Detailed hydrogeological mapping in parts of the Nilgiri Biosphere Reserve

MARCH 2018

Conducted by

Advanced Center for Water Resources Development and Management (ACWADAM)

For

Keystone Foundation, Kotagiri

Detailed hydrogeological mapping in parts of the Nilgiri Biosphere Reserve

Submitted to

Keystone Foundation, Kotagiri

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March 2018

Technical Report Number: ACWA/Hydro/2018/H68

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INTRODUCTION

Keystone Foundation based out of Kotagiri in the Nilgiris district has been rigorously and fervently working in the Nilgiri Biosphere Reserve (NBR) with indigenous communities through an approach of "eco-development" – a principle of sustainable development. The main aim of Keystone Foundation is to improve the lives and livelihood by empowering the communities on aspects such as apiculture, organic farming, environment, etc.

One such theme that Keystone Foundation undertakes is water and sanitation. The team is working with several tribal communities all across the NBR on different sources. More than 150 water sources have already been inventoried by the team (Figure 1). Among these, in a few locations, the Keystone water team has trained local village members to measure rainfall with the help of manual rain gauges and monitor the discharge of springs and measure water levels in open wells.

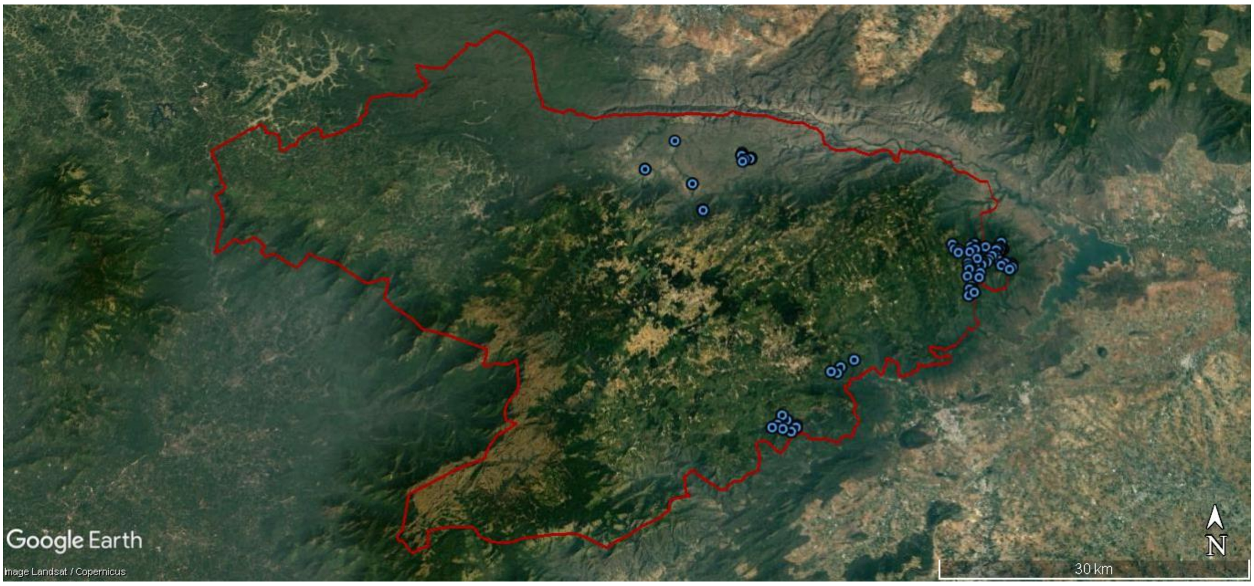


Figure 1: Location of select springs inventoried in the Nilgiris district

In a few select villages of the Nilgiris district, Keystone is developing water security plans for better water management and conservation. Data from 59 groundwater sources such as springs, open wells and bore wells reveals that 21 springs are still in their pristine condition discharging groundwater throughout the year (Figure 2). But in the last few years, several community members are reporting reduced flows especially in the lean summer seasons.

In the Nilgiris district, open wells are more prevalent in the plains of the north. Nonetheless, a few are also witnessed in the valleys of the Nilgiri hills. Of the 18 open wells, 9 are still perennial. The open wells in this region are characteristically small in dimension with maximum diameter of 4m and depths varying between 3-11m only.

The NBR and the Nilgiri district in particular, where bore well were still unknown, till a few years ago, has witnessed an increase in the drilling of these sources in many villages. Data of 10 bore wells shows that 50% of them yield water throughout the year.

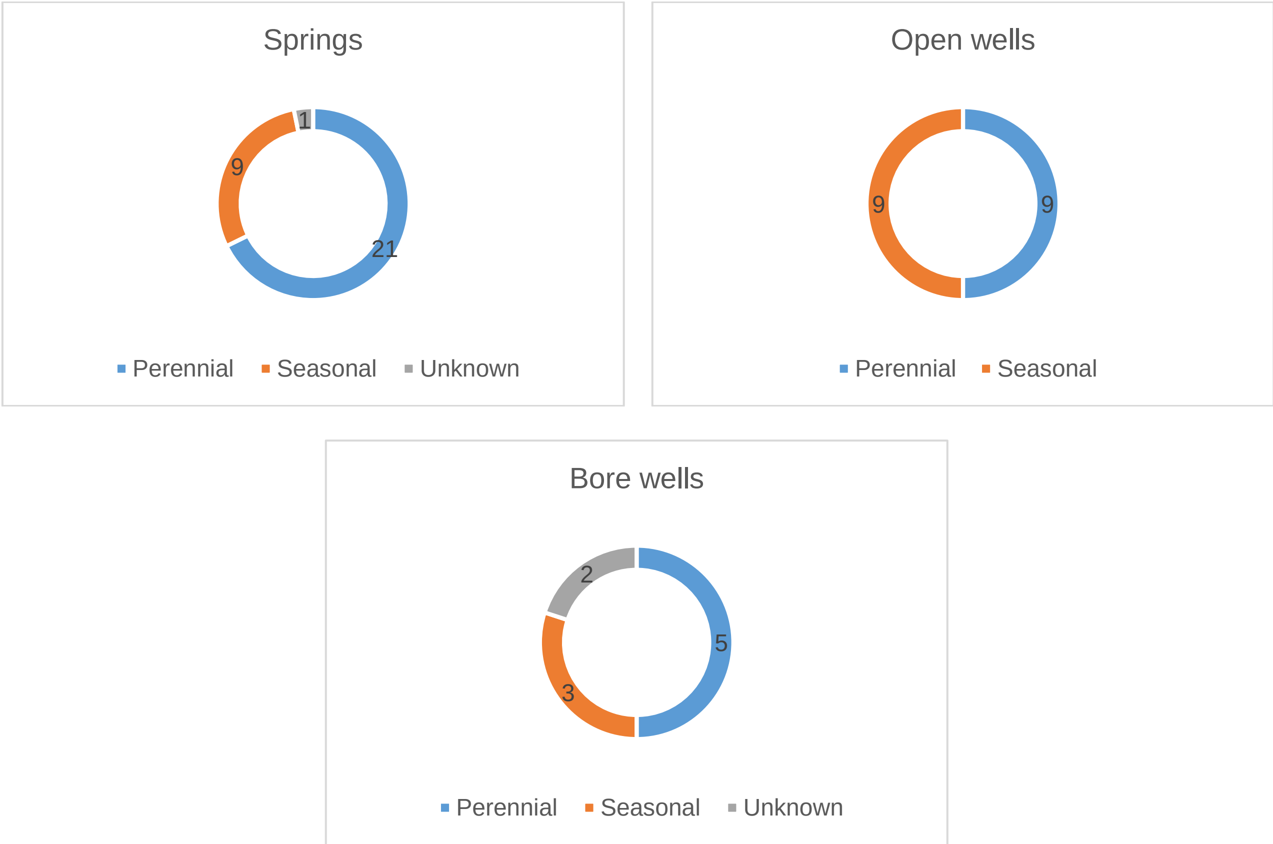


Figure 2: Seasonality of different water sources from select regions of the Nilgiri Biosphere Reserve

Springs are groundwater discharge points that emerge on the surface whenever and wherever the aquifer intersects the surface topography. In simple words, it depends on the physical disposition and hydrological properties of the aquifer. Unlike open wells and bore wells, these are naturally formed discharge points or areas. Therefore, the lands in which they spring out maybe anybody's land. Out of the 31 springs, 9 are owned by the village community members while 16 emerge in forest and private lands. Only 3 springs are under the panchayat ownership. Thus, the location and ownership of springs poses a challenge while working on the conservation and management of spring water. As against springs, 78% open wells and 60% of bore wells are owned by the panchayat (Figure 3).

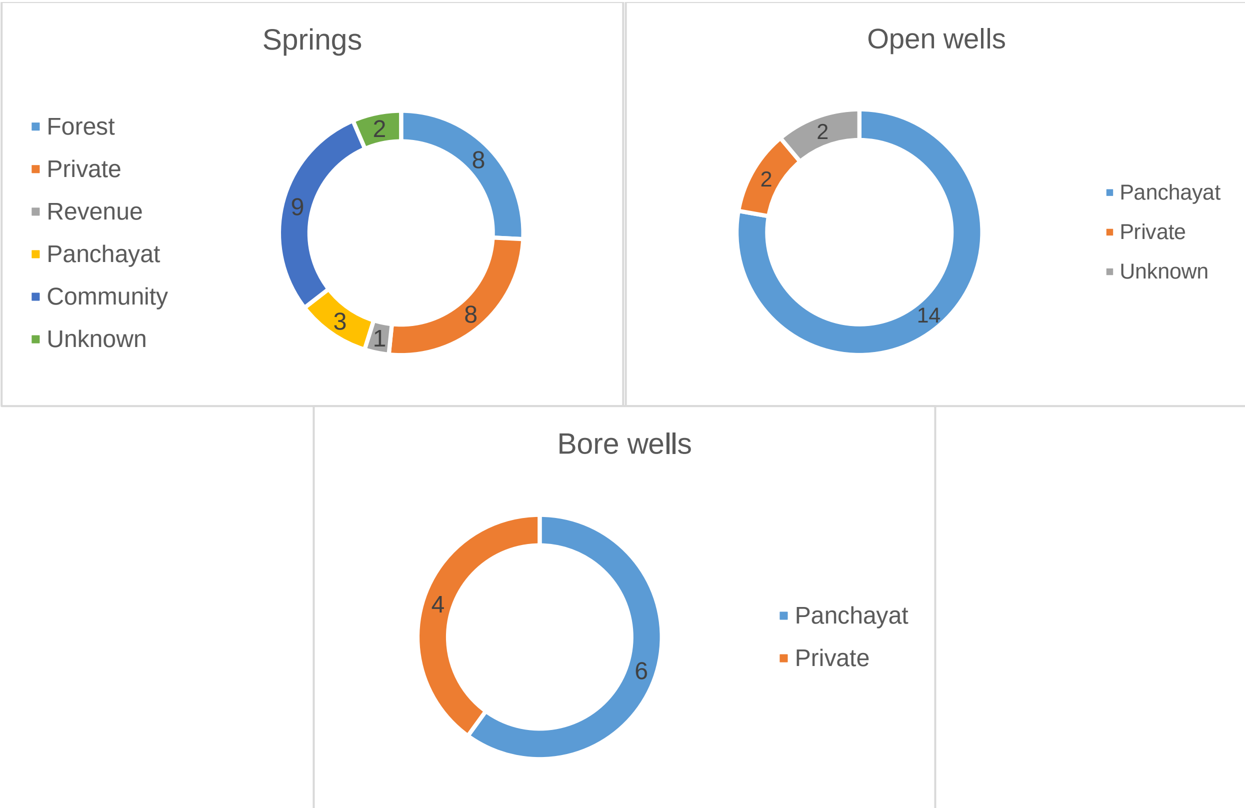


Figure 3: Ownership of different groundwater sources from select regions of the Nilgiri Biosphere Reserve

In order to improve the discharge of springs and revive old open wells, as well as enhance the water quality of different groundwater sources, systematic studies to understand the resource have to be undertaken. The first step towards this, is identifying the different types of rock and their structures. The nature of these rocks, that is their orientation, extent of weathering and openness of fractures and joints needs to be mapped out in the entire springshed or watershed.

In the previous visit conducted in September 2017, broad hydrogeological investigations in the regions of Aracode, Coonoor, Ooty and Sigur was undertaken. Regional scale hydrogeological maps were prepared based on the visit.

While the earlier report was a compilation from a rapid hydrogeological survey, this report synthesises detailed observations made for a few selected springs and open wells in the NBR. Close to 30 different groundwater sources and their springshed or watershed areas were closely studied to understand the subsurface lithology, aquifers and its characteristics.

Along with geological information, daily rainfall data, spring discharges, open well water level data and water quality data collected by Keystone Foundation over a period of 1 – 1.5 years, has also been analysed to understand the aquifer characteristics. Data from 59 sources which includes 31 springs, 18 open wells and 10 bore wells is analysed in this report.

FIELD OBSERVATIONS

OOTY TALUKA

In Ooty Taluka, two villages, namely *Chokkanalli* of Kadanadu Panchayat and *Chemmanatham* in Masinagudi Panchayat were visited.

The closest available rainfall data to these villages is from gauge RG004 located in Sigur. Data from this gauge is being recorded since June 2017. Analysis shows that in a span of eight months between June 2017 and January 2018, a total of 466mm of rainfall was recorded. 50% of this precipitation was received in the month of September. Months of August and October recorded only 40mm and 84mm respectively.

Closer analysis of rainfall for the month of September in 2017, shows that 246mm of rainfall was unevenly distributed across the month, with few days measuring as high as 70mm of precipitation. Such variation in rainfall result in high surface runoff, and therefore poor infiltration and recharge of groundwater.

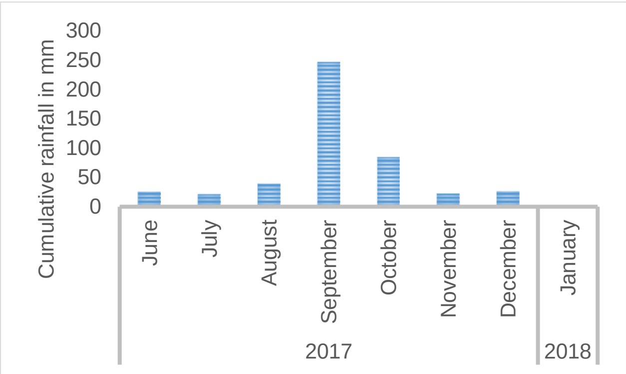


Figure 4a: Cumulative rainfall measured between June 2017 and January 2018 at rain gauge (RG004) installed in Sigur

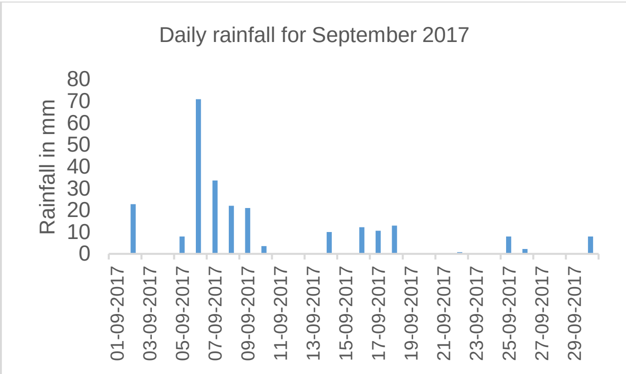


Figure 4b: Distribution of daily rainfall measured in the month of September 2017 in Sigur

Chokkanalli Village

Figure 5: Location of different water sources in and around Chokkanalli village

Traditionally, Chokkanalli village was dependent on water from a nearby stream water for its daily needs. However, in the past few years, the stream flow is observed to have reduced. Interaction with the local resource person and community members revealed that the main cause of decreased e-flows was the confinement of stream water in large dams in its upper reaches. Another possibility as stated by the members was the perceived reduction in precipitation with passing years. Thus, currently the village is dependent on a panchayat owned open well to cater to its drinking and domestic water requirements (Photo 1). There is also one privately owned bore well which is used by one family for drinking. A few families, harvest rain water and use the same for meeting their domestic needs.

The 10.58m deep panchayat open well (KADW004) constructed in 2002 is the main drinking and domestic water source. Sometimes, during the summer season, when there is very little water in the well, spring water located close to the well is used. The village has two Ground Level Reservoirs (GLRs). Water from the community well is pumped for approximately 30 minutes on a daily basis into the two GLRs which have storage capacities of 10,000 lits and 30,000 lit.

Photo 1 : Main community drinking water well for Chokkanalli village

Agriculture is the main occupation of the members from this village. Majority of them have 2 acres of land and cultivate crops such as millets, beans, vegetables, pulses, grams, etc. There are also a few households which are landless and therefore work as wage labourers.

Geological mapping in this region was conducted by studying surface exposures, stream beds and well sections. However, limited surface rock outcrops in this region suggest that the subsurface was weathered. This zone is approximately 5m thick which is inferred by the lining observed in open wells. Below the weathered zone is an unfoliated garnet bearing charnockite which is seen exposed in the stream bed and below the lining in wells. This rock shows presence of few fractures trending in the N-S, ENE-WSW, WNW-ESE and NW-SE directions (Figure 6).

Agriculture lands located to the south-west of the village, across the stream, were also studied to help develop a subsurface understanding. Here too, the lining in open wells and absence of fresh, un-weathered rock outcrops suggests that a thick weathered profile exists below the surface. Bore wells were also surveyed in this region to reveal the presence of deep seated water bearing fractured rock that are yielding water to these sources (Photo 2).

Photo 2: Agricultural land parcels to the southeast of Chokkanalli village, irrigated through bore wells

With the help of above information, it can be gathered that the region is underlain by 3 aquifers – one shallow unconfined and two deep confined aquifer systems at approximately 40m and 90m below the surface.

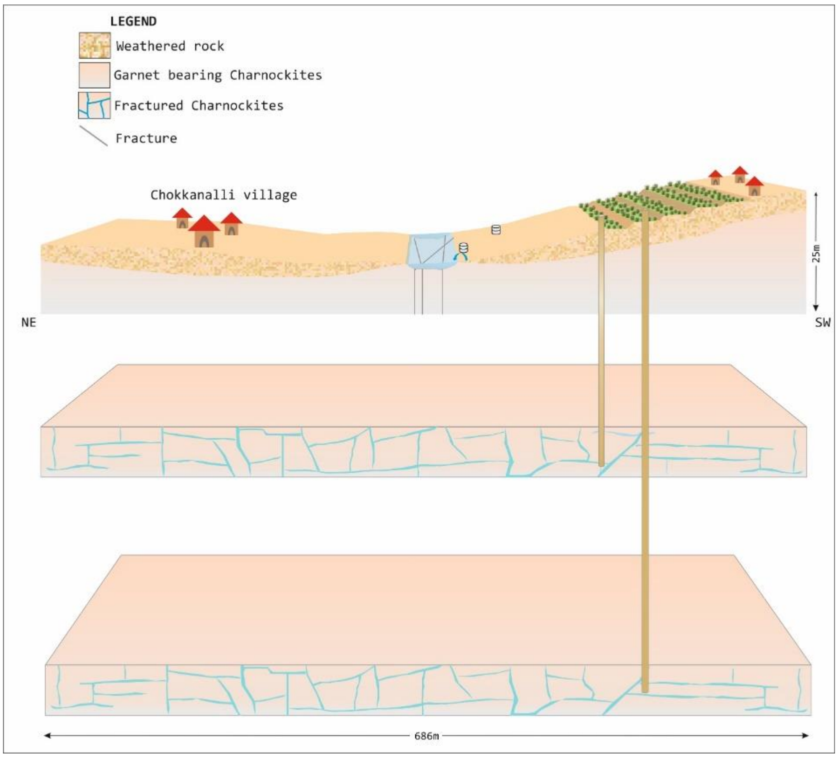


Figure 6: Subsurface geological map of Chokkanalli village showing the different aquifers tapped by the springs, open wells and bore wells

In Chokkanalli village, there are a total of 4 springs, 2 open wells and 5 bore wells. While each of the four springs emerge in forest, private or revenue lands, the open wells are under government ownership and the bore wells by either government or individuals.

Source	Number of sources	Source Code	Ownership	Seasonality
Spring	4	KAD101,KAD102, KAD103,KAD104	Forest, Revenue, Private	3 perennial, 1 seasonal
Open wells	2	KADW003,KADW004	Panchayat	1 perennial, 1 seasonal
Bore wells	5	KADW001,KADW002, KADW006, KADW007,KADW008	2 Panchayat, 3 Private	1 perennial, 1 seasonal, 3 unknown

One time discharge data for three springs shows that each spring is distinct from the other. Data for the seasonal spring KAD102 in the months of September and October 2017 varied between 1.5 and 0.6 lpm respectively. However, in July 2017, the discharge for spring KAD003 was 17.6 lpm while that for KAD004 was as high as 46.2 lpm.

Regular water quality measurements conducted on water from four springs between November 2016 and October 2017 reveals that TDS values are well within the desirable limits (500mg/lit) of potable drinking water standards (BIS 2012). However, occasionally the TDS values measured for springs KAD101 and KAD102, is observed to be higher than 500 mg/lit. pH values remain between 6.5 and 8.5 throughout the year.

In situ water quality testing of two open wells confirms that the TDS and pH values of the drinking water well (KADW004) are within drinking water standard limits and therefore is fit for consumption.

The water sources were also tested for biological contamination with the help of H_2S vials. None of the spring water showed the presence of pathogenic contamination but open wells KADW004 and KADW005 tested positive for bacteria in the month of April 2017. The same wells were absent of coliform in the peak monsoon months of September and October.

Source Type	Code	Total Dissolved Solids (TDS) (mg/l)	pH
Spring	KAD101	235 – 823	7.25 – 8.23
	KAD102	337 – 681	6.57 – 7
	KAD103	67.7	6.7
	KAD104	94.2	6.4
Open well	KADW003	526	7.44
	KADW004	349 - 474	6.78 – 7.74

Chemmanatham village

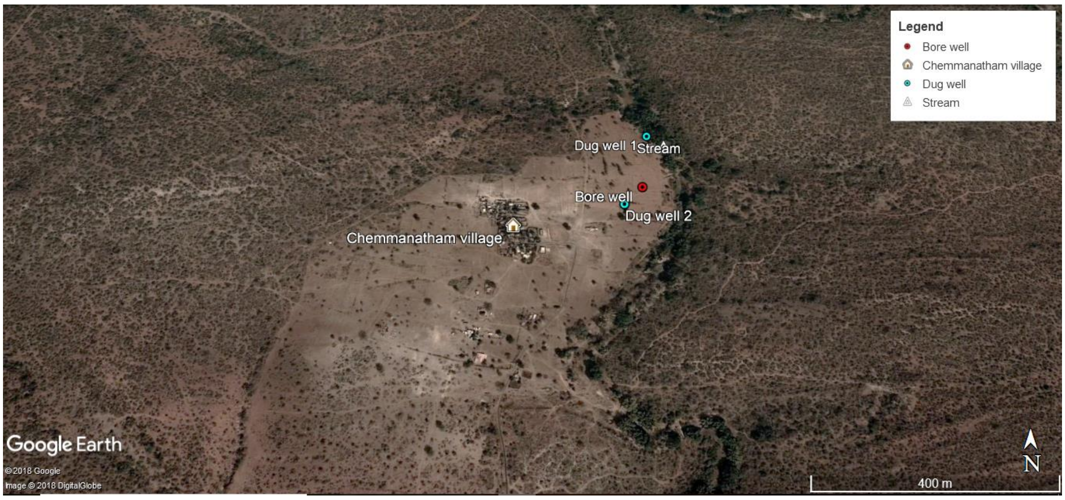


Figure 7: Location of different water sources in Chemmanatham village

Chemmanatham village is a small tribal village located in the heart of the Masinagudi forest. For this village, the basic water requirements of drinking and domestic uses are met by water supplied from the Pykara dam. Water from this dam is supplied to this village only once every week which is stored in the community GLR.

By tradition, these community members practiced agriculture. However, due to high uncertainty attached to rainfall, very little agriculture is prevalent today. Today, on the 2-3 acres of land owned by each household, millets are cultivated. The second most widespread occupation is as wage labourers in private tourist resorts or tea and coffee estates.

Unlike Chokkanalli, in Chemmanatham village, numerous surface exposures along with exposed well sections helped in better geological mapping. The dominant rock type here is foliated garnet bearing charnockites. The foliations trend in the east-west direction with dips towards the north. The thickness of weathered rock that overlies the massive charnockite is variable along the topography. To the south-west this thickness maybe upto a maximum of 0.5 – 1 m given the prevalence of several rock exposures. The weathered section increases in thickness towards the northeast direction up to almost 6-7 m. To the northeast of the village, a 2m wide hard, resistant pegmatite vein running along the northwest-southeast direction is seen intruding into the charnockite (Photo 3).

Photo 3: 2m wide pegmatite vein intruding in to charnockites in Chemmanatham village

In some places, the charnockite is fractured. Two such near vertical fractures with trends northeast-southwest dipping in the southeast and west directions were delineated (Figure 8).

The Chemmanatham village is underlain by a shallow unconfined aquifer system comprising of the weathered rock. The aquifer has low storativity as the two open wells situated to the northeast are seasonal, thus implying that the aquifer gets completely desaturated by February every year.

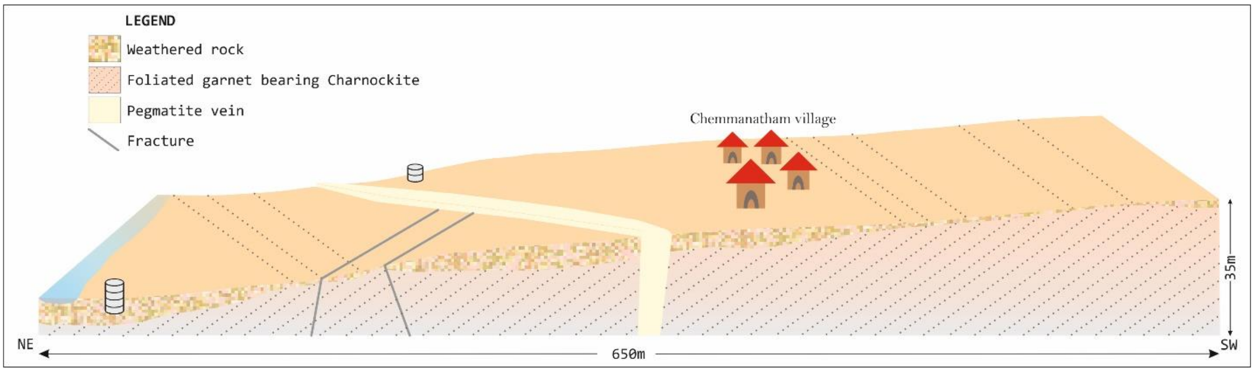


Figure 8: Geological cross section of Chemmanatham village showing the diverse rock types and water sources

The other water sources of the village are 1 spring, 4 open wells and 4 bore wells. Spring MAS001, located to the northeast of the village in a stream is perennial and used for all purposes. None of the open wells are in use but water of some bore wells such as MASW004 and MASW017 are used for drinking and domestic requirements.

In situ water quality analysis of open well MASW005 showed that TDS values were as high as 1.05 ppt.

Source	Number of sources	Source Code	Ownership	Seasonality
Spring	1	MAS001	Panchayat	Perennial
Open wells	4	MASW003,MASW005, MASW006,MASW007	3 Panchayat, 1 private	All seasonal
Bore wells	4	MASW001,MASW002, MASW004,MASW017	3 Panchayat, 1 private	3 perennial, 1 seasonal

COONOOR BLOCK

In Coonoor block, five villages namely *Pilloormattam*, *Mel Korangamedu*, *Kil Korangamedu*, *Annaipallam* and *Sadaiyankombai* from the Hulical Panchayat were surveyed.

Figure 9: Location of different springs in a valley of the Coonoor region

All these small tribal villages, located in thick forest regions in the southern most boundary of the district are largely dependent on springs and streams. There are no open wells or bore wells in this region.

Rainfall in this region is being measured in Annaipallam village since August 2017. Between August and December 2017, 799mm of precipitation was measured. This rainfall in evenly distributed between three months of September, October and November with more than 300mm recorded in each month.

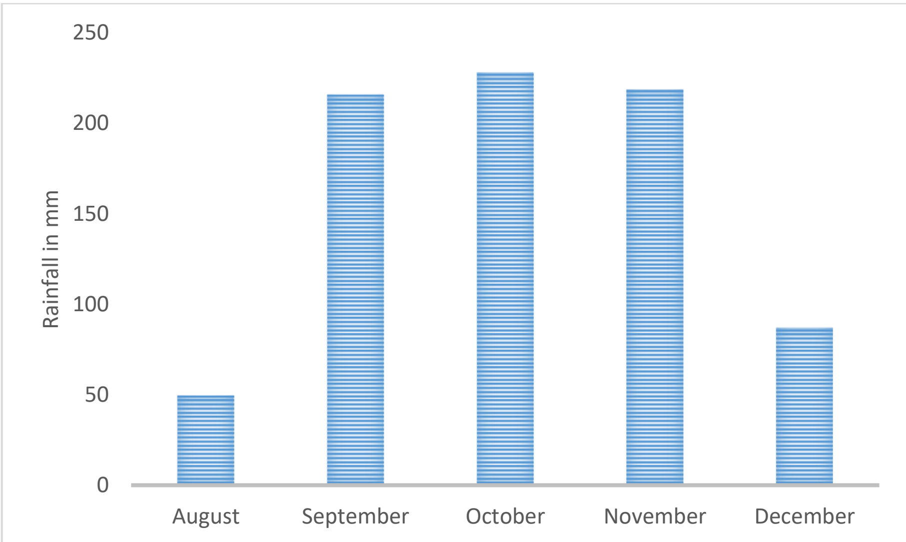


Figure 10: Cumulative daily rainfall measured between August and December 2017 at rain gauge RG005 installed in Annaipallam

To study the geology in this region, traverses were made along streams, road sections and on the hill tops. Geology along the valley slopes could not be conducted as they are thickly forested and are inaccessible.

In the upper regions of the watershed, foliated garnet bearing charnockites are exposed. Although the foliations of these rocks is highly variable in the region, majority of the foliations strike in the east-west direction and dip by 60-80° to the south (Figure 11). The rocks here show the presence of numerous fractures. While some of them are vertical running in the north-south direction, there are several others that are inclined and dip to the north by 60-80°. In some places the rocks are also highly weathered with the weathered layer being nearly 7-8m thick. Such exposures were visible on the southern hill tops and northern hill slopes, as observed along the road.

Photo 4: Rock exposures in stream flowing in a valley below Annaipallam village

Further southeast, along the stream, the garnet bearing charnockites grade in to charnockites or granite gneiss that are devoid of garnets. These rocks run in the northeast-southwest direction and dip by angles of 45° to the southeast. The fractures in these rocks are also parallel to the foliations. A few others are vertical.

On the basis of the geology and the presence of numerous fractures, it can be gathered that the springs for this region are either of the contact or fracture type.

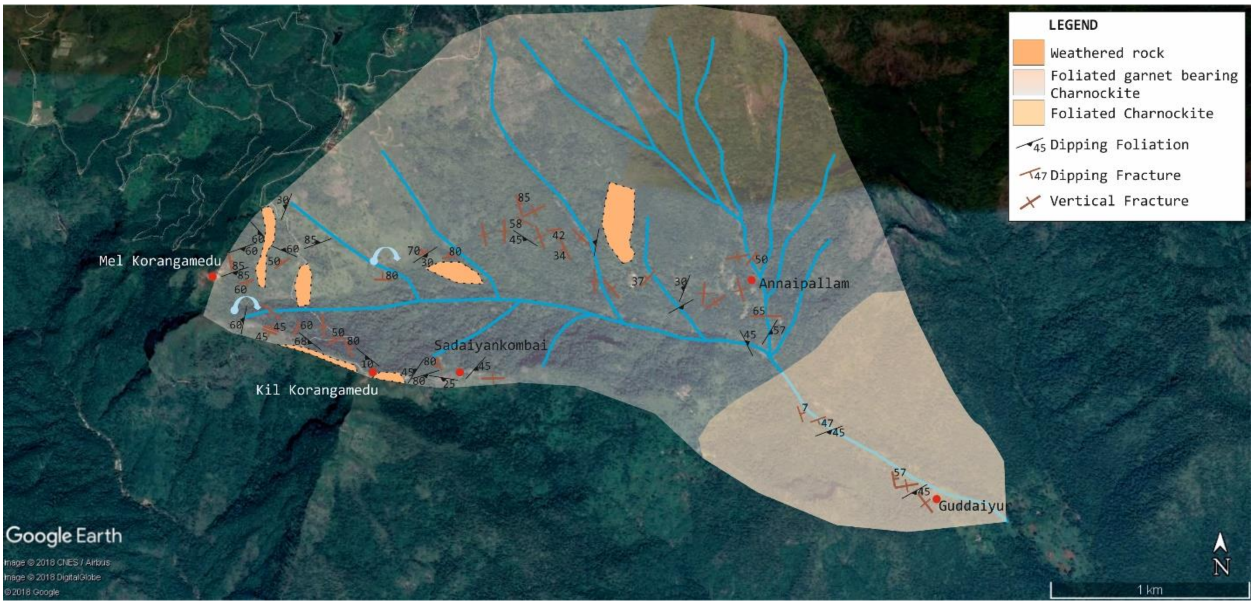


Figure 11: Different rock types and varying foliations and fractures as observed in the valley of Mel Korangamedu and Annaipallam in the Coonoor region

All the springs near Annaipallam and higher up in the valley, close to Mel Korangamedu emerge in private lands. One of the springs, located below Annaipallam in the streams falls under the forest jurisdiction. Majority of them are perennial sources of groundwater.

Source Type	Number of sources	Source Name / Code	Ownership	Seasonality
Spring	5	Muniswaran aaru (HUL006), Gellathakundi (HUL007), Bangala spring (HUL010), Estate road side spring (HUL015) Kuttaiyur	4 private, 1 Forest	3 perennial, 2 seasonal

Spring discharge data for HUL007 that emerges just below Mel Korangamedu and NEL006 that springs out below Annaipallam in the stream, was analysed for the period of six months between August 2017 and January 2018. For HUL 007, highest discharge of nearly 12 lpm was measured in early November, while the least (0.5 lpm) was recorded in late December and early January.

For NEL006, the variations in discharge are more pronounced than those seen in HUL007. In early October, lowest discharge of 2.7 lpm was measured and the highest of 47.8 lpm was recorded in mid-November. Correlation of rainfall and spring NEL006 shows that there is some delay between the response of precipitation and the rise in spring discharge. This could imply that the recharge area for this spring lies slightly far away than that for spring HUL007.

Water quality analysis for data collected during the same period of August 2017 to February 2018 shows that like most other regions, the spring remains fresh with TDS ranges of 70.7 – 269 and pH values of 7.56 – 8.8.

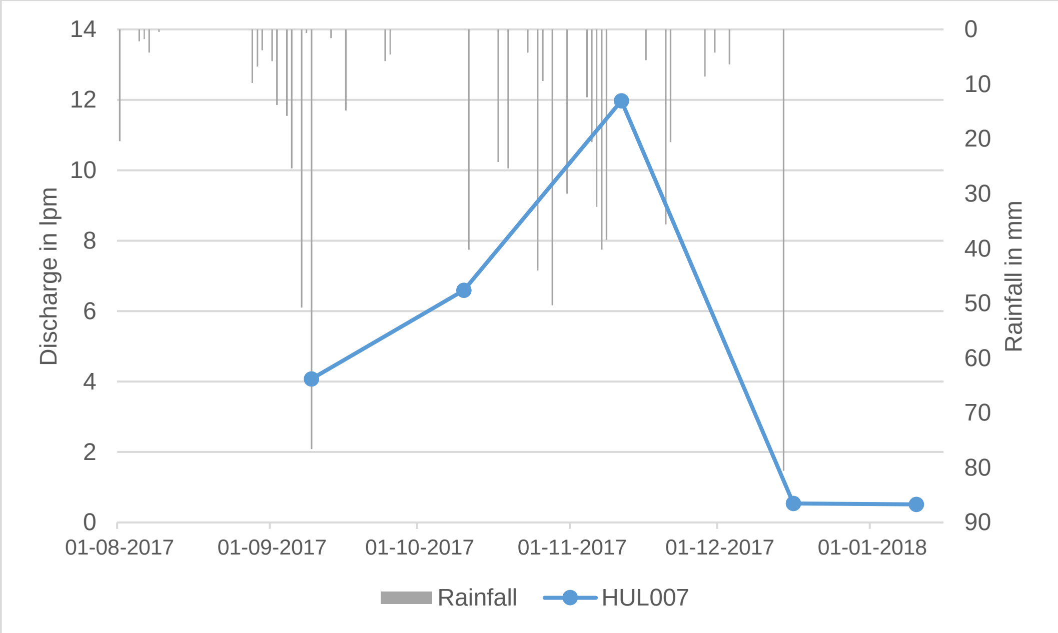


Figure 12: Spring hydrograph for period between September 2017 and January 2018 for spring HUL007

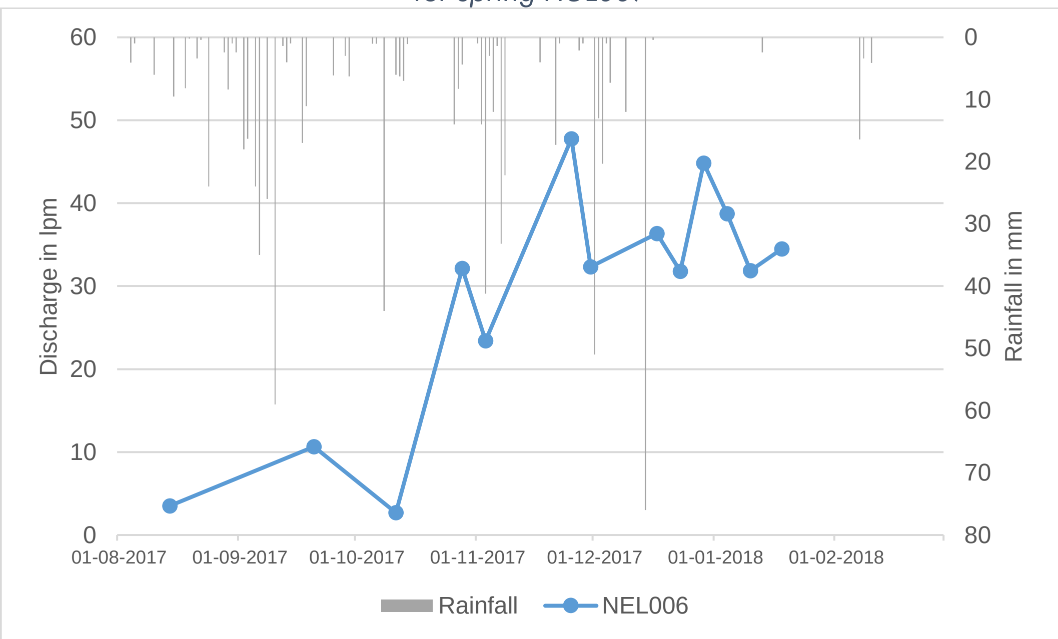


Figure 13: Spring hydrograph for NEL006 between August 2017 and January 2018

KOTAGIRI BLOCK

In Kotagiri block, seven villages from Aracode and Kunjapanai panchayats were studied. From Aracode panchayat, *Samaigudar*, *Vakkanamaram*, *Banglapadigai*, *Kokode*, *Garikyur*, *Mallikoppaiyur*, *Pambarai*, *Selarai*, *Vellarikombai* and *Koovakarai* were visited to examine the water sources.

For this entire region spanning more than 15 km^2, a rain gauge has been installed at Garikyur village. Data collected at the manual rain gauge RG003 between June 2016 and March 2018 is analysed.

In 9 months, 594mm of precipitation was recorded in this gauge. More than 60% of this rainfall (363mm) was measured in the month of September, with scanty rains in August and November (69mm and 82mm respectively). Close analysis of daily rainfall for the month of September in 2017 shows that the rainy days were highly skewed. While on three events, rainfall in excess of 50mm occurred, on the other days less than 5mm was recorded.

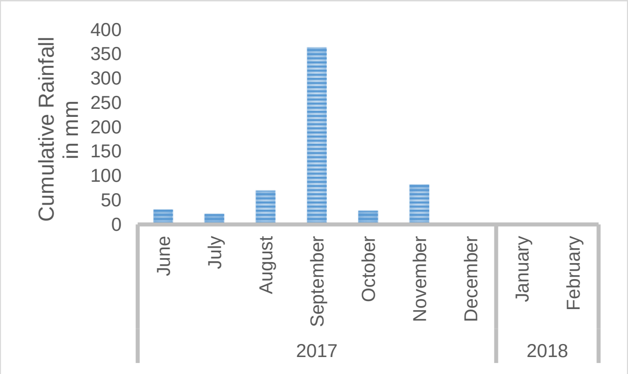


Figure 14: Cumulative rainfall measured between June 2017 and February 2018 at rain gauge RG003 installed at Garikyur village

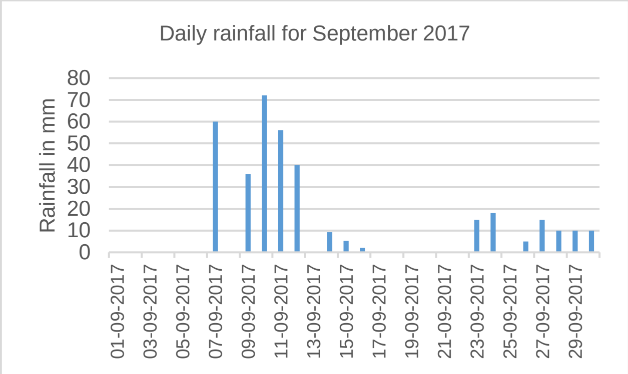


Figure 9b: Distribution of daily rainfall measured in the month of September 2017 in Garikyur village

Samaigudar Village

Samaigudar village is situated at a height of about 995m above msl in the southeast corner of Aracode region. This village's daily drinking and domestic water requirement as well as irrigation water is sourced from one spring namely Kongarai (ARA011) and one well named Kadangarai (ARAW016). Both the spring and well are seasonal and dry up by the month of February or March.

The primary occupation for 50% of the households is agriculture. The land owned by these farmers vary from 1 acre to 8 acres on which coffee plantations, spices, silk cotton and jack fruit are grown. The remaining 50% are landless and serve as labourers. Close to the Kadangarai well one of the farmer has 0.5 acres of land on which a leafy vegetable named Chow Chow and silver oak trees are planted. Irrigation for this land is sourced from the Kandangarai well. According to the local resource person, Chow Chow is a water intensive plant which requires close to 20 litres of water per plant.

Figure 15: Water sources and check dams in the region of Samaigudar village

Systematic traverses in the springshed was conducted to map the different rock types and structures, identify the spring type and locate the recharge zones.

Kongarai spring emerges at an elevation of 1015m above msl at the contact between weathered rock and garnet bearing charnockites. The charnockite has foliations that run east-west and dip by approximately 50° to the north. Several parallel semi-vertical fracture sets trending north-south are observed to the north of the spring. At higher elevations, above the spring, 3-4m of thick weathered rock is seen (Figure 16).

Photo 5: Nearly dried up Kongarai spring in Samaigudar village in February 2018

Kadangarai well located in the middle of the valley below Samaigudar village is 3.2m deep and 2.5m in diameter. It is completely lined till the base with stones exposing fresh rock at the base. To the upstream, the flow in the stream is impeded at several places with nearly 8 small check dams. Here, the rocks are fresh and show very less degree of weathering compared to that observed on the eastern slopes of the valley. Another spring emerges at nearly 1008m above msl below Vakkanamaram village. The rock surrounding the spring is semi-weathered in nature and it springs out between the contact of the weathered layer and hard compact charnockite.

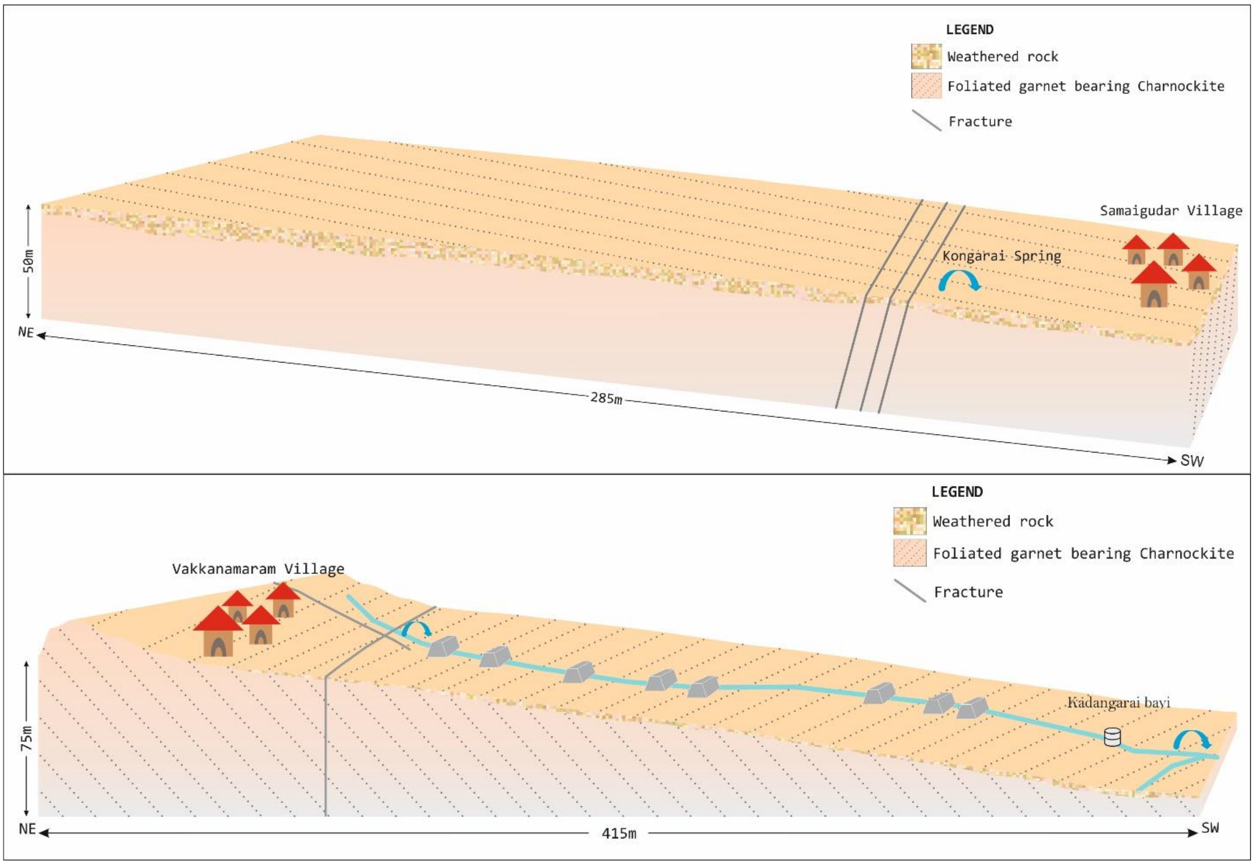


Figure 16: Geological cross section of two springs and one well in Samaigudar village

Both the springs can be classified as a combination of depression and contact type. Inflows in Kadangarai well come at the base of the lining.

Both the Kongarai spring and Kadangarai well were perennial but in the last 5-6 years they have been observed to go dry by the month of February or March every year. Spring located upstream of Kadangarai well, was perennial 15 years ago. Since then the spring discharge has reduced with reasons such as reduced land cover in the recharge area sited by the local resource person.

Out of the total 3 groundwater sources surrounding Samaigudar, all of them are owned either by the panchayat or the community.

Source Type	Number of sources	Source Name / Code	Ownership	Seasonality
Spring	2	Maakkerai (ARA009), Kongarai (ARA011)	Community	1 perennial, 1 seasonal
Open well	1	Kadangarai (ARAW016),	Panchayat	1 seasonal

Discharge data for Kongarai could not be measured by the resource person due to either very little water in the spring or because of difficulty in measurement. Static water level (SWL) data for well ARAW016 was utilised to develop hydrographs(Figure 17). Although the data is inconsistent, it can be seen that there are large fluctuations in the water level. The highest water level in the well was reached in mid-September and the shallowest in mid-November. There is a slight delay of almost 10 days between the maximum rainfall events and the highest water levels, thus implying a delayed recharge in to the aquifer. However, high frequency data over at least one to two years is essential to understand the aquifer dynamics.

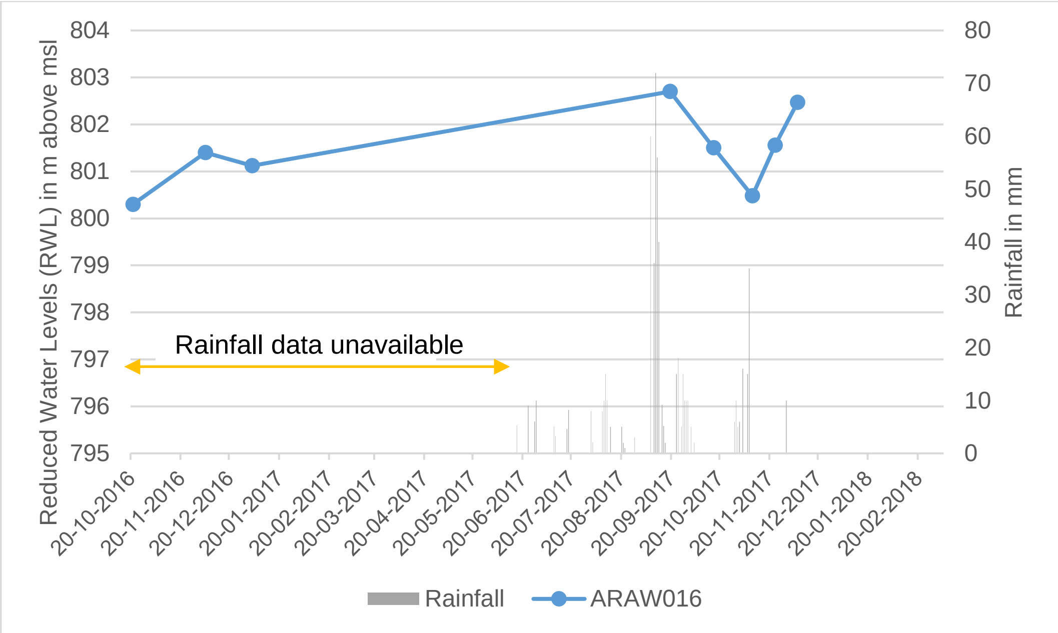


Figure 17: Hydrograph for Kadangarai well over a period of 1.5 years

Water quality measured since October 2016 shows that values for both TDS and pH are within the desirable limits stated by BIS. Comparison of TDS values between the two source types shows that the values are much higher for well water than that for spring water.

Source type	Source Code	TDS (mg/l)	pH
Spring	ARA009	180.6 – 254	6.33 – 6.55
	ARA011	112 – 116.9	6.53 – 6.87
Well	ARAW016	181 – 365	6.33 – 6.93

Banglapadigai Village

The village of Banglapadigai and Kokode are situated in the adjacent valley to the northwest of Samaigudar village. The two villages are dependent on three springs and wells. During the visit, two springs and three wells were studied.

Agriculture is the main occupation in both the villages, but farmlands in Kokode are slightly larger than those in Banglapadigai. Coffee plantations, silk cotton and jack fruit are the principal crops.

Figure 18: Location of the springs and wells in Banglapadigai and Kokode village

Dhonikkerai spring located in Kokode village, emerges at a height of 1150m above msl. Dhonikkerai springs are actually two springs emerging along the same contour line a few metres apart. Close to the springs are two wells namely ARAW019 of depth 4.6m and diameter 3.7m and ARAW020 which is 4.9m deep and 3.7m wide.

The spring and wells are both perennial. The spring water is stored in a small storage tank (located between the two wells) having dimensions 3.3 x 3.7 and 1.7m deep. Water from this tank is then taken down by gravity through pipe system to Kokode village located at 1110m above msl. This spring water is used for domestic needs and drinking water needs of humans, livestock and wildlife. The open well water although perennial, is not much in use but is occasionally fetched manually by some members of Kokode village for drinking and domestic use.

Pulimavakere is another spring slightly downhill of Dhonikkerai spring within the same watershed. Pulimavakere discharges at nearly 1042m above msl and supplies water to Banglapadigai village.

The entire watershed is underlain by garnet bearing charnockites with foliations in the northeast-southwest direction dipping to the northwest by 40°. Above the charnockite is a layer of weathered rock which is approximately 4 – 5 metres thick. The thickness of the layer is non-uniform with thicker weathered zone to the southwest above the Dhonikkerai spring.

In the rocks exposed along the road, two to three, sub-vertical fractures sets striking north-south and northwest-southeast are visible.

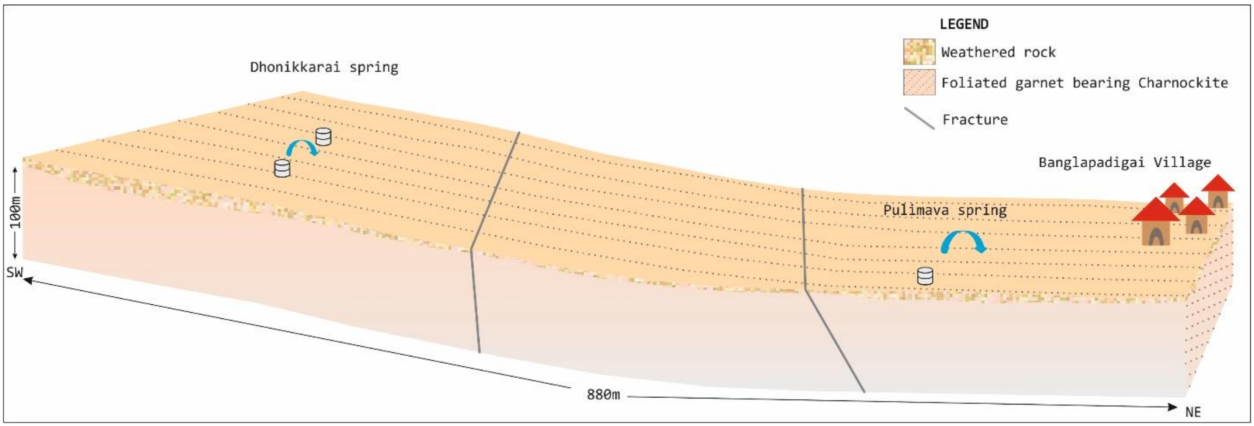


Figure 19: Hydrogeological cross section of rocks underlying Banglapadigai and Kokode village

Based on the geological studies, Dhonikkerai and Pulimavakere springs are classified as depression type.

The 9 water resources around villages of Kokode and Banglapadigai are perennial and owned either by the community or the Aracode panchayat.

Source Type	Number of sources	Source Name / Code	Ownership	Seasonality
Spring	4	Pulimavakere_1(ARA007), Dhonikkerai (ARA008), Sanakkapadigai (ARA013), Pulimavakere_2 (ARA045)	2 Community, 1 Panchayat, 1 unknown	All perennial
Open well	5	Eshemaram bavi (ARAW006), Pulimavabavi (ARAW012), Dhonikkarai 1 (ARAW019), Dhonikkarai 2 (ARAW020), Bangalapadikai (ARAW029)	Except one which is unknown, all are Panchayat owned	All perennial

One year discharge data for spring ARA007 shows that during the summer season the minimum discharge of the spring is 0.3 – 1.2 lpm only while during the peak monsoon months of September and October the discharge increases to an average of 6-8 lpm. In the middle of September 2017, the spring had a discharge of nearly 14 lpm. Limited data for spring ARA045 shows an increase from 5.2 lpm to 10.5 lpm in just 15 days in the month of December 2016.

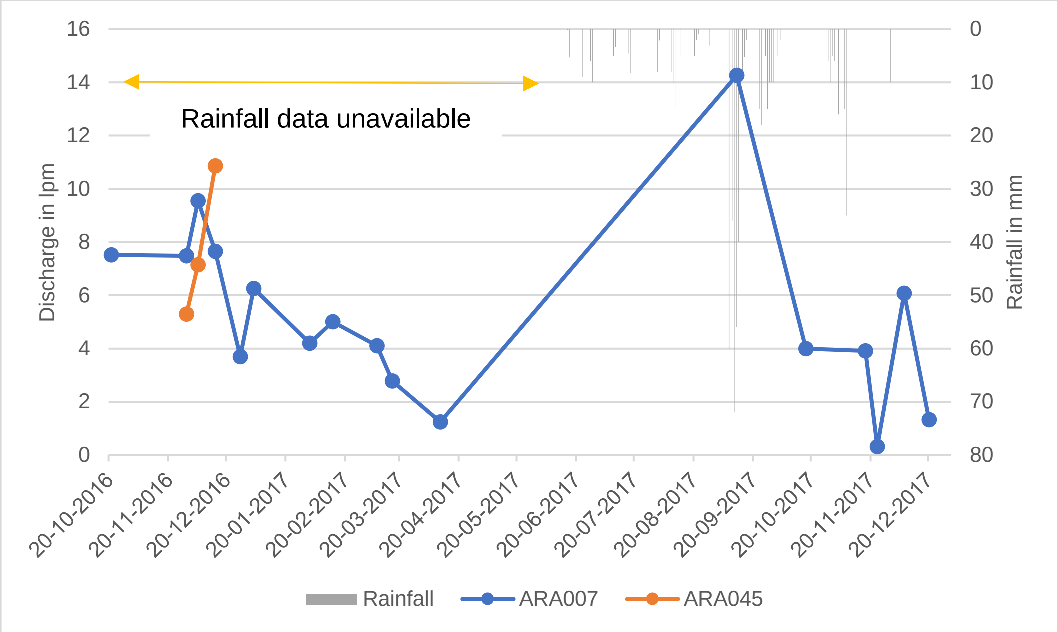
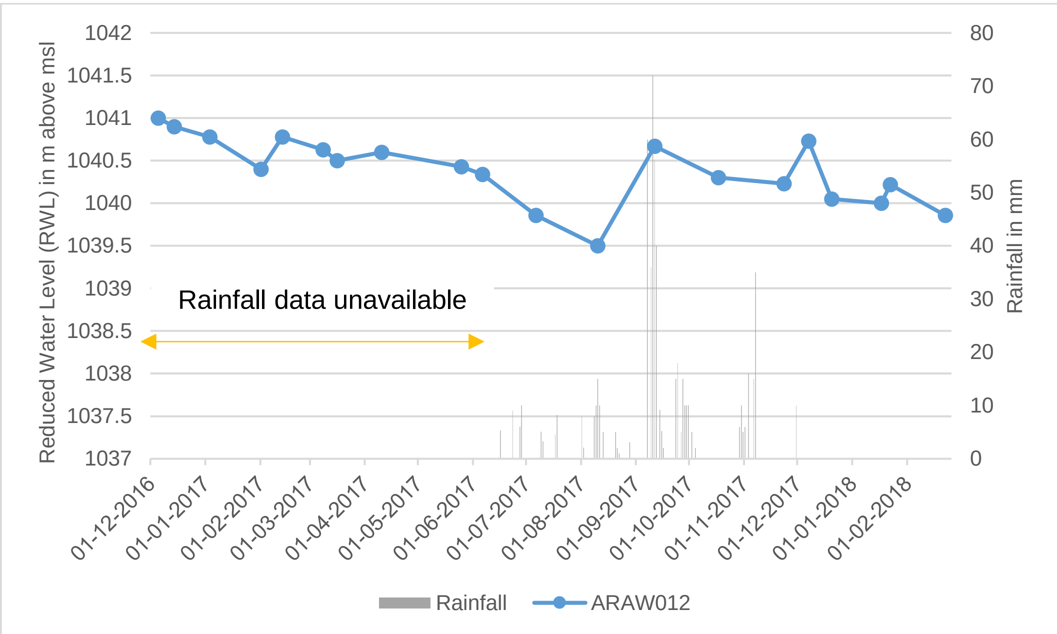


Figure 20: Spring hydrograph for ARA007 and ARA045 between October 2016 and December 2017

Hydrographs for wells ARAW012, ARAW019 and ARAW020 shows the response of water levels to rainfall. The two graphs show that in the summer season (typically between March and May) the water levels decline and as the monsoon arrives, the water levels show a steady rise. Water level data between October 2016 and February 2018 shows that during this period, the deepest water level were recorded in the month of May 2017 for ARAW019 and ARAW020 while for ARAW012 it was observed in August 2017. The shallowest water levels were measured during December 2016 and January 2017. However, all the three wells show almost an immediate response to rainfall.



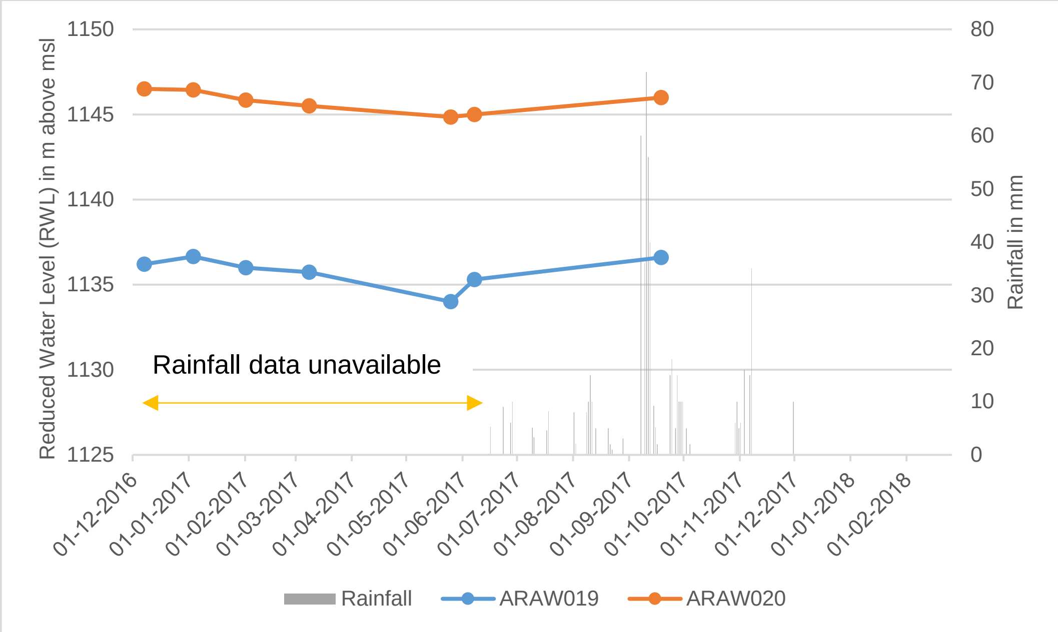


Figure 21: Well hydrographs for Pulimavakere (ARAW012) and two Dhonikkerai wells (ARAW019 and ARAW020) for the period of December 2016 to February 2018

In situ water quality data collected between October 2016 and February 2018 was analysed to show that broadly the levels of TDS are higher in well water than spring water. The pH of spring water is slightly alkaline in nature while that of open well water is acidic. Spring ARA080 and wells ARAW019 and ARAW020 show almost similar values for TDS.

Field observations, geological mapping and water quality confirm that the Dhonikkerai spring and its two adjacent wells are fed by the same weathered unconfined aquifer.

Source type	Source Code	TDS (mg/l)	pH
Spring	ARA007	118 – 301	6.3 – 8.43
	ARA008	150 – 217	7.25 – 8.7
	ARA013	115 – 256	6.72 – 7.53
	ARA045	211 – 256	6.3 – 7.13
Open Well	ARAW006	332 – 333	6.1 – 6.8
	ARAW012	226 – 249	6.06 – 6.58
	ARAW019	112 – 277	6.77 – 7.85
	ARAW020	155 – 214	6.86 – 7.44
	DENW005	43.5 – 44.6	6.54 – 6.78

Pambarai and Selarai villages

The two villages of Pambarai and Selarai get their water from three springs namely Kalva (ARA032), Sakkaimara (ARA039) and Puttalamara (DEN007) and one well named Thave bavi (ARAW030).

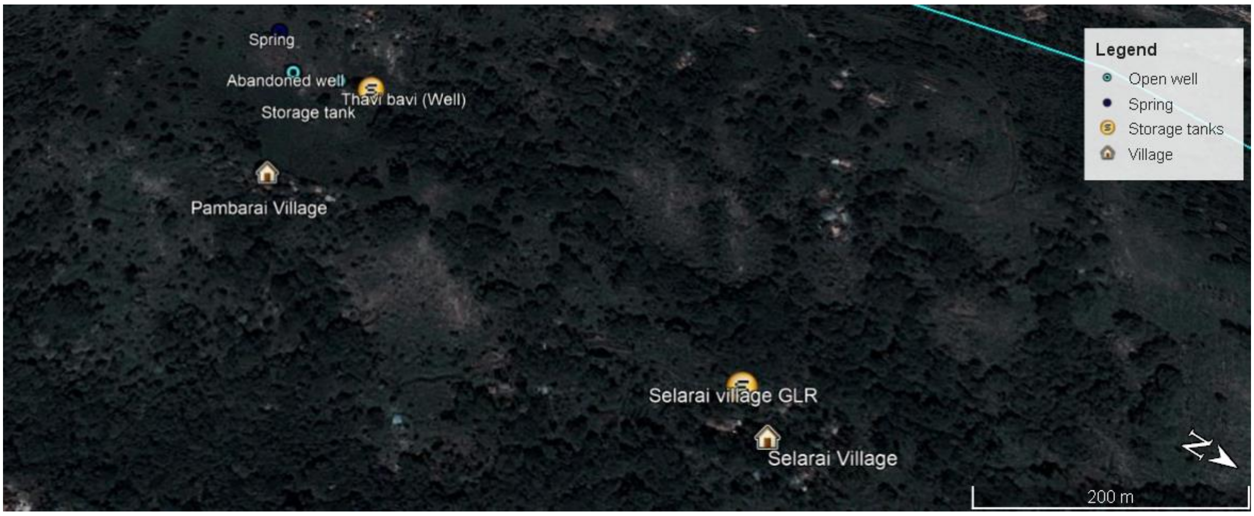


Figure 22: Location of the wells and spring with respect to Pambarai and Selarai villages

All the three springs emerge in tea estates which are private lands. The Thave bavi well is owned by the panchayat. Another well named Kal bavi (ARA033) located to the northeast of the springs is also owned by the tea estate owner. Initially, this well was used for drinking water by the tea labourers but since the last 5 years the tea estate owner has prevented the labourers from using it by dropping in tree trunks.

Source Type	Number of sources	Source Name / Code	Ownership	Seasonality
Spring	3	Kalva (ARA032), Sakkaimara (ARA039), Puttalamara (DEN007)	All emerge in private tea estate area	2 perennial, 1 seasonal
Open well	1	Thave bavi (ARAW030)	Panchayat	Perennial

Beneath the springs and wells is a 5-7m thick weathered layer which is underlain by charnockites and has foliations trending east-west that dip by 30-40° to the north. The thickness of the weathered rock increases downhill in the northern direction.

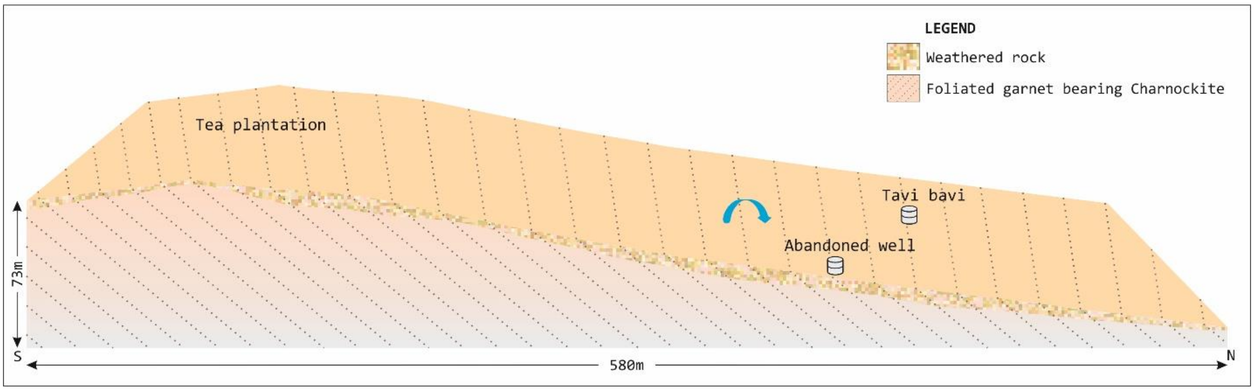


Figure 23: Geological cross section of the region underlying Pambarai village

The three springs are classified as depression type or a combination of depression and contact.

The stream water that flows down from the spring at 1650m is collected in a small storage tank below the Thave bavi well. This tank is connected with a pipe which takes water by gravity to the GLR at a height of 1540m above msl in Selarai village.

Discharge data and water level data for none of the springs could be collected by the resource person due to technical difficulties. However, discharge measured in the storage tank in mid-February 2018 gave values of 38lpm. The TDS value for the spring and well remains below 50 mg/lit throughout the year. But, the pH of water detected both from the spring and well water is acidic in nature.

Source type	Source Code	TDS (mg/l)	pH
Spring	DEN007	36.6 – 39.1	5.37 – 5.8
Well	ARAW030	31.70 – 45.7	6.13 – 6.70
Storage tank		36.8	7.60

Garikyur and Mallikoppaiyur villages

The villages of Garikyur, Mallikoppaiyur and Karappanai villages are situated to the northwest of Banglapadigai, across the stream. These villages use both surface and ground water for their daily domestic use including drinking as well as for irrigation. Among the groundwater sources four springs and two wells are in use.

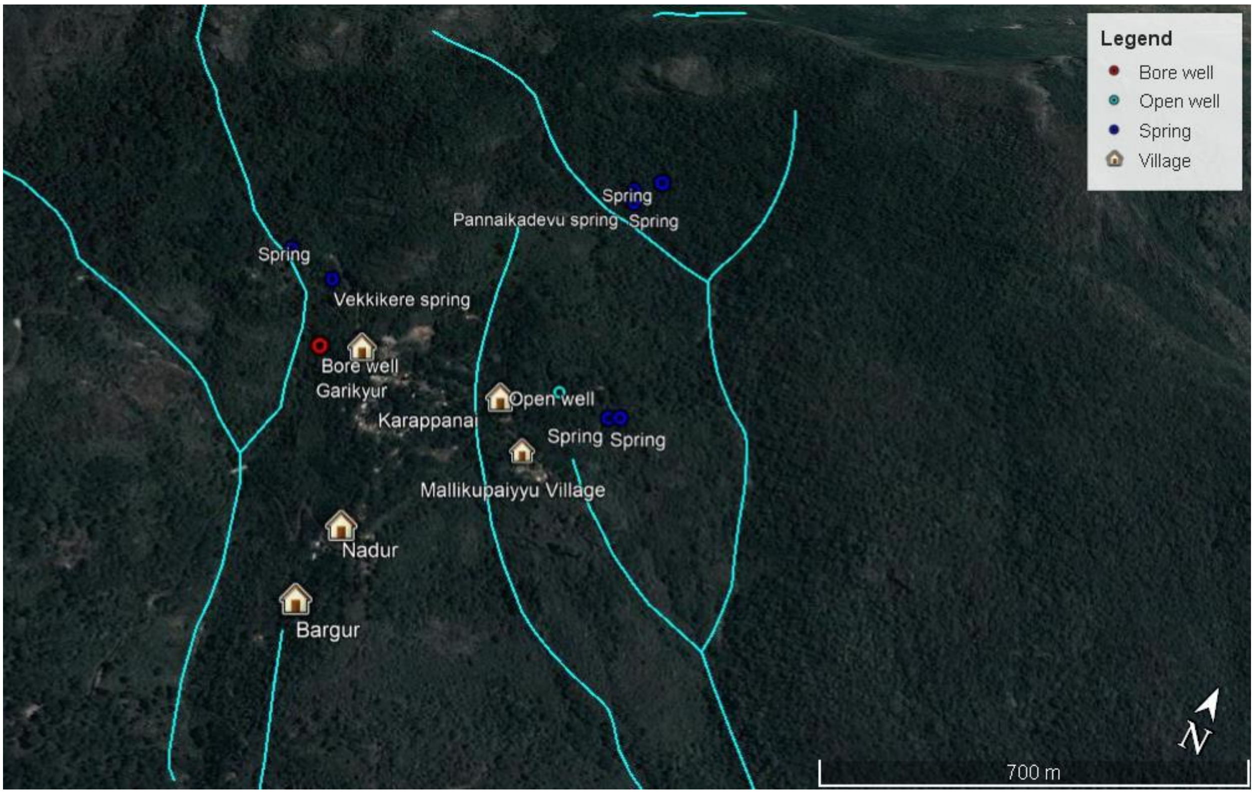


Figure 24: Numerous water sources in the region of Garikyur village

Majority of the villagers are either farmers or labourers. The average land size owned by an individual in Garikyur is slightly more than 1 acre, few owning 3-4 acre lands. In Mallikoppaiyur, the largest land parcel is 2 acres; the average being less than 1 acre. Like the other regions of Aracode, coffee, silk cotton, spices, jack fruit are the preferred crop choices.

Hydrogeological mapping in this region was conducted on three springs and one open well that are situated in the two adjacent valleys of Garikyur village.

Photo 6: Vekkikere spring emerging out of fractures near Garikyur village

The Vekkikere spring located just below the road, emerges at an elevation of 1250m above msl (Photo 6). The main rock around the spring area and the springshed region is charnockite. These rocks have foliations running in the north-south direction and dips of 30-40° to the east. The rock also has fractures with low angle dips of 10-20° (Figure 25). This fracture when traced uphill, gives rise to another spring (ARA002) at 1280m above msl, located along the road side. Both springs emerge at the intersection of the fracture with the topography. Here the degree of weathering is very limited. Thus, on the basis of the rock structure these springs are termed as fracture types.

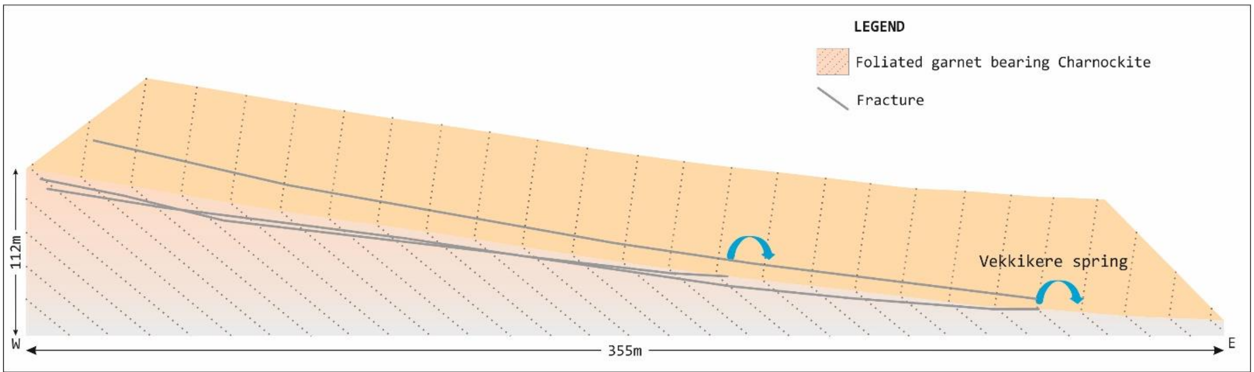


Figure 25: Geological cross section of Vekkikere spring

Mallikoppaiyur village has one well and three springs. The main spring is Pannaikadevu at 1290m above msl. Two other smaller springs are located to its upstream. Here too, charnockites are exposed which have foliations in the east-west direction and dip to the south. However, the rock around the three springs is completely weathered which is derived from the underlying rock. Based on the geology, these springs are of the depression type.

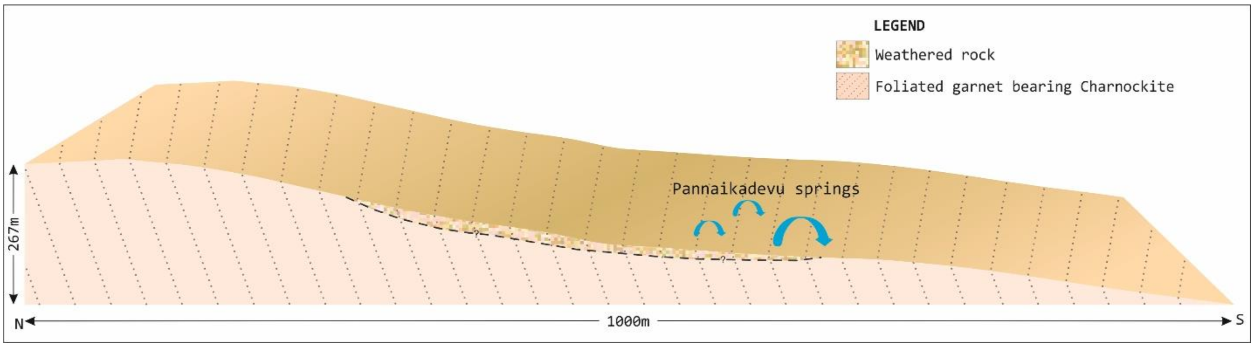


Figure 26: Geological cross section of Pannaikadevu springs

Two other springs ARA005 and ARA006 emerge at 1160m above msl to the northeast of Mallikoppaiyur. All around the two springs, loose, weathered rock is seen exposed with some small semi-weathered rock outcrops. Since these emerge at the sudden change in topography from loose material they are categorised as depression type springs.

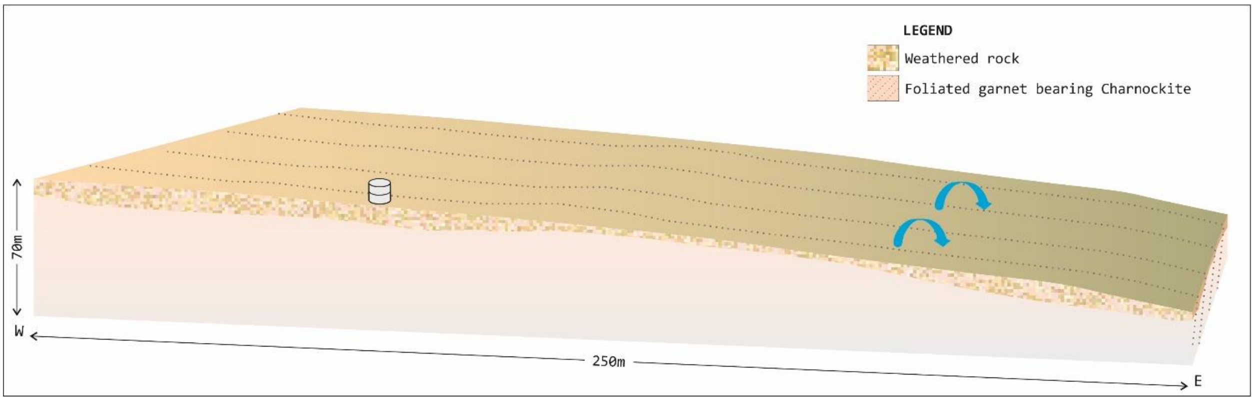


Figure 27: Geological cross section of the springs and well at Mallikoppaiyur village

Data collected by Keystone for 11 water sources in this region shows that 3 out of the 6 springs fall under the forest jurisdiction while the other 3 emerge in private lands. Among the 4 open wells, 3 are panchayat owned and one private. The bore well drilled at Garikyur is under the ownership of the panchayat. While all the springs yield water throughout the year, the open wells and one bore well are seasonal in nature.

Source Type	Number of sources	Source Name / Code	Ownership	Seasonality
Spring	6	Vaagaigundi (ARA002), Koppaikerai (ARA003), Pannaikadevu (ARA004), Kodappaalai_1 (ARA005), Kodappaalai_2 (ARA006), Kolikodagu (ARA017)	3 forest, 3 private	All perennial
Open well	4	Senthubavi (ARAW001), Karappanai bavi (ARAW002), Kerkeraibavi (ARAW007), GTRHS (ARAW027)	3 panchayat, 1 private	1 perennial, 3 seasonal

Bore well	1	Garikyur bore (ARAW028)	Panchayat	Seasonal

At the time of field survey, the discharge of Vekkikere spring was calculated to be about 62 lpm. According to the local resource person, the average discharge measured for this spring at the village was approximately 2 lpm. Discharge for springs at Mallikopaiyyur could not be measured.

Photo 7: Water quality measurement carried out for water from Pannaikadevu spring

Discharge data of springs ARA002 and ARA003 between mid-October 2016 mid-February 2018 shows that the values range between 1.5 lpm and 19 lpm for the former and 1.2 lpm and 21 lpm for the latter. For ARA004, ARA005 and ARA006 the discharges measured in a span of 4 months between November 2017 and February 2018 is highly variable. While the minimum discharge is less than 1 lpm the maximum is around 3-3.5 lpm.

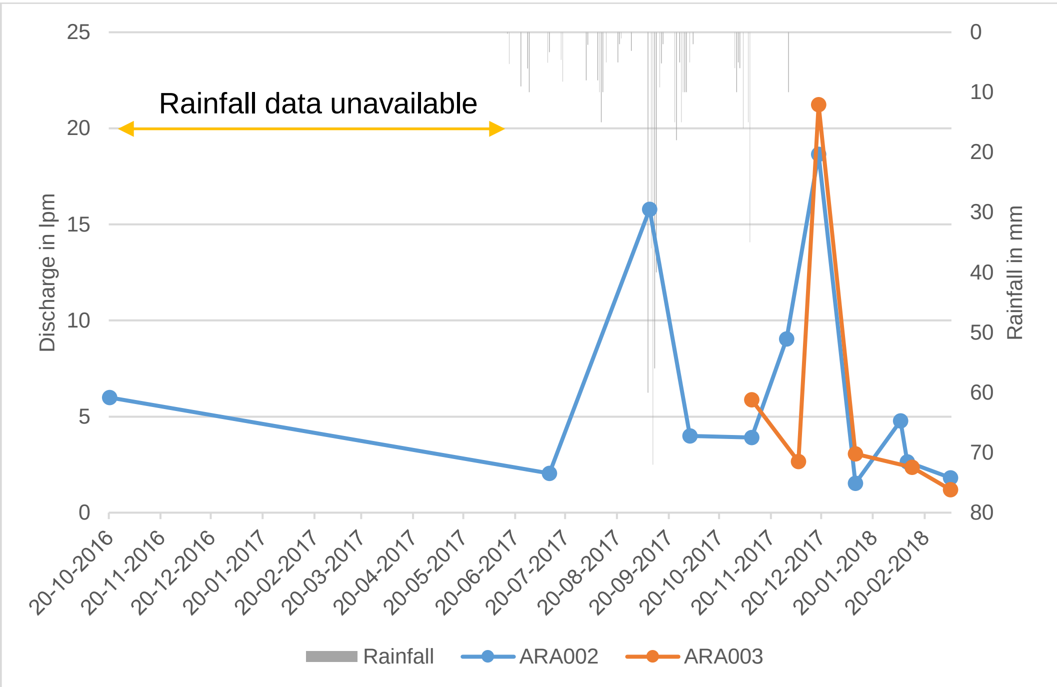


Figure 28: Spring hydrographs for two springs between October 2016 and February 2018 in Garikyur village

In ARAW001 between is 3m wide and 11m deep. The deepest water was 9.65 in November 2017 while the shallowest was recorded in January 2017 of 5.2. the total fluctuation measured in this well was about 4.5m in one year.

The in-situ water quality for all the sources shows that the water is fresh in nature with TDS value below 500 mg/l. The pH of water of some sources seems to be slightly acidic on some occasions.

Source type	Source Code	TDS (mg/l)	pH
Spring	ARA002	86.3 – 286	6.12 – 8.56
	ARA003	86 – 347	6.78 – 8.89
	ARA004	167 – 173	7.25 – 7.64
	ARA005	168 – 260	6.33 – 7.76
	ARA006	156 – 202	6.24 – 7.54
	ARA017	217 – 222	7.26 – 7.5
Well	ARAW001	152 – 455	6.15 – 8.4
	ARAW002	74.1 – 256	6.44 – 6.82
	ARAW007	151 – 356	6.53 – 7.4

METTUPALAYAM BLOCK

In the Mettupalayam block, *Poochamarathur* village in Kemmarampalayam panchayat was studied.

The nearest rainfall data for this village is from the gauge RG009 at Pillur. The data measured here shows that in a period of 8 months between June 2017 and January 2018, 752mm of rainfall was recorded. Unlike precipitation recorded at the other rain gauge, here, the rainfall was well distributed across five months. While maximum rainfall was received in the month of September, October to December also witnessed more than 100mm in each month.

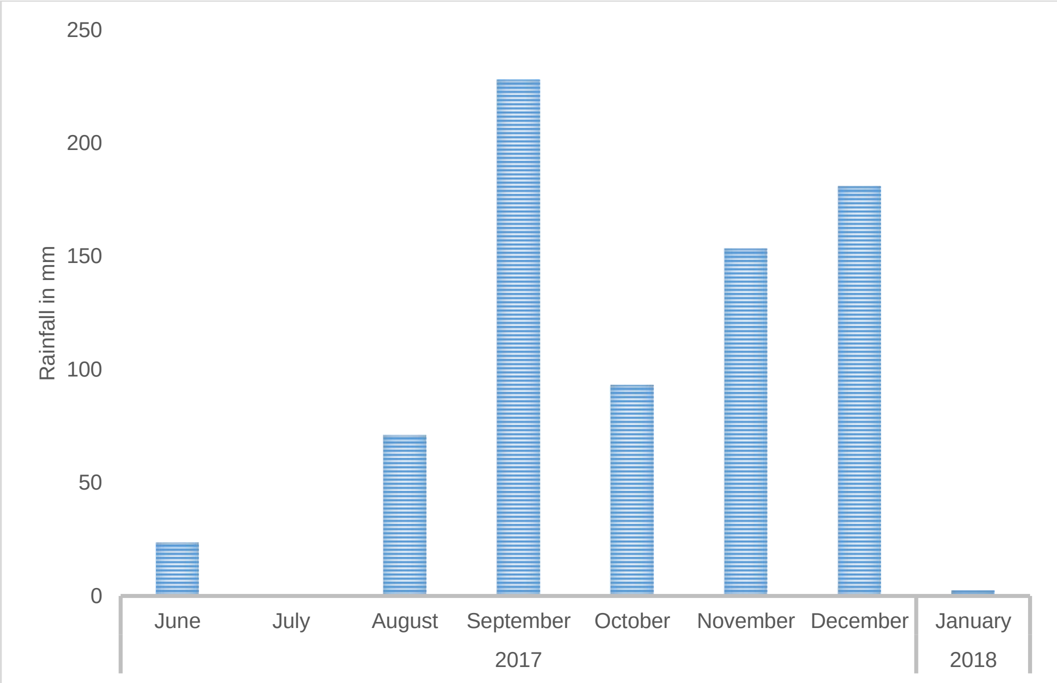


Figure 29: Cumulative daily rainfall measured at gauge RG009 at Pillur between June 2017 and January 2018

Poochamarathur Village

Figure 30: Location of different water sources in Poochamarathur village

Poochamarathur village situated at a height of 450m above msl is a village that is located very close to the Pillur dam backwaters. The community here therefore is largely dependent on the dam water for all its daily requirements. There is also an old open well to the east of the village which was earlier used by the community members. In addition to the dam water and open well, a bore well was drilled in the year 2012-2013. While the main drinking water source remains surface water, water from the bore well is pumped into the GLR for use. Water from the dam is fetched manually.

The average land holdings in this village is 3.5 acres which is higher than that observed in regions of Aracode and Coonoor. Despite having a total of 42 acres of land, agriculture is practiced only on 12 acres with banana the main choice.

Photo 8: Old well exposing the subsurface geology in Poochamarathur village

With respect to the underlying geology, a thin layer of loose weathered rock overlies hard and compact banded granite gneiss. These rocks are foliated in the northeast-southwest direction. They are seen exposed in the old community well below 5m from the ground surface. A fracture trending in the NNE-SSW direction is also visible in the well.

Apart from the dam water and bore well, there are two springs located in a mountain valley to the south-east of the village. Water from on spring Munikarai (KEM102) is stored in a check dam close to the village and is used for domestic and drinking purposes. Spring water from Munikarai (KEM103) is used only for livestock and wildlife.

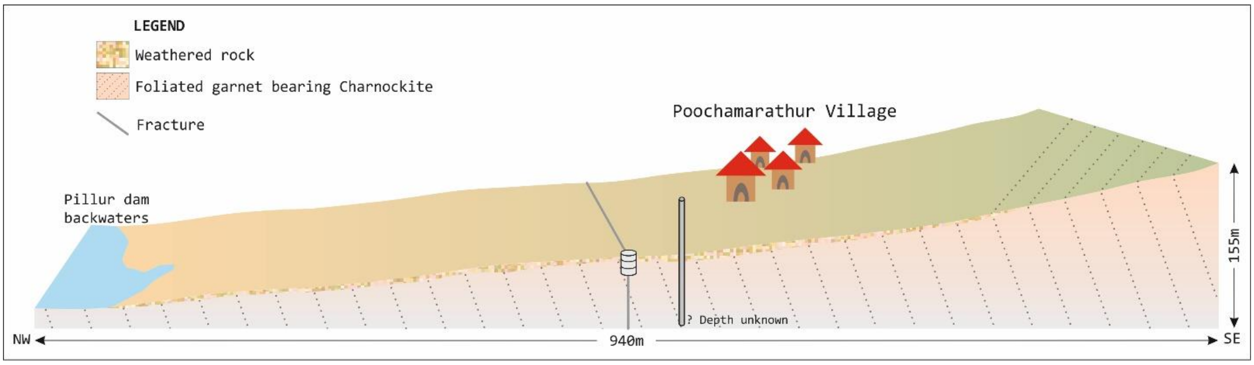


Figure 31: Cross section of Poochamarathur village

The old well is 8m wide and 16m deep. According to the village resource person, the water struck in the bore well was around 18-20m.

Source Type	Number of sources	Source Name / Code	Ownership	Seasonality
Spring	2	Munikarai (KEM102), Munikarai (KEM103)	Forest	Both seasonal
Open well	1	Poochamarathur (KEMW006)	Unknown	Perennial
Bore well	1	KEMW008	Panchayat	Perennial

Water quality data collected in the year 2017 shows that groundwater has more dissolved solids in the month of February.

Depths of the bore well and old open well along with the water quality confirm that both the sources tap the same aquifer.

Source type	Source Code	TDS (mg/l)	pH
Open well	KEMW006	259 – 810	6.11 – 7.54
Bore well	KEMW008	779	7.94

KOTAGIRI BLOCK

In Kotagiri, the water sources that provide water to *Vellarikombai* and *Koovakarai* village of Kunjapanai panchayat were studied.

At a rain gauge in Kotagiri, cumulative rainfall of 567mm was recorded in a span of 7 months between the months of August 2017 and February 2018. Here, similar to Pillur region, precipitation is more well distributed in the months of September to December 2017. This drastically reduced in 2018 when less than 5mm each was recorded in January and February.

Closer analysis reveals that in September 160mm of rainfall occurred over 12 rainy days, while 171mm of rainfall in December was received only on 6 rainy events. On one of the events, more than 70mm of precipitation was recorded.

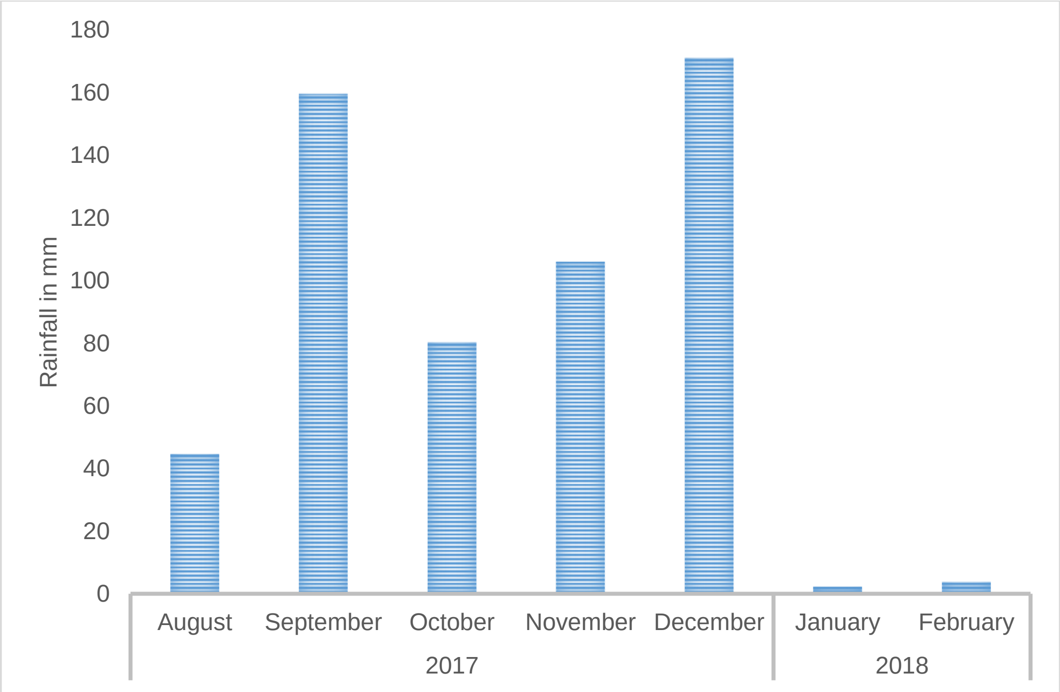


Figure 32: Cumulative daily rainfall measured at a rain gauge in Kotagiri betwen August 2017 and February 2018

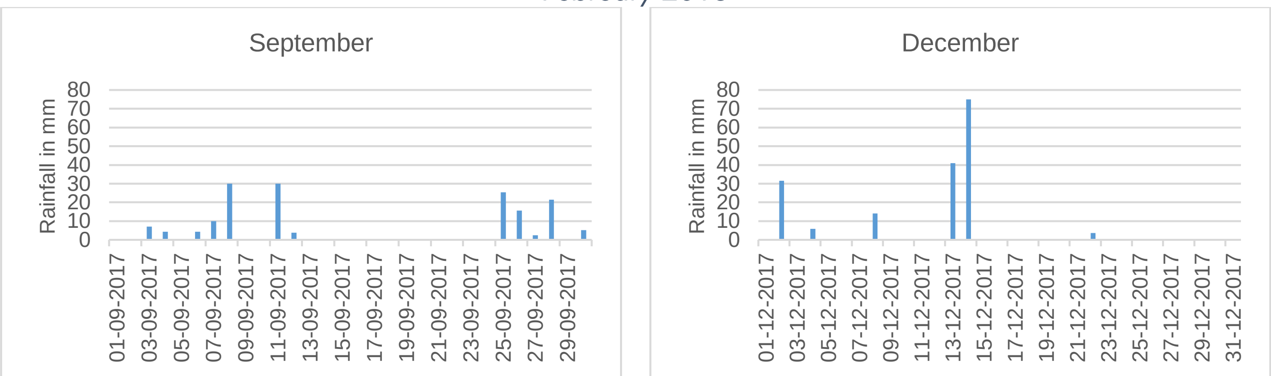


Figure 33: Comparison between the distribution of daily rainfall recorded in the months of September and December 2017

Vellarikombai village

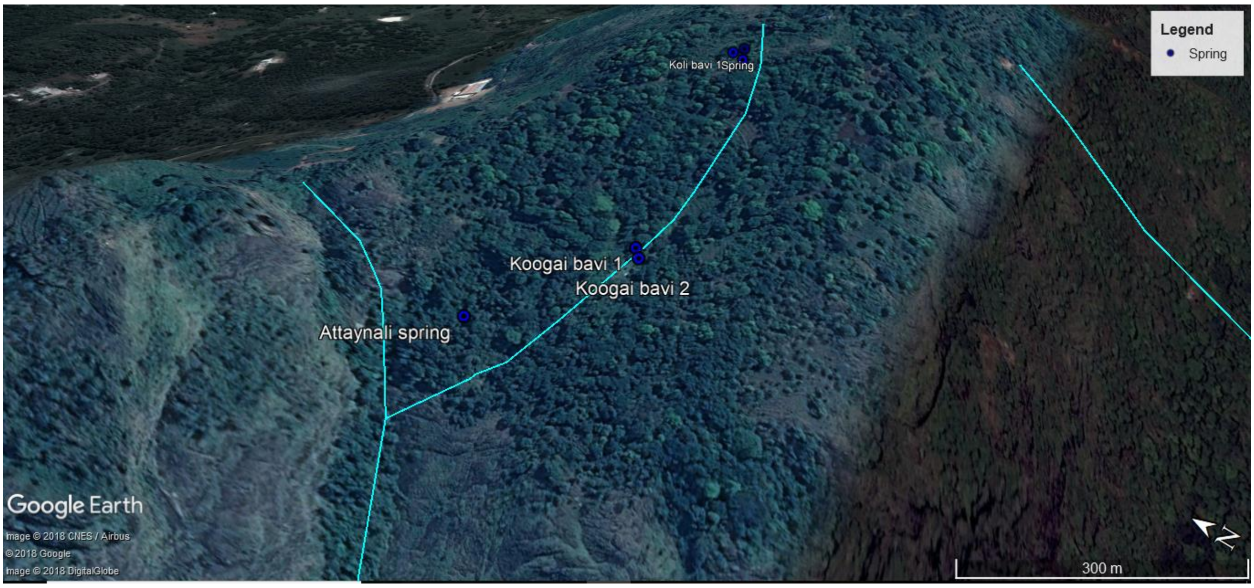


Figure 34: Location of six springs in the Koovakarai region

Vellarikombai village with 50 members is completely dependent on spring water. There are a total of 8 springs, out of which 2 were studied in this visit. Two of the surveyed springs are located at the top of the hill at 1200m and 1175m while the others are situated on the hill slopes.

6 out of the 8 springs discharge water throughout the year and are owned by the community themselves. While Attaynaali spring emerges in forest land, Koogai spring is owned by the Kunjapanai panchayat.

Source Type	Number of sources	Source Name / Code	Ownership	Seasonality
Spring	8	Devayerai (KUN004), Kabugundi (KUN005), Boothiedugu (KUN006), Orange Baavi (KUN007), Kovaal baavi (KUN008), Neribaavi (KUN009), Attaynaali (KUN010), Koogai baavi_2 (KUN036)	6 community, 1 forest, 1 panchayat	6 perennial, 2 seasonal

The entire region surrounding the springs exposes garnet bearing charnockites. The extent of weathering of the rock is quite variable in this region. Two of the three springs namely Koli bavi 1 and 2 emerge at the top of the hill at 1300m above msl. Here, the charnockite is highly weathered with loose material being nearly 3-4m in thickness. Another spring emerges a few metres downhill at approximately 1295m above msl. Here, fresh foliated and fractured charnockites are seen. The foliations dip to the south by an angle of 40-50°. There are 2-3 vertical fractures and a few open low dipping fractures which trend east-west (Figure 35).

Thus, Koli bavi 1 and 2 are classified as depression or a combination of depression and contact type and the other lower spring as a fracture spring. Water from these sources is used by habitants of Koovakarai village.

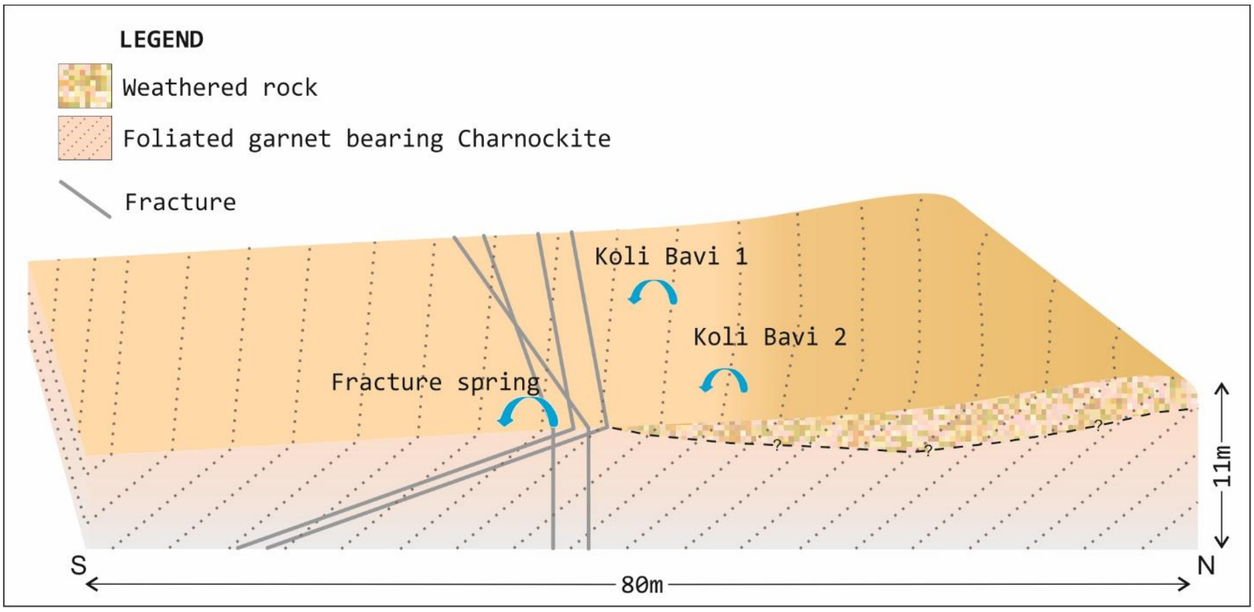


Figure 35: Lithological cross section of region underlying the Koli bavi and fracture springs

Further down in the valley, two springs, Koogai bavi 1 and 2 emerge at 1205m. Water from Koogai bavi 1 is used by Koovakarai village and the second one by Vellarikombai. The charnockites have the same foliations trends as that in the upper reaches. The weathered rock is thicker in this region upto almost 5-6m. The region between the two springs is a wetland. The inflow to Koogai bavi 1 is from the east and for Koogai bavi 2 is from the northeast and south. Majority of the hill slopes are thickly forested.

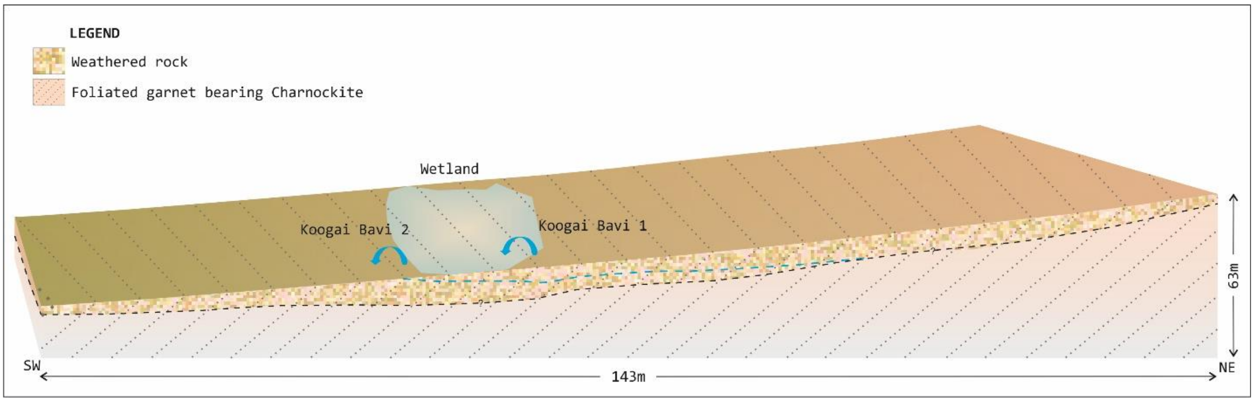


Figure 36: Geological cross section around the Koogai springs

Attaynali spring emerges in the middle of the valley at 1174m. Very few rock outcrops are seen in this area but the spring area exposes hard fractured rock. This is a fracture spring that springs out from the point where the fracture set intersects the topography. This spring comes out in forest land with majority of the uplands thickly forested. The forest is the main recharge area for the spring.

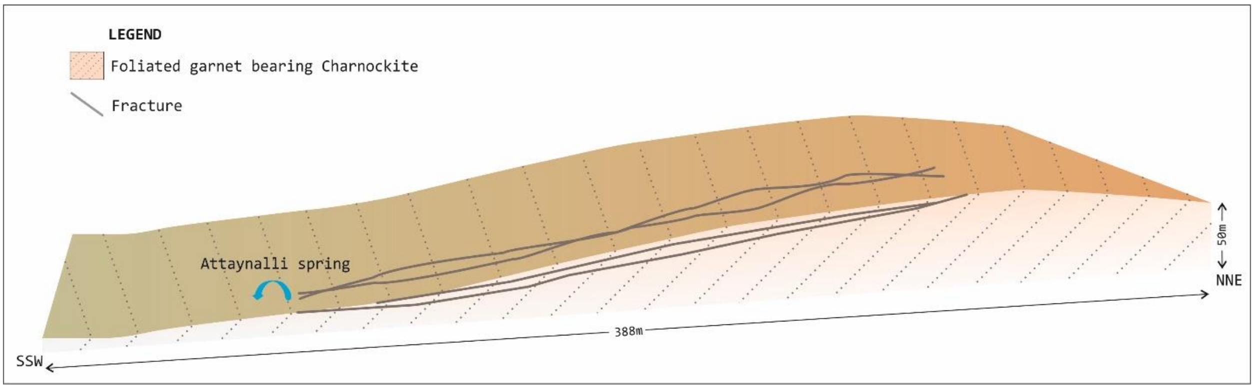


Figure 37: Geological cross section of the Attaynalli spring

Discharge data for KUN010 is available from August 2017 to December 2017 and that for KUN036 for 2-3 months between December 2017 and February 2018.

For KUN010, the discharge varied between 5 – 18 lpm with the highest discharge in December. In a 2-3 month period the discharge for KUN036 went down from 28 lpm in December to 0.6 lpm in early January. This increased to close to 3 lpm by early-mid February.

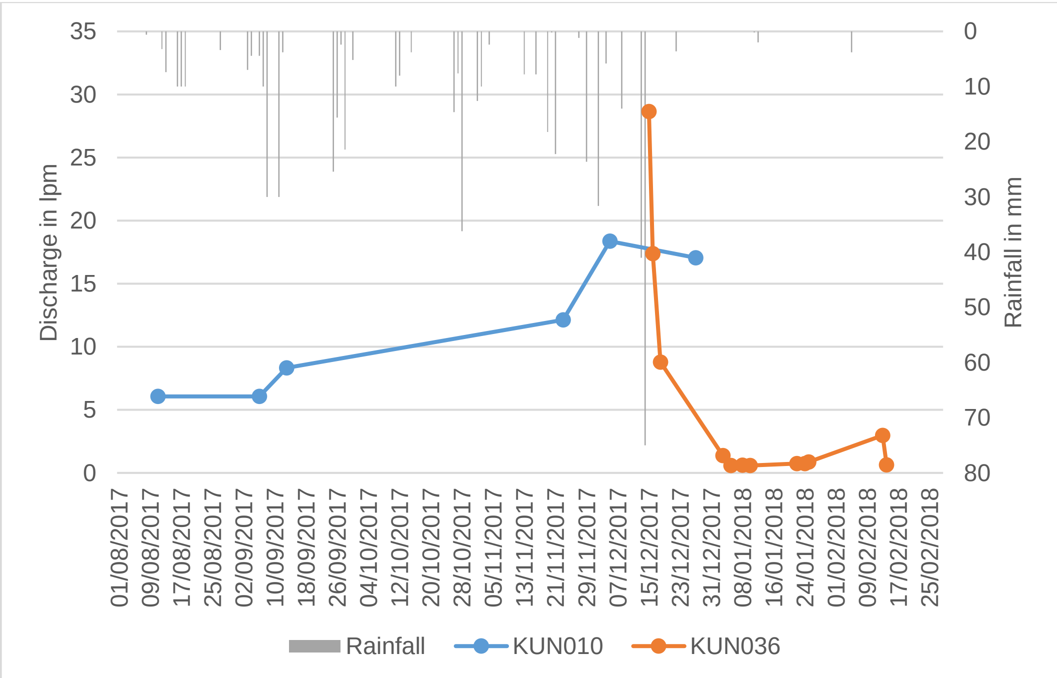


Figure 38: Spring hydrograph for KUN010 and KUN036 between August 2017 and February 2018

In-situ water quality testing for all the six springs was undertaken. It shows that the TDS values for springs in the upper reaches was slightly better than that detected for the Koogai bavi springs. The highest TDS was measured in Attaynalli spring in February. The pH values are also within the desirable limits.

Source type	Source Code	TDS (mg/l)	pH
Spring	Koli bavi 1	71.7	6.96
	Koli bavi 2	66.8	7.60
	Fracture spring	72	7.46
	Koogai bavi 1	103.7	6.16
	Koogai bavi 2	112.6	6.24
	Attaynali	105 – 143.6	7.88 – 7.98

RECOMMENDATIONS

For the Nilgiris district, springs are a lifeline, for both the indigenous and non-indigenous communities. The different springs and open wells that were surveyed during the visit, are being used primarily for domestic use including drinking water, and agriculture. But in the recent past few years, the Nilgiri district, is facing water issues primarily due to either decreased rainfall, or the change in land use and land cover patterns, increase in agriculture, etc. Thus increasing pressure on the existing water sources.

Measures need to be taken in order to make this region more sustainable and self-sufficient by conserving and protecting the recharge area of springs and open wells. In order to achieve this, systematic studies which include both hydrogeological and social surveys have to be conducted.

Based on the field observations, and understanding the common difficulties faced during by the local resource persons, some recommendations and suggestions have been provided below:

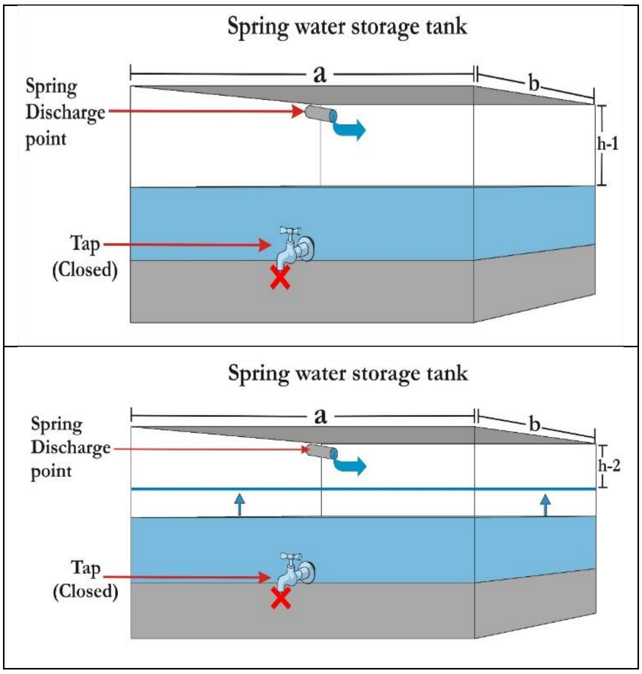
Some of the recommendations and suggestions are as follows:

- Springs, open wells or bore wells are all groundwater sources which are fed by different aquifers. Thus, in order to revive these sources, in depth understanding of aquifers is the first step. This requires mapping out the aquifer area and its thickness with the help of hydrogeological mapping.
- In areas where open wells are used, pumping tests need to be performed. These tests provide information about the aquifer characteristics, such as *specific yield* and *transmissivity*.
- Looking at the rate at which bore wells are increasing in the district, it is important to collect as much detailed information as possible for bore wells. Some of the key questions related to this include: depth of bore well, depth at which water was struck, different types of material that was encountered at the time of drilling, water level, etc. This information may be gathered through narrative logs by asking the above key questions. Such information will help generate aquifer maps which is the first step in groundwater management.
- With respect to bore wells especially, if they are to be brought into the regular water supply system, pumping tests and water quality analysis ought to be performed. This is because compared to shallow unconfined aquifers, that are tapped by springs and open wells, deeper aquifers have lower specific yields, implying lesser groundwater availability. Being a region dominated by hard, crystalline rocks, the region is also susceptible to iron and fluoride contamination.
- A common observation in many of the regions that were surveyed, was that the spring water where it emerges in to a small puddle or depression, is unclean with a lot of fallen rotten leaves. In such cases, with the help of

locally available material, a clean mesh can be used to cover it up thus preventing leaves from falling into it but providing the necessary aeration.

- In order to develop robust water security plans, good, accurate and long-term data is essential. However, in particular, the spring discharge data collected by Keystone Foundation over 1-1.5 years is quite inconsistent. One of the major hurdles was the extremely low discharge, with negligible flow, making measurements very difficult during the lean season. In such areas, alternative methods of discharge measurement may be used. Two such processes have been described below

The water level drop method



- Measure the dimensions of the spring box or of the depression
- Measure the water level with the help of a measuring scale or tape from a fixed point
- Remove a known quantity of water.
- Measure the new reduced water level from the same fixed point
- Note the time taken, for this water level to again rise to the original water level
- To calculate the discharge first estimate the total volume of water risen in the spring box
- Volume in m^3 = Length x Breadth x Rise in water level
- Discharge in lpm = Volume in m^3/ (Time taken in minutes x 1000)

Discharge in flowing stream

- Firstly channelise the spring water is such a way that all of the water flows through the stream, freely, without obstruction
- Measure a certain length of the stream and mark it with the help of small twigs or any other resistant object
- Measure the average breadth and depth of the stream within the selected stream length
- Now collect small leaves of approximately the same size and drop them one by one in to the water and note the time taken for it to travel the known length of the stream
- Volume in m^3 = Length x Breadth x Depth
- Discharge in lpm = Volume in m^3/ (Time taken in minutes x 1000)