HYDROGEOLOGICAL INVESTIGATON AND EXPLOITATION OF GROUNDWATER IN SPRING ZONE

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ABSTRACT

A hydrogeological investigation program was carried out to assess the potential sustainable yields of ground water associated with natural springs geographically distributed 80 km sq. in Beliatta area of southern Sri Lanka.

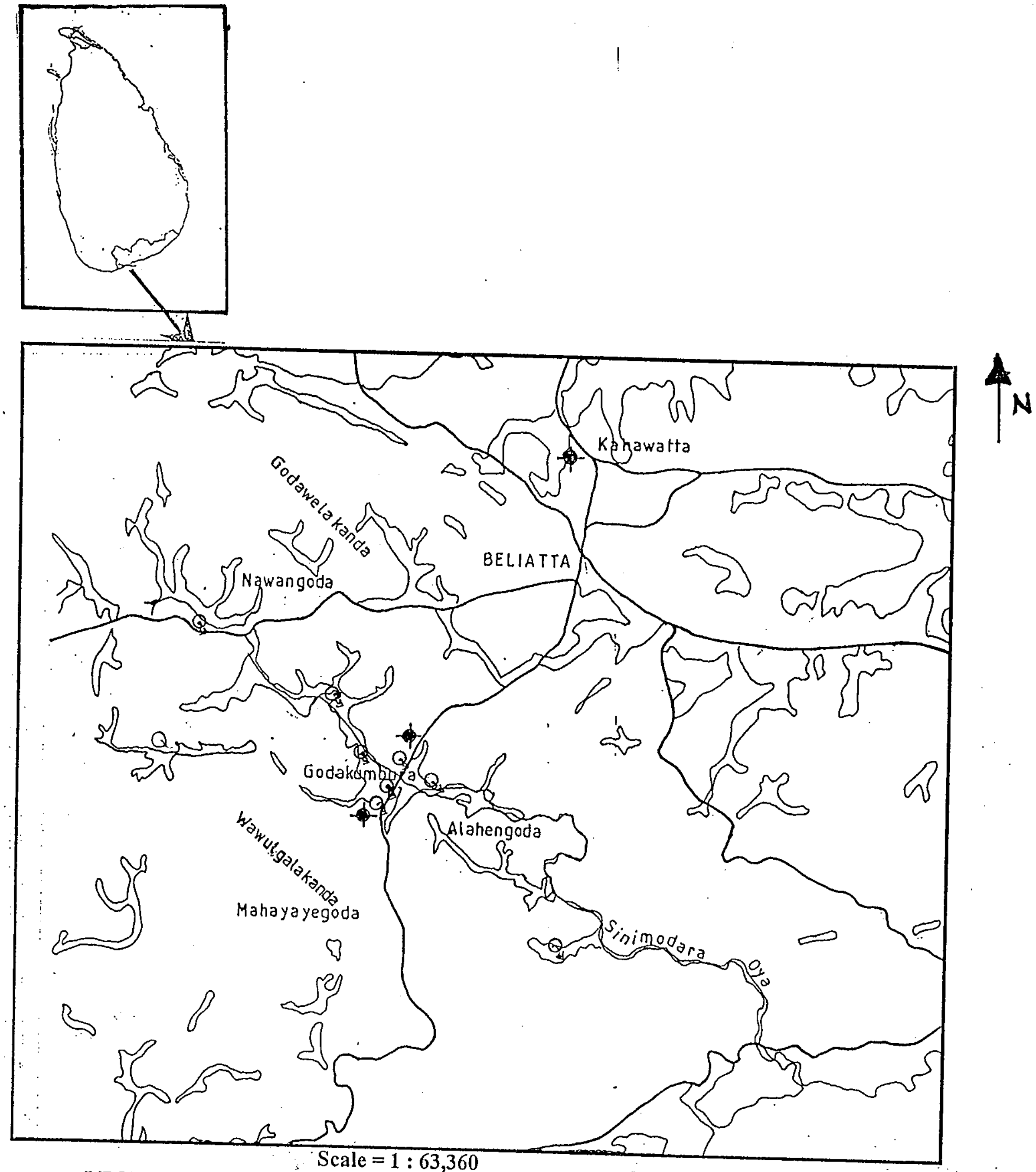
Investigation program aimed to establish the interaction between natural springs and the local hydrological cycle and also to find impacts of groundwater abstraction on the health of groundwater dependent Eco-systems including modification of spring flow and base flow of Sinmodara oya, when groundwater is pumped from the spring zone for Beliatta Water Supply Scheme.

The area studied lies between 80^0, 38' and 6^0, 05' and 80^0, 47' and 6^0, 58' and is situated in Hambantota district (see Fig. 1) and falls into the intermediate zone with the average annual rainfall of 1675 mm

The community of the spring area insisted that groundwater is important for their paddy cultivation. But the community who does not have access to potable water reported that drinking water is a paramount problem. Therefore, Hydrogeological investigation of this area was performed in order to design tube wells as the water sources, in such a way that impact resulting from groundwater abstraction through tube wells on the environment is negligible while ensuring cost effectiveness. In the process of investigation, it was not limited only to find sources and also extended to delineate aquifers and identification of probable recharge. As high productive aquifer is fractured hard rock aquifer, much emphasis was laid to find areas, which have high degree of fracture intensity, interconnections, lengthy extensions with good recharge, to abstract substantial amount of groundwater.

High productive groundwater potential is limited to the North - West geological fault zone, along side of which most of springs emerge and Siniomodara oya flows. Perennial springs that have occurred through fractured hard rock feed the Sinimodara oya from the start to the end. Further, productivity of springs depend on various factors such as degree of fracture intensity, width of fracture opening, their interconnections, water saturation, and the ground water storage of regollith of hard rock, etc. Recharges of springs are probably from the mountain regions of Godawelaknda and Wawulugalakanda with substantial thickness of regolith through geological lineaments.

LOCATION MAP OF THE STUDY AREA



Scale = 1 : 63,360

LEGEND

ROAD

PADDY FIELDS

NATURAL SPRINGS

PRODUCTIVE TUBE WELLS DRILLED FOR WSS

Fig.1

1.0 INTRODUCTION

The groundwater in the spring zone of Sinimodara oya basin is a significant community asset, being generally of high quality, and productivity. It provides water predominantly for irrigation activity especially paddy cultivation through natural springs and in addition for drinking and other activities through dug wells and tube wells.

In early 1960s, Beliatta Town Water Supply Scheme was implemented using a natural spring as a source, also used by farmers. It was reported that at the beginning there had not been any complaints on shortage of water for irrigation. As time passed with the development of the area, farmers were affected by shortage of water for paddy cultivation. The main cause highlighted for shortage of water for paddy cultivation was the usage of spring for town water supply.

At present, this spring is pumped for 10 hours a day and is allowed to free flow to the channel for the irrigation purposes. The total daily abstraction from the spring for town supply is about 570 m3/day. But the present demand is estimated to be 1500 m3/day for the 8000 people. Due to the objection from farmers against the use of spring for augmentation of Beliatta Water Supply Scheme, it is essential to find new sources.

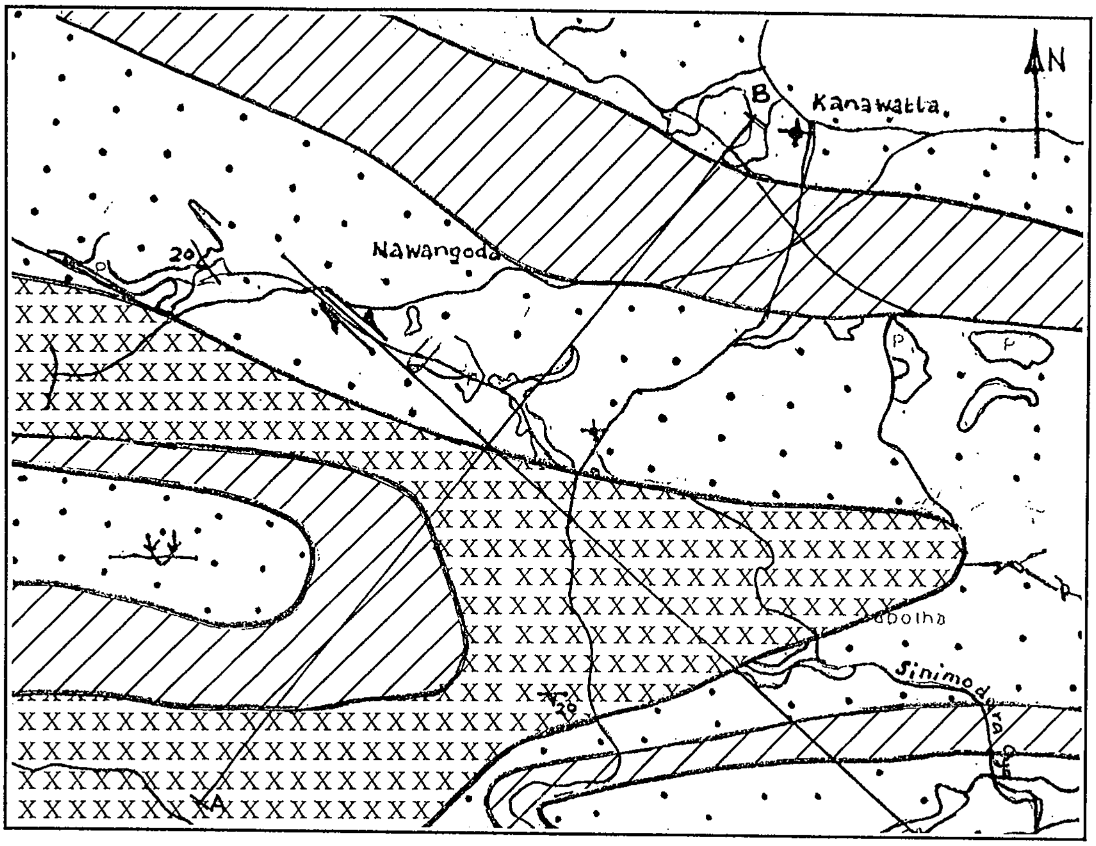
As there is no perennial and reliable surface water source in the vicinity of Beliatta town and the groundwater was found to be the only reliable and economical source, it was proposed to abstract groundwater through tube wells, which seemed to be the most appropriate. Locations for tube wells were earmarked in the vicinity of spring zone.

Residents who lives in the area where natural springs occur do not favor the locations of tube wells in their territory, on the ground that such large abstraction might exhaust their exiting water resources with time. It was decided to construct several tube wells in high productive zones with a substantial distant apart and no influence on each other.

Subjected to the result of hydrogeological investigation and also the views of the community, productive tube wells were constructed at the most promising zones. The wells were subjected to long term pumping test during the drought with a view to understand groundwater scenarios and to evaluate the aquifers. Even though each tube well has sufficient capacity to meet the demand of Beliatta W.S. S, three tube wells were constructed at different locations with the controlled rate of abstractions subjected to the results of pumping test in order to have negligible impact on environment.

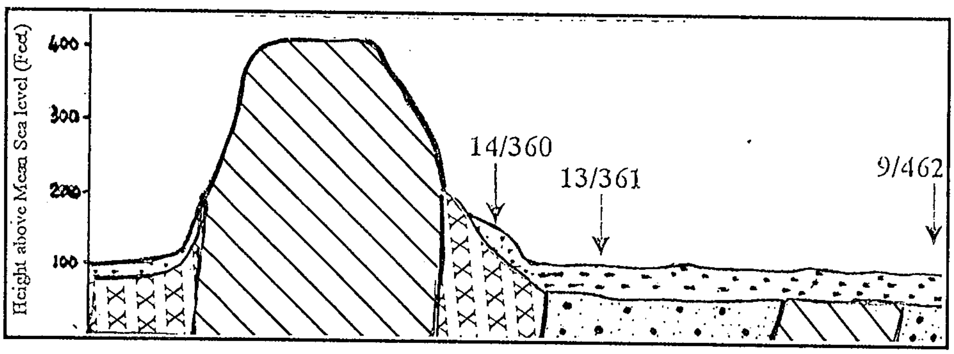
As hard rock fracture aquifer is more productive, more emphasis was given to the study of tectonic pattern to locate tube well sites. At the sametime, geological structures and lithologies were also studied through interpretation of aerial photographs.

GEOLOGY MAP OF THE STUDY AREA



SCALE 1:63,360

GEOLOGICAL CROSS SECTION ALONG LINE "AB"



LEGEND

- Garnet Sillimanaite Gneiss
- Undifferentiated Meta-Sediments
- Charnockite
- Regolith
- Fault
- Foliation Direction
- Overturned Syncline
- Geological Boundary

Fig. 2

2.0 BACKGROUND

2.1 Topography

The study area is mainly in the coastal peneplain of Sri Lanka with an elevation below 200 meters and shows "undulating topography" with a few isolated hills. Low mountains range namely "Wawulugalakanda" and "Godawela kanda" lay trending in the direction more or less in the North-West with few peaks. Main dranage in the study area, Sinimodara oya flows in between these two mountains. Kirama oya flows north of Godawala kanda.

2.1 Geology

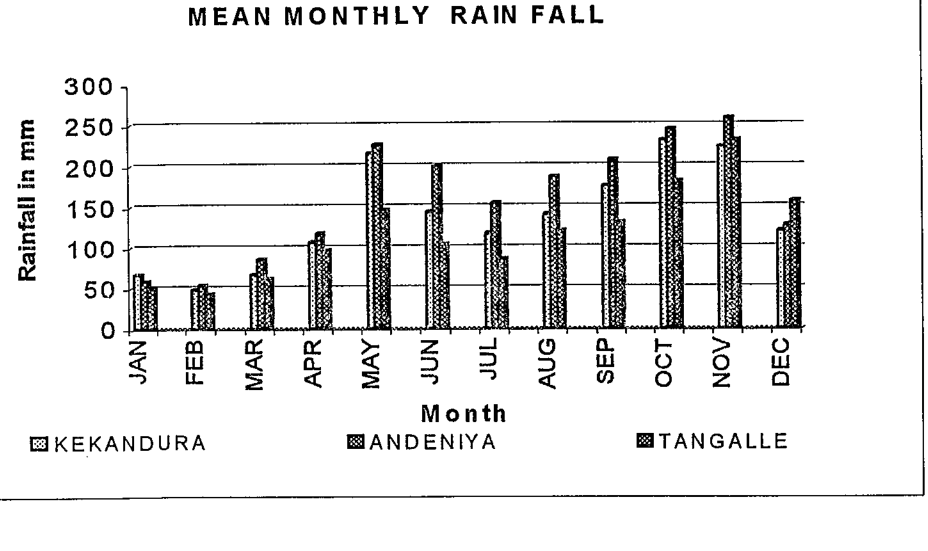
The study area occupies charnockite, garnet sillimanite gneiss, undifferentiated meta-sediments (garnet granulite and garnet biotite gneiss) and intrusive rock such as granite and pegmatite. Overturned syncline and anticline are trending in East – West direction and plunging towards West (see Fig. 2). Regional trend of rock is in East-West direction and dipping towards South. Rock dipping varies and ranges from 20^0 to $50^{0.}$ Regional geological faults extend in Northwest direction. While geological lineaments exist extending in various directions with more or less vertical dipping.

Thickness of soil cover of hard rock varies from place to place. They are thicker on garnet sillimanite gneiss whereas thinner on charnockite. Alluvium is developed along lower reaches of Sinmodra oya alongside geological fault. Thickens of alluvium cover is generally shallow.

2.3 Climate

The study area falls into intermediate zone bordering the wet zone from the West and dry zone from the East. According to monthly mean rainfall of past thirty years, highest rain prevails during October to November while dry weather prevails in Januray to March. The mean annual rainfall is 1675mm (see Fig 3).

Fig. 3



2.4 Drainage

The study area drain water mainly through Sinimodara oya and minor portion through Kirama oya. Sinimodara oya is seasonal stream and catchment of the Sinimodara oya is 38 Sq.Km. It carries substantial amount of water to the sea during rainy season and it is estimated to be 82 cum x10^{6}, 35% of precipitation (National Atlas). Interesting feature of Sinimodara oya is that perennial natural springs fed the stream from start to nearing to the sea.

NATURAL SPRINGS

There are seven major springs and many number of small springs found in thick clay cover and hard rock areas. Out of these springs, the highest yield is recorded from Eldeniya spring and its yield is 800 lpm during the dry season in 1986. The quantity fed to the stream by measurable springs is about minimum of 3500 lpm (1.8 cumx 10^{6} annually).

3.0 HYDROGEOLOGY

Hydrogeology of the study area is very closely related to the lithology, tectonic, geologic structure, topography, vegetation and the climate. According to the occurrence of groundwater, aquifers can be categorized into three main groups;

1. Regolith of Hard rock
2. Weathered rock
3. Fractured hard rock.

These aquifers can be further subdivided into three main groups according to hydrostatic pressure namely unconfined aquifer, leaky aquifer and confined aquifer. Generally regolith and weathered rock aquifers show unconfined condition. They are seasonal and limited to where regolith cover is less. Water from the unconfined aquifer which exists in the strike ridges and flows downward through regolith cover as well as hard rock fissures. Water which flows through hard rock fissures and emerge at lower reaches as springs

3.1 Regolith Aquifer

Regolith aquifer of hard rock, unconsolidated deposit over the hard rock is of important for domestic water supply by means of shallow dug wells. This aquifer spreads all over the study area and it is seasonal to areas wherever hard rock encounters at shallow depths. The yield of regolith aquifer is low and estimated to be in the rang of 5 to 100 lpm. The important factors of this aquifer are thickness of aquifer, hydraulic conductivity and the storage. Thickness of regolith cover varies from 0 to 22 m and it is thick over the garnet sillimanite gneiss rock. It is shallow along the path of Sinimodra oya and wherever charnockite rock and granite occur.

3.2 Weathered rock aquifer

This aquifer is little important because it is thin and it lies between the regolith and the fresh hard rock.

3.2 Fractured Hard rock aquifer

This aquifer is important for all the activities such as irrigation through natural springs, drinking and other purposes through tube wells. This aquifer has a characteristic of high permeability wherever fracture has substantial width of fracture opening, extend widely depending on the degree of the post-tectonic involvement. It is also important in carrying water from far distant along major lineament. Natural spring found in the study area is fed through hard rock fractures that exist in prominent lineament patterns. The yield of this aquifer varies drastically, 1 to 3500 lpm, depending on the degree of opening of fracture, and infilling of fractures by weathered products of fracture plane. Local fractures exist generally just below the weathered portion of rock and the yield is moderate (1 to 50 lpm). Tube well, which encounters only this fracture system, is not reliable since it is attributed to limited extension of the aquifer. According to results of 109 no. of tube wells drilled in the area for various reasons, air flushing yield on fracture depths were studied and variation of air flushing yield is shown in 4a. Frequency of occurrence of tube wells by air flushing yield in the study area is shown in Fig. 4b.

3.3 Ground water quality

Water quality of regolith aquifer is of acceptable in almost all the areas studied, except southeastern part. Electrical conductivity of water in Northwestern hilly terrain is low 90 micro mho/cm while in southeastern part it rises to 1000 micro mho/cm. However, in fractured hard rock aquifer, it is very high, as much as 10000 micro mho/cm, in southeastern part.

4.0 PROCESS OF INVESTIGATION

Hydrogeological investigation includes chemical quality surveys, preparation of tectonic maps with the aid of interpretation of aerial photographs, geo-electrical soundings, hydro-geological mapping, drilling of tube wells and performing of pumping tests in the study area. In the process of hydrogeological investigation, much emphasis of was laid on identification of possible impacts on the spring zone, due to abstraction of water for the above town water scheme.

Ground water information data such as tube well information, geologaical map of the area, aerial photographs, and data of previous works etc, also were collected. Tectonic map prepared through interpretation of aerial photographs was superimposed on geological maps and topographic map. Exact location of major predominant geological

VARIATION OF AIR FLUSHING YIELDS WITH FRACTURE DEPTHS

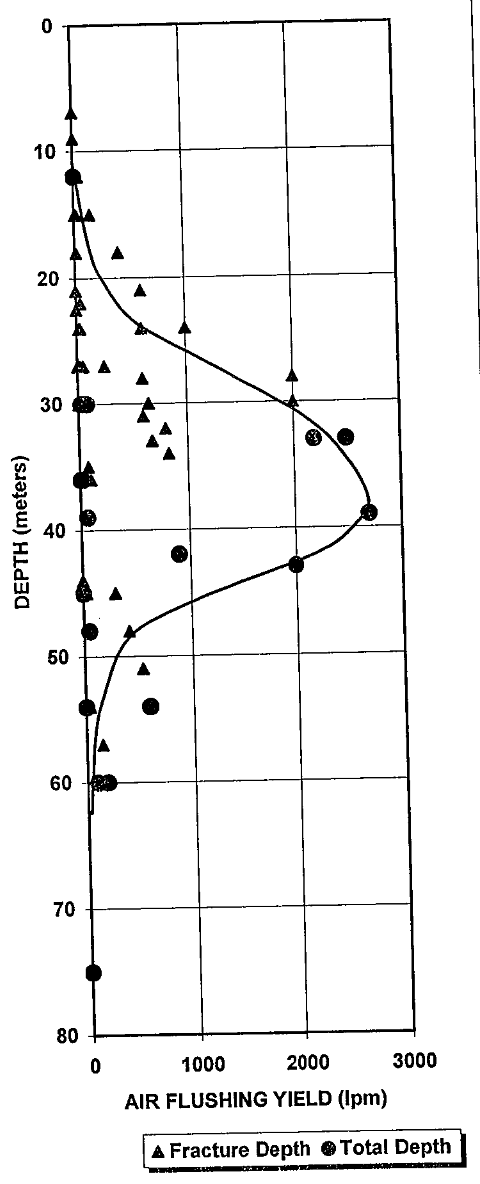


FIG. 4a

FREQUENCY OF OCCURRENCE OF TUBE WELLS BY AIRF LUSHING YIELDS

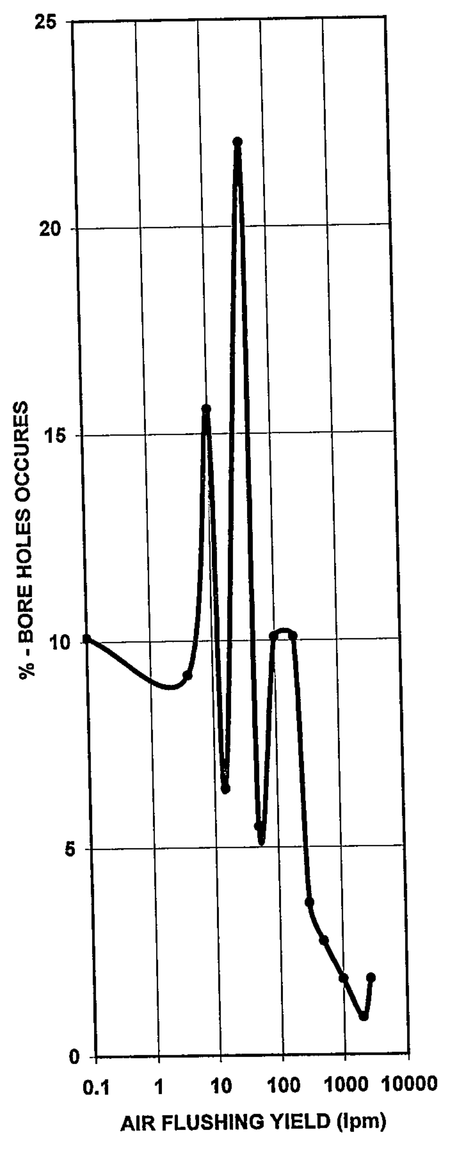


Fig 4b

Fig 4

lineaments, which were identified through the study of geological maps and aerial photographs, were located in the field running electrical resistively profiling. The possible locations were further studied by electrical soundings using sclumberger array.

Water samples collected from shallow dug wells, of which temperature and electrical conductivity were measured in the filed. The samples were analyzed chemically in the laboratory in order to find clues to delineate aquifers.

Locations for drilling sites were selected in consultation with the community in the spring area to avoid disputes among users. After construction of tube wells, they were subjected to perform pumping test for 3 days following step draw down tests. Prior to the pumping tests, water level of tube wells were monitored fixing auto recorders for few weeks to understand the pattern of water table fluctuations. During the process of pumping tests, pumping water level, water levels of wells in the vicinity of pumping well were monitored and springs were also gauged.

The pumping test data were analyzed using numerical model for two zone layered aquifers formulated by Prof. K. S. Rathod and K. R. Rushton. After calibration of model for feeding well and aquifer data, the curve was extrapolated to six months to obtain desired drawdowns at given rates.

Finally pumping rates were recommended to abstract groundwater from the fractured hard rock aquifer so that impacts on springs and nearby shallow well due to groundwater pumping are to be insignificant. In order to meet the demand of Beliatta water supply scheme, two tube wells in Sinimodara oya basin and one in Kirama oya basin were constructed.

5.0 NATURAL SPRING AND HYDROLOGIC CYCLE

Natural springs situated in this area are recharged locally. Schematic diagram of occurrence of springs and recharge is shown in the fig 5.

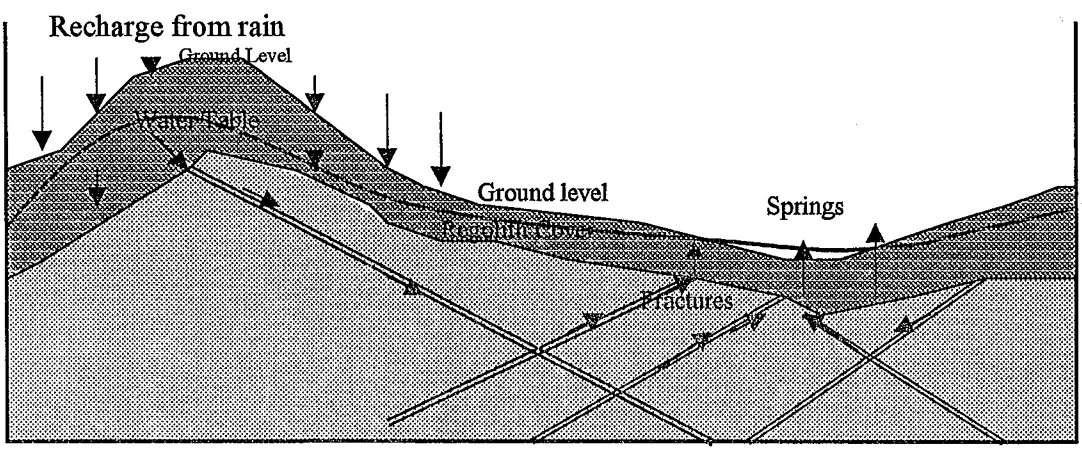
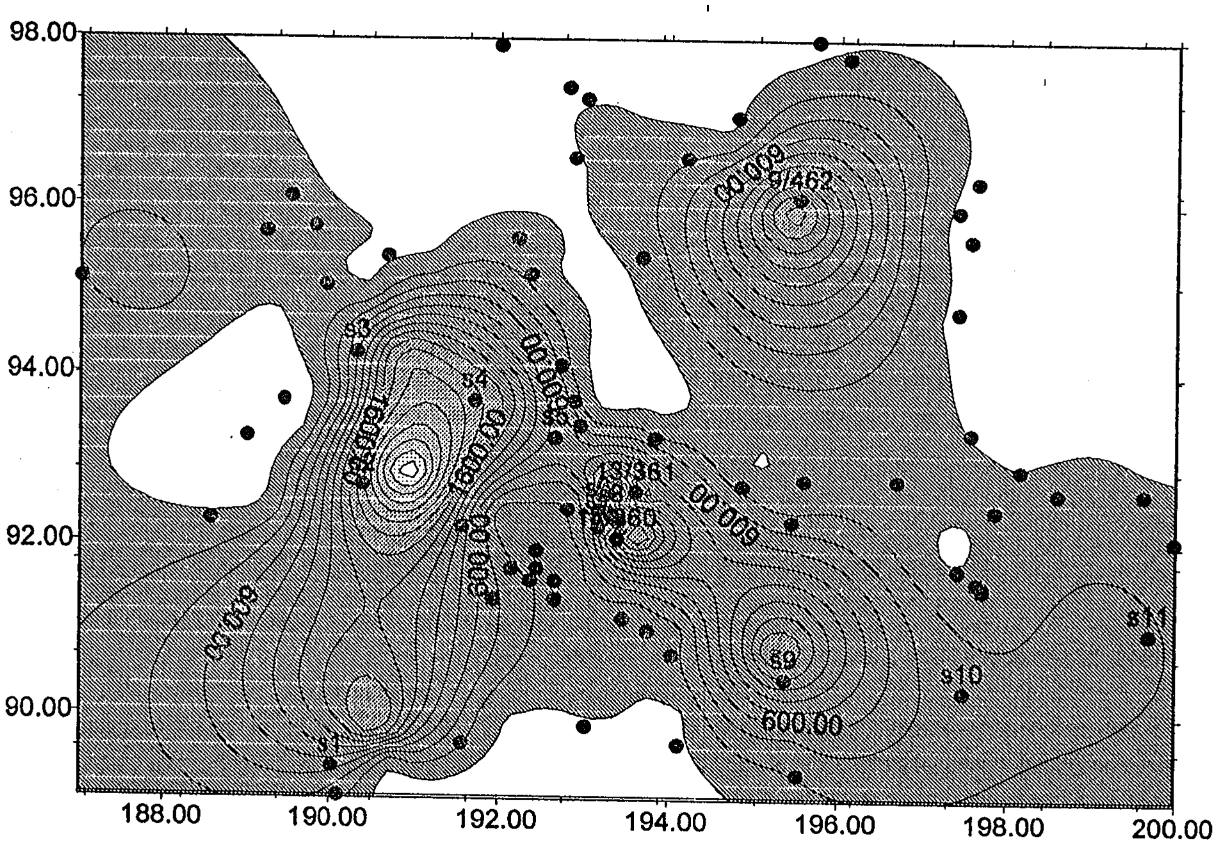
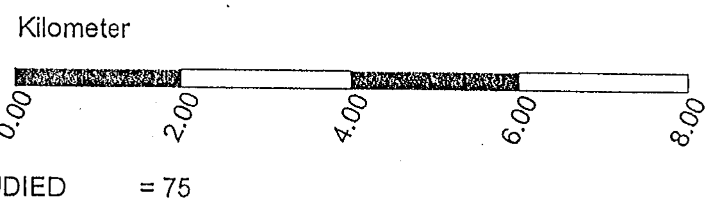


Fig. 5 Shematic diagram of Occurrence of spring and probable way of recharge

ISOLINE MAP OF AIR FLUSHING YIELD OF TUBE WELLS IN THE STUDY AREA





NO OF TUBE WELLS STUDIED = 75

Origin of Metric Scale is 200 Km South and 200 Km West of Pidurutalagala

Fig. 6

When the groundwater potential is concerned, groundwater scenario must be visualized and it is also needed to establish water balance in the study area. The catchment of water balance could be represented in following equation.

Precipitation of Rain	= Evapotranspiration + Surface Run-off + Change in soil moisture content + Ground water withdrawal + change in Ground water storage + Under flow to other regimes + Under flow to the sea + Etc.
Change in ground water storage	= Recharge from Rain – (Evapotranspiration + Surface Run-off + change in Soil moisture content + Ground water withdrawal + Under flow to other regimes + Under flow to the sea + Etc.)

The above equation shows that change in groundwater storage is a function of man made activities, such as land degradation and groundwater withdrawal through wells, and the natural phenomenon of hydrological cycle. Ground water withdrawal to meet the demand of the development process, whenever it is more economical and reliable, is inevitable to control the abstraction. However, groundwater loss due to increasing of paved areas, soil erosion, etc. could be minimized through implementation of community awareness Programme.

CONCLUSION

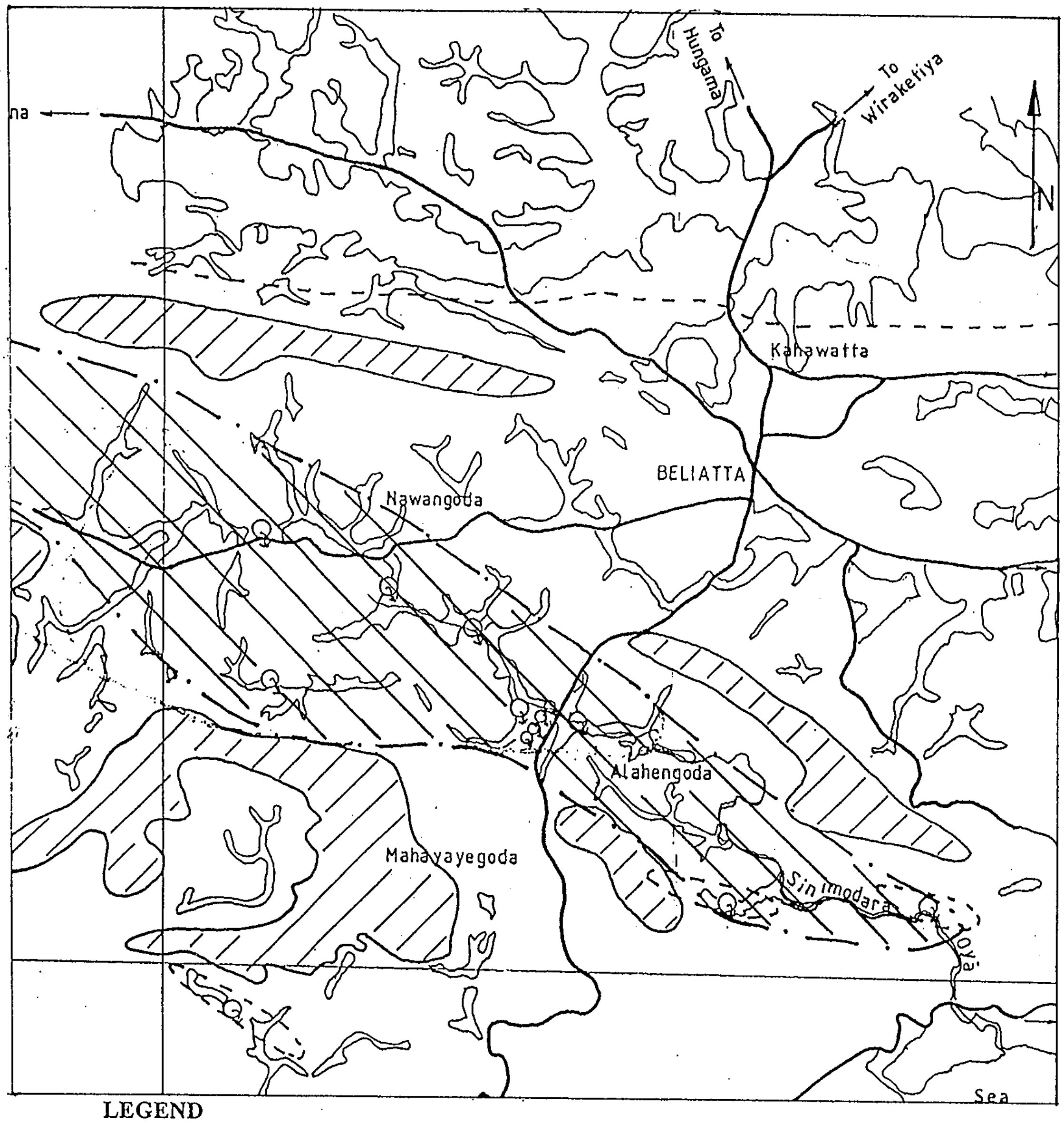
Productivity of hard rock aquifers could be approximated by the air-flushing yield during the process of well construction. When air-flushing yields of tube wells are plotted and contoured, it shows a pattern. High yielding tube wells are concentrated in direction of Northwest and Southwest directions parallel to the predominant lineaments (See Fig. 6). In addition, they are also situated in adjacent to prominent major geological lineament. Tube wells in the Northwest fault zone is the most productive zone in the studied area.

Based on the results of hydrogeological investigations, a map was prepared according to hydrogeological characteristics of aquifers (see Fig 7). Seasonal regolith aquifer confines to charnockite and undifferentiated metasediment rock with shallow overburden.

Non pumping water levels on productive tube wells show two lows and highs per day to be suggested to have a relationship with the sea tides.

Temperatures on all spring waters remain consistent and were 26^0 Celsius, which is 1^0-2^0 higher than in shallow dug wells in recharge zone. Temperature in dug wells with stagnant water show high values attributed to dosage of solar energy.

HYDROGEOLOGICAL MAP OF THE STUDY AREA



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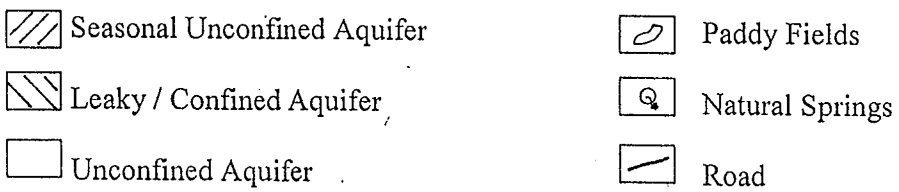

Fig. 7

Each tube well constructed for the said water supply scheme has a capacity to pump the demand. But to minimize the impacts to other users three wells were constructed too apart from each other.

It was observed that earlier forest cover has been removing by people settling in higher reaches. This cause lands degradation and in turns reducing contribution from rainfall to groundwater by increasing of runoff. This phenomenon plays a main role in reducing water in springs other than ground water withdrawal for various purposes. This could be corrected through the community awareness program to grow vegetative cover to minimize the run off.

References

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