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विभाग, जल शक्ति मंत्रालय

भारत सरकार

Central Ground Water Board

Department of Water Resources, River Development and Ganga Rejuvenation,

Ministry of Jal Shakti

Government of India

AQUIFER MAPPING AND MANAGEMENT OF GROUND WATER RESOURCES

NELAMANGALA TALUK, BANGALORE RURAL DISTRICT, KARNATAKA

दक्षिण पश्चिमी क्षेत्र, बैंगलोर

South Western Region, Bengaluru

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GOVERNMENT OF INDIA
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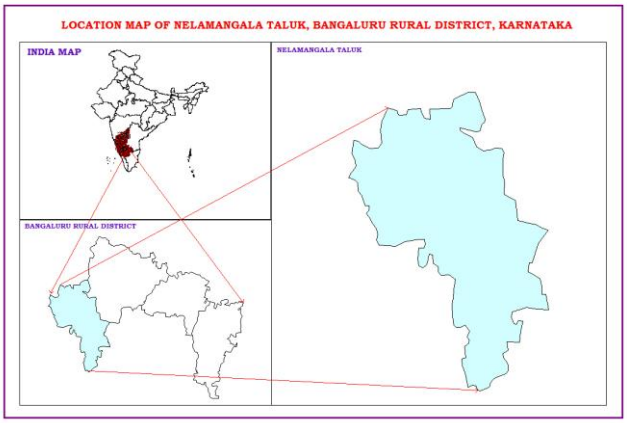
AQUIFER MANAGEMENT PLAN OF NELAMANGALA TALUK, BANGALORE RURAL DISTRICT, KARNATAKA STATE



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AQUIFER MANAGEMENT PLAN OF NELAMANGALA TALUK, BANGALORE RURAL DISTRICT, KARNATAKA STATE

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AQUIFER MANAGEMENT PLAN OF NELAMANGALA TALUK, BANGALORE RURAL DISTRICT, KARNATAKA STATE

1. SALIENT INFORMATION

Name of the taluk: **NELAMANGALA**
District: Bangalore Rural
State: Karnataka
Area: 507 sq.km.
Population: 2,10,889 (as per 2011 census)
Annual Normal Rainfall: 836 mm

1.1 Aquifer management study area

Aquifer mapping studies were carried out in Nelamangala taluk, Bangalore Rural district o f Karnataka, covering an area of 507sq.km under National Aquifer Mapping Project. Nelamangala taluk of Bangalore Rural district. The taluk is located between north latitude 12^{o} 57'57"and 13^{o}19'24"& east longitude 77^{o}10'55" and 77^{o}25'57" and is bounded by Tumkur taluk on North West, Doddaballapur Taluk on north East, Bangalore Urban district to east and South East, Ramnagara district on South and South west. Location map of Nelamangala taluk of Bangalore Rural district is presented in **Fig.1.1.**

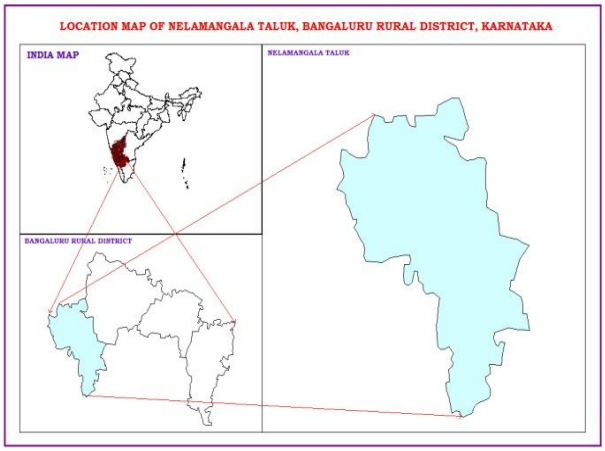

Fig.1.1: Location Map of Nelamangala taluk, Bangalore Rural district

Nelamangala taluk is located in Bangalore Rural district of Karnataka State. Taluk administration of Nelamangala taluk is divided into 3 Hoblies, 24 gram panchayaths and two towns. There are 231 inhabited and 11 uninhabited villages in the taluk.

1.2 Population

According to 2011 census, the population in Nelamangala taluk is 210889, of which 77% people lives in rural areas and 23% lives in urban areas. In 2011 there were total 107504 females and 103385 males residing in Nelamangala Taluk. The taluk has an overall population density of 415 persons per sq.km.

1.3 Rainfall

Nelamangala taluk enjoys semi-arid climate. Dryness and hot weather prevails in major part of the year. The area falls under Eastern Dry agro-climatic zone of Karnataka state and is categorized as drought prone.

The climate of the study area is quite agreeable and free from extremes. The year is usually divided into four seasons: summer from March to May; rainy season or south-west monsoon season from June to September; post-monsoon season covering the months of October and November and dry or winter Season from December to February.

There is one rain gauge station located in Nelamangala taluk **(Table 1.1)**. The data in respect of this station from the year 1981 to 2010 is analysed and presented in **Table 1.2**. The data pertaining to these gauges is of long term nature and are well maintained. It is presumed that they are representative of the taluks and the same is used for analysis. Normal annual rainfall in Nelamangala taluk for the period 1981 to 2010 is 836 mm.

Table 1.1: Raingauge and its location in Nelamangala taluk

Station	Latitude	Longitude	Altitude
Nelamangala taluk	13.10	77.45	844.6

Statistical analysis

Computations were carried out for the 30 year blocks of 1981- 2010 on Mean, Standard deviation and coefficient of variation of each month pre monsoon, monsoon, post monsoon and annual and are shown in **Table 1.2**.

The mean monthly rainfall at Nelamangala taluk is ranging between 42 mm during January to 159 mm during September. The CV percent for premonsoon, monsoon and post monsoon season is 58, 42 & 54 percent respectively. Annual CV at this station works out to be 37 percent.

Table 1.2: Statistical Analysis of Rainfall Data of Nelamangala Taluk, Bangalore Rural District for the Period 1981 to 2010

STATION		JAN	FEB	MAR	APR	MAY	PRE MONSOON	JUN	JUL	AUG	SEP	SW MONSOON	OCT	NOV	DEC	NE MONSOON	ANNUAL RAINFALL
Nelamangala	Normal Rainfall (mm)	2	6	9	48	97	162	64	96	133	159	452	155	58	11	222	836
	STDEV	5	24	20	46	61	94	42	70	94	99	190	97	54	23	121	305
	CV%	262	402	216	97	63	58	65	73	71	62	42	63	93	211	54	37

Assessment of Drought

Rainfall data has been analysed for 103 years using IMD method to assess the drought condition in Nelamangala taluk. The results of the classification are listed in the **Table 1.3**. It is observed that the Nelamangala taluk has experienced alternating no drought to acute drought conditions over the years.

Table 1.3: Classification of drought and its periodicity (IMD, 1971)

% Deviation (Di)		>0	0 to -25	-25 to -50	50 to 75	<-75	Probability of drought occurrences
Category		No drought	Mild (Normal)	Moderate	Severe	Acute	
		Years					
Taluk	Nelamangala	26	50	23	3	1	Once in 4 years

The details of the drought assessment are discussed as herein under. Out of 103 years of analysis in Nelamangala taluk, "No Drought" condition is experienced in 25 years, "Mild Drought" condition is experienced in 48 years and "Moderate Drought" condition experienced in 23 years. Further it is observed that "Severe Drought" condition is experienced in 3 years i.e., during 1908 and 1972 and "Acute Drought" condition is experienced in 2 years i.e., 1982, 1984 and 1985 and "Acute Drought" condition is experienced in 1 years i.e., during 1986 in Nelamangala taluk. Based on occurrence and frequency of past drought events, the probability of occurrence of various intensities of drought at each station has been studied. It has been observed that the frequency of occurrence of drought is **once in 4 years** at Nelamangala taluk.

1.4 Agriculture and Irrigation

Agriculture is the main occupation in Nelamangala taluk. Food grains are the major crop grown in the taluk accounting for almost 80 percent of the total crop area. Cereals (71 %), Pulses (12%) fruits (13%), Vegetables(5%) and Oil seeds (1%), of the total crop area respectively **(Table 1.4)**.

Table 1.4: Cropping pattern in Nelamangala taluk 2016-2017(Ha)

Year	Cereals	Pulses	Food Grains	Oil seeds	Fruits	Vegetables	Sugarcane	Cotton
2016-17	11897	1565	13462	236	2150	900	0	0

Photo 1: Tomato cultivation near Yentaganahalli in Nelamangala taluk

Photo 2:Marigold cultivation near Baradi in Nelamangala taluk

It is observed that net sown area accounts for about 52% of total geographical area, while area sown more than once is 0.5% of total geographical area in the taluk **(Table 1.5).** As per the data available, the taluk uses only tube wells for irrigation. Around 3911 tube wells are used for irrigation purpose **(Table 1.6).** Land use pattern of the taluk is represented as **Fig.1.2**.

Table 1.5: Details of landuse in Nelamangala taluk 2016-2017(Ha)

Total Geographical Area (ha)	Area under Forest	Land put to non agricultural use	Barren and uncultivable land	Total	Other uncultivated land	Fallow land	Net area sown	Area sown more than once	Total
50967	1708	11928	3535	15463	3953	3474	26369	276	26645

Source: District at a glance 2016-17, Govt. of Karnataka

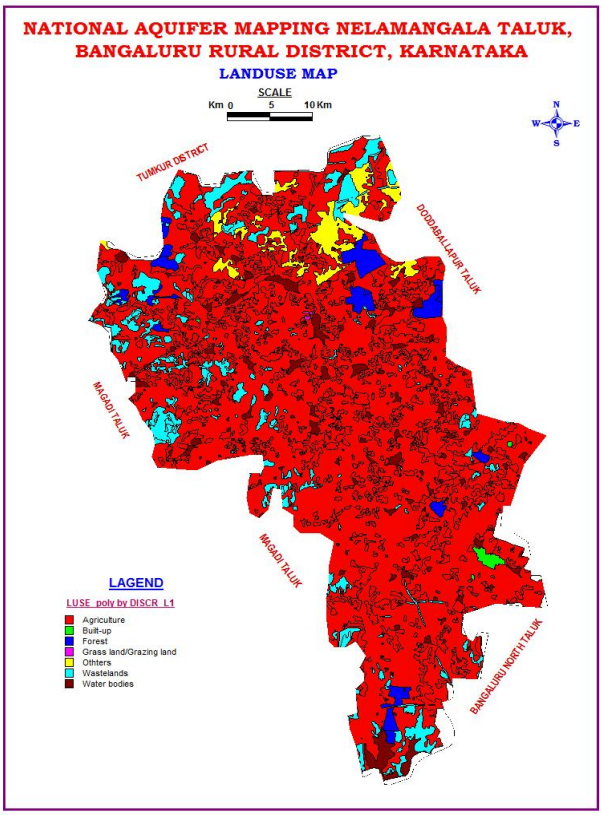

Fig.1.2: Landuse Map of Nelamangala Taluk, Ramnagara District

Table 1.6: Irrigation details in Nelamangala taluk (Ha)

Source of Irrigation	Area irrigated (Ha)
Canals	0
Tanks	0
Wells	0
Tube wells	3911
Lift Irrigation	0
Other Sources	0
Total	3911

Source: District at a Glance 2016-17, Government of Karnataka

1.5 Geomorphology, Physiography and Drainage

The entire taluk is categorised as Plains of denundational origin **(Fig. 1.3).** Low to medium dissected hillocks and valleys also occur as patches in the taluk. The ground altitude varies from 720 to 1080 m above MSL. The taluk is drained by Arkavati, and Shimsha river. Kumudavathi a tributary of Arkavathy river is draining part of the Taluk. The drainage pattern in the area can be described as semi dendritic to dendritic. The rivers and streams originate from small watersheds and empty into number of tanks in the taluk and the district **(Fig.1.4).**

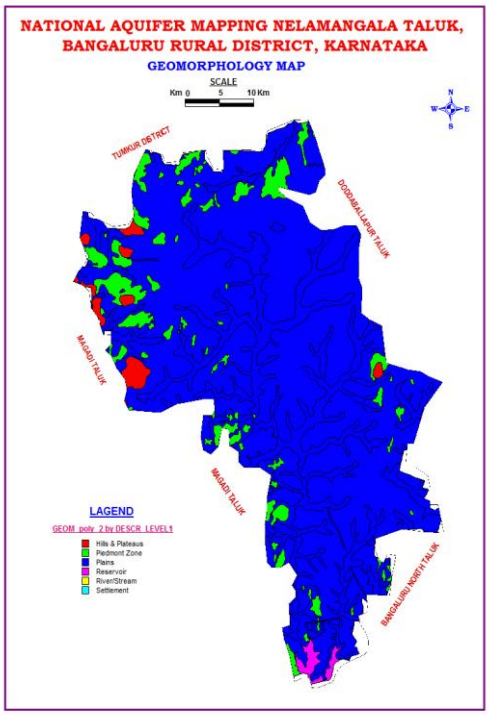

Fig.1.3: Geomorphology

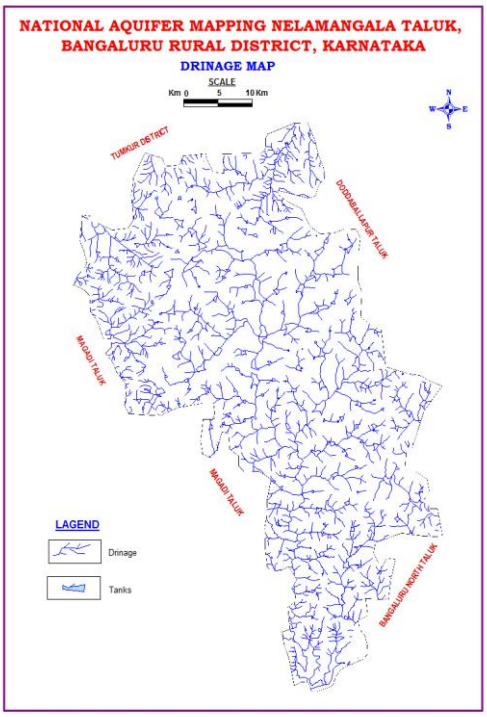

Fig.1.4: Drainage

1.6 Soil

The taluk is occupied by two types of soils viz. Clayey and clayey mixed soils (rocky) generally occur on hilly to undulating land slope on granite and granite gneisses. Formation of various types of soils is a complex function of chemical weathering of bedrocks, vegetative decay and circulation of precipitated water. Soils are mostly insitu in nature **(Fig.1.5).**

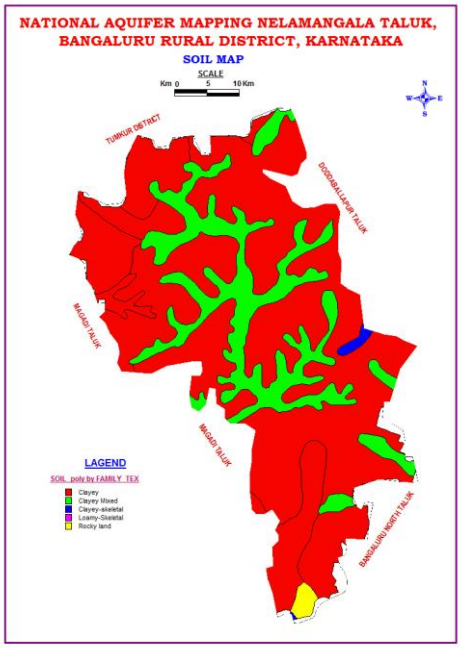

Fig.1.5: Soil Map

1.7 Ground water resource availability and extraction

Aquifer wise total ground water resources up to 200 m depth are given in **Table 1.7** below.

Table 1.7: Total GW Resources (as on March 2017) (Ham)

Taluk	Annual Replenishable GW resources	Fresh In-storage GW resources		Total availability of fresh GW resources
		Phreatic	Fractured (down to 200 m)	Dynamic + Phreatic in-storage + fractured
Nelamangala	5053	18751	2998	26802

1.8 Existing and future water demands (as per GEC-2017)

Net ground water availability for future irrigation development: 94 ham

Domestic and Industrial sector demand for next 25 years: 146 ham

1.9 Water level behaviour

Aquifer-I

Depth to water level in aquifer I is dry. Only point values of Water level observed in the localised patches

Pre-monsoon: 1.65 – 9.68 mbgl

Post-monsoon: 2.70 – 8.95 mbgl

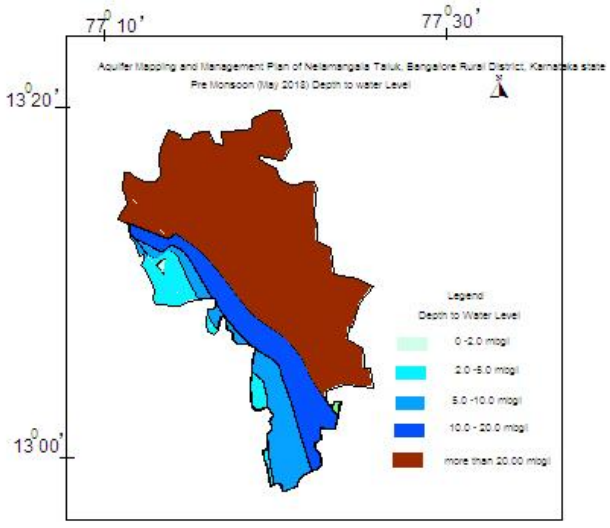

Fig : 1.6 a Depth to water level - Pre Monsoon (May 2018),

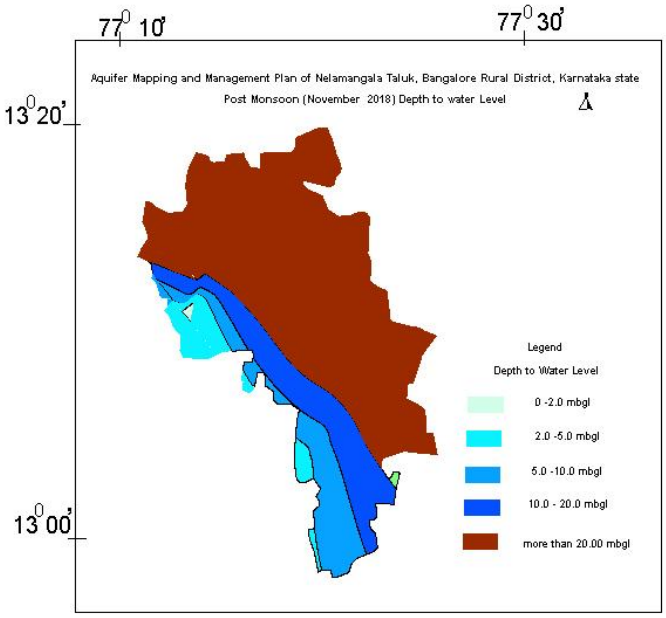

Fig : 1.6 b Depth to water level - Post Monsoon (Nov 2018),

Aquifer-II

Pre-monsoon: 3.32–60.85 mbgl

Post-monsoon: 1.4–54.98 mbgl

(b) Water level fluctuation

Aquifer-I

No seasonal fluctuation in most of the areas as the aquifer is dry. The Seasonal Fluctuation obtained in the perched aquifer is rise in the range of 0.05 m to 2 m and fall of 0.88 m to 3.5 m.

Aquifer-II

Seasonal Fluctuation: Rise in the range of 2.2–9.29 m and fall in the range 0-5.65m

2. AQUIFER DISPOSITION

The Nelamangala taluk is underlain by banded gneissic complex and granites of Archaean age. **(Fig 2.1)** Both the rock types are weathered.

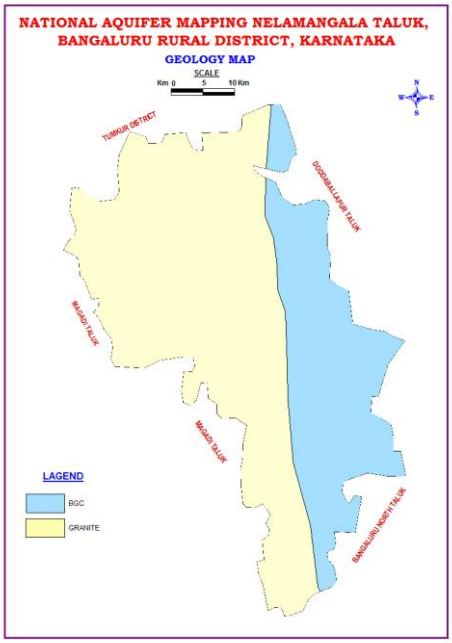

Fig.2.1: Geology

Photo 3A: Sectional view of the weathered formation at Nelamangala

Photo 3 B : Massive rock exposure of granite at Sivaganga

2.1 Number of aquifers: In Nelamangala taluk, the hard rock aquifers comprising of Granites and Granite gneisses. There are mainly two aquifer systems;

i. Aquifer -I (Phreatic aquifer) & ii. Aquifer II (Fractured aquifer)

i. Aquifer -I (Phreatic aquifer)

The phreatic aquifer forms the aquifer I in the weathered portions of the hard rocks. Thickness of weathered zone ranges from 3 mbgl to 80.1 mbgl at bolmrahalli with an average thickness

of 28m. The occurrence of groundwater in the I is only in localised patches as a small stretch in Shivaganga-Ganganepura area towards the northwest part of taluk and another patch in the south Mahadevapura -Yentaganahalli area. (Photo 4). Large rectangular well in Shivaganga. Although isolated patches in topographical lows are seen yielding seasonally, that too for very short durations, in general the phreatic aquifer in Nelamangala Taluk is dried out. The presence of number of large diameters of 8 to 10m stone-lined wells with depth of 15-20 m which are now found abandoned are reminiscences of previously yielding shallow aquifers in the taluk.

Photo 4: Large rectangular Temple well of Shivaganga temple tapping in phreatic aquifer Nelamangala Taluk.

The thickness of weathering map of Phreatic aquifer in Nelamangala Taluk was prepared and is given in **Fig. 2.2.**

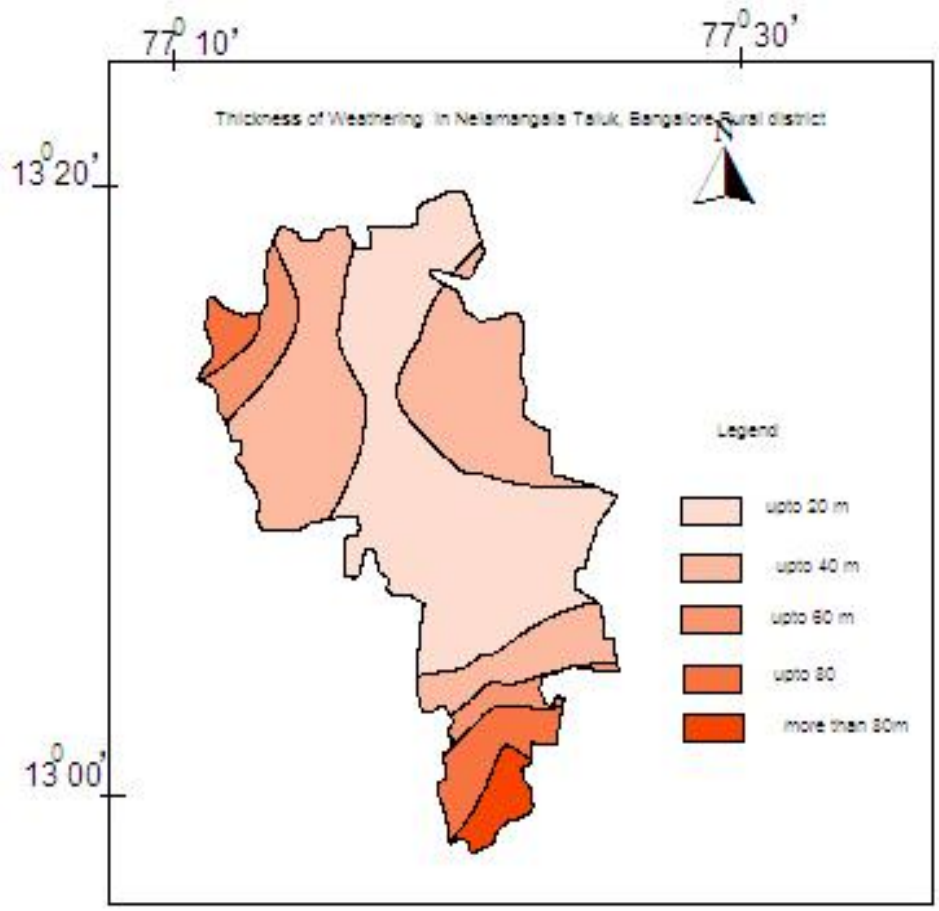

Fig 2.2: Thickness of Weathering in Nelamangala Taluk

Aquifer II (Fractured aquifer)

In Nelamangala taluk, fractured granite and gneisses are now the major water bearing formations. Groundwater occurs within fractured Granite under semi-confined to confined conditions. In taluk bore wells were drilled from a minimum depth of 25. mbgl to a maximum of 250.mbgl **(Table 2.1)**. Ground water exploration reveals that aquifer-II fractured formation was encountered between the depths of 7.5 to 182 m bgl. Yield ranges from 0.31 to 5.5 lps.

Disposition of the Aquifers are depicted in **Fig 2.2 a, b,& c.**

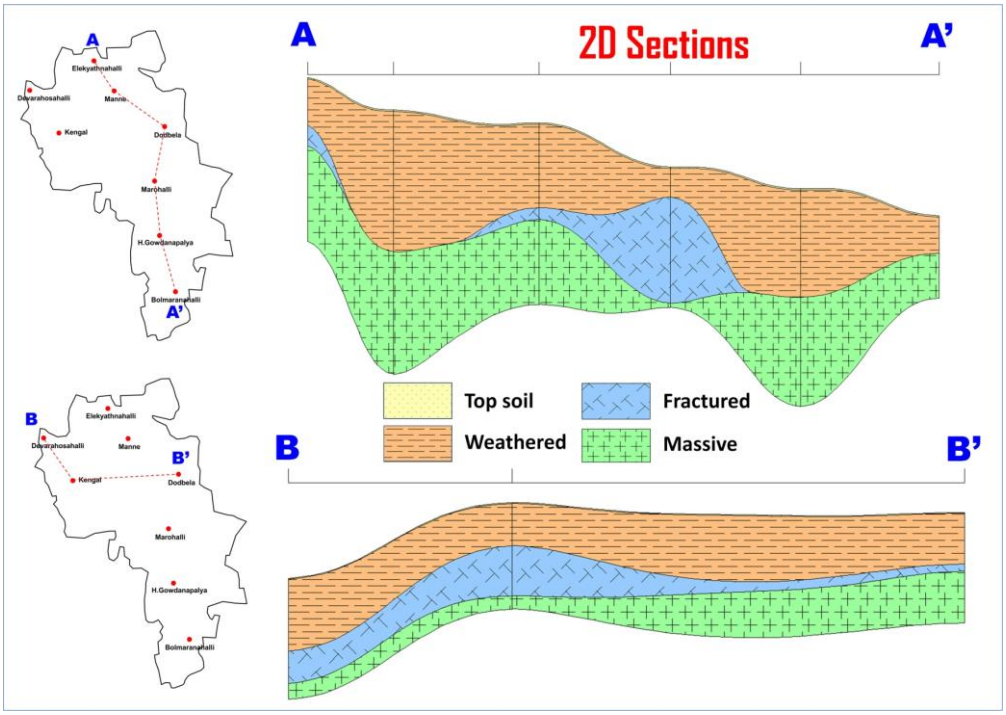

Fig.2.2 a: 2D Cross section along line A-A' and B-B' in Nelamangala Taluk

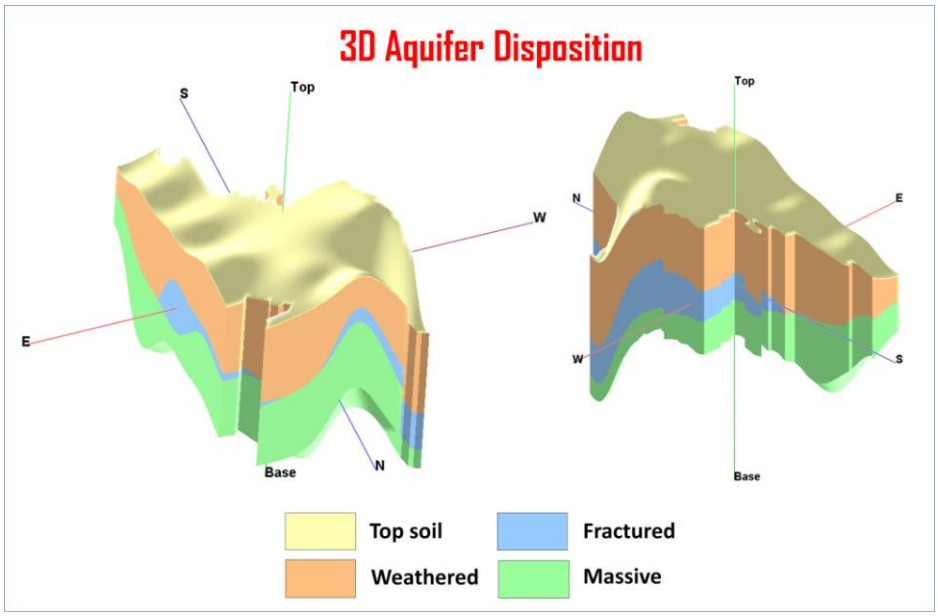

Fig. 2.2b: 3D Aquifer disposition in Nelamangala taluk

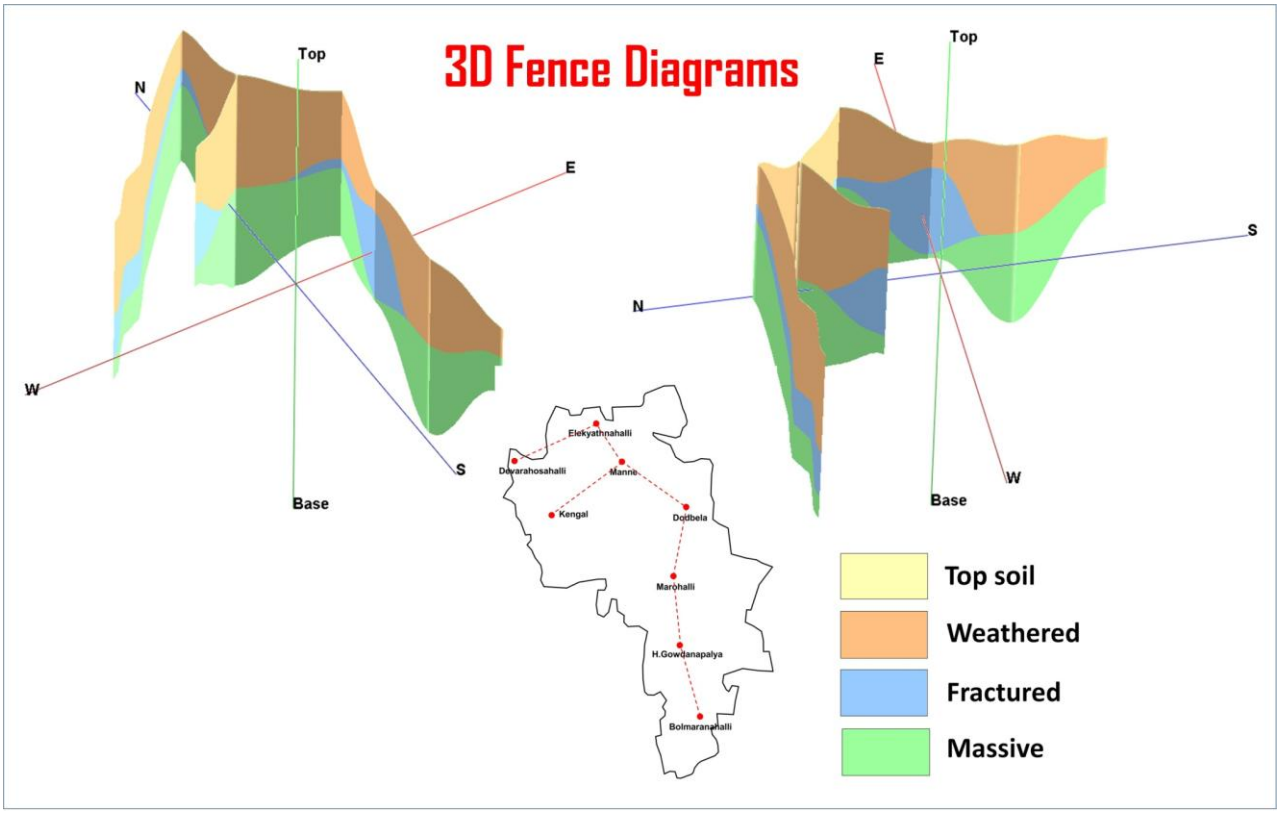

Fig 2.2c: 3D Fence diagram showing disposition of the Aquifers in Nelamangala Taluk

Table 2.1: Details of Ground water Exploration

Sl No.	Location	Latitude in decimal	Longitude in decimal	Depth drilled (m bgl)	Casing (m)	Rock Type Hard Rock (H)	Zones Tapped	Static Water level (m bgl)	Discharge (lps)	Drawdown (m)	EC (Microsiemens per cm at 25 deg cent)
1	Devarahosahalli-EW	12.9544	77.1131	200	55.5	Gniess	86-87=0.43lps, 129.5-130.52.08lps, 157-158=6.73lps, 181.4-182=8.22lps 193.6-194.3=10.8lps	82	10.8	-	473
2	Devarahosahalli-OW	12.9547	77.1136	168	67.5	Gniess	102-102.5=Dry, 120.4-121.4=0.75lps, 133.7-134.5=2.08lps, 165-166=10.8lps	105	10.8	-	511
3	Kengal-EW	13.2108	77.2272	200	32.5	Gniess	50.2-51=0.02lps, 123.4-124=0.08lps, 141.7-142.5=1.19lps, 187.5-188=Dry	92.57	1.7	-	-
4	Dodbela-EW	13.2183	77.3506	200	29.6	Gniess	60-61=Dry, 107.5-108=Dry	Dry	Dry	-	-
5	Hanumanthaya Gowdanapalya-EW	13.0917	77.3447	176	12.6	Gniess	139.5-140.0=0.21lps, 142.5-143=5.41lps	89	5.5	0.23	1177

6	Hanumanthaya Gowdanapalya-OW	13.0922	77.3450	200	10.7	Gniess	140.5-141=5.41lps,	86.5	5.5	3.8	1443
7	Elekyatanahalli-EW	13.2947	77.2681	200	20.8	Granite	32-33=0.07lps, 52-53=0.41lps, 73-74=1.0lps	65.35	1	0.65	555
8	Bolmaranahalli	13.02639	77.3633	80.5 /	80.1	Granite Gneiss	10.50-13.50, 35.6-37.6, 41-50	5.673	7	1.72	640
9	Bolmaranahalli(S)	13.02639	77.3633	72	5.5	Granite Gneiss	7.5-11.5,26.5-26.55, 28.5-28.55, 32-32.6,34-34.5,47.25 to-53,57-66	5.215	8.74	1.95	
10	Bolmaranahalli(S)	13.02639	77.3633	25.00	3	Granite Gneiss	9.15-12.77, 18.77-20.39	7.4	Negl		
11	Manne	13.25972	77.2917	250	17.04	Granite Gneiss		6.175	2.19	33.96	440
12	Marohalli	13.155	77.3389	179.79	17.25	Granite Gneiss	20-22,34-35, 35-37, 49-50, 56-58,134-136, 176-178, 176-179	15.47	4.3	6.95	630
13	Marohalli	13.155	77.3389	140.69	14.32	Granite Gneiss	32-34,52-54, 64-66, 136-138	14.8	6.7	0.62	660
14	Marohalli (S)	13.155	77.3389	35.63	18.34	Granite Gneiss	18.34-30-34, 32-34	14.097	0.31	0.775	640

3. GROUND WATER RESOURCE, EXTRACTION, CONTAMINATION AND OTHER ISSUES

3.1 **Aquifer wise resource availability and extraction is given in Table 3.1 a .** Table 3.1b gives the status of resource in 2017 &c gives comparison with previous groundwater resource estimations in 2013 & 2011

Table 3.1 (a) Present Dynamic Ground Water Resource (2017) in ham

Net Annual Ground Water Availability	Existing Gross Ground Water Draft For Irrigation	Existing Gross Ground Water Draft For Domestic And Industrial Water Supply	Existing Gross Ground Water Draft For All Uses	Allocation For Domestic And Industrial Use For Next 25 Years	Net Ground Water Availability For Future Irrigation Development	Existing Stage Of Ground Water Development (%)	Category
5053	5418	140	5558	146	94	110	Over Exploited

(b) Total Ground Water Resource (as on March 2013)

Taluk	Annual Replenishable GW resources	Fresh In-storage GW resources		Total availability of fresh GW resources
		Phreatic	Fractured (down to 200 m)	Dynamic + Phreatic in-storage + fractured
Nelamangala	5391	18751	2998	26802

(c) Comparison of Ground Water Availability and Draft Scenario in Nelamangala taluk

Taluk	GW Availability (Ham)	GW Draft (Ham)	Stage of GW Development	GW Availability (Ham)	GW Draft (Ham)	Stage of GW Development	GW Availability (Ham)	GW Draft (Ham)	Stage of GW Development
	2011			2013			2017		
Nelamangala	5755	6741	117%	6829	6519	95%	5053	5558	110%

3.2 Chemical Quality of Ground Water and Contamination

Ground Water Quality (May 2016)

The water samples collected from shallow aquifers of Key wells during pre-monsoon and analysed in the Regional Chemical Laboratory for 13 parameters pH, Electrical Conductivity (EC), Total Hardness, Calcium, Magnesium, Sodium, Potassium, Carbonate, Bicarbonate, Chloride, Sulphate, Nitrate and Fluoride by employing Standard methods. (Table 3.2)Based on the hydro chemical data, the portability of these samples has been assessed as per the Standards prescribed by the Bureau of Indian Standards (IS 10500: 2012) and categorized into 'Desirable', 'Permissible' and 'Unsuitable' classes.

Table 3.2 Chemical analysis of Groundwater samples from shallow aquifers in Nelamangala taluk

Sl. No	Location	PH	EC	TH	Ca	Mg	Na	K	CO3	HCO3	Cl	SO4	NO3	F
1	Gangenapura	8.10	470	110	20	15	58	2	0	146	57	16	11	0.72
2	Mahadevapura	8.23	660	100	32	5	79	1	0	73	128	39	29	0.72
3	Shivaganga	8.02	449	80	16	10	41	0	0	159	50	11	15	0.74
	Average	**8.12**	**526**	**97**	**23**	**8**	**59**	**1**	**0.00**	**126**	**77**	**22**	**18**	**0.73**

All the parameters are within permissible limit of drinking water. The electrical conductivity in water samples is an indication of total dissolved ions. Thus the higher the EC, the higher the levels of dissolved ions in the sample. The perusal of the data indicates that the distribution of electrical conductivity in the taluk shows wide variations. The BIS has recommended a drinking water standard for total dissolved solids a limit of 500mg/l (corresponding to about EC of 750 µS/cm at 25^0C) can be extended to a TDS of 2000mg/l (corresponding to about 3000 µS/cm at 25^0C) in case of an alternate source. Water samples having TDS more than 2000mg/l are not suitable for drinking purpose. In general, EC values range from 449 to 660 µ/mhos/cm at 25^oC.
One of the essential elements for maintaining normal development of healthy teeth and bones is Fluoride. Lower concentrations of fluoride usually below 0.6mg/l may contribute to dental caries. However, continuing consumption of higher concentrations, above 1.2mg/l however cause dental fluorosis and in extreme cases even skeletal fluorosis. Most of the fluoride found in groundwater is of geogenic origin. F value ranges between 0.72 – .74 mg/l.

Nitrate is a problem as a contaminant in drinking water (primarily from groundwater and wells) due to its harmful biological effects. High concentrations can cause methemoglobinemia, and have been cited as a risk factor in developing gastric, an intestinal cancer. Nitrate in drinking water should not exceed 45 mg/l as per BIS (ISO: 10500: 2012) standard, In the taluk Nitrate

value ranges between 11 to 29 mg/l. Thus the samples collected from the taluk indicates that the ground water is suitable for drinking purpose and irrigation purposes.

Deeper aquifers: The quality of groundwater from the deeper aquifers are also good and potable. The EC 440-1443 micro siemens at 25^{o}C range from . The Nitrate and Fluoride values are also within permissible limit. The groundwater can be used for drinking and irrigation purposes.

4. GROUND WATER RESOURCE ENHANCEMENT

As per the latest Groundwater resource estimation (GEC 2017), Nelamangala is categorised as an Over exploited Taluk. Hence, there is an urgent need for proper management of the resource and make it sustainable for future. This is possible by enhancing the existing Ground water resource and lessening the extraction of resources so to maintain a balance between the two and make the situation sustainable for future generation. The present trend of declining water levels and drying up of wells has to be controlled to achieve sustainability. Various management techniques such as artificial Recharge of groundwater, Change in Irrigation Pattern, Change in Cropping Pattern, Restricting free power supply etc can be adopted to bring about the change. Many stakeholder departments and even NGO's. *Art of Living* is an NGO, which has taken up water management and conservation projects in the taluks. River Rejuvenation project in the Kumudvati basin of Nelamangala taluk is one of the projects of Art of Living. Under the project, the NGO has carried out watershed management including rainwater harvesting and artificial recharge, afforestation, revitalization of traditional water bodies schemes.

4.1 Supply side interventions: Enhancing the groundwater resources is proposed to be brought about by Artificial recharge and rainwater harvesting, watershed management measures and various other innovative water conservation techniques.

4.1.1 Aquifer wise space available for recharge and proposed interventions

The pre-condition for artificial recharge is presence of uncommitted surface run off and storage space in the aquifers to be recharged. The Aquifer potential available for recharge is 63 MCM but the uncommitted surface run-off available for recharge is 10.02 MCM. Under the circumstances, the recharge structures feasible in the phreatic aquifer in the taluk are check dams (62 Nos), percolation tanks (4 nos) & point recharge structures (7 Nos) **Table 4.1.** However, the location of recharge structures should be site specific and restricted to areas already identified as feasible for artificial recharge.

Table 4.1: Quantity of non-committed surface runoff and expected recharge through AR structures

Artificial Recharge Structures Proposed	Nelamangala Taluk
Non committed monsoon runoff available (MCM)	10.02
Number of Check Dams	62
Number of Percolation Tanks	4
Number of Point Recharge structures	7
Tentative total cost of the project (Rs.in lakhs)	230
Excepted recharge (ham)	568
Expected rise in water level (m)	0.654
Cost Benefit Ratio (Rupees /cu.m. of water harvested)	4.26

During the study it was observed that whereas all the dug wells monitored during the study were dry in december 2019, one dug well on the down stream side of check dam across stream at Mandigere, which is joining the Kamudavathi river was found to be containing 2.5m column of water.

Photo 5 : Check dam across stream at Mandigere across stream joining Kamudavathi river in Nelamangala

Photo 6:A dug well in down stream side of check dam with water

4.2 Improvement in GW availability due to Artificial Recharge, Nelamangala taluk

Table 4.2: Improvement in GW availability due to Artificial Recharge Nelamangala taluk

	Net annual ground water availability	Existing	Existing stage of ground water development	Expected recharge from proposed artificial recharge structures	Cumulative annual ground water availability	Expected improvement in stage of ground water development after the implementation of the project	Expected improvement in overall stage of ground water development
Nelamangala	HAM	HAM	%	HAM	HAM	%	%
	5053	5558	110	568	5621	12	98

After implementation of Artificial Recharge structures for GW recharge, the annual ground water availability will increase from 5053 to 5621 ham and the expected improvement in stage of development is 12% from 110% to 98%.

4.3 Dug well recharge : Recharging of Abandoned dug wells

In Nelamangala taluk a number of large diameter dug wells are present which are found abandoned as they are dry. These Large diameter abandoned dug wells can be converted into recharge wells by diverting the runoff water into the wells. Before entering the wells the water may be passed through a filter bed to prevent silting of the well. Alternatively the abandoned wells can be converted into dug cum bore recharge well by drilling bore well inside the dug well. Slots may be provided in the lower half of the casing. The casing of the bore well may be extended up to ground level and the open well filled with good sand and gravel around the slotted casing. A coir filter may also be provided around the slotted section. The flood water is then directed into the open well filled with sand. The suspended material gets settled on the top of the sand and filtered water enters into the bore hole. Since there is good head available recharge is faster. The farmers are practising dug well recharge by surface run off water which is let in through a filter chamber at Sompura.

Photo 6 : A dug well with arrangement for recharge of surface run off at Sompura

Bore-well recharge: A pumping well can be converted into recharge well by digging a filter bed of 3m square and 2m to 3m depth adjoining the pumping well and filled with filter material. This can be connected to the pumping well through a 300mm diameter pipe at the bottom of the filter bed. This will prevent silt and other matter entering into the pumping well. The first flood should not be tapped if the catchments consist of agricultural land as it may carry residual chemical.

4.4 Rejuvenation of tanks and other water bodies - The tanks and water bodies noticed in the valley areas may be desilted and embankments strengthened /renovated so as to water which in turn will serve to recharge the groundwater too.

4.5 Revival of Traditional water bodies : The taluk has a number of traditional water bodies called Kalyanis. They are step wells seen attached to temples . These may be revived by desilting and periodic maintenance. reviving Kalyanis and other step wells, desilting and maintaining the tanks.

4.6 Creation of water pools : Water pools can be made at the inlet of streams that will hold water beyond the monsoons and help provide water for livestock and percolation. Well maintained water pools are visible in the watershed areas of Kamudvathi river.

4.7 Roof Top Rain Water Harvesting (RTRWH)

Roof Top Rain Water Harvesting is the technique of collection and storage of rainwater at rooftop at surface or in sub-surface aquifer. Rainwater available from rooftops of buildings/houses can be recharged to aquifer. The Rooftop rain water can be harvested for

storage in tanks / sump in roof tops, ground level or can be diverted to recharge aquifer through the dugwell/bore-wells available.

In residential areas, water falling on rooftops can be collected and diverted to the open well / bore well by providing a filter bed around it. Many roof rainwater filters are available in the market, including the rainy filter and the pop-up filter. They can be used while recharging the bore wells. storm water may be diverted to recharge deeper aquifers through Bore wells in public places such as parks or open playgrounds. Clean storm water can be filtered thoroughly through a recharge pit filled with materials such as stone, charcoal and sand and then allowed into bore wells.

Nelamangala taluk being a part of Bangalore rural district is more or less an urban area. 22.6 % of population of Nelamangala taluk are Urban. There are 2 towns in the taluk namely Nelamangala with a population of 37232 covering an area of 14.1 Sq km and Arasikunte with a population of 10567. The urban area has 11913 households . Considering an average roof size of 50 sq.m, Rainwater availability through the rooftops works out to a total of 0.215 MCM during monsoon and 0.182 MCM during non-monsoon periods **(Table. 4.3)** which can utilised for storage or artificial recharge.

Assuming that 10% of the houses have a dugwell or borewell in the premises, which can be targeted for recharging ground water reservoir through roof top rainwater harvesting, around 4 ham can be recharged to the ground water system.

All precautionary measures already available in the literature on RTRWH may also be ensured while implementing. During rainy season, the whole system (roof catchment, pipes, screens, first flush, filters, tanks) should be checked before and after each rain and preferably cleaned after every dry period exceeding a month. At the end of the dry season and just before the first shower of rain is anticipated, the storage tank should be scrubbed and flushed off all sediments and debris.

Table 4.3: Availability of Roof Top Rain Water from Individual Houses In Urban Areas in Nelamangala taluk

	No of houses	**Roof top area available**	**Normal Monsoon Rainfall (m)**	**Vol. of water on Roof Top in Monsoon(MCM)**	**Normal Rainfall in Non Mon(m)**	**Vol. of water on RoofTop in Non-Monsoon(MCM)**
Urban	11913	0.59565	0.452	0.2692338	0.384	0.2287296
Total (80%)				**0.215**		**0.182**

4.8 Inter basin transfer

Proposed Yettinahole Project

The source water available for recharge is insufficient to recharge the potential of the aquifer. Hence alternate source water can be arranged for recharging the aquifers apart from meeting the water demands. The State government is implementing Yettinahole project, which is inter basin transfer of water. The project envisages Drinking Water Supply Scheme to Bangalore Rural district along with other six districts ie. Kolar, Bangalore Rural, Ramanagaram, Tumkur, Hassan and Chickmagalur by Karnataka Neeravri Nigam Ltd, Government of Karnataka. The project proposal comprises two components namely, drinking water and tank filling, Implementation of the project helps to recharge to groundwater by which there will be increase in the groundwater availability and the stage of GW development will come down .

As per yettinahole project proposal 0.007 TMC of water is allocated to fill two tanks in Nelamangala taluk. Assuming a source of 5.2 MCM (520ham)of water is received from Yettinahole project to fill the dried up tanks. This shall enable recharge of ground water at the rate of 50 % of the volume in tanks. Hence it will create a recharge potential of 260 ham of water.

Table 4.4: Artificial recharge schemes proposed for source water from Inter basin transfer

Artificial Recharge through inter basin transfer proposed	Nelamangala Taluk
Filling up of dried up tanks by inter basin transfer as per Yettinahole project)	520 ham
Expected recharge of groundwater (50% of Tank recharge)	260

On implementation of the artificial recharge schemes the expected improvement in stage of development is by 38.24 % so that the stage of development is 60.06 % **(Table 4.5).**

Table 4.5: Improvement in stage of development in Groundwater in Nelamangala taluk by implementation of Inter basin transfer of water

Net annual ground water availability	**Existing stage of ground water development**	**Expected recharge from proposed artificial recharge structures/inter basin transfer**	**Cumulative annual ground water availability**	**Expected improvement in overall stage of ground water development**
HAM	%	HAM	HAM	%
5053	110	568	5621	99
	98.3	250	5871	95

5. DEMAND SIDE INTERVENTIONS

5.1 Advanced irrigation practices

In Nelamangala taluk both rainfed irrigation and irrigation from tanks and borewells are used practiced. There are around 38,000 farmers in the taluk. Some of the farmers are using water use efficiency measures for saving the ground water resources. The State agriculture dept is offering subsidy to farmers under PMKSY, RADF, etc Sprinkler irrigation to the extent of 80 % for general category and 90% for Sc/St category of farmers. Around 1000 farmers have availed the sprinkler mode of irrigation. Efficient irrigation practices like Drip irrigation and sprinkler has to be adopted by all farmers.

Photo 8: Drip irrigation of Chilly crop at Mahadevapura in Nelamangala Taluk

Table 5.1: Crop water requirement in Nelamangala taluk

Sl. No.	Name of Crop	Existing Crop Area (ha)	Unit Crop Water Requirement (m)	Draft (ha m)	Existing GW Draft (ha)
1	Paddy	147	1.20	176	176
2	Jowar	2	0.00	0	
3	Bajra	5	0.00	0	
4	Maize	1423	0.00	0	
5	Ragi	10312	0.30	3094	3094
7	Other Cereals & Minor millets	8	0.00	0	
8	Pulses	1565	0.00	0	
10	Oil seeds	236	0.50	12	12
11	Total Fruits	2150	0.50	108	108
12	Total Vegetables	900	0.50	281	281
		16748		**3671**	**3671**

Proposal for Saving of water by using drip irrigation practice in Nelamangala Taluk

Draft with existing Cropping Pattern (ham)	**3671**
% of Water to be saved by adopting WUE practices	**30**
Quantity of water that can be saved due to adopting WUE measures (ham)	**1101**
Draft after adopting WUE measures (ham)	**2569**

The crop water requirement is 3671 ham. By using drip irrigation practice expected water used for irrigation shall be 2569 ham .30 % saving is expected

5.2 Change in crops: Nelamangala being over exploited taluk water intensive crops may not to be promoted for cultivation. Water intensive crops like paddy, banana and sugarcane should be avoided as far as possible in ground water stressed areas. Paddy requires about 4 times more water as compared to other crops like ragi, wheat, jowar, bajra, pulses and ground nuts etc. The farmers may be advised to shift over to less water intensive crops. Already in Nelamangala taluk, the farmers have started practising cultivation of less water intensive crops. Here, food grains are the major crops and among these the major cereal crops are Maize and Ragi which are mostly rainfed.

5.3 Regulation and Control

The entire taluk is in non-command area with the stage of development 110% and is falling under over exploited category (GEC 2017). The Karnataka Ground Water Authority (KGWA) has notified the taluk for regulation in development of groundwater and NOC has to be obtained. Strict regulation has to be enforced by KGWA for controlling the over exploitation of ground water in the taluk. Groundwater recharge component needs to be made mandatory in the taluk to save the situation from deteriorating further.

Spacing of drinking water bore wells: Bore wells are drilled close to each other, sometimes less than 100mts, resulting in mutual interference and dwindling of yield and eventually drying up of these bore wells. The spacing of bore wells may be regulated and indiscriminate drilling of irrigation bore wells close to the drinking water wells . Artificial recharge structures may be constructed to sustain the sources of drinking water supply.

Restricting of Power Supply: It is observed that there is continuous pumping of the irrigation bore-wells continuously during morning and again in the evening during power supply time. This should be regulated to need based pumping.

5.4 Recycle and Reuse of Water:

The grey water generated from domestic sewage can be treated and reused/ recycled for gardening/ car washing/ toilets etc**.** The grey water availability is calculated as 50 % by the

adopting methodology given as per *National Environmental Engineering Research Institute(NEERI), Nagpur, - "Guidance Manual for use of Grey water in Rural schools "*which says 50-60 % of the water supplied can be considered quantity of as grey water generated. 60 ham of grey water is available for reuse in Nelamangala taluk considering 50% of domestic water extraction as per GEC 2017.

5.5 Other measures proposed:

Maintenance of artificial recharge structures:

Maintenance of artificial recharge structures is essential as the process of recharge is a continuous one and the benefits would be felt over a period of time and mostly of indirect in nature. Further, the measures adopted are mainly oriented towards protecting and improving the natural ground water environment.

Capacity building and training:

The involvement of the public and their participation in implementing artificial recharge scheme is another important criteria for proper water conservation and management. This needs proper awareness and understanding of such schemes. Hence, awareness and training programmes are essential. The water harvesting and recharging of ground water would require group action by communities, societies, and farmers with financial assistance from govt. and financial institutions.

Key well monitoring and Rain fall monitoring:

Sufficient number of Key wells may be established for monitoring the water level in the aquifers and also to have a historical data bank on the groundwater conditions. Raingauge station is to be established to have data on rainfall pattern. One rain gage station is existing at Gubbi.

Groundwater quality monitoring:

The quality of groundwater may be monitored from the key wells.

5.6 Summary

The summary of Management plan of Nelamangala taluk is given in **Table 5.2.**

Table 5.2: Summary of Management plan of Nelamangala taluk

SUPPLY SIDE INTERVENTIONS	
Artificial recharge measure Expected additional recharge from monsoon surplus runoff (MCM) -568 ham Improvement in Stage of GW development from 110 to 99%	Construction of Artificial recharge structures check dams - 62 Nos percolation tanks - 4 Nos point recharge structures -7 Nos
Inter Basin Transfer of water by Yettinahole project filling up of Tanks resulting in recharge to ground water -5.2 MCM of water. Improvement in Stage of Extraction to 95 %	Expected recharge potential of 250 ham (50% of tank filling)
Rejuvenation of water bodies	Reviving of Kalyanis/ Tanks/ other water bodies
Afforestation	Planting of trees to prevent soil erosion and improvement in soil moisture content and percolation to recharge groundwater
Rain Water Harvesting	Recharge of abandoned dug wells
	Storm water recharge of bore-wells
	Conversion of abandoned dug wells into bore-well recharge structures by drilling bore-wells inside the large dia dug wells with the annular space converted into filter media
Roof Top Rain Water Harvesting	Individual Houses in Urban Areas In Nelamangala taluk = 0.397 MCM
DEMAND SIDE INTERVENTIONS	
Advanced irrigation practices	**Water user efficiency -** Practice of Drip irrigation and Sprinkler irrigation massive scale. **Increase in recharge potential by 1101 ham**
	Change in crops - Shift from water intensive cereal crops like Paddy to less water intensive Ragi and Maize
	Multi cropping practices. cultivate banana, horticulture etc with Arecanut
	Mulching of crops to reduce evaporation
	Organic farming practices

Regulation and Control	Enforcement of NOC in notified block for GW extraction Maintain spacing between well Regulating extraction by need based pumping instead pumping full time during power supply
Recycle and Reuse of water	60 ham of grey water is available for reuse in Nelamangala taluk considering 50 % of domestic water extraction as per GEC 2017.
O & M	Maintenance of water conservation/ artificial recharge structures
Capacity building and Training Program	Awareness creation among public and participation of public/ panchayat bodies in water related activities
Creation of data base and Monitoring of water levels and rainfall	Maintain key wells for monitoring and Raingage station
Quality monitoring	Regular monitoring of quality of groundwater

Overall improvement in net groundwater availability due to Aquifer Management Plan proposal and resulting improvement in Stage of extraction from in groundwater Over exploited Nelamangala taluk to Semi-critical Taluk.

Existing stage of Ground water extraction(%)	1	**110**
Existing net Ground water Availability (ham)	2	**5053**
Expected recharge after implementing ARS/ ARS through Inter Basin transfer source water)	3	**818**
Cumulative annual ground water availability after implementing AR structures / Inter basin transfer (ham)	4	**5871**
Expected Stage of groundwater extraction after implementing proposed recharge measures %	5	**95**
Additional Saving due to adopting WUE measures (ham)	6	**1101**
Saving due to adopting grey water(ham)	7	**60**
Cumulative annual ground water availability after adopting WUE+ Grey Water (4+6+7)	8	**7032**
Final overall stage of ground water extraction after implementing WUE (8/2)*100	9	**79**
Total water saved (ham)	10	**1979**
Over all additional irrigation potential that can be created by these measures (ha)	11	**4948**

If the stage of extraction is to be maintained at 110%, the additional recharge potential of ground water accumulated consequent to aquifer management proposal 1979 ham can be utilised to create an irrigation potential of 4948 hectares assuming 0.4 ham of extraction per hectare for cropping by water user efficiency irrigation practices.

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