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IDENTIFICATION OF SUITABLE SITES FOR SUBSURFACE DAMS IN SWARNAMUKHI RIVER

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Abstract: - India is a basically agricultural country with an increasing interest for hydropower. Water management problems such as sedimentation and evaporation have been of high concern for subsurface water reservoirs for many years. Hence, subsurface dam is the best solution due to many advantages such as low cost of construction, the least evaporation, no contamination, utilization of land over the dam and better storage. The objective this study is to evaluate the suitability of the selected site location for construction of subsurface dams and a case study on Swarnamukhi River by using a simple, safe and affordable technology to solute the aridity and water shortage in this area of arid to semi-arid climate in Swarnamukhi watershed within the stream deposits. Google earth Maps through satellite images and digital elevation model (DEM) interpretation and analysis have facilitated the investigation with more accuracy. Google earth Maps helped in construction of thematic maps of the studied area. The geologic, structural, geomorphologic, hydrological survey shows the suitability of the selected site location for construction of subsurface dam. The methodology presented here shows promising results and could be used in early planning to locate suitable sites at Tandlam, Jeepalem, Munagalapalem and Bandarupalle on Swarnamukhi River for construction of subsurface dams.

Keywords: - Subsurface dam, Google earth Maps, Swarnamukhi River and Water harvest.

I. INTRODUCTION

The amount of water present in earth is always constant. It is transformed from one form to another in a specified manner. Though two by third of earth is filled with water, the usable water for irrigation and drinking purpose is only two percentage of total available. So, proper management of the available water is very important for the sustainable utilization of it. The major share of usable water is present in the inner part of earth known as groundwater. Increase in the ground water storage of a region is the direct measure of water richness. Water harvesting technique plays a vital role in increasing the ground water recharge.

Harvesting is the technique which is used to effectively trap the surface runoff. In technical terms, water harvesting is a system that collects rainwater from where it falls around its periphery rather than allowing it to go as runoff. By constructing water harvesting structures in appropriate sites it is possible to increase the ground water recharge and level of water table. In this study the suitable sites for constructing subsurface dams (water harvesting structures) in Swarnamukhi watershed is identified using Google earth Maps, contour maps and hydrological data, geological data which is collected from suitable authority of hydrological and geological departments. In this study 4 sites (Tandlam, Jeepalem, Munagalapalem and Bandarupalle) may be selected along the Swarnamukhi River to construct the subsurface dams.

II. LITERATURE REVIEW

Antoifi Abdoulhalik et al. (2017): The main objective of this paper is to examine how aquifer layering impacts the ability of subsurface dams to retain Sea Water Intrusion (SWI) and to clean up polluted coastal aquifers using both experimental and numerical techniques. The findings presented here are expected to have significant implication from water resource management prospective. Results shows that limitation of considering the common assumption of homogenous when attempting to assess the performance of subsurface dams, which lead to large erroneous estimation of their ability to retain salt water intrusion mechanism and clean-up previously contaminated coastal aquifers.

Ahmed and Omed (2016): This paper emphasizes the significance of this type of structures and reviews the general characteristics and historical development of groundwater dams. Historically, these kinds of structures were constructed in Roman times in Sardinia and around Carthage, in present-day Tunisia. A groundwater dam is any structure that serves to intercept or obstruct groundwater flow through an aquifer, both natural and artificial, and thereby provide storage of water underground.

Yosef and Asmamaw (2015): The objective of this study is the in-situ and ex-situ rainwater harvesting techniques have shown significant impact on improved soil moisture, runoff and ground water recharge; and increased agricultural production, which in turn reduces risks and deliver positive impacts on other ecosystems. Besides, rainwater harvesting has a potential of addressing spatial and temporal water scarcity for domestic consumption, agricultural development and overall water resources management. High water loss through seepage, lack of awareness and being very labor intensive to irrigate the whole fields by pumping the water manually from the pond and applying directly to the crop has been the main challenges of adopting harvested water technologies.

Imarn Ali Jamalim et al. (2014): This paper deals with A Spatial Multi-Criteria Analysis Approach for Locating Suitable Sites for Construction of Subsurface Dams in Northern Pakistan. This paper aims to develop and test a methodology to locate suitable sites for construction of subsurface dams using Spatial Multi-Criteria Analysis (SMCA) in the northern parts of Pakistan. For the study, spatial data on geology, slope, land cover, soil depth and Topographic Wetness Index (TWI) was used. Two weighting techniques, i.e. the Analytic Hierarchy Process (AHP) and the Factor Interaction Method (FIM), were employed and compared.

Olofsson et al. (2013): The paper presents a new methodology to locate suitable sites for the construction of subsurface dams using GIS software supported by groundwater balance modeling in a study area Boda-Kalvsvik, Sweden. Under Groundwater resources were calculated based on digital geological data and assumptions regarding stratigraphic layering taken from well archive data and geological maps. These estimates were then compared with future extractions for domestic water supply using a temporally dynamic water balance model. Suitability analyses for subsurface dams were done based on calculated Topographic Wetness Index (TWI) values and geological data, including stratigraphic information.

Masoud Fakharinia et al. (2012): The objective of this study is investigation of subsurface dam construction and its effects on water table height in consumption location and interception of nitrate transport. Therefore, the Shahrekord aquifer model was replicated by Mudflow and MT3D models. Hydrodynamic coefficients and uncertain parameters of solute transport was calibrated using sampled data. Water table situation and nitrate concentration can be drawn and analyzed using ArcGIS9.3 software before and after dam construction. The results show that the subsurface dam will raise groundwater level in 4 kilometers distance of upstream areas, thereupon available volume of water increased about 1.5 MCM. Nitrate concentration didn't have considerable difference rather than initial state.

Satoshi Ishida et al. (2011): This paper study the basics about underground dams, the construction of underground dams around the world, and the problems involved in the sustainable use of groundwater. According to a recent study of the construction of underground dams, the scale of underground dam projects has increased. Some problems with underground dams reported in the past, i.e., sedimentation, flooding, collapse, and salination, occurred because of human error, as well as the unripens and complexity of geological features.

Xingxin et al. (2009): The main of this paper is Ground-Penetrating Radar (GPR) detection of several common subsurface voids inside dikes and dams. GPR technique has been used in detecting several common subsurface voids inside dikes and dams in south of China. GPR technique was applied to detect termite nests inside dikes and dams, and satisfactory detection results were obtained in a real-time manner for nests populated by living termites and empty nests left by dead termites. Also, GPR application appears to be less affected by terrain location or climatic features, so is preferred to other conventional methods for termite nest location.

III. METHODOLOGY

A. Water harvesting:

Water harvesting is the colleting of rainwater, where it falls and captures the rainwater. Rain was the primary form of water that we know in the hydrological cycle. Hence, rain is primary source of water for us. The secondary sources of water are rivers, lakes and groundwater. As increasing of global warming, now a day we depend entirely on these secondary sources of water. In these processes, we forgotten that rain is the main source that feeds all these secondary sources and remain benighted of its value. Water harvesting means to know the value of rainwater, and to make minimum use of the rainwater. It means collecting the rainwater where it falls or capturing the run off in your own village or town. And take that water to keep that water clean by not allowed polluting particles to take place in the catchment.

B. Subsurface dams:

Subsurface dam is one of the rain waters harvesting structure. Subsurface dams obstruct the groundwater in the sand upstream of their dam wall which is built across a sandy dry riverbed to a height of 0.4 m below the surface of the sand. Water in subsurface dams is stored in the voids between the sand particles from where ideally up to 35% of water can be extracted from coarse sand particles with large voids. This means that 350 liters of water can be extracted from 1 cubic meter of coarse sand while less than 70 liters of water can be extracted from 1 cubic meter of fine-textured sand.

Subsurface dams are rejuvenated by rainwater that runs off a catchment and into riverbeds as floodwater on its devastating way to the sea. Conflicting to sand dams, which are highly unprotected and often damaged by the floodwater because their walls project above the surface of the riverbed, floodwater passes over subsurface dams as these dams lay at an unreachable location of 0.4 meters under the surface of riverbeds. The advantage of subsurface dam is that they are simple and cheap to design and construct. However, the important advantage is that subsurface dams do not require any repairs or maintenance at all. Therefore, the choice of whether to construct subsurface dams should therefore be obvious.

C. Site selection for subsurface dams in Swarnamukhi River (case study)

The first step is to carry out a site survey, which involves analyzing the geological and physical characteristics of the site, especially the underlying rock structures and soil properties. Riverbeds which are having crystalline rocks and coarse sand have higher yield compared with volcanic rocks. Comparably, river valleys and regions sloping between 1 and 2%

are ideal sites for sand dams as they normally give the highest water storage. Knowledge of hydrological data is useful for evaluating the total stream flow, size of river transportation thereby affects the height and thickness of the wall. Information of geological and topographical characteristics and even hydrological data can be sourced from relevant Government departments.

Location requirements:

- The distribution of geological layers (reservoir layers) must allow for effective porosity and hydraulic conductivity so groundwater can be stored and collected.
- Inside part of the reservoir, the basement must be reducing the permeability, and by closing off a part on top of this basement, efficient storage can sufficiently be expected.
- The basement surface must be at suitable depth where construction is possible if the point of the dam axis is established. In addition, cut off is economically possible (construction area for dam extension).
- There must be a groundwater charging area to match the proposed water amount for development. There must be little existing use of groundwater.
- The water quality should be in a range permissible for usage. There must be a less effect on the lower catchment area.

D. ***Geological data***

The area under study consists of granites and dykes of Achaean age covered by recent alluvial deposit consist of boulders, pebbles and sandy alluvium. The granitic 13ck is mainly consists of quartz and potash feldspars as essential minerals and hornblende, biotitic as accessory minerals. Few quartz veins are observed through the granitic rock. The dolerite dykes trending-W directions are, observed at number-of locations as outcrops even in the riverbed. The nature and structure of geological formations have many indirect influences on agricultural land use and the geological formations of Swarnamukhi river basin as shown in below Fig.1 and geological sequence of the study area as given in table 1.

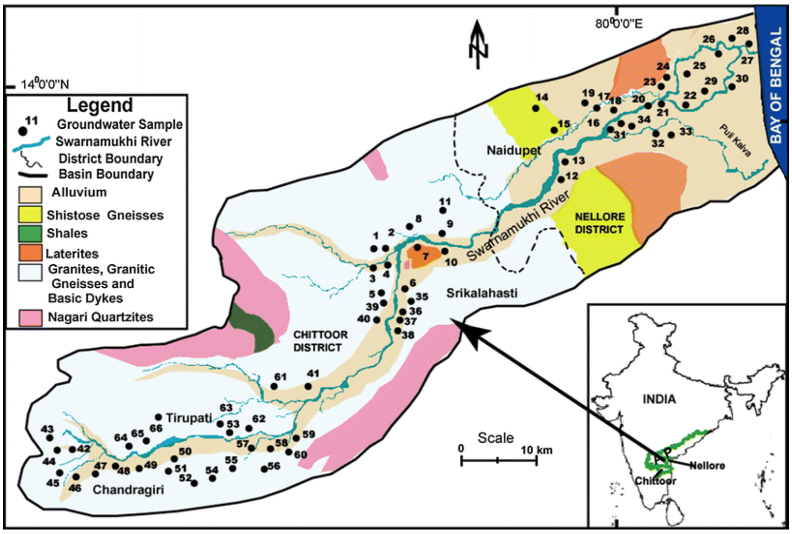

Fig.1. Geological study area of Swarnamukhi River

Geological formations are providing the basic materials and structures for the parent materials of the soils. Though the relief and the geological formations have a strong impact on climate and hydrology, these geological formations were studied in greater depth assuming them as land resources, which is also a land resource.

Table 1 The geological sequence of the study area

Age	Formation
Quaternary	-
Sub recent –alluvium	Gravels, course to fine sands, silts and clays 3 to 5m thick.
Recent –Talus	Pebbles and other debris in valley fill areas.
Pleistocene-Laterite	Very hard and compact rocks of fine quartz graining in ferruginous material
Upper Gondwanas	Conglomerates of quartzite pebbles embedded in ferruginous matrix.
Lower Kadapa – Nagari	Quartzite's with intercalating shales.
Achaeans – Dharwars and other Crystalline	Dolerite Dykes, granites and gneisses with (Porphyritic) feldspar, quartz, mica and hornblende.

The rock types met within the study area are of diverse types ranging in age from Achaean to Recent. The area in Chittoor district / Chandragiri Mandal is mostly covered by pre-Cambrian granites, which are highly magmatised. Kadapa and upper Gondwana's occur as deviation at one or two places.

The storage capacity of sand storage dams and subsurface dams constructed in riverbeds is function of the specific yield of river sediments. Therefore, dams are preferably constructed in geological environments where the weathering products contain a substantial amount of sand and Gravel. As a consequence, cases where dam construction has met with success are mostly found where the bedrock consists of granite, gneiss, and quartzite, whereas areas underlain by rocks such as basalt and rhyolite tend to be less favorable. Climate has a great influence on sediment characteristics in that it governs the relationship between mechanical and chemical weathering.

Low rate of chemical weathering in arid climates may be result in more coarse-grained sediments. The stage following weathering in the sediment cycle is the erosion of the particles. Topography and land use govern the extent of erosion, and an engineer interested in constructing; sand storage dams would be happy to find steep slopes and low vegetation cover in the catchment area, generally very contrary to the preferences of agricultural and hydraulic engineers.

Subsurface dams are mostly commonly constructed in riverbed aquifers consisting of sander gravel. Other types of aquifers that may be dimmed are weathered zones, alluvial or colluvial layers, or any type of overburden with sufficiently good aquifer characteristics. Infiltration conditions should be such that the reservoir is properly recharged during the rainy period. The storage reservoir must be contained by impervious or low-permeability layers that prevent vertical and lateral seepage losses. In most cases bedrock will serve as the natural container, but there are also examples of low-permeability overburden layers serving this purpose, such as buried clay layers of alluvial origin, the upper clayey portion of the weathered profile, or the lithomarge in laterite profiles. The proposed 4 sites (Tandlam, Jeepalem, Munagalapalem and Bandarupalle) have the bed rock depth 5 m, 6.30 m, 3 m and 3 m respectively.

The containing layer must be at such a depth that it is technically possible to carry out the excavation at reasonable cost. In general, the limit seems to be at around 4-5 m, but, depending on the scale of the scheme, it may be possible to extend this considerably. If injected cutoffs are used instead of the conventional construction of dams in trenches, there is no practical limit to the depths possible.

E. Topographical data

In this study the suitable sites for constructing water harvesting structures in Swarnamukhi watershed is identified using Google earth maps and simple affordable technologies. Criteria for selecting suitable sites were based on topographical, geological, soil depth and land cover data. The river Swarnamukhi is one of the most important rivers in Chittoor district. It takes its birth near Sankampalli in the district and flow a distance of 155 kilometers, crossing Chittoor and Nellore districts before joining the Bay of Bengal. The river has nine main tributaries and its catchment area, measuring approximately 3, 09,248 hectares, covers nine mandals in Chittoor district, including reserve forest in the region. Though it is not a perennial river, Swarnamukhi plays an important role in facilitating rain water percolation, water table control. Apart from meeting the irrigation needs, it also helps in supplying drinking water for nearly 400 habitations.

The drinking water needs of the temple towns are Tirupati, Tirumala and Srikalahasthi are met from the river Swarnamukhi. Swarnamukhi river is an ephemeral river and flows in October to December of every year and merges into Bay of Bengal near Pamanji village of Vakadu Mandal, Nellore district. Based on topographical conditions and geological data the proposed 4 sites Tandlam, Jeepalem, Munagalapalem and Bandarupalle may be consider as a best for construction for subsurface dam. The site locations as shown in Google earth map in below Fig. 2

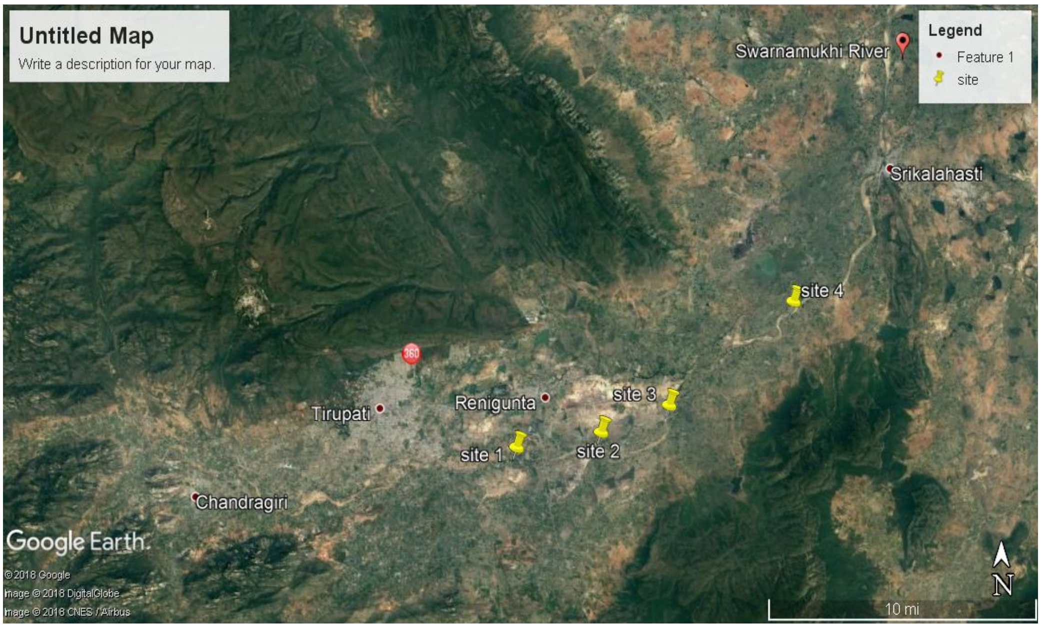

Fig. 2. Google earth map for suitable locations of subsurface dam construction on Swarnamukhi River.

The Swarnamukhi is an East flowing river; computed discharge of this River is 2, 00,000 cusecs. It rises at an elevation of 300m in the Eastern Ghats ranges near Pakala village in Chittoor district of A.P (N.Lat.13^{o} 28’ and E Long. 79^{o} 09’). It runs generally in the North-Eastern direction passing through the famous Tirupati hills, before joining the sea -Bay of Bengal. Its total length is 130Km. This has 9 tributaries viz., Beema, Kalyani, Dasala Vanka, Pamba Kalva, Kona Kalva, Rala Kalva, Valagamanda Kalva etc., The average annual Rainfall in the Swarnamukhi basin decreases from 1270mm at the Eastern extremity of the basin to 762mm at the western extremity.

The North- East monsoon sets in the month of October and withdraws by the end of November. In Chittoor District the Swarnamukhi basin consisting of Nine Sub- basins and ten mandals namely Pakala, Chandragiri, Tirupati rural, Tirupati Urban, Ramachandrapuram, Renigunta, Yerpedu, Srikalahasti, Thottambedu, Vadamalapeta having a catchment area of 202260 Ha-m. The average annual rainfall is about 933. 40mm.The stage of the ground water usage in Swarnamukhi basin is 66% and total no. of villages in Swarnamukhi basin is 263. The river flows in the heart of Srikalahasti Town. An Anicut was constructed in the year 1956 at a cost of Rs.6.75/11.66 lakhs. The anicut is situated D/S of Poothalapattu-Naidupet E Road Bridge at latitude of 13 ° 45’ 20’’ and longitude of 79° 43’15”.

F. Contour Maps

The below Fig.3 shows a contour map (1: 50,000) of Sanambatla reserve forest, Mungilipattu reserved forest and rocky knobs and also the famous Tirumala hills, from where rain water transports coarse sand to the riverbeds that originate from the north eastern side of the hills. This indicates that riverbeds containing of rocky catchments are the most potential for wells, subsurface dams and sand dams. The catchment below the hills consists of flat farmland from where rain water transports soil particles into the riverbeds and deposits it as fine textured sand, from where lee than 5% of water can be extracted. The world-famous Lord Sri Venkateswara Temple is situated on the Seshachalam hills and the Temple is situated outside the boundary of the study area on the east. The Mandal slopes down from west to east from an average elevation of about 750 M on the west to about 150 M.

Fig. 3. Contour maps (1:50,000)

The east Tirupati railway station which is hardly 10 Km from the study area is situated at an elevation of 120 M above mean sea level (MSL). The coordinates in maps can be used for zooming in Google earth satellite images for closer inspection of specific sites. The proposed 4 site locations Tandlam, Jeepalem, Munagalapalem, and Bandarupalle have slopes down from west to east 1 in 500, 1 in 360, 1 in 450 and 1 in 900.

G. Hydrological Data

The area under irrigation in Chittoor District, drought prone area of Rayalseema region of Andhra Pradesh, is about 2.02 lakhs hectares which mainly depends on groundwater as there are no major irrigation projects. The groundwater in the basin over a period has-been overexploited leading to water scarcity and deterioration of its quality.

Degradation of catchment area, indiscriminate groundwater use, erratic rainfall and sand quarrying are some causes for the present status. From the piezometric and rain gauge stations, ground water fluctuations (shown in table 2) and rain fall data (The average annual rainfall is about 933.40mm) was collected. The location of rain gauge stations in Swarnamukhi river basin as shown in Fig.4

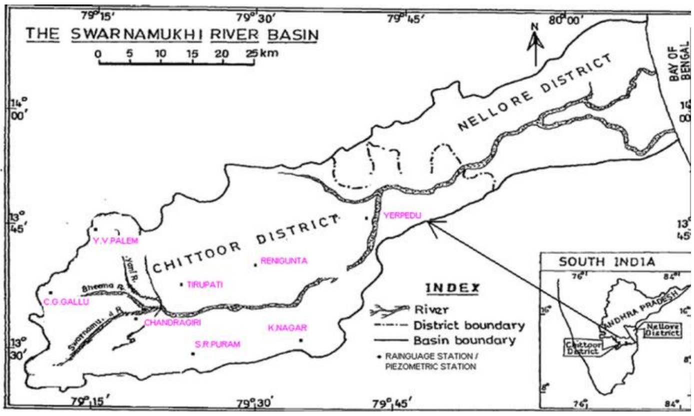

Fig.4. Piezometric and rain gauge stations located in the basin

The drainage of study area is dendrite to sub-dendrite which the characteristic feature of granitic terrain is Stream courses are common up to 3rd order. All the tributaries of Swarnamukhi such as Kalyani, Bhima and Dosalavanka consist of loose boulders in their courses. Throughout the Swarnamukhi valley a number of springs with good discharges were noted until the middle of the century. The ancient rulers like Sri Krishnadevaraya has constructed channels to divert this spring water to low lying areas for irrigation. They are very large particularly in the Plain land in the eastern part of Chandragiri Mandal.

Ground water supplies are profuse in recent years and with the help of which one can see the patches of cultivation here and there in the Mandal. The famous temples like Srinivasa Venkateswara swami and Agastheeswara Swami are situated in the catchment area of Swarnamukhi River.

Drainage:

The catchment area of the river up to Chandragiri is 600 Ha. The drainage patterns dendrite to sub dendritic. At present, the maximum flood discharge in the river is 5600TMCof water on an average in a good rainfall year. The existing level of utilization of the river water is very minimal.

Except the Swarnamukhi anicut, Mallimadugu reservoir and Kalyani dam, there are no other major schemes to harvest the river water for irrigation and drinking purposes. The salient features of Swarnamukhi river basin are given below.

1. Catchment area in Chittoor district 2217Km^2
- Hills and forest area 1014Km^2
- Uncultivable area 494 Km^2
- Cultivable area 709 Km^2

2. No, of sub basins 18Nos
3. Total yields available 13,740Mcft
- Utilization in the basin 10; 663 Mcft

4. Balance yield available 3,077Mcft

It is evident that still 3,077 Mcft of water as per the irrigation dept. is available in the Swarnamukhi basin of Chittoor District mostly as base flow. If this base flow is arrested at suitable locations, then the groundwater is getting recharged, which in turn can be utilized for further irrigation.

Present status of the river:

The Swarnamukhi River over a period has been over exploited leading to the scarcity of water. The followillg are identified as the main causes for the present status of the Swarnamukhi River.

I) Degradation of the catchment area
II) Indiscriminate use of groundwater
III) Erratic variation of rainfall
IV) Sand quarrying

H. *Hydro geological investigations*

A detailed well inventory data has been collected from the existing wells in and around the proposed location of the subsurface dam. The wells are dug wells, dug-cum-bore wells, and bore wells. No shallow tube wells are observed in the area under study. From the well inventory the nature of layers and their thickness are given in table 2.

Table 2 Lithology of study area

Lithology	Thickness (m)
Top Sand and Soil	3.0 - 11.5
Clay	1.5 - 5.0
Boulders, pebbles with clay	1.0 - 4.0
Disintegrated rock	2.0 – 30
Fractured rock	6.0 – 32

The water table is recorded as 4 m during the rainy season 13 m during the summer.

IV. CONCLUSION

The following conclusions should be drawn from this paper

- Google earth maps, Digital elevation model and contour maps and also using available digital data suitable points for construction of subsurface dams were identified.
- Tandlam, Jeepalem, Munagalapalem and Bandarupalle site points are identified as feasible and economical to construct subsurface dam.
- The hydrological study indicated that the selected 4 site locations for the project are suitable. This is due to the low fluctuations of ground water level in surrounding area of site locations. Based on Hydro geological survey, an alignment is selected for the construction of subsurface dams and also to know the thickness of over burden and end conditions.

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