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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

KALPENI ISLAND, U.T.OF LAKHDWEEP

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केंद्रीय भूमिजल बोर्ड / CENTRAL GROUND WATER BOARD,

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

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Table of Contents

List of Annexures

List of Figures

List of Tables

1. Introduction

Lakshadweep, the smallest Union Territory of India is an archipelago consisting of 36 islands scattered in the Arabian Sea between latitude 8^0 00' and 12^0 13'N and longitude 71^0 00' and 74^0 00'E. It is a uni-district Union Territory with an area of 32 sq km according to the Survey of India whereas as per revenue records the area is only 28.5 sq km., which represents only the land use area. Lakshadweep Island comprises of 12 atolls, three reefs, five submerged banks, and ten inhabited islands. The inhabited islands are Kavaratti, Agatti, Amini, Kalpeni, Kiltan, Chetlat, Bitra, Andrott, Kadmat, and Minicoy.

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 no intermediary panchayat in this territory. Each of the ten inhabited Islands will have a *Dweep Panchayat*. The District Panchayat has its headquarters at Kavaratti.

Kalpeni is an inhabited island that forms part of the cluster of islands north of the nine-degree channel. It is oriented in a NE-SW direction. It is almost club-shaped with a large lagoon on its west. There is a tiny island called the Cheriam on the northeast of it, which is approachable during low tide. Other inhabited islands are Tilakkam and Pitti. Kalpeni island comes under the Andrott tehsil and Kalpeni subdivision. The map showing the locations of inhabited islands of Lakshadweep is given in Fig.1.

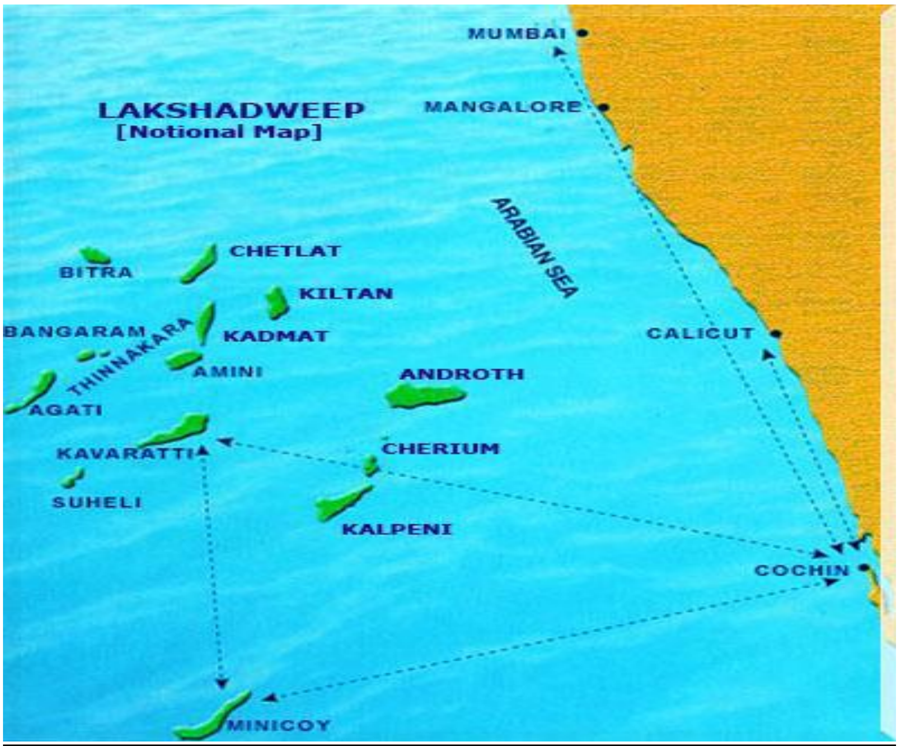


Fig. 1: Major islands in the UT of Lakshadweep

1.1 Extent

Kalpeni Island, with a land-use area of 2.28 sq km, lies between north latitude 10°03’ and 10°07’ and east longitude 73°37’and 73°39’. The island lies southeast of Kavaratti island and midway between Androth and Minicoy. According to Survey of India, the Kalpeni island has an areal extent of 2.79 sq km and a lagoonal area of 25.60 sq km with a maximum length of 5 km and a maximum width of 1.25 km and stretched in a NE-SW direction

1.2 Population

As per the 2011 Census statistics, the total population of the island is 4419 out of which the male population is 2324 and the female population is 2095, and the Density of population is 1938 persons/sq km. Fishing, coconut cultivation, and coir twinning are the main occupation of the islanders. The literacy rate of the island is 84.72.

1.3 Climate

Lying well within the tropics and extending to the equatorial belt, the Climate of Kalpeni is similar to the climatic condition of Kerala. Kalpeni 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 on the island. The temporal variation is usually high in small islands whereas the spatial variation is a function of the physiography of the islands. The inter-annual variability of rainfall is often high in the Lakshadweep islands.
The rain gauge station maintained by the Indian meteorological department at Kalpeni island is analysed. About 78% of the rain is received from May to September, 19% from October to December, and 3 % in the remaining months. The monthly rainfall of Kalpeni (2010-17) is given in Table 1 and Fig. 2 represents the monthly average rainfall of Kalpeni Island.

Table 1: Rainfall Data of Kalpeni island in mm)

Year	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
2010	0	0	0	0	84.4	386.2	401.2	347.3	165.4	186.8	240.9	56.4	1868.6
2011	0		1.2	8.6	106.2	245.8	447.4	319.3	484.6	132	172	0	1917.1
2012	6.4	6.4	22.6	8	0	302.9	269	390.7	141.7	145.8	18.4	23	1334.9
2013	18	79.4	22.6	23.2	98.8	467.8	290.6	196.9	338.8	99.9	114.3	25.2	1775.5
2014	10.2	0	0	2.2	129.8	186	190.7	708.6	159.2	227.8	110.2	53.6	1778.3
2015	5.6	0	10.2	72.6	130.8	373.8	219.1	264.6	131.4	190.8	237.5	142.9	1779.3
2016	17.8	1.4	0	0	202.4	420.4	462.5	104.2	80.4	24.4	69.4	53	1435.9
2017	9.4	8.2	52	0	215.6	480.8	152.2	314.8	213	178.4	68.6	72.4	1765.4

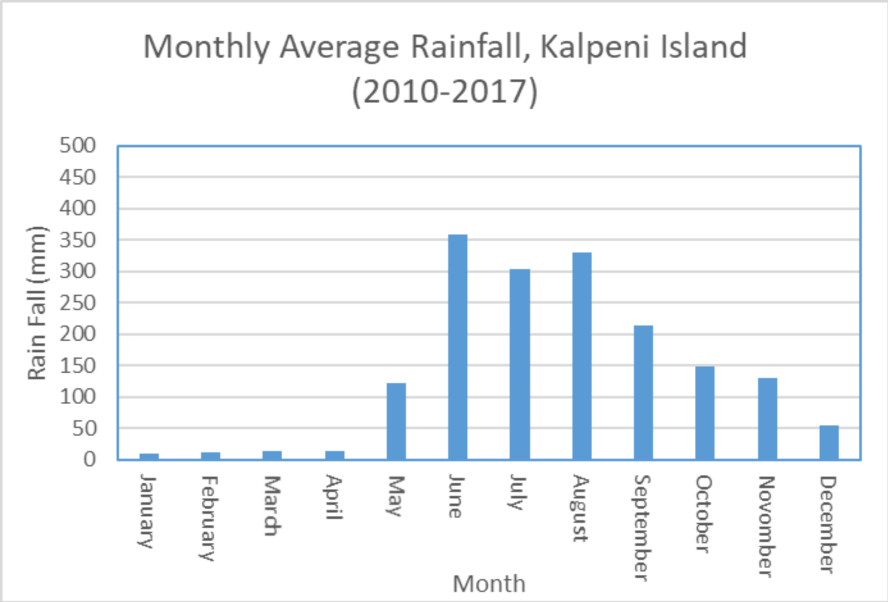


Fig. 2: Monthly average rainfall of Kalpeni island

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 the temperature to the mercury level between 27-30°.

1.3.4 Evapotranspiration: 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 traveling 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, Kalpeni 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 vegetation of this type is referred to as phreatophytes and is 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. Kalpeni Island is also connected to other islands through boat services. Only BSNL provides telecommunication services to Kalpeni 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.
- Many 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 several gaps, the prominent being the nine-degree channel.

Kalpeni, a club-shaped island is broader in the southern part and narrows towards the northern part. It is oriented in a NE-SW direction. This flat-topped island generally rises 2-4 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. There is a tiny island called the Cheriam on the northeast of it, which is approachable during low tide.

Kalpeni, a typical atoll type island is in its intermediate stage of development. 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 the peaks 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.

Kalpeni islands are mainly atoll type 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. This hard coral limestone is characterised 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 the coral sand 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 2 – 3 m below ground level, is seen as a thin lens floating over seawater and in hydraulic continuity with the seawater. Large diameter wells are the most common and traditional groundwater abstraction structures.

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

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

where h = ratio of the thickness of the freshwater lens below msl to that above msl,
σs = density of seawater (normally 1.025) and
σf = 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 on Christmas Island (Falkland, 1984). The freshwater- 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 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.

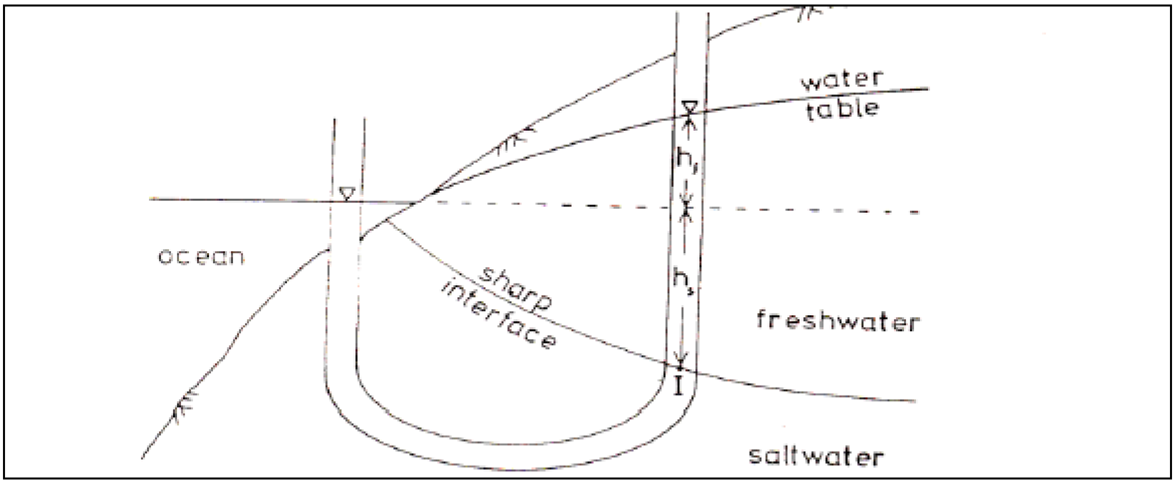


Fig. 3: Ghyben-Herzberg approximation for oceanic islands

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 the 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 Lakshadweep islands and the salient features of Kalpeni island are given in Table 2. Islands with an aspect ratio greater than 0.5 are found to have a stable freshwater lens, under identical geomorphological settings. The aspect ratio of Kalpeni island is 0.6.

Table 2: Salient Features of Kalpeni Island

Area in SQ.km	2.28
Maximum Length	5
Maximum width	1.25
Aspect Ratio i.e. A/(L/B)	0.6
Shape	Club
Trend of Longer axis	NE-SW

4.1 Groundwater scenario

The hydrogeological conditions of Kalpeni are almost similar to other islands, with freshwater floats over seawater in hydraulic continuity with it (Fig. 4).

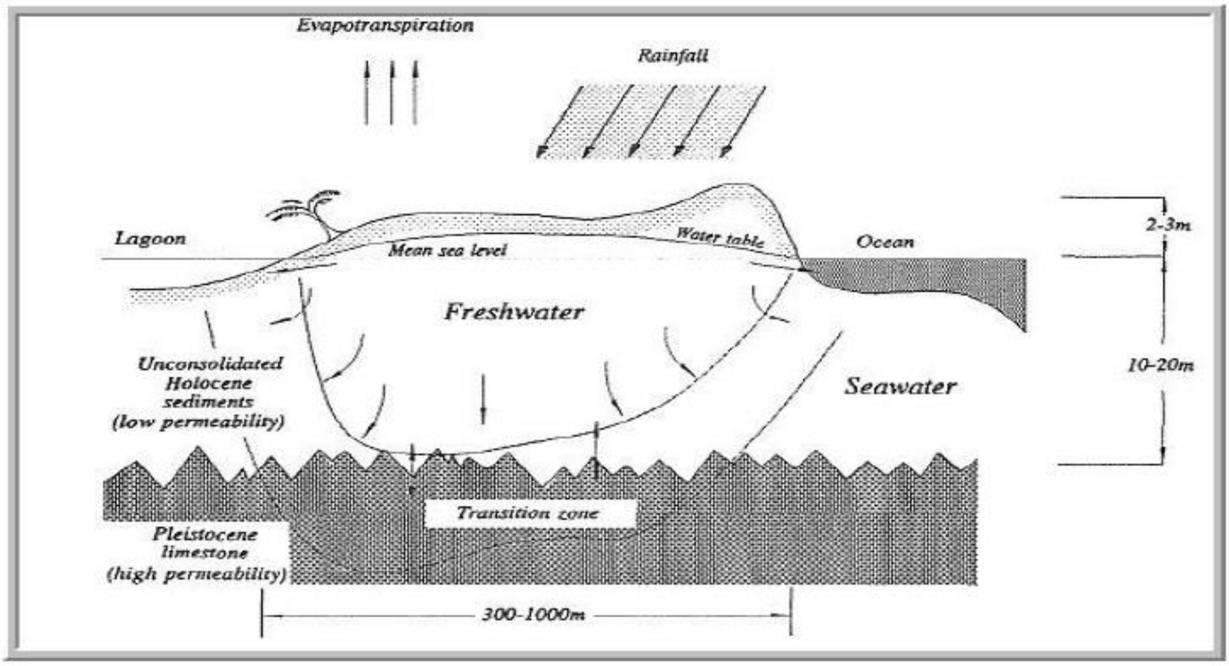


Fig. 4: ***Freshwater lens in small Islands (Exaggerated vertical scale)***
[Source: A.C.Falklands (1993): Hydrology and water management on small tropical islands- Hydrology of Warm Humid Regions (Proceedings of the Yokohama Symposium, July 1993). IAHS Publ. no. 216, 1993.]

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 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. 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 the 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 condition of the island has been studied in detail, the island has a freshwater lens and a brackish zone below it. There exists a high magnitude of temporal and spatial variations in thickness, shape as well as the water quality of these lenses. The exact geometry of these lenses, chemical quality, behaviour under various stresses, and their potential are 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 water 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 of Kalpeni islands were studied. The hydrogeological details of wells inventoried are presented in Annexure-I

There are 730 wells on the island with a well density of about 320/sq km. The depth to water level ranges from 0.7 to 3.85 m, while the depths of wells are in the range of 1.70 to 4.24 m. The comparison of long-term water levels does not show any definite pattern and shows both fall as well as a rise in water levels without any specific pattern in spatial distribution. The fluctuations in water level due to the tidal effect in these wells range from 0.10 to 0.21m. The maps showing locations of the key wells, depth to water table (pre-monsoon), and hydrogeology of the island are given in Figs 5, 6, and 7 respectively. The weekly water level from the 10 Observation Wells of LPWD is presented in Annexure-II. The comparison of DTW with rainfall for Kalpeni island is presented in Fig. 8. The figure shows that there is no much fluctuation due to rainfall in water level and the fluctuation is mainly due to tidal influences. Due to the highly porous nature of coral sands, the rainfall gets dispersed very fast and hence there is no much water level rise due to rain.

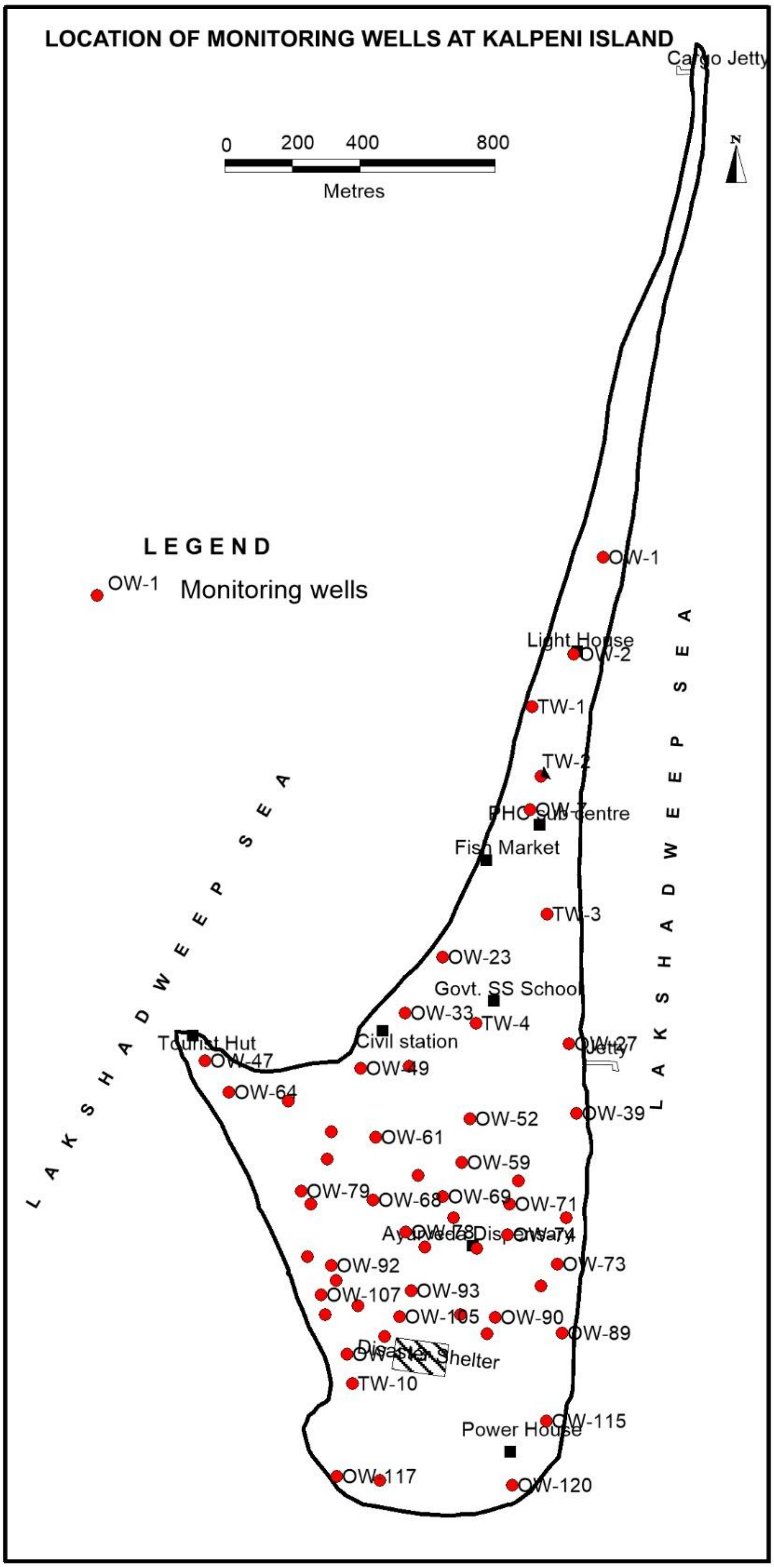


Fig. 5: Key well locations in Kalpeni island

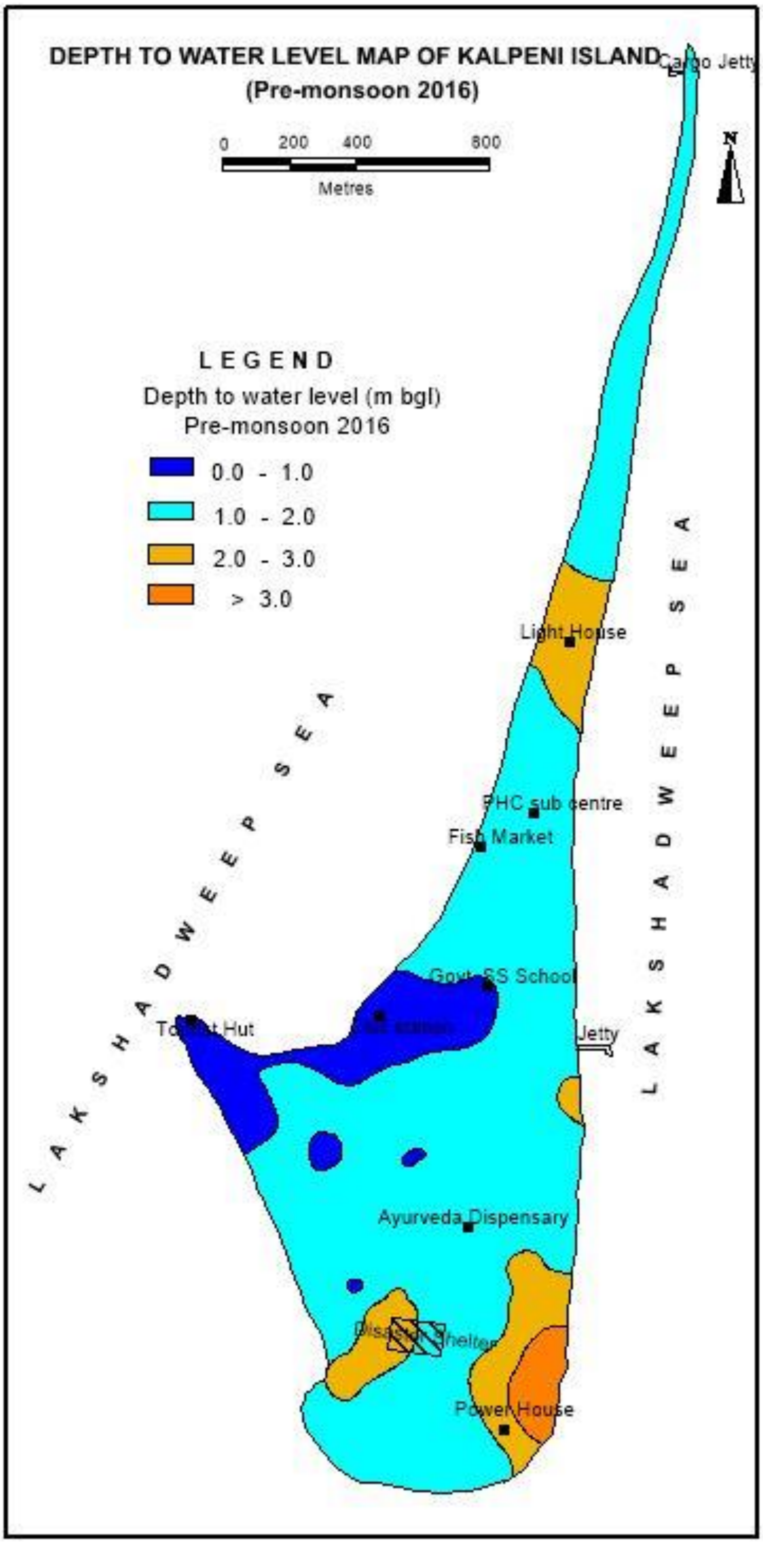


Fig. 6: Depth to water level map of Kalpeni island

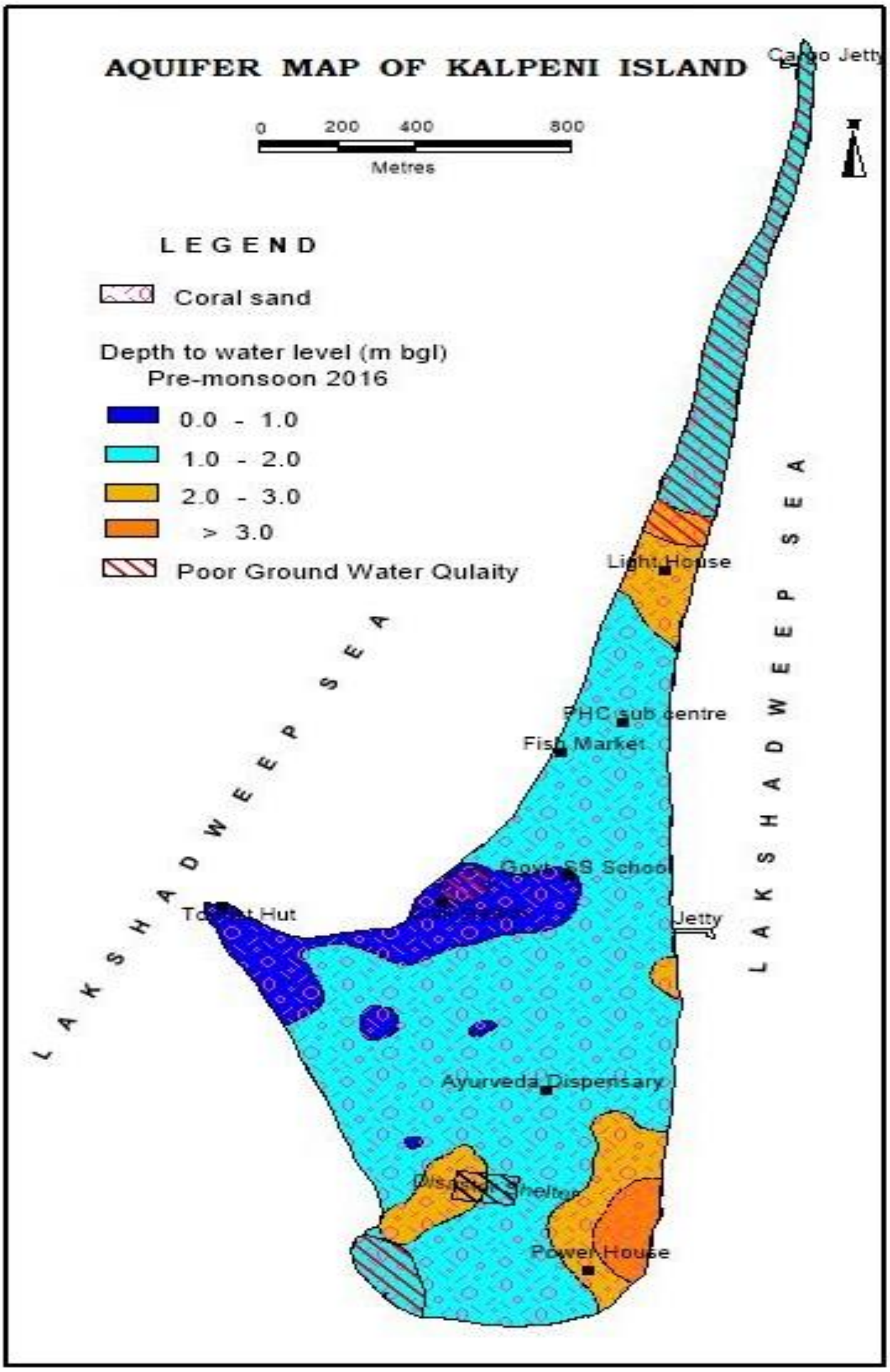
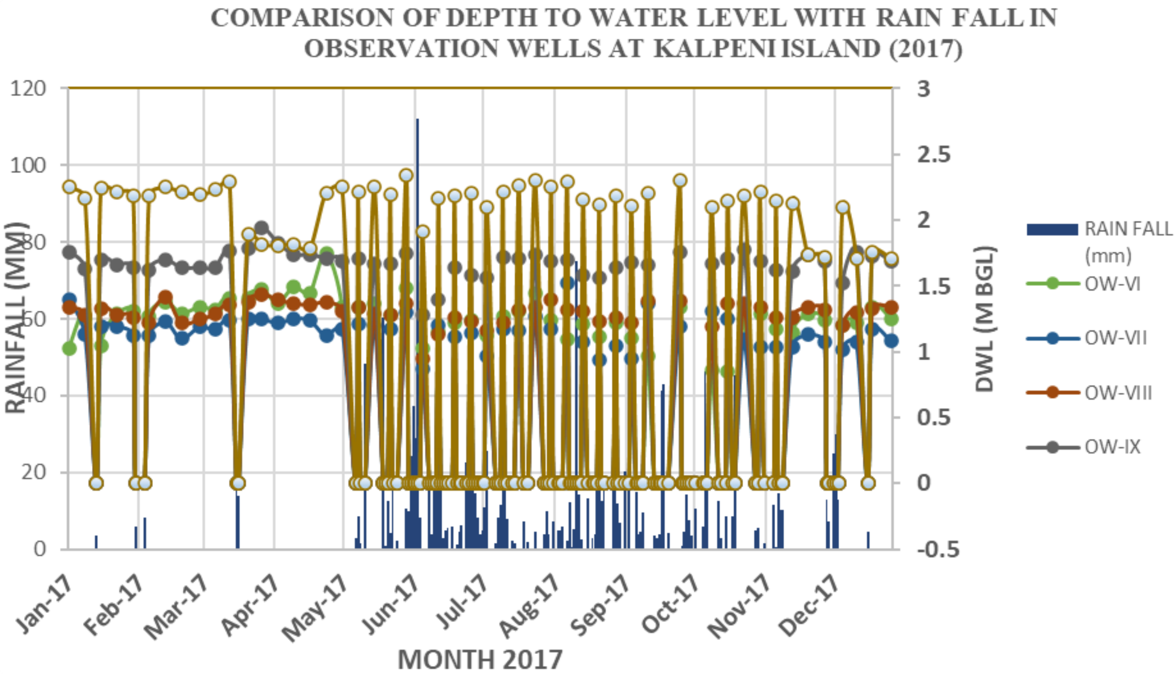


Fig. 7: Aquifer map of Kalpeni island



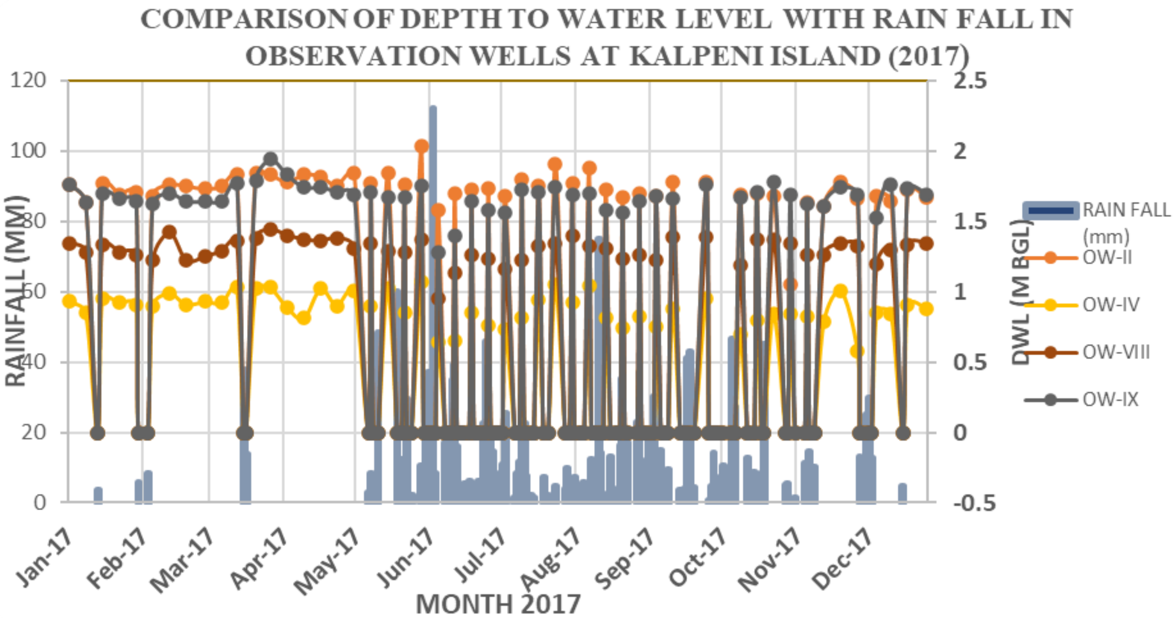


Fig. 8: Comparison of DTW with Rainfall in Observation Wells in Kalpeni Island

5. Quality of groundwater

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. 3.

Table 3: Hydrochemistry of selected groundwater samples collected from open wells in Kalpeni Island.

No of Samples	pH	EC (µS/cm)	TDS (mg/l)	Total Hardness(mg/l)	Ca (mg/l)	Mg (mg/l)	Cl (mg/l)
45	6.9-7.95	180-15030	101-8417	66—3140	40-1200	80-1840	40-5730

Groundwater quality characteristics of Kalpeni island are controlled by its shapes, climate, water use pattern, etc. The best quality of groundwater is encountered in the central part of the island, whereas the water is very fresh with the EC value are within the range of 180- 1204 µS/cm at 25ºC. The water is brackish in the northern tail of the island. A zone of high conductivity is observed in the southwestern part of the island also. About 90 % of the water samples shown the EC <3000 µS / cm at 25°C and Chloride <1000mg/l. The spatial variations in EC are depicted in Fig. 9. A comparison of EC of observation wells with rainfall of Kalpeni islands is shown in Fig. 10. The chemical analysis data of Kalpeni island by CGWB is given in Annexure III, Chemical analysis data of LPWD is given in Annexure IV and V.

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 on 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 the 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.

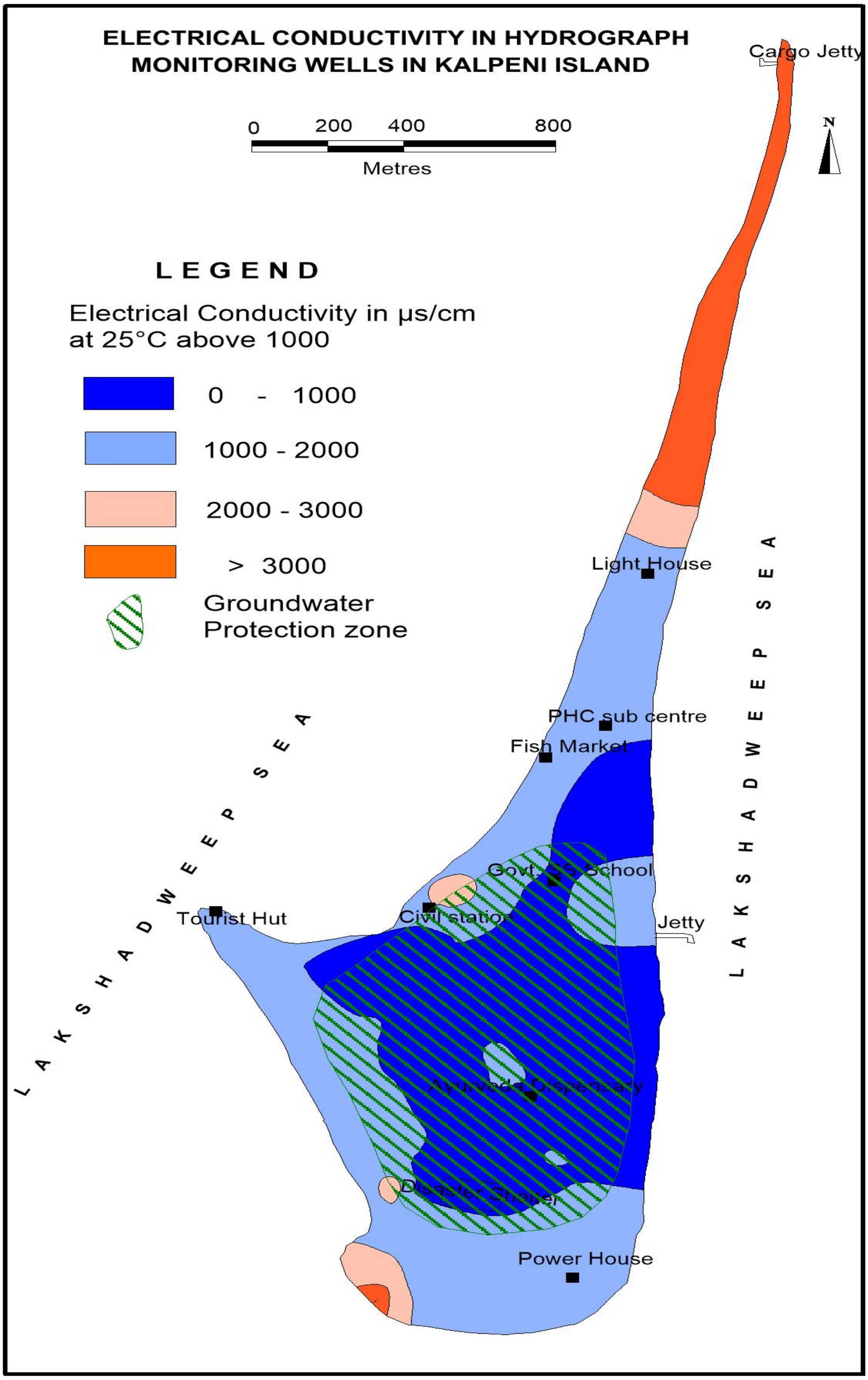


Fig. 9: Spatial variations in EC in Kalpeni islands

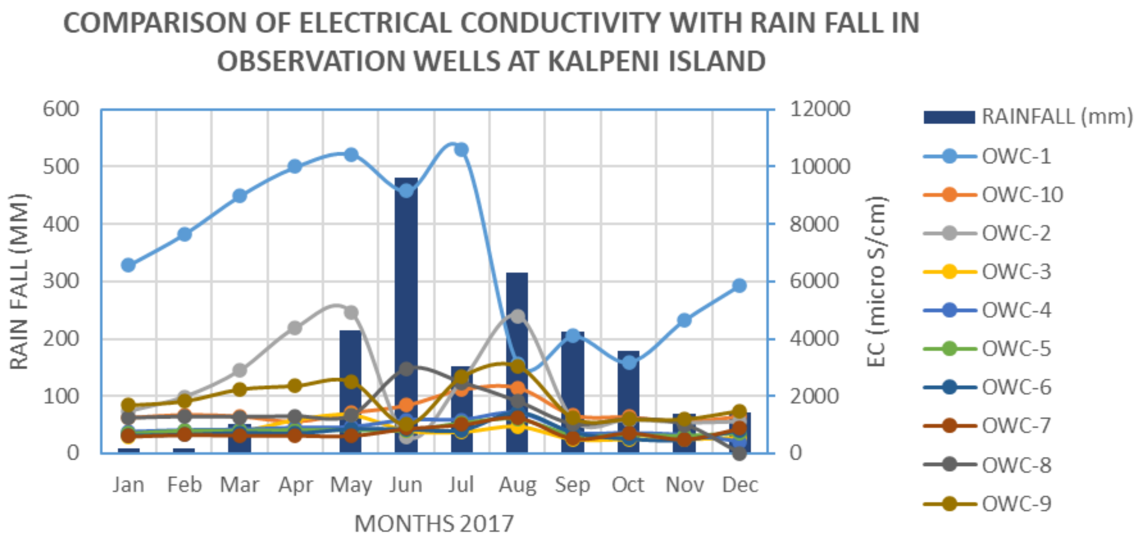


Fig. 10: Comparison of EC with rainfall in Observation Wells, Kalpeni Island

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 ratios of Kalpeni island is 0.6 and the value above 0.5 indicates that the freshwater lens is somewhat stable 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. Drilling activities also create a quality problem as they act as a conduit for seawater upconing.

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 Kalpeni Island 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 the Kalpeni 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 on 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 the island.

6.4 Groundwater draft

The major component of the groundwater draft in the Kalpeni island 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. The stage of groundwater extraction on the island is 53.07% and categorized as safe.

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.

6.7Computation 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 base flow 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 4.

Table 4: 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
15Annual 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 (3) (Ha.m)]	Buffer zone for reserve during delayed or lesser monsoon period [20% of (3)] (Ha.m)	Balance available resource (Ha.m)	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
Kalpeni	4479	228	1.355	30	92.7	24.8	18.5	18.5	30.9	16.4	16.4	14.5	53.07	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 alternate resources (surface water source) 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 the islands plays a significant role in its occurrence and stability.
- 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 Kalpeni 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 the 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 the Island 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 the island 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 on the island are:

- **Rehabilitation, restoration, renovation, and protection of available ponds and wells.**
  - According to the available data (Basic statistics 2014 of U.T of Lakshadweep), 456 ponds and 711 wells are existing in Kalpeni Island. These water sources are to be protected and abandoned ones 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.

- o The pumping of water from dug wells directly to multi-storied buildings may be stopped. For multi-story buildings, the pumped water has to be collected in ground-level storage tanks, and from there water may be pumped to multi-storied buildings.
- o Encouraging the use of water-efficient domestic fixtures like taps/ flush tanks to improve water use efficiency and reduce wastage. Thus encourage judicious use of precious 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 scientifically designed 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

- Kalpeni Island with an area of 2.79 sq km has a tropical humid, warm climate and the islands are flat, rising 2-4m 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 water level in the islands varies from 0.7 to 3.85 m and the depths of wells range from 1.7 to 4.24 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 stage of groundwater development of the island is 53.07 %.
- 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 180 to 15030μS/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.
- Though 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 on 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 the scientifically designed septic tank, Decentralised Waste treatment Plant and Sensitization of Public are the other management strategies.

Annexure I: HYDROGEOLOGICAL DATA OF DUG WELLS INVENTORIED IN KALPENI ISLAND (CGWB) Month of monitoring: December 2014

#	LPWD Well ID.	Longitude	Latitude	Depth (m bgl)	Dia (m)	MP (magl)	DWL (mbgl)	EC (µS/cm)	Temp (oC)	pH	Lining material	Lifting device
1	OW-1	73.6486	10.0863	2.4	1.8*1.5	0.6	1.76	3100	27.8	9	CSCM	EM
2	OW-2	73.0143	10.082	3.6	1.8	0.8	2.86	1640	27.4	9	CR	B&R
3	OW-7	73.6359	10.0765	1.98	1.8	0.7	1.3	1200	28	9	CSCM	EM
4	OW-23	73.0103	10.071	2.25	2.2*2.0	0.65	1.5	1340	27.8	8.7	CR	EM
5	OW-27	73.6271	10.0674	2.62	1.8	0.7	1.9	1520	28.2	8.4	CS	EM
6	OW-39	73.0144	10.0643	2.9	1.5	0.7	2.02	220	27.8	8.5	CS	B&R
7	OW-52	73.6143	10.0632	1.98	1.5*1.6	0.7	1.32	630	28.4	8.4	CR	B&R
8	OW-33	73.0091	10.0655	1.44	2.5	0.7	0.7	2200	26.7	8.5	CSCM	B&R
9	OW-49	73.6015	10.0629	1.95	1.75	0.65	0.81	640	27.6	9.1	CR	B&R
10	OW-47	73.003	10.0623	1.52	1.0*1.0	0.7	0.82	1820	28.2	8.5	CS	EM
11	OW-64	73.5883	10.0605	1.7	1.1*1.1	0.7	0.72	1290	27.6	8.7	CS	EM
12	OW-63	73.0055	10.0594	1.85	2.5	0.75	1.15	940	26.8	9	CR	EM,1.5
13	OW-61	73.584	10.0576	2.35	1.4	0.7	1.31	840	27.5	8.7	CR	EM,1.5
14	OW-59	73.0108	10.056	1.93	1	0.65	1.09	640	28.2	9	CS	EM
15	OW-58	73.5798	10.0547	2.14	1.8	0.7	1.32	580	27.8	8.9	CS	B&R
16	OW-73	73.0138	10.0548	2.32	1	0.6	1.45	610	28.6	8.9	CR	B&R
17	OW-74	73.5711	10.0551	1.97	1.3	0.9	1.13	770	28.6	8.6	CS	B&R
18	OW-76	73.0106	10.0551	2.64	1.25	0.6	1.3	1070	28.8	8.5	CS	EM,B&R
19	OW-69	73.561	10.0515	2.04	1.2	0.6	1.43	1120	28	8.6	CS	EM
20	OW-68	73.0081	10.0507	1.73	1.4	0.75	1.11	840	28.1	8.6	CR	EM
21	OW-67	73.5496	10.0514	1.85	1.4	0.8	0.95	1020	28	8.6	CS	EM
22	OW-72	73.014	10.0532	2.4	1.2	0.75	1.85	910	28.8	9.2	CR	B&R
23	OW-71	73.5475	10.0488	1.92	1.2	0.7	1.3	650	29.2	9.1	CS	EM,B&R
24	OW-78	73.0091	10.0518	2.11	1.3	0.6	1.44	640	28	9	CR	B&R
25	OW-79	73.5337	10.048	1.5	1.1	0.65	1.05	1190	28.3	8.6	CR	EM
26	OW-82	73.0062	10.0471	1.84	1.2	0.6	1.02	1080	28.3	8.6	CR	EM,0.5
27	OW-84	73.5302	10.0501	2.26	1.1*1.0	0.8	1.76	920	27.5	8.7	CS	B&R
28	OW-85	73.0113	10.0497	2.13	1.2	0.8	1.4	880	28.5	8.6	CR	EM
29	OW-87	73.5267	10.0481	2.96	1	0.6	2.33	620	27.8	8.7	CR	B&R
30	OW-89	73.0139	10.0464	3.67	2	0.65	2.93	960	27.4	8.8	CR	EM,0.5
31	OW-90	73.5185	10.0464	2.05	0.9*0.9	0.35	1.67	1020	27.5	8.6	CR	EM
32	OW-93	73.0093	10.0469	2.14	1.2*1.2	0.6	1.64	940	27.8	8.6	CS	EM,B&R
33	OW-92	73.5068	10.0473	1.75	1.05	1.05	1.28	1200	28	8.4	CR	EM

#	LPWD Well ID.	Longitude	Latitude	Depth (m bgl)	Dia (m)	MP (magl)	DWL (mbgl)	EC (µS/cm)	Temp (oC)	pH	Lining material	Lifting device
34	OW-98	73.007	10.0465	2.14	0.7	0.8	1.4	1480	27.8	8.5	CR	EM
35	OW-102	73.5043	10.0451	1.67	2.2*2.2	0.8	1.2	920	27	8.6	CR	B&R
36	OW-103	73.0116	10.0442	2.56	1.8	0.7	1.62	960	27.4	8.6	CR	B&R,EM
37	OW-105	73.4961	10.0444	2.5	1.8	0.55	2.1	520	27.5	8.9	CR	EM
38	OW-106	73.0076	10.0444	1.58	0.6	0.95	0.95	1120	27.5	8.4	CSCM	B&R
39	OW-107	73.4875	10.0444	2.2	1.6	0.6	1.57	1440	27.4	8.2	CR	B&R
40	OW-113	73.0073	10.0423	2.1	1.8	0.88	1.41	2300	27.4	8.2	CR	EM,B&R
41	OW-110	73.4834	10.0425	3.1	0.9	0.7	2.4	550	27.6	8.9	CR	EM
42	OW-117	73.0064	10.0365	2.2	6*6	0.3	1.5	3200	27.6	8.3	CSCM	EM
43	OW-119	73.4774	10.0376	1.7	0.85	0.6	1.2	1720	27.8	8.7	CR	EM
44	OW-120	73.0123	10.0372	2.8	1.7*1.8	0.9	1.94	1510	27.8	8.6	CR	B&R
45	OW-115	73.4768	10.0388	4.24	1.8	1.2	3.85	1430	27.6	8.5	CR	EM,2Nos
46	TW-1	73.0129	10.053	2.06	1*1.2	0.6	1.44	1760	28.2	8.8	CR	EM
47	TW-2	73.471	10.0505	2.22	1.8	0.6	1.7	1280	28	8.6	CR	B&R
48	TW-3	73.0134	10.046	2	2.2*2.2	0.7	1.35	680	27.8	9.2	CR	B&R
49	TW-4	73.4636	10.0424	1.9	1.5	0.6	0.8	920	28.1	8.8	CR	B&R
50	TW-5	73.0092	10.0408	1.58	1.2	0.5	0.93	1010	27.4	8.8	CR	B&R
51	TW-6	73.4539	10.0385	1.84	1.1*1.1	0.7	1.22	590	28	8.8	CS	EM
52	TW-7	73.0094	10.0369	1.7	2*2	0.7	0.98	790	28.8	8.8	CR	B&R
53	TW-8	73.4479	10.0416	1.7	1.2	0.7	1.3	1730	28.5	8.4	CR	EM
54	TW-9	73.0066	10.0397	2.3	0.9	0.9	1.6	1160	27.8	8.4	CS	EM
55	TW-10	73.4442	10.0374	2.9	1.8	1	2.16	1580	27.1	8.4	CR	EM

*: 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: Water level data of Observation well in Kalpeni Island (Jan 2016 To December 2016)

Date	OW-I		OW-II		OW-III		OW- IV		OW-V		OW- VI		OW- VII		OW- VIII		OW- IX		OW- X	
	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM
04-01-2016	1.58	1.72	1.72	1.8	1.34	1.47	0.9	1.01	0.91	1.03	0.99	1.09	1.4	1.5	1.24	1.35	1.66	1.77	2.2	2.28
11-01-2016	1.54	1.78	1.64	1.85	1.31	1.48	0.86	1.1	0.87	1.04	0.92	1.11	1.32	1.8	1.22	1.37	1.6	1.78	2.13	2.28
18-01-2016	1.59	1.65	1.68	1.75	1.4	1.43	0.86	0.91	0.9	0.91	0.99	1.05	1.35	1.45	1.18	1.26	1.58	1.65	2.21	2.26
25-01-2016	1.52	1.62	1.63	1.73	1.28	1.36	0.86	0.97	0.84	0.91	0.89	0.99	1.29	1.41	1.17	1.27	1.54	1.65	2.08	2.18
01-02-2016	1.6	1.63	1.72	1.72	1.38	1.39	0.91	0.92	0.91	0.93	1.01	1.02	1.42	1.4	1.21	1.24	1.61	1.64	2.19	2.22

Date	OW-I		OW-II		OW-III		OW- IV		OW-V		OW- VI		OW- VII		OW- VIII		OW- IX		OW- X	
08-02-2016	1.7	1.63	1.67	1.79	1.63	1.35	0.86	0.99	0.87	1.01	0.92	1.02	1.3	1.27	1.21	1.34	1.59	1.66	2.13	2.25
15-02-2016	1.63	1.58	1.86	1.8	1.42	1.33	0.96	0.89	0.97	0.92	1.05	1.03	1.47	1.42	1.24	1.17	1.73	1.65	2.22	2.25
22-02-2016	1.58	1.79	1.68	1.76	1.35	1.44	0.89	1.01	0.88	1.01	0.98	1.05	1.37	1.46	1.32	1.32	1.64	1.62	2.17	2.24
29-02-2016	1.72	1.6	1.8	1.68	1.48	1.43	1.02	0.91	1.05	0.96	1.1	1.03	1.5	1.36	1.33	1.12	1.74	1.65	2.3	2.19
07-03-2016	1.5	1.71	1.62	1.76	1.25	1.45	0.84	1.01	0.86	1	0.89	1.05	1.29	1.48	1.22	1.37	1.61	1.75	2.13	2.35
14-03-2016	1.63	1.6	1.72	1.58	1.46	1.33	0.96	0.85	0.94	0.83	1.07	0.94	1.48	1.38	1.28	1.16	1.64	1.61	2.22	2.12
21-03-2016	1.53	1.63	1.63	1.76	1.25	1.43	0.81	0.94	0.85	0.95	0.9	1.02	1.3	1.21	1.22	1.12	1.6	1.5	2.12	2.1
28-03-2016	1.71	1.62	1.78	1.65	1.49	1.42	1.01	0.92	0.99	0.89	1.1	0.95	1.51	1.32	1.34	1.17	1.79	1.72	2.27	2.15
04-04-2016	1.53	1.65	1.62	1.76	1.29	1.46	0.89	1	0.89	1	0.96	1.11	1.37	1.55	1.31	1.45	1.68	1.8	2.19	2.36
11-04-2016	1.78	1.55	1.87	1.65	1.63	1.31	1.06	1.01	1.02	0.95	1.49	1.2	1.52	1.11	1.34	1.29	1.79	1.89	1.77	1.73
18-04-2016	1.65	1.7	1.73	1.85	1.37	1.5	0.93	1.03	0.97	1.2	1.34	1.4	1.16	1	1.34	1.34	1.69	1.69	1.77	1.79
25-04-2016	1.78	1.6	1.9	1.7	1.59	1.35	1.09	0.94	1.17	1	1.45	1.25	1.3	1	1.39	1.4	1.81	1.78	1.8	1.77
02-05-2016	1.64	1.63	1.73	1.78	1.28	1.38	0.95	0.94	1.03	1.01	1.3	0.75	1.17	1.15	1.34	1.38	1.71	1.74	1.75	1.77
09-05-2016	1.79	1.55	1.85	1.71	1.59	1.25	1.08	0.88	1.13	0.98	1.45	0.74	1.27	1.06	1.36	1.24	1.76	1.77	1.79	1.71
16-05-2016	1.56	1.6	1.7	1.7	1.3	1.33	0.83	0.86	0.97	0.95	1.21	1.24	1.1	1.1	1.26	1.27	1.6	1.64	1.73	1.68
23-05-2016	1.79	1.57	1.95	1.73	1.58	1.3	1.15	0.91	1.11	1	1.147	1.24	1.2	1.11	1.33	1.25	1.73	1.66	1.79	1.72
30-05-2016	1.7	1.66	1.73	1.69	1.42	0.57	0.95	0.74	0.97	0.98	1.25	1.13	1.17	1.13	1.23	1.16	1.61	1.55	1.66	1.6
06-06-2016	1.68	1.63	1.77	1.73	1.57	1.47	0.76	0.93	0.83	0.8	1.21	1.15	1.17	1.11	1.24	1.2	1.58	1.54	2.15	2.08
13-06-2016	1.65	1.71	1.78	1.84	1.4	1.46	0.81	0.87	0.93	1.35	1	0.76	1.33	1.41	1.14	1.21	1.54	1.62	2.12	2.23
20-06-2016	1.59	1.56	1.7	1.78	1.38	1.42	0.76	0.85	0.87	0.95	0.94	1.02	1.27	1.35	1.1	1.15	1.49	1.546	2.06	2.14
27-06-2016	1.66	1.69	1.77	1.82	1.38	1.43	0.79	0.84	0.9	0.95	0.98	1.01	1.31	1.39	1.15	1.2	1.53	1.6	2.13	2.17
04-07-2016	1.7	1.74	1.81	1.84	1.42	1.45	0.81	0.86	0.85	0.9	1.03	1.08	1.31	1.37	1.16	1.18	1.58	1.63	2.16	2.21
11-07-2016	1.74	1.47	1.62	1.36	1.21	0.41	0.66	0.6	0.75	0.71	1.23	1.17	0.97	0.89	1.08	1.04	1.42	1.36	2.03	1.97
18-07-2016	1.6	1.5	1.64	1.58	1.35	0.83	0.73	0.59	0.85	0.69	1.15	1.05	1.22	0.91	1.21	1.04	1.54	1.39	2.12	2.07
25-07-2016	1.62	1.48	1.69	1.56	1.33	1.09	0.71	0.64	0.8	0.57	0.86	0.69	1.269	1.11	1.15	0.99	1.51	1.35	2.11	1.94
01-08-2016	1.6	1.63	1.73	1.79	1.39	1.41	0.72	0.73	0.8	0.8	1.07	1.11	0.92	0.97	1.2	1.24	1.67	1.69	2.1	2.13
08-08-2016	1.66	1.61	1.72	1.72	1.45	1.35	0.9	0.79	0.99	0.95	1.3	1.2	1.16	1.07	1.28	1.22	1.67	1.64	2.22	2.17
16-08-2016	1.62	1.6	1.73	1.72	1.41	1.42	0.91	0.9	0.95	0.93	1.03	1	1.4	1.39	1.33	1.34	1.7	1.39	2.22	2.2
22-08-2016	1.62	1.64	1.78	1.8	1.44	1.47	0.93	0.96	0.9	0.95	0.93	0.95	1.13	1.16	1.3	1.33	1.68	1.75	2.2	2.22
29-08-2016	1.55	1.63	1.68	1.78	1.3	1.37	0.82	0.91	0.91	0.98	1.17	1.27	1.05	1.15	1.32	1.39	1.66	1.75	2.22	2.26
05-09-2016	1.7	1.64	1.76	1.7	1.23	1.15	0.92	0.86	0.97	0.9	1.3	1.25	1.15	1.1	1.34	1.23	1.72	1.69	2.22	2.17
12-09-2016																				
19-09-2016	1.75	1.69	1.78	1.75	1.48	1.38	1	0.96	1.07	1.05	1.35	1.34	1.23	1.16	1.44	1.49	1.78	1.75	2.22	2.32
26-09-2016	1.65	1.75	1.76	1.84	1.37	1.45	0.94	1.04	1.02	1.12	1.33	1.39	1.2	1.22	1.43	1.46	1.83	1.91	2.31	2.41
03-10-2016	1.68	1.64	1.76	1.73	1.43	1.4	0.96	0.99	1.02	1.04	1.06	1.03	1.45	1.44	1.42	1.44	1.79	1.82	2.3	2.32
10-10-2016	1.53	1.58	1.72	1.77	1.38	1.4	0.91	0.98	1.01	1.05	1.3	1.34	1.19	1.27	1.5	1.54	1.79	1.82	2.23	2.24
17-10-2016	1.59	1.79	1.68	1.76	1.35	1.43	0.88	1.03	0.95	1.07	1.25	1.36	1.07	1.19	1.37	1.47	1.72	1.83	2.21	2.28
24-10-2016	1.58	1.62	1.66	1.71	1.29	1.33	0.89	0.93	0.98	1.03	1.25	1.31	1.11	1.17	1.33	1.36	1.74	1.79	2.2	2.24

Date	OW-I		OW-II		OW-III		OW- IV		OW-V		OW- VI		OW- VII		OW- VIII		OW- IX		OW- X	
31-10-2016	1.6	1.63	1.75	1.78	1.36	1.4	0.91	0.94	0.97	1	1.15	1.25	1.11	1.13	1.39	1.42	1.74	1.76	2.24	2.27
07-11-2016	1.62	1.68	1.74	1.79	1.33	1.42	0.92	0.97	1.02	1.09	1.27	1.37	1.13	1.17	1.39	1.5	1.74	1.81	2.24	2.35
14-11-2016	1.6	1.9	1.63	1.58	1.21	1.53	0.8	1.01	0.88	1.15	0.85	1.39	1.27	1.37	1.31	1.79	1.7	2.14	2.15	2.37
21-11-2016	1.8	1.9	1.48	1.43	1.38	1.32	0.9	0.86	0.99	0.95	1.3	1.25	1.31	1.32	1.74	1.84	2.04	2	2.22	2.17
28-11-2016	1.78	1.86	1.6	1.83	1.33	1.53	0.86	1.06	1	1.19	1.25	1.45	1.37	1.37	1.09	1.24	1.74	1.45	2.21	2.37
05-12-2016	1.68	1.7	1.76	1.77	1.4	1.41	0.91	0.92	1.01	1	1.31	1.29	1.77	1.18	1.39	1.4	1.74	1.75	2.27	2.29
12-12-2016	1.52	1.54	1.64	1.66	1.21	1.23	0.84	0.87	0.93	0.97	1.2	1.22	1.29	1.3	1.29	1.31	1.68	1.7	2.17	2.2
19-12-2016	1.66	1.6	1.78	1.7	1.42	1.38	0.95	0.94	1.05	0.97	1.05	0.98	1.44	1.37	1.44	1.38	1.74	1.61	2.22	2.1
26-12-2016	1.57	1.63	1.68	1.78	1.24	1.31	0.88	0.93	0.98	1.06	0.98	1.06	1.37	1.43	1.32	1.37	1.72	1.77	2.23	2.3

Annexure –III: CHEMICAL ANALYSIS OF GROUNDWATER SAMPLES IN KALPENI 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	Kalpeni (JB School)	08.05.10	8.35	432	162	3.2	37	14	0.9	2.4	188	10	36	1.35	1.1
		25.11.10	7.8	600	205	52	18	50	0.7	0	262	15	46	0.5	1
2	Kalpeni (Puthiya Palli)	08.05.10	7.83	556	235	52	26	9.7	0.4	0	311	9.1	21	1.24	1
		25.11.10	7.63	605	270	82	16	17	0.2	0	390	14	21	0.58	0.1
3	Kalpeni (Marina Cycle Works)	08.05.10	7.63	567	245	62	22	13	0.5	0	329	6.7	32	0.82	1.1
		25.11.10	8.08	432	168	42	15	14	0.1	0	226	12	21	0.56	0.1
4	Kalpeni (Juma Masjid)	08.05.10	8.07	380	160	53	6.3	8.6	0.7	0	202	14	20	0.57	1.4
		25.11.10	7.87	580	230	64	17	28	1.6	0	336	16	39	0.37	1.6
5	Kalpeni (Seethi Palli)	08.05.10	8.39	768	265	24	50	40	1.8	12	287	43	85	0.66	1
		25.11.10	8.04	1204	390	78	47	88	2.8	0	549	46	114	0.44	0.3
6	Kalpeni (Govt. Nursery School)	08.05.10	8.06	918	435	40	81	43	3.9	0	500	30	60	0.89	1.2
		25.11.10	8.35	1016	270	30	47	99	10	Tr	390	33	121	0.58	2

Annexure IV: CHEMICAL ANALYSIS RESULTS OF WATER SAMPLES COLLECTED FROM PERMANENT OBSERVATION WELLS –KALPENI 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	06/05/2016	0.35	7.37	5490	3094	1530	840	120	720	416	2764
2	OW-2	06/05/2016	0.25	7.61	5580	3125	1270	820	140	680	400	2294
3	OW-7	06/05/2016	0.30	7.28	5810	3254	1290	700	80	620	544	2294
4	OW-23	11/05/2016	4.25	7.20	1722	964	150	420	60	360	472	27127
5	OW-27	12/06/2016	0.39	7.36	1813	1015	210	520	100	420	448	379

#	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)
6	OW-39	13/05/2016	0.90	7.41	2810	1574	430	66	100	560	536	777
7	OW-52	18/05/2016	0.21	7.35	458	256	40	280	80	200	352	72
8	OW-33	12/05/2016	3.50	7.69	2320	1299	310	620	60	560	600	560
9	OW-49	17/05/2016	0.92	7.28	620	347	60	320	40	280	400	108
10	OW-47	17/05/2016	0.68	6.95	15030	8417	5730	3140	1200	1840	648	10381
11	OW-64	19/05/2016	0.50	7.68	1848	990	410	540	140	420	480	931
12	OW-63	19/05/2016	1.14	7.15	1725	825	394	700	140	560	576	668
13	OW-61	19/05/2016	0.5	7.22	528	318	120	630	120	320	400	91
14	OW-59	19/05/2016	1.20	7.12	957	538	180	834	60	340	552	181
15	OW-58	18/05/2016	1.66	6.90	823	461	80	300	80	240	552	145
16	OW-73	24/05/2016	0.19	7.14	830	465	120	300	80	220	472	297
17	OW-76	24/05/2016	0.63	7.18	1124	629	160	440	80	360	608	289
18	OW-69	24/05/2016	0.42	7.30	980	549	150	280	80	200	488	271
19	OW-68	19/05/2016	0.88	7.72	472	264	60	300	60	240	218	108
20	OW-67	19/05/2016	0.57	7.24	804	450	120	440	140	300	449	217
21	OW-72	24/05/2016	0.42	7.10	844	473	110	300	60	240	464	199
22	OW-71	24/05/2016	1.25	7.57	446	250	40	260	40	220	328	72
23	OW-78	26/05/2016	0.16	7.35	650	364	60	320	80	240	440	145
24	OW-79	26/05/2016	0.26	7.33	1180	616	170	320	80	240	440	145
25	OW-82	26/05/2016	0.09	7.30	870	487	100	340	100	240	440	181
26	OW-84	27/05/2016	0.8	7.42	690	538	180	480	100	380	488	253
27	OW-85	27/05/2016	057	7.30	650	364	90	420	80	340	424	163
28	OW-87	27/05/2016	0.32	7.37	560	314	80	240	120	220	352	145
29	OW-89	31/05/2016	0.74	7.56	300	168	60	240	100	140	264	108
30	OW-90	31/05/2016	1.02	7.66	180	101	90	140	60	80	144	163
31	OW-93	02/06/2016	1.44	7.84	782	438	140	360	80	280	440	253
32	OW-92	02/06/2016	1.25	7.70	310	174	60	220	70	150	208	108
33	OW-98	03/06/2016	0.81	7.24	1280	605	220	340	100	240	488	397
34	OW-102	03/06/2016	0.64	7.50	500	280	80	380	80	300	352	145
35	OW-103	08/06/2016	1.28	7.53	690	386	110	260	60	200	352	199
36	OW-105	08/06/2016	0.22	7.20	567	318	60	320	80	240	464	108
37	OW-106	08/06/2016	0.20	7.19	748	419	110	380	80	300	480	199
38	OW-107	08/06/2016	0.48	7.38	1030	577	160	200	60	140	592	289
39	OW-110	09/06/2016	0.31	7.28	500	280	40	280	80	200	376	72
40	OW-113	09/06/2016	1.30	7.29	1204	674	200	220	60	160	664	361
41	OW_117	10/06/2016	0.60	7.95	1700	952	660	480	100	380	256	1192
42	OW-119	10/06/2016	1.81	7.27	1350	756	400	380	60	320	496	723
43	OW-120	10/06/2016	1.03	7.34	1667	934	460	480	60	420	480	867

#	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)
44	OW-115	10/06/2016	0.43	7.24	1045	585	200	380	120	260	584	361
45	OW-116	10/06/2016	0.60	7.22	866	485	140	400	160	240	504	253

Annexure V: MONTHLY CHEMICAL ANALYSIS RESULTS OF WATER SAMPLES COLLECTED FROM PERMANENT Ob. WELLS –KALPENI ISLAND (LPWD Lab Data)

Sl No	Observation Well No	Month of 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	OWC-1	January-2017	0.35	7.52	6570	3679	2030	1140	120	1020	560	3667
2	OWC-1	February-2017	0.05	7.39	7650	4284	3680	1280	260	1020	560	6648
3	OWC-1	March-2017	0.98	7.43	8990	5034	3780	1300	100	1200	488	6829
4	OWC-1	April-2017	0.09	7.42	10000	5666	3500	1300	160	1140	560	6323
5	OWC-1	May-2017	0.28	7.70	10440	5846	3280	1400	140	1260	544	5925
6	OWC-1	June-2017	0.61	7.84	9160	5130	2600	900	180	720	496	4697
7	OWC-1	July-2017	0.58	7.70	10580	5925	2330	880	160	720	640	4209
8	OWC-1	August-2017	0.80	7.87	3150	1764	800	640	100	540	416	1445
9	OWC-1	September-2016	0.04	7.82	4100	2296	1060	940	180	760	632	1915
10	OWC-1	October-2016	1.95	7.15	3190	1786	1030	740	60	680	632	1861
11	OWC-1	November-2016	0.11	7.80	4650	2604	2430	1160	180	980	568	4390
12	OWC-1	December-2016	0.64	8.42	5870	3287	1580	980	160	820	520	2853

Sl No	Observation Well No	Month of 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	OWC-2	January-2017	1.61	7.13	1468	822	250	480	60	420	520	452
2	OWC-2	February-2017	0.22	6.94	1970	1103	320	460	140	320	496	578
3	OWC-2	March-2017	0.76	7.01	2890	1607	700	540	100	440	528	1265
4	OWC-2	April-2017	0.04	7.32	4380	2453	1000	800	120	680	496	1806
5	OWC-2	May-2017	0.74	8.14	4920	2755	1230	760	140	620	576	2222
6	OWC-2	June-2017	0.33	8.74	581	325	120	240	80	160	200	217
7	OWC-2	July-2017	ND	7.90	2550	1428	340	320	100	220	424	614
8	OWC-2	August-2017	0.88	7.76	4800	2688	740	640	100	540	608	1337
9	OWC-2	September-2016	0.15	8.08	1160	650	120	540	80	460	488	219
10	OWC-2	October-2016	ND	7.85	1180	661	130	400	60	340	464	235
11	OWC-2	November-2016	0.18	7.26	1070	599	100	580	160	420	512	181
12	OWC-2	December-2016	0.47	8.68	1104	618	140	380	40	340	456	253

Sl No	Observation Well No	Month of 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	OWC-3	January-2017	0.30	7.19	593	332	40	400	40	380	200	72
2	OWC-3	February-2017	0.18	7.23	770	431	70	400	80	320	416	126
3	OWC-3	March-2017	0.62	7.23	774	433	100	380	80	300	400	181
4	OWC-3	April-2017	0.06	7.38	1180	661	160	340	100	240	416	289
5	OWC-3	May-2017	3.00	7.46	1360	762	150	360	100	260	528	271
6	OWC-3	June-2017	0.31	7.51	797	446	70	260	100	160	344	126
7	OWC-3	July-2017	ND	7.81	750	420	50	220	40	180	368	90
8	OWC-3	August-2017	0.73	7.55	948	531	80	280	80	200	400	145
9	OWC-3	September-2016	0.01	7.63	490	363	40	420	60	360	296	72
10	OWC-3	October-2016	ND	7.66	485	272	30	260	40	220	240	54
11	OWC-3	November-2016	0.14	7.46	490	274	30	360	100	260	360	54
12	OWC-3	December-2016	0.59	8.26	546	306	40	320	60	260	360	72

Sl No	Observation Well No	Month of 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	OWC-4	January-2017	0.37	7.06	749	419	40	360	60	300	280	72
2	OWC-4	February-2017	0.90	6.98	810	454	60	300	100	200	512	108
3	OWC-4	March-2017	1.08	7.07	830	465	80	360	60	300	488	145
4	OWC-4	April-2017	0.32	7.54	890	498	80	380	80	300	496	145
5	OWC-4	May-2017	1.70	7.63	920	515	80	340	120	220	520	145
6	OWC-4	June-2017	0.36	7.46	1166	653	80	320	60	260	480	145
7	OWC-4	July-2017	ND	7.64	1176	656	70	260	60	200	480	126
8	OWC-4	August-2017	ND	7.62	1411	790	120	360	60	300	576	217
9	OWC-4	September-2016	0.80	7.35	730	409	40	400	60	340	492	92
10	OWC-4	October-2016	ND	7.30	710	398	40	300	40	260	576	72
11	OWC-4	November-2016	ND	7.31	640	358	40	380	120	260	472	72
12	OWC-4	December-2016	1.48	7.27	407	40	260	60	200	360	404	72

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1	OWC-5	January-2017	0.82	7.32	702	393	50	420	100	320	480	90
2	OWC-5	February-2017	0.46	6.95	800	448	90	380	160	220	504	163
3	OWC-5	March-2017	0.90	7.10	798	447	60	300	80	220	432	108
4	OWC-5	April-2017	0.60	7.21	820	459	80	380	80	300	472	145

5	OWC-5	May-2017	1.82	7.65	820	459	60	340	140	200	472	108
6	OWC-5	June-2017	0.55	7.39	798	447	50	300	80	220	400	90
7	OWC-5	July-2017	0.30	7.43	1069	599	60	280	60	220	520	108
8	OWC-5	August-2017	1.20	7.35	1200	692	60	320	60	260	552	108
9	OWC-5	September-2016	0.58	7.77	650	364	30	400	40	360	392	54
10	OWC-5	October-2016	0.10	7.59	649	363	30	300	60	240	440	54
11	OWC-5	November-2016	0.30	7.42	620	347	40	420	160	260	456	72
12	OWC-5	December-2016	0.77	8.30	719	403	40	340	80	260	416	72

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1	OWC-6	January-2017	1.03	7.27	633	354	70	380	40	340	320	126
2	OWC-6	February-2017	0.07	7.29	670	375	90	400	100	300	352	163
3	OWC-6	March-2017	0.31	7.33	730	409	100	360	60	300	344	181
4	OWC-6	April-2017	0.14	7.24	710	398	100	340	100	240	360	181
5	OWC-6	May-2017	0.06	7.89	860	482	90	320	120	200	408	163
6	OWC-6	June-2017	0.21	7.59	851	477	60	280	80	200	296	108
7	OWC-6	July-2017	0.06	7.82	824	461	70	240	40	200	320	126
8	OWC-6	August-2017	0.92	7.49	1423	797	120	340	80	260	576	217
9	OWC-6	September-2016	0.06	7.54	740	414	50	420	60	360	408	90
10	OWC-6	October-2016	0.10	7.73	524	293	60	240	20	220	256	108
11	OWC-6	November-2016	0.04	7.70	490	274	50	320	80	240	328	90
12	OWC-6	December-2016	1.28	8.22	820	459	60	360	120	240	424	108

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1	OWC-7	January-2017	0.59	7.36	605	339	70	340	40	300	360	126
2	OWC-7	February-2017	ND	7.23	660	370	80	340	80	260	320	145
3	OWC-7	March-2017	0.31	7.34	644	361	80	280	80	200	312	145
4	OWC-7	April-2017	0.86	7.48	640	358	100	260	60	200	312	181
5	OWC-7	May-2017	0.53	7.86	630	353	50	320	100	220	448	90
6	OWC-7	June-2017	0.31	7.54	872	488	80	280	100	180	328	145
7	OWC-7	July-2017	0.04	7.55	1014	568	70	240	60	180	384	126
8	OWC-7	August-2017	1.71	7.80	1248	699	100	320	100	220	488	181
9	OWC-7	September-2016	0.02	7.83	530	297	40	260	80	180	264	72
10	OWC-7	October-2016	ND	7.59	722	404	60	280	40	240	424	108
11	OWC-7	November-2016	ND	7.63	510	286	70	340	80	260	296	126

12	OWC-7	December-2016	0.322	7.80	881	493	60	340	100	240	512	108

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1	OWC-8	January-2017	0.71	7.04	1231	689	170	380	40	340	520	307
2	OWC-8	February-2017	0.10	7.03	1280	717	200	420	80	340	552	361
3	OWC-8	March-2017	0.53	7.20	1267	710	200	360	60	300	488	361
4	OWC-8	April-2017	0.08	7.17	1290	722	180	340	100	240	488	325
5	OWC-8	May-2017	0.36	7.74	1320	739	160	440	140	300	416	289
6	OWC-8	June-2017	0.14	7.51	2950	1652	480	440	80	360	536	867
7	OWC-8	July-2017	ND	7.30	2470	1384	230	360	60	300	576	416
8	OWC-8	August-2017	1.52	7.68	1809	1013	180	360	40	320	472	235
9	OWC-8	September-2016	0.48	7.28	1020	571	130	420	80	340	488	506
10	OWC-8	October-2016	0.05	7.45	1189	666	160	380	40	340	552	289
11	OWC-8	November-2016	0.13	7.30	1000	560	130	420	120	300	520	235
12	OWC-8	December-2016	0.15	8.30	1221	684	130	420	80	340	504	235

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1	OWC-9	January-2017	0.30	7.02	1680	941	320	500	80	420	560	578
2	OWC-9	February-2017	0.08	7.09	1820	1019	390	480	160	320	592	705
3	OWC-9	March-2017	0.43	7.11	2230	1232	460	480	100	380	552	831
4	OWC-9	April-2017	0.40	7.14	2350	1316	440	560	120	440	560	795
5	OWC-9	May-2017	0.79	7.60	2500	1400	460	480	120	360	672	831
6	OWC-9	June-2017	0.82	7.75	1014	568	140	280	100	180	168	253
7	OWC-9	July-2017	0.51	7.40	2670	1495	280	400	80	320	624	506
8	OWC-9	August-2017	1.63	7.57	3030	1697	400	640	80	560	720	723
9	OWC-9	September-2016	0.12	7.43	1230	756	140	430	60	420	600	271
10	OWC-9	October-2016	0.08	7.33	1196	670	150	360	20	340	480	271
11	OWC-9	November-2016	2.30	7.34	1200	672	210	480	120	300	520	235
12	OWC-9	December-2016	1.68	8.40	1494	837	230	480	60	420	520	416

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1	OWC-10	January-2017	0.40	7.08	1263	707	200	480	80	400	480	361

2	OWC-10	February-2017	0.34	6.94	1360	762	250	500	80	420	584	452
3	OWC-10	March-2017	0.68	6.96	1309	733	240	300	80	300	512	434
4	OWC-10	April-2017	0.34	7.34	1130	633	180	400	100	300	480	325
5	OWC-10	May-2017	3.60	7.57	1430	801	180	380	100	280	536	325
6	OWC-10	June-2017	0.48	7.54	1687	945	240	300	10	180	456	434
7	OWC-10	July-2017	0.46	7.38	2230	1249	220	360	60	300	552	397
8	OWC-10	August-2017	0.93	7.54	2290	1282	240	400	80	320	664	433
9	OWC-10	September-2016	0.29	7.64	1350	756	140	430	60	420	504	253
10	OWC-10	October-2016	0.15	7.28	1280	717	200	330	80	300	520	361
11	OWC-10	November-2016	ND	7.04	1130	633	200	440	80	360	536	361
12	OWC-10	December-2016	1.43	8.17	1306	731	180	360	40	320	512	325