ASSESMENT OF GROUNDWATER POTENTIAL ZONES FOR BRUHAT BANGALORE MAHANAGARA PALIKE USING GIS

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Abstract

Groundwater is an important natural resource in present day, but of limited use due to frequent failures in monsoon, undependable surface water, and rapid urbanization and industrialization have created a major threat to this valuable resource. The present work is an attempt to integrate RS and GIS based analysis and methodology in groundwater potential zone identification in the BBMP study area with an aerial extent of 715.95 km^2. The information on geology, geomorphology, soil, slope, rainfall, water level and land use/land cover was gathered, in addition, GIS platform was used for the integration of various themes. The composite map generated was further classified according to the spatial variation of the groundwater potential. Four categories of groundwater potential zones namely poor, moderate, good and very good were identified and delineated. The hydrogeomorphological units like valley fills and alluvial plain and are potential zones for groundwater exploration and development and valley fills associated with lineaments is highly promising area for ground water recharging. The spatial variation of the potential indicates that groundwater occurrence is controlled by geology, land use / land cover, slope and landforms.

Keywords: *Geology, Geomorphology, Landuselandcover, GIS, Capability .*

INTRODUTION

General

Groundwater is dynamic and replenishing natural resource. But in hard rock terrains, availabity of groundwater is of limited extent. Groundwater plays a vital role in the rapidly expanding Urban, industrial, and agricultural water requirements, in the study area. Therefore the quantification of the current rate of groundwater recharge is a necessity for the efficient and sustainable groundwater resource management. Groundwater recharge is generally considered as that amount of water, which contributes to the temporary or permanent increase of groundwater resources. The actual recharge reaching the water table may be considerably less than the potential recharge due to the influence of the unsaturated zone. Water-resource evaluation requires information on recharge over large spatial scales and decadal time scale, which requires detailed in-formation on spatial variability and preferential flow. Therefore, the complexity of water movement has to be followed critically from the very time it enters the soil profile, until it reaches the water table.

The factors which control the ground water occurrence include rock type, landforms and soil type, recharge characteristic of soils/overburden material etc., in crystalline hard rock integrated terrain analysis for identifying suitable site for groundwater planning & development studies. The development of remote sensing technology, the resources mapping, monitoring and management have become much simpler. Remote Sensing technique has emerged as one of the powerful tool by providing synoptic view, repetitive coverage, and capability to study inaccessible area at relatively low cost and less time when compared to the conventional techniques. The information generated through remote sensing techniques on landforms, lithology, soil, land use/cover, etc., integrating the same provides an evidence about groundwater occurrence. Thus the remote sensing based groundwater prospects zone map prepared for an area serves as basic information for further development through hydrogeological & geophysical methods to locate the favorable sites. The resultant utility of remote sensing technique is commonly acceptable, not only due to reliable information, but also by its time and cost effectiveness.

It has been reported that the success role of locating favorable sites for groundwater prospects using remote sensing techniques along with other conventional data is much more than compared to conventional methods alone. Many studies have demonstrated that the integration of thematic maps prepared through visual interpretation/analysis. Apart from the mapping of groundwater prospective zones, utility of remote sensing techniques have also been found efficient in locating and planning terrain, the groundwater is mainly confined to weathered zones from where most of the dug wells draw their water, while, the deeper bore wells get their water supply from linear openings like fissures, fractures and joints. The satellite based remote sensing data and Geographic Information System (G1S) are being efficiently utilized to demarcate the various groundwater controlling parameters as well as groundwater prospective zones. It can be noted that both remote sensing and geographical information system technique provides not only the qualitative information about the condition of the water resources in a particular area, but also helps to narrow down the target area for further detailed study.

LOCATION OF STUDY AREA

The study area is located between Latitude 12º50′15″N to 13º9′20″N and Longitude 77º27′30″E to77º47′00″E

The mean annual rainfall is about 880 mm with about 60 rainy days a year. Bangalore is known as the 'IT city' or'silicon valley' of India due to the presence of several software companies. It is the fifth largest city of India with population of about 7 million, located around100 km from the Kaveri River.

The study area covers an area of 715.95 km^2 and attains maximum elevation 950m and minimum elevation of 850m. physiography of the area is characterized by undulating topography with pediplains, pediment and valley fills. Bangalore is the capital of Karnataka state.

The mean annual total rainfall is about 768 mm with about 60 rainy days a year over the last ten years.The summer temperature ranges from 17° C to 36° C, while the winter temperature ranges from 12° C to 25° C. Thus, Bangalore enjoys a salubrious climate all round the year.

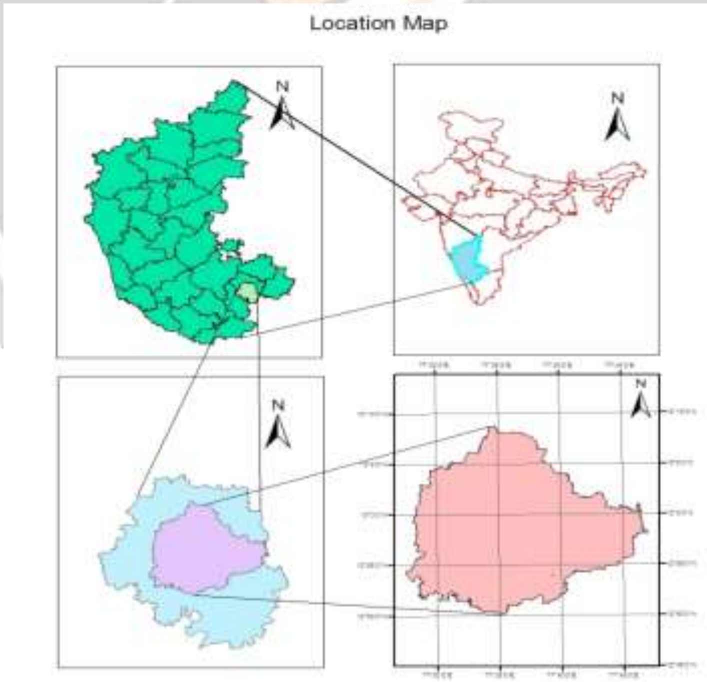

Figure 1

PHYSIOGRAPHY AND DRAINAGE

Physiographically the study area falls in the southern maiden region, which is characterized by undulating valleys. The land forms are considered ancient and have undergone an extensive pediplantation, leading to the present landscape. The major part of the district lies in Cauvery basin. The major rivers draining the area are Cauvery, South Pennar, North Pennar and Polar. Cauvery along with its tributaries like Kanva, Arkavathi and Shimsha drain 67% of the area. South Polar, North Polar and Polar originate from the NandiHills in the northern part of the district drain 33% of the area

GEOMORPHOLOGY SETUP

In the study area, broad categories of landforms developed over Gneiss lithounit and their distribution have been interpreted from the remotely sensed data and confirmed on the ground. The different landform features delineated through image interpretation includes pediments, pediplains, pedilain eroded, valley fills, and water bodies

PEDIMENTS

Gently undulating or slopping rocky surfaces resulting from pediplanation of gneisses often covered by a thin layer of soil and occurring at the transition zone between the residual hills and the neighboring plains. On imagery, this unit is observed as dotted outcrops mainly constituting granites and gneisses, exhibiting light grey tone are closepet granite and pale red tonal characteristics are gneissic rocks with coarse & smooth texture as well. Hydrogeomorphically this pediment unit's act as surface runoff zones, hence groundwater prospects are poor. The presence of lineaments of fractures and their intersections in this unit may provide some scope for movement and storage of groundwater.

PEDIMENT INSELBERG COMPLEX

These are mostly barren, rocky, usually smooth undulating plains dotted with small mounds which are survived by the denudational processes. At places the occurrence of pediment Inselberg are not uncommon, and quite difficult to separate them. Hence they have been classified as a single unit called pediment Inselberg complex. From the groundwater point of view this unit acts as moderate recharge zones.

MAPPING GROUNDWATER POTENTIAL ZONES

GIS technology has opened new paths in groundwater studies. In the present study, an attempt has been made to identify the Ground Water Prospect sites in the BBMP Area of Bangalore District of Karnataka based on GIS techniques. The groundwater prospect map is a systematic effort and has been prepared considering major controlling factors. The map depicts hydrogeomorphological aspects, which are essential as basis for planning and execution of groundwater mapping.

In order to demarcate the groundwater potential zones using GIS for the study area the following thematic maps were used. Geology, Slope, Soil, Land use land covers, Rainfall and Hydro-geomorphology.

Suitable Capability Values (Cv) and weighted capability values (WCV) have been assigned to each component of the thematic layer and classified them into four categories viz., Very good, good, Moderate and Poor based on the characteristic features listed in Table 1

TABLE 1 CHARACTERISTIC FEATURES OF THEMATIC LAYER

Thematic Layers	Characteristics
Geomorphology	Land forms, weathering zones etc.,
Lithology	Rock type, weathering character, thickness of weathering, joints, fracture etc.,
Land use and Land Cover	Forest are, barren land, vegetation land etc.,
Rainfall	Depth of rainfall
Slope	Slope percent
Soil	Permeability, porosity, texture

GEOMORPHOLOGY SETUP (L1)

The storage capacity of the rock formations depends on the porosity of the rock. In the rock formation the water moves from areas of recharge to areas of discharge under the influence of hydraulic gradients depending on the hydraulic conductivity or permeability. The combined units in which the lithology, landform, structure and recharge conditions are unique are called „hydrogeomorphic units‟. They are considered as three dimensional homogenous entities with respect to hydrogeological properties and the recharge condition. In other words, they are treated as the aquifers. The ground water prospects are expected to be uniform in a hydrogeomorphic unit. The hydrogeomorphological map, as shown in figure2, was prepared following the guidelines of Ground Water Prospect Mapping under Rajiv Gandhi National Drinking Water Mission by NRSC, Hyderabad (2012).

Therefore, this zone is classified as very good. Realizing the importance of hydro geomorphology, capability values from 1 to 5 and WCV weights of 5, 10, 15, 20 and 25 are assigned to different types of landforms (Table 2).

TABLE 2: DIFFERENT HYDROGEOMORPHIC UNITS AND THEIR INFLUENCE ON GROUNDWATER REGIME

Geomorphic unit /Landform	Description	Influence on ground water regime
Inselberg (I)	An Isolated hill of massive type abruptly rising above surrounding plains.	Mainly act as runoff Zone
Valleys	Low lying depressions and negative landforms of varying size and shape associated with stream / nala courses	Favorable zones for ground water accumulation.
Intermontane Valley (IV)	Small valleys occurring within the hill ranges / composite hills and residual hills.	Very good recharge from surrounding hills, subject to good rainfall. Ground water prospects depend on the underlying rock types, structures, thickness of valley fill and its composition.
Pediment Inselberg Complex (PIC)	Pediment dotted with a number of inselbergs which cannot be separated and mapped as individual units.	Inselbergs form runoff zones. Pediment contributes for limited to moderate recharge.
Pediplain Weathered (PP) – Shallow (PPS)	Gently undulating plain of large areal extent often dotted with inselbergs formed by the coalescence of several pediments.	Pediplains form good aquifers depending on their composition. In hard rocks, they form very good recharge and storage zones depending upon the thickness of weathering /accumulated material, its composition and recharge conditions .
Valley Fill (VF)	Valleys of different shapes and sizes occupied by valley fill material (partly detrital and partly weathered material).	Form moderately productive shallow aquifers, subject to thickness of valley fill material, its composition and recharge conditions.

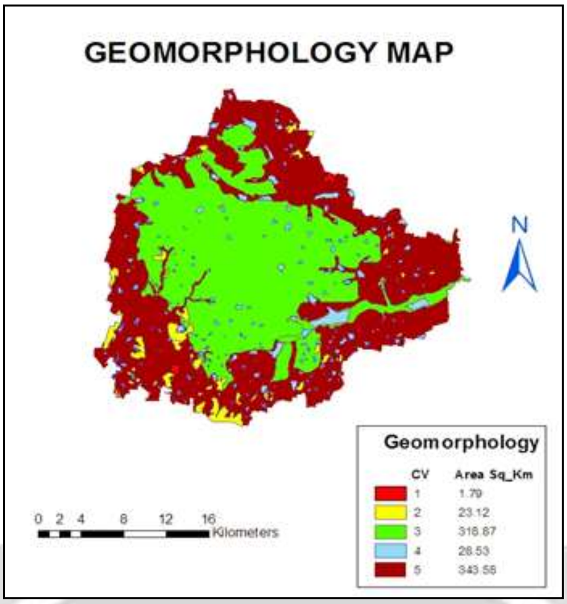

Figure 2

GEOLOGICAL/LITHOLOGICAL SETUP (L2)

It is a well established fact that geological setup of an area plays a vital role in the distribution and occurrence of groundwater (Krishnamurthy and Srinivas, 1995). The study area entirely lies on Indian Shield where ancient Precambrian igneous and metamorphic rocks are exposed (Kumar Ravindra, 1992). The study area forms a Bangalore urban district of Karnataka state. Lithologically the area is composed of gneiss, (Fig 3). Since the study area comprises gneiss litho unit the occurrence and movement of groundwater varies considerably and also has different percentage of porosity and permeability factors Based on water holding capacity of litho unit in the basin, capability values 3 and WCV weights of 15 is assigned (Table 3).

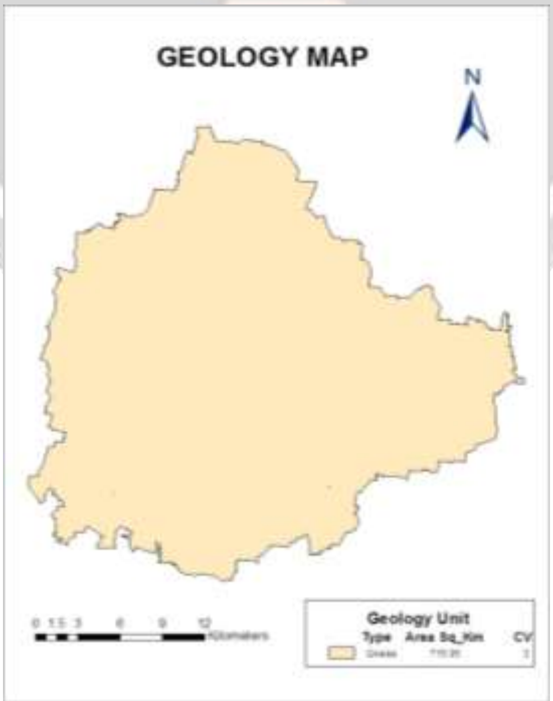

Figure 3

LAND USE AND LAND COVER SETUP (L3)

The land use land cover study area has been attempted in order to identify and map the various types of land use/land cover classes in the area. The classification system was developed by Remote sensing Agency (NRSA,2012), Land use refers to mans activities and various uses which are carried on land “Land cover refers” to “Natural vegetation, Water bodies, rock / soil, artificial cover and other resulted due to land transformation. The following are the different Land use/Land cover classes of the study area Built up land (town, village), crop land, fallow land, agriculture plantation, dense forest, fair dense forest, scrub forest, dense grass land forest plantation, land with scrub, barren rock, mining, waterlogged area, Industrial area, lakes/tank

Land use plays a significant role in the development of groundwater resource. Nature of surface material and land use pattern controls infiltration and runoff. The rate of infiltration is directly proportional to the crown density of forest cover, i.e. if the surface is covered by dense forest, the infiltration will be more, and the runoff will be less. As land use changes from dense forest to agriculture to rural setup and further urbanization, infiltration of water show decreasing trend. Realizing the importance of land use and land cover (Fig 4), the capability values from 1 to 5 has been assigned and WCV weights of 5, 10, 15, 20 and 25 are assigned to various land use and land cover according to their role in capability of infiltration of water (Table 3)

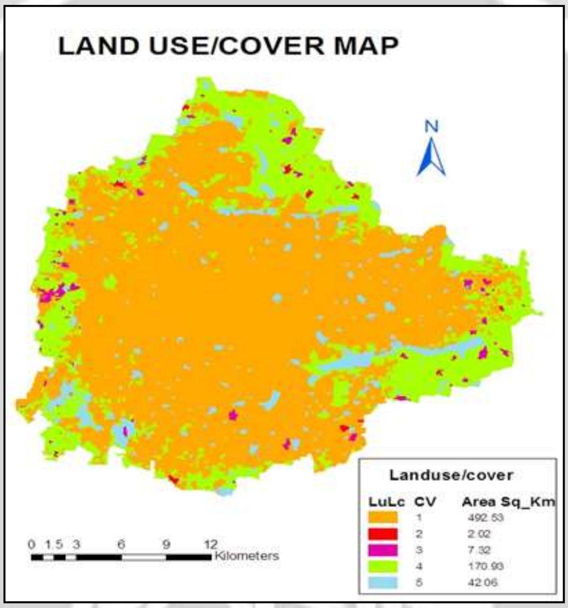

Figure 4

RAINFALL (L4)

The principal source of all surface and groundwater in the study area is precipitation. 15 years (1998-2012) monthly rainfall data from 14 stations (Yelahanka, GKVK campus, Hebbal, Krishnarajpur, Utarahalli, Kengeri,Surjapura, Basapura, Bangalore city Railway station, Bangalore Palace, Bangalore Lalbagh, Tavarakere, Surjapura, Whitefield, Varthur) situated within the basin are collected and Isohyetal map has been prepared. The average annual rainfall varies from 600 to 1100 mm (Fig 5) in the study area. Based on the depth of rainfall in the study area the capability values from 1 to 5 and WCV weights of 5, 10, 15, 20 and 25 are assigned (Table 3).

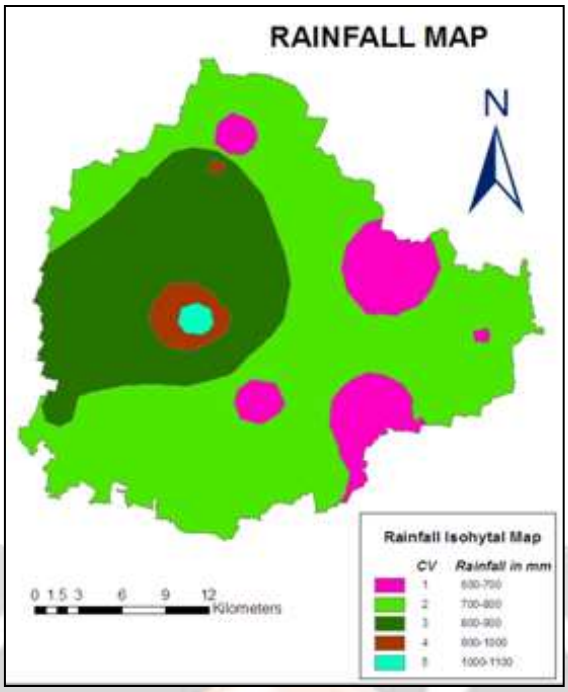

Figure 5

SLOPE (L5)

The slope of a surface refers to the maximum rate of change in height across a region of the surface. Slope is an important terrain parameter and it affects the land stability. The slopes in the study area have been categorized into seven classes as per the IMSD Guidelines (NRSA, 1995). The following slope classes were mapped for the study area: nearly level, very gently sloping, gently sloping and moderately sloping. The nearly level and very gently sloping areas support for infiltration and groundwater recharge while, moderate slopes promotes surface run-off and less infiltration. The different types of slope are shown in Fig 6. On the basis of infiltration capacity the capability values are assigned to individual slope categories from 1 to 5 and WCV weights of 5, 10, 15, 20 and 25 are assigned for slope classes (Table 3)

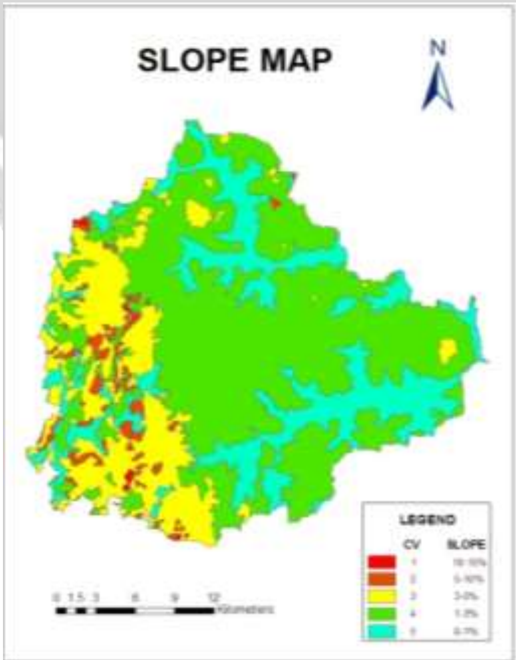

Figure 6

SOIL (L6)

Soils are the products of weathering of rocks. Soil is a natural body of mineral and organic constituents, differentiated into horizons of variable depths, which differs from the materials below in morphology, physical make up, chemical properties and composition and biological characteristics. The characteristics of soil particles along with soil water and soil air in combination influences the physical properties of soil. In the study area, about 5 series of soils have been identified as 1, 2, 3, 4 and 5 (Fig 7). Based on their hydrogeological properties capability values from 1 to 5 and WCV weights of 5, 10, 15, 20 and 25 are assigned (Table3).

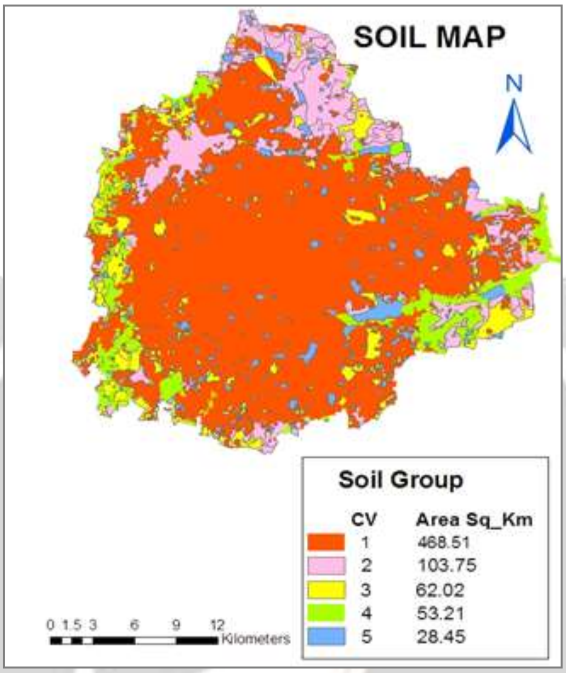

Figure 7

METHODOLOGY

In the first step of integration, Geomorphology layer (L1) and Lithology layer (L2) maps were integrated by intersect option and a new integrated layer (R1) is generated 376 polygons of layer L1 (geomorphology layer) and 1 polygon of layer L2 (geology layer) has resulted in the generation of integrated layer (R1) with 376 polygons. The minimum and maximum WCV are 20 and 40 respectively.

In the second step, the integrated layer R1 layer containing 376 polygons (the resultant of geomorphology and lithology) was intersected with the landuse and land cover layer (L3) which has 1063 polygons and it resulted in the generation of integrated layer R2 with 1776 polygons. The minimum and maximum WCV are 25 and 65 respectively.

In the third step, integrated layer R2 containing 1776 polygons was intersected with the rainfall (L4) which has 9 polygons, which resulted in the generation of integrated layer R3 containing 1904 polygons. The minimum and maximum WCV are 35 and 80 respectively.

In the fourth step, Slope layer (L5) containing 109 polygons was intersected with the integrated layer R3 having 1904 polygons, this resulted in the generation of integrated layer R4 containing 3118 polygons. The minimum and maximum WCV are 40 and 105 respectively.

In the fifth step, Soil layer (L6) containing 849 polygons was intersected with the integrated layer R4 having 3118 polygons, which resulted in the generation of integrated layer R5 containing 4324 polygons. The minimum and maximum WCV are 45 and 125 respectively.

Theoretically, if WCV of the all the layers which are integrated, a maximum of 140 and minimum of 30 WCV must be obtained. But practically maximum of 125 and minimum of 45 WCV are obtained. This shows that the overlap of some of higher weights polygons with one another in the integrated layer. Based on the total weights obtained by integration the study area has been delineated into Very good, Good, Moderate, Poor groundwater potential zones (Table 5.3, Fig 5.7).

Table 3 Thematic layers CVand WCV

Thematic layers	Map Weight (Wi)	Categories	Capability Values (CV)	Weighted Capabilities Values (WCV)
Geomorphology	5	Pediplain Eroded	1	5
		Pediment/ Valley Floor	2	10
		Settlement	3	15
		Water Body Mask	4	20
		Valley Fill/Filled in Valley	5	25
Geology	1	Gneiss	3	15
Land Use &Land Cover	5	Barren Rock, Industrial Area, Minning	1	5
		Fallow land, Town/Cities	2	10
		Forest Plantation, Gullied Land, Village	3	15
		Agricultural Plantation , Double crop, Karif crop, Land with Scrub	4	20
		Dense Grass Land, Lakes/Tanks, Scrub Forest, Waterlogged Area	5	25
Rainfall in mm	5	600-700	1	5
		700-800	2	10
		800-900	3	15
		900-1000	4	20
		1000-1100	5	25
Slope	5	0-1%	5	25
		1-3%	4	20
		3-5%	3	15
		5-10%	2	10
		10-15%	1	5
Soil	5	Habitation Mask and Rock outcrops	1	5
		Moderately deep red clay soils associated with moderately deep red clay soils,deep red clay soils,shallow red gravelly clay soils & deep lateritic clay soils.	2	10
		Deep alluvial clay soils occurring associated with shallow alluvial clay soils & Deep alluvial loam soils.	3	15
		Deep Latritic clay soils associated with shallow latertic clay soils & moderately deep red gravelly clay soils	4	20
		Water body mask	5	25

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This shows that the overlap of some of higher weights polygons with one another in the integrated layer. Based on the total weights obtained by integration the study area has been delineated into Very good, Good, Moderate, Poor groundwater potential zones (Table 4, Fig 8).

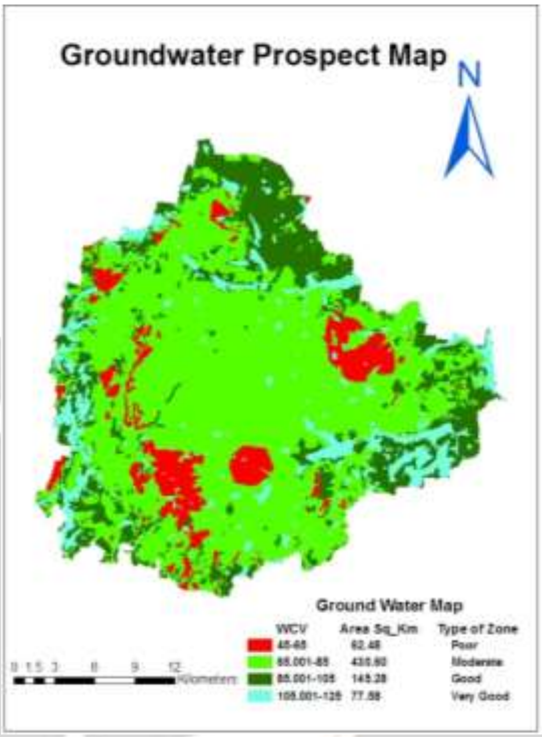

Figure 8

TABLE 4

Sl No.	Ground water category	Area Km2	% of the total area	Higher Weightage value	Lower weightage value	Ground water structures feasible
1	VERY GOOD	77.58	10.84	125	105	Dug wells fitted with low power pumps and tube wells fitted with hand pumps
2	Good	145.28	20.29	105	85	Dug well, dug well cum bored well and tube well fitted with hand pump
3	Moderate	430.60	60.14	85	65	Dug well, dug-cum bored well, with tube well
4	Poor	62.48	8.73	65	45	Generally, groundwater structures will not be successful. Dug well dug-cum-bored well may be constructed. Surface water should be harnessed and roof top rainwater harvesting schemes may be adopted.

CONCLUSIONS

From Groundwater Potential map (figure 8), it is observed that BBMP area is having Moderate Ground water prospect zone. Ground water potential maps thus developed will be useful for planning surface drainage networks and construction of ground water recharge structures in very good ground water potential zones.

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