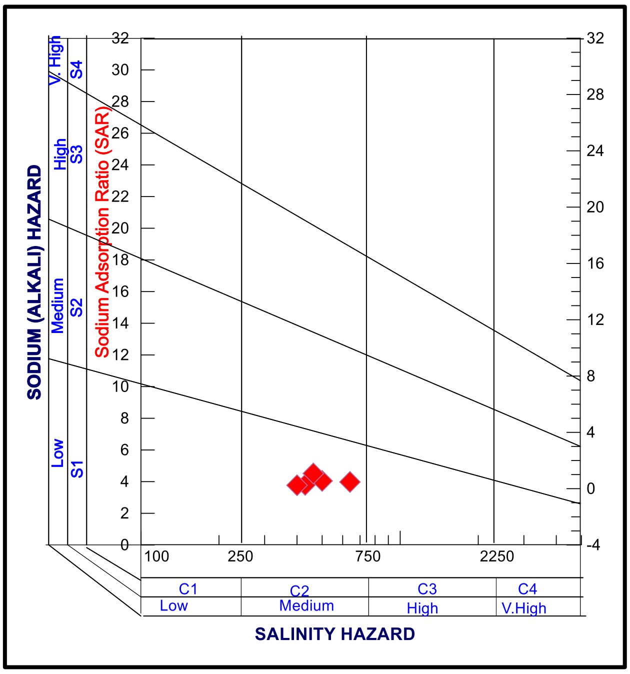


Fig. 6.6c USSL Salinity Diagram for Island – wise average

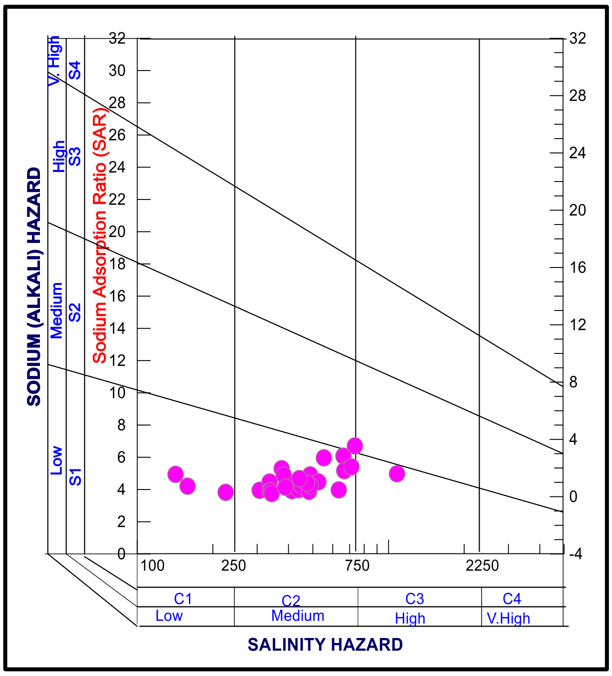


Fig. 6.6d USSL Salinity Diagram of for individual wells in Great Nicobar Island

Table 6.6 Status of Irrigation Groundwater Quality of Great Nicobar Islands

Parameters	Min	Max	Avg.	Std. Dev.
Sodium Adsorption Ratio (SAR)	0.2	3.5	1.1	0.8
Soluble Sodium Percentage (% Na)	8.0	65.8	29.0	14.8
Magnesium Hazards (MH)	9.9	72.3	46.7	13.6
Kelly's Index (KI)	0.1	1.9	0.5	0.4
Permeability Index (PI)	40.6	97.6	67.3	14.7

C. Industrial Use

Water used in manufacturing and other industrial processes should be free of contaminants that could damage equipment or affect the quality of the final product. The pH level and mineral content of the water should meet specific manufacturing requirements. In Nicobar district Island-wise average total hardness ranged from 165 to 253 ppm and classified as ***Hard*** to ***Very hard*.** However, total hardness values are within BIS prescribed limit of 300 ppm. In industrial use, this may cause scale formation in pipes and boilers.

Table 6.7 Total Hardness Classification of groundwater

Classification	Total hardness ($CaCO_3$ ppm)	Island Average
Soft	0 – 60	–
Moderately hard	61 – 120	–
Hard	121 – 180	Car Nicobar, Nancowry, Great Nicobar
Very hard	≥ 181	Katchal, Kamorta

(As per USGS, 2018 Classification)

6.7 Surface water Quality

Present study has not covered surface water quality. However, Pre-Feasibility Report (2021) of survey carried out by AECOM for Niti Aayog incorporates summary of surface water quality. As per the said report analytical results indicate that pH is within 6.38 to 7.28, which is well within the specified BIS standard 6.5-8.5. Observed TDS is within 69 mg/l to 35400 mg/l with higher side values near ocean. Dissolved oxygen ranges between 5.6 mg/l and 6.2 mg/l. The chloride and sulphate are in the range of 18 mg/l to 16300 mg/l and 4.8 mg/l to 2150 mg/l respectively. Bacteriological load varies between 580 MPN/100ML and 910 MPN/100ML.

Chapter 7

Groundwater Resource Estimation

Estimation of ground water resources on scientific basis for different States of India was made for the first time following the guidelines prescribed by 'Ground Water Over-exploitation Committee' – 1979, constituted by Agricultural Refinance and Development Corporation (ARDC) headed by the Chairman, CGWB. CGWB and State Ground Water Departments computed the gross water availability by ARDC norms. To make the methodology more realistic, Govt. of India constituted a new committee on ground water estimation (GEC) in 1982 headed by the Chairman, CGWB. The Committee prescribed guidelines for estimation, which was known as GEC' 1984 Methodology. Later estimation methodology is modified and became known as GEC' 1997 Methodology. Ground water estimation methodology is further modified in 2015 namely, GEC 2015 Methodology. As per GEC' 2015 Methodology island-wise groundwater resource availability are calculated as part of a separate exercise in 2022.

7.1 Principal Attributes of GEC' 2015 Methodology

The methodology recommends aquifer-wise ground water resource assessment of both the Groundwater resources components*, i.e.*, Replenishable Ground Water Resources or Dynamic Ground Water Resources and In-storage Resources or Static Resources. Wherever the aquifer geometry is not firmly established for the unconfined aquifer, the in-storage ground water resources is to be assessed in the alluvial areas down to the depth of bed rock or 300 m, whichever is less. In case of hard rock aquifers, the depth of assessment would be limited to 100 m. In case of confined aquifers, if it is known that groundwater extraction is being done from this aquifer, the dynamic as well as in-storage resources are to be estimated. If it is firmly established that there is no ground water extraction from this confined aquifer, then only in-storage resources of that aquifer is to be estimated. Until aquifer geometry is established on appropriate scale, the existing practice of using watershed in hard rock areas and blocks/ mandals/ firkas in soft rock areas may be continued.

7.2 Parameters Considered

In contrast to standard methodology, where C.D. Blocks are considered as assessment unit, here inhabited islands form the assessment units. In an island, the inter-montané valley and relatively flat topographical areas are considered as its recharge areas. The hilly areas having slope more than 20% are deducted from the geographical area of the islands. Since water level data for Nicobar group of Islands are not available, only rainfall infiltration method is adopted for computation of ground water resource. Considering, variation in lithology, rainfall infiltration factor is applied island-wise and range from 0.04 to 0.22. Total annual rainfall in Nicobar district is taken as 2805 mm.

In absence of major intervention structures, only pond recharge is considered as additional source of recharge. At present, all the ponds constructed by irrigation department / APWD are of similar size and are of 30m × 22m × 3m dimension. For recharge by ponds, 1.44 mm/ha/day recharge rate is considered. In these islands rainfall takes place for about 8 months *i.e.* 240 days and the rest *i.e.* 125 days are non-rainfall days. It is considered that the ponds contain water for 60 days out of 125 non- rainfall days.

As these islands show high slope areas, Natural Ground Water Discharge of 10% of Annual Replenishable Ground Water Resources is considered. Per capita per day ground water draft is considered as 55 litres as per APWD norm. Projected Census (2011) population figures are utilized to arrive at total groundwater draft.

7.3 Assessment Tools

Ground Water Resource Assessment (2022) for Nicobar district is carried out as per GEC 2015 guidelines through 'IN-GRES' tool. IN-GRES is a software/web-based application developed by Central Ground Water Board (CGWB) in collaboration with Indian Institute of Technology-Hyderabad for assessment of ground water resources.

The IN-GRES tool provides common and standardized platform for Ground Water Resource Assessment for the entire country based on Ground Water Resource Estimation Committee-2015 (GEC-2015) methodology. It also helps in Pan-India operationalization for Joint assessment by CGWB and State Ground Water Departments. Visibility dashboards allow users to view the data/map and download reports along with GIS based thematic map of assessment units.

7.4 Groundwater Resource Position

Reassessment of Dynamic Ground Water Resource (2022) is carried out as a joint exercise of CGWB and APWD. The State Level Committee (SLC) supervised the entire work. The estimation was completed and placed before the empowered SLC on 30.08.2022, wherein it was approved and adopted. Island-wise groundwater resource position is given in **Table 7.1**. Graphical representation of island-wide variation in Annual Extractable Ground Water Resource as per GWRE – 2022 in Nicobar District is given in **Fig. 7.1.** Total Annual Extractable Ground Water Resource in Nicobar district is 0.31 bcm as per GWRE – 2022

As such all the islands are under ***Safe*** category with overall Stage of Groundwater Extraction (SGWE) of the district 0.28 % with the exception of Chowra Island, which has been categorized as ***Saline.*** Graphical representation of island-wide variation in stage of groundwater extraction as per GWRE – 2022 in Nicobar District is given in **Fig. 7.2.** It shows that groundwater regime of Nicobar district is till-date quite pristine.

7.5 Comparison with Earlier Estimation

The District had also been assessed for its' groundwater resource during 2020. As such there is no change in categorization of any island. However, depending on rainfall pattern of assessment year (2022) and demographic variation over time, a minor change in Recharge-Draft scenario is observed. Based on that, overall Stage of Groundwater Extraction (SGWE) of the district is improved from 0.61% to 0.28% in terms of fresh groundwater resource. District-level comparison of groundwater resource position during 2020 and 2022 are given in **Table 7.2**.

7.6 Future of Groundwater Resource Position

In view of modeled rainfall pattern, the northern group of islands will experience diminishing quantity of rainfall, the southern group of islands will experience increased quantity of rainfall with middle group of islands will not experience much change in quantity of rainfall. As earlier exercises indicated that rainfall is directly proportional to groundwater resource, the northern group of islands will deplete in groundwater resource, the southern group of islands will enrich in groundwater resource with middle group of islands will not experience much change.

Table 7.1 Island-wise GW Resource Position as per GWRE – 2022 in Nicobar District

Sl. No	Assessment Unit Name / Island Name	Recharge from Rainfall (M)	Recharge from Other Sources (M)	Recharge from Rainfall (NM)	Recharge from Other Sources (NM)	Total Annual Ground Water Recharge	Total Natural Discharges	Annual Extractable Ground Water Resource	Irrigation Use	Industrial Use	Domestic Use	Total Extraction	Annual GW Allocation for Domestic Use as on 2025	Net Ground Water Availability for future use	Stage of Ground Water Extraction (%)	Categorization
1	TERESSA	161.7	0.0	214.0	0.0	375.7	37.6	338.1	0.0	0.2	6.4	6.6	6.8	331.1	1.9	*Safe*
2	CAR NICOBAR	1014.2	0.1	1342.5	0.0	2356.9	235.7	2121.2	0.2	0.2	42.5	42.9	45.5	2075.3	2.0	*Safe*
3	TRINKET	87.6	0.0	116.0	0.0	203.7	20.4	183.3	0.0	0.0	0.0	0.0	0.0	183.3	0.0	*Safe*
4	GREAT NICOBAR	11397.3	0.7	15086.9	0.2	26485.0	2648.5	23836.5	0.0	0.1	19.2	19.3	20.5	23815.8	0.1	*Safe*
5	KAMORTA	724.4	0.0	959.0	0.0	1683.4	168.3	1515.1	0.0	0.1	8.8	8.9	9.4	1505.5	0.6	*Safe*
6	KATCHAL	776.2	0.0	1027.5	0.0	1803.7	180.4	1623.4	0.0	0.1	4.6	4.7	4.9	1618.3	0.3	*Safe*
7	CHOWRA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	*Saline*
8	TILLANGCHANG	101.7	0.0	134.6	0.0	236.3	23.6	212.7	0.0	0.0	0.1	0.1	0.1	212.6	0.0	*Safe*
9	KONDUL	49.7	0.0	65.8	0.0	115.5	11.6	103.9	0.0	0.0	0.0	0.0	0.0	103.9	0.0	*Safe*
10	NANCOWRIE	142.7	0.0	188.9	0.0	331.6	33.2	298.4	0.0	0.1	2.4	2.6	2.6	295.7	0.9	*Safe*
11	BAMPOOKA	73.3	0.0	97.0	0.0	170.3	17.0	153.3	0.0	0.0	0.0	0.0	0.0	153.3	0.0	*Safe*
12	LITTLE NICOBAR	374.5	0.0	495.7	0.0	870.2	87.0	783.2	0.0	0.0	0.7	0.7	0.8	782.4	0.1	*Safe*
13	PULO MILO	13.8	0.0	18.2	0.0	32.0	3.2	28.8	0.0	0.0	0.0	0.1	0.1	28.7	0.2	*Safe*

(M: Monsoon; NM: Non-Monsoon; All figs except SGWE are in ha-m)

Table 7.2 Comparison of GWRE'2022 and GWRE'2020, Nicobar District

GW Type	Year	Annual Replenishable Recharge			Environmental Flow	Annual Extractable Recharge	GW Extraction				Stage of GW Extraction (%)
		Rainfall	Other sources	Total			Domestic	Industrial	Irrigation	Gross	
Fresh	**2022**	34663.16	1	34664.16	3466.4	31197.75	84.67	0.94	0.25	85.84	0.28
	2020	15184.09	1	15185.09	1518.51	13666.58	82.26	0.94	0.44	83.63	0.61
Saline	**2022**	348.40	0.00	348.40	34.84	313.56	3.02	0.00	0.00	3.03	0.97
	2020	299.74	0.00	299.74	29.97	269.77	2.94	0.00	0.00	2.94	1.09

(All figs except SGWE are in ha-m)

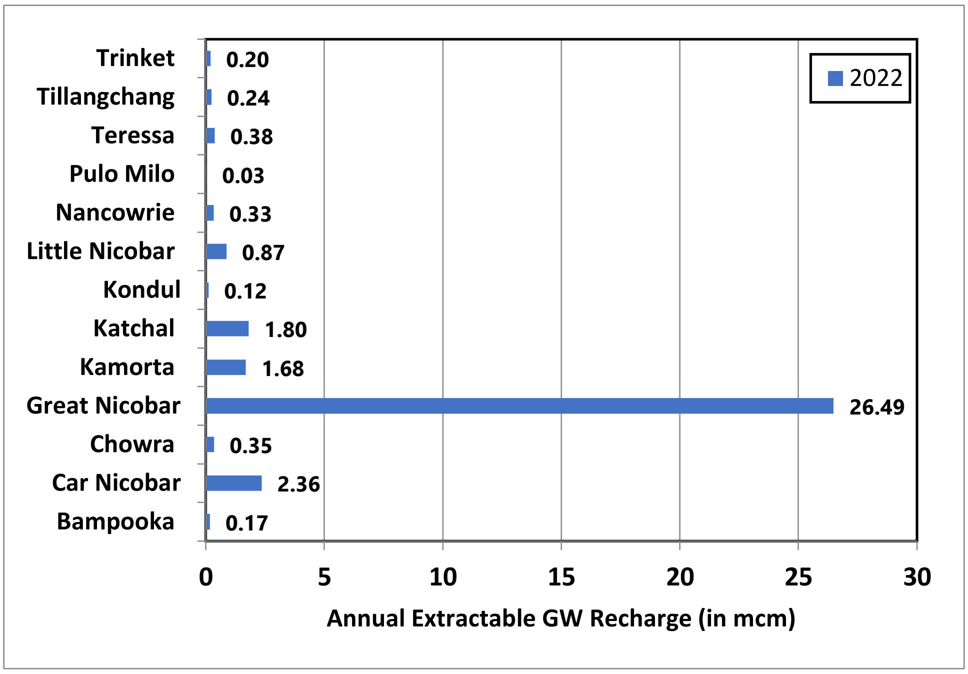


Fig 7.1 Island-wise Annual Extractable Ground Water Resource as per GWRE – 2022 in Nicobar District

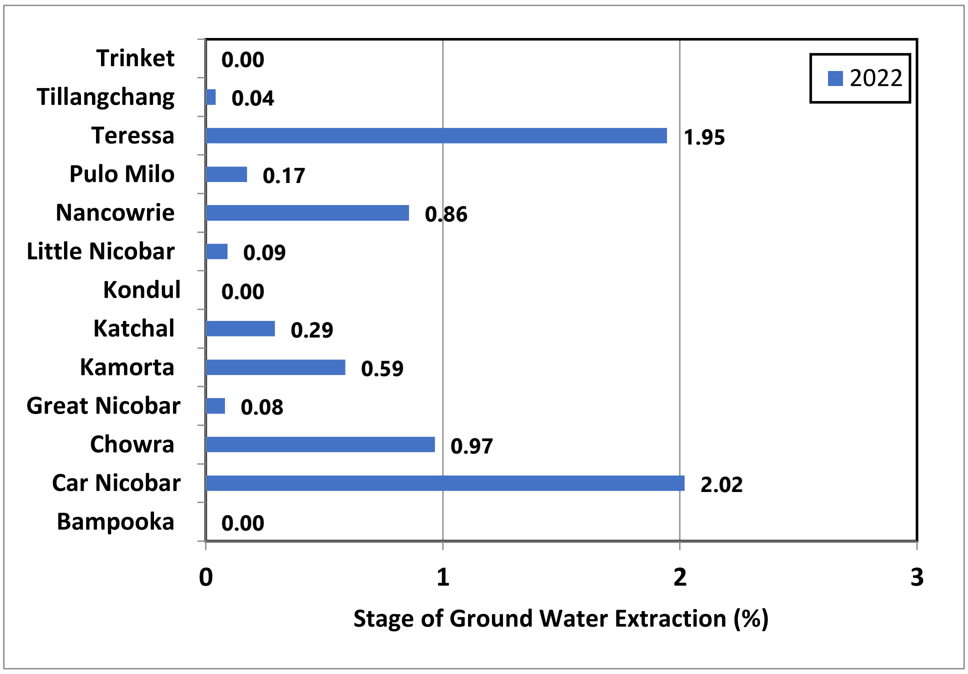


Fig 7.2 Island-wise Stage of Ground Water Extraction (%) as per GWRE – 2022 in Nicobar District

Chapter 8

Groundwater Management Strategy

Groundwater development of an area is the net result of groundwater use by various sectors including domestic, agricultural, industrial, *etc*. It's already discussed in previous Chapter-7 that all the islands of Nicobar District are under *Safe* category with overall Stage of Groundwater Extraction (SGWE) of the district 0.28 % only. This indicates that groundwater regime of Nicobar district is till-date quite untouched. However, this also indicates limited availability and restricted occurrence of groundwater in the unfavorable hydrogeological setting. Whatever groundwater resource is available in these islands is not open to standard groundwater extraction methodology. Being oceanic islands, fresh groundwater commonly occurs as freshwater lens over saline water at bottom. This freshwater lens in the islands is formed due to the radial movement of the freshwater from center of the island towards the coast, as a dynamic system in hydraulic continuity with seawater. Any extraction from the freshwater lens leads to upconing of saline water from bottom. Under such circumstances strategic management of groundwater resource is essentially needed for its sustainability as well as socio-economic development of the region.

Essentially with the setup of Nicobar group of islands, there are two basic aspect of water requirement, A) Drinking and Domestic need; and B) Economic need in terms of Agricultural-Industrial activities. With growth in population, in drinking and domestic need for water is surely to be increased. Demand for food production and allied activities are also to be increased. A rough estimate of per capita fresh water resource availability in the island is carried out considering average groundwater resource of 0.25 bcm and average surface water resource of 0.003 bcm. Srivastava and Ambast (2009) attempted water resource estimation of the island, however in that attempt entire rainwater received by the islands was considered as water resource, hence not used in the present study. Surface water resource of these islands is not estimated in recent surface water resource estimate of India by CWC (2019). Hence, surface water resource is estimated considering 2500 mm rainfall, 99% runoff in view of island profiles, absence of major perennial rivers and large water bodies, 90% evapotranspiration loss and 40% groundwater recharge along with reserve in perennial river Galathea and Alexandrea. Results are given in **Table 8.1** and graphically presented in **Fig. 8.1**. Results show that, per-capita Fresh Water Resource availability declined from about 39000 m^3 in 1901 to 6800 m^3 in 2011 and approaching water scarcity. In view of proposed development of Great Nicobar Island with proposed 6.5 lakh population it will further dwindle to a meager 392 m^3 and reach "absolute" water scarcity (< 500 m^3 per year per capita, as per FAO classification). Climate change related rainfall variation will lead to further woos.

Table 8.1 Per-capita Fresh Water Resource Availability

Year	Population	Per capita Groundwater Resource	Per capita Surface Water Resource	Per capita Total Water Resource
1901	6511	38397	731	39128
1911	8818	28351	540	28891
1921	9272	26963	514	27477
1931	10240	24414	465	24879
1941	12452	20077	382	20459
1951	12009	20818	396	21214
1961	14563	17167	327	17494
1971	21665	11539	220	11759
1981	30454	8209	156	8365
1991	39208	6376	121	6497
2001	42068	5943	113	6056
2011	36842	6786	129	6915
2050 (P)	650000	385	7	392

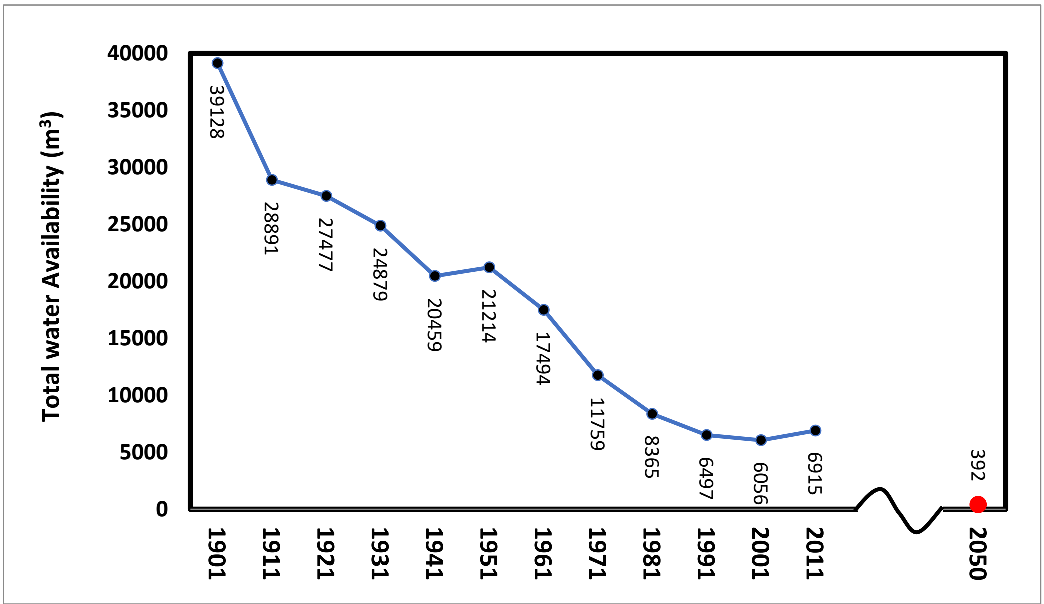


Fig. 8.1 Per-capita Fresh Water Resource Availability in Nicobar

8.1 Demand Projection

For any management present and future demand for the resource should be understood. This is needed to understand and predict resource availability – exploitation under various scenarios so that proper planning may be done.

A) Drinking and Domestic Demand

Nicobar district as a whole show very low population density of 19.52 persons /sq. km, though with strong island-wise variation. Maximum population density is observed in Car Nicobar and Chowra Island as per Census (2011) population. In general small islands show low population density. Anomalously, Great Nicobar Island on the other hand is the largest island show one of the lowest population density. This resulted in to island-wise variation in water demand for drinking and domestic purposes.

For Nicobar group of islands, considering Census (2011) population and as per APWD norm for water supply, *i.e.* 55 litres per capita per day, annual water demand for drinking and domestic purpose is 0.74 mcm. Details of computation are given in **Table 8.2**. As discussed earlier (Sec 1.4), groundwater is the main source of drinking water supply being 89.9% of all structures. Surface water contributes in 8.6% structures and rain water in 1.5% structures.

Table 8.2 Present Domestic Demands

	Island	Population Density	Population	Daily Domestic Water Need	Annual Domestic Water Need
		Persons/ Sq. km	(Census 2011)	(lt/day)	(lt/yr)
1	Car Nicobar	140.58	17841	981255	358158075
2	Great Nicobar	7.70	8046	442530	161523450
3	Chowra	153.38	1270	69850	25495250
4	Teressa	19.10	1934	106370	38825050
5	Katchal	15.40	2685	147675	53901375
6	Nancowry	15.25	1019	56045	20456425
7	Kamorta	19.61	3688	202840	74036600
8	Pilo millo	15.50	20	1100	401500
9	Little Nicobar	1.89	301	16555	6042575
10	Tillang chong	2.26	38	2090	762850
	Total =	**19.52**	**36842**	**2026310**	**739603150**
					0.74 mcm

With current decline in population, expected population in 2050 will about 25000 i.e. 1970-80's level, which will result in a water demand of 0.58 mcm of water. However, in view of proposed development of Great Nicobar Island, the island will harbor a total population of 6.5 lakh by the year 2050. Pre-Feasibility Report (2021) of survey carried out by AECOM for Niti Aayog estimated that this population translates to a water demand of 160 MLD which translates to 58.4 mcm of water demand annually. Of this 58.4 mcm water, potable water need is 32.9 mcm. Historical and Projected domestic water demands are given in **Fig. 8.2**.

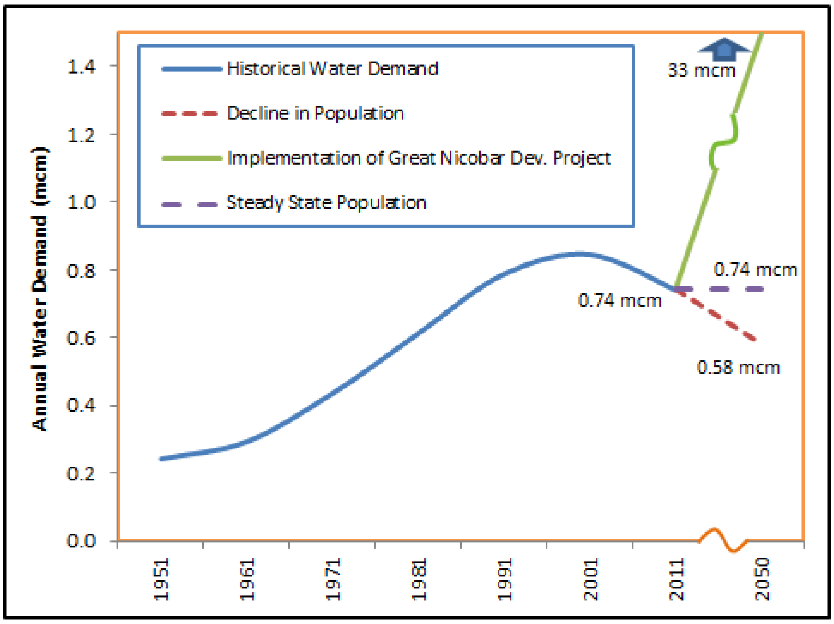


Fig. 8.2 Historical and Projected domestic water demands

B) Industrial and Infrastructural Demand

As such there is no significant industry in the district. The area is industrially backward area and classified as category 'A' (MSME, 2015). Fishing is the main economy of the area along with minor agricultural produces. This resulted in to development of very few food and fish processing units. Except this minor tailoring units, carpentry units, coir processing units and port and vehicle maintenance related units exists. All these units belong to micro and small enterprises (MSE) category.

Ground Water Resource Assessment (2022) for Nicobar district estimated about 0.94 ha-m of groundwater draft based upon industrial demand (**Table 8.3**). With current economic scenario, growth in industrial demand for water is expected only in Great Nicobar Island in the context of proposed development plan. Pre-Feasibility Report (2021) of survey carried out by AECOM for Niti Aayog estimated that industrial and infrastructural water demand of 70 MLD in Great Nicobar Island which translates to 25.6 mcm of water demand annually in 2050. Hence, altogether the district will have a water demand of 26.5 mcm annually.

Table 8.3 Island-wise Industrial Demands (Present)

Island Name	Estimated Industrial Draft (ha-m)		Total Draft
	Monsoon	Non-Monsoon	(ha-m)
Car Nicobar Island	0.065	0.133	0.20
Great Nicobar Island	0.010	0.133	0.14
Kamorta Island	0.003	0.133	0.14
Katchal Island	0.002	0.133	0.14
Nancowri Island	0.003	0.133	0.14
Teressa Island	0.061	0.133	0.19
Total =			**0.94**

(Source: A & N GWRE, 2022)

C) Irrigational Demand

As per land-use data, about 97% of reported area of these islands is under forest cover and the remaining only 3% is available for other land uses including agriculture. In Nicobar district, net sown area is only 267.9 ha. Most of the farmers in these islands are allotted with 02 ha of hilly land and 02 ha of paddy land. The hilly lands are utilized for cultivation of plantation and horticulture crops. Agricultural system is mostly rain-fed with support irrigation from ponds and dug wells. Ground Water Resource Assessment (2022) for Nicobar district estimated about 0.44 ha-m of groundwater draft based upon agricultural demand (**Table 8.4**).

In view of current trend in population growth and water scarcity not much growth in agricultural sector can be expected. Coconut and Arecanut being cash crop, is expected to grow their share in total produce. However, in the context of proposed development plan of Great Nicobar Island, vegetable produce will surely increase by many fold and will become cash crop in presence of high demand and low supply (due to remoteness of the island) scenario. This will also impact the nearby islands. Expecting 300% growth in agricultural area with 150% to 200% cropping intensity, annual agricultural water demand in 2050, will be in the tune of 2.63 mcm.

Table 8.4 Island-wise Irrigational Demands

Island Name	Estimated Irrigation Unit Draft (ha-m)			No of Abstraction Structure*	Total Draft (ha-m)
	Monsoon	Non-Monsoon	Annual		
Katchal Island	0.0002	0.0004	0.0006	10	0.006
Kamorta Island	0.0002	0.0004	0.0006	15	0.009
Nancowrie Island	0.0002	0.0004	0.0006	17	0.0102
Teressa Island	0.0002	0.006	0.0062	30	0.186
Car Nicobar Island	0.0002	0.006	0.0062	32	0.1984
Great Nicobar Island	0.0002	0.0004	0.0006	49	0.0294
Total =					**0.44**

*Cumulative representative (Source: A & N GWRE, 2022)

8.2 Demand Management

With the present and projected demand figures at hand, proper management may take suitable measures to diminish the future demand retaining the socio-economic development potentials. These steps taken at present time will pave the way towards optimal resource allocation in future.

A) Drinking and Domestic Demand Management

It's evident that Drinking and Domestic demand is the most important sector as it contributes 98.2 % of total fresh water demand. As per estimate (**Fig 8.1**), though there is a population de-growth observed in 2011, water demand expected to hover around present level of 0.74 mcm annually. However, in view of proposed development plan of Great Nicobar Island, the demand may increase to about 33 mcm annually.

As such, the district has a total water resource of 31473 ha-m (315 mcm) with groundwater component of 31197 ha-m and surface water component of 476 ha-m which is sufficient to handle the demand for water with Stage of Ground Water Extraction (SGWE) going up to only about 11%. However, considering the water table fluctuation of 1 – 1.5 m between Pre- and post- monsoon level, and saline – fresh water boundary at 10 - 20 m bgl, water table can only be lowered by maximum of 1.5 m in post- monsoon without significantly disturbing the interface. Dynamic groundwater resource by definition is groundwater present within the fluctuation zone. With such condition, no water can be withdrawn during pre-monsoon season, if anthropogenic upconing of interface is to be avoided. However, water supply systems are commonly designed for a sustained development of groundwater resources without distinction between pre-monsoon / post-monsoon scenario. In such condition, main water supply scheme should be surface water based with augmentation by groundwater based schemes.

A.1. Surface water based Water Supply

Estimated surface water resource is only 476 ha-m, which is a hindrance for the designing surface water based main water supply scheme. With such situation at hand augmentation of surface water resource is the prime need. However, a good amount of water is flowing off the island as surface run off. In absence of river gauzing data, surface run-off is estimated at 65% of rainfall after ET loss as estimated earlier. The results are summarized in **Table 8.5**. Considering run-off coefficient of 0.1 with 22 mm/hr rainfall intensity, 2200 m^3/hr peak run-off is expected per square kilometer area.

Table 8.5 Estimation of Surface Run-off

Island Name	Area	Surface Runoff
	Sq. km.	mcm
Car Nicobar	126.9	210.3
Chowra	8.2	13.6
Teressa	101.4	168.1
Katchal	174.4	289.1
Kamorta	188.2	311.9
Nancowry	66.9	110.9
Little Nicobar	159.1	263.7
Great Nicobar	1045.1	1732.3
Tillang Chong Island	16.84	27.9
Pulomillow Island	1.3	2.2
Battimaly	2.01	3.3
Meroe	0.52	0.9
Treis	0.26	0.4
Menchal	1.3	2.2
Trak	0.26	0.4
Cubra	0.52	0.9

Island Name	Area	Surface Runoff
	Sq. km.	mcm
Bompuka	13.3	22.0
Kondul	4.6	7.6
Trinket	86.3	143.0
Total	**-**	**3310.7**

Hence about 3.3 bcm of rain water gets wasted through surface run-off of which Great Nicobar island itself contributes 1.7 bcm. Several perennial river based reservoirs are needed to be constructed for the purpose of surface water based water supply scheme. Proposed artificial recharge structures specially Check Dams is expected to supplement the reservoirs.

A.2. Ground water based Water Supply

Ground water based Water Supply should be in low-key considering fragility of groundwater system in these islands. During pumping of freshwater from an aquifer having both fresh and brackish/saline water, the pressure head in the vicinity of well is lowered which ultimately leads to the rise of brackish/saline water.

Total Annual Extractable Ground Water Resource in Nicobar district is 310 mcm as per GWRE – 2022. However, estimate is on higher side considering only coastal area observations and extrapolating them to the entire island. Total Annual Extractable Ground Water Resource in Nicobar district may be ball parked at 150 mcm. Moreover, groundwater development should be done only through the suggested structures (**Table 8.6)**.

Table 8.6 Suggested structure for groundwater abstraction

Type of Structure	Depth	Topographic Feature Type	Elevation Class
Skimming Wells	Very Shallow	Coastal plains	3 – 10 m
Large diameter Dug well	Shallow (< 8m)	Foot Slope	10 – 20 m
Shallow Tube well	Moderately Shallow (< 15m)	Upland	20 – 50 m
Deep Tube well	Deep (< 30m)	Highland	> 50 m

Detailed designs of the suggested structures

As observed, water table fluctuation is within 1 – 1.5 m between Pre- and post-monsoon level and saline – fresh water boundary is lying at 10 - 20 m bgl. Based on these, topographic profile of islands and expected behavior of freshwater lens, detailed designs of the suggested structures are given below. **Table 8.7** summarizes the structure design.

A) Skimming Wells: These structures may be built in the coastal plain part of the islands where ground elevation is within 10 m. Groundwater mound is expected to be coinciding with sea level in those areas. However, groundwater from this zone should not tapped as far as possible. Various type of skimming well is possible in these areas, e.g. a) Radial collector well; b) Skimming tube well; and c) Scavenger Wells.

a) Radial collector well consisting of an open well and input radial drains on one or more sides result into shallower penetration (Kamra et al., 2019). As the radial drains collect water from defused source points at shallow depth, up-coning of saline water is greatly prevented.

b) Skimming tube well may be defined as the tube well to extract freshwater from the fresh–brackish/–saline aquifer by specifying the extraction rate so as to limit the rise of fresh–brackish/saline interface to reach effective pumping zone of the well (Vashisht and Shakya, 2016). As in these areas, freshwater zone thickness is less than 30m, multi-bore skimming tube well technique is suggested. A schematic design of multi-bore skimming tube well is given in **Fig. 8.3**.

c) **Scavenger Wells** involve the simultaneous abstraction of fresh and saline water through wells having screens in different quality zones to control the rise of the interface (Kamra *et al.*, 2019). The development of dual discharge heads due to simultaneous pumping of these wells restricts the mixing of freshwater with brackish/saline water. The discharge rates of the two wells may be adjusted in such a way that the up-coning caused by pumping from the production well could be countered by the down-coning of the interface caused by pumping from the scavenger well (Vashisht and Shakya, 2016). A schematic design of Scavenger Well System is given in **Fig. 8.4**.

Manual abstraction is preferable in radial collector well, if unavoidable, fitted pump must not exceed 1 hp. Pumping may be done only for stored water with a limit of ½ of the standing water column. In case of skimming tube wells, well to be constructed at 40% penetration ratio, i.e. only 40% of saturation thickness above fresh-saline water interface may be tapped. In all cases subsurface guard wall (Length should be three times of well depth and down to same depth) may be constructed at seaward side of the well. This will help in maintaining groundwater mound at well point. Skimming wells should not be operated continuously.

B) Large diameter Dug well: These structures may be built in the foot-slope part of the islands where ground elevation is > 10 m. Groundwater mound is expected to be strongly dipping towards coast following elevation profile in those areas. Hence, site must be a plain section within the overall slope. A 6 m diameter dugwell of maximum 8 m depth is expected to suffice the purpose. Fitted pump must not exceed 3 hp. Pumping may be done only for stored water with a limit of ¾th of the standing water column.

C) Shallow Tube well: These structures may be built in the upland part of the islands where ground elevation is > 20 m. Groundwater mound is expected to be start gently dipping towards coast in those areas. A 4" diameter slim hole of maximum 15 m depth with 3 – 5 m casing is expected to suffice the purpose. Study indicates about absence of major water bearing fracture at greater depth. Fitted pump must be below 5 hp.

D) Deep Tube well: These structures may be built in the central part of the islands where groundwater mound height is expected to be at its maximum. A 6" diameter slim hole of maximum 30 m depth with 3 – 5 m casing is expected to suffice the purpose. Hydrogeological study indicates about absence of major water bearing fracture at greater depth. Fitted pump must be below 7.5 hp.

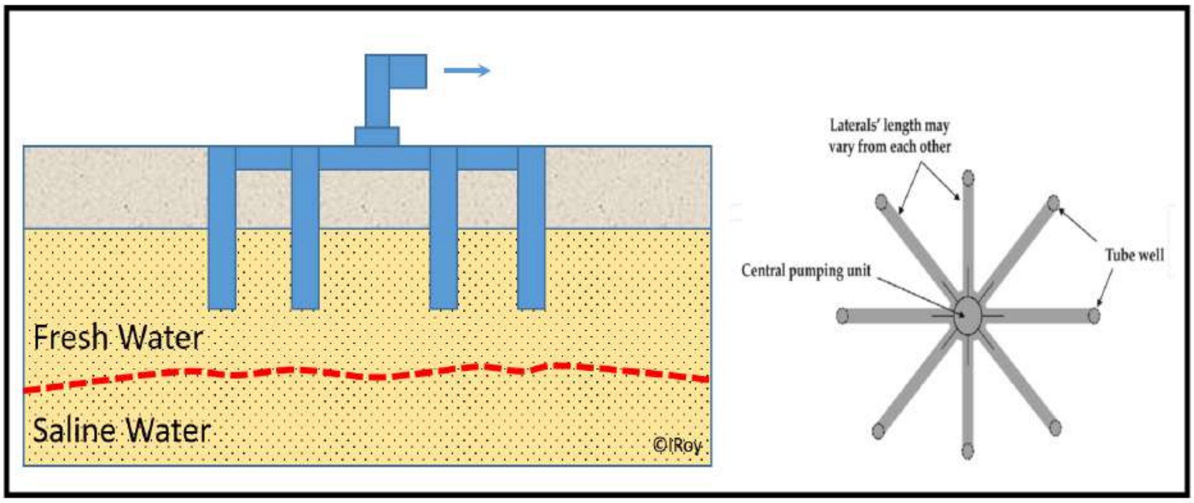


Fig. 8.3 Schematic Design of Multi-Bore Skimming Tube Well

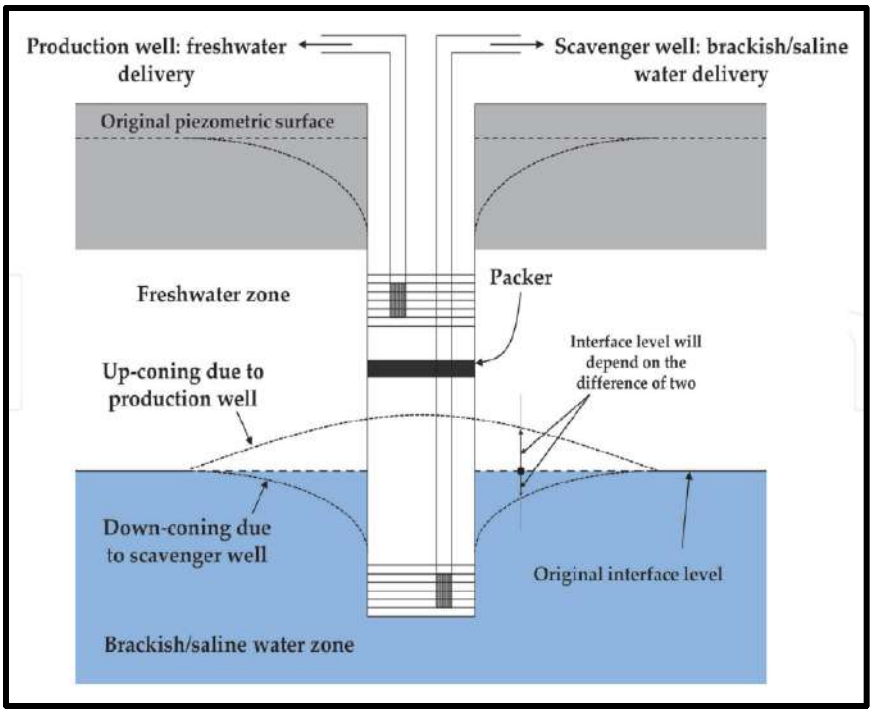


Fig 8.4 Schematic sketch showing scavenger well system installed in a single-bore hole (Vashisht and Shakya, 2016)

Table 8.7 Summary of Structure Design

Type of Structure	Maximum Depth	Diameter	Lining /Casing	Maximum Pump Capacity
Skimming Wells	3m	-	-	1 hp
Large diameter Dug well	8m	6 m	Entire	3 hp
Shallow Tube well	15m	6"	3 – 5 m	5 hp
Deep Tube well	30m	8"	3 – 5 m	7.5 hp

B) Industrial and Infrastructural Demand Management

For industrial – infrastructural demand management, suitable water planning is extremely necessary. Projected major Industrial – Infrastructural Demands in 2050 in Great Nicobar is 11.7 mcm, say 12 mcm (**Table 8.8**). With other decentralized demands, total industrial – infrastructural sector is expected to have a water demand of 26.5 mcm (AECOM, 2021).

In order to harness the water already used in domestic and drinking sector, extensive water recovery through STP and recycling it to industrial need, will lead to maximum utilization of scarce water resource. Expected, sewerage generation is 65 MLD, hence a centralized STP may reclaim about 24 mcm of water. With installation of decentralized STP, additional 3 mcm of water can be reclaimed. Hence, as such, industrial – infrastructural demand may be entirely met with recycled water. However, dual plumbing system for use of recycled water must be installed.

Table 8.8 Projected Industrial – Infrastructural Demands in 2050 in Great Nicobar

Sl.	Industry/ Infrastructure	Daily	Annual
		MLD	MCM
1.	Proposed Industries	5	1.8
2.	Green area/ Open area/ Road - Gutter washing, *etc.*	10	3.7
3.	Sea Port/ Airport, *etc.*	3	1.1
4.	Hospitals/ Medical Center *etc.*	5	1.8
5.	Defense Area/ Eco-tourism Area/ Utilities, *etc.*	7	2.6
6.	Fire Demand @1% of total	2	0.7
	Total =	**32**	**11.7**

C) Irrigational Demand Management

For irrigational demand management, suitable crop planning and intensification is most important step. In order to harness the maximum benefit from existing water resources, water management may be practiced at farm level introducing planning to modify cropping pattern as well as to meet crop-water requirement. This will ensure maximization of crop per drop of water. It can be achieved by introducing modern crop management techniques as well as modern irrigation equipments *e.g.* Drip Irrigation System.

ICAR in the context of Andaman and Nicobar Island suggested introduction of multistoried cropping in the existing coconut and arecanut plantations under organic cultivation (Velmurugan, 2016). This will result in coproduction of vegetables and spices along with coconut and arecanut. This will also help in protecting lower-tier produce from intense precipitation as well as reduce soil erosion. Similarly, introduction of drip irrigation facilities to wide spaced fruit crops like banana and papaya, intercropping with seasonal vegetables will increase water productivity.

Based upon the ICAR suggestions, PMKSY documents, and discussions with agricultural scientists of CIARI-ICAR, suggestive crop alignment with expected cropping intensity suitable for Nicobar district is prepared and given in **Table 8.9**. If implemented along with Drip Irrigation System, this is expected to reduce water consumption by about 40% by reducing area as well as increasing cropping intensity. Hence, annual agricultural water demand in 2050 will be reduce to the tune of 1.58 mcm, thereby reducing a demand of 1.05 mcm of irrigation water need.

8.3 Artificial Recharge Prospect

Considering Island setup, geomorphological context, land-use pattern and relative groundwater potentialities of underground aquifer system, only a few types of artificial recharge / conservation structures are possible for augmentation & conservation of ground water resources.

Table 8.9 Envisioned Crop Alignment and expected Cropping Intensity

Sl.	Existing cropping pattern	Proposed Modifications	Suggested Irrigation Method	Source of Water	Expected Cropping Intensity (%)
1	Coconut	Coconut + Black Pepper + Tree	Tank- Dug well with Drip	SW / GW	150
		Spices + Pineapple or Fodder	Dug well with Drip	GW	
		Coconut + Black Pepper + Vegetables	Lined Pond with Gravity-fed Drip	SW	
2	Arecanut	Arecanut + Black Pepper + Tree	Tank- Dug well with Drip	SW / GW	150
		Spices + Pineapple or Fodder	Dug well with Drip	GW	
3	Banana / Papaya and others	Fruits + Vegetables	Dug well with Drip	GW	150
		Sugarcane + Vegetables	Lined pond with Gravity-fed Drip	RW	
4	Vegetables	Vegetables - High value Crops	Dug-well with Water Pipes / Drip	GW	200
		Protected Cultivation of High Value Vegetables			
5	Waste land / Backyards	Vegetable - Vegetable	Land Shaping - Dug well	GW	200
		Protected Cultivation of High Value Vegetables	Dug well with Drip	GW	
		Floriculture Unit	Dug well	GW	
		Peri-Urban Horticulture	Rainwater Harvesting - Treated Urban Runoff	RH / TW	
6	Backyard	Fruits and Vegetables in the backyard	Dug well - Rainwater Conservation	GW / RH	150
		Community Garden in Tribal Areas			

(SW: Surface Water; GW: Ground Water; RH: Rainwater; TW: Treated Water) (Source: modified after PMKSY, 2016)

Based on topographic criterions (**Table 4.1**) and underlying lithology, individual islands have specific needs. Island specific (for main inhabited islands only) suitable Artificial Recharge Structures are given in **Table 8.10a**. Details of norms adopted for considering various Artificial Recharge Structures are given in **Table 8.10b**.

Table 8.10a Island specific suitable Artificial Recharge Structures

Islands	Gully Plug	Contour Bunding	Nala Bunding	Check Dam	Farm Pond
Car Nicobar	Y	–	Y	–	Y
Chowra	–	–	–	–	Y
Teressa	–	–	Y	–	Y
Katchal	–	Y	–	Y	Y
Kamorta	–	–	–	–	Y
Nancowry	Y	–	Y	–	Y
Little Nicobar	–	Y	–	Y	Y
Great Nicobar	–	Y	–	Y	Y

Y: Feasible

Table 8.10b Suggested norms for various Artificial Recharge Structures

Recharge Structure Type	Recharge %	Storage Capacity (MCM)	Number of Filling	Dimension	Unit Cost (in lakhs) (Approx.)
Gully Plug	60%	0.05	05	6 m x 1 m	0.4
Contour Bunding & Trenching	60%	0.05	05	300 – 400 m	1.0
Check Dam	50%	0.20	02	15 m x 3 m	15.0
Nala Bunding	60%	0.05	05	10 m x 2 m	0.6
Farm Pond	25%	0.05	05	15 m x 10 m x 3 m	2.0

Suggested locations of Check Dams are given in **Fig. 8.5.** Based on Satellite Imagery, prepared digital elevation map, drainage map and aquifer map, seventy (70) sites are selected in Great Nicobar Island. However, final locations are subject to field verification. It is expected that out of these 70 proposed sites, 30-35 site will fulfill engineering criteria. Considering implementation of 30 Check Dams sites, expected groundwater recharge is expected to the tune of 15 mcm annually.

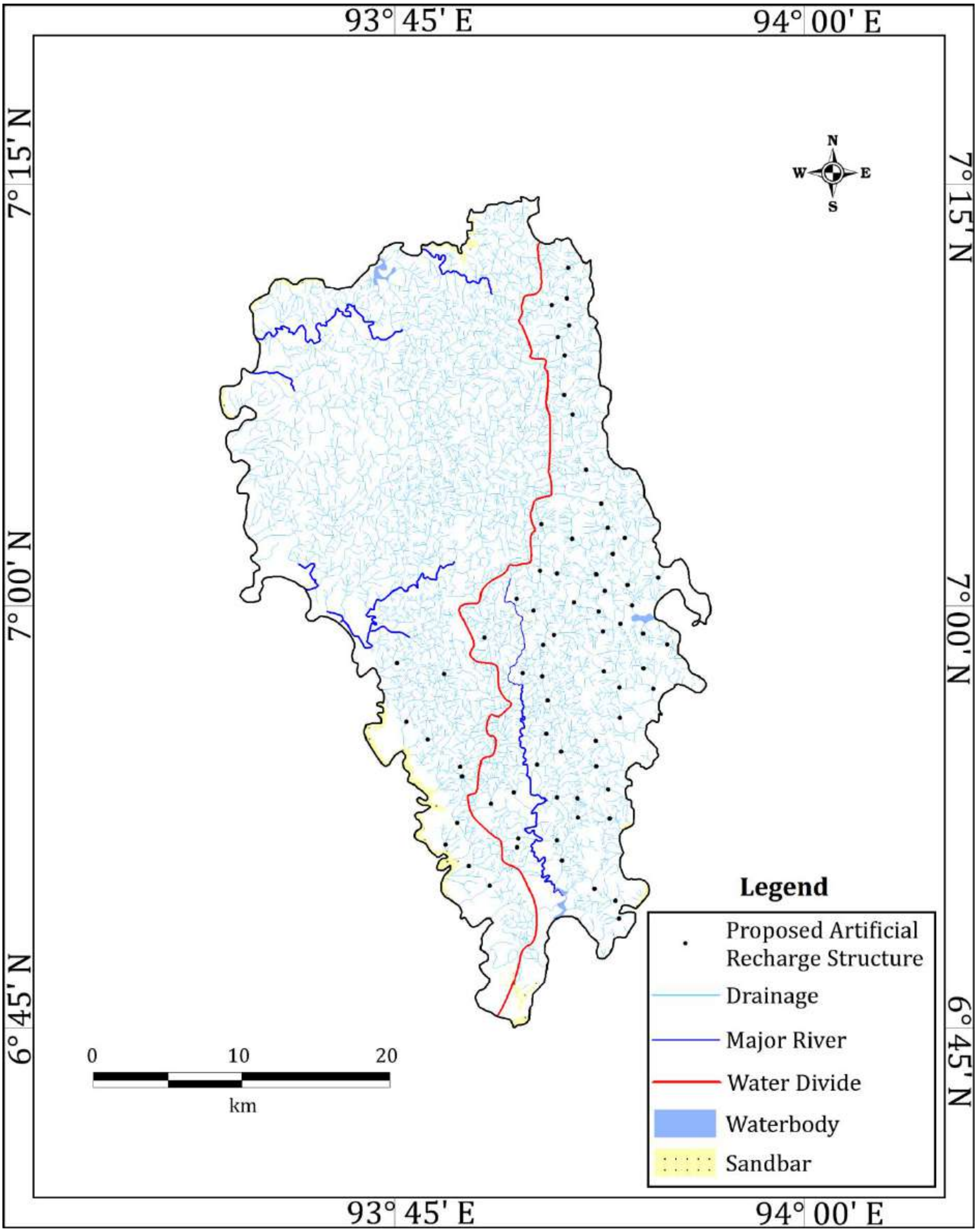


Fig. 8.5 Proposed locations of Check Dam subject to site verification

8.3 Roof-Top Rainwater Harvesting Possibility

During summer season, water becomes scarce in Nicobar Group of Islands. Roof-top rainwater collection is an essential tool to tackle such situation.

A. Possibility of Rainwater Harvesting in Traditional Tribal Houses

Two tribes namely, Nicobari and Shompen, live in the district. Nicobari constitutes the larger part and they reside in all the inhabitant Islands of the District. Shompen is on the other hand semi - nomadic tribe and reside only in certain pockets of Great Nicobar Island. Shompens being semi-nomadic, build only hutments of temporary nature. On the other hand, Nicobarese prepare permanent settlements with variety of huts.

Nicobarese Houses

A Nicobarese village consists of four types of huts, each for a specific purpose. The main circular hut with conical top called the '*ma pati tuhet*' is the principal house of a family. The '*taliko*' is the kitchen, which has a ridged roof with a long floor. The '*pati yong nyeo*' is the communal birth and the fourth type is '*pati kupah*' or death houses (Angne, 2022) (**Fig. 8.6**). Most of the Island including Car Nicobar and Chowra, near each village by the sea- shore, has '*Elpanam*' where the public buildings of the village consisting of a meeting house, a lying-in house, a mortuary and the cemetery (ANA, 2023).

These huts are often of considerable size, containing an entire family. They stand on thick piles, about 7 feet high, but vary in design. The living-houses (tuhet), are about 20 feet in diameter, and 15-20 feet in height from floor to apex. They are in the shape of something between an inverted basin and a pie-dish, covered with a heavy thatch of Lalang grass or Nipah palm. Aluminium sheets are now common, since the introduction of Indira Awas Yojana (ANA, 2023). Roofs are fastened to the framework by lashings of the cane.

Altogether, a typical *tuhet* provides a roof area of about 2722 sq. ft. (considering 20 feet diameter and 12 feet height) or say 250 m^2. With average annual rainfall of 2545 mm in the area, and assuming 60% collection efficiency considering various roof-materials, about 382 m^3 of rain water may be collected annually from each *tuhet* with monthly collection of 6 to 50 m^3 of rain water (**Table 8.11**). Considering 10% evaporation loss, the collected water may be routed through storm water drains and stored in specifically constructed pond of 30 m^3 storage capacity.

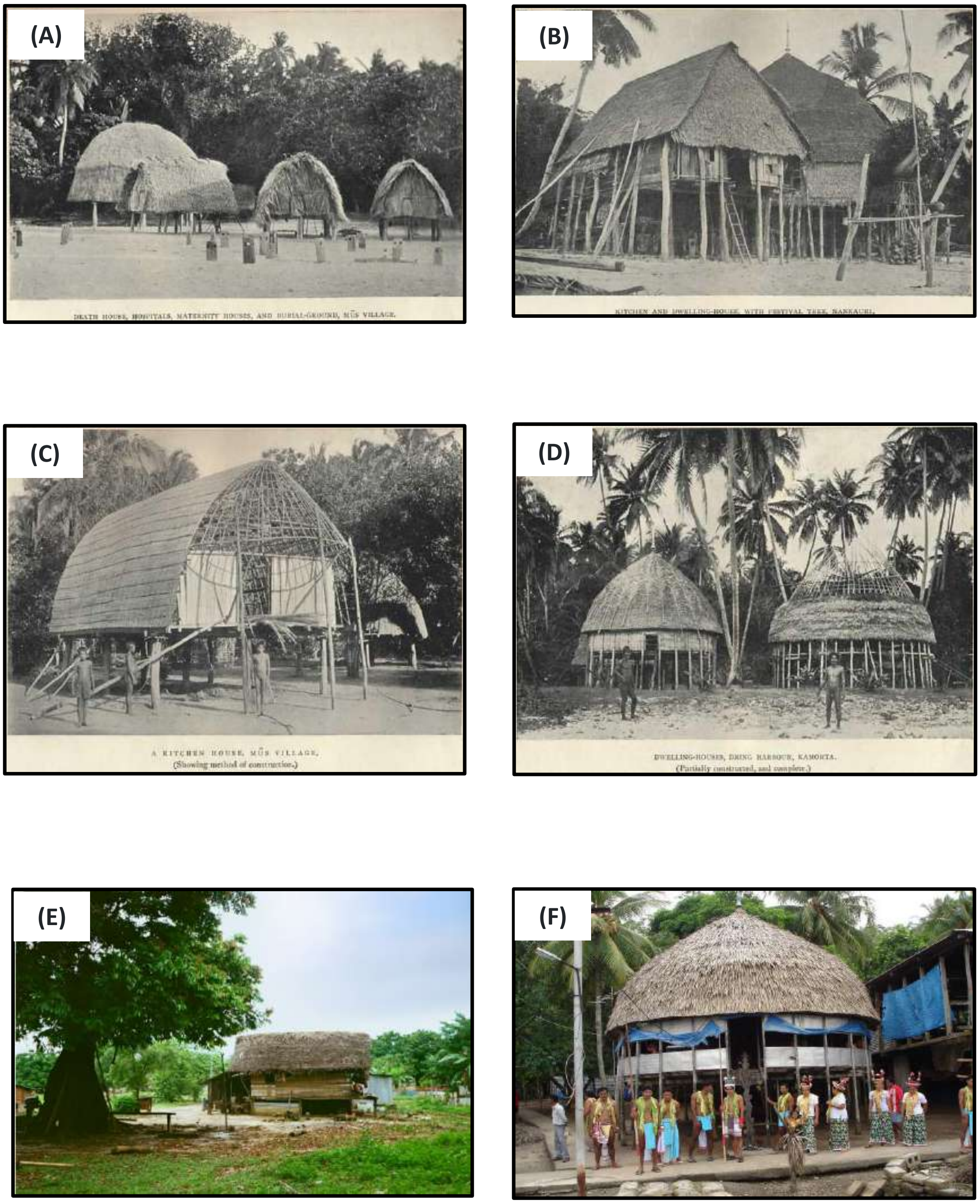


Fig. 8.6 Nicobarese Huts: (A) to (D) 120 years earlier (Boden Kloss, 1903); and (E) to (F) Modern;

The collected rainwater can be effectively used to provide irrigation to crops grown in the homestead garden during dry season and as drinking water for livestock. Island-wise potential for rainwater conservation through *Tuhets* are summarized in **Table 8.12.**

Table 8.11 Rainwater Potential of *Tuhet*

Month	Average Rainfall	Rainfall on roof of 250 m^2	Collectable Water at 60% efficiency
	(mm)	(m^3)	(m^3)
Jan	99.3	24.8	14.9
Feb	42.3	10.6	6.4
Mar	105.7	26.4	15.8
Apr	101.8	25.5	15.3
May	333.2	83.3	50
Jun	312.7	78.2	46.9
Jul	222.8	55.7	33.4
Aug	260.1	65	39
Sep	321.8	80.5	48.3
Oct	263.3	65.8	39.5
Nov	291	72.8	43.7
Dec	191.2	47.8	28.7
Total =	**2545.2**		**381.9**

Table 8.12 Quantum of Rainwater Conservation through *Tuhet*

Sl.	Island	Estimated Number of Tribal Family	Estimated Number of *Tuhet*	Ponds to be constructed	Total Water Conserved (m^3)
1	Car Nicobar	2000	500	500	15000
2	Great Nicobar	200	50	50	1500
3	Chowra	350	87	87	2610
4	Teressa	400	100	100	3000
5	Katchal	10	2	2	60
6	Nancowry	125	31	31	930
7	Kamorta	500	125	125	3750
8	Pilomillow	5	1	1	30
9	Little Nicobar	60	15	15	450
10	Tilongchang	4	1	1	30
	Total =	**3654**	**912**	**912**	**27360**
					0.027 mcm

(Considering 01 *tuhet* for 04 household)

B. Possibility of Rainwater Harvesting in Modern Houses

Using Census (2011) data, Nicobar district has about 5600 modern residential houses. Using rainfall pattern of Nicobar district with 70% efficiency of the system, every 100 m^2 of roof-area, has potential to collect 35.3 m^3 of rainwater through roof-top rainwater harvesting system. Details are given in **Table 8.13**. Design of simplified collection system is given in **Fig. 8.7**. Quantum of rainwater conservation through modern houses in various islands is in **Table 8.14.**

Table 8.13 Rainwater Potential of Individual household

Month	Average Rainfall (mm)	Volume Rainfall on roof of 100 m^2 area (m^3)	Collectable Water at 70% efficiency (m^3)	Domestic Water Use (500 lit tank)	GW Recharge (m^3)
Jan	99.3	9.9	6.9	6.9	0.0
Feb	42.3	4.2	2.9	2.9	0.0
Mar	105.7	10.6	7.4	7.4	0.0
Apr	101.8	10.2	7.1	7.1	0.0
May	333.2	33.3	23.3	15.0	8.3
Jun	312.7	31.3	21.9	15.0	6.9
Jul	222.8	22.3	15.6	15.0	0.6
Aug	260.1	26.0	18.2	15.0	3.2
Sep	321.8	32.2	22.5	15.0	7.5
Oct	263.3	26.3	18.4	15.0	3.4
Nov	291.0	29.1	20.4	15.0	5.4
Dec	191.2	19.1	13.4	13.4	0.0
	2545.2	**254.5**	**178.0**	**131.4**	**35.3**

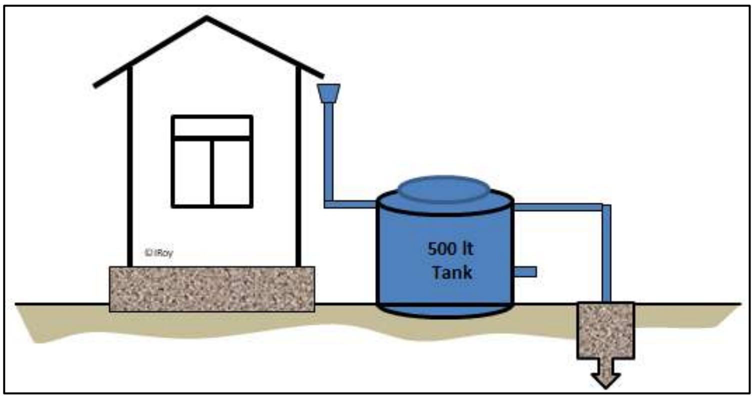


Fig. 8.7 Rainwater Harvesting in Modern Houses

Table 8.14 Quantum of Rainwater Conservation through Modern Houses

Sl.	Island	Estimated Number of Houses	Annual GW Recharge (m^3)	Total Water Conserved (m^3)
1	Car Nicobar	2250	35	78750
2	Great Nicobar	1980	35	69300
3	Chowra	17	35	595
4	Teressa	151	35	5285
5	Katchal	705	35	24675
6	Nancowry	113	35	3955
7	Kamorta	415	35	14525
8	Pilomillow	0	35	0
9	Little Nicobar	3	35	105
10	Tilongchang	0	35	0
	Total =	**5634**		**197190**
				0.2 mcm

8.3 Groundwater Recharge Initiative

Towards groundwater recharge, under ***Amrit Sarovar*** initiative of Govt. of India, 76 sources are chosen in the district. Of them 22 are in Car Nicobar Sub-district, 27 are in Great Nicobar Sub-district and 27 are in Nancowri Sub-district. As per Amrit Sarovar Mission Dashboard, (https://amritsarovar.gov.in/Masterreport) details of the work is summarised in **Table 8.15**.

Being Island, that also nearly entirely forested, developing and rejuvenating suitable water bodies is problematic mainly due to space constraint. Hence, under the scheme more farm-ponds may be constructed as in Pulobaha at Afra Bay or Govind Nagar in Great Nicobar Island. These will act as groundwater recharge structure as well as drinking and agricultural water sources. Rainfall pattern in the islands also support this type of structures.

Table 8.15 Rejuvenation of Water Bodies under *Amrit Sarovar* Scheme

Block	Total Sites	Work Initiated	Island	Village	Type of Structure	Sarovar ID
Car Nicobar	22	18	Car Nicobar	Kimious	Dug well	101216
			Car Nicobar	Perka	Pond	101217
			Car Nicobar	Malacca	Pond	101219
			Car Nicobar	Sawai	Pond	101222
			Car Nicobar	Tee-top	Dug well	101226
			Car Nicobar	Small Lapathy	Dug well	101228
			Car Nicobar	Malacca	Dug well	101229
			Car Nicobar	Big Lapathy	Dug well	101230
			Car Nicobar	Sawai	Dug well	101232
			Car Nicobar	Arong	Dug well	101235
			Car Nicobar	Tamaloo	Dug well	101238
			Car Nicobar	Kinyuka	Dug well	101240
			Car Nicobar	Chukchucha	Dug well	101244
			Car Nicobar	Kinyuka	Dug well	101252
			Car Nicobar	Mus	Dug well	101254
			Car Nicobar	Kakana	Dug well	101257
			Car Nicobar	Kakana	Dug well	101262
			Car Nicobar	Chukchucha	Dug well	101267
Great Nicobar	7	5	Great Nicobar	Govind Nagar	Pond	100142
					Pond	100824
					Pond	100890
					Pond	100900
					Pond	101215
	5	0	Great Nicobar	Gandhi Nagar		
	1	0	Great Nicobar	Kiyang		
	10	0	Little Nicobar	Pulobaha		
	1	0	Great Nicobar	Sastri Nagar		
	3	1	Great Nicobar	Vijay Nagar	Pond	100275
Nancowry	11	0	Nancowri	Kamriak		
	7	2	Kamorta	Knot	Pond	101233
					Pond	101241
	7	0	Teressa	Luxi		
	2	0	Kamorta	Mus		

(Source: https://amritsarovar.gov.in/Masterreport Accessed on 08/02/2023)

Renovated Groundwater Well at Malacca,
Car Nicobar Island

Renovation of Pond at Perka Village,
Car Nicobar Island

Renovation of Farm Pond at Vijay Nagar,
Great Nicobar Island

Renovation of Pond at Knot Village,
Kamorta Island

Fig. 8.8 *Amrit Sarovar* initiatives in Nicobar District

8.3 Expected Net-outcome of Management Interventions

Management Interventions are intended for preservation of precious water resource. In an island scenario, the resource is already scanty and its availability is vital for survival of life. Carried out aquifer mapping process is expected to improve our understanding of the geologic framework of aquifers, their hydrologic characteristics, water levels in the aquifers and how they change over time in the Nicobar group of Islands.

Based on the findings of aquifer mapping in the Nicobar group of Islands along with its demand – supply scenario at present as well as projected, several management interventions are proposed in the previous discussions. Projected and Modified Freshwater Requirements are summarized in **Table 8.16a**. Proposed management interventions are expected to cut the demand by 45% i.e. by lowering the total demand from 62.13 mcm to 34.58 mcm annually.

Intervention type specific quantitative impacts on water resource are summarized in **Table 8.16b**. It shows that management interventions are oriented more towards augmentation of resource and reuse-recycling of resource. This is to maintain the fine balance of Saline-Freshwater boundary in these islands, which if disturbed may spoil much of fresh water resource.

Table 8.16a Projected and Modified Freshwater Requirement at 2050

Need	Projected Fresh Water Resource Requirement	Management Intervention	Modified Fresh Water Resource Requirement after Management Intervention
	mcm	(Type)	mcm
Drinking & Domestic	33	Augmentation of SW + GW	33
Irrigation	2.63	Crop Modification	1.58
Industrial	26.5	Waste Water Recycling	-Nil-
Total	**62.13**		**34.58**

Table 8.16b Intervention type specific Quantitative Impact on Water Resource

Intervention	Demand Class	Impact on Water Resource			Major Impact on
		Augmented	Load Reduced	Depleted	
		mcm	mcm	mcm	
Reservoir Creation	Drinking & Domestic	20	–	–	SW + GW
Check Dam Creation	Drinking & Domestic	15	–	–	SW + GW
Groundwater Pumping	Drinking & Domestic	–	–	03	GW
Desalination Plant	Drinking & Domestic	Strategic	–	–	Sea Water
Wastewater Recycling	Industrial & Infrastructure	–	26.5	–	SW + GW
Rainwater Harvesting	Drinking & Domestic + Agriculture	0.23	–	–	GW
Other Recharge Initiatives (*eg.* Amrit Sarovar)	Drinking & Domestic + Agriculture	0.01	–	–	GW
Crop Orientation and Drip irrigation	Agriculture	–	1.05	1.58	GW
Total		`			

Most importantly, it's the People's participation that matters in water security in these islands. It is not simply providing water sources. Just because the water is available does not mean that it's being used correctly. This is where the public participation and social awareness come in. There is a need to start educating the communities on how to use water and integrate positive practices. In future scenario of developing prospect of these islands, where more than 60% of people will come to these islands from mainland, will not properly understand or undervalue the water scenario. Hence awareness generation should be the prime aim for successful implementation of all suggested management interventions. Towards this aim Central Ground Water Board (CGWB) organized a People's Participation Program (PIP) in Campbell Bay Area of Great Nicobar Island on 14th March, 2023, graced by Assistant Commissioner, Great Nicobar Sub Division and all Panchayet Pradhans along with villagers and school kids.

Fig. 8.9 People's Participation Program (PIP) in Campbell Bay Area of Great Nicobar Island on 14th March, 2023

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Annexures

Annexure – 1

Details of Key Observation Wells in Great Nicobar Island

SL no	Well ID	Island	Village	Latitudes	Longitudes	Type	Depth	Dia	MP	Approachability
							m	m	m	
1	NGN1	Great Nicobar	Joginder Nagar	6.974444444	93.92305556	Dugwell	4.5	2.72	0.45	In Chingen Basti downward to the Boundary before health & wellness centere Chingen Basti.
2	NGN2	Great Nicobar	Joginder Nagar	6.962777778	93.92194444	Dugwell	4	1.75	0.85	Infront of the godown of Shri Sandeep Kalyan, in Joginder Nagar Village WN 05 at the Culvert.
3	NGN3	Great Nicobar	Joginder Nagar	6.957222222	93.91416667	Dugwell	7	2	0.75	10km joginder nagar Inside Betel nut Garden in open space of the Billu (nick name) RHS of the road.
4	NGN4	Great Nicobar	Joginder Nagar	6.960833333	93.92027778	Dugwell	10	6	1.15	Inside the Vijaynagar Senior Secondary School Playground, Jogindar Nagar Village.
5	NGN5	Great Nicobar	Joginder Nagar	6.959444444	93.92277778	Dugwell	7	2	0.9	LHS of the main road, inside the coconut orchid of Shri Sikandi Singh. After Relex Industries pvt limited phase3 (coconut factory) Joginder Nagar.
6	NGN6	Great Nicobar	Joginder Nagar	6.958888889	93.92222222	Dugwell	7	2	0.9	RHS of the main road, inside the coconut orchid of Shri G Balu (care taker). After Relex Industries pvt limited phase3 (coconut factory) Joginder Nagar.
7	NGN7	Great Nicobar	Joginder Nagar	6.955833333	93.91611111	Dugwell	4.5	2	0.72	The well is LHS of the road, before 8km milestone and after beach side road, on Vijaynagar main road., before Clay loading location.
8	NGN8	Great Nicobar	Joginder Nagar	6.958888889	93.92222222	Dugwell	4	2	0.9	LHS of the road when going towards vijaynagar, after 9km milestone Vijay nagar /2km Jogindernagar. The well is downward infront of the Shri Bhupender singh's house after crossed road inside coconut garden. Farmer

SL no	Well ID	Island	Village	Latitudes	Longitudes	Type	Depth	Dia	MP	Approachability
							m	m	m	
										name Bhupender singh S/o Sh Jaspal singh.
9	NGN9	Great Nicobar	Joginder Nagar	6.952222222	93.92055556	Dugwell	3.2	2	0.9	DW is located near Jogindernagar beach side, owner Shri. Satnam Singh coconut orchid, when facing sea ward Dw is LHS near Old Bricks Factory.
10	NGN10	Great Nicobar	Joginder Nagar	6.950833333	93.91722222	Dugwell	3.1	2.5	0.1	RHS of the beach when facing seaward Dw is without ring Kacha well, owner Shri. Manjeet Singh S/O Shri Jagjeet Singh. Cement brickss work,M/s Manjeet traders.
11	NGN11	Great Nicobar	Vijay Nagar	6.920555556	93.90611111	Dugwell	7	1.3	0.6	Inside the House of Shri R. Daisy. LHS inside the Coconut Orchid when come from Main road to Vijay Nagar.
12	NGN12	Great Nicobar	Laxminagar	6.892222222	93.88916667	Dugwell	8	2	0.9	Inside the Coconut orchid LHS of the road before Laxminagar Village. Owner Rjaesh Chaddha and Somaru Ram.
13	NGN13	Great Nicobar	Laxminagar	6.887222222	93.89555556	Dugwell	5	1.3	0.6	At the Laxminagar sea beach side, near Sea adjecent to the Nallah.
14	NGN14	Great Nicobar	Laxminagar	6.8875	93.895	Dugwell	6	1.3	0.7	At the Laxminagar sea beach side, adj to te Old house now abondoned after tsunami,near old medical building .
15	NGN15	Great Nicobar	Laxminagar	6.888055556	93.89138889	Dugwell	8	2	1	Inside the Coconut Orchid of Shri Gyanappu, Before Ts make.
16	NGN16	Great Nicobar	Laxminagar	6.888888889	93.89444444	Dugwell	7	1	0.6	On the Bank of sea Laxminagar Old area. DW is inside the coconut orchid of Nawnath patel.
17	NGN17	Great Nicobar	Laxminagar	6.891388889	93.89194444	Dugwell	8	2	1	Inside the Coconut Garden Owner/Farmer of Shri Girish Joshi S/o Lt Shri VK Joshi.
18	NGN18	Great Nicobar	Laxminagar	6.892222222	93.89	Dugwell	8	2	0.4	The DW is inside the Coconut Orchid of Shri Ban Das S/o Mahendra Sabkal. DW s towards Sea.
19	NGN19	Great Nicobar	Laxminagar	6.891666667	93.89	Dugwell	8	2	0.8	Inside the coconut orchid of Shri Ramkrishna Bankar.

SL no	Well ID	Island	Village	Latitudes	Longitudes	Type	Depth	Dia	MP	Approachability
							m	m	m	
20	NGN20	Great Nicobar	Laxminagar	6.892777778	93.89083333	Dugwell	6	0.85	0.35	Inside the Coconut Garden of Shri Hanumant Kokere. A small dia DW is situated.
21	NGN21	Great Nicobar	Gandhinagar	6.843888889	93.89222222	Dugwell	4.5	2.3	0.9	At 30 km Gandhinagar village. Opposite to milestone and 6km Laxminagar. RHS of the road inside the house of Md. Rafique desai.
22	NGN22	Great Nicobar	Gandhinagar	6.843611111	93.8925	Dugwell	4	1.25	0.65	After 200 m from 30 km Gandhinagar RHS of the road in the Land of Shri Gangaram & Ashok Singh.
23	NGN23	Great Nicobar	Gandhinagar	6.842222222	93.89277778	Dugwell	2.5	2	0.65	At 30 km Gandhinagar village in the land of Shri Kumar Swami S/O P Kumar Swami.
24	NGN24	Great Nicobar	Gandhinagar	6.836111111	93.89166667	Dugwell	4	5.5	1.1	A Large dia DW is inside the Premises of Agriculture Sub Depot office Gandhinagar. Adj. to Type 2 quarters.
25	NGN25	Great Nicobar	Gandhinagar	6.8375	93.88861111	Dugwell	5	3	0.65	Backside of the Gandhinagar Filter Bed Plant. New DW Constructed near Spring.
26	NGN26	Great Nicobar	Gandhinagar	6.837777778	93.88916667	Dugwell	4	3	0.6	A DW is Backside of the Gandhinagar Church, Adj to the Nallah bearing a check weir.
27	NGN27	Great Nicobar	Shastrinagar	6.816944444	93.89638889	Dugwell	7	5.95	0.95	Inside the Sastrinagar Filter bed (water treatment plant) a large dia well.
28	NGN28	Great Nicobar	Shastrinagar	6.817777778	93.89638889	Dugwell	5	2	0.85	Before filter bed RHS of the road Just Adj to the Coconut Garden, In front of a House.
29	NGN29	Great Nicobar	Shastrinagar	6.808333333	93.88944444	Dugwell	5	2.75	0.85	At 35 km just at the hospital turning LHS of the Trijunction, in front of the house of Sh. Bhupendra Singh.
30	NGN30	Great Nicobar	Shastrinagar	6.808055556	93.88916667	Dugwell	4	1.2	0.6	35.05 km RHS of the road 4 pump fitted in it used for All purpose very clear water.
31	NGN31	Great Nicobar	Shastrinagar	6.806388889	93.88861111	Dugwell	6	2.25	1.05	RHS of the road at Trijunction at Galathia and Indirapoint road inside the coconut orchard of Shri Parsuram Singh.

SL no	Well ID	Island	Village	Latitudes	Longitudes	Type	Depth	Dia	MP	Approachability
							m	m	m	
32	NGN32	Great Nicobar	Shastrinagar	6.806388889	93.88833333	Dugwell	5	1.2	0.9	Just at the trijunction corner RHS on Galathia Indirapont road. A small dia DW made by Govt of Agriculture. Used for all.
33	NGN33	Great Nicobar	Shastrinagar	6.806666667	93.88611111	Dugwell	5	1.4	0.65	At Last point of Shastrinagar inside the Coconut Orchard of Shri. Ravindra Nair. 500 m from the trijunction on Galathia Indirapoint road. Clear water.
34	NGN34	Great Nicobar	Govindnagar	7.001111111	93.91138889	Dugwell	4	1.2	0.75	Starting from main road take RHS turn on Govind nagar road. DW is LHS Just 100 m after main road inside the Agriculture Land of Shri. Sukhdev Singh a small dia DW make before TS
35	NGN35	Great Nicobar	Govindnagar	7.001666667	93.91055556	Dugwell	6	1.45	1	RHS on the road inside the Agriculture Land of Shri Bittu Singh.
36	NGN36	Great Nicobar	Govindnagar	7.001666667	93.91027778	Dugwell	5	1.2	0.65	RHS on the road after 50 m from the Bittu singh land a DW is inside the land of Shri Dilip Singh.
37	NGN37	Great Nicobar	Govindnagar	7.001388889	93.90527778	Dugwell	9	1.95	0.85	take RHS and going upward after 22 km Shampon Bast milestone, Adj to the House of Shri Bodhram Kullu Govind nagar Shelter.
38	NGN38	Great Nicobar	Govindnagar	7.000833333	93.90555556	Dugwell	8.5	2	1	Adj to the Shiv temple (Govind Nagar 6km), used for all purpose.
39	NGN39	Great Nicobar	Govindnagar	7.000833333	93.90666667	Dugwell	9	2	0.85	Downward from the Shiv Temple, in the Land of Shri. Sandeep Kerketa. At 6 km Govind Nagar shelter. Return back to Govindnagar main road.
40	NGN40	Great Nicobar	Govindnagar	6.999444444	93.89916667	Dugwell	9	2	1	On the Main road in front of the Health & Wellness center Govind Nagar village.
41	NGN41	Great Nicobar	Govindnagar	6.999444444	93.89527778	Dugwell	10	1.95	0.95	Inside the Land and House of Sh. Tushar Mondal. At 7km LHS of the road 40 m downward from the road.
42	NGN42	Great Nicobar	Govindnagar	6.999722222	93.89888889	Dugwell	6	1.2	0.2	RHS of the road opposite health and wellness center Govindnagar a small dia

SL no	Well ID	Island	Village	Latitudes	Longitudes	Type	Depth m	Dia m	MP m	Approachability
										well.
43	NGN43	Great Nicobar	Govindnagar	7.000833333	93.89527778	Dugwell	6	1.3	0.95	RHS of the road before 500 m from 7 km Govindnagar at upper side.
44	NGN44	Great Nicobar	Govindnagar	6.998333333	93.98583333	Dugwell	6	1.6	0.6	Opposite to the Pursh Baba poda Niwas and adj. to the field ground. LHS of the road.
45	NGN45	Great Nicobar	Govindnagar	7.000555556	93.9125	Dugwell	3	1.1	0.7	At the starting of the RHS road from main road and backside of the Bus rest shed. All sceap machinery dumped in the land of Shri Dharmveer Sing Bansal. A small dia DW sea ward.
46	NGN46	Great Nicobar	Rajivnagar	7.016944444	93.925	Dugwell	5	1.3	0.8	Adjacent to the Airport gate of INS BAAZ LHS of the army land road, RHS of the gate. Rajivnagar 1km.
47	NGN47	Great Nicobar	Rajivnagar	7.016944444	93.92388889	Dugwell	5	1.9	0.5	Adjacent to the wall of Airport INS BAAZ 2nd well LHS of the road when going towards Army land.
48	NGN48	Great Nicobar	Rajivnagar	7.018333333	93.92416667	Dugwell	6	1.2	0.75	Opposite to the INS BAAZ 2nd well RHS going upward 50-60m inside habitation the DW is in front of the house of Smt Roduliya Ex. Pradhan.
49	NGN49	Great Nicobar	Rajivnagar	7.021944444	93.92583333	Dugwell	5	2	0.55	Inside the Rajeevnagar Machi Basti (Fishery colony) constructed by Shri. Venket Rao.
50	NGN50	Great Nicobar	Campbell bay	7.009444444	93.93388889	Dugwell	5	9	1.1	Large dia DW inside the APWD Workshop Babu lane.
51	NGN51	Great Nicobar	Campbell bay	7.006944444	93.93388889	Dugwell	5	2	0.8	Indiranagar Campbell bay Adj to the house of Mami, backside of Post office after a large dia DW (abandoned). RHS of the road when facing seaward or post office side.
52	NGN52	Great Nicobar	Campbell bay	7.006944444	93.93472222	Dugwell	5	1.2	0.8	LHS of the road when coming from Post office. In front of Skill Development Centre and INPT Guest House road. A square DW

SL no	Well ID	Island	Village	Latitudes	Longitudes	Type	Depth	Dia	MP	Approachability
							m	m	m	
53	NGN53	Great Nicobar	Campbell bay	7.004444444	93.93583333	Dugwell	5	6.1	0.75	Large dia DW in front of the gate of Coast Guard jetty Bazar area. Indian coast guard district HQ no 10 Nicobar. Adj to the Panchayat Guest house.
54	NGN54	Great Nicobar	Campbell bay	7.0125	93.92416667	Dugwell	5	10	0.9	Inside INS BAAZ DW1 adj to the Overhead tank and fuel Parking area.
55	NGN55	Great Nicobar	Campbell bay	7.013055556	93.925	Dugwell	3.1	10	0.1	Inside INS BAAZ ward room area
56	NGN56	Great Nicobar	Campbell bay	7.013055556	93.92555556	Dugwell	2.6	1.25	0.05	Inside INS BAAZ at last of ward room area in front of logistic officer room & SATCO
57	NGN57	Great Nicobar	Campbell bay	7.016111111	93.92472222	Dugwell	3.5	1.3	0.2	Inside INS BAAZ campus after air strip the other side on DSC adj to the transformer & adj to the qtr no P/123 block.
58	NGN58	Great Nicobar	Campbell bay	7.0125	93.92916667	Dugwell	3.5	1.3	0.7	LHS from the main road towards AINIDCO shop RHS of the road Purana Machhi Basti.
59	NGN59	Great Nicobar	Campbell bay	7.003055556	93.93555556	Dugwell	4.2	1.2	0.55	Inside the Kamal Basti after Kamal basti primary School RHS turn and DW is LHS. Pump fitted.
60	NGN60	Great Nicobar	Campbell bay	7.001666667	93.93555556	Dugwell	4	1.8	0.85	Inside the Kamal Basti. DW is adj to the house of Sh Etua, RHS of the shop of Gopi Seth.

Annexure – 2

Field Values for various Parameters measured in Key Observation Wells

Wet: Wet Season (May, 2022)
Dry: Dry Season (March, 2023)

Well ID	Water Level		Water Level		EC		pH		Temperature	
	m bmp	m bgl	m bgl	m bmp	μs/cm				°C	
	Wet	Wet	Dry	Dry	Wet	Dry	Wet	Dry	Wet	Dry
NGN1	1.55	1.1	0.9	1.35	200	226	8.1	9.3	28.1	27.4
NGN2	1.25	0.4	0.4	1.25	800	757	8.3	8.4	30.3	29
NGN3	1.35	0.6	0.8	1.55	160	156	8.7	8.9	29.8	29
NGN4	1.9	0.75	0.55	1.7	290	274	7.8	8.6	31.3	30.4
NGN5	1.72	0.82	0.9	1.8	480	470	7.4	7.5	28.3	27.7
NGN6	1.45	0.55	0.3	1.2	630	600	7.6	7.9	29.5	29.4
NGN7	1.1	0.38	0.83	1.55	240	252	8.4	7.8	29.5	28.7
NGN8	1.2	0.3	0.3	1.2	500	556	8.5	7.7	29.3	29
NGN9	1.65	0.75	0.95	1.85	720	721	8.1	8.7	28.6	27.4
NGN10	1.6	1.5	1.85	1.95	550	597	8.4	9.2	28	29.7
NGN11	4.22	3.62	1.75	2.35	1080	990	7.9	6.7	27.2	26.8
NGN12	3.9	3	2.55	3.45	490	422	8.1	7.1	27.2	28.3
NGN13	1.3	0.7	0.7	1.3	1220	520	9	7.6	30.2	28.1
NGN14	2.1	1.4	1.4	2.1	900	770	8.5	8.9	28.8	27.1
NGN15	2.2	1.2	0.95	1.95	870	833	8.7	9.5	28.5	28.2
NGN16	2	1.4	1.15	1.75	620	588	8.4	8.9	29.5	28.6
NGN17	2.2	1.2	0.35	1.35	580	811	8.5	8	28.7	29.5
NGN18	1.62	1.22	1.3	1.7	590	916	8.4	9.8	29.6	29.6
NGN19	3.1	2.3	2	2.8	490	900	8.5	9.3	28.6	29.2
NGN20	0.7	0.35	0.44	0.79	540	870	8.7	9.6	30	29.3
NGN21	1.6	0.7	1.15	2.05	720	738	7.8	6.5	29.1	27.4
NGN22	1.6	0.95	0.83	1.48	540	588	7.9	7	27.8	27
NGN23	0.98	0.33	1.35	2	120	590	8.3	7	27.3	27.3
NGN24	1.52	0.42	0.65	1.75	220	600	8.5	7.6	30.3	27.5
NGN25	1.4	0.75	0.53	1.18	430	506	8.4	7.9	29.7	29.4
NGN26	0.85	0.25	0.58	1.18	330	530	8.4	8	28.6	28.8
NGN27	4.55	3.6	3.5	4.45	820	450	6.9	7.8	28.5	28
NGN28	2.1	1.25	1.56	2.41	960	380	9	8.9	28.3	29.1
NGN29	3.4	2.55	2.96	3.81	760	858	7.3	6.2	28	28
NGN30	1.5	0.9	1.3	1.9	750	665	8.9	6.2	28.1	28

Well ID	Water Level		Water Level		EC		pH		Temperature	
	m bmp	m bgl	m bgl	m bmp	µs/cm				°C	
	Wet	Wet	Dry	Dry	Wet	Dry	Wet	Dry	Wet	Dry
NGN31	1.55	0.5	1.05	2.1	710	800	8.5	7.8	28.4	26.5
NGN32	1.75	0.85	1.49	2.39	380	750	8.1	7.9	27.9	27.1
NGN33	1.25	0.6	1.55	2.2	570	520	6.2	5.5	27.3	27
NGN34	1.1	0.35	0.37	1.12	520	490	8.9	8.6	28.7	27.2
NGN35	2.45	1.45	2.5	3.5	260	275	8.6	8.3	28.7	27.2
NGN36	0.85	0.2	0.5	1.15	70	276	8.3	8.4	27.5	26.5
NGN37	1.55	0.7	1.35	2.2	770	801	8.9	9.2	27.1	27.7
NGN38	1.05	0.05	0.75	1.75	510	620	9.3	8.1	30.4	29
NGN39	1.1	0.25	0.35	1.2	530	446	9.2	8	30.1	29.1
NGN40	1.08	0.08	0.8	1.8	500	410	9.1	7.2	29.6	28
NGN41	1.1	0.15	0.05	1	150	157	9.5	7.8	28.8	28.3
NGN42	0.65	0.45	1.25	1.45	350	299	9	6.9	29.5	28.2
NGN43	1.3	0.35	0.15	1.1	320	200	8.9	7.2	30	28.7
NGN44	0.75	0.15	0.65	1.25	240	228	9.3	7.4	28.9	27.9
NGN45	1.1	0.4	1.15	1.85	700	646	8.7	6.7	27.9	29.1
NGN46	0.9	0.1	0.2	1	700	770	9.1	7.6	30.4	29.1
NGN47	0.9	0.4	1	1.5	660	664	8.4	7.4	32.2	29.8
NGN48	1.3	0.55	0.6	1.35	600	676	9.1	8.8	27.7	26.9
NGN49	0.65	0.1	0.22	0.77	550	450	9.1	7.7	32.4	30.1
NGN50	4.3	3.2	1.35	2.45	930	823	9.2	8.9	30.1	30.7
NGN51	1.4	0.6	0.48	1.28	840	710	9.6	8.3	29.6	29.1
NGN52	1.1	0.3	0.85	1.65	810	1000	9.4	7.6	30.1	28
NGN53	0.9	0.15	0.27	1.02	440	380	9.1	7.7	32.2	31
NGN54	1.5	0.6	1.2	2.1	1430	1982	8.7	7.2	30.3	31
NGN55	0.15	0.05	0.45	0.55	4640	3750	9.1	7.8	31.3	31.1
NGN56	1	0.95	1.28	1.33	790	519	8.7	7.6	29.6	27.6
NGN57	0.3	0.1	1.2	1.4	360	1292	8.9	8.7	30.5	28.3
NGN58	1.35	0.65	1.25	1.95	820	785	8.6	8.4	30.5	29.2
NGN59	2	1.45	1.73	2.28	930	880	8.4	8.3	29.4	28.2
NGN60	1.1	0.25	0.85	1.7	740	680	8.5	8.6	30.5	28

Annexure – 3

Lithological logs of Exploratory Wells in Campbell Bay

Govindnagar - I				
Lithology	**Simplified Lithology**	**From**	**To**	**Thickness**
Thin surface soil underlain by claystone, soft, yellowish, with broken shell fragments	Top Soil	0.00	13.10	13.10
Argillaceous sandstone, poorly compacted, dark grey with shell fragments	Sandstone	13.10	22.40	9.30
Claystone, dark grey, soft changing to yellowish colour, with broken shells and muscovite flakes	Mudstone	22.40	27.10	4.70
Claystone, grey, soft, with thin alternations of argillaceous sandstone and ferruginous concretions	Mudstone	27.10	34.40	7.30
Claystone, grey, soft, changing to yellowish grey downward, with shale fragments	Mudstone	34.40	64.10	29.70
Shale, hard, dark grey with thin alternations of quartzitic sandstone	Shale	64.10	80.50	16.40

Note: The borehole was dry; hence abandoned

Govindnagar-II				
Lithology	**Simplified Lithology**	**From**	**To**	**Thickness**
Thin surface soil, broken coral rag and shell fragments and coralline limestone	Coralline Sand	0.00	6.30	6.3
Claystone, soft, grey showing laminations	Mudstone	6.30	12.90	6.6
Argillaceous sandstone, light grey to greenish composed of quartz, feldspar and rock fragments. Some shell fragments are present	Sandstone	12.90	15.60	2.7
Claystone, soft, grey with shell fragments	Mudstone	15.60	24.90	9.3
Siltstone, hard and compact	Sandstone	24.90	27.36	2.46

NOTE

1. Drilling below 27.36 m was not possible by Rotary Rig due to hard formation
2. The borehole was dry and hence abandoned

Army Land - I				
Lithology	**Simplified Lithology**	**From**	**To**	**Thickness**
Thin top soil and weathered rock fragments in sticky clay	Top Soil	0.00	1.80	1.80
Sandstone very fine to fine grained, loosely compacted, with sparse globular microfossils	Sandstone	1.80	13.10	11.30
Sandstone, medium to fine grained, loosely compacted with granules of quartz and rock fragments, muscovite flakes and abundant globular microfossils	Sandstone	13.10	17.80	4.70
Sandstone, medium to coarse, with microfossils and rock fragments as above, matrix dominantly argillaceous	Sandstone	17.80	41.50	23.70
Claystone, grey, soft with thin laminations of fine to medium grained sandstone loose	Mudstone	41.50	73.60	32.10
Sandstone, loose, fine to medium grained, dark grey, with thin laminations of hard, grey, shale with occasional microfossils	Sandstone	73.60	92.20	18.60
Claystone, dark grey, soft, lumpy	Mudstone	92.20	94.80	2.60
Sandstone, fine to medium grained, loose, with microfossils	Sandstone	94.80	99.50	4.70
Claystone, soft, lumpy, arenaceous	Mudstone	99.50	101.00	1.50

NOTES:

1. A piezometer has been constructed screening zones	20.00	40.00	m bgl
	76.00	81.00	m bgl
	86.00	92.00	m bgl
2. Discharge by air compressor:	<200 lph		
3. Quality:	Good		

Army Land - II				
Lithology	**Simplified Lithology**	**From**	**To**	**Thickness**
Surface soil, yellow underlain by grey, clayey sand with shell fragments	Top Soil	0.00	6.30	6.30
Claystone with thin sandstone laminations, grey, sand fine to medium, composed of rock fragments	Mudstone	6.30	36.20	29.90

Army Land - II				
Lithology	**Simplified Lithology**	**From**	**To**	**Thickness**
Sandstone, semi-consolidated, fine to medium grained, grey with thin laminations of claystone	Sandstone	36.20	38.80	2.60
Claystone, grey, soft	Mudstone	38.80	48.20	9.40
Sandstone, semi-consolidated, medium to fine grained, grey, with broken shell fragments	Sandstone	48.20	50.20	2.00
Claystone, grey, soft with broken shell fragments	Mudstone	50.20	59.40	9.20

NOTE: The borehole was dry, hence abandoned.

Civil Hospital				
Lithology	**Simplified Lithology**	**From**	**To**	**Thickness**
Clayey top soil with fragments of weathered rock	Top Soil	0.00	3.60	3.60
Claystone, ash grey, soft with thin layers of rock fragments and ferruginous nodules	Mudstone	3.60	40.80	37.20
Siltstone, massive, fine grained, grey	Siltstone	40.80	43.50	2.70
Claystone with shell fragments	Mudstone	43.50	57.40	13.90
Shale dark grey, with fagments of calcareous siltstone	Shale	57.40	66.70	9.30
Claystone, soft with thin black shale bands	Mudstone	66.70	76.00	9.30
Shale, dark grey with ferruginous concretions in the lower part	Shale	76.00	80.66	4.66

NOTE:

1. A piezometer was constructed with	39.00	43.00	m bgl
screens placed at depth ranges	56.00	60.00	m bgl

Power House				
Lithology	**Simplified Lithology**	**From**	**To**	**Thickness**
Surface soil with coral rags and shell fragments	Coralline Sand	0.00	4.80	4.80
Sandy clay, light grey to greenish with broken shell fragments, sand medium to coarse grained with rock fragments	Sandy Clay	4.80	13.00	8.20
Mudstone, sticky, grey with broken shell fragments	Mudstone	13.00	15.00	2.00
Sandstone, soft poorly compacted, greyish to greenish, composed of quartz, feldspar and rock fragments in an argillaceous matrix	Sandstone	15.00	28.95	13.95
Mudstone, greyish to greenish, soft	Mudstone	28.95	31.60	2.65
Sandstone, soft as above	Sandstone	31.60	40.90	9.30
Mudstone, greenish, soft, becoming sandy downwards	Mudstone	40.90	47.55	6.65
Mudstone-sandstone alternations in thin beds	Mudstone	47.55	52.20	4.65
Sandstone, coarse to fine grained, greyish, composed of sub-angular to subrounded grains of quartz, feldspar and rock fragments in argillaceous matrix	Sandstone	52.20	60.50	8.30

E.C. 4503 Micro-mhos/cm at 25° C
Cl: 1259 ppm

Yatrik Saw Mill, Magar Nala				
Lithology	**Simplified Lithology**	**From**	**To**	**Thickness**
Sand, loose, coarse to medium grained, grey, mixed with broken corals, shells and rock fragments	Coralline Sand	0.00	6.50	6.5
Claystone, grey, hand when dry, mixed with shells (gastropods) corals and fine to medium sand	Mudstone	6.50	17.80	11.3
Sandstone, unconsolidated, grey, fine to coarse grained mixed with corals and shale fragments, clayey at the bottom	Sandstone	17.80	25.10	7.3

Yatrik Saw Mill, Magar Nala				
Lithology	**Simplified Lithology**	**From**	**To**	**Thickness**
Claystone, dark grey, soft, mixed with corals and medium sand	Mudstone	25.10	27.10	2
Sandstone, unconsolidated dark grey, fine to medium grained, with broken shells and corals	Sandstone	27.10	31.80	4.7
Claystone, black, soft and sticky	Mudstone	31.80	39.10	7.3
Sandstone, unconsolidated, dark grey, fine grained, clayey at the bottom	Sandstone	39.10	43.70	4.6
Claystone, dark grey, sticky	Mudstone	43.70	53.00	9.3
Soft claystone and fine grained grey sandstone in thin bedded sequence	Mudstone	53.00	60.65	7.65

NOTE:

1. The borehole was unproductive.
2. Electrical Conductivity of the borehole fluid varied from 2000-3333 micro mhos/cm at 25° C
3. The borehole was abandoned.

Magar Nala				
Lithology	**Simplified Lithology**	**From**	**To**	**Thickness**
Top soil, fine sand and silt brownish to greyish broken shales and corals	Coraline Sand	0.00	6.30	6.30
Claystone, soft, grey, lumpy and sticky when wet with broken shells and corals	Mudstone	6.30	8.30	2.00
Siltstone, soft, with clayey inter-laminations, greyish	Siltstone	8.30	12.90	4.60
Claystone, dark grey, soft, with sand size corals	Mudstone	12.90	15.60	2.70
Sandstone, soft, fine to very fine grained, greyish to brownish with small chips of hard, calcareous siltstone in the lower part	Sandstone	15.60	20.20	4.60
Claystone, grey, soft with fine semi consolidated sandstone inter-laminations	Mudstone	20.20	22.20	2.00
Siltstone, semi consolidated, calcareous, greyish white with small, broken coral fragments	Siltstone	22.20	34.20	12.00
Claystone grey, soft with fine semi consolidated sandstone inter-laminations	Mudstone	34.20	43.50	9.30

Magar Nala				
Lithology	**Simplified Lithology**	**From**	**To**	**Thickness**
Calcareous siltstone, soft, grey, with claystone interlaminations	Siltstone	43.50	50.10	6.60
Claystone, soft, grey with small siltstone granules and laminations	Mudstone	50.10	57.40	7.30
Siltstone, hard, calcareous, alternating with black shale	Siltstone	57.40	63.10	5.70

NOTE:
1. A zone test was conducted between 15-20 m bgl.
2. The discharge was insignificant, E.C.: 1200 micro-mhos/cm at 25° C.
3. The borehole was abandoned.

Annexure – 4

Chemical Analysis results of selected Key Well Samples in Great Nicobar Island (May, 2022)

Sample no	Well no	Village	Type of sample	Temp	pH	EC	TH	Ca	Mg	Na	K	CO_3	HCO_3	TA	Cl	NO_3	SO_4	F	TDS	Fe
c1	NGN1	Joginder Nagar	DW	28.1	7.2	224.9	120	24	14.6	7.6	12.6	0	134.2	110	24.8	5.8	-BDL-	0.20	179.8	1.06
c2	NGN2	Joginder Nagar	DW	30.3	7.7	634.0	300	66	32.8	18.8	0.4	0	231.8	190	49.6	12.3	45	0.21	378.6	0.35
c3	NGN11	Vijay Nagar	DW	27.2	7.8	661.5	165	36	18.2	83.6	5.3	0	280.6	230	81.5	3.7	-BDL-	0.09	399.6	0.03
c4	NGN12	Laxmi nagar	DW	27.2	7.7	307.0	150	38	13.3	12.5	1.0	0	201.3	165	14.2	3.5	-BDL-	0.19	247.5	0.63
c6	NGN4	Joginder Nagar	DW	28.3	7.9	426.7	180	48	14.6	15.6	0.9	0	201.3	165	28.4	19.4	-BDL-	0.06	255.7	1.57
c7	NGN5	Joginder Nagar	DW	29.5	7.8	158.6	125	20	18.2	18.8	2.9	0	122.0	100	24.8	0.0	36	0.00	210.0	0.46
c9	NGN6	Laxmi nagar	DW	28.8	7.7	553.2	180	38	20.6	83.6	1.7	0	183.0	150	81.5	21.3	51	0.00	453.3	0.23
c10	NGN3	Laxmi nagar	DW	28.5	7.7	734.8	90	26	6.1	77.4	4.0	0	170.8	140	70.9	4.4	-BDL-	0.00	303.9	0.18
c11	NGN14	Laxmi nagar	DW	29.5	7.8	336.4	100	36	2.4	23.5	0.2	0	164.7	135	17.7	0.0	-BDL-	0.00	196.0	0.40
c12	NGN15	Laxmi nagar	DW	28.7	7.7	375.7	90	10	15.8	42.6	1.9	0	158.6	130	35.5	2.6	-BDL-	0.12	224.4	2.25
c13	NGN16	Laxmi nagar	DW	29.6	7.4	336.3	180	42	18.2	12.3	1.9	0	213.5	175	14.2	0.0	2	0.36	221.3	1.03
c14	NGN17	Laxmi nagar	DW	28.6	8.1	487.7	180	62	6.1	46.9	4.7	0	317.2	260	28.4	0.0	-BDL-	0.41	358.1	1.60
c16	NGN18	Gandhinagar	DW	29.1	7.8	340.5	250	38	37.6	15.0	1.7	0	219.6	180	24.8	16.3	30	0.04	311.7	0.69
c17	NGN19	Gandhinagar	DW	27.8	8.0	436.4	175	40	18.2	19.8	6.6	0	225.7	185	39.0	2.0	-BDL-	0.25	288.9	0.18
c18	NGN20	Gandhinagar	DW	27.3	8.0	342.9	205	30	31.6	7.1	1.9	0	164.7	135	31.9	0.0	21	0.29	224.5	0.29
c20	NGN21	Gandhinagar	DW	29.7	7.7	412.8	180	38	20.6	12.8	1.5	0	195.2	160	35.5	0.0	-BDL-	0.00	242.5	0.21
c21	NGN22	Gandhinagar	DW	28.6	7.7	382.8	125	34	9.7	38.9	2.7	0	225.7	185	35.5	0.0	-BDL-	0.00	272.4	0.29
c24	NGN31	Shastri Nagar	DW	28.4	7.9	426.1	175	28	25.5	29.5	0.7	0	250.1	205	31.9	0.0	-BDL-	0.00	282.2	0.26
c25	NGN33	Shastri Nagar	DW	27.3	8.0	437.8	205	50	19.4	16.2	1.8	0	268.4	220	28.4	2.0	5	0.00	306.6	0.72
c26	NGN34	Govind Nagar	DW	28.7	7.8	452.1	180	32	24.3	22.7	2.1	0	170.8	140	35.5	10.2	18	0.83	287.8	0.29
c27	NGN38	Govind Nagar	DW	30.4	7.9	388.7	175	40	18.2	20.2	4.2	0	244.0	200	21.3	5.2	12	0.08	277.6	0.18
c28	NGN40	Govind Nagar	DW	29.6	7.7	142.1	80	16	9.7	32.0	1.3	0	122.0	100	21.3	9.0	16	0.11	179.8	0.35
c30	NGN46	Rajivnagar	DW	30.4	7.7	482.8	200	40	24.3	11.9	3.1	0	244.0	200	31.9	0.0	3	0.89	277.6	0.40
c31	NGN47	Rajivnagar	DW	32.2	7.8	525.7	250	44	34.0	37.5	3.3	0	286.7	235	35.5	6.1	20	0.03	379.5	0.35
c32	NGN50	Campbell bay	DW	30.1	7.9	490.1	200	38	25.5	24.6	2.4	0	213.5	175	49.6	6.0	8	0.25	293.6	0.21

c33	NGN51	Campbell bay	DW	29.6	7.9	666.5	200	40	24.3	58.9	6.4	0	317.2	260	70.9	4.0	5	0.06	412.0	0.40
c34	NGN54	Campbell bay	DW	30.3	7.8	1081.0	240	42	32.8	56.9	10.3	0	225.7	185	99.3	2.1	15.6	0.03	405.7	0.29
c35	NGN56	Campbell bay	DW	29.6	7.9	473.7	185	38	21.8	29.9	0.2	0	219.6	180	63.8	0.0	5.2	0.02	302.0	0.21
c36	NGN59	Campbell bay	DW	29.6	7.8	441.8	230	40	31.6	43.9	5.2	0	244.0	200	39.0	12.5	53	0.04	383.1	0.09
c37	NGN60	Campbell bay	DW	30.5	8.0	711.8	225	42	29.1	71.7	6.4	0	366.0	300	67.4	18.1	-BDL-	0.09	467.0	0.32
S1		Gandhinagar	Spring	26	8.0	289.4	145	36	13.3	29.8	1.7	0	189.1	155	17.7	7.7	5.6	0.53	236.7	0.60
S3A		Gandhinagar	Spring	26.3	8.0	283.9	210	34	30.3	14.0	2.1	0	176.9	145	31.9	9.0	22.52	-BDL-	260.8	0.83
N1		Laxmi nagar	Nallah	28.8	7.9	148.8	105	16	15.8	10.0	1.7	0	109.8	90	24.8	2.1	10.2	0.02	156.6	0.77
N2		Laxmi nagar	Nallah	28.2	7.8	144.1	85	16	10.9	10.2	2.0	0	103.7	85	21.3	0.0	0.0	-BDL-	132.6	1.43

Annexure – 5

Chemical Analysis results of selected Key Well Samples in Great Nicobar Island (March, 2023)

Well no	Village	Type of sample	Temp	pH	EC	TH	Ca	Mg	Na	K	CO_3	HCO_3	TA	Cl	NO_3	SO_4	F	TDS
NGN33	Shastrinagar	DW	27.3	6.98	548.5	180	40	19.4	43.51	7.93	0	231.8	190	42.5	-BDL-	0.2	0.2	295.2
NGN21	Gandhinagar	DW	29.1	7.44	733.2	300	76	26.7	17.61	3.02	0	317.2	260	31.9	3.83	0.05	0.23	352.8
NGN12	Laxmi nagar	DW	27.2	7.15	445.8	210	38	27.9	9.96	4.62	0	244	200	17.7	-BDL-	0.81	0.09	248.0
NGN11	Vijaynagar	DW	27.2	7.06	1077	210	52	19.4	83.13	2.21	0	384.3	315	63.8	2.73	0.33	0.46	458.5
NGN5	Jogindernagar	DW	28.3	7.29	481	190	32	26.7	30.02	3.9	0	231.8	190	31.9	-BDL-	0.52	0.11	266.6
NGN46	Rajivnagar	DW	30.4	7.19	768.2	195	60	10.9	36.5	8.93	0	341.6	280	35.5	2.29	0.18	0.13	362.8
NGN52	Campbell Bay	DW	26.2	6.99	1162	235	54	24.3	109.57	2.06	0	427	350	109.9	0.39	0.11	0.2	561.0
S1	Gandhinagar	Spring	26	7.58	445	170	22	27.9	21.54	10.9	0	244	200	28.4	-BDL-	0.73	0.1	260.4

Annexure – 6

Soil Infiltration Test observations in Great Nicobar Island

Jogindernagar		Govindnagar	
Time	**Depth**	**Time**	**Depth**
min	**cm**	**min**	**cm**
0	34	0	30
2	33.8	2	28.8
4	33.7	4	27.2
6	33.6	6	25.9
11	33.49	8	24.6
16	33.41	10	23.7
21	33.35	12	22.8
26	33.29	14	22
36	33.19	16	21.2
46	33.11	18	20.4
56	33.05	20	19.5
		25	18.4
		30	16.9
		35	15.4
		40	14.5
		45	13.6
		50	12.7
		55	11.8
		60	11.3
		65	10.5
		70	10.1
		75	9.7
		80	9.3
		90	8.7
		100	8
		110	7.3
		120	6.9

Annexure – 7

Water level Recovery Test observations in Great Nicobar Island

A. Large diameter APWD Dug-well at Campbell Bay

APWD Dug well				
Depth	7.90 m bmp		M.P	1.16 m abg
Diameter	9.0 m		Aquifer	Fine SSt, soft, Mithakhari Gp
Date	**10.12.1986**		Time	in Minutes
Time in Hours	**Time since Pumping started**	**D.T.W (in m bmp)**	**Drawdown (m)**	**Remarks**
9:25:00 AM	-	4.707	-	S.W.L
9:55:00 AM	30	4.802	0.095	Pumping started at 09:25 hrs.
10:25:00 AM	60	4.875	0.168	
10:55:00 AM	90	4.943	0.236	Pumping stopped at 10:55 hrs.
Time in Hours	**Time since Pumping stopped**	**D.T.W (in m bmp)**	**R.D.D. (m)**	**S1/S2**
10:57:00 AM	2	4.945	0.238	-
11:00:00 AM	5	4.944	0.237	-
11:05:00 AM	10	4.929	0.222	1.063
11:11:00 AM	16	4.935	0.228	-
11:17:00 AM	22	4.928	0.221	1.067
11:30:00 AM	35	4.915	0.212	1.113
11:45:00 AM	50	4.913	0.206	1.145
12:00:00 PM	65	4.906	0.199	1.185
2:10:00 PM	195	4.857	0.15	1.573
2:30:00 PM	215	4.85	0.143	1.65
2:48:00 PM	233	4.842	0.135	1.748
3:05:00 PM	240	4.84	0.133	1.774
3:20:00 PM	255	4.823	0.116	2.034
3:50:00 PM	285	4.822	0.115	2.052
4:15:00 PM	310	4.811	0.104	2.269

4:20:00 PM	315	4.809	0.102	2.31
4:45:00 PM	340	4.802	0.095	2.484
5:00:00 PM	355	4.796	0.089	2.651
5:15:00 PM	370	4.79	0.083	2.843
Repeat Test				
Date	**11.12.1986**			
Time in Hours	**Time since Pumping started**	**D.T.W (in m bmp)**	**Drawdown (m)**	**Remarks**
9:20:00 AM	-	4.58	-	Pump started at 09:20 hrs.
12:20:00 PM	180	5.03	0.45	Pump stopped at 12:20 hrs.
Time in Hours	**Time since Pumping stopped**	**D.T.W (in m bmp)**	**R.D.D. (m)**	**S_1/S_2**
12:21:00 PM	1	5.028	0.448	1.004
12:23:00 PM	3	5.025	0.445	1.011
12:25:00 PM	5	5.019	0.439	1.025
12:31:00 PM	11	5.027	0.435	-
12:35:00 PM	15	5.009	0.429	1.048
12:50:00 PM	30	4.99	0.41	1.09
1:10:00 PM	50	4.988	0.4	1.125
2:17:00 PM	117	4.947	0.367	1.226
2:30:00 PM	130	4.942	0.362	1.243
3:00:00 PM	160	4.932	0.352	1.278
3:30:00 PM	190	4.92	0.34	1.323
4:00:00 PM	210	4.907	0.327	1.376
4:30:00 PM	240	4.893	0.313	1.437
5:00:00 PM	270	4.886	0.306	1.47
5:20:00 PM	290	4.88	0.3	1.5
Date	**12.12.1986**			
7:00:00 AM	1120	4.666	0.086	5.23
7:20:00 AM	1140	4.66	0.08	5.62

B. Large diameter Dug-well at APWD PWSS Campbell Bay

Depth	6 m bmp		M.P	0.46 m
Diameter	7.75 m		Aquifer	Coralline sand over Mithakhari Group
GeoRef.	7.0115467 N 93.919635 E		Pump	5 HP
Time	in Minutes		Delivery pipe	3inch
Pre pumping SWL	2.09 m bmp			
Date	16.03.2023			
Time in Hours	**Time since Pumping started**	**D.T.W (in m bmp)**	**Drawdown (m)**	**Remarks**
07:30 AM	0	2.09	0	
	90	1.95	0.14	
	150	1.75	0.34	
11:05 AM	215	1.58	0.51	
Time in Hours	**Time since Pumping stopped**	**DTW (in m bmp)**	**R.D.D. (m)**	**S_1/S_2**
11:05 AM	0	1.58	3.42	
	2	1.64	3.36	1.018
	4	1.65	3.35	1.021
	6	1.66	3.34	1.024
	8	1.66	3.34	1.024
	10	1.67	3.33	1.027
	12	1.68	3.32	1.030
	14	1.69	3.31	1.033
	16	1.7	3.3	1.036
	18	1.71	3.29	1.040
	20	1.72	3.28	1.043
	25	1.75	3.25	1.052
	30	1.79	3.21	1.065
	35	1.82	3.18	1.075
	40	1.86	3.14	1.089
	45	1.9	3.1	1.103
	50	1.92	3.08	1.110

	55	1.94	3.06	1.118
12:05 AM	60	1.97	3.03	1.129
	70	2.01	2.99	1.144
	80	2.04	2.96	1.155
	90	2.07	2.93	1.167
	100	2.1	2.9	1.179
	110	2.14	2.86	1.196
01:05 PM	120	2.18	2.82	1.213
	130	2.21	2.79	1.226

Annexure – 8

Island-wise – Habitation-wise Drinking Water Supply Status in Nicobar District

Sl.	Island	Habitation Name	HH	Pop	Req. (LPCD)	Planned Supply (m^3)	Dug well	Infiltration Well	Nallah	Spring	Pond	Rain Water	Pvt. DW	SW Source Name
1	Car Nicobar	Arong	233	1194	150.75	180	2	0	0	0	0	0	0	
2	Car Nicobar	Big Lapati	271	1098	182.15	200	1	0	0	0	0	0	0	
3	Car Nicobar	Chuckchucha	231	1021	121.45	124	1	0	0	0	0	0	0	
4	Car Nicobar	IAF Camp	31	731	136.80	100	1	0	0	0	0	0	2	
5	Car Nicobar	Kakana	231	841	188.80	159	2	0	0	0	0	0	0	
6	Car Nicobar	Kimois	92	382	196.34	75	1	0	0	0	0	0	0	
7	Car Nicobar	Kinmai	152	574	174.22	100	1	0	0	0	0	0	0	
8	Car Nicobar	Kinyuka	309	1120	156.25	175	1	0	0	0	0	0	0	
9	Car Nicobar	Malacca	368	1637	111.79	183	1	0	0	0	0	0	0	
10	Car Nicobar	Mus	365	1553	135.22	210	1	0	0	0	0	0	0	
11	Car Nicobar	Perka	711	2527	197.86	500	1	0	0	0	0	0	0	
12	Car Nicobar	Sawai	286	1247	192.46	240	1	0	0	0	0	0	0	
13	Car Nicobar	Small Lapati	242	938	159.91	150	1	0	0	0	0	0	0	
14	Car Nicobar	Tamaloo	379	1515	115.51	175	1	0	0	0	0	0	0	
15	Car Nicobar	Tapoiming	214	941	116.90	110	1	0	0	0	0	0	0	
16	Car Nicobar	Teetop	135	522	191.57	100	1	0	0	0	0	0	0	
17	Great Nicobar	7 Km Farm	37	141	190.00	27	0	0	1	0	0	0	0	Chingam Nallah
18	Great Nicobar	Campbell Bay	1608	5736	102.86	590	2	0	2	0	0	0	0	Magar Nallah (02 Sources)
19	Great Nicobar	Chingen	3	12	191.67	2	0	0	1	0	0	0	0	Chingam Nallah
20	Great	Govinda	194	676	143.49	97	0	0	0	1	0	0	0	

Sl.	Island	Habitation Name	HH	Pop	Req. (LPCD)	Planned Supply (m^3)	Dug well	Infiltration Well	Nallah	Spring	Pond	Rain Water	Pvt. DW	SW Source Name
	Nicobar	Nagar												
21	Great Nicobar	Gandhi Nagar	13	69	144.93	10	0	0	1	0	0	0	0	Gandhi Nagar Nallah
22	Great Nicobar	Joginder Nagar	208	693	173.16	120	0	0	1	0	0	0	0	Prem Bahadur Nallah
23	Great Nicobar	Laxmi Nagar	13	230	108.70	25	0	0	1	0	0	0	0	Laxmi Nagar Nallah
24	Great Nicobar	Sastri Nagar	6	15	200.00	3	1	0	0	0	0	0	0	
25	Great Nicobar	Vijoy Nagar	12	100	10.00	1	1	0	0	0	0	0	0	
26	Little Nicobar	Afra Bay	2	10	1.00	0	1	0	0	1	0	0	0	
27	Little Nicobar	Makhahu Or Makachua	17	47	106.38	5	1	0	0	1	0	0	0	
28	Little Nicobar	Pulloullo Or Puloulo	16	81	135.80	11	1	0	1	0	0	0	0	
29	Little Nicobar	Pulobha Or Pulobahan	6	52	10.00	1	1	0	0	0	0	0	0	
30	Little Nicobar	Pulomilo	5	29	1.00	0	0	0	1	0	0	0	0	
31	Little Nicobar	Pulopanja	16	75	200.00	15	1	0	1	0	0	0	0	
32	Chowra	Alhiata	59	190	1.00	0	0	1	0	0	0	1	0	
33	Chowra	Chongkamong	38	150	10.00	2	0	1	0	0	1	0	0	
34	Chowra	Kuitasuk	77	277	10.00	3	0	1	0	0	0	0	0	
35	Chowra	Raihio N	74	276	1.00	0	0	1	0	0	0	1	0	
36	Chowra	Tahaila	119	377	10.00	4	0	1	0	0	0	1	0	
37	Kamorta	Alukian Or Alhukheck	10	46	10.00	0	0	10	0	0	0	0	0	
38	Kamorta	Berainak Or	38	188	194.68	37	1	10	0	0	0	0	0	

Sl.	Island	Habitation Name	HH	Pop	Req. (LPCD)	Planned Supply (m^3)	Dug well	Infiltration Well	Nallah	Spring	Pond	Rain Water	Pvt. DW	SW Source Name
		Badnak												
39	Kamorta	Changua Or Changup	36	146	10.00	1	0	10	0	0	0	0	0	
40	Kamorta	Chota Inak	42	237	118.14	28	1	10	0	0	0	0	0	
41	Kamorta	Daring	27	115	10.00	1	0	10	0	0	0	0	0	
42	Kamorta	Kakana	71	270	185.19	50	1	10	0	0	0	0	0	
43	Kamorta	Kamorta Kalatapu	513	1815	188.86	343	0	10	0	2	0	0	0	Reservoir (02 nos.)
44	Kamorta	Munak Incl Ponioo	24	117	192.31	23	1	10	0	0	0	0	0	
45	Kamorta	Payuha	5	24	166.67	4	1	10	0	0	0	0	0	
46	Kamorta	Pilpilow	62	282	146.27	41	2	10	0	0	0	0	0	
47	Kamorta	Ramzoo	23	98	10.00	1	0	10	0	0	0	0	0	
48	Kamorta	Vikas Nagar	48	235	193.62	46	1	10	0	0	0	0	0	
49	Katchal	Mildera	403	1350	92.59	125	1	0	0	0	0	0	0	
50	Nancowry	Al Hit Touch Or Balu Basti	59	19	1.00	0.0	1	1	0	0	0	0	0	
51	Nancowry	Alteak	8	30	200.00	6	1	0	0	0	0	0	0	
52	Nancowry	Champin	33	143	139.86	20	1	0	0	0	0	0	0	
53	Nancowry	Hitui or Itoi	41	181	191.71	35	1	0	0	0	0	0	0	
54	Nancowry	Malacca	35	158	10.00	2	1	0	0	0	0	0	0	
55	Nancowry	Tapong and Kabila	62	271	134.81	37	1	0	0	0	0	0	0	
56	Theresa	Aloorang	68	271	10.00	3	1	0	0	0	0	0	0	
57	Theresa	Bengali	150	354	10.00	4	1	0	0	0	0	0	0	
58	Theresa	Chukmachi	69	237	10.00	2	1	0	0	0	0	0	0	
59	Theresa	Enam	56	223	10.00	2	1	0	0	0	0	0	0	

Sl.	Island	Habitation Name	HH	Pop	Req. (LPCD)	Planned Supply (m^3)	Dug well	Infiltration Well	Nallah	Spring	Pond	Rain Water	Pvt. DW	SW Source Name
60	Theresa	Kalasi	78	335	10.00	3	1	0	0	0	0	0	0	
61	Theresa	Kanahinot	15	60	10.00	1	1	0	0	0	0	0	0	
62	Theresa	Luxi	59	149	1.00	0	1	0	0	0	0	0	0	
63	Theresa	Minyuk	76	305	1.00	0	1	0	0	1	0	0	0	
	Total		**8884**	**34736**		**4512**	**50**	**126**	**10**	**6**	**1**	**3**	**2**	

Annexure – 9

Identified Geo-electrical Layers with layer resistivity and thickness in Great Nicobar Island

A. Layer Properties

VES ID	VES Locations	Latitude	Longitude	R1	H1	R2	H2	R3	H3	R4	H4	R5	H5	R6
				Ohm-m	m	Ohm-m	m	Ohm-m	m	Ohm-m	m	Ohm-m	m	
VES1	Rajiv Nagar-1	93.927112	7.023832	9.4	4.5	1.39	8.73	4.3	42	1878				
VES2	Rajiv Nagar-2	93.925222	7.0215	11.4	1.2	3.4	2.7	7.4	6	3.2	20	13.9		
VES3	Army Land 1	93.9116111	7.017639	37	3.2	28	16.1	7.4	30.9	66.3				
VES4	Army Land 2	93.913556	7.018944	20	13.6	49.2	20.9	0.06						
VES5	INS Baaz	93.9177889	7.011856	60.7	5.5	2.15	11.5	5177						
VES6	Govindnagar-1	93.888762	7.002027	19.1	2.3	146	5.1	2	12.2	1898				
VES7	Govindnagar-2	93.89958	6.999558	29.8	3.2	8	13.1	2.1	24.2	71.7				
VES8	Govindnagar-3	93.909852	7.000549	58.1	1.2	173	2.9	32.4	13	2.2	31.3	15.7		
VES9	Govindnagar-4	93.886972	6.866083	1024	0.7	60.5	3.5	8.7	21.7	1.7	39.2	15.8		
VES10	Jogendernagar-1	93.9191111	6.9521111	167	1.6	622	3.2	48.5	15	4.7	31.7	1042		
VES11	Jogendernagar-2	93.920083	6.960861	73.6	1	27.3	2.8	95.2	6.3	1.5				
VES12	Jogendernagar-3	93.920083	6.960861	0.9	0.6	148	19.5	2						
VES13	Viajynagar-1	93.903861	6.924833	11.3	0.7	2.1	1.8	23.3	4	3.2	9.7	33.6		
VES14	Vijaynagar-2	93.893556	6.925278	85.2	5.71	12.5	16.5	2833						
VES15	Laxminagar-1	93.885504	6.89242	127	2.3	52.1	10.7	31.4						
VES16	Laxminagar-2	93.890539	6.889274	123	6.5	27	19.5	2.84						
VES17	Laxminagar-3	93.895847	6.888185	119	3.3	4.4	22.4	0.016						
VES18	Gandhinagar-1	93.894358	6.841442	387	3	26.6								
VES19	Gandhinagar-2	93.89171	6.839447	29	1.2	19.3	2.5	42	5.3	21.9	23.8	8.9	23.8	50.1

VES ID	VES Locations	Latitude	Longitude	R1	H1	R2	H2	R3	H3	R4	H4	R5	H5	R6
				Ohm-m	m	Ohm-m	m	Ohm-m	m	Ohm-m	m	Ohm-m	m	
VES20	Gandhinagar-3	93.889694	6.839056	108	1.3	33.7	3.2	126	6.49	31.9	39.5	5.73		
VES21	Gandhinagar-4	93.886972	6.866083	56.2	1.2	122	5.3	59.5	23.8	26.7	50.1	3.6		
VES22	Shastrinagar-1	93.88816	6.806561	40.1	0.8	15	2	75.8	5.1	0.4	10.8	5.3		
VES23	Shastrinagar-2	93.886957	6.806776	28.9	4.2	6.1	23.3	0.85	47.7	7.9				
VES24	Shastrinagar-3	93.895058	6.816037	13.3	1.7	5.2	3.1	34.7	6.3	4.2	77.8	0.13		

B Inferred Layer Lithology

VES ID	Inferred Lithology					
	R1	R2	R3	R4	R5	R6
VES1	Top Soil	Weathered Formation(Clayey)	Clay	Compact Formation		
VES2	Top Soil	Weathered Formation(Clayey)	Clay	Clay/Brackish Formation	Fine Grained Sand with Fresh Water	
VES3	Top Soil	Medium Grained Sand with Fresh Water	Clay	Medium to Coarse Grained Sand with Fresh Water		
VES4	Top Soil	Medium Grained Sand with Fresh Water	Sand Formation saturated with Saline Water			
VES5	Top Soil	Clay	Compact Formation			
VES6	Top Soil	Weathered Formation (Gravelly)	Clay	Compact Formation		
VES7	Top Soil	Clay	Clay	Sand Formation saturated with Fresh		

VES ID	Inferred Lithology					
	R1	R2	R3	R4	R5	R6
				Water		
VES8	Top Soil	Coral Sand	Medium Grained Sand with Fresh Water	Sand Formation saturated with Brackish Water	Fine Grained Sand with Fresh Water	
VES9	Top Soil	Coral Sand	Clay	Sand Formation saturated with Brackish Water	Fine Grained Sand with Fresh Water	
VES10	Top Soil	Weathered Formation	Medium to Coarse Grained Sand with Fresh Water	Clay/Brackish Formation	Compact Formation	
VES11	Top Soil	Fine to Medium Grained Sand with Fresh Water	Coarse Grained Sand with Fresh Water	Brackish Formation		
VES12	Top Soil	Coarse Grained Sand with Fresh Water	Brackish Formation			
VES13	Top Soil	Clay	Medium Grained Sand with Fresh Water	Clay/Brackish Formation	Medium Grained Sand with Fresh Water	
VES14	Top Soil	Sand Formation saturated with Fresh Water	Compact Formation			
VES15	Top Soil	Weathered Formation	Medium Grained Sand with Fresh Water			
VES16	Top Soil	Medium Grained Sand with Fresh Water	Sand with Brackish water			
VES17	Top Soil	Clay/Sand with Brackish water	Sand Formation saturated with Saline Water			

VES ID	Inferred Lithology					
	R1	R2	R3	R4	R5	R6
VES18	Top Soil	Medium Grained Sand with Fresh Water				
VES19	Top Soil	Fine Grained Sand with Fresh Water	Medium to Coarse Grained Sand with Fresh Water	Medium Grained Sand with Fresh Water	Clay/Brackish Formation	Coarse Grained Sand with Fresh Water
VES20	Top Soil	Medium Grained Sand with Fresh Water	Medium to Coarse Grained Sand with Fresh Water	Medium Grained Sand with Fresh Water	Clay	
VES21	Top Soil	Weathered Formation (Gravelly)	Medium to Coarse Grained Sand with Fresh Water	Medium Grained Sand with Fresh Water	Brackish Formation	
VES22	Top Soil	Fine Grained Sand with Fresh Water	Medium to Coarse Grained Sand with Fresh Water	Brackish Formation	Clay	
VES23	Top Soil	Sand with Brackish water	Sand with Brackish water	Clay		
VES24	Top Soil	Clay	Medium Grained Sand with Fresh Water	Clay	Saline Formation	