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Potable water exploration: Kavaratti Island

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1.0 INTRODUCTION

1.1 Kavaratti is one among the several islands in the group called Lakshadweep in the Indian Ocean within the territory of India and is the seat of administration for the group. It is long and narrow with an area of 3.6 sq.km and a population of 6608 as per 1981 census. Ithas a lagoon on the western side and a storm beach on the eastern side.

1.2 The island is very much under developed and is without protected water supply. This paper is based on the studies made to explore the possibilities of providing protected drinking water to the islanders.

2.0 EXISTING FACILITIES

2.1 The inhabitants draw their requirements of water mostly from unprotected shallow wells. Some of them are masonry open-draw wells and a few are walk-in types. Enquiries indicated that the islanders are tolerating the existing quality of the unprotected water which contains some chlorides and sulphates.

3.0 SCOPE OF THE STUDY

3.1 Time available for the study was short. There were no seasoned bore wells in the island to analyse water samples at various depths from different parts. The study therefore, was limited to observations of shallow existing wells, enquiries with the inhabitants and limited field studies based on established theoretical concepts using available equipments.

4.0 INVESTIGATION APPROACH

4.1 Investigation was mainly aimed at finding out whether good ground water of adequate quantity is available for a protected water supply scheme. Field observations revealed that the ground water tables in the existing wells fluctuate with tidal variations indicating hydraulic continuity of ground water with sea water. Therefore it is inferred that the water that is available is in the form of "fresh water lens".

5.0 THEORETICAL CONCEPT OF "LENS"

5.1 In an island surrounded by the ocean rain water percolates depending on the nature of the subsoil. This water joins the body of fresh water of earlier collection which remains in a lens-shaped body that lies over salty ground water that seeped in from the surrounding ocean. Depending on the permeability of the strata and the amount of percolating water, the underlying water may flow outwards into the sea on all sides, from the lens maintaining equilibrium. In the equilibrium condition, the ground water table attains stability.

5.2 Ideal "Ghyben-Herzberg" lens: The lens shaped fresh ground water bodies that exist in oceanic islands called "Ghyben-Herzberg lens" is shown in Fig.1. The

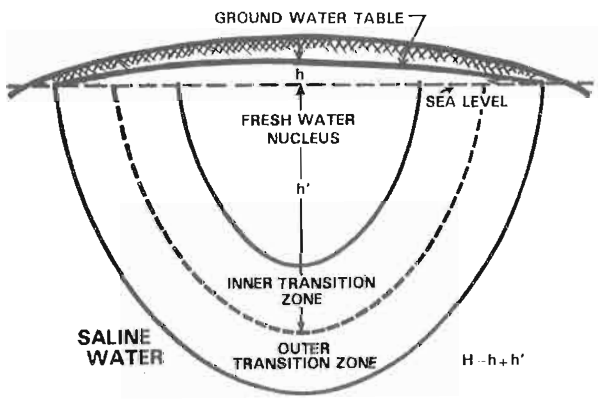

FIG. 1. GHYBEN-HERZBERG LENS

upper surface is the water table that separates the aerated zone from the underlying saturated zone. The middle line (dotted line in Fig.1) is taken as the interface separating fresh ground water and the underlying saline water by the "Ghyben-Herzberg principle". In the simplest case, the lens is in hydrostatic equilibrium so that the elevation of the water table above sea level and the depth of interface below sea level are mututally related. This relationship is the "Ghyben-Herzberg principle". In mathematical terms, it can be expressed as:

$$h' = \frac{p_f}{p_s - p_f} \times h = ah$$

Where h' is the depth of interface below sea level,
h is the elevation of water table from sea level,
p_s is the density of sea water (= 1.025)
p_f is the density of fresh ground water (= 1)
ah is the Ghyben-Herzberg balance (= 1/0.025 = 40)

The total thickness of fresh water column:

$$H = h'+h = ah + h = h(a+1) \text{ or}$$
$$H = 41\ h$$

That is, the thickness of the lens at any point is 41 times the elevation of the water table from sea level at that point. This implies that lowering of the water table above sea level by one unit height by extraction of fresh water creates a corresponding rise of the interface by 40 times at the point of extraction.

5.3 It is to be noted that fresh water and the saline water are not separated by surface of zero thickness like ice-berg floating on sea water. In reality, the water table and the interface are continuously fluctuating and the two waters do mix. The result is a transitional zone of mixed water, the percentage of sea water progressively increasing away from the fresh water. Thus the fresh water nucleus is the interface (middle line) bounded lens minus the upper half of the transition zone (Fig.1)

6.0 EFFECT OF MONSOON ON THE LENS

It is assumed that rain water percolates into the ground and gets stabilized in the "fresh water lens". Once the water that is drawn from the saturated lens is recharged and equilibrium established, further infiltration will not add to the quantity of "fresh water lens". The excess quantity of percolating water during the times of excess rain will be purged into the sea from the "fresh water lens".

7.0 RAINFALL AND QUALITY OF GROUND WATER

7.1 Rainfall: Rainfall details of Kavaratti are not available. Assuming that the pattern of rainfall is similar to Amini, a nearby island in the Lakshadweep group whose rainfall details are available, the probable rainfall is assumed to be around 1500 mm in an year. Allowing for marginal area in the vicinity of ocean and narrow strip of island area, the effective catchment area is assumed as 2.27 sq.km. Data regarding evaporation and evapo-transpiration losses are not available in the island. Only 15% of rain is assumed as useful percolation (Ref.1). To allow for fluctuations in rainfall, it is assumed that only 75% of the percolating water, i.e. $2.27 \times 10^6 \times 1.5 \times 0.75 m^3$/year or $0.38 \times 10^6 m^3$/year or 1×10^6 l/day will be available for extraction from ground water without seriously affecting equilibrium conditions of fresh water lens. This quantity is sufficient for the domestic requirements of the island.

7.2 Quality: Laboratory tests of water samples from various parts of the island indicated that the quality of water can be brought to drinking water standards by simple treatment followed by filtration and disinfection.

8.0 PRINCIPLE ADOPTED IN TRACING "LENS"

8.1 Procedure adopted is based on the assumption that interface bounded lens under saturation condition is in equilibrium and its volume is constant. Therefore the depth of fresh water in the lens is constant at any point irrespective of the position of the lens. That is, even when the lens oscilates due to tidal fluctuations, the depth of fresh water remains constant. According to Ghyben-Herzberg principle, depth of fresh water is 41 times the thickness of fresh water above sea level. Therefore, the depth of fresh water above sea level in the lens remains constant irrespective of the position of the lens. This means that the profile of the ground water moves up or down in unison with the oscillation of the sea level maintaining the depth of fresh water above sea level constant.

8.2 The volume vacated by the lens as it rises during the course of an oscillation is immediately filled with sea water that flows into the island. In a similar way this volume of sea water is purged from the island during the declining phase of of the water table oscillation. The effect of oscillation is of decreasing magnitude inland depending on the amplitude and period of oscillation, the distance from the shore line and permeability of the sub-strata.

8.3 If the average ground water profile for a section and the average sea level are determined simultaneously, the difference between sea level and the ground water profile will give the depth of fresh water above sea level for that section. By extending this process for other portions, the difference between average ground water table and average sea level can be determined for the entire area. This difference at any point will be constant under saturated equilibrium condition of the lens as the volume does not change.

9.0 TRACING GROUND WATER TABLE

9.1 To determine the profile of ground water at a section of the island on a particular day, the average water levels for the day at different points in the section are necessary. The average water level for the day at a point (well) is determined by monitoring the fluctuations of water level at that point for 24 hours using simple levelling instruments and accessories. A graph is plotted with the observed fluctuations against time. From the curve of fluctuations, the average water level at that point is determined by measuring the area covered by the curve for 24 hours and averaging the area for 24 hours (Fig.2). This

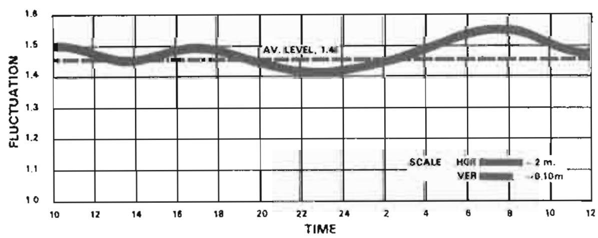

FIG. 2. AVERAGE WATER LEVEL ON 20-1-83 AT WELL

process is repeated for different points (wells) in the particular cross section. The average levels of all points (wells) in the cross section are plotted against the distance of each point (well) at the cross section. The line connecting these points will represent average ground water table at that cross section for the day (Fig.3). This process is repeated for

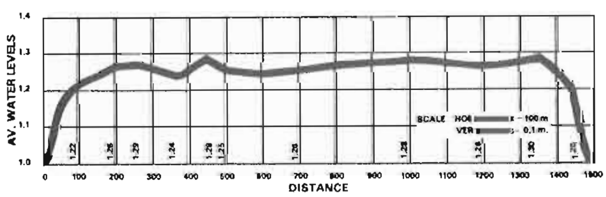

FIG. 3. AVERAGE GROUND WATER TABLE AT CROSS SECTION ON 20-1-83

other cross sections also.

10.0 AVERAGE SEA LEVEL

10.1 Sea level fluctuations due to tidal variations for 24 hours are observed. The readings are plotted and a graph is drawn. From the curve of fluctuations, the average sea level is determined by measuring the area covered by the curve for 24 hours and averaging the area for 24 hours (Fig.4).

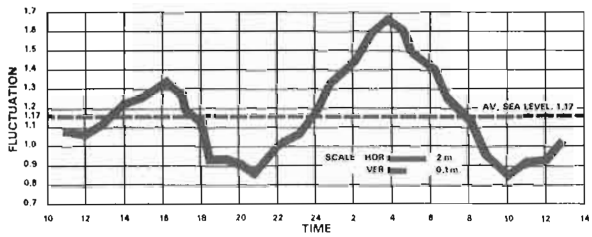

FIG. 4. AVERAGE SEA LEVEL ON 20-1-83

11.0 MAPPING THE PROFILE OF THE "LENS"

11.1 The line of average sea level for a particular day is interposed on the curve of average ground water profile for the section for that day. From this graph, applying Ghyben-Herzberg principle of 1:40 ratio, the profile of fresh water lens below ground water table can be drawn by measuring the depth of water above average sea level. The bottom profile will then represent the middle line of the transition zone. The real fresh water profile which lies above the middle line cannot be determined for want of detailed data regarding salinity content. For practical extraction purposes, Bugg and Lloyd (Ref.2) suggest a ratio of 1:25. In view of many possible limitations in this study, a depth ratio of 1:20 is assumed and the bottom profile is drawn accordingly (Fig 5). Similarly the profile of fresh water lens for the different cross sections are drawn. From these data contour of safe fresh water depths in the island is mapped (Fig 6).

12.0 LIMITATIONS OF FIELD OBSERVATIONS

12.1 The reliability of the findings entirely depend on the measurement of the fluctuations of ground water table and the sea level. Any error in field observations in this regard will reflect on the ultimate findings. The possible time lag due to the effect of permeability of sub soil on ground water fluctuations was ignored. The fresh water lens is

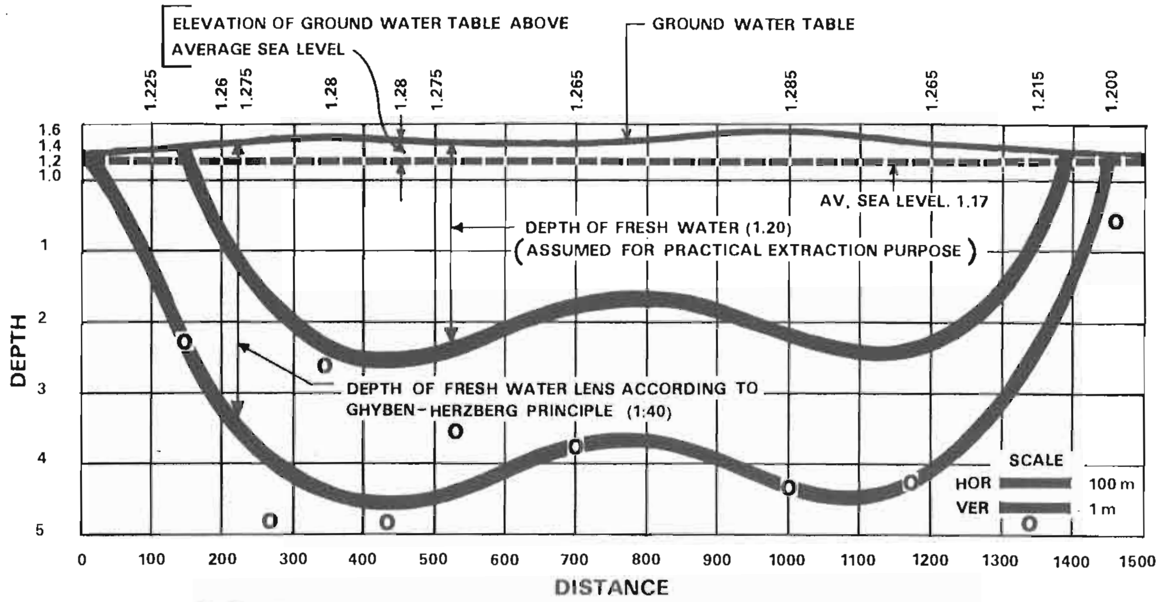

FIG. 5 FRESH WATER PROFILE AT CROSS SECTION

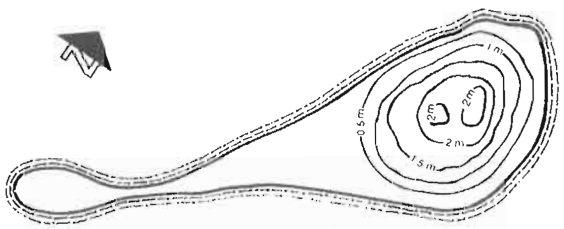

FIG. 6. KAVARATTI ISLAND
CONTOUR OF FRESH WATER DEPTHS

assumed to be in saturated equilibrium. Also, the findings of this study were not compared with the actual determination of the salinity of water at various depths.

13.0 CONCLUSIONS

13.1 The findings of this study indicate that in an island where fresh water is present in the form of fresh water lens, an approximate mapping of the profile of the lens can be done by measuring the fluctuations of sea level and ground water table. Even though the reliability of result greatly depends on the accuracy of field observations, the method provides a simple means of determining the profile of the lens with limited equipments in a short time. The procedure adopted in this study could be used for conducting similar studies in under-developed country situations by the available local technical expertise.

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2. Bugg, Stephen Frederick and Lloyd, John William, A Study of Fresh Water Configuration in the Cayman Island Using Resistivity Methods, Quarterly Journal, Engng. Geol. Vol.9, 1976.

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