केंद्रीय भूमि जल बोर्ड

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विभाग, जल शक्ति मंत्रालय

भारत सरकार

Central Ground Water Board

Department of Water Resources, River Development and Ganga Rejuvenation, Ministry of Jal Shakti

Government of India

AQUIFER MAPPING AND MANAGEMENT OF GROUND WATER RESOURCES

KADMAT ISLAND, U.T.OF LAKHDWEEP

केरल क्षेत्र, तिरुवनंतपुरम

Kerala Region, Thiruvananthapuram

भारत सरकार / GOVERNMENT OF INDIA

जल शक्ति मंत्रालय / MINISTRY OF JAL SHAKTI

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केंद्रीय भूमिजल बोर्ड / CENTRAL GROUND WATER BOARD,

केरल क्षेत्र / KERALA REGION

AQUIFER MAPS AND MANAGEMENT PLAN OF KADMAT ISLAND, UNION TERRITORY OF LAKSHADWEEP

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1. Introduction

The Lakshadweep Islands constitute a uni-district territory with 4 *Tehsils* (Amini, Andrott, Kavaratti & Minicoy) and 9 Sub-divisions (Agatti, Amini, Andrott, Chetlat (Bitra), Kadmat, Kalpeni, Kavaratti, Kiltan & Minicoy). According to the new Panchayat Regulation, there will be a two-tier system of Panchayats in Lakshadweep, consisting of Dweep Panchayats and District Panchayat and in this territory. Each of the ten inhabited Islands will have a *Dweep Panchayat*. The District Panchayat has its headquarters at Kavaratti.

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Kadmat an inhabited island of Lakshadweep is oriented in an NNE-SSW direction. It is elongated in shape. The map showing the locations of inhabited islands of Lakshadweep is given in Fig.1.

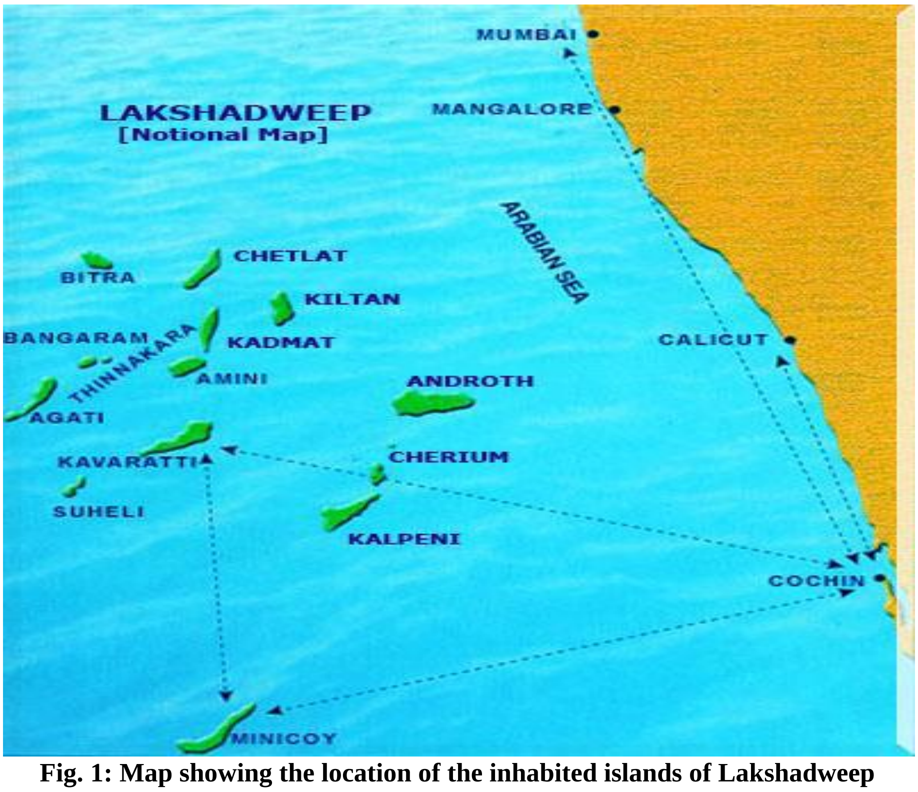


Fig. 1: Map showing the location of the inhabited islands of Lakshadweep

1.1 Extent

Kadmat Island, the fourth largest island in the archipelago based on land use area (3.12Sq km) is located between Amini island in the south and Chetlat island in the north. The island lies between north latitude 11°10'55" and 11°15'30" and east longitudeb72°45'32" and 72°47'29". According to Survey of India, the Kadmat island has an areal extent of 3.20sq km and lagoonal area of 37.50 sq km with a maximum length of 8 km and a maximum width of 0.57 km and stretched in an NNE-SSW direction

1.2 Population

As per the 2011 Census statistics, the total population of the island is 5404 out of which the male population is 2690 and the female population is 2714, and the Density of population is 1732 persons/sq km. Fishing, coconut cultivation, and coir twinning are the main occupation of the islanders. The literacy rate of the island is 95.50.

1.3 Climate

Lying well within the tropics and extending to the equatorial belt, the Climate of Kadmat is similar to the climatic condition of Kerala. Kadmat island has a tropical humid, warm, and generally pleasant climate.

1.3.1 Rainfall

Rainfall distribution, including its quantity and its spatial and temporal variation and evapotranspiration, are the major components controlling the availability of freshwater resources. The temporal variation is usually high in small islands whereas the spatial variation is a function of the islands' physiography. The inter-annual variability of rainfall is often high in the Lakshadweep islands.

The weather station and Rain gauge station maintained by the Indian meteorological department at Amini island are analysed as there is no meteorological station in Kadmat island. About 75% of the rain is received from May to September, 22 % from October to December, and 3 % in the remaining months. The normal rainfall of Amini island is 1504mm and no of rainy days are 80. The monthly rainfall (2005-17) is given in Table 1and Fig. 2 represents the monthly average rainfall of Amini island.

Table 1: Rainfall data of Amini Island (in mm)

Year	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
2005	1.2	11.4	0	35.2	70	156.6	364.2	126.6	236	75.2	106.4	7.2	1190
2006	11	0	19.4	0	458.8	245.2	93	9.2	323.1	58.5	40.2	0	1258.4
2007	8.6	9.2	0	0	206.8	546.8	386.4	282.1	270	260	91	73	2133.9
2008	0	0	54.6	0	49.3	333.3	412.5	178.45	95.1	269.9	22.3	189.6	1605.05
2009	0	0	0	0	56.1	290.3	340.8	286.4	152.8	76.8	150.4	98	1451.6
2010	52	0	0	27.4	101.6	276	299.2	302.8	71.4	241.6	128.2	33.6	1533.8
2011	0	0	0	54.8	68.8	102.2	188.4	176.2	167.8	125	50.8	2.4	936.4
2012	12.4	0	0	25	0	304.6	140.8	306.6	88.8	176.5	10.6	0	1065.3
2013	0	22.2	0	0	76.4	437.3		.	.	55.8	110.4	0	
2014	62.5	0	0	0	107.2	129.6	59.6	271.3	74.9	183.4	91.6	99.2	1079.3
2015	0	0	3.8	48.8	81.8	285.4	138.4	147.8	105	133.4	205.6	144.2	1294.2
2016	53	0	0	0	16	263.1	139	55.1	0	45.3	94.8	0	666.3
2017	0	0	0	40	81.6	303.2	113.4	247.6	188.2	68	74	120	1236

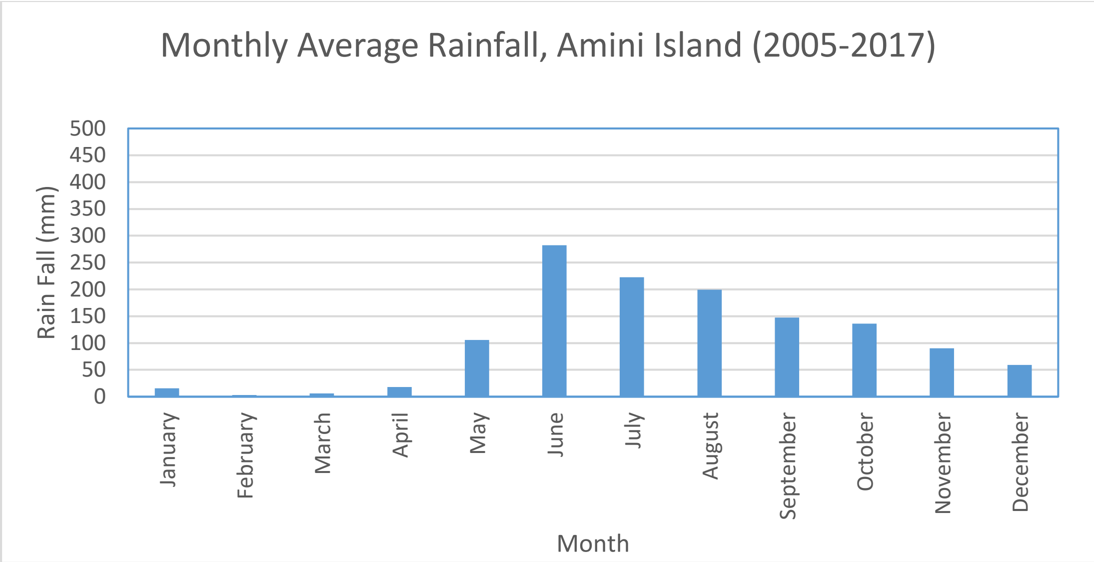


Fig. 2: Graph showing average monthly rainfall of Amini island

1.3.2 Humidity: The Humidity is high throughout the year and is generally higher in the morning hours compared to the evening hours. Humidity ranges from 70-75% for most of the year.

1.3.3 Temperature: March to May is the hottest period of the year and December and January are the coldest months. The temperature ranges from 28°C to 32°C. The monsoon period raises temperature to the mercury level between 27-30°.

1.3.4 Evapotranspiration has a vital role in the hydrological cycle of tropical small islands. This is very high and most of the months except in high rainfall season it exceed the rainfall making the water surplus on the negative side.

1.3.5 Special weather phenomena: A few cyclonic depressions and storms, which form in the south Arabian Sea during April and May, affect the weather over the territory. During the post-monsoon months of October to December also, a few of such systems originating in the Bay of Bengal and travelling westwards emerge into the south Arabian sea, and occasionally affect these islands. In association with these, strong winds and heavy rains are common. The cyclonic storms are believed to be responsible for the deposition of coral debris around the islands forming coral beach and the lagoons.

1.4 Soils

Like most of the islands of Lakshadweep, Kadmat island also has a soil layer overlying coral limestone. The soils are mainly derived from the fragmentation of coral atolls and include coral sands, lagoonal sands, and mud. The coral sand covering the major part of the island is yellowish-white in colour and is made of assorted medium to fine grained sand.

From a groundwater resource perspective the rate of infiltration, the thickness, and the moisture contents at both field capacity and wilting point are the relevant soil characteristics. The coral sand is highly permeable and allows rainfall to readily infiltrate, with the result that surface run-off does not occur except in local areas of compacted soils. In some areas of the islands, such as along the coast and around the lagoon, the soils are far less permeable and ponded water is often found after rainfall. These less permeable soils cover only a small proportion of the islands and it can reasonably be assumed from a water resources viewpoint that surface runoff into the sea or lagoon is nil.

1.5 Vegetation

Coconut is the major crop of the island. Breadfruit, banana, red grass, sweet potato, groundnut, papaya, drumstick, neem, and vegetables are other crops. Coconut trees have a bearing on the groundwater resource of islands.

From a water balance viewpoint, the vegetation in the Islands can be classified as either shallow-rooted or deep-rooted. The shallow-rooted vegetation includes grasses, crops, and shrubs obtaining their moisture requirements from the soil moisture zone. The deep-rooted vegetation consists of those trees whose roots can, where conditions are favourable, penetrate below the soil moisture zone and through the unsaturated zone to the water table. Coconut trees are a typical example of deep-rooted vegetation in the islands of Lakshadweep. In relatively shallow areas, coconut trees typically have some roots within the soil moisture zone and some which penetrate the water table. The significance of roots that can reach the water table is that transpiration can occur directly from the freshwater lens, even during drought periods. The transpiration losses through coconut trees are common on coral atolls where the depth to the water table is typically 2 to 3 m. below ground level.

1.6 Transport and Communication

Lakshadweep island is connected to the mainland by air and sea. Islands are connected through boat services. Kadmat island is also connected to other islands through boat services. Only BSNL provides telecommunication services to Kadmat island.

1.7 Studies carried out by Central Ground Water Board

- Hydrogeological studies by Central Ground Water Board in Lakshadweep Islands dates back to 1978 when a reconnaissance investigation on the groundwater resources of the Islands was carried out.
- All the inhabited islands except Bitra (0.1 sq.km) have been studied by Central Ground Water Board through systematic hydrogeological surveys and subsequently by micro-level studies.
- CGWB periodically assess the dynamic groundwater resources of the Lakshadweep islands and issued the report. The latest assessment was as of March 2017.
- Several reports have been published on various aspects of groundwater resources in the Lakshadweep Islands based on the studies, as listed below:
  - Groundwater Resources and Management in the Union Territory of Lakshadweep (1997).
  - Hydrogeological Atlas of Lakshadweep Islands. (2004).

2. Geomorphology and Origin

The entire Lakshadweep group of islands lies on the northern edge of the 2500 km long North-South aligned submarine Lakshadweep-Chagos ridge. The Lakshadweep Sea separates this ridge from the west coast of India. The ridge rises from a depth of 2000-2700 m along the eastern side and 400 m along the western side. The eastern flanks of this ridge appear to be steeper compared to the western portion. It has a number of gaps, the prominent being the nine-degree channel.

Kadmat is a long and narrow island that is broader in the northern part and narrows towards the southern part. This flat-topped island generally rises 2-3 m above sea level. The geomorphology features of the island are reef flat, reef slope, lagoon, sandy beach, island vegetation, etc. The lagoon on the western side of the island is quite large and deep and with a narrow beach along the eastern side. The depth of the lagoon varies from 2-3 m. The lagoon side of the shore is a sandy beach and during low tide beach rock also gets exposed at some locations. The reef flat is about 50 m wide and gets exposed during low tide.

Kadmat, a typical atoll type coral island in its intermediate stage of development of the island. The island is developed on the eastern side of the atoll. The development and growth of the islands on the eastern reef margin have been controlled by several factors. The cyclones from the east have piled up coral debris on the eastern reef while the very high waves generated annually during the southwest monsoon have pounded the reef and broken this into coarse and subsequently to fine sediments which were then transported and deposited on the eastern side behind the coral boulders and pebbles on the eastern reef.

The Lakshadweep islands are of coral origin which developed around volcanic peaks. It seems that they first rose to the surface in the form of shallow oval basins and under the protection of the reef, the eastern rim gradually developing towards the center, forming the islands. The process of development towards the center of the lagoon is still going on in some of the islands.

3. Geological setting

The Lakshadweep Group of atolls lie on the prominent N-S Lakshadweep ridge and the alignment appears to be a continuation of the Aravalli strike of Rajasthan. Based on this, many geologists have speculated that the islands are a buried continuation of the Aravalli mountain chain and that the Deccan Traps have been faulted down in the sea along the West coast of India. A great thickness of traps and associated sediments occur to the west. Based on a seismic study (Ermenko and Datta, 1968), it is inferred that the Indian shield (continental crust) extends as far as to the Lakshadweep. The transition zone separating the continental and oceanic crust occurs to the west of the Lakshadweep. Further, using seismic refraction measurements (Francis and Shor, 1966), it was postulated that 1.5 km to 2 km thick volcanic rocks lie below the seafloor on the Lakshadweep ridge.

Kadmat islands are mainly atoll type of coral islands, consisting of coral reefs, crystalline limestone and carbonate/coral sands, formed by wind and wave action. The island is covered by medium to fine grained assorted coral sand which is underlain by a thin hard coral limestone at a depth of 1.5 to 3.0 m. This hard coral limestone is characterized by cavities. Loose coral sands underlie the hard coral limestones.

4. Hydrogeological framework

Beneath a thin layer of vegetal humus, there is fine coral sand extending over the surface of the islands. Below this is a compact crust of coral limestone, and beneath this crust, there is another layer of sand.

The coral sands and the coral limestone form the principal aquifer in the islands. Groundwater, existing under phreatic conditions at a depth of generally 2 – 3 m below ground level, is seen as a thin lens floating over and in hydraulic continuity with the seawater. Large diameter wells are the most common and traditional groundwater abstraction structures. In almost all the wells, hard coral limestone is exposed near the bottom.

The hydrogeologic conditions of all the islands are almost similar. Freshwater floats over seawater and thus it has got hydraulic continuity with seawater. The occurrence of the freshwater lens over saline water in island conditions was studied by Badon W Ghyben in the year 1888 in the Netherlands and by Mike Herzberg in the year 1901, in the islands of North Sea off the German coast (Ghassemi. et al. 1990). Both these workers established the relation between the freshwater head above mean sea level (hf) and the depth to freshwater - saltwater interface (hs) to form a freshwater lens floating over saline water as shown in fig. 3. This is popularly known as the Ghyben-Herzberg (GH) approximation. In the simplified form of the GH approximation, the ratio of the thickness of the freshwater lens below and above mean sea level can be presented as

$$h = \frac{\sigma f}{\sigma s - \sigma f}$$

where h = ratio of the thickness of the freshwater lens below msl to that above msl,
s = density of seawater (normally 1.025) and
f = density of freshwater (normally 1.000).

The Ghyben-Herzberg relation determines the depth of the interface between freshwater and seawater. The Ghyben- Herzberg relation is applicable when the water is above mean sea level, it slopes towards the periphery and it is in hydraulic continuity with seawater. Any withdrawal of groundwater creating a cone of depression of one-unit results in the upcoming of seawater by 40 units under normal conditions depending on the density of the seawater. However, studies in small islands indicate that the ratio of the 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). The fresh- seawater interface is theoretically a sharp one but seldom seen in nature where groundwater is developed. This is usually seen as a zone and is termed 'transition zone'. The dispersion as well as the fluctuation causes continuous mixing of water of different salinities, creating the transition zone. The width of the transition zone depends on the geology, which controls the branching nature of the flow paths, resulting in dispersion and the fluctuation in water levels due to tides and in response to recharge and discharge. The higher the fluctuation, the thicker is the transition zone. Depending upon the permeability and porosity the shape and thickness of the freshwater lens also vary. The water is highly influenced by the tides as it is in hydraulic continuity with the seawater.

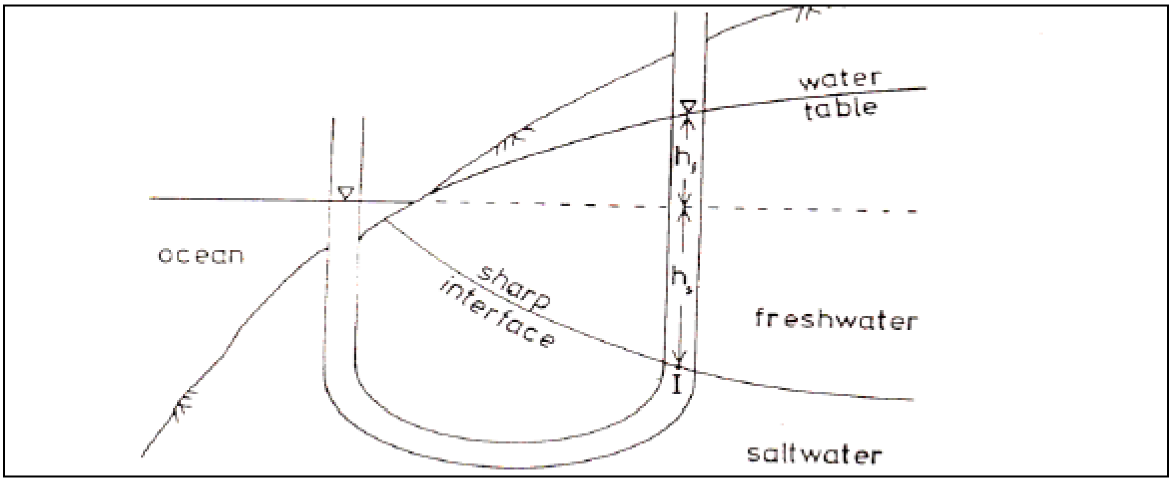


Fig. 3: Ghyben-Herzberg approximation for oceanic islands

In order to identify the role of the shape of the island in deciding the freshwater lens, the aspect ratio of the islands is made use of. Since the shape of the islands does not conform to any geometric form, the aspect ratio is computed taking into consideration the length, breadth, and area of the island (Najeeb, 2003). The island area is divided by ratio of its length to breadth to get the aspect ratio. This ratio has been used to study the stability of the freshwater lens in the islands and the salient features of Kadmat island are given in Table 2. Islands with an aspect ratio greater than 0.5 are found to have stable freshwater lens, under identical geomorphological settings.

Table 2: Salient Features of Kadmat Island

Area in SQ.km	3.12
Maximum Length	8
Maximum width	0.55
Aspect Ratio i.e. A/(L/B)	0.2
Shape	Elongated
Trend of Longer axis	NNE-SSW

4.1 Groundwater scenario

The hydrogeological condition of Kadmat is almost similar to other islands, with freshwater floats over seawater in hydraulic continuity with it (Fig. 4).

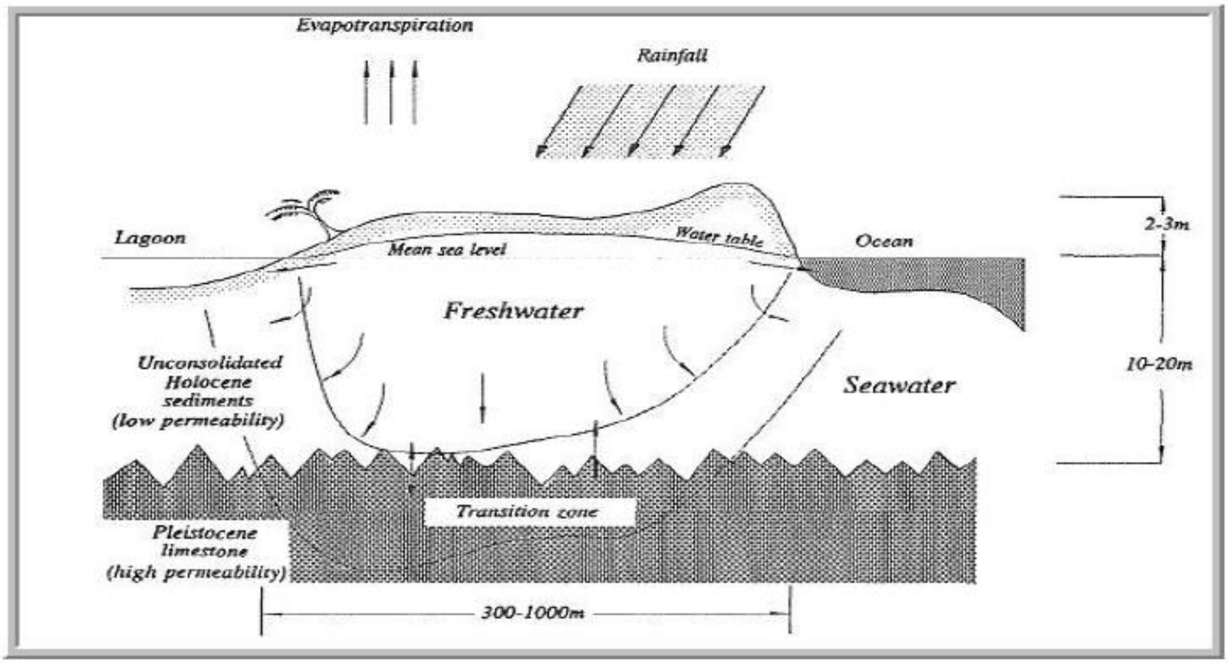


Fig. 4: Freshwater lens in small Islands (Exaggerated vertical scale)

[Source: A.C.Falklands (1993): Hydrology and water management on small tropical islands- Hydrology of Warm Humid Regions (Proceedings of the Yokohama Symposium, July 1993). IAHS Publ. no. 216, 1993.]

The calcareous sands overlying these islands are highly porous and infiltrate the bulk of the rainfall received. The infiltrating rainfall displaces the saline water to a freshwater lens due to density difference and the hydraulic continuity of groundwater with seawater. There is no rejected recharge of groundwater even during heavy rainfall. About 18 to 51 percent of the annual rainfall gets recharged into the groundwater depending on the intensity, frequency, and distribution of rainfall. However, the rise in water level due to recharge gets adjusted within the lens as per the Ghyben-Herzberg (GH) approximation and hence appreciable increment in the water level is not observed. Rainfall received in the Lakshadweep Islands are fully recharged and adjusted in the freshwater lens, as a result of which significant rise in water levels are not discernible in the wells even after the monsoon rains.

Coral atolls generally consist of a layer of recent (Holocene) sediments, comprising mainly coral sands and fragments of coral, on top of older limestone. An unconformity separates these two layers at typical depths of 10m to 20 m below mean sea level. Several deeper unconformities may exist due to fluctuations in sea level which results in alternate periods of emergence and submergence of the atoll. During periods of emergence, solution and erosion of the reef platform can occur, while further deposition of coral limestone can occur during periods of submergence. The upper sediments are of primary importance from a hydrogeological viewpoint as freshwater lenses occur solely or mainly within this layer. The occurrence of such lenses within this layer is due to its moderate permeability (Typically 5 to 10 m/day) compared with higher permeability of the older limestone (typically 50 to 100 m/day). Permeabilities greater than 1000 m/day occur in solution cavities within the limestone. These extremely high permeabilities allow almost unrestricted mixing of freshwater and seawater which is less likely to occur in the upper sediments. The upper unconformity, therefore, is one of the main controlling features of the depth of the freshwater lens.

The hydrogeological conditions of the islands have been studied in detail, the islands have a freshwater lens and saline to brackish lens. There exists a high magnitude of temporal and spatial variations in thickness, shape as well as the groundwater quality of these lenses. The exact geometry of these lenses, chemical quality, behaviour under various stresses and their potential is of great significance for planning and effective management of the freshwater resources in these islands. Groundwater is developed by dug/open wells and to a limited extent through shallow filter point wells. The groundwater levels on the island are highly influenced by tides.

The Lakshadweep Public Works department had established Observation Wells in all the Islands for periodic quality monitoring and the weekly monitoring of water levels of the dug wells. For the hydrogeological studies, select wells from LPWD observation wells and other dug wells and filter point wells were studied. The hydrogeological details of wells inventoried are presented in Annexure-I and weekly water level data of the island is given in Annexure-II.

Kadmat is an elongated island because of its shape (maximum width of 0.5 km), the occurrence of the freshwater lens is very limited. There are about 925 wells with a density of 296 wells/sq km. The depth to water level varies from 0.43 to 4.35 m and the depths of wells range from 1.61 to 6.58 m. bgl. The tidal fluctuation ranges from 0.13 to 0.38m. The maps showing locations of the key wells, depth to water table (pre-monsoon 2016), and hydrogeology of the island is given in figures 5, 6, and 7 respectively.

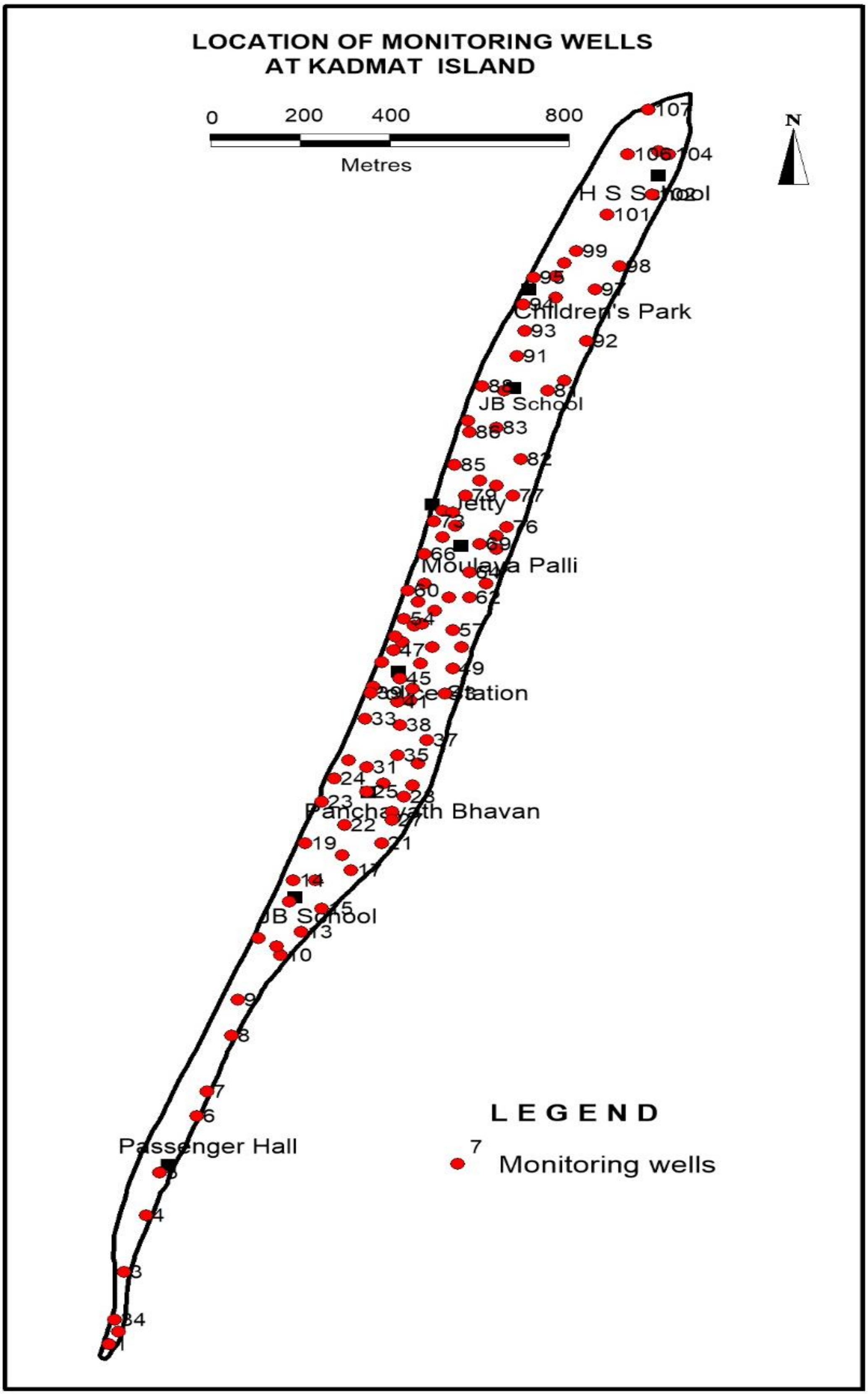


Fig. 5: Key well locations in Kadmat island

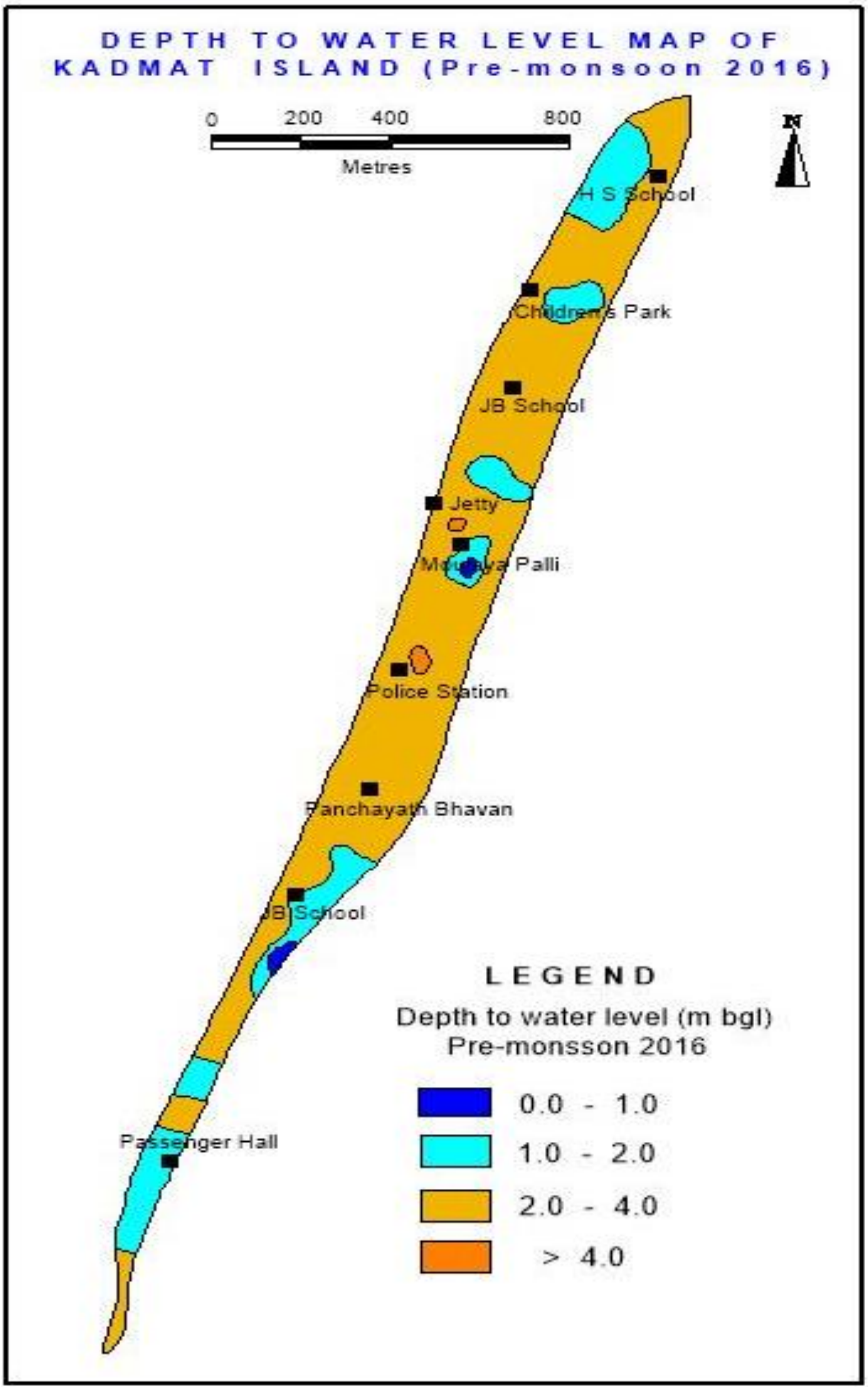


Fig. 6: Depth to water level map of Kadmat island

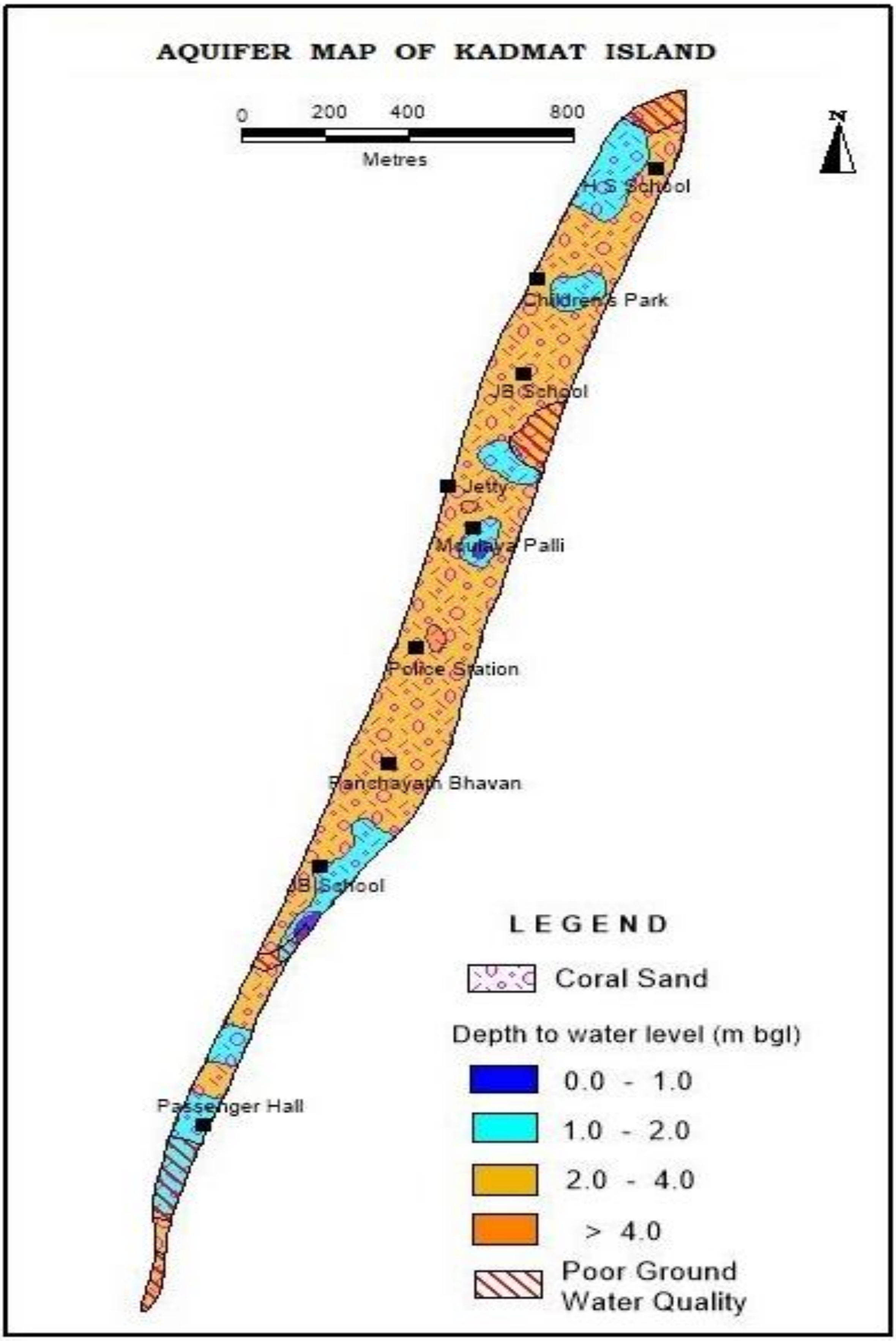


Fig. 7: Aquifer map of Kadmat island

4.2 Surface Geophysical Surveys in Kadmat Island, UT of Lakshadweep

In Kadamat island one Wenner profile has been carried out from the western coast end to a length of 350 m to know the groundwater condition. A total of 3 No VES has been carried out on the island. The surface geophysical survey was conducted by using an ABEM Terrameter from ABEM Instrument's AB, Sweeden. Profiling has been carried out by using Wenner configuration with inter-electrode spacing (a) is 5 m and the VES survey was done with maximum AB spacing of 120 m by using Wenner configuration. The Location maps of the Wenner Profiling line and Vertical Electrical Soundings carried out in Kadamat Island are compiled in **Fig. 8.**

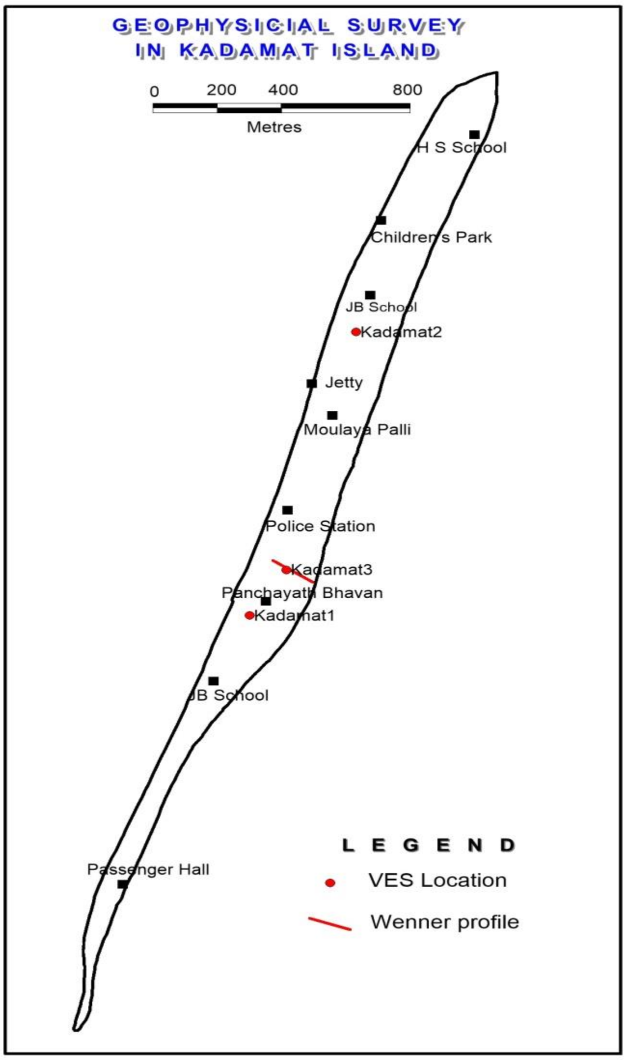


Fig. 8: location map of Profiling & VES at Kadamat Island

Wenner profiling has been carried out in Kadamat Island with a station interval of 5 m and the distance between two adjacent electrodes is 5m. The results of Wenner profiling have been shown in below **fig. 9.** From the graph, it is indicating that from a distance of 50 m to 100 m in the X-axis is showing below 10 ohm.m resistivity which is giving information about the brackish water in that area at 5 m below ground level, other than that the remaining part of the profile line the resistivity value is showing more the 50 ohms.m, which is giving information about the freshwater available in that area at 5 m below ground level.

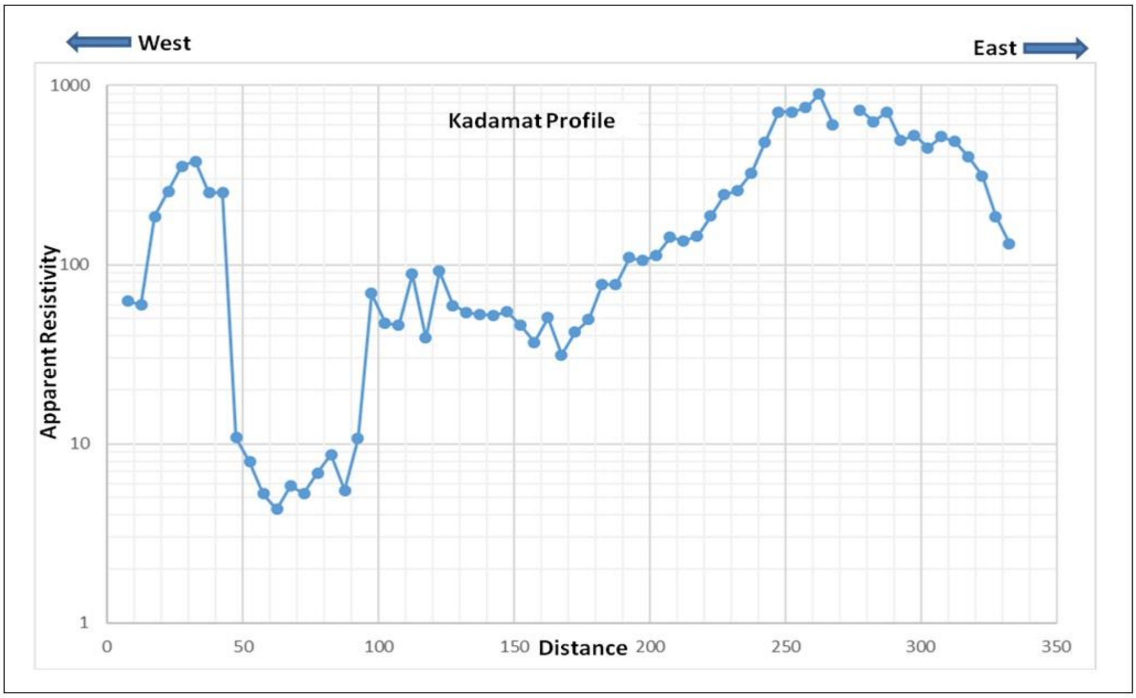


Fig. 9: Wenner Profiling in Kadamat Islands

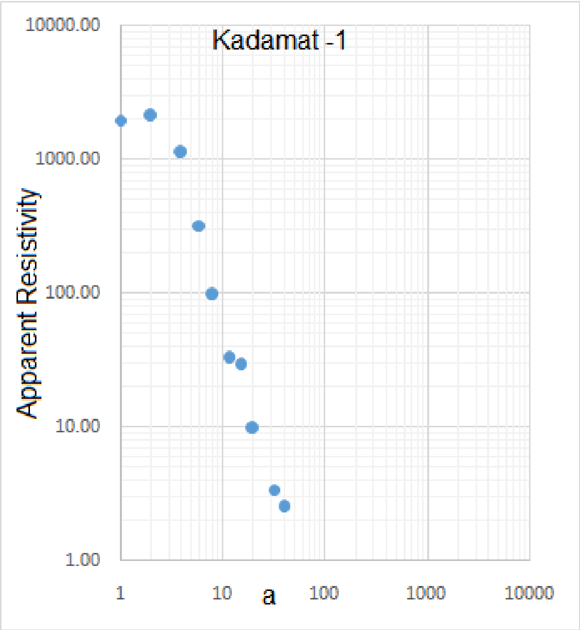
In Kadamat Islands 3 sites have been investigated by conducting 3 VES. The interpreted results have given rise to 3 to 4 layered geoelectric sections. In all 3 VES, the last geoelectric layer is showing the decreasing trend due to Salinity. The main type of curve observed in this island is QQ.

The first geoelectric layer resistivity was varying in the range of 1701 to 2680 ohm.m, and the thickness of this geoelectric layer is varying in the range of 0.5 to 2.1 m, which is giving information about top Soil. The second geoelectric layer resistivity was varying in the range of 238 to 350 ohm.m, and the thickness of this geoelectric layer is varying in the range of 1.0 to 1.2 m, which is giving information about the freshwater lens. The third geoelectric layer resistivity was varying in the range of 44 to 54 ohm.m and the thickness of this geoelectric layer is 8.6 m, which is also giving information about freshwater lens at the top and slightly becoming brackish at the bottom. The fourth geoelectric layer resistivity was varying in the range of 2 to 3 ohm.m, this geoelectric layer was extending in nature which is giving information about the starting of saline water from 10 m to 12 m below ground level. The interpreted results were presented in **Table 3**. The Resistivity of the curves in the entire area is showing that it is decreasing with increasing a-separation between adjacent Electrodes the examples of representation of field curves in Kadamat Island is presented in **Fig.10**.

Table 3: Interpreted results of VES in Kadamat Island, U.T of Lakshadweep

#	Village Name	Ves no	Interpreted Results								AB (m)	Remarks
			Resistivity (Ohm.m)				Thickness (m)					
			ρ_1	ρ_2	ρ_3	ρ_4	h_1	h_2	h_3	Total(H)		
1	Kadamat	1	2680	350	44	2	2.1	1.2	8.6	11.9	120	
2		2	1701	238	54	3	0.5	1.0	8.6	10.1	110	
3		3	Not Interpretable								20	

ρ_1 - First layer resistivity in ohm.m. h_1 - First layer thickness in m.



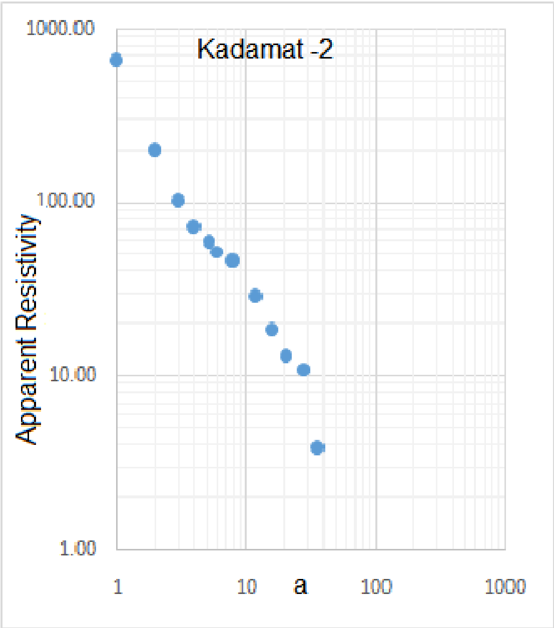


Fig. 10: Representation of field curve at Kadamat - 1 & Kadamat -2

5. Quality of ground water

Lateral, vertical, and temporal changes in the quality of groundwater are observed in islands. Groundwater in the Island is generally alkaline. The dissolution of $CaCO_3$ during rainwater infiltration leads to high pH of groundwater. However, samples from the pumping wells immediately after pumping are found to be slightly acidic. This is because of the precipitation of $CaCO_3$ from water due to the instability of equilibrium between Calcium and bicarbonate ions. $CaCO_3$ precipitate is quite often seen at the bottom of such pumping wells. The decrease of pressure that accompanies pumping from a certain depth below water level is likely to cause a decrease of dissolved CO_2 and to render the water more saturated with calcite than it originally was (Mandal, S, and Shiftan, Z.L, 1981). The overall reaction describing $CaCO_3$ dissolution and precipitation is given below:

$$CaCO_3 + H_2O + CO_2 \Leftrightarrow Ca^{++} + 2HCO_3^-$$

The LPWD is maintaining chemical lab in all the islands and is monitoring the periodic chemical quality of the Observation Wells. pH, EC, and concentrations of important chemical constituents in the observation wells are utilized for the study. Higher concentrations of the dissolved solids are generally seen along the periphery of the islands and also close to pumping centers. Analytical results of samples collected from select open wells tapping the freshwater lens are shown in Table. 4.

Table 4: Hydrochemistry of selected groundwater samples collected from open wells in Kadmat island

No of Samples	pH	EC (µS/cm)	TDS (mg/l)	Total Hardness(mg/l)	Ca (mg/l)	Mg (mg/l)	Cl (mg/l)
107	7.43-8.12	960-14940	538-8366	240-2650	100-200	130-2450	90-5350

Groundwater quality characteristics of Kadmat island are controlled by its shapes, climate, water use pattern, etc. In general, the groundwater quality of the island is fresh with EC in the range of 960 to3000 µS/cm at 25º C. The southern portion lying to the south of Bader palli has brackish water with EC of >3000 µS/ cm, whereas the north-central parts of the island have freshwater with EC within 3000 µS/ cm. Water is slightly alkaline with pH values in the range of 7.43 to 8.12. The chloride content shows a wide variation of 90- 5350 mg/l. About 85 % of samples shown the EC range <3000 µS/cm at 25º C and 89 % of samples shown the chloride range <1000 mg/l. The spatial variations in EC are depicted in Fig. 11. The chemical data of CGWB observation wells at Kadmat is given in Annexure III and Chemical analysis results of water samples collected from LPWD is given in Annexure IV.

5.1 Variations in groundwater quality

The groundwater quality variations in the Islands could be lateral, vertical, and temporal. The quality is also highly variable and reversible. The quality variation is higher in the fringe areas of the freshwater lens during various seasons as compared to that of the central part of the freshwater lens, where the water is fresh all through.

The quality of groundwater in the islands varies with time too. Wells from which water is drawn by hand retain more or less the same quality over a long period, whereas quality deterioration is observed around pumping centers. A trend towards seawater composition is observed with increasing electrical conductivity in and around pumping centers. Similarly, brackish water is seen along topographic lows and in areas where coarse pebbles and corals are seen.

Various factors affecting the quality of water in the coral aquifer system is discussed below in brief:

5.1.1 Rainfall

It is observed that the quality of groundwater in the island improves with rainfall. It is established from the studies that a water surplus of 20mm is sufficient to reverse the deteriorating trend in water quality in summer months. A water surplus of above 100mm gives a marked improvement in quality that sustains for the next two to three months with the normal rate of draft. The freshwater lens continuously contracts in the absence of rainfall, due to the effect of water lost due to mixing, draft by vegetation, and draft for domestic consumption.

5.1.2 Tidal influence

As the groundwater is in hydraulic continuity with seawater, its quality is influenced by the diurnal tidal fluctuations of the sea. Quality variation is observed with tidal fluctuation and some of the wells located in areas where the freshwater lens is very thin and are brackish during low tides yield freshwater during high tides. It is established that the quality variation due to tides is not very significant. However, it is seen that best quality of water available is during high tide and more specifically, during the rising limb of high tide.

5.1.3 Effect of groundwater overdraft

The freshwater-salt water interface in Lakshadweep islands is in a delicate equilibrium and any undue stress on this equilibrium by overdraft results in the up-coning of the saline water from beneath. Thus the movement of the saline front is not horizontal as in the case of inland aquifers. Heavy withdrawal of groundwater from a point source induces the up-coning of saline water and the quality deterioration due to pumping is evident even on limited pumping.

5.1.4 Effect of groundwater recharge

Studies in Lakshadweep Islands revealed that there is no rejected recharge of groundwater even during heavy rainfall. About 18 to 51 percent of the annual rainfall gets recharged into the groundwater depending on the intensity, frequency, and distribution of rainfall. The Ghyben-Herzberg (GH) equation (Todd 1959) indicate that the depth to interface between fresh and saltwater is about forty times the thickness of freshwater above mean sea level in small islands in ideal situations. Thus a fractional increment in the freshwater lens above mean sea level influences the depth of the transition zone. Thus the quality of the freshwater lens improves. The effect of rainfall is evident in improvement in the quality of the freshwater lens, which is very well elucidated from various studies.

5.1.5 Aspect ratio of Islands

The shape and size of the islands have a role in the water quality as well as the stability of the freshwater lens. Hence, the aspect ratio of the islands was worked out to study the behaviour and stability of the freshwater lens, as mentioned in one of the previous sections. The aspect ratio of Kadmat island is 0.2 and the value below 0.5 indicates the vulnerability of freshwater lens to changes in draft and recharge.

5.1.6 Marine aerosols

The rainwater quality in Lakshadweep Islands is influenced by aerosols in the atmosphere. The atmosphere in the coastal parts and islands are enriched in Chloride ions, which gets washed down to the ground during the rains. The first rain, after a long dry spell, will have a higher concentration of Chloride compared to the rains received after continuous rainy days. Similarly, the concentration of chloride is less as we go towards the central part of the islands as the thick vegetation obstructs the aerosols.

5.1.7 Groundwater contamination by anthropogenic activity

The contamination of groundwater is a major threat to groundwater in the Lakshadweep islands. Human waste, sewerage, use of detergents for washing, presence of soak pits/ septic tanks biological wastes, and fertilizers are the major agents of pollution of groundwater. The traditional burial grounds also contribute to groundwater contamination to some extent.

6. Status of groundwater resources

The groundwater resource availability in Lakshadweep Islands is restricted to the top few meters of the phreatic aquifers, composed of coral sands and coral limestone. Central Ground Water Board, as part of its activities, periodically assess the dynamic groundwater resources of the islands, the salient details of which are described briefly in the following sections.

6.1 Unit of Computation

The unit of computation is taken as an island. An island with well-defined hydrogeological boundaries is an appropriate Hydrogeological unit for groundwater resource estimation.

6.2 Groundwater recharge

In small island conditions, the estimation of recharge based on the groundwater fluctuation method is not practicable unlike in the case of continental coastal aquifers as the head build-up due to rainfall recharge dissipates within 2-3 days and diurnal fluctuation is nearly the same as seasonal fluctuation. Therefore, the water table fluctuation method cannot be adopted for assessing the dynamic groundwater potential of the Lakshadweep islands.
The groundwater recharge in Lakshadweep Islands has been computed for six months from May to October using the rainfall Infiltration method. The Normal Monsoon Rainfall (NMR) is taken as 1355 mm for Kadmat islands. In areas with no coconut trees, the recharge to groundwater is about 50% of the rainfall and as the coconut tree increases to a full cover, the recharge can reduce to about 30% of the rainfall. A rainfall infiltration factor of 0.30 is adopted for the entire islands.

The evapotranspiration (ET) value for coconut tree is taken as 80% of that of shallow-rooted vegetation which in turn is assumed to be equal to the PET of a reference crop. The proportions of the freshwater lens area covered by deep-rooted vegetation can be estimated from ground observations or aerial photographs. For the Lakshadweep islands, the proportion is taken as 30%. The PET from the coconut trees has been estimated for 6 non-monsoon months @ 30 liters/ day/ tree for 180 days.

6.3 Total available groundwater resource

About 20% of the total recharge from rainfall in the island is considered lost due to mixing with seawater during tides and another 20% is allocated for reserve for use during periods of delayed or low rainfall. These components, along with the transpiration losses from coconut trees are deducted from the total recharge for getting the total available resource on each island.

6.4 Groundwater draft

The major component of the groundwater draft in the Lakshadweep islands is the extraction through wells for domestic consumption. Almost all households have their dug well and more than 75% of the wells are fitted with small capacity (normally 0.5 HP) electric pumps. A per capita consumption of 150 lpd has been considered for domestic draft calculation, based on the population as per the 2011 census. Irrigation draft is negligible in the islands as almost all the crops are rain-fed.

6.5 Stage of groundwater development

The stage of groundwater development (SD) has been computed using the following formula

SD = {B/A} x 100

Where, B is the gross groundwater draft A is the total available groundwater resource

6.6 Categorization of islands

The categorization of islands as per the GEC-2015 methodology is not applicable in island conditions due to the peculiar nature of the hydrogeological regime. The freshwater lens will quickly adjust with the incremental additions or abstractions by virtue of its floating nature thereby making long-term trends insignificant. However, categorization has been attempted in this estimation purely based on the stage of groundwater extraction.

6.7 Computation of groundwater resources

The dynamic groundwater resources have been assessed by computing various components of recharge and draft. Rainfall is the only source of recharge in the Islands, whereas domestic draft, evapotranspiration losses, and water loss due to diffusion into the sea are the major components of the draft. A part (20%) of the annual water surplus is reserved as a buffer zone for reserve during delayed or deficit monsoon years. The dynamic groundwater resources of the island are detailed in table 5.

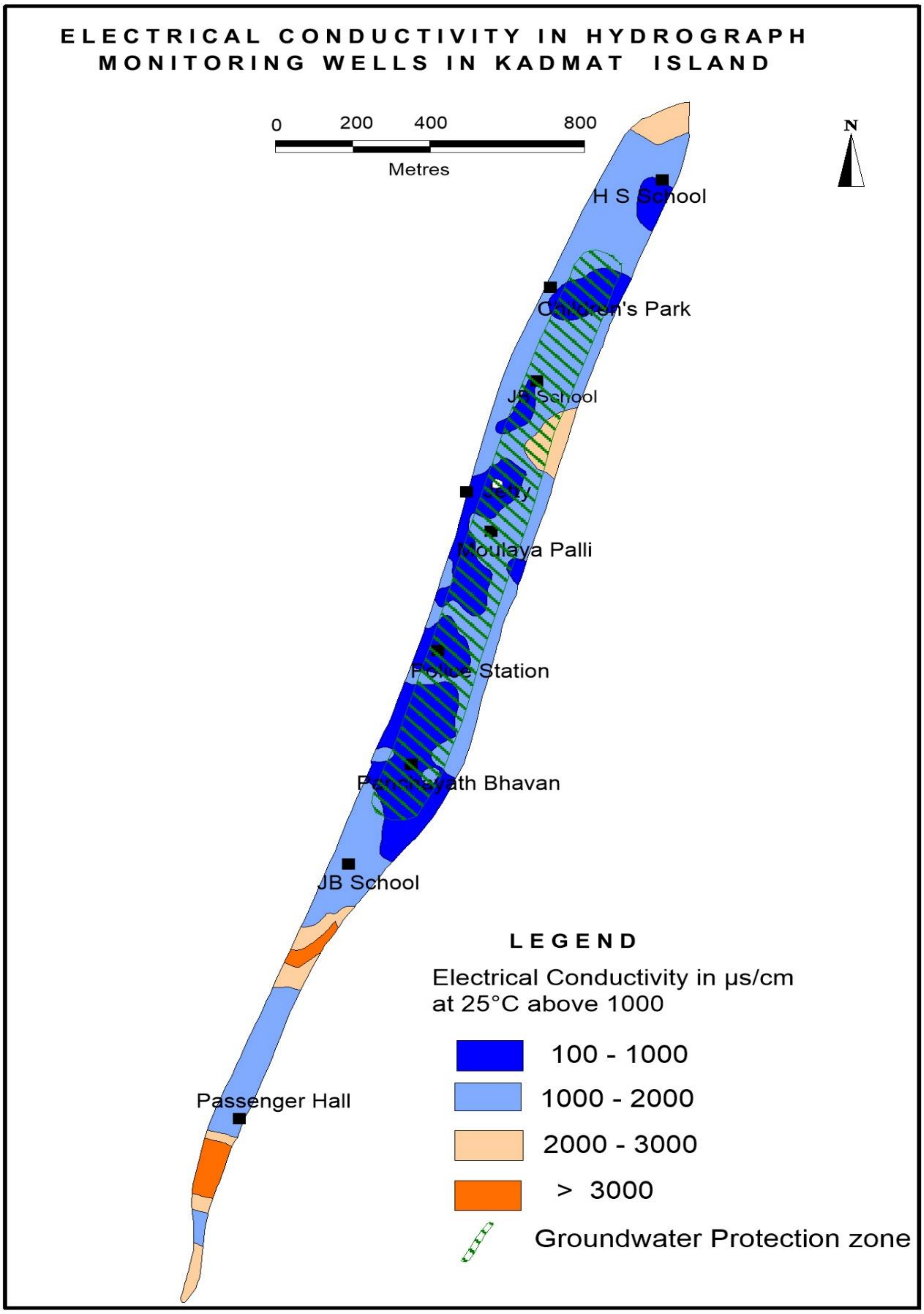


Fig. 11: Spatial variations in EC in Kadmat islands

Table 5: Dynamic Ground Water Resources of Kadmat Islands (As in March 2017)

Sl no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Annual components of Water Balance	Population (Projected as on 2017)	Area (Ha)	Normal Monsoon Rainfall (m)	Rainfall Infiltration Factor (%)	Total Resource (Water Surplus) (Ha.m)) [2*3*4]	ET loss from Trees for 6 non-monsoon months (Ha.m)	Water loss due to outflow to sea [20% of (5) (Ha.m)]	The buffer zone for reserve during delayed or lesser monsoon period [20% of (5)] (Ha.m)	Balance available resource (Ha.m) (5-(6+7+8))	Domestic Extraction @100 lpcd [1*100*365] (Ha.m)	Gross Annual GW Extraction (Ha.m)	Groundwater balance available [9-11](Ha.m)	Stage of groundwater extraction [11*100/9]	Category
Kadmat	5446	312.0	1.355	30	126.8	33.8	25.4	25.4	42.3	19.8	19.8	22.6	46.7	SAFE

7. GROUNDWATER ISSUES

The groundwater issues of the island can be summarized as:

- Requirements to meet the needs of a growing population and the non-availability of alternatives resources (surface water source) are likely to put the limited groundwater resources in Islands under increasing stress.
- Both groundwater level and quality are influenced by the tide.
- Deterioration of groundwater quality due to natural reasons especially during summer months.
- Groundwater pollution due to anthropogenic activities. Unscientific septic tanks and burial places in the Island are potential microbial contaminant sources
- Existing supplies unable to cope with the rapidly increasing demands for drinking and domestic uses.
- The freshwater lens in the islands is fragile and the shape of islands plays a significant role in its occurrence and stability. The Kadmat Island with aspect ratio 0.20 is vulnerable to seawater mixing.

- Indiscriminate groundwater extraction at places, resulting in the up-coning of saline water and consequent quality deterioration.

8. Management interventions for sustainable development

In the Kadmat Island, groundwater occurs in phreatic condition and is in hydraulic continuity with seawater. The management strategy suitable for aquifer in the continental land is not appropriate for the tiny islands. Since surface runoff is absent and recharge of rainfall is taking place naturally, the need for artificial recharge is ruled out. Management strategy needs to concentrate on limited groundwater withdrawal and optimum utilization. The people should be educated about the danger of over-exploitation of the precious resource and the limitations of island conditions.

Requirements to meet the needs of a growing population and the non-availability of alternatives are likely to put the limited groundwater resources in Islands under increasing stress in the coming years. As the full requirement of freshwater in the islands cannot be met with from the limited groundwater resources, water supply schemes in all islands must resort to a combination of groundwater, desalinated water, and rainwater harvesting.
Some of the feasible management interventions to ensure the long-term sustainability of groundwater in the islands are:

- **Restoration, renovation, and protection of available ponds and wells.**
  - According to the available data (Basic statistics 2014 of U.T of Lakshadweep), 267 ponds and 948 wells are existing in Kadmat Island of which 99 ponds and 26 wells are not in use. Abandoned wells and ponds are to be rejuvenated and protected and wells should not be converted into garbage disposal pit.

- The freshwater lens on the island is vulnerable to change in groundwater draft and recharge. Indiscriminate pumping especially through energized methods lead to saline water up-coning hence discontinuous low duration pumping with low capacity pump is recommended. Pumps above 0.25 hp should not be allowed. Hand drawn wells are to be encouraged.
- The pumping of water from dug wells directly to multi-storied buildings may be regulated.
- Encouraging the use of water-efficient domestic fixtures like taps/ flush tanks to improve water use efficiency and reduce wastage. And thus encourage judicious use of freshwater resources.

- **Regulation/control of the indiscriminate extraction of groundwater through mechanical devices**. The indiscriminate extraction of groundwater through electric pumps from tube wells needs to be regulated for protecting the limited water resources from salinization due to the up-coning of seawater. The constitution of Lakshadweep Ground Water Authority under the Lakshadweep Ground Water (Development & Control) Regulation, 2001 needs to be expedited to control and regulate the extraction and use of water in any form in any of the islands in Lakshadweep.

- **Large scale implementation of rooftop rainwater harvesting schemes:** Rainwater harvesting and storage is the most suitable and cost-effective water conservation measure in the Lakshadweep islands. Rooftop rainwater harvesting can provide reliable freshwater for the islands during a part of the year. Individual and community-based rainwater harvesting systems can reduce the dependence on groundwater to a considerable extent. Efforts to popularize rainwater harvesting needs to be accelerated, through incentives wherever necessary, to reduce the increasing stress on the limited groundwater resources. Legal provisions to make rainwater harvesting mandatory for all future civil constructions may also be made. Rooftop Rainwater harvesting should be mandatory, and people of the saline zone should be given preference.

- **Groundwater protection zone:** The groundwater protection zones are demarcated during the aquifer mapping studies are shown in Fig. 9 and such zone should not be allowed for other construction activities. The Lakshadweep Building development Board was constituted for supervising and regulating building permits on the island and locating the sites for building. Huge building and infrastructure projects can be located at water scares barren land and such project may not be located in groundwater worthy areas and very shallow groundwater level areas. By construction of big buildings shallow groundwater area, the foundation of the building touches the water table, thereby mixing of cement and construction materials with freshwater and which leads to pollution of the aquifer.

The tourism activities may be concentrated in the unused/poor groundwater quality areas so that the tourism activities may flourish with the support of local people. The facilities for the tourists with drinking water from desalination plants may reduce the inconvenience to local people due to tourism.

- **Promotion of collector wells:** Promote the extraction of groundwater through collector wells, which envisages the extraction of groundwater through radial perforated pipes of 5 m length located at specified shallow depths. The groundwater flows under gravity through these pipes and collects in a collector well. This mechanism of groundwater extraction is better than any point source extraction as the area of extraction is distributed over a large area, extraction is limited to some depth and it does not allow the seepage of water from the bottom.

- **Installation of scientific septic tank:** The shallow, thin floating lens of groundwater is easily prone to contamination, efforts for proper sewage disposal are to be given top priority. The U.T. administration has taken steps to ensure the installation of scientific septic tanks in all newly constructed houses and other buildings. However, the existing soak pit/leach pit toilets need special attention Ensure installation of scientific septic tank in all newly constructed houses and other buildings.

- **Waste treatment Plant:** The freshwater lens of the island is vulnerable to quality deterioration. Anthropogenic activities are a cause of groundwater pollution. Decentralized garbage/waste treatment systems should be practiced to prevent contamination of available freshwater resources.

- **Installation of desalination plants in the Islands to reduce stress on groundwater:** The Low-Temperature Thermal Desalination (LTTD) plants presently available at Kavaratti, Agatti and Minicoy Islands with suitable capacities may be installed in the remaining islands to supplement groundwater resources for domestic purposes. Water supply through desalination plants is not to be taken as an alternate source but it should be taken as a supplementary source.

- **Sensitization of Public**: Sensitization and capacity building of stakeholders at all levels on the importance of water conservation and ways and means for its judicious management for ensuring the long-term sustainability of water resources.

9. Conclusions and recommendations

- Kadmat Island with an area of 3.20 Sq km, has a tropical humid, warm climate and the island is flat, rising 2-3m above mean sea level. Island consists of fine coral sand and coral limestone.
- The island is of coral origin and is a typical atoll type in its intermediate stage of development.
- The island is characterized by the absence of surface drainage and does not have any rivers or other surface water bodies.
- Groundwater exists under phreatic conditions occurs as a thin freshwater lens floating over the saline water in the porous formation and is in hydraulic continuity with the seawater. The freshwater lenses are tapped by open wells.
- The depth to the water level in the islands varies from 0.43 to 4.35 m and the depths of wells range from 1.61 to 6.58 m. bgl.

- The depth to water level is influenced by the tides. The water level fluctuation in these islands is significantly controlled by tides when compared to the groundwater recharge and draft.
- The freshwater lens in the Lakshadweep islands is fragile and the shape of islands plays a significant role in its occurrence and stability. The Kadmat island with aspect ratio 0.20 is vulnerable to seawater mixing.
- The stage of groundwater development of the island is 46.7 %.
- The water level suddenly rises to a fraction of meters immediately after the rainfall and again falls to the original level within hours. Hence the magnitude of seasonal fluctuation in water level due to groundwater recharge is not so significant when compared to tidal fluctuations.
- The Electrical Conductivity of groundwater ranges from 960 to 14940µS/cm at 25º C.
- The quality variation is vertical, temporal, and also lateral. Brackish water is present along topographic lows and in places where coarse pebbles and corals are present.
- Human waste, sewerage, and other biological wastes are major sources of groundwater contamination in the islands.
- Groundwater is limited in quantity and its salinity level increases as a function of time during withdrawal in the dry periods.
- Water supply in the Islands is through a combination of groundwater extracted through collection wells and harvested rainwater.
- The "Lakshadweep Ground Water (Development and Control) Regulation, 2001" was promulgated on August 6, 2001, for control and regulate the extraction and use of water in any form in any of the islands in Lakshadweep through the constitution of Lakshadweep Ground Water Authority, the same was constituted in 2019.
- Important constraints in the sustainable development of the limited groundwater resources in the Islands include the absence of surface water resources in the islands putting stress on the limited groundwater resources available, deterioration of groundwater quality during summer months, rapidly increasing demands for drinking and domestic uses, indiscriminate groundwater extraction at places, resulting in up-coning of saline water and consequent quality deterioration, lack of proper sanitation, resulting in large scale bacterial contamination. Burial places in the Island are potential microbial contaminant sources.
- As the freshwater requirements in the islands cannot be met with from the limited groundwater resources, water supply schemes in the island must resort to a combination of groundwater, desalinated water, and rainwater harvesting. The Low-Temperature Thermal Desalination (LTTD) plants presently available at Kavaratti, Agatti and Minicoy Islands with suitable capacities may be installed in the Kadmat islands also to supplement groundwater resources for domestic purposes.
- Restoration and protection of available ponds and wells, Regulation/control on the indiscriminate extraction of groundwater through mechanical devices, Large scale implementation of rooftop rainwater harvesting schemes, Fortification of Groundwater protection zone, Promotion of radial collector wells, Installation of scientific septic tank, Decentralised Waste treatment Plant and Sensitization of Public are the other management strategies.

ANNEXURE 1: HYDROGEOLOGICAL DATA OF DUG WELLS INVENTORIED IN KADMAT ISLAND (CGWB) Month of monitoring: December 2014

#	LPWD Well ID.	Longitude	Latitude	Depth (mbgl)	Dia (m)	MP (magl)	DWL (mbgl)	EC (µS/cm)	Temp (°C)	pH	Lining material	Lifting device
1	OW-1	72.7618	11.1832	3.95	1.15	0.72	2.6	2800	27.9	8	CR	Pump
2	OW-2	72.7621	11.1839	3.35	1.17	0.52	2.34	2300	28.5	7.7	CSCM	Rope & Bucket
3	OW-3	72.7628	11.1876	3.22	1.03	0.55	2.05	1840	28.5	7.7	CSCM	Rope & Bucket
4	OW-4	72.7636	11.1908	3	0.97	0.7	1.72	5100	27.8	7.7	CSCM	Pump
5	OW-5	72.764	11.1935	2.71	1.02	0.55	1.58	1520	28.3	7.8	CSCM	Pump
6	OW-6	72.7658	11.1969	3.45	8.87	0.7	2.2	1450	28	7.9	CSCM	Pump
7	OW-7	72.7663	11.1984	3.02	1.04	0.7	1.75	1570	28.5	7.4	CR	Rope & Bucket
8	OW-8	72.7734	11.2021	3.9	1.03	0.8	2.37	1860	28.5	7.5	CR	Pump
9	OW-9	72.7678	11.2039	3.88	1.8	0.92	2.27	3100	27.6	7.6	CSCM	Nil
10	OW-10	72.7699	11.2066	1.61	0.84	0.68	0.43	3000	28.7	7.1	CR	Pump
11	OW-11	72.7697	11.2071	3.25	1.35	0.68	1.92	1250	28.6	7.5	CSCM	Pump
12	OW-12	72.7688	11.2076	4.42	0.98	0.55	3.3	1000	28.8	7.6	CSCM	Rope & Bucket
13	OW-13	72.7709	11.208	2.52	1.05	0.5	1.78	1530	28.3	7.6	CR	Pump
14	OW-14	72.7705	11.2111	3.95	0.9	0.64	2.62	1510	29.6	7.2	CSCM	Pump
15	OW-15	72.7719	11.2094	3	1.3	0.62	1.5	1190	28.2	7.6	CSCM	Rope & Bucket
16	OW-16	72.7703	11.2098	3.7	1.6	0.62	1.98	1310	29.5	7.4	CSCM	Pump
17	OW-17	72.7733	11.2117	2.64	0.92	0.48	1.75	750	28.5	7.3	CR	Pump
18	OW-18	72.7716	11.2111	3.3	2.7	0.68	2.17	1220	29.5	7.1	CSCM	Pump
19	OW-19	72.7711	11.2133	3.8	1.1	0.67	2.43	1890	28.6	7.4	CSCM	Pump
20	OW-20	72.7729	11.2126	3.42	2.9	0.78	1.89	900	28.3	7.7	CSCM	Pump
21	OW-21	72.7748	11.2133	3.75	1.25	0.5	2.6	820	28.1	7.8	CS	Pump
22	OW-22	72.773	11.2144	4.12	2.7	0.68	2.98	750	28.3	7.4	CSCM	Pump
23	OW-23	72.7719	11.2158	3.8	0.9	0.8	2.58	900	28.3	7.6	CSCM	Pump
24	OW-24	72.7725	11.2172	4.6	4.6	1	3.83	1080	28.1	7.3	CS	Pump
25	OW-25	72.7741	11.2164	3.9	0.92	0.65	2.55	880	27.8	7.7	CSCM	Nil
26	OW-26	72.7753	11.2152	3.5	0.88	0.63	2.12	1110	28	7.2	CS	Pump
27	OW-27	72.7753	11.2147	3.6	1.2	0.46	2.45	660	28.1	7.8	CS	Pump
28	OW-28	72.7759	11.2161	3.37	0.85	0.6	2.08	990	28.1	7.4	CS	Pump
29	OW-29	72.7763	11.2168	3.94	1	0.58	2.52	1340	28	7	CS	Pump
30	OW-30	72.7749	11.2169	3	0.85	0.4	2.23	960	28.1	7.2	CS	Pump
31	OW-31	72.7741	11.2179	4.58	2.8	0.72	3.24	670	27.9	7.6	CSCM	Pump
32	OW-32	72.7732	11.2183	4.25	1.07	0.58	3.32	650	28.4	7.4	CS	Pump
33	OW-33	72.774	11.2208	5.2	1.15	0.7	3.75	880	28.6	7.5	CSCM	Pump
34	OW-35	72.7756	11.2186	3.45	0.95	0.58	2.14	790	28.6	7.1	CS	Pump

#	LPWD Well ID.	Longitude	Latitude	Depth (mbgl)	Dia (m)	MP (magl)	DWL (mbgl)	EC (µS/cm)	Temp (°C)	pH	Lining material	Lifting device
35	OW-36	72.7766	11.2181	3.47	0.82	0.55	2.23	1000	27.9	7.4	CS	Pump
36	OW-37	72.777	11.2195	3.2	0.98	0.48	2.08	1040	28.1	7.5	CR	Pump
37	OW-38	72.7757	11.2204	4.38	1.07	0.7	2.98	630	27.9	7.8	CSCM	Pump
38	OW-39	72.774	11.2225	4	0.85	0.53	2.87	1160	28.1	7.6	CS	Pump
39	OW-40	72.7744	11.2227	4.35	1.08	0.6	3	810	28.3	7.5	CSCM	Pump
40	OW-41	72.7756	11.2218	4.62	1	0.5	3.45	1040	28.2	7.3	CS	Pump
41	OW-42	72.7762	11.2219	4.3	1.08	0.67	2.93	1020	28.1	7.2	CS	Pump
42	OW-43	72.7779	11.2223	4	1.08	0.8	2.5	1070	28.4	7.9	CR	Pump
43	OW-44	72.7763	11.2226	4.93	1.15	0.58	3.68	690	27.8	7.6	CR	Pump
44	OW-45	72.7757	11.2232	4.7	1.15	0.53	3.27	730	27.9	7.5	CS	Pump
45	OW-46	72.7748	11.2242	3.6	0.95	0.34	2.66	790	28.2	7.7	CSCM	Pump
46	OW-47	72.7754	11.2249	5	0.94	0.88	3.22	800	28.3	7.4	CSCM	Pump
47	OW-48	72.7767	11.2241	6.58	1	0.88	4.22	950	28.7	7.7	CS	Pump
48	OW-49	72.7787	11.2251	3.77	0.45	0.96	2.02	1260	28.5	7.5	CSCM	Pump
49	OW-51	72.7773	11.2251	2.4	0.8	0	0	1060	28.6	7.5	CS	Pump
50	OW-52	72.7758	11.2254	4.95	0.88	0.65	3.65	890	28.5	7.7	CS	Pump
51	OW-53	72.7753	11.2258	3.32	1.05	0.37	2.48	1230	28.2	7.6	CSCM	Pump
52	OW-54	72.7759	11.2268	4.5	0.95	0.6	3.2	880	28.8	7.4	CS	Pump
53	OW-55	72.7764	11.2264	4.95	1.15	0.52	3.88	1070	28.5	7.3	CSCM	Pump
54	OW-56	72.7783	11.2261	3.2	0.98	0.6	2.01	1000	28.5	7.2	CR	Pump
55	OW-57	72.7774	11.2273	4.18	1.03	0.37	3.55	690	28.2	7.8	CS	Pump
56	OW-59	72.7766	11.2278	4.8	0.95	0.76	3.49	970	28.9	7.3	CR	Pump
57	OW-60	72.7758	11.2285	3.9	0.83	0.48	2.97	1170	28.5	7.3	CS	Pump
58	OW-61	72.7769	11.2289	4.6	1.45	0.72	3.08	740	28.2	7.6	CSCM	Pump
59	OW-62	72.7791	11.2281	3.54	0.9	0.62	2.28	1240	27.6	7.2	CSCM	Pump
60	OW-63	72.7799	11.2289	3.87	1.15	0.77	2.63	870	27.4	7.4	CR	Pump
61	OW-64	72.7791	11.2296	3.7	0.92	0.55	0.8	1310	27.5	7.8	CS	Nil
62	OW-65	72.7781	11.2281	5.45	1	0.68	4	660	27.9	7.5	CS	Pump
63	OW-66	72.7744	11.2314	4.45	1.33	0.58	3.28	790	27.6	7.9	CR	Pump
64	OW-67	72.7778	11.2317	5	1.25	0.86	3.56	1170	27.9	7.8	CR	Pump
65	OW-68	72.7796	11.2313	3.15	1.3	0.8	1.4	1340	28.2	7.5	CS	Pump
66	OW-69	72.7804	11.231	3.9	0.9	0.68	2.42	1620	27.9	7.5	CS	Pump
67	OW-71	72.7804	11.2318	3.7	0.95	0.7	2.3	1950	27.7	7.6	CS	Pump
68	OW-72	72.7784	11.2324	5.6	1.3	0.7	4.35	870	27.6	8	CS	Pump
69	OW-73	72.7771	11.2328	3.72	1.05	0.3	2.8	950	28.1	7.7	CR	Pump
70	OW-74	72.7778	11.2333	3.85	1	0.6	2.8	780	27.9	7.6	CS	Pump
71	OW-75	72.7783	11.2332	4.7	1.1	0.75	3.49	650	27.9	7.9	CS	Pump

#	LPWD Well ID.	Longitude	Latitude	Depth (mbgl)	Dia (m)	MP (magl)	DWL (mbgl)	EC (µS/cm)	Temp (°C)	pH	Lining material	Lifting device
72	OW-76	72.7809	11.2323	4	0.95	0.96	2.34	1460	27.6	7.8	CR	PUMP
73	OW-77	72.7812	11.2342	3.2	0.95	0.85	1.95	1700	28.2	7.7	CS	PUMP
74	OW-78	72.7804	11.2348	2.7	0.94	0.93	1.12	870	27.7	7.8	CS	PUMP
75	OW-79	72.7789	11.2342	4.95	1.1	0.4	3.9	12.5	28.6	7.6	CS	Pump
76	OW-80	72.7829	11.2405	3.6	0.94	0.58	2.42	1660	27.7	7.6	CR	Pump
77	OW-81	72.7816	11.2364	3.4	1	0.5	2.2	2600	27.5	7.5	CR	Pump
78	OW-82	72.7804	11.2383	3.25	0.95	0.62	2.23	800	28.2	8.1	CS	PUMP
79	OW-83	72.7796	11.2351	2.6	0.9	0.63	1.1	820	28.4	7.6	CS	Pump
80	OW-85	72.7778	11.2361	4	1.2	0.77	2.63	1290	28.1	7.9	CR	Pump
81	OW-86	72.7791	11.238	4	0.9	0.6	2.8	950	27.9	7.8	CS	PUMP
82	OW-87	72.779	11.2387	4.65	9.23	0.8	3.35	1340	28.1	7.7	CR	Pump
83	OW-88	72.7791	11.2409	3.9	1	0.7	2.5	1950	29.1	7.9	CS	PUMP
84	OW-89	72.7808	11.2405	4.35	1.25	0.65	3	950	28.5	8.1	CS	PUMP
85	OW-90	72.7837	11.2411	4.15	1.1	0.96	2.59	1930	28.3	7.7	CR	Pump
86	OW-91	72.7814	11.2426	4.45	1.17	0.68	3.12	1060	28.4	8	CS	Pump
87	OW-92	72.7848	11.2435	3.6	1.03	0.6	2.2	1410	28.1	7.8	CS	Pump
88	OW-93	72.7818	11.2441	3.9	1.5	0.7	2.4	1070	28.7	7.6	CS	Pump
89	OW-94	72.7817	11.2457	5.2	0.93	0.9	3.55	1020	30.4	7.7	CR	Pump
90	OW-95	72.7822	11.2473	5.1	1.05	1.05	3.45	1310	29.2	7.8	CR	Pump
91	OW-96	72.7833	11.2474	4.2	1.3	0.8	2.75	1080	28.8	7.8	CS	Pump
92	OW-97	72.7852	11.2466	3.4	1.4	0.84	1.91	640	29.6	8.1	CS	PUMP
93	OW-98	72.7864	11.248	3.35	1.1	0.6	3.1	1140	28.4	7.7	CSCM	PUMP
94	OW-99	72.7843	11.2489	4.1	0.9	0.75	2.55	1180	29.3	7.9	CR	Pump
95	OW-100	72.7837	11.2482	4.1	0.9	0.75	2.5	1330	30	7.6	CS	Pump
96	OW-101	72.7858	11.2511	3.6	1.5	0.9	1.8	1150	28.2	7.9	CSCM	Pump
97	OW-102	72.788	11.2523	3.9	0.95	0.3	2.3	850	28.3	8	CR	Pump
98	OW-103	72.7888	11.2547	3.8	2.9	0.8	2.2	1430	28.6	8	CSCM	Pump
99	OW-104	72.7883	11.2549	3.6	2.9	0.75	2.15	1690	29.5	7.4	Bricks	Pump
100	OW-105	72.7868	11.2547	3.2	2.9	0.75	1.5	1100	28.5	8.1	Bricks	Pump
101	OW-106	72.7878	11.2574	3.35	1.1	0.5	2.2	2700	28.3	7.8	CS	PUMP
102	OW-107	72.7833	11.2461	2.75	1.5	0.84	1.51	490	28.8	8.1	CS	PUMP

*: Square well **EC** : Electrical conductivity in Microsiemens/cm @ 25o C**,B&R**: Bucket& Rope ,**EM** : Electric Motor
CSCM : Coral stone lining with cement mortar **CR** : Concrete ring **CS** : Coral stone

ANNEXURE II: WEEKELY GROUND WATER LEVEL DATA KADMAT ISLAND (CGWB) (FEB 2017 TO JAN 2018)

	SL.NO	MP (m agl)	Well No	07.02.2017				14.02.2017				21.02.2017				28.02.2017			
				Time	***DTW (m bgl)***	***Time***	***DTW (m bgl)***	***Time***	***DTW (m bgl)***	***Time***	***DTW (m bgl)***	***Time***	***DTW (m bgl)***	***Time***	***DTW (m bgl)***	***Time***	***DTW (m bgl)***	***Time***	***DTW (m bgl)***
Feb-17	1	0.8	TW-1	10.15	1.55	16	1.66	10.15	1.71	16.02	1.65	10.1	1.67	16	1.82	10	1.52	16.02	1.46
	2	0.65	TW-2	10.22	0.87	16.08	0.97	10.22	1.04	16.1	0.99	10.17	1.02	16.08	1.13	10.07	0.83	16.1	0.78
	3	1	TW-3	10.3	0.65	16.15	0.74	10.28	0.77	16.2	0.72	10.26	0.74	16.15	0.82	10.15	0.63	16.2	0.59
	4	0.75	TW-4	10.35	1.65	16.23	1.77	10.35	1.75	16.25	1.7	10.31	1.99	16.23	1.78	10.22	1.64	16.25	1.59
	5	0.7	TW-5	10.44	2.5	16.31	2.62	10.4	2.62	16.32	2.57	10.4	2.57	16.31	2.66	10.3	2.39	16.32	2.44
	6	0.72	TW-6	10.5	2.12	16.38	2.26	10.45	2.25	16.4	2.16	10.48	2.18	16.38	2.28	10.38	2.15	16.4	2.05
	7	0.6	TW-7	10.55	0.55	16.46	0.69	11	0.75	16.55	0.65	10.53	0.65	16.46	0.77	10.43	0.53	16.55	0.47
	8	0.7	TW-8	11.05	2.12	17.53	2.22	11.1	2.35	17	2.3	11.03	2.26	17.53	2.4	10.52	2.12	17	2.05
	9	0.8	TW-9	11.15	0.7	17	0.84	11.15	0.84	17.05	0.78	11.1	0.75	17	0.86	11.07	0.74	17.05	0.69
	10	0.6	TW-10	11.22	0.99	17.1	1.13	11.2	1.25	17.1	1.19	11.2	1.15	17.1	1.27	11.17	1.19	17.1	1.13

	SL.NO	MP (m agl)	Well No	07.03.2017				14.03.2017				21.03.2017				28.03.2017			
				Time	***DTW (m bgl)***	***Time***	***DTW (m bgl)***	***Time***	***DTW (m bgl)***	***Time***	***DTW (m bgl)***	***Time***	***DTW (m bgl)***	***Time***	***DTW (m bgl)***	***Time***	***DTW (m bgl)***	***Time***	***DTW (m bgl)***
Mar-17	1	0.8	TW-1	10.15	1.52	16	1.6	10.15	1.65	16.02	1.54	10.1	1.64	16	1.71	10	1.62	16.02	1.59
	2	0.65	TW-2	10.22	0.84	16.08	0.91	10.22	0.94	16.1	0.84	10.17	0.98	16.08	1.02	10.07	0.92	16.1	0.89
	3	1	TW-3	10.3	0.6	16.15	0.67	10.28	0.7	16.2	0.64	10.26	0.72	16.15	0.75	10.15	0.71	16.2	0.68
	4	0.75	TW-4	10.35	1.6	16.23	1.67	10.35	1.7	16.25	1.62	10.31	1.69	16.23	1.73	10.22	1.69	16.25	1.66
	5	0.7	TW-5	10.44	2.46	16.31	2.52	10.4	2.57	16.32	2.45	10.4	2.56	16.31	2.6	10.3	2.54	16.32	2.53
	6	0.72	TW-6	10.5	2.08	16.38	2.2	10.45	2.22	16.4	2.1	10.48	2.2	16.38	2.23	10.38	2.32	16.4	2.26
	7	0.6	TW-7	10.55	0.55	16.46	0.67	11	0.69	16.55	0.51	10.53	0.67	16.46	0.69	10.43	0.75	16.55	0.69
	8	0.7	TW-8	11.05	2.16	17.53	2.28	11.1	2.3	17	2.16	11.03	2.28	17.53	2.3	10.52	2.38	17	2.32
	9	0.8	TW-9	11.15	0.78	17	0.9	11.15	0.92	17.05	0.8	11.1	0.94	17	0.97	11.07	0.96	17.05	0.88
	10	0.6	TW-10	10.22	1.21	17.1	1.29	11.22	1.33	17.1	1.19	11.2	1.21	17.1	1.23	11.17	1.27	17.1	1.19

	SL.NO	MP (m agl)	Well No	04.04.2017				11.04.2017				18.04.2017				28.04.2017			
				Time	***DTW (m bgl)***	***Time***	***DTW (m bgl)***	***Time***	***DTW (m bgl)***	***Time***	***DTW (m bgl)***	***Time***	***DTW (m bgl)***	***Time***	***DTW (m bgl)***	***Time***	***DTW (m bgl)***	***Time***	***DTW (m bgl)***
Apr-17	1	0.80	**TW-1**	10.15	**1.65**	16.00	**1.67**	10.15	**1.63**	16.02	**1.55**	10.10	**1.66**	16.00	**1.62**	10.00	**1.62**	16.02	**1.59**
	2	0.65	**TW-2**	10.22	**0.98**	16.08	**1.01**	10.22	**0.84**	16.10	**0.81**	10.17	**0.97**	16.08	**0.95**	10.07	**0.92**	16.10	**0.89**
	3	1.00	**TW-3**	10.30	**0.71**	16.15	**0.73**	10.28	**0.70**	16.20	**0.65**	10.26	**0.71**	16.15	**0.70**	10.15	**0.71**	16.20	**0.68**
	4	0.75	**TW-4**	10.35	**1.69**	16.23	**1.71**	10.35	**1.69**	16.25	**1.64**	10.31	**1.71**	16.23	**1.69**	10.22	**1.69**	16.25	**1.66**
	5	0.70	**TW-5**	10.44	**2.57**	16.31	**2.58**	10.40	**2.55**	16.32	**2.52**	10.40	**2.58**	16.31	**2.52**	10.30	**2.54**	16.32	**2.53**
	6	0.72	**TW-6**	10.50	**2.26**	16.38	**2.28**	10.45	**2.22**	16.40	**2.12**	10.48	**2.29**	16.38	**2.26**	10.38	**2.32**	16.40	**2.26**
	7	0.60	**TW-7**	10.55	**0.78**	16.46	**0.81**	11.00	**0.59**	16.55	**0.47**	10.53	**0.81**	16.46	**0.79**	10.43	**0.75**	16.55	**0.69**

	8	0.70	**TW-8**	11.05	**2.41**	17.53	**2.42**	11.10	**2.22**	17.00	**2.12**	11.03	**2.42**	17.53	**2.40**	10.52	**2.38**	17.00	**2.32**
	9	0.80	**TW-9**	11.15	**0.85**	17.00	**0.86**	11.15	**0.84**	17.05	**0.76**	11.10	**0.94**	17.00	**0.91**	11.07	**0.96**	17.05	**0.88**
	10	0.60	**TW-10**	11.22	**1.29**	17.10	**1.31**	11.22	**1.08**	17.10	**1.01**	11.20	**1.25**	17.10	**1.23**	11.17	**1.27**	17.10	**1.19**

	SL.NO	**MP (m agl)**	**Well No**	**02.05.2017**				**09.05.2017**				**16.05.2017**				**23.05.2017**			
				Time	***DTW (m bgl)***	***Time***	***DTW (m bgl)***	***Time***	***DTW (m bgl)***	***Time***	***DTW (m bgl)***	***Time***	***DTW (m bgl)***	***Time***	***DTW (m bgl)***	***Time***	***DTW (m bgl)***	***Time***	***DTW (m bgl)***
May-17	1	0.8	TW-1	10.15	1.68	16	1.63	10.15	1.64	16.02	1.6	10.1	1.69	16	1.6	10	1.6	16.02	1.58
	2	0.65	TW-2	10.22	1.01	16.08	0.96	10.22	0.97	16.1	0.93	10.17	1.02	16.08	0.91	10.07	0.91	16.1	0.89
	3	1	TW-3	10.3	0.73	16.15	0.69	10.28	0.69	16.2	0.66	10.26	0.73	16.15	0.7	10.15	0.71	16.2	0.69
	4	0.75	TW-4	10.35	1.73	16.23	1.69	10.35	1.7	16.25	1.67	10.31	1.74	16.23	1.67	10.22	1.7	16.25	1.69
	5	0.7	TW-5	10.44	2.62	16.31	2.57	10.4	2.55	16.32	2.52	10.4	2.64	16.31	2.57	10.3	2.54	16.32	2.53
	6	0.72	TW-6	10.5	2.28	16.38	2.23	10.45	2.24	16.4	2.2	10.48	2.3	16.38	2.22	10.38	2.23	16.4	2.2
	7	0.6	TW-7	10.55	0.83	16.46	0.79	11	0.65	16.55	0.61	10.53	0.82	16.46	0.75	10.43	0.62	16.55	0.59
	8	0.7	TW-8	11.05	2.43	17.53	2.35	11.1	2.27	17	2.22	11.03	2.44	17.53	2.36	10.52	2.27	17	2.25
	9	0.8	TW-9	11.15	0.91	17	0.88	11.15	0.88	17.05	0.85	11.1	0.97	17	0.9	11.07	0.84	17.05	0.82
	10	0.6	TW-10	10.22	1.17	17.1	1.13	11.22	1.07	17.1	1.03	11.2	1.18	17.1	1.12	11.17	1.09	17.1	1.07

	SL.NO	**MP (m agl)**	**Well No**	**06.06.2017**				**13.06.2017**				**20.06.2017**				**27.06.2017**			
				Time	***DTW (m bgl)***	***Time***	***DTW (m bgl)***	***Time***	***DTW (m bgl)***	***Time***	***DTW (m bgl)***	***Time***	***DTW (m bgl)***	***Time***	***DTW (m bgl)***	***Time***	***DTW (m bgl)***	***Time***	***DTW (m bgl)***
Jun-17	1	0.8	TW-1	10.15	1.52	16	1.56	10.15	1.6	16.02	1.48	10.1	1.58	16	1.55	10	1.72	16.02	1.66
	2	0.65	TW-2	10.22	0.77	16.08	0.8	10.22	0.83	16.1	0.71	10.17	0.83	16.08	0.8	10.07	0.91	16.1	0.83
	3	1	TW-3	10.3	0.5	16.15	0.52	10.28	0.58	16.2	0.49	10.26	0.68	16.15	0.64	10.15	0.7	16.2	0.62
	4	0.75	TW-4	10.35	1.51	16.23	1.53	10.35	1.57	16.25	1.48	10.31	1.65	16.23	1.61	10.22	1.68	16.25	1.6
	5	0.7	TW-5	10.44	2.55	16.31	2.57	10.4	2.52	16.32	2.41	10.4	2.49	16.31	2.46	10.3	2.6	16.32	2.52
	6	0.72	TW-6	10.5	2.17	16.38	2.2	10.45	2.25	16.4	2.13	10.48	2.19	16.38	2.15	10.38	2.27	16.4	2.2
	7	0.6	TW-7	10.55	0.61	16.46	0.65	11	0.74	16.55	0.67	10.53	0.61	16.46	0.57	10.43	0.78	16.55	0.72
	8	0.7	TW-8	11.05	2.26	17.53	2.28	11.1	2.35	17	2.24	11.03	2.23	17.53	2.2	10.52	2.4	17	2.32
	9	0.8	TW-9	11.15	0.85	17	0.87	11.15	0.92	17.05	0.84	11.1	0.82	17	0.8	11.07	0.95	17.05	0.88
	10	0.6	TW-10	10.22	1.05	17.1	1.08	11.22	1.13	17.1	1.07	11.2	1.07	17.1	1.04	11.17	1.07	17.1	1.01

	SL.NO	**MP (m agl)**	**Well No**	**04.07.2017**				**11.07.2017**				**18.07.2017**				**25.07.2017**			
Jul-17				***Time***	***DTW (m bgl)***	***Time***	***DTW (m bgl)***	***Time***	***DTW (m bgl)***	***Time***	***DTW (m bgl)***	***Time***	***DTW (m bgl)***	***Time***	***DTW (m bgl)***	***Time***	***DTW (m bgl)***	***Time***	***DTW (m bgl)***
	1	0.8	TW-1	10.15	1.66	16	1.56	10.15	1.72	16.02	1.64	10.1	1.61	16	1.58	10	1.69	16.02	1.62
	2	0.65	TW-2	10.22	0.89	16.08	0.79	10.22	1	16.1	0.92	10.17	0.91	16.08	0.87	10.07	0.96	16.1	0.88

	3	1	TW-3	10.3	0.69	16.15	0.65	10.28	0.76	16.2	0.67	10.26	0.65	16.15	0.61	10.15	0.67	16.2	0.6
	4	0.75	TW-4	10.35	1.67	16.23	1.57	10.35	1.74	16.25	1.64	10.31	1.64	16.23	1.6	10.22	1.73	16.25	1.66
	5	0.7	TW-5	10.44	2.46	16.31	2.37	10.4	2.62	16.32	2.54	10.4	2.5	16.31	2.45	10.3	2.62	16.32	2.54
	6	0.72	TW-6	10.5	2.16	16.38	2.08	10.45	2.32	16.4	2.2	10.48	2.19	16.38	2.15	10.38	2.31	16.4	2.25
	7	0.6	TW-7	10.55	0.77	16.46	0.71	11	0.78	16.55	0.71	10.53	0.73	16.46	0.69	10.43	0.77	16.55	0.71
	8	0.7	TW-8	11.05	2.38	17.53	2.3	11.1	2.42	17	2.31	11.03	2.3	17.53	2.24	10.52	2.4	17	2.35
	9	0.8	TW-9	11.15	0.91	17	0.8	11.15	1	17.05	0.88	11.1	0.88	17	0.83	11.07	0.98	17.05	0.9
	10	0.6	TW-10	10.22	1.05	17.1	0.97	11.22	1.09	17.1	1.01	11.2	1.03	17.1	0.99	11.17	1.07	17.1	1.02

	SL.NO	**MP (m agl)**	**Well No**	**01.08.2017**				**08.08.2017**				**22.08.2017**				**29.08.2017**			
				Time	***DTW (m bgl)***	***Time***	***DTW (m bgl)***	***Time***	***DTW (m bgl)***	***Time***	***DTW (m bgl)***	***Time***	***DTW (m bgl)***	***Time***	***DTW (m bgl)***	***Time***	***DTW (m bgl)***	***Time***	***DTW (m bgl)***
Aug-17	1	0.8	TW-1	10.15	1.73	16	1.69	10.15	1.76	16.02	1.68	10.1	1.7	16	1.62	10	1.68	16.02	1.64
	2	0.65	TW-2	10.22	0.98	16.08	0.94	10.22	0.99	16.1	0.92	10.17	0.97	16.08	0.89	10.07	0.91	16.1	0.87
	3	1	TW-3	10.3	0.72	16.15	0.7	10.28	0.72	16.2	0.67	10.26	0.7	16.15	0.64	10.15	0.66	16.2	0.63
	4	0.75	TW-4	10.35	1.7	16.23	1.67	10.35	1.74	16.25	1.67	10.31	1.69	16.23	1.62	10.22	1.64	16.25	1.61
	5	0.7	TW-5	10.44	2.56	16.31	2.52	10.4	2.62	16.32	2.52	10.4	2.57	16.31	2.48	10.3	2.5	16.32	2.46
	6	0.72	TW-6	10.5	2.26	16.38	2.22	10.45	2.2	16.4	2.17	10.48	2.22	16.38	2.1	10.38	2.2	16.4	2.15
	7	0.6	TW-7	10.55	0.73	16.46	0.7	11	0.77	16.55	0.65	10.53	0.77	16.46	0.67	10.43	0.66	16.55	0.62
	8	0.7	TW-8	11.05	2.34	17.53	2.3	11.1	2.36	17	2.32	11.03	2.32	17.53	2.26	10.52	2.28	17	2.24
	9	0.8	TW-9	11.15	0.9	17	0.86	11.15	0.86	17.05	0.84	11.1	0.9	17	0.78	11.07	0.79	17.05	0.75
	10	0.6	TW-10	10.22	1.11	17.1	1.08	11.22	1.13	17.1	1.09	11.2	1.15	17.1	1.06	11.17	1.11	17.1	1.06

	SL.NO	**MP (m agl)**	**Well No**	**05.09.2017**				**12.09.2017**				**19.09.2017**				**26.09.2017**			
				Time	***DTW (m bgl)***	***Time***	***DTW (m bgl)***	***Time***	***DTW (m bgl)***	***Time***	***DTW (m bgl)***	***Time***	***DTW (m bgl)***	***Time***	***DTW (m bgl)***	***Time***	***DTW (m bgl)***	***Time***	***DTW (m bgl)***
Sep-17	1	0.8	TW-1	10.15	1.83	16	1.78	10.15	1.72	16.02	1.64	10.1	1.82	16	1.84	10	1.84	16.02	1.8
	2	0.65	TW-2	10.22	1.04	16.08	0.99	10.22	0.99	16.1	0.93	10.17	1.03	16.08	1.05	10.07	1.05	16.1	1.02
	3	1	TW-3	10.3	0.78	16.15	0.75	10.28	0.71	16.2	0.67	10.26	0.77	16.15	0.78	10.15	0.82	16.2	0.8
	4	0.75	TW-4	10.35	1.75	16.23	1.72	10.35	1.69	16.25	1.64	10.31	1.72	16.23	1.74	10.22	1.76	16.25	1.72
	5	0.7	TW-5	10.44	2.6	16.31	2.57	10.4	2.57	16.32	2.47	10.4	2.58	16.31	2.59	10.3	2.62	16.32	2.58
	6	0.72	TW-6	10.5	2.3	16.38	2.26	10.45	2.26	16.4	2.17	10.48	2.22	16.38	2.25	10.38	2.28	16.4	2.22
	7	0.6	TW-7	10.55	0.77	16.46	0.72	11	0.73	16.55	0.67	10.53	0.65	16.46	0.65	10.43	0.73	16.55	0.66
	8	0.7	TW-8	11.05	2.38	17.53	2.35	11.1	2.37	17	2.3	11.03	2.25	17.53	2.27	10.52	2.3	17	2.22
	9	0.8	TW-9	11.15	0.94	17	0.9	11.15	0.87	17.05	0.81	11.1	0.87	17	0.88	11.07	0.86	17.05	0.8
	10	0.6	TW-10	10.22	1.15	17.1	1.11	11.22	1.11	17.1	1.04	11.2	1.08	17.1	1.1	11.17	1.13	17.1	1.07

	SL.NO	MP (m agl)	Well No	07.11.2017				14.11.2017				21.11.2017				28.11.2017			
				Time	*DTW (m bgl)*	*Time*	*DTW (m bgl)*	*Time*	*DTW (m bgl)*	*Time*	*DTW (m bgl)*	*Time*	*DTW (m bgl)*	*Time*	*DTW (m bgl)*	*Time*	*DTW (m bgl)*	*Time*	*DTW (m bgl)*
Nov-17	1	0.8	TW-1	10.15	1.74	16	1.72	10.15	1.76	16.02	1.85	10.1	1.66	16	1.71	10	1.68	16.02	1.72
	2	0.65	TW-2	10.22	0.92	16.08	0.89	10.22	0.94	16.1	1.06	10.17	0.99	16.08	1.03	10.07	0.95	16.1	0.99
	3	1	TW-3	10.3	0.73	16.15	0.7	10.28	0.77	16.2	0.78	10.26	0.7	16.15	0.74	10.15	0.7	16.2	0.74
	4	0.75	TW-4	10.35	1.68	16.23	1.65	10.35	1.6	16.25	1.69	10.31	1.65	16.23	1.69	10.22	1.69	16.25	1.73
	5	0.7	TW-5	10.44	2.5	16.31	2.48	10.4	2.36	16.32	2.44	10.4	2.38	16.31	2.42	10.3	2.5	16.32	2.6
	6	0.72	TW-6	10.5	2.16	16.38	2.08	10.45	2.12	16.4	2.24	10.48	2.1	16.38	2.17	10.38	2.18	16.4	2.28
	7	0.6	TW-7	10.55	0.55	16.46	0.52	11	0.6	16.55	0.72	10.53	0.62	16.46	0.66	10.43	0.6	16.55	0.67
	8	0.7	TW-8	11.05	2.18	17.53	2.12	11.1	2.22	17	2.32	11.03	2.3	17.53	2.36	10.52	2.21	17	2.31
	9	0.8	TW-9	11.15	0.75	17	0.74	11.15	0.67	17.05	0.8	11.1	0.73	17	0.76	11.07	0.73	17.05	0.81
	10	0.6	TW-10	10.22	1.15	17.1	1.11	11.22	1.08	17.1	1.15	11.2	1.11	17.1	1.15	11.17	1.13	17.1	1.18

	SL.NO	MP (m agl)	Well No	05.12.2017				12.12.2017				19.12.2017				26.12.2017			
				Time	*DTW (m bgl)*	*Time*	*DTW (m bgl)*	*Time*	*DTW (m bgl)*	*Time*	*DTW (m bgl)*	*Time*	*DTW (m bgl)*	*Time*	*DTW (m bgl)*	*Time*	*DTW (m bgl)*	*Time*	*DTW (m bgl)*
Dec-17	1	0.8	TW-1	10.15	1.42	16	1.5	10.15	1.71	16.02	1.8	10.1	1.72	16	1.8	10	1.71	16.02	1.81
	2	0.65	TW-2	10.22	0.71	16.08	0.81	10.22	1	16.1	1.07	10.17	1.01	16.08	1.09	10.07	0.99	16.1	1.04
	3	1	TW-3	10.3	0.53	16.15	0.6	10.28	0.76	16.2	0.82	10.26	0.75	16.15	0.83	10.15	0.76	16.2	0.79
	4	0.75	TW-4	10.35	1.62	16.23	1.67	10.35	1.69	16.25	1.75	10.31	1.67	16.23	1.75	10.22	1.73	16.25	1.74
	5	0.7	TW-5	10.44	2.45	16.31	2.52	10.4	2.57	16.32	2.64	10.4	2.47	16.31	2.52	10.3	2.51	16.32	2.54
	6	0.72	TW-6	10.5	2.12	16.38	2.22	10.45	2.15	16.4	2.22	10.48	2.2	16.38	2.25	10.38	2.24	16.4	2.27
	7	0.6	TW-7	10.55	0.49	16.46	0.57	11	0.63	16.55	0.75	10.53	0.63	16.46	0.77	10.43	0.7	16.55	0.78
	8	0.7	TW-8	11.05	2.1	17.53	2.12	11.1	2.28	17	2.32	11.03	2.24	17.53	2.35	10.52	2.31	17	2.36
	9	0.8	TW-9	11.15	0.64	17	0.68	11.15	0.68	17.05	0.76	11.1	0.76	17	0.82	11.07	0.8	17.05	0.83
	10	0.6	TW-10	10.22	0.88	17.1	0.95	11.22	0.95	17.1	1.03	11.2	1.03	17.1	1.09	11.17	1.05	17.1	1.11

	SL.NO	MP (m agl)	Well No	02.01.2018				09.01.2018				16.01.2018				23.01.2018			
				Time	*DTW (m bgl)*	*Time*	*DTW (m bgl)*	*Time*	*DTW (m bgl)*	*Time*	*DTW (m bgl)*	*Time*	*DTW (m bgl)*	*Time*	*DTW (m bgl)*	*Time*	*DTW (m bgl)*	*Time*	*DTW (m bgl)*
Jan-18	1	0.8	TW-1	10.15	1.54	16	1.67	10.15	1.62	16.02	1.71	10.1	1.55	16	1.66	10	1.63	16.02	1.74
	2	0.65	TW-2	10.22	0.88	16.08	0.96	10.22	0.91	16.1	1.01	10.17	0.84	16.08	0.97	10.07	0.86	16.1	0.88
	3	1	TW-3	10.3	0.67	16.15	0.72	10.28	0.68	16.2	0.73	10.26	0.68	16.15	0.72	10.15	0.72	16.2	0.74
	4	0.75	TW-4	10.35	1.65	16.23	1.67	10.35	1.66	16.25	1.71	10.31	1.64	16.23	1.68	10.22	1.68	16.25	1.72
	5	0.7	TW-5	10.44	2.44	16.31	2.54	10.4	2.52	16.32	2.62	10.4	2.45	16.31	2.52	10.3	2.53	16.32	2.57
	6	0.72	TW-6	10.5	2.12	16.38	2.16	10.45	2.13	16.4	2.2	10.48	2.12	16.38	2.18	10.38	2.16	16.4	2.2
	7	0.6	TW-7	10.55	0.55	16.46	0.69	11	0.61	16.55	0.69	10.53	0.5	16.46	0.57	10.43	0.53	16.55	0.59
	8	0.7	TW-8	11.05	2.06	17.53	2.12	11.1	2.22	17	2.28	11.03	2.12	17.53	2.2	10.52	2.16	17	2.25

	9	0.8	TW-9	11.15	0.66	17	0.74	11.15	0.65	17.05	0.73	11.1	0.62	17	0.66	11.07	0.63	17.05	0.69
	10	0.6	TW-10	10.22	0.81	17.1	0.93	11.22	1	17.1	1.09	11.2	0.91	17.1	0.97	11.17	0.95	17.1	0.99

ANNEXURE–III: CHEMICAL ANALYSIS OF GROUND WATER SAMPLES IN KADMAT ISLAND (PRE AND POST MONSOON 2010)

SL.NO	LOCATION	DATE OF COLLECTION	pH	Ec in µS/cm. at 25°C	TH as $CaCO_3$	Ca	Mg	Na	K	CO_3	HCO_3	SO_4	Cl	F	NO_3
					mg/l										
1	Kadmath (JB School South)	24.04.10	8.16	881	300	72	29	46	2.1	0	378	44	89	1.05	3.3
		13.11.10	7.75	770	340	92	27	25	1.7	0	433	22	43	0.59	4.3
2	Kadmath (Water Supply Well near OHT)	24.04.10	8.3	688	300	74	28	17	1.3	0	409	14	36	0.91	1.4
		13.11.10	7.62	551	250	68	19	15	1.9	0	329	10	25	0.38	1.7
3	Kadmath (High School)	24.04.10	7.66	820	285	72	25	36	8.3	0	317	29	100	0.93	21
		13.11.10	8.06	651	245	72	16	33	6.5	0	299	24	53	0.53	14
4	Kadmath (Census Office)	24.04.10	7.97	494	234	57	22	7.4	0.4	0	303	9	20	0.83	2.4
		13.11.10	7.94	567	270	80	17	13	0.7	0	335	11	25	0.61	2
5	Kadmath (Govt. Quarter near Fisheries Deptt.)	24.04.10	7.72	819	315	78	29	33	3.1	0	366	27	64	0.57	35
		13.11.10	7.84	831	300	72	29	54	12	0	427	27	68	0.22	8.9
6	Kadmath (Govt.Quarter near Govt. Press)	24.04.10	8.02	435	190	44	19	9.9	0.1	0	246	13	17	0.8	3.4
		13.11.10	7.79	949	365	86	36	71	0.2	0	500	23	85	0.6	1.7
7	Kadmath (Agriculture office, Soil Testing Lab.)	24.4.10	8.18	499	178	33	23	20	3.3	0	195	30	50	0.98	2.7
		13.11.10	7.9	419	210	57	17	13	0.1	0	268	19	21	0.43	0.4

ANNEXURE IV: CHEMICAL ANALYSIS RESULTS OF WATER SAMPLES COLLECTED FROM PERMANENT OBSERVATION WELLS –KADMAT ISLAND (LPWD Lab Data)

#	Sample reference	Date f Sample Collection	Turbidity (NTU)	PH	Conductivity (µS/cm)	TDS (mg/l)	Chloride (mg/l)	TH (mg/l)	Ca-Hardness (mg/l)	Mg-Hardness (mg/l)	Alkalinity (mg/l)	Salinity (mg/l)
1	OW - 1	Mar-17		8.05	7260	4066	2350	1250	200	1050	760	4245
2	OW - 2	Mar-17		8.06	3270	1831	950	820	200	620	836	1716
3	OW - 3	Mar-17		7.72	6200	3472	1500	1530	190	1340	840	2710
4	OW - 4	Mar-17		8.1	11240	6294	3700	2100	200	1900	560	6684
5	OW - 5	Mar-17		8.12	3320	1859	950	650	190	460	560	1716
6	OW - 6	Mar-17		7.89	14940	8366	5350	2650	200	2450	792	9665
7	OW - 7	Mar-17		7.79	6650	3724	2000	1510	190	1320	664	3613
8	OW - 8	Mar-17		7.74	9180	5141	2500	2190	180	2010	552	4516
9	OW - 9	Mar-17		7.87	8460	4738	2450	1950	190	1760	552	4426
10	OW - 10	Mar-17		7.84	10110	5662	3050	2360	200	2160	792	5510

#	Sample reference	Date f Sample Collection	Turbidity	PH	Conductivity	TDS (mg/l)	Chloride (mg/l)	TH (mg/l)	Ca-Hardness	Mg-Hardness (mg/l)	Alkalinity	Salinity (mg/l)
11	OW - 11	Mar-17		7.84	2970	1663	620	830	190	640	728	1120
12	OW - 12	Mar-17		7.86	4770	2671	1450	960	200	760	512	2619
13	OW - 13	Mar-17		7.87	2660	1490	600	680	180	500	612	1084
14	OW - 14	Mar-17		7.86	3490	1954	960	840	190	650	556	1734
15	OW - 15	Mar-17		7.89	2960	1658	740	710	200	510	512	1337
16	OW - 16	Mar-17		8.08	2990	1674	730	670	180	490	490	1319
17	OW - 17	Mar-17		7.83	1670	935	250	480	170	310	528	452
18	OW - 18	Mar-17		7.96	2350	1316	560	550	190	360	560	1012
19	OW - 19	Mar-17		7.7	4460	2498	1300	980	190	790	620	2349
20	OW - 20	Mar-17		7.86	1640	918	270	460	180	280	550	488
21	OW - 21	Mar-17		8.1	1850	1036	310	600	180	420	400	560
22	OW - 22	Mar-17		7.9	1460	818	190	400	130	270	400	343
23	OW - 23	Mar-17		8.09	1500	840	210	400	170	230	364	379
24	OW - 24	Mar-17		7.85	1760	986	220	450	170	280	416	397
25	OW - 25	Mar-17		8.05	1370	767	150	500	180	320	412	271
26	OW - 26	Mar-17		7.9	2110	1182	330	550	160	390	456	596
27	OW - 27	Mar-17		8.05	1400	784	140	380	150	230	400	253
28	OW - 28	Mar-17		7.76	1900	1064	250	500	120	380	480	452
29	OW - 29	Mar-17		7.69	1950	1092	280	520	150	370	480	506
30	OW - 30	Mar-17		7.84	1670	935	230	520	190	330	512	416
31	OW-31	Mar-17		8.1	1250	700	90	330	100	230	352	163
32	OW-32	Mar-17		8	1400	784	170	430	100	330	364	307
33	OW-33	Mar-17		7.97	1520	851	180	440	120	320	360	325
34	OW-34	Mar-17		7.99	1530	857	150	350	100	250	484	271
35	OW-35	Mar-17		7.8	1180	661	120	360	140	220	360	217
36	OW-36	Mar-17		7.74	1830	1025	200	520	150	370	504	361
37	OW-37	Mar-17		7.59	1820	1019	200	540	100	440	496	361
38	OW-38	Mar-17		7.84	1330	745	160	390	120	270	476	289
39	OW-39	Mar-17		7.61	1570	879	210	420	160	260	448	379
40	OW-40	Mar-17		8.07	1560	874	220	430	140	290	376	397
41	OW 41	Mar-17		7.88	1790	1002	250	530	170	360	400	452
42	OW -42	Mar-17		7.89	1390	778	100	390	150	240	460	181
43	OW - 43	Mar-17		8.1	2120	1187	380	550	160	390	440	686
44	OW - 44	Mar-17		8.08	1370	767	170	400	140	260	360	307
45	OW - 45	Mar-17		7.92	1140	638	120	380	160	220	408	217
46	OW - 46	Mar-17		8.09	1540	862	140	430	170	260	304	253

#	Sample reference	Date f Sample Collection	Turbidity	PH	Conductivity	TDS (mg/l)	Chloride (mg/l)	TH (mg/l)	Ca-Hardness	Mg-Hardness (mg/l)	Alkalinity	Salinity (mg/l)
47	OW - 47	Mar-17		8.09	1540	862	140	440	180	260	352	253
48	OW - 48	Mar-17		7.93	1500	840	130	400	180	220	344	235
49	OW - 49	Mar-17		7.85	2110	1182	290	570	170	400	472	524
50	OW - 50	Mar-17		7.76	2350	1316	430	660	190	470	408	777
51	OW - 51	Mar-17		7.86	1800	1008	250	560	160	400	420	452
52	OW - 52	Mar-17		8.09	1350	756	140	400	140	260	364	253
53	OW - 53	Mar-17		7.77	2190	1226	370	580	160	420	424	668
54	OW - 54	Mar-17		7.9	1520	851	170	400	150	250	392	307
55	OW - 55	Mar-17		7.68	1580	885	180	430	160	270	400	325
56	OW - 56	Mar-17		8	1290	722	130	330	130	200	408	235
57	OW - 57	Mar-17		8.1	1740	974	200	460	170	290	480	361
58	OW - 58	Mar-17		8.09	1370	767	160	420	140	280	384	289
59	OW - 59	Mar-17		8.1	1440	806	150	330	130	200	360	271
60	OW - 60	Mar-17		8.09	1630	913	240	430	140	290	392	434
61	OW - 61	Mar-17		8.09	1380	773	170	350	120	230	400	307
62	OW - 62	Mar-17		7.88	1690	946	240	560	160	400	456	434
63	OW - 63	Mar-17		8.1	2150	1204	380	580	150	430	500	686
64	OW - 64	Mar-17		7.94	1350	756	140	450	130	320	472	253
65	OW - 65	Mar-17		8.09	1320	739	130	330	140	190	480	235
66	OW - 66	Mar-17		8.1	1300	728	150	380	100	280	432	271
67	OW - 67	Mar-17		8.1	1340	750	150	390	150	240	420	271
68	OW - 68	Mar-17		8.04	1420	795	130	470	140	330	352	235
69	OW - 69	Mar-17		8	1350	756	100	350	150	200	436	181
70	OW - 70	Mar-17		8.1	1740	974	230	450	140	310	376	416
71	OW - 71	Mar-17		7.94	2700	1512	400	730	160	570	570	723
72	OW - 72	Mar-17		8	1650	924	200	430	180	250	384	361
73	OW - 73	Mar-17		7.86	1550	868	180	450	160	290	412	325
74	OW - 74	Mar-17		8.07	1430	801	150	400	150	250	424	271
75	OW - 75	Mar-17		7.93	1240	694	130	360	170	190	368	235
76	OW - 76	Mar-17		7.75	2530	1417	490	750	190	560	584	885
77	OW - 77	Mar-17		7.98	2560	1434	430	650	160	490	536	777
78	OW - 78	Mar-17		7.89	1580	885	230	440	160	280	520	416
79	OW - 79	Mar-17		7.98	1700	952	190	450	170	280	360	343
80	OW-80	Mar-17		8.1	1590	890	170	400	140	260	448	307
81	OW-81	Mar-17		7.98	2470	1383	420	650	180	470	520	759
82	OW-82	Mar-17		7.6	2920	1635	560	790	200	590	592	1012
83	OW - 83	Mar-17		7.9	1320	739	150	430	120	310	360	271

#	Sample reference	Date f Sample Collection	Turbidity	PH	Conductivity	TDS (mg/l)	Chloride (mg/l)	TH (mg/l)	Ca-Hardness	Mg-Hardness (mg/l)	Alkalinity	Salinity (mg/l)
84	OW -84	Mar-17		8.09	1270	711	100	360	140	220	448	181
85	OW -85	Mar-17		8.1	2770	1551	580	640	200	440	568	1048
86	OW -86	Mar-17		7.43	1260	706	140	370	140	230	440	253
87	OW -87	Mar-17		7.97	1280	717	170	390	130	260	400	307
88	OW -88	Mar-17		8.11	5290	2962	1210	1330	200	1130	660	2186
89	OW -89	Mar-17		8	1470	823	180	490	130	360	456	325
90	OW -90	Mar-17		8.05	3310	1854	780	810	190	620	540	1409
91	OW -91	Mar-17		7.9	1490	834	180	470	190	280	432	325
92	OW -92	Mar-17		7.93	2300	1288	400	680	140	540	528	723
93	OW -93	Mar-17		7.96	1840	1030	200	570	180	390	504	361
94	OW -94	Mar-17		7.89	2060	1154	350	500	180	320	464	632
95	OW -95	Mar-17		7.85	1860	1042	250	420	160	260	408	452
96	OW -96	Mar-17		7.99	1350	756	150	280	150	130	480	271
97	OW -97	Mar-17		8.05	1470	823	130	380	120	260	384	235
98	OW -98	Mar-17		7.7	1650	924	200	480	160	320	456	361
99	OW -99	Mar-17		7.9	1730	969	200	430	120	310	464	361
100	OW -100	Mar-17		7.88	1840	1030	230	500	170	330	480	416
101	OW-101	Mar-17		8.04	1770	991	280	430	170	260	476	506
102	OW-102	Mar-17		8.05	1290	722	150	350	120	230	408	271
103	OW-103	Mar-17		8.09	1940	1086	330	520	160	360	482	596
104	OW-104	Mar-17		7.93	1630	913	270	370	150	220	384	488
105	OW-105	Mar-17		7.94	1620	907	240	390	140	250	384	434
106	OW-106	Mar-17		7.96	1750	980	220	440	170	270	424	397
107	OW-107	Mar-17		8.09	4100	2296	1100	770	190	580	540	1987