Water Management Related to the Calcareous Sandstone Coastal Aquifer, Village Murud, District Ratanagiri, Maharashtra

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INTRODUCTION

Deccan Plateau basalts have a wide areal extent, up to the tune of 50,000 km^2, in Maharashtra state. Basalts provide a very monotonous terrain, which is not very conducive for groundwater movement and occurrence. The presence of any sedimentary deposit above, below or in between basaltic flows such as Intertrappeans, Gondwanas, buried channels and coastal alluvium provide a positive weightage ridden hope to the groundwater explorer. One such sedimentary horizon of calcareous sandstone is found to occur near Murud. Murud is a village in the coastal tract falling in District Ratanagiri, Maharashratra state of India Fig.1. The wells tapping this horizon have been studied for their productivity, well characteristics and aquifer parameters. Besides these aspects the hydrochemistry and suitable groundwater management technique required to sustain groundwater abstraction for domestic and irrigational purposes are attempted. The studies, in respect of, depositional environment, provenance and specific design for artificial recharge are beyond the scope of this lecture.

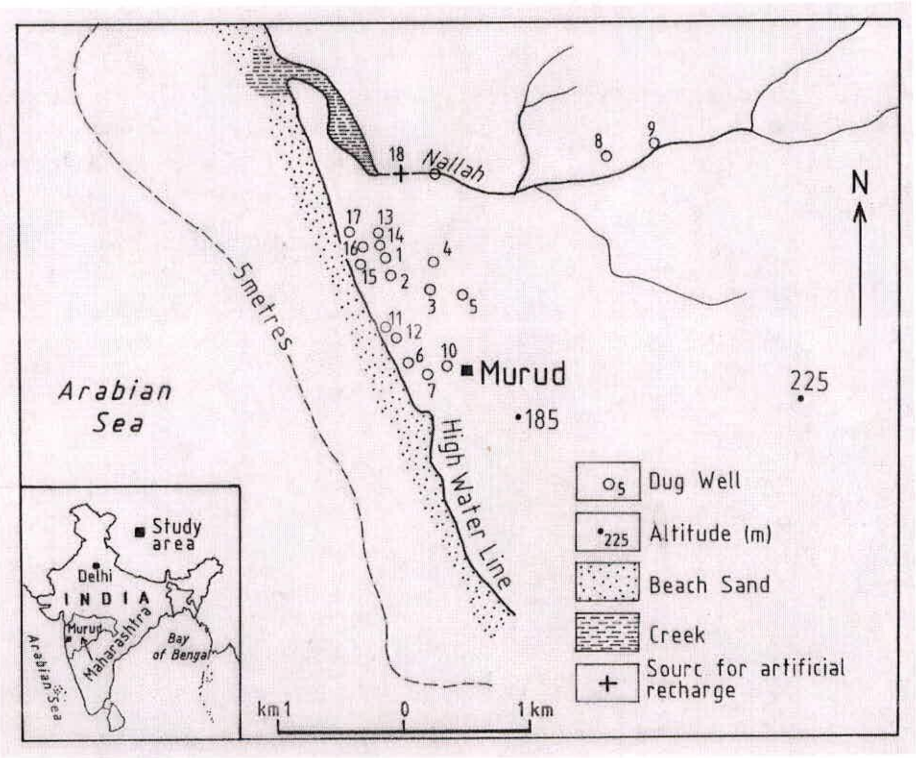

Fig. 1 Location map of Murud area

THE STUDY AREA

Village Murud is inhabited within 0.75 km on shore from the high water line. Farming and fishing are the main occupations of the people. Near the coast the land is occupied mainly by inland creeks and small hillocks with scanty vegetation, wherever basalts are altered into laterites, the vegetation is dense. Small patches of plain land are available for inhabitation and cultivation and for the same reason the farmers have very small land holdings. Coconut, pepper, betel nut and wheat are the main crops. Coconut is the cash crop, which is water intensive. The crop production depends upon water availability.

The average annual rainfall, in the area, is 2600 mm. The rainfall is received from southwest monsoon and most of it goes as runoff. Groundwater is the only source to meet irrigational and domestic requirements. The scenario is such that on one side there is vast Arabian Sea with unpotable water and on the other side dug wells, tapping basaltic aquifers, with limited yield.

GEOLOGY

The geological sequence, in the area around Murud, is given below:

AGE	LITHOLOGY
Recent	Soil, laterite spread, coastal alluvium and calcareous sandstone
Pleistocene	Laterite, secondary laterite
Cretaceous-Eocene	Basaltic lava flows

A geological map has been prepared which is shown in Fig.2. The basaltic lava flows are the main rock formations in the study area. The basaltic flows are almost horizontal in their disposition and consist of two units, viz:(1) Massive basalts and (2) Vesicular or amygdaloidal basalts.

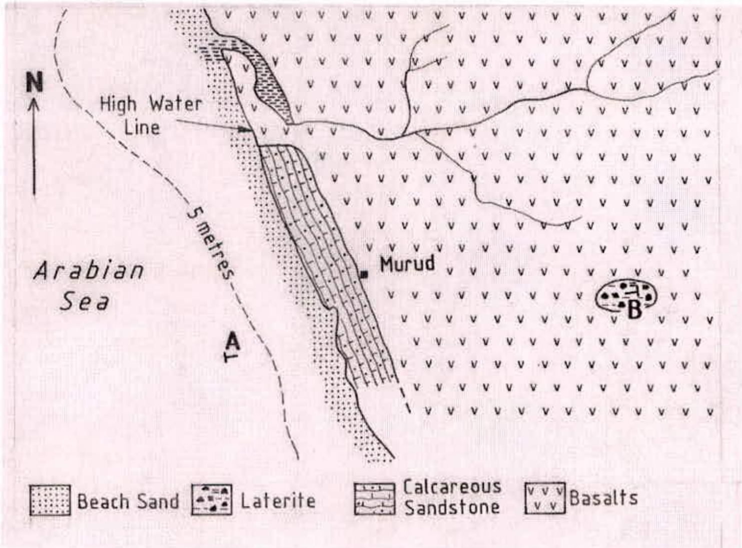

Fig. 2 Geological map of Murud area

The massive basalts occur as the lower unit of a flow. These are dense dark gray to black, fine to medium grained hard and compact rocks. The vesicular basalts form the upper unit of a flow. It is friable reddish brown to greenish brown with vesicles which may occur as voids or filled with secondary minerals such as zeolites and calcite. East of Murud, at higher altitudes basalts are altered into laterites. In the plain area around Murud laterites are not exposed. An east- west geological cross section, along AB, has been given in Fig.3.

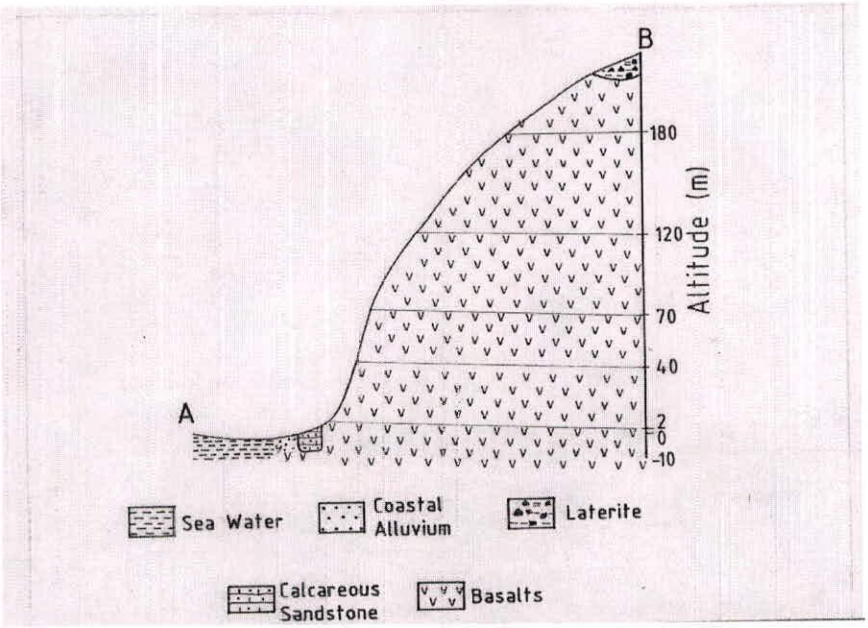

Fig. 3 Geological cross-section along AB

Basalts are overlain by a peculiar calcareous sandstone horizon in this village, which is very significant from groundwater point of view. The contact of calcareous sandstone with basalts is not exposed. The horizon occurs below a thin soil cover and can be seen in well sections (Fig.4). It has an aerial extension of about 1.0 km^2 with horizontal disposition. The thickness of the horizon is 8 to 10.0 m. The local name of calcareous sandstone is 'Karal'. It is a coarse grained semi-consolidated hard and friable rock which can bear moderate hammering. In the lower portion of the horizon the grains are of bigger gravel size. Upwards the grain size decreases and calcium content increases. In the upper 1.5 m portion of the horizon, calcium carbonate content is significantly high which is revealed by the presence of caverns (Fig.5). Shells of marine organisms are embedded with calcareous sandstone. West of Murud coastal alluvium overlies the basalts with a thickness up to 6.0 m.

HYDROGEOLOGY

Groundwater occurs under phreatic conditions in the weathered or jointed/fractured massive basalts and it is developed through dug wells ranging in depth from 3.0 to 8.0 m bgl. Depth to water level, in the area, ranges between 2.48 and 6.27 m bgl (Period: Premonsoon, 2010). Due to the limited interconnection of vesicles and secondary filling of zeolites, the yield is very less in vesicular basalts. A number of bore holes drilled, to tap the deeper aquifers, reveal that either the bore - hole yield is negligible or it is completely dry. The dug wells tapping basaltic aquifers, in peak summer, either go dry or yield few buckets of water.

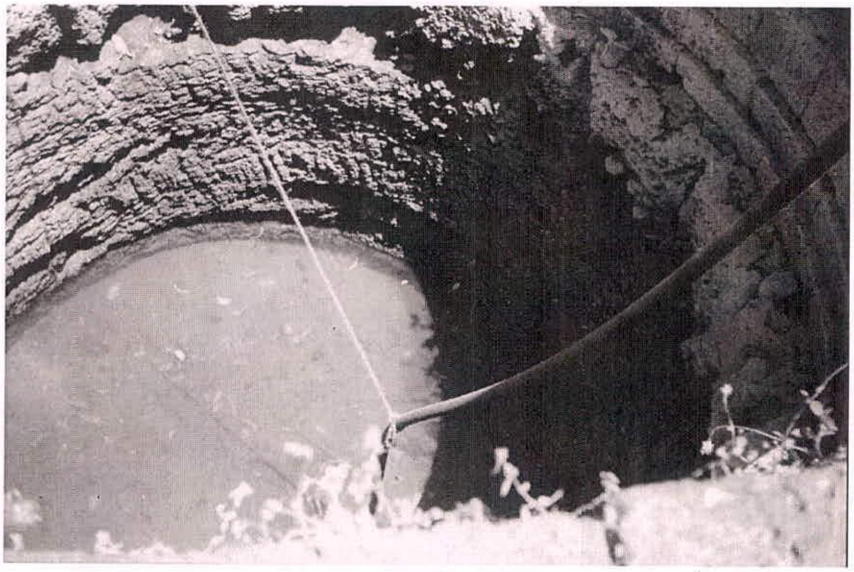

Fig. 4 Dug well showing calcareous sandstone horizon

Fig. 5 Caverns in the upper portion of the calcareous sandstone horizon

Groundwater in calcareous sandstone and coastal aquifers also occurs in phreatic conditions. The calcareous sandstone is a porous and permeable rock and forms potential aquifer. The thickness, as inferred from the dug well sections, is up to 10.0 m. The groundwater abstracted from these wells is used for domestic and irrigation purposes. The farmers go for three cycles of pumping, two hours each using a two- horse- power pump as they grow water intensive crops like coconut.

WELL CHARACTERISTICS

To estimate and compare productivity of wells, eight pumping tests were conducted on open wells tapping different formations. Slichter's formula (Slichter, 1906) is used to determine the specific capacity of the wells which is given below:

$$C = A/t\ 2303 \log S_1/S_2$$

Where,

C = Specific capacity of the well (LPM/m of drawdown)
A = Area of cross section (m^2)
t = Time since pumping stopped (minutes)
S_1 = Total drawdown (m)
S_2 = Residual drawdown (m)

The specific capacity of a well is the measure of its productivity, which is significantly influenced by its area of cross section and aquifer thickness. If the specific capacity of the wells is calculated for unit area and unit thickness, then the influence of area and thickness is nullified and the potential of different wells may be compared, the parameters so obtained are termed as unit area specific capacity and specific capacity index respectively. However, if the specific capacity is estimated per unit area per unit thickness then the effect of area and thickness both is annulled and the parameter so obtained is termed as unit specific capacity.

The transmissivity of the aquifers is computed by using modified equilibrium formula of Theim (Adyalkar and Mani, 1972). According to this formula, when the specific capacity of the well is multiplied by an empirical factor, the value of transmissivity is obtained. The empirical factor is calculated with the following formula:

$$M = 527.7 * \log R / r * 10^{-3}$$

well. Experiments carried out by Deshpandey (1973) through pumping of wells and observing the effects in the adjoining wells indicate no interference in any two wells located 50 m apart. In this paper the value of R is taken 50 m to estimate the transmissivity of the aquifers.

Hydraulic conductivity, of the aquifer, is calculated on dividing the transmissivity by its saturated thickness. The results of the well characteristics and aquifer parameters are given in Table 1.

HYDROCHEMISTRY

One surface water sample and ten groundwater samples were analyzed for their Calcium, Magnesium, Sodium, Potassium, Carbonate, Bicarbonate, Chloride, Sulphate, Nitrate, pH and electrical conductivity. In order to classify the waters, their chemical constituents are plotted on the Piper Trilinear Diagram (Piper, 1944). The plots are given in Fig. 6 and the results are summarized in Table 2. Forty percent of the groundwater samples form a cluster in field 5, where alkaline earths and weak acids dominate the waters. The plotting position of this cluster, in field 5, is very close to its lower vertex, which shows that the weak acids are much higher in comparison to the strong acids. Twenty percent of the samples fall in field 8 where alkalies exceed 50% and the waters are dominated by weak acids i.e. CO_3 + HCO3. Forty percent of the samples fall in field nine where no cation or anion pair exceeds 50% and the waters are of intermediate type. The plot of the water sample collected from the *nallah* (surface water) falls nearer to the upper vertex of field 5 whereas the groundwater samples falling in the same field are nearer to the lower vertex. This shows that the surface water has higher proportion of alkaline earths and strong acids in comparison to the groundwater.

Table.1 Well characteristics and aquifer parameters for different rock formations

S.No	Aquifer	Well No	Specific Capacity LPM/m of draw-down	Specific Capacity Index LPM/m^2	Unit Area Specific Capacity LPM/m^3	Unit Specific Capacity LPM/m^4	Empirical Factor	Transmissivity m^2/day	Hydraulic Conductivity m/day
1	Calcareous Sandstone	10	134.98	91.20	10.74	7.26	0.74	99.88	67.49
2	Calcareous Sandstone	11	110.98	85.36	8.23	6.33	0.73	81.02	62.32
3	Calcareous Sandstone	12	63.00	17.50	4.14	1.15	0.72	45.36	12.60
4	Coastal Alluvium	15	68.61	44.26	6.75	4.35	0.72	49.40	31.88
5	Coastal Alluvium	16	71.35	40.54	8.44	4.80	0.78	55.65	31.61
6	Vesicular Basalts	13	29.86	10.66	3.68	1.31	0.78	23.29	8.31
7	Vesicular Basalts	14	41.80	12.11	4.61	1.34	0.78	32.60	9.44
8	Massive Basalts	06	18.50	04.39	1.34	0.317	0.78	14.43	3.42
9	Massive Basalts	07	20.82	10.35	1.77	0.88	0.75	15.62	7.77

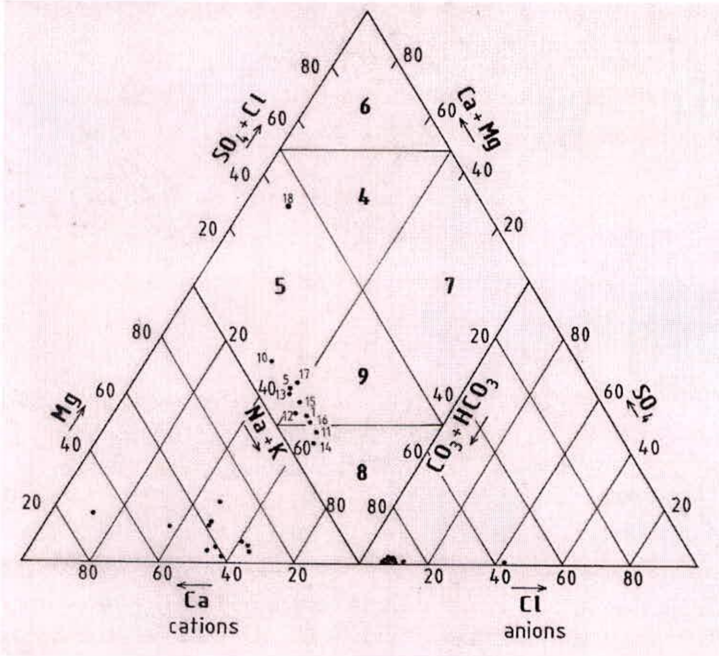

Fig.6. Classification of water on trilinear diagram (Piper, 1944)

Table 2. Distribution of waters in different classes

S.No	Source	Sample Nos.	No. Of Samples (%)	Field No.	Characteristics of the field
1	Surface Water	18	1 (100)	5	Carbonate hardness exceeds 50% Inferring that alkaline earths and weak acids dominate the chemical properties of the water.
2	Ground Water	5,10,13,17	4 (40)	5	Do
3	Do	11,14	2(20)	8	Carbonate alkali exceeds 50%. Inferring that the waters are inordinately soft in proportion to their content of dissolved solids.
4	Do	1,12,15,16	4(40)	9	No one cation - anion pair exceeds 50%

To assess the suitability of groundwater and surface water for irrigation purpose the analytical results are plotted (Fig.7) on the US Salinity Diagram (Richards, 1954). Ninety percent of the groundwater samples fall in C2S1 class. Only one sample (10%) falls in C3S1 class and that too is very close to the cluster of the plots in C2S1 field. The only sample of surface water falls in C1S1 class.

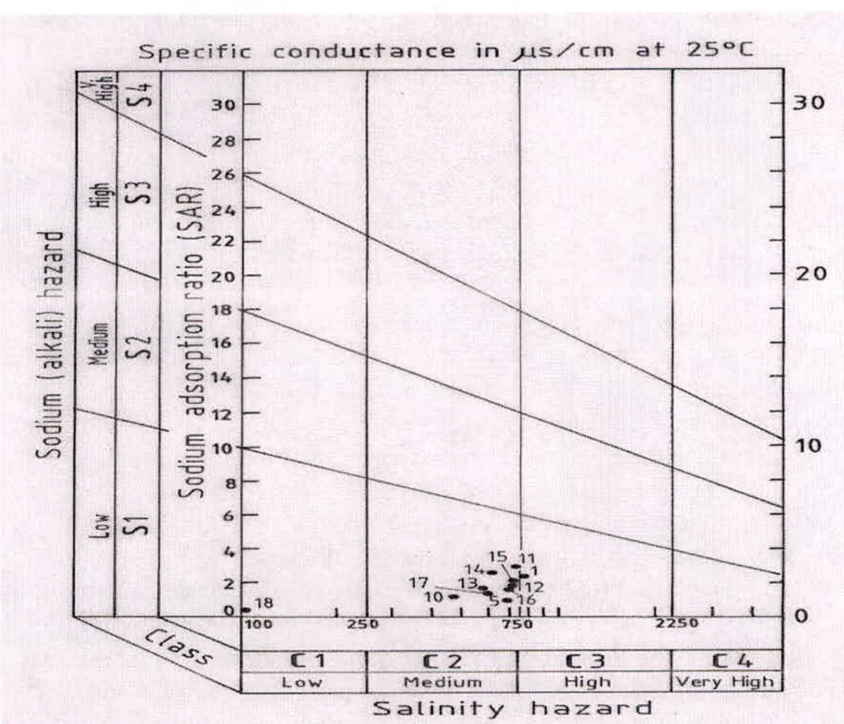

Fig.7 Classification of water on U.S salinity diagram (Richard, 1954)

DISCUSSIONS

Calcareous sandstone with an aerial extension of about 1 km^2 forms a productive horizon in the coastal tract where the main rocks are basalts. Groundwater occurs under phreatic conditions and it is developed through dug wells. Depth to Water ranges between 2.40 and 6.20 m bgl (Pre-monsoon, 2010). The calcareous sandstone horizon forms an aquifer, which yields higher than the basalts owing to its better porosity and hydraulic conductivity. The specific capacity of the wells tapping calcareous sandstone, coastal alluvium, vesicular basalts and massive basalts ranges from 110.98 to 134.98, 63 to 68.61, 29.86 to 41.80 and 18.50 to 20.82 LPM/m of drawdown, respectively. These results reveal that calcareous sandstone forms an aquifer better productive than the basalts. The wells tapping coastal alluvium are somewhat comparable with the calcareous sandstone.

Specific capacity index, unit area specific capacity and unit specific capacity are the parameters, which help comparing the wells tapping different formations. The specific capacity index ranges from 17.50 to 91.20, 40.54 to 44.26, 10.66 to12.11 and 4.39 to 10.35 LPM/m^2 for the wells tapping calcareous sandstone, coastal alluvium, vesicular basalts and massive basalts respectively. The wells intersecting calcareous sandstone, coastal alluvium, vesicular basalts and massive basalts have their unit area specific capacity in the range from 4.14 to 10.74, 6.75 to 8.44, 3.68 to 4.61 and 1.34 to 1.77 LPM/m^3 respectively. The unit specific capacity of the wells constructed into calcareous sandstone, coastal alluvium and vesicular basalts and massive basalts ranges from 1.15 to 7.26, 4.35 to 4.80, 1.31 to 1.34 and 0.317 to 0.88 LPM/m^4 respectively. These values clearly differentiate between the basalts and sedimentary formations and suggest that the later have better yielding capacity. However, calcareous sandstone and coastal alluvium are in close proximity in respect of their water yielding potential. Vesicular basalts and massive basalts both have low yielding potential but out of the two, vesicular basalts are better to tap.

Transmissivity and hydraulic conductivity are aquifer properties. The transmissivity of calcareous sandstone, coastal alluvium, vesicular basalts and massive basalts ranges from 45.36 to 99.88, 49.40 to 55.65, 23.29 to 32.60 and 14.43 to 15.62 m^2 /day. Further the permeability of these formations, in the same sequence, range from 12.60 to 67.49, 31.61 to 31.88, 8.31 to 9.44 and 3.42 to 7.77 m/day. The aquifer parameters also show that calcareous sandstone and coastal alluvium both have comparable transmissivity and permeability values, which are higher than the basalts.

On comparison with the guide lines recommended by the Bureau of Indian Standards (BIS, 1991), for drinking purpose, it is found that all the analyzed constituents fall within the permissible limits and the groundwater and surface water both are suitable for drinking purpose. However, the surface water has the possibility of bacterial contamination. By and large alkaline earths dominate the alkalies in groundwater and surface water both. Further the plots show that in both the sources of water, the weak acids greatly dominate over the strong acids as the sulphate content is almost nil and the chloride content is low. The C2S1 and C3S1 classes represent ninety and ten percent of groundwater samples respectively. Surface water belongs to C1S1 class. These results reveal that both groundwater and surface water are suitable for irrigation.

Village Murud is located on the sea- coast and agriculture is the main occupation of the people. The farmers grow water intensive cash crop like coconut and practice three cycles of pumping to get the maximum return from their small land holdings. The calcareous sandstone and coastal alluvium are the main productive horizons as revealed from the aquifer parameters and the groundwater from these formations help boosting the agricultural production. It is observed that there are only few wells in the coastal- alluvium as this formation is very close to the sea and hence calcareous sandstone is the formation which contributes maximum to the irrigational use.

The topography of the Murud area is such that it forms a small catchment to recharge the aquifer. The recharge is through meteoric water only and the maximum of which takes place during the monsoon period. The practice of groundwater abstraction of this magnitude, in this terrain, is bound to lead to the menace of seawater intrusion. Groundwater management practice is required to sustain the present use of water by maintaining its quality and quantity both. This could be accomplished by practicing artificial recharge of groundwater for which an additional source of water with suitable quality is required. A perennial *nallah* flows about 0.70 km north of village Murud (Fig.1). The width of the nallah is 5 to 6.0 m. The nallah bed has a depth of about 2.5 m with a gentle slope towards west. The water of this nallah should be stored by making a small barrage across the nallah with a surplussing arrangement. The water should be stored in a sump and transposed to the dug wells located on the eastern side of village Murud. PVC pipe should be used for transposing the water from the sump to the wells. The hydraulic connection of this kind will help recharging the aquifers in the study area. The water of this *nallah* is suitable for drinking and irrigation both and may be used as the source for artificial recharge. The groundwater management practice will not only help increasing the crop production but also evade away the apprehension of seawater intrusion.

CONCLUSIONS

The results, of this study, show that calcareous sandstone is the main producing horizon. Though limited in extension yet help meeting most of the drinking and irrigation requirements. Coastal alluvium is somewhat comparable with the calcareous sandstone but cannot be effectively used as it is very close to the sea. The yield, from the basaltic aquifers, is poor. The quality, of both surface and groundwater, is suitable for domestic and irrigation purposes. The economy of the people is agrarian with small landholdings and to maximize the output they indiscriminately use the groundwater. Coconut is the main cash crop, which requires water in redundancy. This requirement is fulfilled through the groundwater abstracted mainly from the calcareous sandstone. Three cycles of pumping per day are being practiced to meet this requirement, which would definitely lead to the seawater intrusion. This study suggests augmenting the groundwater potential by transposing the surface water from the nearby flowing perennial *nallah.* The surface water quality is suitable for drinking and irrigation purposes and will not cause any ill effect on the groundwater. The transposition of water, in this way, will result in recharging the aquifers in the area around Murud and the groundwater may be used optimally without any apprehension of seawater intrusion.

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